

**IN THE ENVIRONMENT COURT  
WELLINGTON REGISTRY**

**I TE KŌTI TAIAO O AOTEAROA  
TE WHANGANUI-A-TARA ROHE**

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|                      |                                                                                                                                                                                                                               |
|----------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>UNDER</b>         | the Resource Management Act 1991                                                                                                                                                                                              |
| <b>IN THE MATTER</b> | of appeals under sch 1, cl 14(1) against the decision of<br>Manawatū-Whanganui Regional Council on Plan Change 2<br>to the One Plan                                                                                           |
| <b>BETWEEN</b>       | <b>TE RUNANGA O RAUKAWA</b><br>ENV-2021-WLG-20<br><br><b>NGĀTI TURANGA</b><br>ENV-2021-WLG-21<br><br><b>ANDREW DAY</b><br>ENV-2021-WLG-22<br><br><b>WELLINGTON FISH AND GAME COUNCIL</b><br>ENV-2021-WLG-23<br><br>Appellants |
| <b>AND</b>           | <b>MANAWATŪ-WHANGANUI REGIONAL COUNCIL</b><br><br>Respondent                                                                                                                                                                  |

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**STATEMENT OF EVIDENCE OF MAREE ELLEN PATTERSON ON BEHALF OF THE  
MANAWATŪ-WHANGANUI REGIONAL COUNCIL**

**WATER QUALITY AND STATE OF ENVIRONMENT**

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Dated: 6 October 2023



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**STATEMENT OF EVIDENCE OF MAREE ELLEN PATTERSON****A. INTRODUCTION**

- [1] My full name is Maree Ellen Patterson. I am currently employed as Senior Environmental Scientist – Water Quality at Manawātū-Whanganui Regional Council (**Horizons**) and have been in this position since July 2012. Prior to this role, I have held a number of positions within the Science team at Horizons since May 2004.
- [2] I hold a Masters in Applied Science (Natural Resource Management) from Massey University, a Postgraduate Diploma in Arts (Geographic Information Systems) from Massey University and a Bachelor of Science (Geography) from the University of Canterbury. I am a member of the NZ Freshwater Sciences Society and the Regional Sector Special Interest Group – Surface Water Integrated Management.
- [3] In my role with Horizons as the Council’s Senior Environmental Scientist – Water Quality I am responsible for initiating, scoping, project managing and contributing to projects relating to water quality and land use interactions with water quality. I have authored and co-authored a range of scientific reports in relation to water quality and the state of the environment in relation to freshwater. I have previously led the state of the environment physico-chemical monitoring for freshwater and discharges. I also provide technical advice for the regulatory team at Horizons on a range of matters.
- [4] I was not involved at the Council-level hearing for Plan Change 2 (**PC2**). Technical reporting on water quality management was the subject of a s 42A report by Ms Abby Matthews. However, I was involved in the development of the water management framework for the Manawatu-Whanganui One Plan (**One Plan**) and was one of the technical witnesses for the Environment Court hearing for the water chapter of the One Plan as it related to Intensive Farming Land Uses (**IFLUs**). My role involved modelling of water quality outcomes for a range of policy scenarios relating to IFLUs for the Court.
- [5] I am familiar with PC2, and am presently overseeing the water quality component of the implementation programme Horizons has underway to

meet its obligations under the National Policy Statement for Freshwater Management 2020 (**NPSFM**) – known as Oranga Wai. This includes the work programme to understand the gap between current state and target state for nutrients, sediment and bacteria and overseeing the modelling of mitigation/limit options to address the difference.

[6] I was directly involved early on in the PC2 process when the initial options were being scoped to address the implementation issues arising from the changes in Overseer. However, I went on maternity leave before this work was completed and became involved in the process again when the decision was made to proceed from mediation to the Environment Court. My recent role has been to oversee the modelling undertaken by Dr Snelder to reflect the implementation of the different policy pathways.

[7] I also recently briefed LWP Ltd to undertake an updated assessment of the state and trends of water quality for River, Lake, Estuary and Coastal water from Horizons State of the Environment monitoring network for all data to the end of June 2022. The state assessment shows where the respective water bodies are currently in relation to achieving One Plan Standards, and a trend assessment demonstrates the direction and magnitude of change over the 10, 20 and 30 year periods ending 30 June 2022.

#### **B. CODE OF CONDUCT**

[8] I confirm that I have read and agree to comply with the Code of Conduct for Expert Witnesses contained in the Environment Court Practice Note 2023. This evidence has been prepared in accordance with that Code. I confirm that I have not omitted to consider material facts that might alter or detract from the opinions that I express. The evidence I am giving is within my area of expertise, except where I state I am relying on the opinion or evidence of other witnesses. I understand it is my duty to assist the Court impartially on relevant matters within my areas of expertise.

#### **C. SCOPE OF EVIDENCE**

[9] In my evidence, I provide an overview of the One Plan framework for managing water quality, including the nutrient management framework and



the regulation of IFLU to limit nutrient leaching. I explain the water quality issues, how they are addressed under the One Plan, and the role of PC2. I refer to the decisions version of PC2 as **DV-PC2**.

[10] I have addressed the following topics as part of my evidence:

- (a) The state and trends in water quality in the Region, with a particular focus on the 'target catchments', and the relevance of IFLU;
- (b) Why we manage nitrogen in river, and how;
- (c) The science and modelling approach that informed the development of the One Plan nutrient management framework;
- (d) An overview of the science and modelling undertaken to inform PC2; and
- (e) The science programme presently underway for Oranga Wai.

[11] My evidence is intended to provide background information to inform the Court's understanding of the One Plan. As set out in the evidence of Ms Foster, PC2 does not seek to review or change the approach underpinning Table 14.2, including the intervention logic behind it. These are matters to address as part of the programme for implementing the NPSFM.

[12] In addition to my own observations, I rely on the technical evidence of Dr Hanly, who addresses the recalibration of Table 14.2 cumulative nitrogen leaching maximum (**CNLM**) for the purposes of PC2; Professor Horne and Dr Jolly who address farm management practices and the proposed consenting pathways (including the risk assessment tool); and Dr Snelder and Dr Cox who outline the nitrogen modelling framework utilised to inform DV-PC2, and the risk management tool proposed since DV-PC2.

#### **D. BACKGROUND**

[13] The One Plan identifies four keystone environmental issues: surface water quality degradation, increasing water demand, unsustainable hill country land use and threatened indigenous biodiversity. Science and monitoring that informed the One Plan showed that the health of many of the Region's

waterways was poor and/or at risk of degradation – particularly with regard to nutrients, sediment and bacteria – and that continued pressure from a range of sources, including point source discharges and land use activities, needed to be addressed.

- [14] At the time the One Plan was developed, it was recognised that intensification of agriculture had occurred over the previous decade, and that the impacts of this intensification had progressively increased over time.
- [15] The One Plan provides a framework for managing water quality, which includes the management of diffuse and point sources of nitrogen, phosphorus, sediment and *E. coli*. In addition to point source discharges (which are addressed separately), the framework includes regulation of IFLU to limit nitrogen lost below the root zone, and reduce the direct access of stock to waterways. Specifically, existing IFLU activities in target catchments are controlled by rules, as I describe below, as well as new IFLU anywhere in the region.
- [16] While nitrogen is the focus of the nutrient management rule framework within the One Plan, improvements in water quality were not intended to be solely limited to reductions in nitrogen. For example, the rule framework includes regulation for stock exclusion from waterways, which will reduce all of the main contaminants (nitrogen, phosphorus, sediment and *E. coli*).
- [17] Reducing both diffuse and point sources of nitrogen (and other contaminants) was, and still is, necessary to work toward achieving One Plan water quality values and targets.
- [18] The DV-PC2 updated One Plan Table 14.2, and introduced specified nitrogen reduction consenting pathways (20% for pastoral and 35% for commercial vegetable growing (**CVG**)) as alternatives to compliance with Table 14.2. Activities that did not meet these controlled activity pathways are considered as discretionary activities under the DV-PC2.

- [19] Following the Council-level hearing of PC2, the Government's response to the Overseer peer review report<sup>1</sup> was released (**the Overseer Report**), which raises concerns over the use of Overseer as a tool for regulatory management of farm practices. Ministry for the Environment guidance has been that regulators should avoid using Overseer modelled N loss as an absolute number and continue to use a range of tools when assessing farms and catchments when managing nutrients in a regulatory context.<sup>2</sup>
- [20] As a result, a risk assessment tool has been developed through conferencing of experts involved in PC2. The risk assessment tool generates an assessed risk profile for nitrogen leaching, based on the nature of the activity to be consented (pastoral or CVG), and the biophysical characteristics of the area in which it will occur. The accompanying rule framework then requires reduction of diffuse discharge risk to specified levels. The risk assessment tool is discussed in detail in the evidence of Professor David Horne, Dr Anne-Maree Jolly, and Ms Foster.
- [21] The risk assessment tool will be an alternative to the recalibrated Overseer-based CNLM contained in Table 14.2 within the One Plan. It is proposed to replace the specified nitrogen reduction pathway in DV-PC2, which required reductions of nitrogen leaching of 20% for pastoral and 35% for CVG (compared to a baseline year), with the risk assessment tool.
- [22] The impact of DV-PC2 was initially assessed using catchment nitrogen models developed for the Region, as outlined in the evidence of Dr Cox and Dr Snelder. On this occasion, to provide a comparison between the outcomes of risk assessment tool and DV-PC2, Dr Snelder utilised the relative changes from baseline in root-zone farm loss modelled by Professor Horne and Dr Jolly. Based on the analysis described in his evidence, Dr Snelder was able to conclude that the same modest improvements in water quality will be achieved from the implementation of the risk matrix tool as were achieved from the implementation of the DV-PC2.

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<sup>1</sup> Ministry for the Environment and Ministry for Primary Industries, August 2021.

<sup>2</sup> Ministry for the Environment and Ministry for Primary Industries, August 2021, page 19.

- [23] Further reductions in nitrogen leaching, beyond those anticipated by PC2, will be required to meet current One Plan water quality targets. PC2 provides an interim solution to the issues with the current One Plan framework, including providing viable pathways for existing IFLUs to apply for a resource consent. As I discuss below, Horizons continues to work toward a notified plan change that establishes catchment limits and/or action plans to address a range of water quality pressures as required by the NPSFM, including revisiting the existing framework for managing diffuse sources of nitrogen.

#### **E. ONE PLAN MANAGEMENT OF WATER QUALITY**

- [24] The water management framework utilised in the One Plan recognises the need to manage water bodies within the Region for the different environmental, cultural, social, and economic values they hold. This is similar to the approach for water management in the NPSFM.
- [25] Water Management Zones (**WMZs**) and Water Management Sub-zones (**WMSZs**) provide the fundamental building blocks for integrating all management issues within an area, in order to obtain the best environmental outcome. The Region is split into 43 WMZs, which are comprised of 124 WMSZs.
- [26] Schedule B of the One Plan identifies ecological, cultural, social and economic values for water bodies within the Region. These are either zone-wide (applying to all water bodies in the WMZs) or reach specific (applying to certain parts of rivers and streams). The One Plan requires that Horizons recognise and provide for these values.
- [27] Management of activities and resource use to achieve the desired outcomes for the values is either through specific water quality targets or through the rule framework within the One Plan (for example the Beds of Rivers and Lakes rules).
- [28] Schedule E of the One Plan identifies quantifiable water quality targets for surface water in order to give protection to the Schedule B values and the outcomes sought for them. Similarly, Schedule I identifies targets for estuaries and the coast. Where the targets are achieved, water quality must

be maintained. Where the targets are not met, improvements must be made to water quality to meet the target. However, unlike the requirements of the NPSFM, the One Plan does not require Horizons to set a timeframe for achieving these water quality targets.

- [29] The desired outcomes for identified water body values, and achievement of water quality targets in Schedule E, are to be achieved through a range of mechanisms (both regulatory and non-regulatory) and not solely by regulating IFLUs.

#### **F. THE NEED FOR MANAGING NITROGEN IN RIVERS, LAKES, AND ESTUARIES**

- [30] The major nutrients in waterways for management purposes are nitrogen and phosphorus. Nitrogen can be present in water in a number of forms (nitrate, nitrite, ammoniacal and organic nitrogen). These can be measured either individually or as a whole or 'total nitrogen' (**TN**). Phosphorus can also be present in water in a number of forms (dissolved reactive phosphorus, dissolved organic phosphorus, particulate phosphorus), all of which can be measured individually and as a whole or 'total phosphorus' (**TP**).
- [31] Nutrients are natural components in waterways but if nutrient concentrations are too high, they can be directly and indirectly toxic to aquatic life and lead to conditions that impact on a range of waterway values. Nutrient concentrations can increase in water through both point and diffuse sources.
- [32] Effects of nutrients on instream values can be complex, and vary depending on the value in question, therefore it is important to manage both nitrogen and phosphorous and not solely rely on the management of one to achieve the outcomes sought for all.<sup>3</sup> However, the remainder of this evidence focuses on the management of nitrogen as PC2 relates to the nitrogen component of the suite of intensive farming rules.
- [33] Nitrogen in waterways is managed to achieve a range of outcomes including:

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<sup>3</sup> Wilcock et al, 2007.

- (a) to meet drinking water quality standards (for the prevention of blue baby syndrome);
  - (b) to prevent direct toxicity to aquatic life; and
  - (c) to limit excessive plant growth - periphyton (the collective name for diatoms, algae, fungi and cyanobacteria found in rivers and streams), phytoplankton (the suspended algae and cyanobacteria in lakes) and both suspended and macro algae (in estuaries).
- [34] Of the management objectives outlined above, the management of plant and algal growth often requires the most stringent water quality targets. Excessive plant and algal growth can lead to effects on life supporting capacity of a waterbody by causing fluctuations in dissolved oxygen and pH, smothering the bed of a river, and reducing habitat availability for fish and invertebrates. It can also affect the assemblage of macroinvertebrates within the waterbody, subsequently affecting the food available for fish. It can also affect human uses of the water by making it unsafe for swimming and recreation (due to the presence of potentially toxic cyanobacteria), and can impact aesthetic values, by looking, feeling and smelling unpleasant and the enjoyment of anglers, due to the algae getting caught on fishing lines.
- [35] Point sources of nitrogen are relatively easy to measure and quantify. Consequently, point sources have been managed through rules in regional plans for a long time. The management of nitrogen was focussed on the removal of dairy shed discharges to water through the Manawatū Catchment Water Quality Regional Plan (1998) and the Land and Water Regional Plan (2003). The last discharge of dairy shed effluent to water ceased in 2012. The introduction of the One Plan required the operators of wastewater treatment plants to change from solely managing phosphorus to managing nitrogen as well. Upgrades to wastewater treatment plants to reduce concentrations of nitrogen through treatment or discharging to land have been occurring since the One Plan was notified.
- [36] Diffuse sources of nitrogen are more difficult to manage. This is because not all nitrogen applied to land makes its way to surface water, and by its very nature these sources are far less direct, meaning its measurement is limited

to the inferences drawn from general State of the Environment (SOE) monitoring.

- [37] In the landscape, nitrogen not utilised for plant (including pasture) growth is lost from below the root-zone and into the subsurface. Once in the subsurface it is subject to biogeochemical processes that include the conversion of nitrate to dinitrogen gas before it reaches surface water. Catchment characteristics such as topography, rainfall, geology, and sub-surface geochemistry affect the transportation and transformation of nitrogen as it moves through the groundwater system and into surface water.
- [38] The reduction in nitrogen from the root-zone to what appears in surface water is referred to as attenuation. Studies carried out in the Horizons Region have demonstrated that attenuation varies spatially and temporally in response to the catchment's characteristics.<sup>4</sup>
- [39] Nitrogen from land use can also enter waterways as run-off from overland flow pathways, direct access of stock to water, or incorrect management of culverts and tracks.<sup>5</sup>
- [40] The amount of nitrogen measured in Horizons SOE monitoring programme is expressed as a concentration ( $\text{g}/\text{m}^3$  or  $\text{mg}/\text{l}$ ) whereas the amount lost from below the root zones is expressed as an export coefficient ( $\text{kg}/\text{ha}/\text{yr}$ ). Multiplying the area (ha) of each land use by its export coefficient gives a load in  $\text{kg}/\text{year}$  (which can be transformed to tonnes/year).
- [41] To relate the concentrations measured in the SOE network to the various source contributions, a load in tonnes/year is calculated for each monitoring location. The load is calculated by combining concentration and flow.
- [42] Drs Cox and Snelder have utilised the loads from the SOE monitoring network, and export coefficients from land use, in the calibration of the catchment basin models utilised to test the efficacy of the policies proposed through DV-PC2.

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<sup>4</sup> Rivas et al, 2020.

<sup>5</sup> Lucci et al, 2015.

## G. IDENTIFICATION OF IFLU

- [43] Horizons identified four land uses likely to have the most impact on water quality when preparing the nutrient management framework. They are: dairy farming, cropping, CVG, and intensive sheep and beef farming (the latter two being sheep and beef farming where irrigation is occurring).<sup>6</sup>
- [44] The identification of the four land uses was supported by Clothier et al. (2007), who summarised loss rates for nitrogen and phosphorus from the four intensive land uses from available literature (Table 1).

**Table 1:** Clothier et al (2007) ranking of annual N and P loss rates from IFLU activities.

| Ranked Nitrogen Loss |                                                   | Ranked Phosphorus Loss |                                                    |
|----------------------|---------------------------------------------------|------------------------|----------------------------------------------------|
| Market Gardening     | (100-300 kg-N ha <sup>-1</sup> yr <sup>-1</sup> ) | Market Gardening       |                                                    |
| Cropping             | (10-140 kg-N ha <sup>-1</sup> yr <sup>-1</sup> )  | Cropping               |                                                    |
| Dairying             | (15-115 kg-N ha <sup>-1</sup> yr <sup>-1</sup> )  | Dairying               | (0.2- 1.0 kg-P ha <sup>-1</sup> yr <sup>-1</sup> ) |
| Sheep/beef           | (6-60 kg-N ha <sup>-1</sup> yr <sup>-1</sup> )    | Sheep/beef             | (0.1-1.6 kg-P ha <sup>-1</sup> yr <sup>-1</sup> )  |

- [45] Extensive (i.e., not intensive) sheep and beef farming covers a large portion of land within most WMSZs, however, the loss rates from this farming activity are much lower than a more intensive footprint (over a smaller area). For this reason, the inclusion of sheep and beef farming in the framework was not considered warranted due to the potential for N reductions from extensive sheep and beef farming being small in comparison to the IFLU.<sup>7</sup>
- [46] The focus was instead on reductions in N-loss from dairy farming, cropping, CVG, and intensive (irrigated) sheep and beef, which were considered to have a greater impact on overall catchment water quality compared to their footprint.

## H. SELECTION OF ONE PLAN TARGET CATCHMENTS FOR NUTRIENT MANAGEMENT

- [47] One Plan Table 14.1 identifies targeted WMSZs, where management of IFLU activities must be specifically controlled (Table 2).

<sup>6</sup> Roygard J, 2009, s42a Report.

<sup>7</sup> McArthur et al, 2010, paragraphs [169]–[172].



**Table 2:** Selected target catchments for the implementation of the nutrient management rule.

| Catchment                      | Water Management Sub-zone                                                                                                                                                                                                                                                                                               |
|--------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Mangapapa                      | Mangapapa (Mana_9b)                                                                                                                                                                                                                                                                                                     |
| Waikawa                        | Waikawa (West_9a)<br>Manakau (West_9b)                                                                                                                                                                                                                                                                                  |
| Other south west catchments    | Lake Papaitonga (West_8)                                                                                                                                                                                                                                                                                                |
| Mangatainoka                   | Upper Mangatainoka (Mana_8a)<br>Middle Mangatainoka (Mana_8b)<br>Lower Mangatainoka (Mana_8c)<br>Mākākahi (Mana_8d)                                                                                                                                                                                                     |
| Other Coastal Lakes            | Northern Manawatū Lakes (West_6)<br>Kaitoke Lakes (West_4)<br>Southern Whanganui Lakes (West_5)                                                                                                                                                                                                                         |
| Coastal Rangitīkei             | Coastal Rangitīkei (Rang_4a)<br>Tidal Rangitīkei (Rang_4b)<br>Pōrewa (Rang_4c)<br>Tūtaenui (Rang_4d)                                                                                                                                                                                                                    |
| Lake Horowhenua                | Lake Horowhenua (Hoki_1a)<br>Hokio (Hoki_1b)                                                                                                                                                                                                                                                                            |
| Upper Manawatū above Hopelands | Upper Manawatū (Mana_1a)<br>Mangatewainui (Mana_1b)<br>Mangatoro (Mana_1c)<br>Weber – Tamaki (Mana_2a)<br>Mangatera (Mana_2b)<br>Upper Tamaki (Mana_3)<br>Upper Kūmeti (Mana_4)<br>Tamaki – Hopelands (Mana_5a)<br>Lower Tamakai (Mana_5b)<br>Lower Kūmeti (Mana_5c)<br>Ōruakeretaki (Mana_5d)<br>Raparapawai (Mana_5e) |
| Manawatū above gorge           | Hopelands – Tīraumea (Mana_6)<br>Upper Gorge (Mana_9a)<br>Mangaatua (Mana_9c)                                                                                                                                                                                                                                           |

[48] Information from Horizons' 2004 SOE report was used to identify hotspots for N, P, sediment and bacteria, which were then used to select potential

candidates for these 'target' catchments for nutrient management. A programme of work reviewed the source of contaminants in these areas to determine whether it was point or diffuse source discharges causing these hotspots, and what land uses were large contributors.<sup>8</sup> Target catchments were identified based on three outcomes:

- (a) Catchments where nutrients were high and the main source of those nutrients was from diffuse rather than point sources – being the Upper Manawatū, Mangatainoka, Mangapapa, Upper Gorge and Waikawa target catchments;
- (b) Catchments where nitrogen targets were meeting the One Plan target but were close to exceeding it, and there was potential for the expansion of the existing footprint due to the availability of water in the allocation framework – being Coastal Rangitikei; and
- (c) Catchments where there was little information but were identified as at risk due to the proportion of IFLU in proximity to them, and the vulnerability of the receiving environment – being the coastal Lakes, Lake Horowhenua, and other southwest catchments.

[49] Catchments such as the Lower Ōroua, Mangawhero, Makotuku and Lower Manawatū were identified as having high nutrients but were excluded from the framework due to the influence of the wastewater discharges from Feilding, Ohakune, Raetihi and Palmerston North.

[50] The contribution of IFLU to overall catchment load was calculated to enable modelling of the relative reductions in nitrogen from implementation of the IFLU rule framework.<sup>9</sup> This is similar to the approach taken by Dr Cox for PC2 to model relative contributions and reductions occurring as a result of the proposed PC2 provisions.

[51] As I discuss in Section M below, Horizons has recently completed an updated assessment of the state of water quality compared to One Plan targets. This updates the SOE reporting available at the Council-level hearing. It shows

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<sup>8</sup> Rivas et al, 2020.

<sup>9</sup> Roygard and Clark, 2012.

that nutrients remain an issue across the Region and within the target catchments.

#### I. DEVELOPMENT OF TABLE 14.2

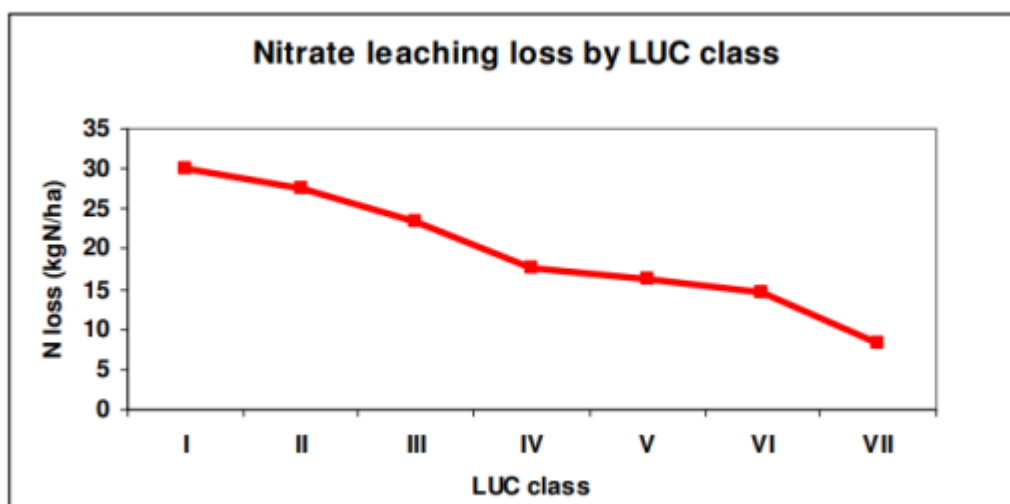
- [52] The One Plan seeks to control the amount of nitrogen to reduce the effects of land use on water quality and associated values, including life supporting capacity, contact recreation, and trout fishery. The One Plan sought to control nitrogen loss from IFLU through the CNLM limits in Table 14.2.
- [53] Within Table 14.2, the CNLM limits are tied to the relevant land's land use capability (**LUC**) class, as a proxy for the productive capability of the land.<sup>10</sup> This has been referred to as the 'natural capital' approach to nitrogen management – the intention being that soils with the highest productive capacity have the highest CNLMs. It was envisaged that the framework would lead to intensive farming land practices being carried out on highly productive soils, while they were discouraged from soils with lower suitability for such intensive use.
- [54] The Upper Manawatū catchment was used as a case study to develop Table 14.2. In summary, the N losses of the soils in the catchment were calculated using the potential stocking rate that could be sustained by a well-managed legume-based pasture (i.e. no imported feeds).<sup>11</sup> These stocking rates were then transformed to pasture production and used in the Overseer nutrient budget model to calculate N leaching loss under pastoral use. As the limitations to use increase (represented by an increase in the LUC number) the underlying productive capacity of the soil to sustain a legume based pasture system declines, and so does the potential N leaching loss (Figure 1).

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<sup>10</sup> McKay A, 2010.

<sup>11</sup> Table 14.2 Cumulative Nitrogen Leaching Maxima (CNLM) are described in more detail in the s 42a report of Dr Alec McKay (2010).

**Figure 1:** Nitrate leaching loss calculated using Overseer (for a developed dairy operation with annual rainfall of 1,200 mm) associated with the potential livestock carrying capacity listed in the extended legend for LUC Classes I-VII in the North Island.



[55] Average N loss per hectare was calculated on the basis of each LUC class being farmed at 90% and 75% of productive capacity and an assumed transmission of 0.5 (i.e. half of what was lost at the root-zone ended up in surface water). These values were used to explore the total resultant in-river N loading caused by proportional reductions. Table 3 shows that the N loading in the river would have been 921 tonnes annually at 90% production and 767 tonnes at 75% production.

**Table 3:** Area of each LUC class, calculated N loss associated with the potential productivity of soils in each LUC class calculated using Overseer, and the contribution of the soils in each LUC class to the N loading in the Upper Manawātū river, and average N loss per ha per year if each LUC class if farmed at 90% and 75% of potential. Source: Mackay (2010).

| LUC class    | Area (ha)      | N Loss based on potential production (kgN/ha/yr) | Fraction of potential | Nitrate loss limit kgN/ha/yr | Transmission coefficient | Total loading river (kg N/yr) | Fraction of potential | Nitrate loss limit kgN/ha/yr | Transmission to efficient | Total loading river (kg N/yr) |
|--------------|----------------|--------------------------------------------------|-----------------------|------------------------------|--------------------------|-------------------------------|-----------------------|------------------------------|---------------------------|-------------------------------|
| II           | 12,424         | 27.4                                             | 0.9                   | 24.7                         | 0.5                      | 153,348                       | 0.75                  | 20.6                         | 0.5                       | 127,790                       |
| III          | 20,257         | 23.5                                             | 0.9                   | 21.1                         | 0.5                      | 213,978                       | 0.75                  | 17.6                         | 0.5                       | 178,315                       |
| IV           | 11,508         | 17.5                                             | 0.9                   | 15.8                         | 0.5                      | 90,729                        | 0.75                  | 13.1                         | 0.5                       | 75,608                        |
| V            | 907            | 16.3                                             | 0.9                   | 14.7                         | 0.5                      | 6,666                         | 0.75                  | 12.3                         | 0.5                       | 5,555                         |
| VI           | 57,254         | 14.5                                             | 0.9                   | 13.1                         | 0.5                      | 373,897                       | 0.75                  | 10.9                         | 0.5                       | 311,580                       |
| VII          | 22,108         | 8.3                                              | 0.9                   | 7.5                          | 0.5                      | 82,431                        | 0.75                  | 6.2                          | 0.5                       | 68,693                        |
| VIII         | 5,180          | 0.0                                              | 0.9                   | 0.0                          | 0.5                      | 0                             | 0.75                  | 0.0                          | 0.5                       | 0                             |
| <b>Total</b> | <b>129,638</b> |                                                  |                       |                              |                          | <b>921,049</b>                |                       |                              |                           | <b>767,541</b>                |

- [56] These N loss values were used to guide the establishment of the year 1 CLNM in Table 14.2 and scenario modelling in relation to in-river N load. The N loss limits then ‘step down’ over time to provide a sinking lid for IFLU N leaching and allow farmers to implement practice changes over a 20 year timeframe.
- [57] The evidence of Ms Marr to the Hearing Panel when the One Plan was being introduced, provides a summary of the step downs:<sup>12</sup>

The year 20 nitrogen loss limit was chosen as a conservative reduction target that would be achievable using current technology. The rate of change towards the year 20 target was chosen to a) align with industry targets and b) implement change towards the target over a reasonable time frame.

- [58] Meeting the CLMN specified in Table 14.2 was not considered to be the silver bullet for achieving SIN targets specified in Schedule E of the One Plan, but a step towards achieving them. Modelling for the Environment Court showed that with an 11% expansion in the dairy footprint and all farms meeting Table 14.2, there would be an estimated 12% reduction in N in the upper Manawatū Mangatainoka. Some parts of the Coastal Rangitīkei and Waikawa catchments were modelled to increase N load by 3% and 4% respectively.<sup>13</sup>

## J. SCIENCE AND MODELLING TO INFORM PC2

- [59] An analysis of state and trends of water quality at the time of the PC2 hearing was provided in the s 42A technical report of Dr Snelder. That report outlined water quality results for the Region in relation to periphyton measured by chlorophyll *a* (**chl-*a***), soluble inorganic nitrogen (**SIN**), macroinvertebrate community index (**MCI**), visual clarity (how far the naked eye can see through the water column) and *E. coli*. This analysis drew on information from three studies in the Region using data to 30 June 2017.<sup>14</sup>
- [60] These studies found that the majority of sites were assigned a fail grade when compared to One Plan targets for all indicators of water quality. The exception was chl-*a* and MCI, for which more than 50% of sites were assigned

<sup>12</sup> Marr, 2009, page 28.

<sup>13</sup> Roygard and Clark 2012.

<sup>14</sup> Snelder, 2018; Fraser and Snelder, 2018, 2020.

a pass grade. For SIN, a high proportion of sites both regionally and within target catchments failed to meet One Plan targets, and a large proportion of these had current concentrations of SIN considerably higher than the One Plan targets (e.g. 36% of sites regionally and 39% of sites in target catchments had SIN concentrations more than 50% higher than their specified target).

- [61] Ten and 20 year trends in SIN predominantly indicated improvement. For the other indicators there was a more even split between improving and degrading trends in the 10 year period. MCI was the only other indicator where a 20 year trend was presented and there was an even split of degrading and improving trends.
- [62] While these results demonstrated that water quality targets were not being met by and large, they indicated two additional things:
- (a) Where targeted efforts to manage IFLUs and nutrient loss generally were being made, improvement was occurring (if in an uneven manner); and
  - (b) Further effort would be required to achieve the One Plan water quality targets.
- [63] At a more technical level, updates to the Overseer Model and the change from Overseer Version 5 to Version 6 saw an increase in the modelled (not actual) nitrogen lost below the root-zone. This meant that the Table 14.2 CNLMs were no longer achievable for most farms. PC2 sought to address this issue by updating Table 14.2 to the latest version of Overseer.
- [64] The updates to Table 14.2 are addressed in the evidence of Dr Hanly. Dr Hanly's reporting showed that estimated N leaching increased 41.3–69.0% between Overseer version 5.2.6 and 6.3.0. As Dr Hanly reports, the recalculation of Table 14.2 does not lead to any actual increased N leaching from dairy farms, nor does it result in fewer farmers being able to achieve Table 14.2 CNLMs. Dr Hanly discusses more recent changes in his evidence.
- [65] Additional to the reporting on the recalibration of Table 14.2, consideration was given to the alternative IFLU consenting pathways. The introduction of a

discretionary activity through PC2 as notified was intended to provide a workable consenting pathway for those who are unable to achieve Table 14.2 CNLMs. This consenting pathway would address issues with the policy framework within the One Plan, as described by Dr Daly and Ms Foster.

- [66] To assess the impact of the update to Table 14.2 and the proposed discretionary pathway, Drs Snelder and Cox developed catchment nitrogen models for the Region. These models were calibrated using the data from Horizons comprehensive river monitoring network. As discussed in the evidence of Dr Snelder, the models were utilised to simulate changes to catchment N loads as a result of implementing PC2 in various forms.
- [67] These pathways are based on land management practice change. Reductions in contaminants, N, P, *E.coli* and sediment, are known to arise from the uptake of improved management practices.<sup>15</sup> The practices that were agreed by the experts comprised of mitigations identified by the Our Land and Water National Science Challenge as well established<sup>16</sup> or less established/emerging.<sup>17</sup> I note that the PC2 rule framework continues to be directive around consideration of adoption of improved farm management practices as part of the consenting process.

#### **K. COUNCIL HEARING OUTCOMES**

- [68] The DV-PC2 updated Table 14.2, and introduced specified nitrogen reduction consenting pathways as alternatives to compliance with Table 14.2. These pathways required modelled reductions in nitrogen leaching to be achieved on farm (20% pastoral and 35% CVG) for the IFLU to be considered as a controlled activity. Activities that did not meet these controlled activity pathways were discretionary activities under the DV-PC2.
- [69] These options were considered as part of the modelled scenarios by Drs Snelder and Cox. As in the initial scenario modelling for the One Plan, it was

<sup>15</sup> Monaghan et al, 2021 and McDowell et al, 2020.

<sup>16</sup> Monaghan et al, 2021.

<sup>17</sup> McDowell et al, 2020.

recognised that PC2 alone will not address all water quality issues in the Region, but it was a step in the right direction. Specifically:

- (a) Consenting the IFLU activities resulted in a reduction in N load in comparison to these activities remaining unconsented;
- (b) The implementation of PC2 would result in a reduction of N lost from 283 dairy farms known to Horizons; and
- (c) The implementation of PC2 would result in 'modest' water quality improvements in the WMSZs.

[70] Modelling by Drs Cox and Snelder showed there was very little difference in terms of water quality outcomes between compliance with Table 14.2 by 'most' IFLUs (as anticipated by the One Plan) and compliance with the alternative pathway. The modest improvements were the product of on farm practice (mitigation) change necessary to reduce nitrogen leaching to the specified levels to access the controlled activity pathway, and would help drive improvement in water quality over time.

[71] It is important to contextualise these results. PC2 deals with existing, unconsented IFLU in targeted WMSZs. This is an (intentionally) narrow selection of activities in the Region, meaning that the results from implementing PC2 will be relatively constrained.

[72] In reality, dealing with this unconsented IFLU alone will not make a decisive contribution in terms of contaminant load reduction. However, methods within PC2, alongside other initiatives like freshwater farm plans and reduction of point source loads, will provide a starting point for delivering these long term targets. Implementation of PC2 will also begin work on achieving water quality improvements sooner than they would otherwise have been seen.

[73] Modelling of water quality outcomes for lakes and estuaries was not carried out explicitly. However, using the models calibrated by Dr Cox and other information from Horizons' water quality monitoring network, some conclusions were able to be drawn by Dr Snelder. Downstream receiving



environments would benefit from a reduction in nitrogen in the target catchments, and reducing leaching on farm would have a positive effect on groundwater and, as a result, a positive effect on the lakes and wetlands fed by groundwater. However, this remained unquantified.

[74] I note that additional protection was provided to lakes and estuaries through amendments to Policy 14-6(e) agreed during the hearing, directing the need to take into account the sensitivity of the receiving environment, particularly where these are lakes or wetlands.<sup>18</sup>

[75] As with rivers, PC2 alone will not address the issues with lakes in the Region. Lake restoration studies show that tailored approaches are necessary to address water quality and ecosystem health issues.<sup>19</sup> Opportunities to address the health of the Region's coastal dune lakes are being considered as part of the Oranga Wai freshwater plan process. As I discuss below, this work is underway, with a limit-setting process being a necessary part of that work. In the short term, however, PC2 provides a workable regulatory pathway for CVG and pastoral land use, which will start the movement towards improved water quality.

#### **L. RISK ASSESSMENT TOOL**

[76] As I note earlier, a risk assessment tool for pastoral and CVG has been developed as part of the appeal process, with a view to addressing the challenges with Overseer identified in the Overseer Reports.

[77] I understand that the risk assessment tool will replace the specified nitrogen reduction pathways in the DV-PC2. However, like those pathways, the risk assessment tool is focused on farm practice change to drive nitrogen loss improvements. Professor Horne and Dr Jolly discuss this in their evidence.

[78] The impact of the risk assessment tool on water quality outcomes has been assessed by Dr Snelder, using data from Dr Jolly and Professor Horne. As

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<sup>18</sup> Recommendation Report of the Independent Hearing Panel – Plan Change 2, March 2021, page 48.

<sup>19</sup> Waters et al, 2018a and 2018b; Woodward and Gibbs, 2019; Gibbs et al, 2020; Verburg et al, 2019.

explained in Dr Snelder's evidence, he is confident that the same modest improvements in water quality in the target WMSZs will occur from implementation of the risk assessment tool, as would have occurred from implementation of the specified reduction controlled pathways.

#### M. UPDATED STATE AND TRENDS OF WATER QUALITY

[79] To demonstrate how the state of water quality in the Region (and in the target catchments) has been changing over time, including since the PC2 decision was released, LWP were engaged (and supplied with data) to undertake an updated assessment of the state of water quality in comparison to One Plan targets and trends of water quality in the Region (Fraser, 2023). The report resulting from that assessment is attached as **Attachment A**. In addition to this analysis, assessment of the state of water quality in comparison to the NPS-FM attribute state bands is complete. This data was made available for each Freshwater Management Unit, as part of the 2023 SOE report update.<sup>20</sup>

[80] The state analysis undertaken by Fraser (2023) follows on from the analysis presented in the PC2 hearing and is for the 5 year period 1 July 2017 – 30 June 2022. The sites have been split into types (Rivers, Lakes, Coast and Estuaries). The summary compliance results are presented in Section P below. See Figure 2 for rivers and Figure 3 for lakes, coast and estuaries.

[81] For rivers, sites have been further split between SOE sites (sites indicative of general patterns of water quality), impact sites (directly at the bottom of the mixing zone of a major point source discharge) and a grouping called discharge sites (these specifically measure the change targets in the One Plan by comparing the change between upstream and downstream monitoring sites around a point source discharge).

[82] The state analysis undertaken by Fraser (2023) found that:

- (a) For River SOE sites, the majority fail to meet their specified targets for dissolved reactive phosphorus (**DRP**), SIN, MCI, *E. coli*, periphyton

<sup>20</sup> <https://freshwater.horizons.govt.nz/science>.

(filamentous algae cover) and visual clarity. The majority of river sites passed the One Plan criteria for ammoniacal-N (**NH<sub>4</sub>-N**), periphyton (mats), particulate organic matter (**POM**), and Dissolved Oxygen Saturation (**DO-Sat**). The results were more mixed for periphyton biomass (*chl-a*). Impact sites showed a similar pattern, with a tendency towards more sites failing to meet Schedule E targets.<sup>21</sup>

- (b) All monitored lakes sites failed the TN and visual clarity criteria, and only Lake Koitiata passed the *chl-a* and TP criteria. All lakes passed the NH<sub>4</sub>-N criteria and the majority of lakes met the *E. coli* criteria.
- (c) For Estuary sites, all sites failed *E. coli* criteria and passed NH<sub>4</sub>-N criteria, the majority of sites failed the SIN and DRP criteria, and Waikawa and Manawatū Estuaries failed the chlorophyll *a* criteria
- (d) For Coastal sites, all sites passed the NH<sub>4</sub>-N criteria and failed the TN, TP and enterococci (bathing) criteria. 2 sites failed and 2 sites passed the chlorophyll *a* criteria.

[83] A summary of the analysis by Fraser (2023) concerning nitrogen both within and outside of target catchments has been presented in the evidence of Dr Snelder. This analysis shows the majority of sites regionally and within target catchments fail to meet their specified SIN, *chl-a* and filamentous algal cover targets. The proportion of sites not meeting these targets within the target catchments is higher than the proportion of sites outside the target catchments.

[84] Dr Snelder further analyses the relative reduction in concentration required to meet the Schedule E SIN target for each site. His analysis shows that the reduction required for SIN is greater than 50% for the majority of sites.

[85] Fraser (2023) calculated trends in water quality for the 10 year period (1 July 2012 – 30 June 2022), the 20 year period (1 July 2002 – 30 June 2023) and the 30 year period (1 July 1992 – 30 June 2022) for sites that met sample

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<sup>21</sup> This statement does not include an analysis of the cause of said failure i.e. we cannot conclude from this that point sources are causing widespread failure of targets without comparing the upstream and downstream grading's for each.

number criteria in each period. It should be noted that increased monitoring by Horizons under the One Plan means a greater number of sites were available for trend analysis in the 10 year period than in the 20 and 30 year periods.

- [86] It is also important to note that this trend analysis only presents the direction of travel for these measures. It does not say anything about the size of the trend, the cause of the trend, or whether the trends will continue.
- [87] The Fraser 2023 analysis showed for the short term (10 year trends) more than half of analysed sites are degrading for SIN, chlorophyll *a*, visual clarity, DRP, MCI, ammoniacal nitrogen, water temperature and percentage cover of mat algae. It also shows that more than half of analysed sites are improving for dissolved oxygen saturation. The results are more mixed for other water quality indicators (Figure 4, section P).
- [88] Over the 20 year period more than half of the analysed sites are degrading for water temperature and more than half of analysed sites are improving for visual clarity, *E. coli* ammoniacal nitrogen and SIN. The results are more mixed for other measures (Figure 5, section P). The 30 year trends (Figure 6, section P) shows mostly improving trends for SIN, Ammonia and MCI and mostly degrading trends for water temperature. The remainder of the 30 year trends are more mixed.
- [89] The continued non-compliance with One Plan targets for nutrients, measures of periphyton (chl-*a* and algal cover), *E. coli* and visual clarity show there is more to be done in the target catchments and across the Region to reduce the effects of nutrients, sediment and bacteria on waterways and the values associated with them.
- [90] The ability to implement the nutrient management framework in the Region will enable Horizons to start to work towards the targets. However, it will not get the whole way there. Further interventions will be required to reduce nitrogen and contaminants, as part of the implementation of the NPSFM.

## **N. NATIONAL POLICY STATEMENT FOR FRESHWATER MANAGEMENT**

- [91] Horizons continues to work through its implementation of the NPSFM.
- [92] Specifically, the National Objectives Framework within the NPSFM sets out a series of steps for councils, iwi and communities to work through. The steps are similar to that of the One Plan – identify visions, values, outcomes, targets and limits or action plans. However, the key difference is that targets are required to be time bound and for some attributes (including nitrate toxicity and periphyton outcomes) Horizons is required to set limits on resource use to achieve water quality targets that give effect to environmental outcomes over this timeframe.
- [93] Currently there are 7 FMUs proposed for the Horizons Region. The target catchments identified within the One Plan currently are parts of the Manawatū, Whanganui, Rangitikei-Turakina, and Waiopheu FMUs.
- [94] Scientists at the Cawthron institute have been engaged by Horizons to Review the river<sup>22</sup> and lake<sup>23</sup> water quality targets in the One Plan and provide recommendations for water quality targets that reflect the NOF. This work will provide an updated set of minimum water quality targets that give effect to environmental outcomes sought by the community.
- [95] Concerning nutrients, the NPSFM has some compulsory attributes that relate directly to nutrients (nitrate and ammonia toxicity, dissolved reactive phosphorus, total nitrogen and total phosphorus). Clause 3.13 requires councils to set nutrient concentration criteria for periphyton and other attributes affected by nutrients, as well as sensitive downstream receiving environments (which will include coastal lakes and estuaries).
- [96] Nutrient targets in the One Plan were established using the best available information at the time. Horizons had limited monitoring data for periphyton (it was collected annually as part of the macroinvertebrate monitoring

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<sup>22</sup> Eveleens et al, 2023.

<sup>23</sup> In progress.

programme).<sup>24</sup> Extensive monitoring has improved the understanding of the nutrient/periphyton dynamic across the Region, and has contributed to the establishment of an updated national model of nutrients and periphyton.<sup>25</sup>

- [97] The updated national periphyton model is being used<sup>26</sup> to provide updated nutrient concentration criteria for the limit setting work around nutrients in the Region. Complementing this work is a programme to calculate and estimated reduction in river loads of nitrogen and phosphorus required to meet the most stringent outcome. At this stage, this work will only look at periphyton and toxicity requirements, but as targets relating to lake and estuary health and other attributes affected by nutrients are completed, these will also be assessed to determine if they have more stringent requirements. As such, the initial analysis will produce an estimate of the minimum reduction required to give effect to environmental outcomes, and tangata whenua and community aspirations for water quality.
- [98] Drs Cox and Snelder have also been contracted by Horizons to calibrate nutrient models for the Region using the SCAMP platform.<sup>27</sup> These models will enable the testing of proposed policy scenarios to determine and estimate of the relative reduction of nutrients achieved at downstream locations as a result of implementation of the policy approaches. This is similar to what has been undertaken when testing the different options that informed the PC2 hearing. The outputs of the scenario modelling will be compared to the minimum load reductions required to achieve the environmental outcomes. In this regard, the modelling will inform Horizons whether further reductions are required.
- [99] The gap in knowledge around lakes in the Region was, and still is, an issue in the implementation plan for the NPSFM. The scientists involved in the national Lakes 380 research programme have been engaged by Horizons to

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<sup>24</sup> The relationships between nutrients and periphyton used to set the targets were based on a national study of 30 rivers and streams in New Zealand (Biggs and Kilroy, 2000).

<sup>25</sup> Snelder and Kilroy (in press).

<sup>26</sup> Through work by Dr Snelder.

<sup>27</sup> Cox and Snelder 2022a, 2022b.

provide advice around the implementation of the NPSFM with regards to lakes.

- [100] The work the Lakes 380 team have carried out to date for Horizons includes a synopsis of what is known about the lakes in the Region and an estimated trophic lake index status for all lakes in the Region.<sup>28</sup> Additionally, an exploration of the history of changes to lake water quality and other indicators through the analysis of sediment cores for 14 lakes in the Region has been undertaken.<sup>29</sup>
- [101] The monitoring and further analysis I have described will be used to review the nutrient concentrations required in rivers and lakes to give effect to environmental outcomes when implementing the NPSFM,<sup>30</sup> and to inform the approaches to management of activities and resource use across the Region in the updated version of the One Plan. However, this work is ongoing, and in my opinion, it does not prevent PC2 being implemented to ensure progress is made towards water quality improvement at the earliest opportunity in the meantime.

## **O. CONCLUSION**

- [102] Nutrients, sediment and *E. coli* were identified as issues for water quality in the development of the One Plan. These are still issues today as Horizons works towards notifying an updated One Plan that implements the requirements of the NPSFM. Water quality continues to be degraded in target catchments. These catchments contain a range of IFLU activities.
- [103] PC2 seeks to limit the loss of nitrogen from IFLUs through a range of mechanisms, all of which involve the adoption of farm practice change. While the focus is on nitrogen leaching, these practice changes will have benefits for sediment, *E.coli* and phosphorus as well.
- [104] Implementation of the DV-PC2 nutrient management framework was modelled to show a modest improvement in water quality. Dr Snelder has

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<sup>28</sup> Wood et al, 2022.

<sup>29</sup> Wood et al (in press).

<sup>30</sup> National Policy Statement for Freshwater Management, clause 3.13.

concluded that the implementation of the risk assessment tool is likely to also achieve this modest improvement for water quality in the target water management sub-zones.

[105] PC2, with inclusion of the risk assessment tool, continues to provide an opportunity for water quality improvements by bringing unconsented existing IFLU into a workable regulatory framework.

[106] Further contaminant reductions will be required as part of the NPSFM freshwater plan change to achieve long-term water quality targets. However, PC2 does not prevent those changes occurring, and in the meantime, will benefit water quality.

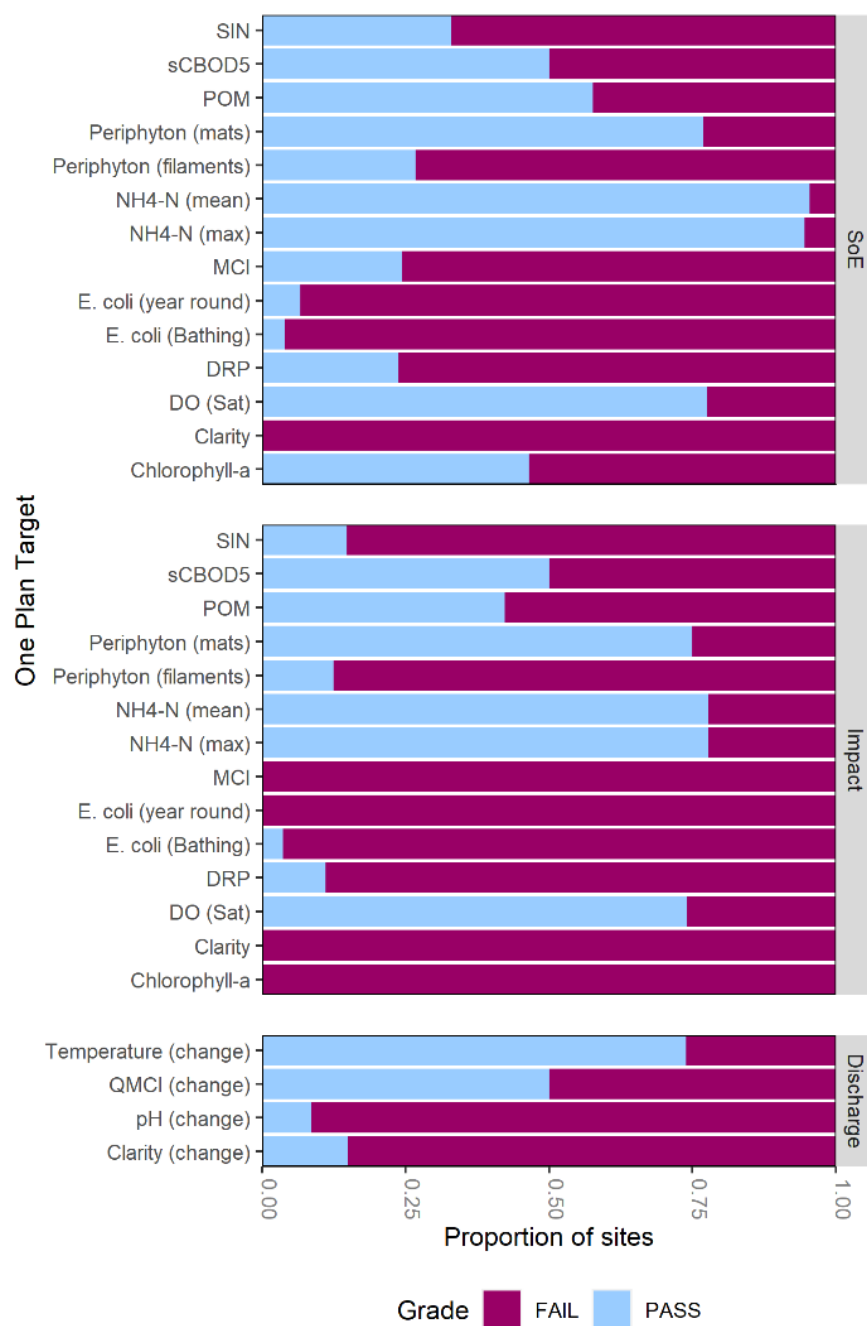
**6 October 2023**

**Maree Ellen Patterson**

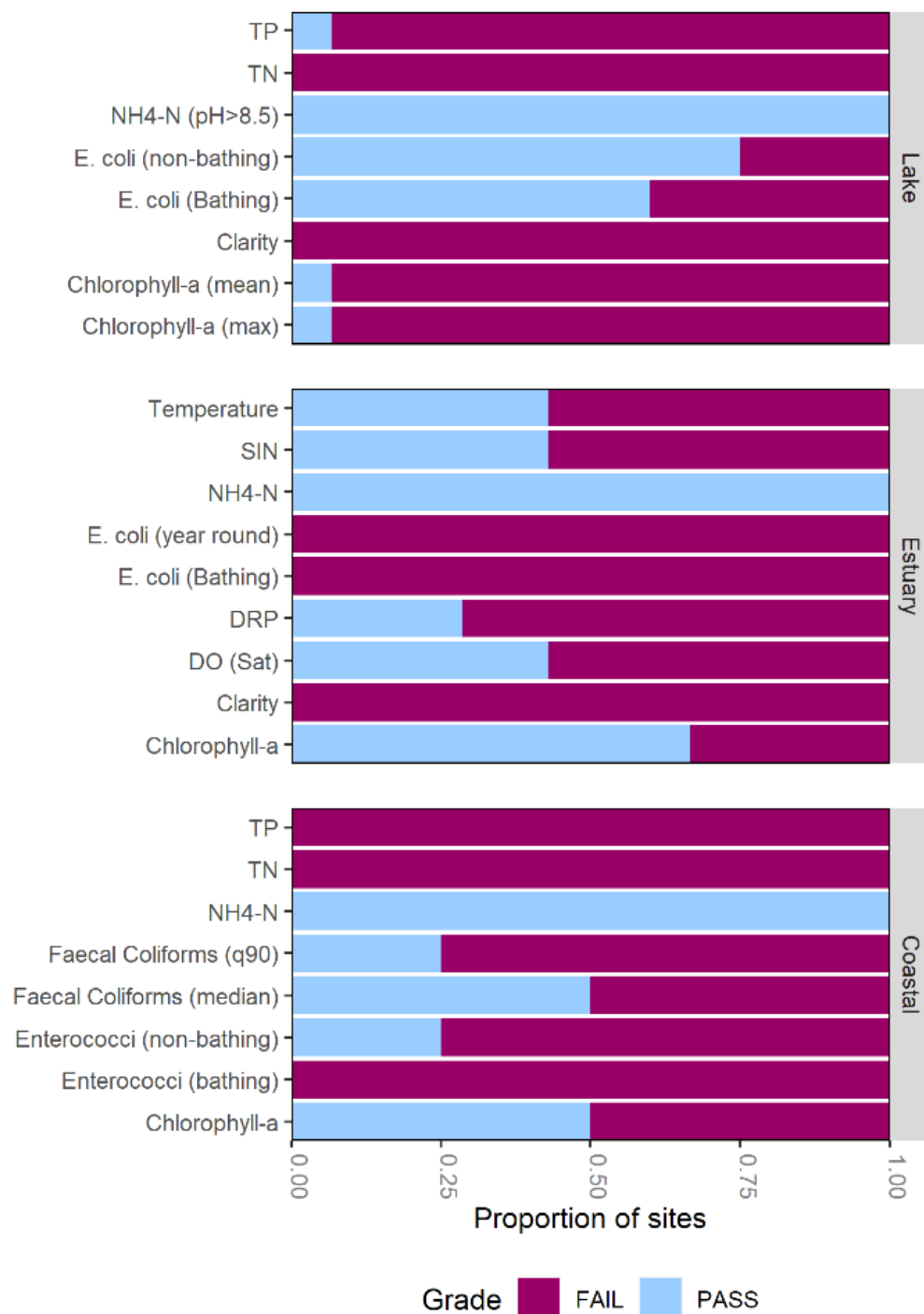


## P. ADDITIONAL FIGURES

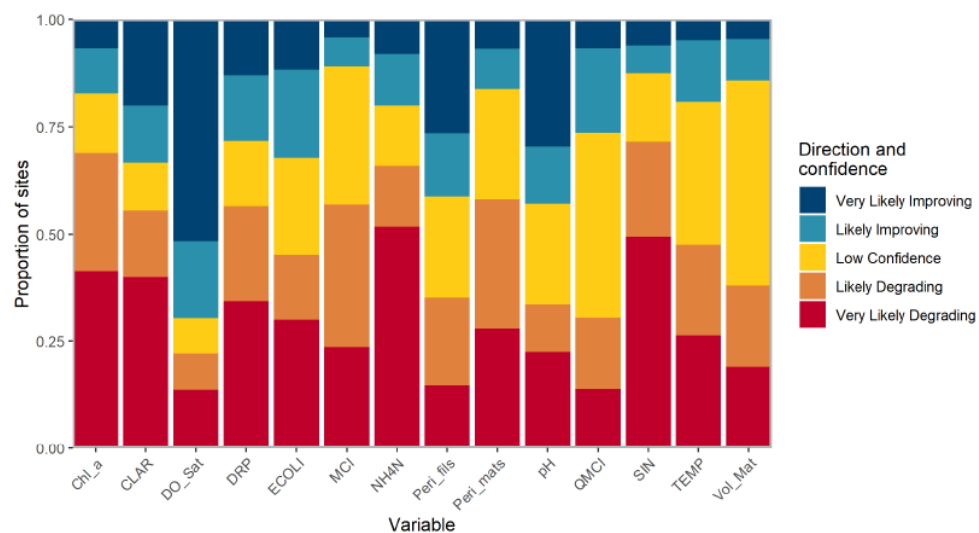
**Figure 2:** Summary statistics for River sites (by monitoring type that pass or fail One Plan Targets).



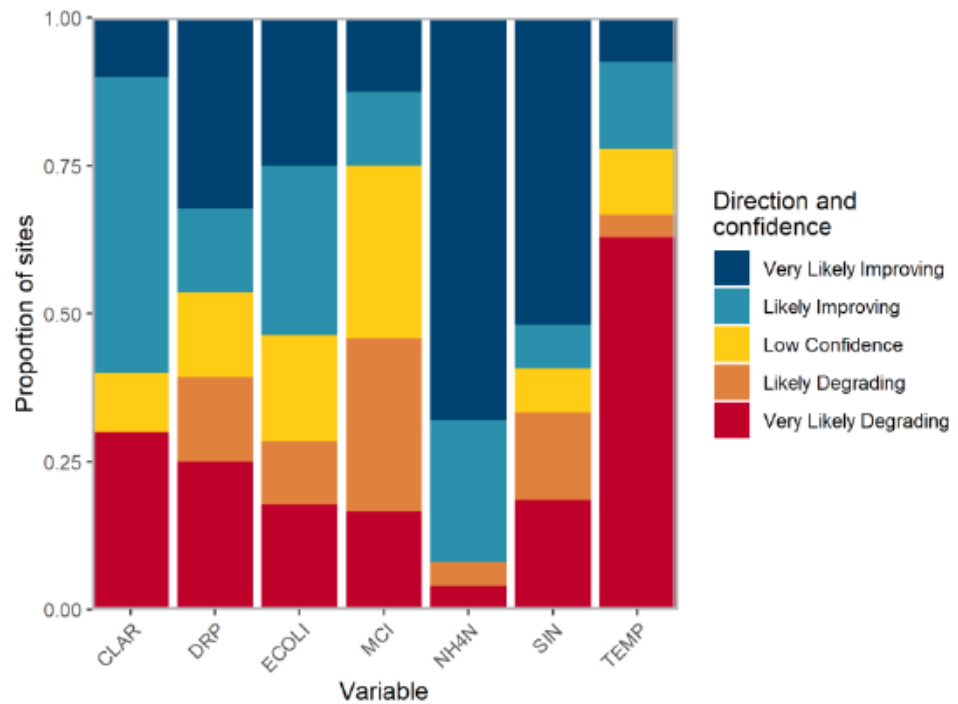
**Figure 3:** Summary statistics for Lake, estuary and coastal sites (by monitoring type that pass or fail One Plan Targets).



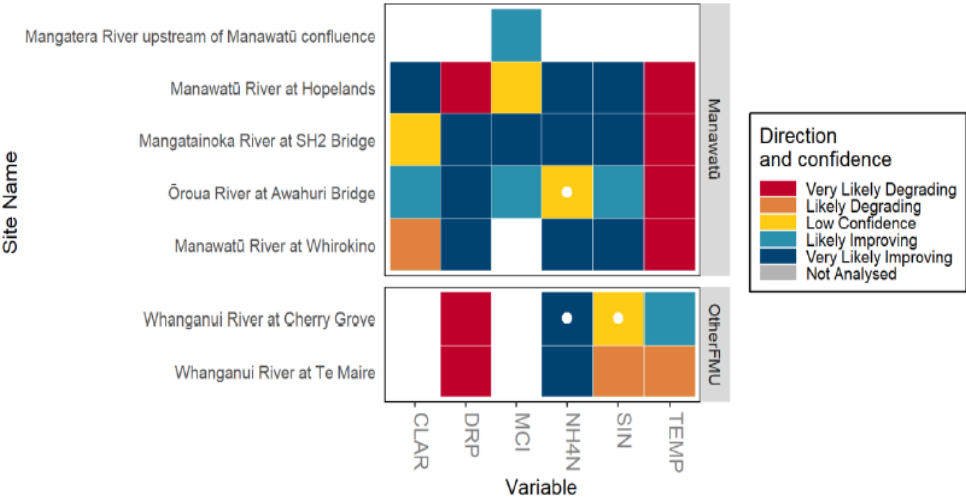
**Figure 4.** Summary plot representing the proportion of SoE river sites each categorical level of confidence and direction for 20-year time period trends. The plot shows the proportion of sites in each of the trend direction and confidence categories defined by LAWA.



**Figure 5.** Summary plot representing the proportion of SoE river sites each categorical level of confidence and direction for 20-year time period trends. The plot shows the proportion of sites in each of the trend direction and confidence categories defined by LAWA.



**Figure 6:** Assessed 30-year raw water quality trend at SoE sites classified by trend confidence and direction. Confidence and direction are expressed categorically based on the levels defined by LAWA. Sites with a Sen Slope of zero are indicated with a white dot.



## Q. REFERENCES

- **Biggs B. (2000).** New Zealand Periphyton Guidelines: Detecting, Monitoring and Managing Enrichment of Streams. Prepared for the Ministry for the Environment by the National Institute for Water and Atmospheric Research (NIWA).
- **Clothier B., Mackay A., Carran A., Gray R., Parfitt R., Francis G., Manning M., Duerer M. and Green S. (2007).** Farm Strategies for Contaminant Management: *A report by SLURI, the Sustainable Land Use Research Initiative, for Horizons Regional Council, Palmerston North, New Zealand.*
- **Cox T. and Snelder T. (2022a),** Manawatū-Whanganui Region Catchment Nutrient Models, Model Updates Supporting Regional Land and Water Management.
- **Cox T. and Snelder T. (2022b).** The Waiopēhu FMU Water Quality Model A tool for simulating catchment nutrient management options.
- **Eveleens R., Holmes R. and Young R. (2023).** Review of compatibility of Horizons One Plan targets with attributes and limits of the National Policy Statement for Freshwater Management. *Nelson: Cawthron Institute. Report prepared for Horizons Regional Council, September 2023.*
- **Fraser C. (2023).** State and Trends for water quality in rivers, lakes and coastal and estuary sites in the Manawatū-Whanganui Region for the period ending 30 June 2022. *LWP Ltd Report prepared for Horizons Regional Council November 2018.*
- **Fraser, C. and Snelder, T. (2018).** State and Trends of River Water Quality in the Manawatū-Whanganui Region: for all records up to 30 June 2017. *Land Water People Report prepared for Horizons Regional Council November 2018.*
- **Fraser, C. and Snelder, T. (2020).** Load calculations and spatial modelling of state, trends and contaminant yields: For the Manawatū-Whanganui Region to 30 June 2017. *LWP Client report prepared for Horizons Regional Council, May 2020.*

- **Gibbs M., Howard-Williams C., Watt A., Shenton C., Champion P., Schallenberg M., Kelly D., Matthews A., Kamke J., Daly E., Brown D. and Brown L. (2020)** Duddings Lake, *Horizons Regional Council Report No. 2020/EXT/1684*.
- **Horizons Regional Council (2023)** State of the Environment report -2023 <https://freshwater.horizons.govt.nz/science> accessed 1/10/2023.
- **Lucci G., Longhurst B., MacKay A. and Laurenson S. (2015)**. Sources of nitrogen, phosphorus and sediment in the Mangatainoka catchment. *Ag Research Report No. RE500/2016/007. Prepared for Dairy NZ and Horizons Regional Council*.
- **Marr H. (2009)** Section 42a report of Ms Helen Marie Marr on behalf of Horizons Regional Council. *Before the hearings panel in the matter of hearings on submissions concerning the Proposed One Plan notified by the Manawatū-Whanganui Regional Council*.
- **McArthur K., Roygard J., Marr H., James N., Barton C. and Gilliland B. (2010)**. End of Hearing report of Kate McArthur, Jon Roygard, Helen Marr, Natasha James, Clare Barton and Barry Gilliland on behalf of Horizons Regional Council. *Before the hearings panel in the matter of hearings on submissions concerning the Proposed One Plan notified by the Manawatū-Whanganui Regional Council*.
- **McDowell R.W., Monaghan R.M, Smith C., Manderson A., Basher L., Burger D.F., Laurenson S., Pletnyakova P., Spiekermann R. and Depree C. (2020)**. Quantifying contaminant losses to water from pastoral land uses in New Zealand III. What could be achieved by 2035? *New Zealand Journal of Agricultural Research*, <https://doi.org/10.1080/00288233.2020.1844763>.
- **McKay A. (2010)**. Section 42a report of Dr Alec Donald McKay on behalf of Horizons Regional Council. *Before the hearings panel in the matter of hearings on submissions concerning the Proposed One Plan notified by the Manawatū-Whanganui Regional Council*.

- **Ministry for the Environment and Ministry for Primary Industries (August 2021).** *The Government response to the finding of the Overseer peer review report.*
- **Monaghan R., Manderson A., Basher L., Spiekermann R., Dymond J., Smith C., Muirhead R., Burger D. and McDowell R. (2021).** Quantifying contaminant losses to water from pastoral land uses in New Zealand II. The effects of some farm mitigation actions over the past two decades. *New Zealand Journal of Agricultural Research*, DOI:10.1080/00288233.2021.1876741.
- **Recommendation Report of the Independent Hearing Panel – Plan Change 2 (March 2021).** *Recommendation Report of the Independent Hearing Panel appointed by the Manawatū-Whanganui Regional Council pursuant to section 34A of the Resource Management Act 1991.*
- **Rivas, A., Singh R., Horne, D., Roygard, J., Matthews, A., Hedley, M. (2020).** Contrasting subsurface denitrification characteristics under temperate pasture lands and its implications for nutrient management in agricultural catchments. *Journal of Environmental Management* 272 (2020) 111067. Retrieved from <https://doi.org/10.1016/j.jenvman.2020>.
- **Roygard J., (2009)** Section 42a report of Dr Jonathon Kelvin Fletcher Roygard on behalf of Horizons Regional Council. *Before the hearings panel in the matter of hearings on submissions concerning the Proposed One Plan notified by the Manawatū-Whanganui Regional Council.*
- **Roygard J. and Clark M. (2012),** Supplementary statement by Jon Roygard and Maree Clark on Nutrient Load Scenarios and Methodology. *Evidence to the environment court in the matter of appeals under clause 14 of the First Schedule to the Resource Management Act 1991 concerning proposed One Plan for the Manawatu-Whanganui region. between FEDERATED FARMERS OF NEW ZEALAND ENV-2010-WLG-000148 and MINISTER OF CONSERVATION ENV-2010-WLG-000150 and DAY, MR ANDREW ENV-2010-WLG-000158 and HORTICULTURE NEW ZEALAND ENV 2010-WLG-000155 and WELLINGTON*



*FISH & GAME COUNCIL ENV-2010-WLG-000157 Appellants and MANAWATŪ-WHANGANUI REGIONAL COUNCIL Respondent. 24<sup>th</sup> of February 2012.*

- **Snelder, T., (2018).** Assessment of Recent Reductions in *E. Coli* and Sediment in Rivers of the Manawatū-Whanganui Region. *LWP Ltd, Christchurch, New Zealand.*
- **Waters S., Kelly D., Doebling K., and Floerl L. (2018a).** Restoration planning for deep dune lakes: data review and recommendations. *Nelson: Cawthron Institute. Report No 3201. Prepared for Horizons Regional Council.*
- **Waters S., Kelly D., Doebling K., and Floerl L. (2018b).** Restoration planning for shallow dune lakes: data review and recommendations. *Nelson: Cawthron Institute. Report No 3202. Prepared for Horizons Regional Council.*
- **Wilcock B., Biggs B., Death R., Hickey C., Larned S. and Quinn J. (2007).** Limiting nutrients for controlling undesirable periphyton growth. Prepared for Horizons Regional Council. NIWA Client Report HAM2007-006.
- **Wood S., Hampton H., and Pearman J. (2022).** Lakes in the Manawatū-Whanganui Region with recommendations for further action. *Nelson: Cawthron Institute. Report prepared for Horizons Regional Council, August 2022.*
- **Wood S., Vandergoes M., Howarth J., Pearman J., Li X., Shepherd C., Gregersen R., Thomson-Laing G., Thompson L., Moody A., Waters S., Thomson-Laing J., Biessy L., Moy C., Short J., Tibby J., Martin R., Rees A., Dahl J., Reyes L., Crouch E., Tremain R., Te Koha TA., Yackulic E., McKay N. (In press).** Paleolimnological analysis of 14 lakes in the Manawatū-Whanganui Region. *Nelson: Cawthron Institute. Report 3949. Prepared for Horizons Regional Council.*
- **Woodward B. and Gibbs M. (2019)** ‘Legacy nutrient’ storage in the sediment of Lakes Pauri, Wiritoa, Waipu and Dudding; amounts, implications and treatment. *Niwa client report 2019267HN, prepared for Horizons Regional Council.*

- **Verburg P., Gibbs M., Albert A., and Olsen G., (2019).** Lake Horowhenua Sediment Legacy. *Niwa client report 2018245HN, prepared for Horizons Regional Council.*

**R. ATTACHMENTS****Attachment A:**

**Fraser C. (2023).** State and Trends for water quality in rivers, lakes and coastal and estuary sites in the Manawatū-Whanganui Region for the period ending 30 June 2022. *LWP Ltd Report prepared for Horizons Regional Council.*



# **State and trends for water quality in rivers, lakes, coastal and estuary sites in the Manawatū-Whanagnui Region**

For the period ending 30 June 2022

September 2023

Prepared for:

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# **State and trends for water quality in rivers, lakes, coastal and estuary sites in the Manawatū -Whanganui Region**

**For the period ending 30 June 2022**

**September 2023**

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## Executive Summary

This study analysed the available water quality data for rivers, lakes, estuaries, and coastal in the Manawātū-Whanganui Region. The state of water quality in the region is reported on a site-by-site basis, relative to targets set in the One Plan (Horizons Regional Council, 2014). In addition, the study assessed water quality trends site by site, reporting both for individual sites and variables, and as regional aggregates for each water quality variable.

We analysed water quality data representing 19 physico-chemical and microbiological variables and biological indicators (see Table 1 for variable names and abbreviations) for 207 monitoring sites in the region. The monitoring sites included river (181), coastal (4), estuary (7) and lake (15) locations. River sites were further categorised as State of the Environment - SoE (representative sites), impact (sites immediately downstream of known discharges) and discharge (effluent) sites. State and trends were evaluated for site type and variable combinations that had an associated One Plan target. Sites were graded as 'pass' or 'fail' for each variable based on a comparison of the assessed state with the One Plan criteria.

A trend assessment was carried out for 10-year, 20-year and 30-year periods to 30 June 2022 for all site and water quality variable combinations that met a minimum requirement for numbers of observations. The methods used for statistical trend analyses are Kendall's test of rank correlation and the Sen slope estimator (SSE), which have both been used for trend analysis of water quality for several decades (Hirsch et al., 1982). Individual site trend assessments were aggregated, to provide an overall picture of trends for the region. This was done graphically using stacked bar charts showing proportions of sites for each variable that fall into different trend direction confidence categories.

## Water quality state

The most obvious pattern associated with the assessment of water quality state was that for many variables the individual sites almost uniformly passed or failed One Plan criteria. A majority of river sites failed the Horizons One Plan criteria for dissolved reactive phosphorus (DRP), macroinvertebrate community index (MCI), *E. coli* and clarity. Conversely, almost all sites passed the One Plan criteria for ammoniacal-N (NH<sub>4</sub>-N), periphyton (mats) and dissolved oxygen (sat). There were similar numbers of State of Environment (SoE) sites passing and failing the One Plan criteria for chlorophyll-a, particulate organic matter (POM), periphyton (filaments) and soluble inorganic nitrogen (SIN). Generally, these patterns in grades were similar for the impact sites. A majority of discharge sites failed the One Plan criteria for change in pH, and percent reduction in clarity. Conversely, most discharge sites the passed the change in temperature criterion.

All lakes sites failed the total nitrogen (TN) criterion, and only Lake Kōitiata passed the chlorophyll-a and total phosphorus (TP) criteria. Grades varied across the region for the *E. coli* (bathing) criteria. For estuary sites, all sites failed *E. coli* criteria and passed NH<sub>4</sub>-N criteria and for coastal sites, all sites based the NH<sub>4</sub>-N criteria and failed the TN, TP and enterococci (bathing) criteria.

There are no immediately obvious geographic patterns associated with the variation in grades, however this does not mean that there are not associations with, for example, river size or catchment land cover. Summaries of the proportion of sites (by monitoring site type) that passed or failed the one plan criteria are shown in Figure A.



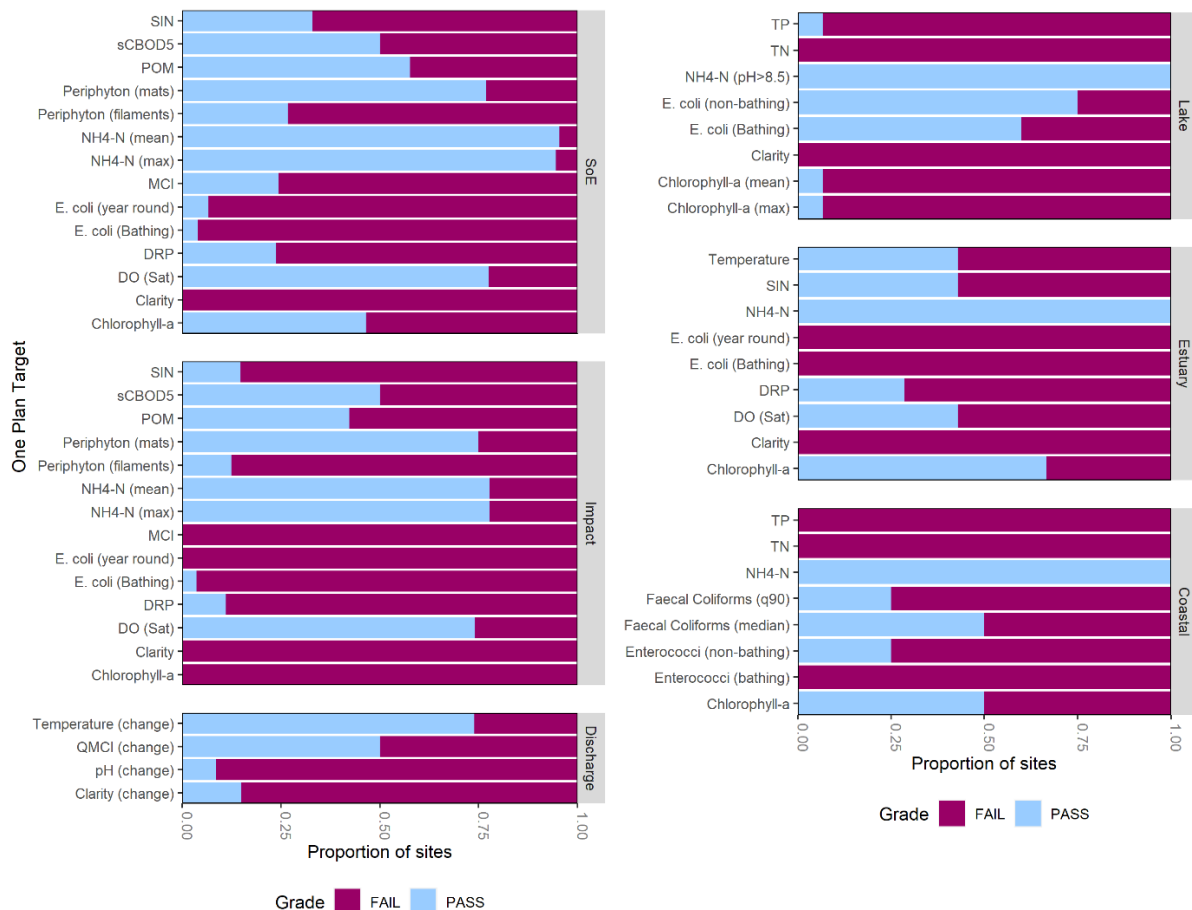


Figure A: Summary of proportions of sites (by monitoring type) that pass or fail One Plan targets.

## Water quality trends

Water quality trends for the 10 year period were assessed for up to 100 (of 112) river SoE sites, 27 (of 27) river impact sites, 24 (of 34) discharge sites, 4 (of 15) lake sites, 6 (of 7) estuary sites and 4 (of 4) coastal sites. Water quality trends for the 20 year period were assessed at up to 28 (of 112) river SoE sites and 2 (of 34) discharge sites. There were insufficient data to calculate 20 year trends at any lake, estuary, coastal or river impact sites. Water quality trends for the 30 year period were also calculated for up to 6 river SoE sites. The difference in numbers of sites between time periods and between total numbers reflects the significant expansion of Horizons Regional Council's river monitoring network over the period 2007-2010, and the lake monitoring network in recent years.

Figure B shows stacked bar charts showing aggregate trends (i.e., proportions of river sites in different trend direction confidence categories) for each variable. There was an insufficient number of sites to evaluate aggregate trends for lakes, coastal and estuaries. For the 10 year period and river SoE site trends, seven of the 15 water quality variables had more than half of sites categorised as "likely degrading" or "Very likely degrading" (Chlorophyll a (Chl\_a), visual clarity (CLAR), DRP, MCI, NH4N, periphyton mats (Peri\_mats), and SIN), whereas only two variables had more than half of sites classes as "likely improving" or "very likely improving" (Dissolved oxygen (DO\_Sat) and 5 day soluble carbonaceous biochemical oxygen demand (sCBOD5)). It is particularly noted that in previous trend assessments (and over the 20 year trend period) NH4N was dominated by improving trends. However, the majority of the NH4N



trends are evaluated as having a Sen slope of zero (i.e., below the rate of detection given by the detection limit and time period).

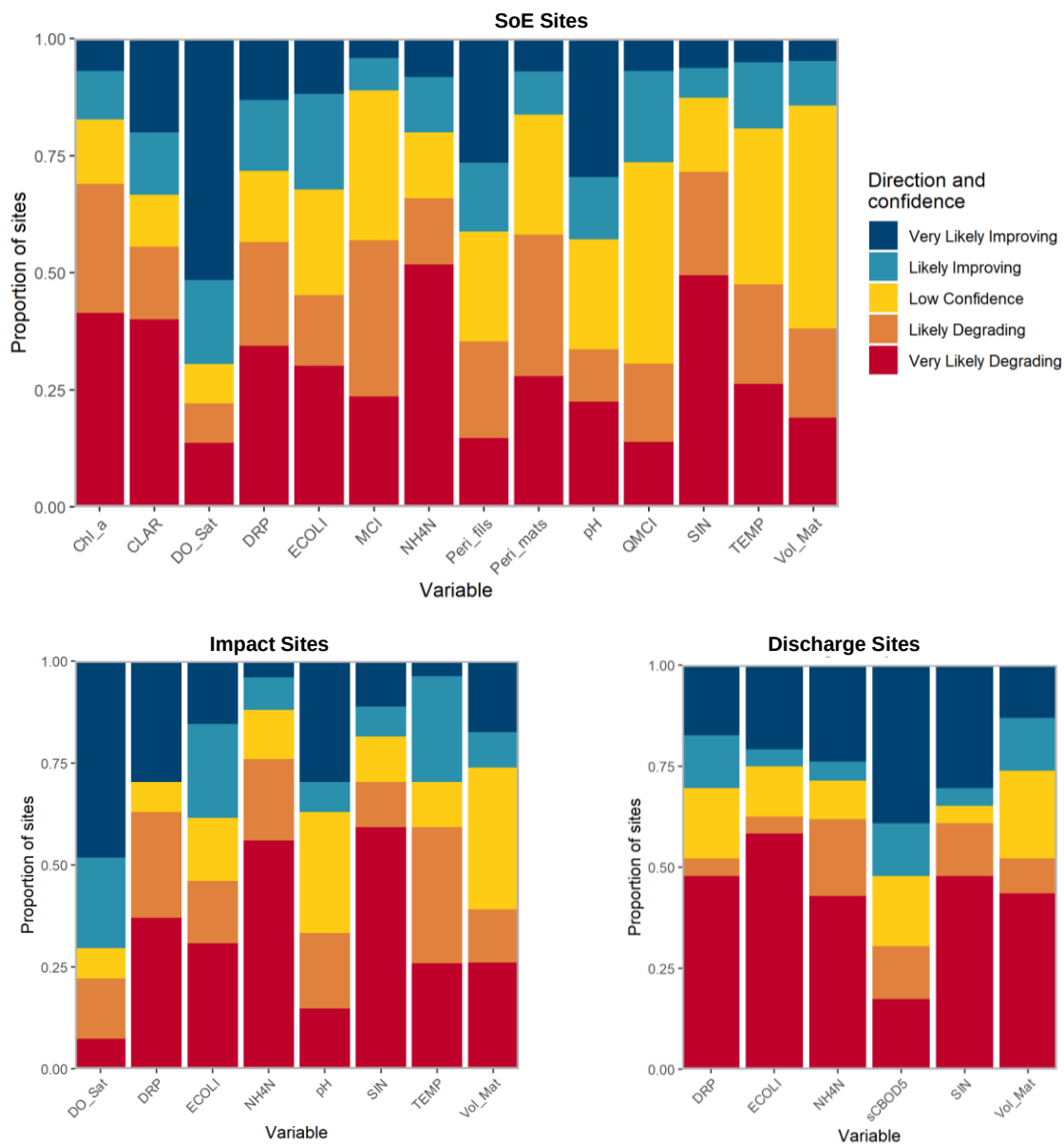


Figure B. Summary plot representing the aggregated proportion of 10-year time period trends for river (SoE, impact and discharge) sites at each categorical level of confidence and direction. The plot shows the proportion of sites in each of the trend direction and confidence categories defined in Table 3.

### Relationships between state and trends

For river and lake sites, the trends with the largest rates of degradation were associated with sites with poor state grades, almost uniformly across all variables. For *E. coli* in rivers, the largest improving trend rates were at sites that failed the One Plan criteria. At estuary sites, all but one site that failed the One Plan *E. coli* criteria had improving trends for *E. coli*. At both lakes and estuaries there was a pattern of larger degrading trend rates with larger (worse) water quality (based on compliance statistics). Trends in chlorophyll-a at coastal sites indicated improvement, both for sites that passed and failed the One Plan chlorophyll-a criterion.

## 1 Introduction

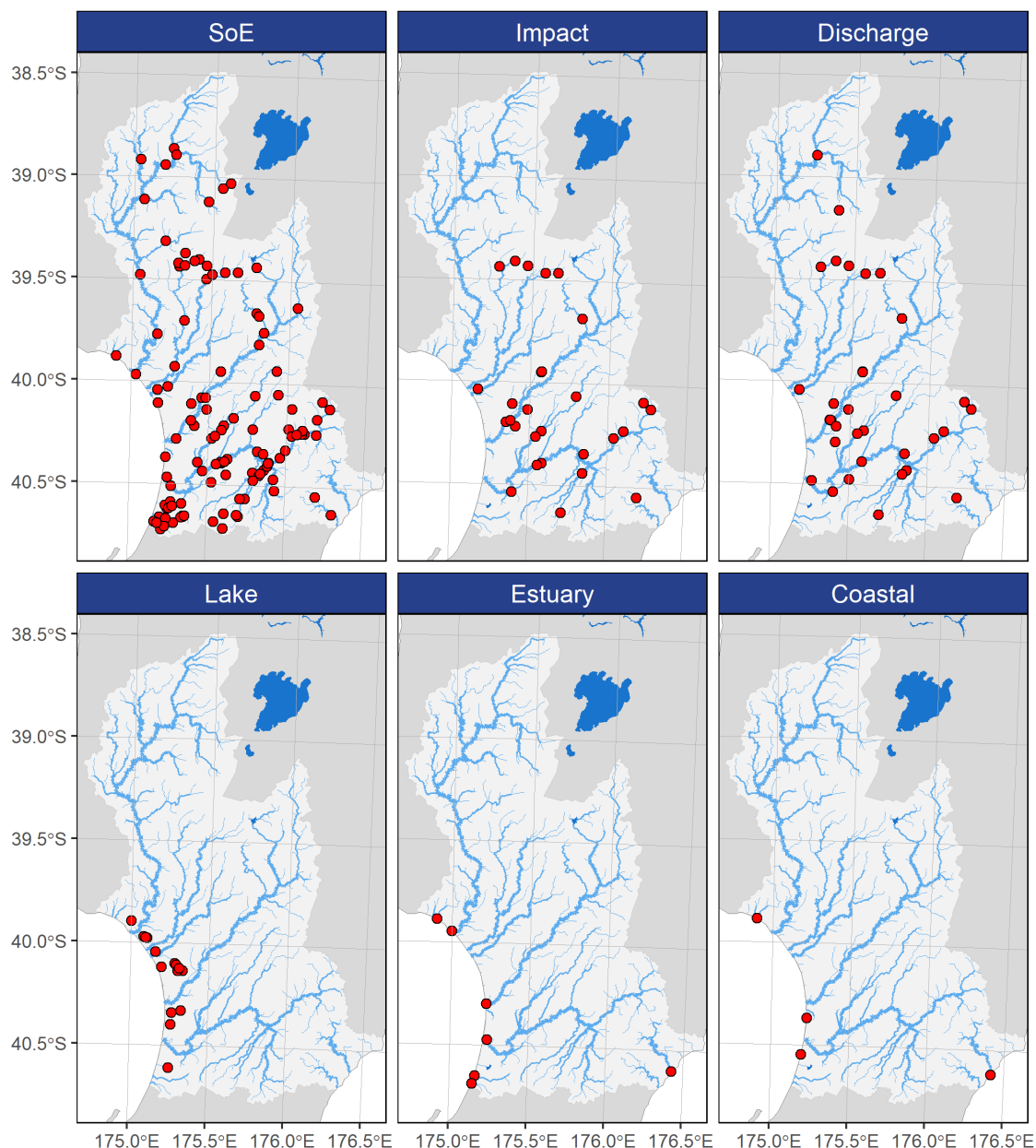
Horizons Regional Council operates an extensive network of water quality and flow monitoring sites throughout the Manawatū-Whanganui Region for monitoring the state and trends in water quality and reporting on policy effectiveness. Prior to mid-2007, there were fewer monitoring sites in the Region (Roygard et al., 2011). Following a review, a more extensive and detailed monitoring programme commenced for rivers in mid-2007 and was rolled out over three years. Since that date, a suite of variables, including physico-chemical and microbiological variables and biological indicators have been measured at 207 sites in the region. These data represent river (State of Environment (SoE), point source discharges and impact), lake (commenced 2014), estuary and coastal (beach) (commenced 2011) monitoring sites.

This study analysed the available water quality data for rivers, lakes, estuaries, and coast in the Manawatū-Whanganui Region. The state of water quality in the region is reported on a site by site basis, relative to targets set in the One Plan (Horizons Regional Council, 2014). In addition, the study assessed water quality trends site by site, and across the region as a whole.

## 2 Data

### 2.1 Water quality data

Water quality data were obtained representing physico-chemical variables, microbiological variables and biological indicators (Table 1) for 207 monitoring sites in the region from the Horizons database. These included river (181), coastal (4), estuary (7) and lake (15) sites (Figure 1).



*Figure 1: Locations of river (top row), lake, estuary and coastal monitoring sites in the Manawatu-Whanganui region that were included in this study.*

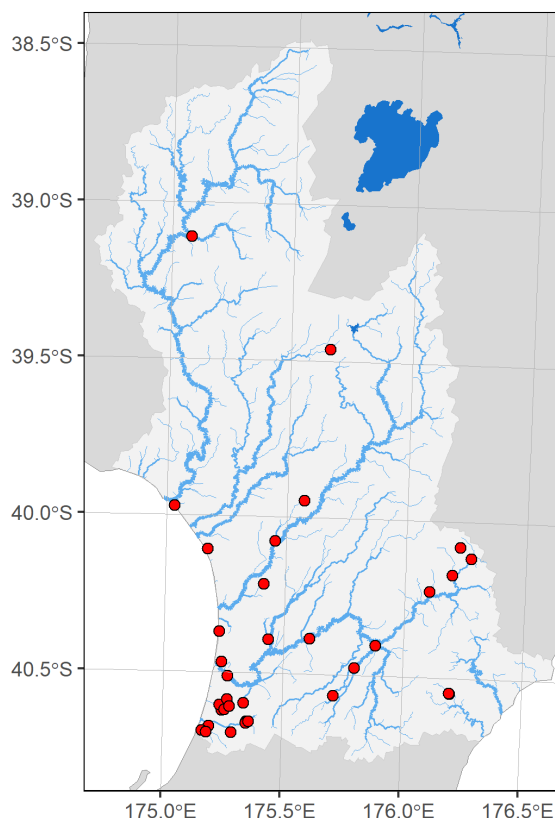
River sites were categorised into three types: discharge, impact and state of environment (SoE) (Figure 4). Discharge and impact sites represent specific point source discharges or locations downstream (at the end of the consented mixing zone) of significant and specific point sources, respectively. It has been assumed SoE sites are not significantly affected by point source discharges and that they reflect both state and trends arising from the combination of diffuse and point sources of contaminants occurring in their catchments. Therefore, SoE sites were assumed to be representative of general regional river water quality conditions. The three categories of river sites were analysed separately in the study.

Table 1: Water quality variables, measurement units and site numbers (by monitoring type) included in this study.

| Variable type     | Variable name      | Description                                    | Units                    | Monitoring site numbers by type |        |           |       |         |         |
|-------------------|--------------------|------------------------------------------------|--------------------------|---------------------------------|--------|-----------|-------|---------|---------|
|                   |                    |                                                |                          | SoE                             | Impact | Discharge | Lakes | Estuary | Coastal |
| Physico- Chemical | CLAR               | Black Disc Visibility                          | m                        | 110                             | 27     | 2         | 4     | 1       | 0       |
|                   | DO_Sat             | Field Dissolved Oxygen Saturation              | %                        | 112                             | 27     | 10        | 0     | 7       | 0       |
|                   | DRP                | Dissolved Phosphorous Reactive                 | g m <sup>-3</sup>        | 112                             | 27     | 34        | 0     | 7       | 0       |
|                   | NH4N               | Ammoniacal Nitrogen                            | g m <sup>-3</sup>        | 112                             | 27     | 34        | 15    | 7       | 4       |
|                   | pH                 | Field pH                                       | pH                       | 112                             | 27     | 10        | 0     | 1       | 0       |
|                   | Vol_Mat            | Volatile Matter                                | g m <sup>-3</sup>        | 88                              | 28     | 34        | 0     | 1       | 0       |
|                   | SIN                | Soluble Inorganic Nitrogen                     | g m <sup>-3</sup>        | 112                             | 27     | 34        | 0     | 7       | 0       |
|                   | Temp               | Field Temperature                              | °C                       | 112                             | 27     | 30        | 0     | 7       | 0       |
|                   | TN                 | Total Nitrogen                                 | g m <sup>-3</sup>        | 0                               | 0      | 0         | 15    | 0       | 4       |
|                   | TP                 | Total Phosphorous                              | g m <sup>-3</sup>        | 0                               | 0      | 0         | 15    | 0       | 4       |
| Micro-biological  | Ecoli              | <i>E. coli</i> by MPN                          | MPN 100mL <sup>-1</sup>  | 110                             | 27     | 34        | 15    | 7       | 0       |
|                   | Entci <sup>a</sup> | Enterococci                                    | MPN 100mL <sup>-1</sup>  | 0                               | 0      | 0         | 0     | 0       | 4       |
|                   | COLIF              | Faecal Coliforms                               | MPN 100mL <sup>-1</sup>  | 0                               | 0      | 0         | 0     | 0       | 4       |
| Biological        | Chl_a <sup>a</sup> | Chlorophyll-a (planktonic)                     | mg Chl-a m <sup>-3</sup> | 0                               | 0      | 0         | 15    | 6       | 4       |
|                   | Chl_a              | Chlorophyll-a (benthic)                        | mg Chl-a m <sup>-2</sup> | 60                              | 9      | 0         | 0     | 0       | 0       |
|                   | Peri_Fils          | Filamentous Periphyton cover                   | %                        | 61                              | 10     | 0         | 0     | 0       | 0       |
|                   | Peri_Mats          | Mat Periphyton Cover                           | %                        | 61                              | 10     | 0         | 0     | 0       | 0       |
|                   | MCI                | Macroinvertebrate Community Index              | MCI                      | 80                              | 7      | 0         | 0     | 0       | 0       |
|                   | QMCI               | Quantitative Macroinvertebrate Community Index | QMCI                     | 80                              | 7      | 0         | 0     | 0       | 0       |

## 2.2 Flow data

Many of the water quality monitoring sites were associated with flow records, which were also obtained from the Horizons database for 123 sites. Flow was needed for the state assessment as some of the environmental targets apply only when flows are in a certain range (see Section 3.2.1). There were two types of flow ranges used in the targets: below the 20<sup>th</sup> flow exceedance percentile (FEP) (4 targets for rivers, 3 targets for estuaries); and below the median flow (2 targets for each of rivers and estuaries). Horizons regional council staff estimated the relevant flow percentiles and assigned each daily observation of flow to one of three flow categories: (1) “below median”; (2) “median to 20<sup>th</sup> FEP”; and (3) “flood”. There were 36 flow sites with an associated water quality sites that had flow categories assigned. There were no flow records provided for estuaries.



*Figure 2: Map of flow monitoring locations with an associated water quality monitoring site and assigned flow categories.*

## 3 Methods

### 3.1 State analysis

#### 3.1.1 Grading of monitoring sites

Sites are graded based on comparing a compliance statistic against Horizons One Plan targets (Table 2; Horizons Regional Council, 2014). For each One Plan target, a “compliance statistic” is calculated and compared to the target e.g., for a site, the mean of ammoniacal-nitrogen is calculated from the water quality record (the compliance statistic) and evaluated as passing or failing, depending on whether the compliance statistic is less than or greater than the One Plan target of 0.4 or 0.32 mg/l (the criteria, which varies by site), respectively. It is noted that, depending on the variable, the observations needed to be either lower than the threshold (e.g., all chemical concentration targets, periphyton abundance targets) or greater than the threshold (e.g., clarity and MCI targets). In the cases where the compliance statistic is a quantile (i.e., the median or 90<sup>th</sup> percentile), the Hazen method was used to calculate the appropriate quantile, following the recommendation in the New Zealand Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas (Ministry for Environment & Ministry of Health, 2003).

The numeric values for Horizons One Plan targets for many variables vary by site based on varying expectations for environmental outcomes (details are provided in Appendix A). Several of the Horizons One Plan targets consider only sampling occasions associated with specified dates or flows (Table 2). This reflects considerations associated with the effects of

the contaminant. For example, nutrients and microbial contaminants are of less concern during high flows. The bathing water microbial concentration targets (*E. coli* (Bathing); Table 2) only apply to the summer season when swimming is likely. These additional details for how the threshold values are compared to observations are provided for each variable in Table 2.

Criteria for discharge sites are based on the change in state between an associated downstream impact site and an upstream SoE site. Appendix B provides a list of the point source discharges and their associated upstream (SoE) and downstream (impact) monitoring sites.

For sites where there was no appropriate flow data available, but where the targets are based on sampling occasions associated with a flow constraint, targets were evaluated against *all* available data; sites for which this has been done are highlighted in the results.

*Table 2: Details of the Horizons One Plan targets for each water quality variable used to grade the state of the river, discharge, lake, estuary and coastal sites.*

|       | Target name                 | Compliance statistic <sup>1</sup> | Flow constraint <sup>2</sup> | Target description                                                                                                                                                                                                                                 |
|-------|-----------------------------|-----------------------------------|------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| River | Chlorophyll-a               | Maximum                           | 100                          | The algal biomass on the river bed must not exceed [...] milligrams of chlorophyll-a per square metre.                                                                                                                                             |
|       | Clarity                     | Minimum                           | 50                           | The visual clarity of the water <sup>^</sup> measured as the horizontal sighting range of a black disc must equal or exceed [...] metres when the river <sup>^</sup> is at or below the 50 <sup>th</sup> flow exceedance percentile..              |
|       | DO (Sat)                    | Minimum                           | 100                          | The Dissolved oxygen (DO) must exceed [...]³% of saturation.                                                                                                                                                                                       |
|       | DRP                         | Mean                              | 80                           | The annual average concentration of dissolved reactive phosphorus (DRP) when the river flow is at or below the 20 <sup>th</sup> flow exceedance percentile must not exceed [...] grams per cubic metre, unless natural levels already exceed this. |
|       | <i>E. coli</i> (Bathing)    | Maximum                           | 50                           | The concentration of <i>Escherichia coli</i> must not exceed [...] per 100 millilitres between 1 November - 30 April (inclusive) when the river <sup>^</sup> flow is at or below the 50 <sup>th</sup> flow exceedance percentile*.                 |
|       | <i>E. coli</i> (year round) | Maximum                           | 80                           | The concentration of <i>Escherichia coli</i> must not exceed [...] per 100 millilitres year-round when the river <sup>^</sup> flow is at or below the 20 <sup>th</sup> flow exceedance percentile*.                                                |
|       | MCI                         | Minimum                           | 100                          | The Macroinvertebrate Community Index (MCI) must exceed [...]⁴.                                                                                                                                                                                    |
|       | NH4-N (max)                 | Maximum                           | 100                          | The maximum concentration of ammoniacal-N must not exceed [...] grams per cubic metre.                                                                                                                                                             |
|       | NH4-N (mean)                | Mean                              | 100                          | The average concentration of ammoniacal-N must not exceed [...] grams per cubic metre.                                                                                                                                                             |
|       | Periphyton (filaments)      | Maximum                           | 100                          | The maximum cover of the visible river bed by periphyton as filamentous algae more than 2 centimetres long must not exceed [...]%.                                                                                                                 |
|       | Periphyton (mats)           | Maximum                           | 100                          | The maximum cover of visible river bed by periphyton as diatoms or cyanobacteria more than 0.3 centimetres thick must not exceed [...]%.                                                                                                           |

|           | Target name           | Compliance statistic <sup>1</sup> | Flow constraint <sup>2</sup> | Target description                                                                                                                                                                                                                              |
|-----------|-----------------------|-----------------------------------|------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|           | POM                   | Mean                              | 50                           | The average concentration of particulate organic matter when the river flow is at or below 50th flow exceedance percentile must not exceed [...] grams per cubic meter.                                                                         |
|           | sCBOD5                | Maximum                           | 80                           | The monthly average five-days filtered / soluble carbonaceous biochemical oxygen demand (sCBOD5) when the river <sup>^</sup> flow is at or below the 20th flow exceedance percentile must not exceed [...] grams per cubic metre.               |
|           | SIN                   | Maximum                           | 80                           | The annual average concentration of soluble inorganic nitrogen (SIN) when the river flow is at or below the 20 <sup>th</sup> flow exceedance percentile must not exceed [...] grams per cubic metre, unless natural levels already exceed this. |
| Discharge | pH (change)           | abs(Maximum)                      | 100                          | The pH of the water must not be changed by more than [...].                                                                                                                                                                                     |
|           | Temperature (change)  | abs(Maximum)                      | 100                          | The temperature of the water must not be changed by more than [...] degrees Celsius.                                                                                                                                                            |
|           | Clarity (change)      | Maximum                           | 100                          | The visual clarity of the water measured as the horizontal sighting range of a black disc must not be reduced by more than [...] %.                                                                                                             |
|           | QMCI (change)         | Maximum                           | 100                          | There must be no more than a 20% reduction in Quantitative Macroinvertebrate Community Index (QMCI) score between appropriately matched habitats upstream and downstream of discharges to water.                                                |
| Lake      | Chlorophyll-a (mean)  | Mean                              | NA                           | The annual average algal biomass must not exceed [...] milligrams chlorophyll a per cubic metre.                                                                                                                                                |
|           | Chlorophyll-a (max)   | Maximum                           | NA                           | Samples must not exceed [...] milligrams chlorophyll a per cubic metre.                                                                                                                                                                         |
|           | Clarity               | Minimum                           | NA                           | The visual clarity of the water <sup>^</sup> measured as the horizontal sighting range of a black disc must equal or exceed [...] metres.                                                                                                       |
|           | E. coli (Bathing)     | Maximum                           | NA                           | The concentration of Escherichia coli must not exceed [...] per 100 millilitres 1 November - 30 April (inclusive).                                                                                                                              |
|           | E. coli (non-bathing) | Maximum                           | NA                           | The concentration of Escherichia coli must not exceed [...] per 100 millilitres 1 May - 31 October (inclusive).                                                                                                                                 |
|           | NH4-N (pH>8.5)        | Maximum                           | NA                           | The concentration of ammoniacal nitrogen must not exceed [...] grams per cubic metre when lake pH exceeds 8.5 within the epilimnion (shallow lakes) or within 2m of the water <sup>^</sup> surface (deep lakes).                                |
|           | TN                    | Mean                              | NA                           | The annual average concentration of total nitrogen must not exceed [...]grams per cubic metre.                                                                                                                                                  |
|           | TP                    | Mean                              | NA                           | The annual average concentration of total phosphorus (TP) must not exceed [...] grams per cubic metre.                                                                                                                                          |
| Coastal   | Chlorophyll-a         | Mean                              | NA                           | The annual average algal biomass must not exceed [...] milligrams of chlorophyll a per cubic metre.                                                                                                                                             |
|           | Enterococci (bathing) | Maximum                           | NA                           | The concentration of enterococci must not exceed [...] per 100 millilitres 1 November - 30 April (inclusive).                                                                                                                                   |



|         | Target name               | Compliance statistic <sup>1</sup> | Flow constraint <sup>2</sup> | Target description                                                                                                                                                                                                                              |
|---------|---------------------------|-----------------------------------|------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|         | Enterococci (non-bathing) | Maximum                           | NA                           | The concentration of enterococci must not exceed [...] per 100 millilitres 1 May - 31 October (inclusive).                                                                                                                                      |
|         | Faecal Coliforms (median) | Median                            | NA                           | The median concentration of faecal coliforms must not exceed [...] per 100 millilitres.                                                                                                                                                         |
|         | Faecal Coliforms (q90)    | 90th                              | NA                           | The 90th percentile concentration of faecal coliforms must not exceed [...] per 100 millilitres.                                                                                                                                                |
|         | NH4-N                     | Mean                              | NA                           | The average concentration of ammoniacal nitrogen must not exceed [...] grams per cubic metre.                                                                                                                                                   |
|         | TN                        | Mean                              | NA                           | The annual average concentration of total nitrogen must not exceed [...]grams per cubic metre.                                                                                                                                                  |
|         | TP                        | Mean                              | NA                           | The annual average concentration of total phosphorus (TP) must not exceed [...] grams per cubic metre.                                                                                                                                          |
| Estuary | Chlorophyll-a             | Mean                              | 100                          | The annual average algal biomass must not exceed [...] milligrams of chlorophyll a per cubic metre.                                                                                                                                             |
|         | Clarity                   | Minimum                           | 50                           | The visual clarity of the water <sup>4</sup> measured as the horizontal sighting range of a black disc must equal or exceed [...] metres when the river <sup>4</sup> is at or below the 50 <sup>th</sup> flow exceedance percentile..           |
|         | DO (Sat)                  | Minimum                           | 100                          | The concentration of dissolved oxygen must exceed [...] % of saturation.                                                                                                                                                                        |
|         | DRP                       | Mean                              | 80                           | The annual average concentration of dissolved reactive phosphorus (DRP) when the river <sup>4</sup> flow is at or below the 20th flow exceedance percentile* must not exceed [...] grams per cubic metre.                                       |
|         | E. coli (Bathing)         | Maximum                           | 50                           | The concentration of <i>Escherichia coli</i> must not exceed [...] per 100 millilitres between 1 November - 30 April (inclusive) when the river <sup>4</sup> flow is at or below the 50 <sup>th</sup> flow exceedance percentile*.              |
|         | E. coli (year round)      | Maximum                           | 80                           | The concentration of <i>Escherichia coli</i> must not exceed [...] per 100 millilitres year-round when the river <sup>4</sup> flow is at or below the 20 <sup>th</sup> flow exceedance percentile*.                                             |
|         | NH4-N                     | Mean                              | 100                          | The average concentration of ammoniacal-N must not exceed [...] grams per cubic metre.                                                                                                                                                          |
|         | SIN                       | Mean                              | 80                           | The annual average concentration of soluble inorganic nitrogen (SIN) when the river flow is at or below the 20 <sup>th</sup> flow exceedance percentile must not exceed [...] grams per cubic metre, unless natural levels already exceed this. |
|         | Temperature               | Maximum                           | 100                          | The temperature of the water <sup>4</sup> must not exceed [...] degrees Celsius.                                                                                                                                                                |

- Where all observations must comply with the target, the compliance statistic is either "Minimum" or "Maximum". Where a statistic of the observation's distribution must comply, the compliance statistic is shown as "Mean" or "Median" percentile (i.e. 80, 90 or 95).
- The maximum flow percentile for an observation to be included in the analysis.
- The symbol [...] indicates that the thresholds used were variable and site specific. The thresholds for all sites are provided in Appendix A.
- Unless natural physical conditions are beyond the scope of application of the MCI. In cases where the river<sup>4</sup> habitat is suitable for the application of the soft-bottomed variant of the MCI (sb-MCI) the Water Quality



### 3.1.2 Handling censored values

Censored values were replaced by imputation for the purposes of calculating the compliance statistics. Left censored values (values below the detection limit(s)) were replaced with imputed values generated using ROS (Regression on Order Statistics; Helsel, 2012) following the procedure described in Larned *et al.* (2015). The ROS procedure produces estimated values for the censored data that are consistent with the distribution of the uncensored values and can accommodate multiple censoring limits. When there are insufficient non-censored data to evaluate a distribution from which to estimate values for the censored observations, censored values are replaced with half of their reported value.

Censored values above the detection limit were replaced with values estimated using a procedure based on survival analysis (Helsel, 2012). A parametric distribution is fitted to the uncensored observations and then values for the censored observations are estimated by randomly sampling values larger than the censored values from the distribution. The survival analysis requires a minimum number of observations for the distribution to be fitted; hence in the case that there were fewer than 24 observations, censored values above the detection limit were replaced with  $1.1 \times$  the detection limit. The supplementary file outputs provide details about whether and how imputation was conducted for each site by target assessment.

### 3.1.3 Time period for assessments

When grading sites based on water quality targets, it is general practice to define consistent time periods for all sites and to define the acceptable proportion of missing observations (i.e., data gaps) and how these are distributed across sample intervals so that site grades are assessed from reasonably comparable data. The time period, acceptable proportion of gaps and representation of sample intervals by observations within the time period are commonly referred to as site inclusion or filtering rules (e.g., Larned *et al.*, 2018).

The current state grading assessments were made for the 5-year time period to end of June 2022. Additionally, rolling state grading assessments for 5-year period windows between July and June were performed over the full length of the records. This involved starting with the first 5-year window of the record, evaluating the state, then shifting the 5-year window incrementally by 1-year and re-evaluating state until the end of the record (which aligns with the current state assessment).

State was assessed based on 5 years of observations because the statistical precision of the compliance statistics depends on the variability of the water quality observations and the number of observations. For a given level of variability, the precision of a compliance statistic increases with the number of observations. This is particularly important for sites that are close to a threshold defined by an attribute band because the confidence that the assessment of state is 'correct' (i.e., that the site has been correctly graded) increases with the precision of the compliance statistics (and therefore with the number of observations). As a general rule, the rate of increase in the precision of compliance statistics decreases for sample sizes greater than 30 (i.e., there are diminishing returns on increasing sample size with respect to precision (and therefore confidence in the assigned grade) above this number of observations; McBride, 2005). In this study, a period of five years represented a reasonable trade-off for most of the attributes because it yielded a sample size of 30 or more observations for many sites and attribute combinations.

Grades at sites that had at least 30 observations (or 5 for annually monitored variables) are given a grade status of "final". In addition, "interim" results are provided for sites with at least 10 observations (monthly monitoring) or 3 observations (annual monitoring). Site grades

which do not meet the final or interim inclusion criteria are not presented in this report but are available in the supplementary materials.

## 3.2 Trend analysis

### 3.2.1 Sampling dates, seasons and time periods for analyses

In trend assessments, there are several reasons why it is important to define the trend period and seasons and to assess whether the observations are adequately distributed over time. First, because variation in many water quality variables is associated with the time of the year or “season”, the robustness of trend assessment is likely to be diminished if the observations are biased to certain times of the year. Second, a trend assessment will always represent a time period; essentially that defined by the first and last observations. The assessment’s characterisation of the change in the observations over the time period will not be robust if the observations are not reasonably evenly distributed across the time period. For these reasons, important steps in the data compilation process include specifying the seasons, the time period, and ensuring adequately distributed data.

Monitoring programs are generally designed to sample with a set frequency, (e.g., monthly, quarterly). The trend analysis ‘season’ is generally specified to match this sampling frequency (e.g., seasons are months, or quarters). There is therefore generally an observation for each sample interval (i.e., each season, such as month or quarter, within each year). Sampling frequency for some variables is annually. For example, annual sampling is common for biological sampling such as macro-invertebrates. In this case the ‘season’ is specified by the year.

Two common deviations from the prescribed sampling regime are (1) the collection of more than one observation in a sample interval (e.g., two observations within a month) and (2) a change in sampling interval within the time period. For type (1) deviations, the median within each sample interval was used. For type (2) deviations, the sampling interval was coarsened to define seasons for the part of the record with the higher sampling frequency. This was achieved by taking the observation in the higher frequency part of the record that was closest to the midpoint of the seasons defined by the coarser part of the record. The reason for not using the median value in this case is that it will induce a trend in variance, which will invalidate the distributional assumptions of the Mann Kendall S test statistic (Helsel et al., 2020).

River dissolved oxygen data was provided as a time series of daily minima for some sites. For the trend assessments, this data is coarsened to a monthly sampling interval. This was done by taking the observation associated with the mid-point of the month. The coarsening of the dissolved oxygen time series was considered necessary for two reasons. Firstly, for water quality variables as sampling frequencies increase, the autocorrelation between observations generally increases. Autocorrelation of samples violates the assumption of the Mann Kendall test that samples are independent (see section 3.2.4). Secondly, to allow robust comparison of trends between sites and variables at the regional level, it is useful to have similar levels of statistical power between assessments, and therefore to have similar numbers of samples for each trend period.

The trend for all site and variable combinations was characterised by the rate of change of the central tendency of the observations through time. Because water quality is constantly varying through time, the evaluated rate of change depends on the time-period over which it is assessed (e.g., Ballantine *et al.*, 2010; Larned *et al.*, 2016). Therefore, trend assessments are

specific for a given period of analysis. HRC requested that trend periods of 10, 20 and 30 years, ending on 30 June 2022, be evaluated.

For a regional study that aims to allow robust comparison of trends between sites and to provide a synoptic assessment of trends across a whole region, such as the present study, it is important that the trends evaluated at each site are commensurate in terms of their statistical power and representativeness of the time period. In these types of studies, it is general practice to define consistent time periods (i.e., trend duration and start date) so that all sites are subjected to the same conditions (i.e., equivalent political, climate, economic conditions). It is also general practice to define the acceptable proportion of gaps and how these are distributed across sample intervals so that the reported trends are assessed from comparable data. The acceptable proportion of gaps and representation of sample intervals by observations within the time period are commonly referred to as site inclusion or filtering rules (e.g., Larned *et al.*, 2018) but this is also termed ‘site screening criteria’ and ‘completeness criteria’.

There are no specific data requirements or filtering rules for trend assessments performed over many sites and variables such as the present study. The definition of filtering rules is complicated by a trade-off: more restrictive rules increase the robustness of the individual trend analyses but will generally exclude a larger number of sites thereby reducing spatial coverage. In general, this trade-off is also affected by the duration of trend period. Steadily increasing monitoring effort over time means that shorter and more recent trend periods will generally have a larger number of eligible sites.

The application of filtering rules for variables that are measured at quarterly intervals or more frequently requires two steps. First, retain sites for which observations are available for at least  $X\%$  of the years in the time period. Second, retain sites for which observations are available for at least  $Y\%$  of the sample intervals. For variables that are measured annually such as MCI, the filtering rules are applied by retaining sites for which values are available for at least  $X\%$  of the years in the trend period.

In this study, filtering rules applied by Larned *et al.* (2019) were used, which set  $X$  and  $Y$  to 80%. Further, the definition of seasons was flexible for lakes, estuaries and coastal sites in order to maximise the number of sites that were included. If the site failed to comply with filter rule (2) when seasons were set as months, a coarsening of the data to quarterly seasons was applied and the filter rule (2) was reassessed. If the data then complied with filter rule (2), the trend results based on the coarser (i.e., quarterly) seasons were retained for reporting. It is noted that the filtering rules imply a tolerance of variable levels of statistical power and temporal representativeness across the sites that were included in the analysis.

### 3.2.2 Handling censored values

For several water-quality variables, true values are occasionally too low or too high to be measured with precision. These measurements are called censored values. The “detection limit” is the lowest value that can be measured by an analytical method (either a laboratory measurement or a measurement made in the field) and the “reporting limit” is the greatest value of a variable that can be measured. Water-quality datasets from New Zealand rivers and lakes often include DRP, TP and NH<sub>4</sub>N measurements that are censored because they are below detection limits, and ECOLI and CLAR measurements that are censored because they are above reporting limits.

Censored values are managed in a special way by the non-parametric trend assessment methods described in section 3.2.4. It is therefore important that censored values are correctly

identified in the data. Detection limits or reporting limits that have changed through the trend time period (often due to analytical changes) can induce trends that are associated with the changing precision of the measurements rather than actual changes in the variable. This possibility needs to be accounted for in the trend analysis and this is another reason that it is important that censored values are correctly identified in the data.

A “high-censor” filter was applied in the trend assessments to minimise biases that might be introduced due to changes in detection limits through the trend assessment period. The high-censor filter identifies the highest detection limit for each water quality variable in the trend assessment period (or some nominated highest detection limit) and replaces all observations below this level with the highest detection limit and identifies these as censored values.

The water quality datasets included a small number of left censored values that were much larger than the apparent detection limit at any given time (outliers). Unsupervised application of the high-censor filter in these circumstances can lead to the unnecessary loss of statistical power in the assessment. To avoid this problem, the following approach was employed. It was expected that systematic changes in detection limit would be relatively consistent for a variable across a monitoring domain (i.e., lakes, rivers, coastal). To explore patterns in detection level, left censored data was plotted over time by variable and domain and used these plots to identify the occurrence of outliers. A maximum realistic detection level was identified for each variable and domain (e.g., rivers, lakes, coastal, estuary) and the high-censor level was capped at these values.

### 3.2.3 Seasonality assessment

For many site/variable combinations, observations vary systematically by season (e.g., by month or quarter). In cases where seasons are a major source in variability, accounting for the systematic seasonal variation should increase the statistical power of the trend assessment (i.e., increase the confidence in the estimate of direction and rate of the trend). The purpose of a seasonality assessment is to identify whether seasons explain variation in the water quality variable. If this is true, then it is appropriate to use the seasonal versions of the trend assessment procedures at the trend assessment step (Section 3.2.4).

Seasonality was evaluated using the Kruskal-Wallis multi-sample test for identical populations. This is a non-parametric ANOVA that determines the extent to which season explains variation in the water quality observations. Following Hirsch *et al.* (1982), site/variable combinations were identified as being seasonal based on the  $p$ -value from the Kruskal-Wallis test with  $\alpha=0.05$ . For these sites/variable combinations, subsequent trend assessments followed the “seasonal” variants, described in section 3.2.4.

The choice of  $\alpha$  is subjective and a value of 0.05 is associated with a very high level of certainty (95%) that the data exhibit a seasonal pattern. In our experience there are generally diminishing differences between the seasonal and non-seasonal trend assessments for seasonality test  $p$ -values values larger than 0.05 (Helsel *et al.*, 2020).

### 3.2.4 Analysis of trends

The purpose of trend assessment is to evaluate the direction (i.e., increasing or decreasing) and rate of the change in the central tendency of the observed water quality values over the period of analysis (i.e., the trend). Because the observations represent samples of the water quality over the period of analysis, there is uncertainty about the conclusions drawn from their analysis. Therefore, statistical models are used to determine the direction and rate of the trend and to evaluate the uncertainty of these determinations.

Trends were evaluated using the LWPTrends functions (Snelder & Fraser, 2021) that are implemented in the R statistical computing software (R Core Team, 2023). A brief description of the theoretical basis for these functions is described below.

### 3.2.4.1 Trend direction assessment

The trend direction and the confidence in the trend direction were evaluated using either the Mann Kendall assessment or the Seasonal Kendall assessment. Although the non-parametric Sen slope regression also provides information about trend direction and its confidence, the Mann Kendall assessment is recommended, rather than Sen slope regression, because the former more robustly handles censored values. However, Sen slope regression is the recommended method for assessing the trend rate (see Section 3.2.4.2).

The Mann Kendall assessment requires no *a priori* assumptions about the distribution of the data but does require that the observations are randomly sampled and independent (no serial correlation) and that there is a sample size of  $\geq 8$ . Both the Mann Kendall and Seasonal Kendall assessments are based on calculating the Kendall  $S$  statistic, which is explained diagrammatically in Figure 3.

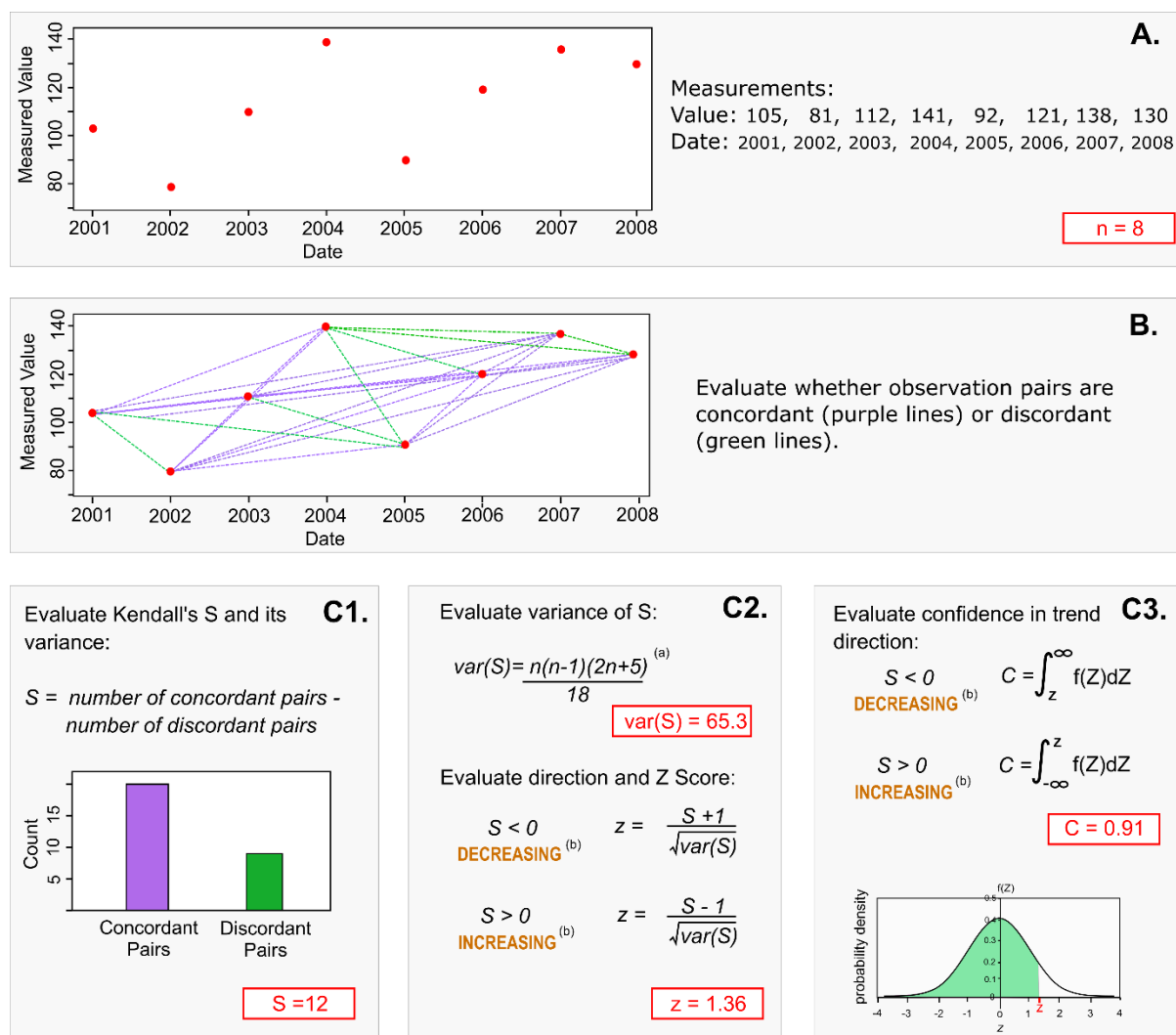


Figure 3. Pictogram of the steps taken in the trend direction assessment to calculate the Kendall  $S$  statistic and confidence in trend direction. Notes: [a] the calculation of the



variance in  $S$  has some adjustments to account for ties (numerically equal values) and censored values. Details of these adjustments can be found in (Helsel 2005, 2012). [b] There is a third alternative, where  $S=0$ . In this case  $C$  is 0.5, and the trend direction is classified as “indeterminate”. Values of  $S$  equal to -1 or 1 will also result in a  $Z$  value of 0, a  $p$ -value of 1 and a  $C$  value of 0.5 and the trend direction is similarly classified as “indeterminate”.

The Kendall  $S$  statistic is calculated by first evaluating the differences between all pairs of water quality observations (Figure 3, A and B). Positive differences are termed ‘concordant’ (i.e., the observations increase with increasing time) and negative differences are termed ‘discordant’ (i.e., the observations decrease with increasing time). The Kendall  $S$  statistic is the number of concordant pairs minus the number of discordant pairs (Figure 3, C1). The water quality trend direction is indicated by the sign of  $S$  with a positive or negative sign indicating an increasing or decreasing trend, respectively (Figure 3, C2).

The seasonal version of the Kendall  $S$  statistic  $S$  is calculated in two steps. First, for each season, the  $S$  statistic is calculated in the same manner as shown in Figure 3 but for data pertaining to observations in each individual season. Second,  $S$  is the sum of values over all seasons ( $S = \sum_1^n S_i$ ), where  $S_i$  is the number of concordant pairs minus the number of discordant pairs in the  $i^{th}$  season and  $n$  is the number of seasons. The variance of  $S$  is calculated for each season and then summed over all seasons.

The sign (i.e., + or -) of the  $S$  statistic calculated from the sample represents the best estimate of the population trend direction but is uncertain (i.e., the direction of the population trend cannot be known with certainty). A continuous measure of confidence in the assessed trend direction can be determined based on the posterior probability distribution of  $S$ , the true (i.e., population) difference in concordant and discordant pairs (Snelder et al., 2022). The posterior probability distribution of  $S$  is given by a normal distribution with mean of  $S$  and variance of  $var(S)$ . The confidence in assessed trend direction can be evaluated as the proportion of the posterior probability distribution that has the same sign as  $S$ .

In practice, confidence can be calculated by first transforming the value of  $S = 0$  on the posterior probability distribution into a standard normal deviate,  $Z$  (panel C2).  $C$  is then calculated as area under the standard normal distribution to the left ( $Z > 0$ ) or right ( $Z < 0$ ) of the value of  $Z$ , using the quantile function for the normal distribution.

The value  $C$  can be interpreted as the probability that the sign of the calculated value of  $S$  indicates the direction of the population trend (i.e., that the calculated trend direction is correct). The value  $C$  ranges between 0.5, indicating the sign of  $S$  is equally likely to be in the opposite direction to that indicated by the true trend, to 1, indicating complete confidence that the sign of  $S$  is the same as the true trend.

As the size of the sample (i.e., the number of observations) increases, confidence in the trend direction increases. When the sample size is very large,  $C$  can be high, even if the trend rate is very low. It is important therefore that  $C$  is interpreted correctly as the confidence in direction and not as the importance of the trend. As stated at the beginning of this section; both trend direction and the trend rate are relevant and important aspects of a trend assessment.

#### 3.2.4.2 Assessment of trend rate

The method used to assess trend rate is based on non-parametric Sen slope regressions of water quality observations against time. The Sen slope estimator (SSE; Hirsch et al., 1982) is the slope parameter of a non-parametric regression. SSE is calculated as the median of all

possible inter-observation slopes (i.e., the difference in the measured observations divided by the time between sample dates; Figure 4).

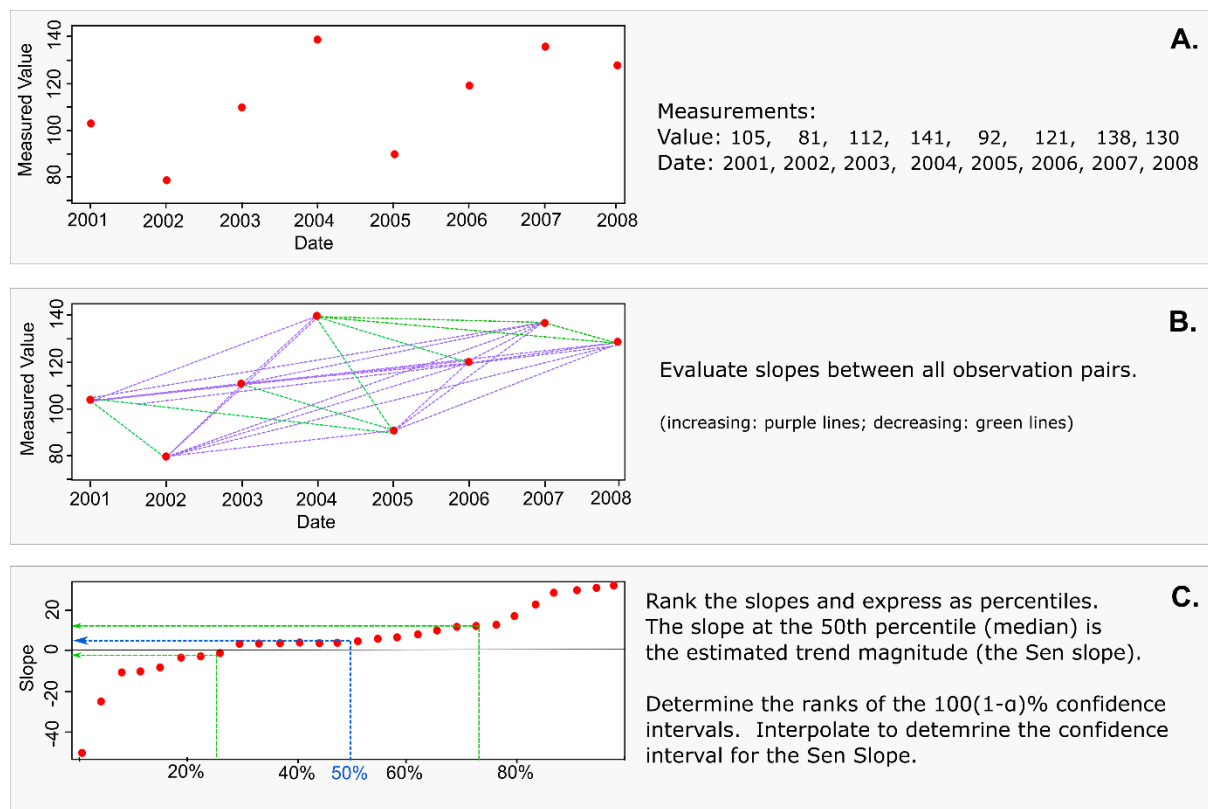


Figure 4. Pictogram of the calculation of the Sen slope, which is used to characterise trend rate.

The seasonal Sen slope estimator (SSSE) is calculated in two steps. First, for each season, the median of all possible inter-observation slopes is calculated in same manner as shown in Figure 4 but for data pertaining to observations in each individual season. Second, SSSE is the median of the seasonal values.

Uncertainty in the assessed trend rate is evaluated following a methodology outlined in Helsel and Hirsch (2002). To calculate the 100(1- $\alpha$ )% two-sided symmetrical confidence interval about the fitted slope parameter, the ranks of the upper and lower confidence limits are determined, and the slopes associated with these observations are applied as the confidence intervals.

The inter-observation slope cannot be definitively calculated between any combination of observations in which either one or both observations comprise censored values. Therefore, it is usual to remove the censor sign from the reported laboratory value and use just the 'raw' numeric component (i.e., <1 becomes 1) multiplied by a factor (such as 0.5 for left-censored and 1.1 for right-censored values). This ensures that in the Sen slope calculations, any left-censored observations are always treated as values that are less than their 'raw' values and right censored observations are always treated as values that are greater than their 'raw' values. The inter-observation slopes associated with the censored values are therefore imprecise (because they are calculated from the replacements). However, because the Sen slope is the median of all the inter-observation slopes, the Sen slope is unlikely to be affected

by censoring when a small proportion of observations are censored. As the proportion of censored values increase, the probability that the Sen slope is affected by censoring increases. The outputs from the trend assessment provide an 'analysis note' to identify Sen Slopes where one or both of the observations associated with the median inter-observation slope is censored.

### 3.2.5 Interpretation of trends

The trend assessment procedure used here facilitates a more nuanced inference than the 'yes/no' output corresponding to the chosen acceptable misclassification error rate. The confidence in direction ( $C$ ) can be transformed into a continuous scale of confidence the trend was decreasing ( $C_d$ ). For all trends with  $S < 0$ ,  $C_d = C$ , and for all  $S > 0$  a transformation is applied so that  $C_d = 1 - C$ .  $C_d$  ranges from 0 to 1.0. When  $C_d$  is very small, a decreasing trend is highly unlikely, which because the outcomes are binary, is the same as an increasing trend is highly likely.

The categorisation of confidence in trend direction used by LAWA was used to present the results. Each site trend was assigned to a category by firstly, converting  $C_d$  into a confidence that a trend was improving ( $C_i$ ). Improvement is indicated by decreasing trends for all the water quality variables in this study ( $C_i = C_d$ ) except for the macroinvertebrate metrics, visual clarity, Secchi depth and dissolved oxygen (for which increasing trends indicate improvement). For these variables,  $C_i$  is the complement of  $C_d$  (i.e.,  $C_i = 1 - C_d$ ). Secondly, each site/variable combination was assigned to a confidence in trend direction category according to its evaluated confidence of improvement and the categories shown in Table 3.

*Table 3. Level of confidence categories used to convey trend confidence and direction.*

| Categorical level of trend confidence and direction | Value of $C_i$ (%) |
|-----------------------------------------------------|--------------------|
| Very likely improving                               | 0.90–1.00          |
| Likely improving                                    | 0.67–0.90          |
| Low confidence in direction                         | 0.33–0.67          |
| Likely degrading                                    | 0.10–0.33          |
| Very likely degrading                               | 0.0–0.10           |

The aggregate proportion of sites in each category shown in Table 3 were calculated for sites and for each variable and these values were plotted as colour coded bar charts. These charts provide a graphical representation of the proportions of improving and degrading trends at the levels of confidence indicated by the categories. As improvement cannot be clearly associated with a particular direction of pH, it has been excluded from results reported based on improvement/degradation. However, results for trends in pH are provided in the supplementary material.

For variables with high levels of censoring, it is possible to obtain results that indicate high confidence in trend direction but have a Sen slope of zero. This occurs due to the censored values being treated as ties in the analysis. The correct interpretation of the zero Sen slope is that it is a rate of change that is below the rate of detection given by the detection limit and time period. To highlight the occurrence of zero Sen slopes, mapped and tabulated site results



for categorical levels of trend confidence and direction also include information to indicate where Sen Slopes were evaluated to be zero.

Outputs from the trend analyses were also classified into four direction categories: improving, degrading, indeterminate, and not analysed. An increasing or decreasing trend category was assigned based on the sign of the S statistic from the Mann Kendall test. An indeterminate trend category was assigned when the Z score equalled zero. Trends were classified as “not analysed” for two reasons:

- 1) When a large proportion of the values were censored (data has <5 non-censored values and/or <3 unique non-censored values). This arises because trend analysis is based on examining differences in the value of the variable under consideration between all pairs of sample occasions. When a value is censored, it cannot be compared with any other value and the comparison is treated as a “tie” (i.e., there is no change in the variable between the two sample occasions). When there are many ties there is little information content in the data and a meaningful statistic cannot be calculated.
- 2) When there is no, or very little, variation in the data because this also results in ties. This can occur because laboratory analysis of some variables has low precision (i.e., values have few or no significant figures). In this case, many samples have the same value, and this then results in ties.

## 4 Results for state assessments

### 4.1 Rivers

#### 4.1.1 Grading of SoE sites

The results for grading the river SoE sites according to targets described in section 3.1.1 are mapped in Figure 5 and shown as colour coded tables in Figure 6 (Manawatū FMU) and Figure 7 (all other FMUs). Plots of rolling state grades for sites, (by target) are provided in Appendix C1.

The cells marked with circles rather than filled cells shown in Figure 6 and Figure 7 indicate that there were insufficient observations to make statistically robust assessments of state (see Section 3.1.1). This occurred more often for variables whose targets included specified flow states, for example clarity, *E. coli*, DRP, and SIN (Table 2) or for those that were monitored annually (e.g., MCI).

More than 75% of sites failed the Horizons One Plan targets for DRP, MCI, *E. coli* and Clarity. Conversely, more than 75% of sites passed the targets for NH<sub>4</sub>-N, periphyton (mats) and DO (Sat). Grades varied across the region for chlorophyll-a, POM, periphyton (filaments) and SIN.



*Figure 5: Maps showing SoE site state grades based on the Horizons One Plan criteria. Grades that are defined as “final” are shown with circles, and “interim” grades are shown with triangles. Smaller sized shapes indicate that the criteria had a flow constraint and there was no flow available at the site.*

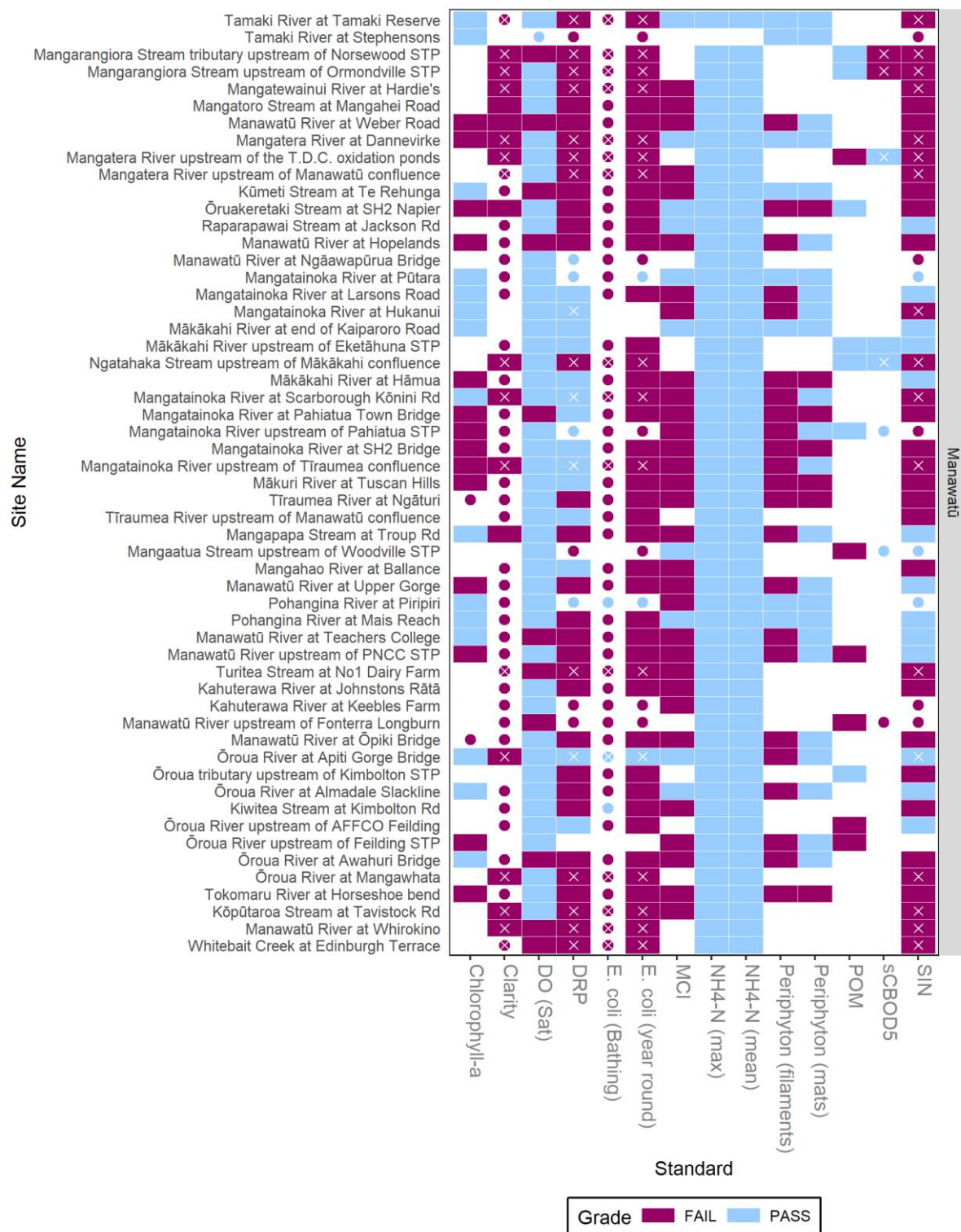


Figure 6: Assessed state for SoE river monitoring sites in the Manawātū catchment. Colours indicate state grade for each site based on the Horizons One Plan criteria. Sites with interim grades are shown with coloured circles. White crosses indicate that the criteria had a flow constraint and there was no flow available at the site. No colour indicates that there were no observations, or fewer than required to define interim grades.

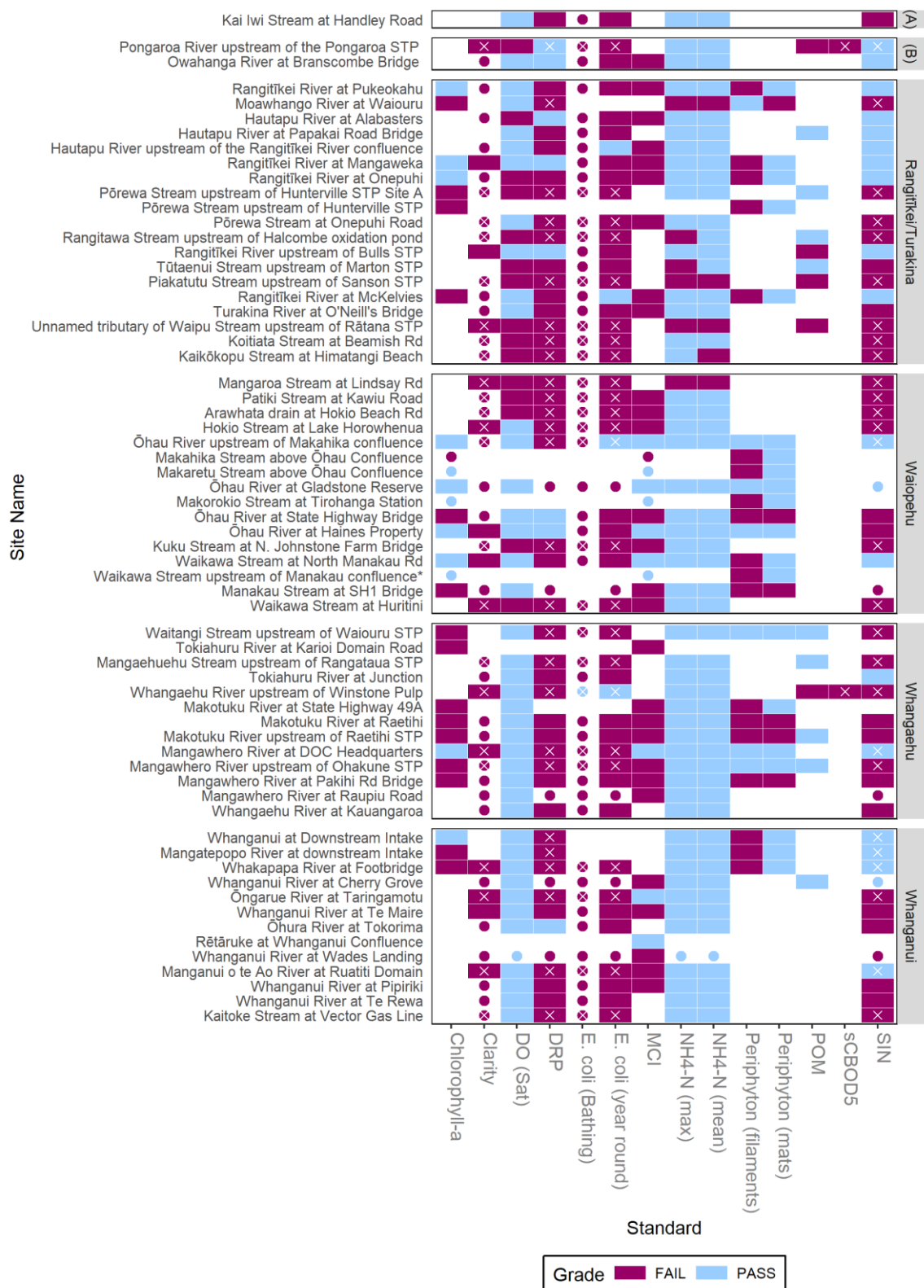


Figure 7: Assessed state for SoE river monitoring sites outside of the Manawātū catchment. Colours indicate state grade for each site based on the Horizons One Plan criteria. Sites with interim grades are shown with coloured circles. White crosses indicate that the criteria had a flow constraint and there was no flow available at the site. No colour indicates that there were no observations, or fewer than required to define interim grades.



#### 4.1.2 Grading of Impact sites

The results for grading the river impact sites according to targets described in section 3.1.1 are mapped in Figure 8 and shown as colour coded tables in Figure 9. Plots of rolling state grades for sites, (by target) are provided in Appendix C2.

More than 75% of sites failed the Horizons One Plan criteria for chlorophyll-a, periphyton (filaments), DRP, SIN, MCI, *E. coli* and Clarity. Conversely, more than 75% of sites passed the criteria for NH<sub>4</sub>-N and periphyton (mats). Grades varied across the region for POM. These patterns are similar to those of the SoE sites, although with a tendency for greater proportions of failing sites.



**Figure 8: Maps showing impact site state grades based on the Horizons One Plan criteria. Grades that are defined as “final” are shown with circles, and “interim” grades are shown with triangles. Smaller sized shapes indicate that the criteria had a flow constraint and there was no flow available at the site.**

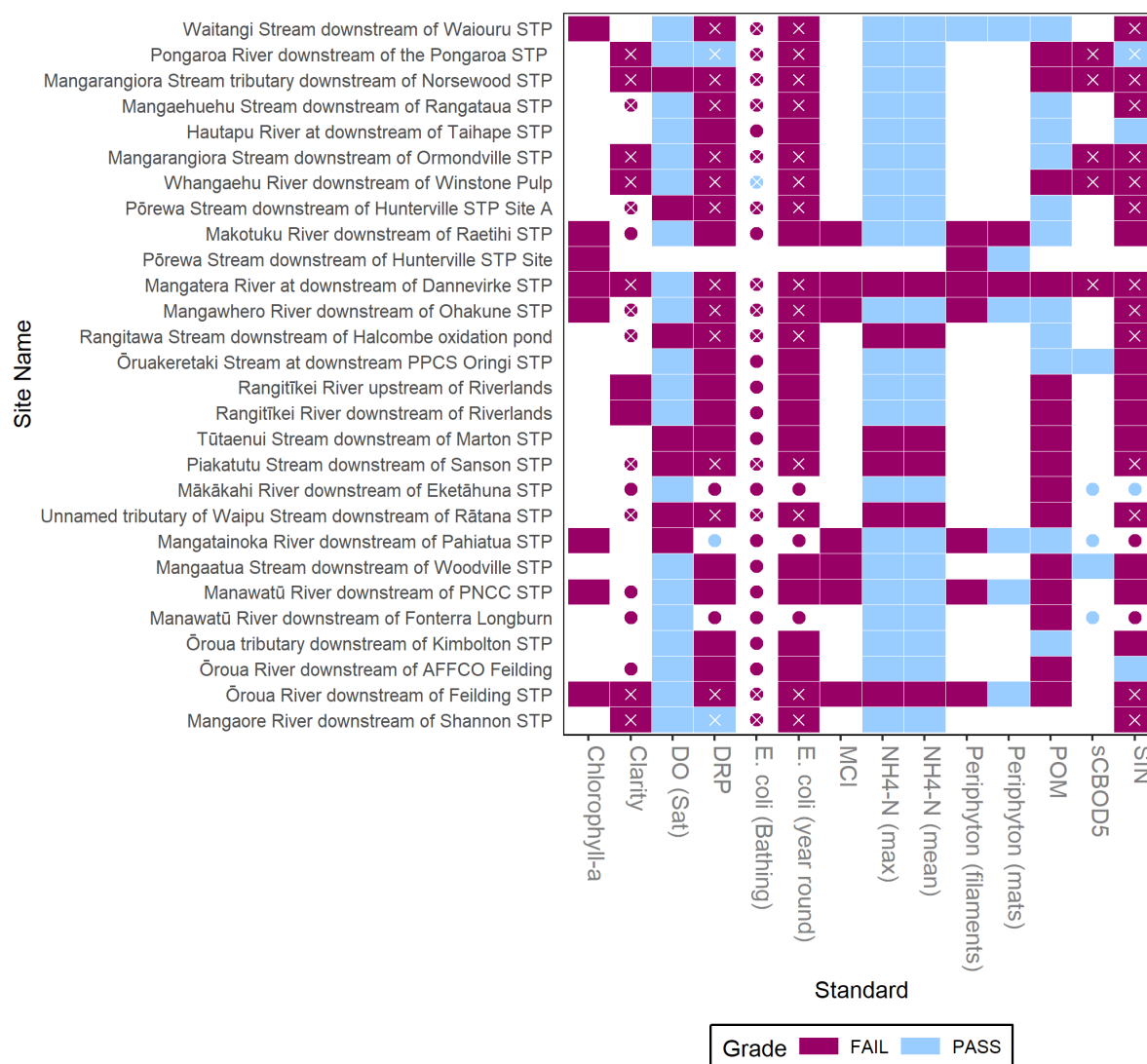
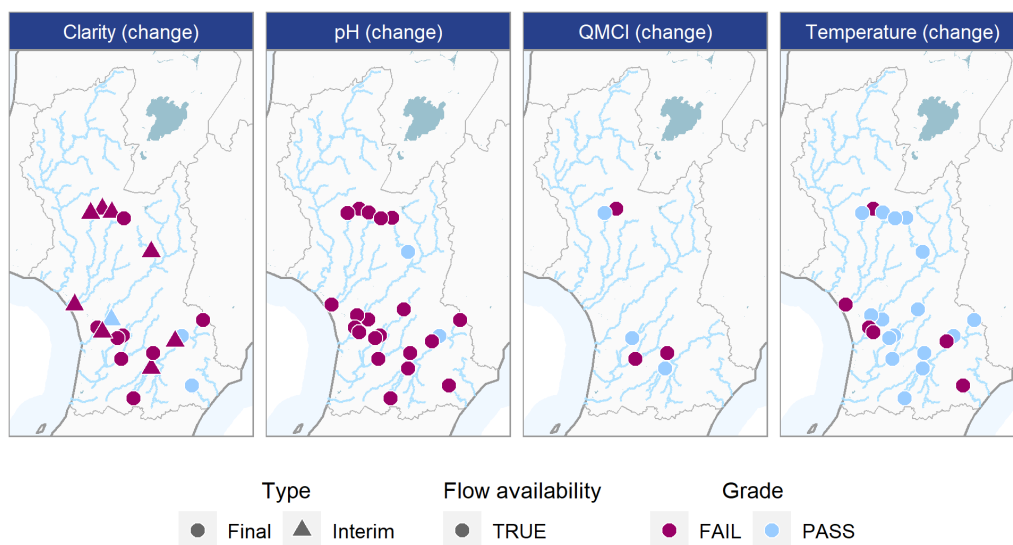


Figure 9: Assessed state for impact river monitoring sites. Colours indicate state grade for each site based on the Horizons One Plan criteria. Sites with interim grades are shown with coloured circles. White crosses indicate that the criteria had a flow constraint and there was no flow available at the site. No colour indicates that there were no observations, or fewer than required to define interim grades.

#### 4.1.3 Grading of discharge sites

The results of grading the discharge sites according to the Horizons One Plan water quality variable change targets are mapped in Figure 10 and shown in Figure 10. Most sites failed the criteria for pH, and Clarity. There were very few sites with QMCI data to allow evaluation of the criteria; of the 6 sites, 50% received a pass grade. Grades varied across the region for the temperature criteria but were slightly dominated by sites meeting the targets (73%).



*Figure 10: Maps showing discharge site state grades based on the Horizons One Plan criteria. Grades that are defined as “final” are shown with circles, and “interim” grades are shown with triangles.*



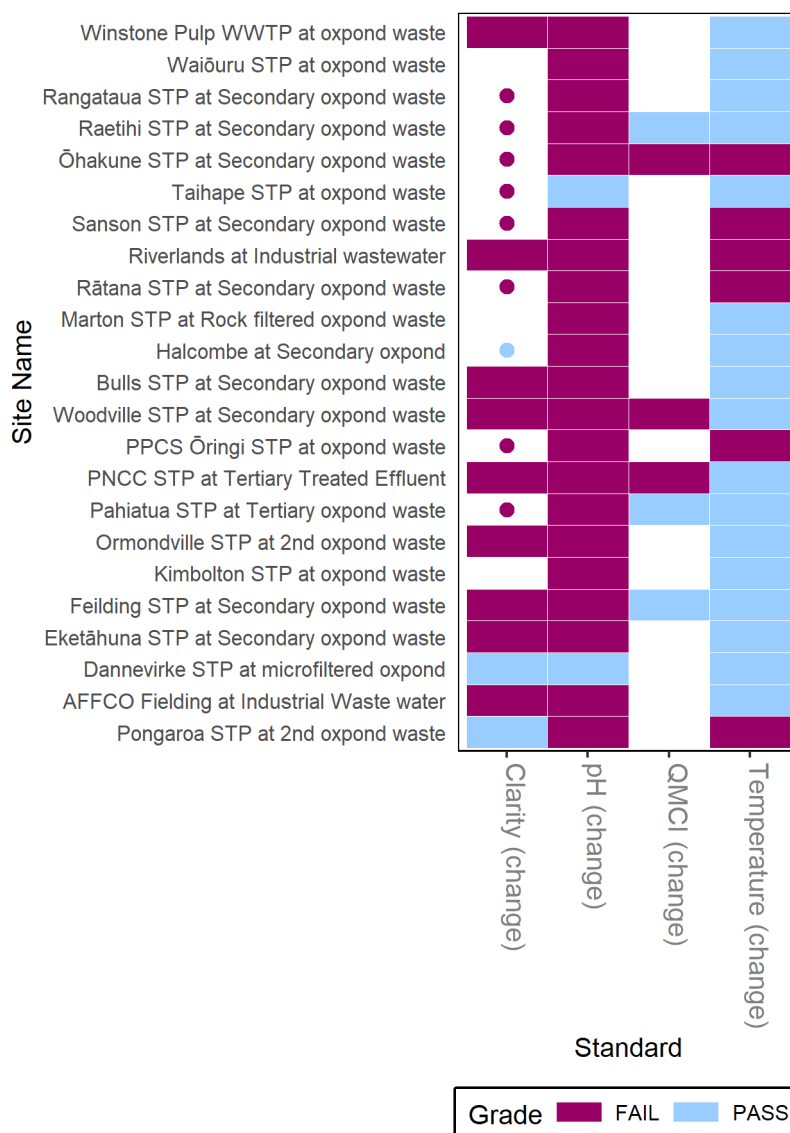


Figure 11: Assessed state for discharge river monitoring sites. Colours indicate state grade for each site based on the Horizons One Plan criteria. Sites with interim grades are shown with coloured circles. No colour indicates that there were no observations, or fewer than required to define interim grades.

## 4.2 Lakes

The results of grading the lake sites according to the Horizons One Plan targets are shown in Figure 12. All sites failed the criteria for TN, and only Lake Koiitiata passed the criteria for chlorophyll-a and TP. Grades varied across the region for the *E. coli* (bathing) criteria but were slightly dominated by sites passing the criteria (60%). Most grades were classed as “interim”, primarily due to the relatively recent start of monitoring at many of these lakes, and because most lakes were only monitored quarterly up until two years ago when the monitoring frequency increased to monthly.

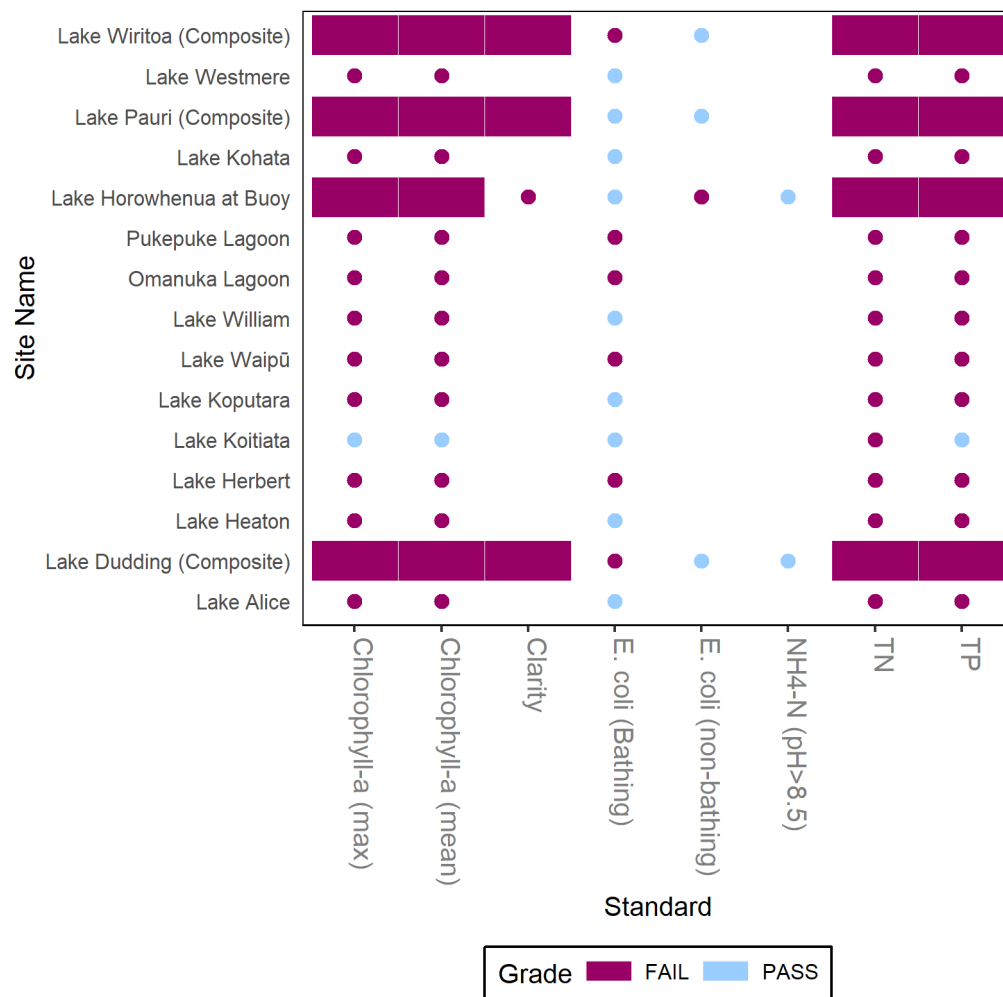


Figure 12: Assessed state for lake monitoring sites. Colours indicate state grade for each site based on the Horizons One Plan criteria. Sites with interim grades are shown with coloured circles. No colour indicates that there were no observations, or fewer than required to define interim grades.

### 4.3 Estuary

The results of grading the estuary sites according to the Horizons One Plan targets are shown in Figure 13. All sites failed the *E. coli* targets and passed the NH<sub>4</sub>-N targets. Only one site (Mōwhānau Stream at Footbridge) had observations of clarity, and this site failed to meet the clarity target. The chlorophyll-a target was achieved at 4 out of 6 sites. The remaining variables (DO (Sat), DRP, SIN, Temperature) were dominated by failing sites (58-72 %).

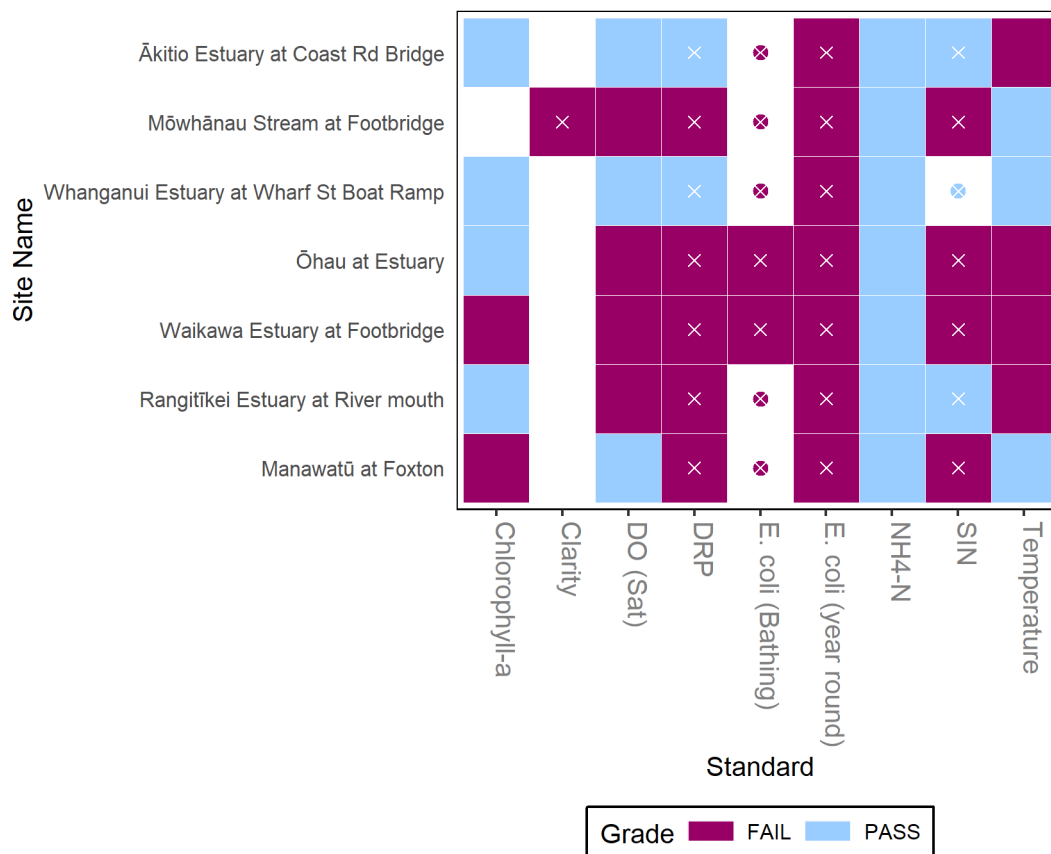


Figure 13: Assessed state for estuary monitoring sites. Colours indicate state grade for each site based on the Horizons One Plan criteria. Sites with interim grades are shown with coloured circles. White crosses indicate that the criteria had a flow constraint and there was no flow available at the site. No colour indicates that there were no observations, or fewer than required to define interim grades.

#### 4.4 Coastal

The results of grading the coastal monitoring sites according to the Horizons One Plan targets are shown in Figure 14. All sites passed the NH<sub>4</sub>N target, and all sites failed the TN, TP and Enterococci (bathing) targets. The grades for the remaining targets (Chlorophyll-a, Enterococci (non-bathing) and Faecal Coliforms) varied across sites, with between 25-50% of sites assigned pass grades.

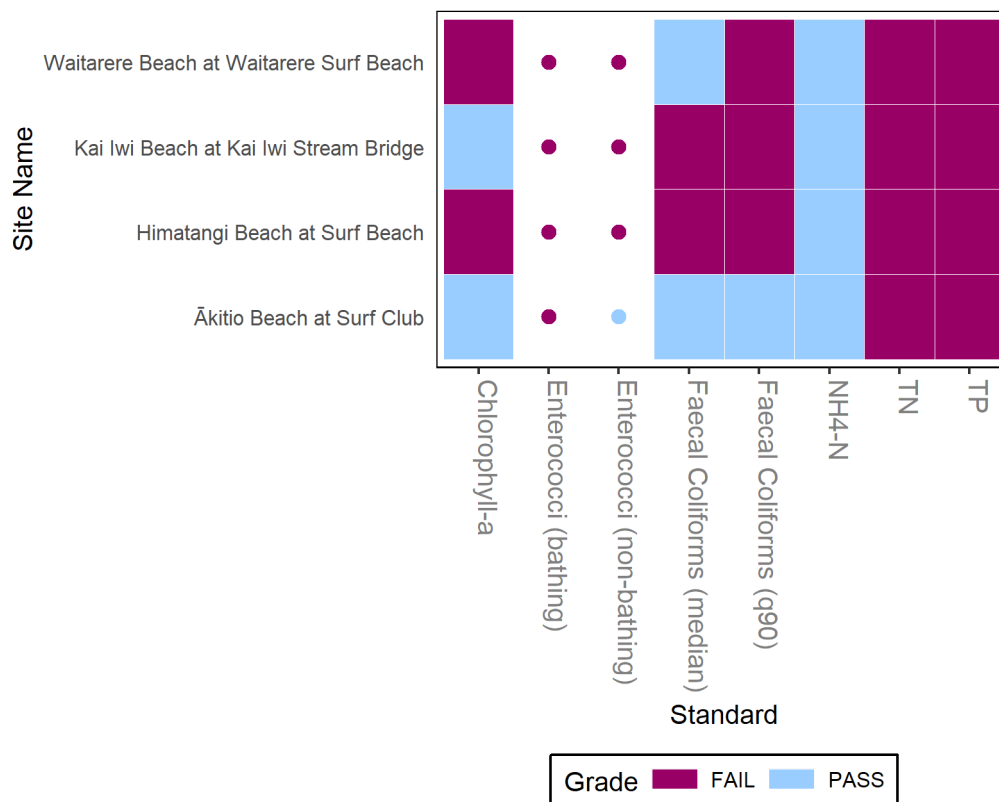


Figure 14: Assessed state for coastal monitoring sites. Colours indicate state grade for each site based on the Horizons One Plan criteria. Sites with interim grades are shown with coloured circles. No colour indicates that there were no observations, or fewer than required to define interim grades.

## 5 Results for trends

### 5.1 Rivers

#### 5.1.1 SoE Sites

Following the application of the filtering rules described in section 3.2.1, the total number of sites that were included in the analyses was reduced from that shown in Table 1. A summary of the site numbers that were included in the final SoE trend assessments is presented in Table 4.

*Table 4. River water quality variables and SoE site numbers for which 10-, 20- and 30-year trends were analysed by this study.*

| Variable  | Number of sites | Number of sites that complied with filtering rules |          |          |
|-----------|-----------------|----------------------------------------------------|----------|----------|
|           |                 | 10 years                                           | 20 years | 30 years |
| Chl_a     | 60              | 29                                                 | 0        | 0        |
| CLAR      | 110             | 45                                                 | 10       | 4        |
| DO_Sat    | 112             | 95                                                 | 1        | 0        |
| DRP       | 112             | 100                                                | 28       | 6        |
| ECOLI     | 110             | 94                                                 | 28       | 0        |
| MCI       | 80              | 72                                                 | 24       | 4        |
| NH4N      | 112             | 97                                                 | 25       | 6        |
| Peri_fil  | 61              | 51                                                 | 0        | 0        |
| Peri_mats | 61              | 51                                                 | 0        | 0        |
| pH        | 112             | 98                                                 | 0        | 0        |
| QMCI      | 80              | 72                                                 | 0        | 0        |
| sCBOD5    | 82              | 10                                                 | 0        | 0        |
| SIN       | 112             | 100                                                | 28       | 6        |
| TEMP      | 112             | 99                                                 | 27       | 6        |
| Vol_Mat   | 88              | 25                                                 | 1        | 0        |

##### 5.1.1.1 10 year trends

The LAWA categorical description for the raw (with high censor filter) trends for the river SoE sites for the 10 year trend period are mapped in Figure 15 and shown in summary tables in Figure 16 (Manawatū FMU) and Figure 17 (all other FMUs).

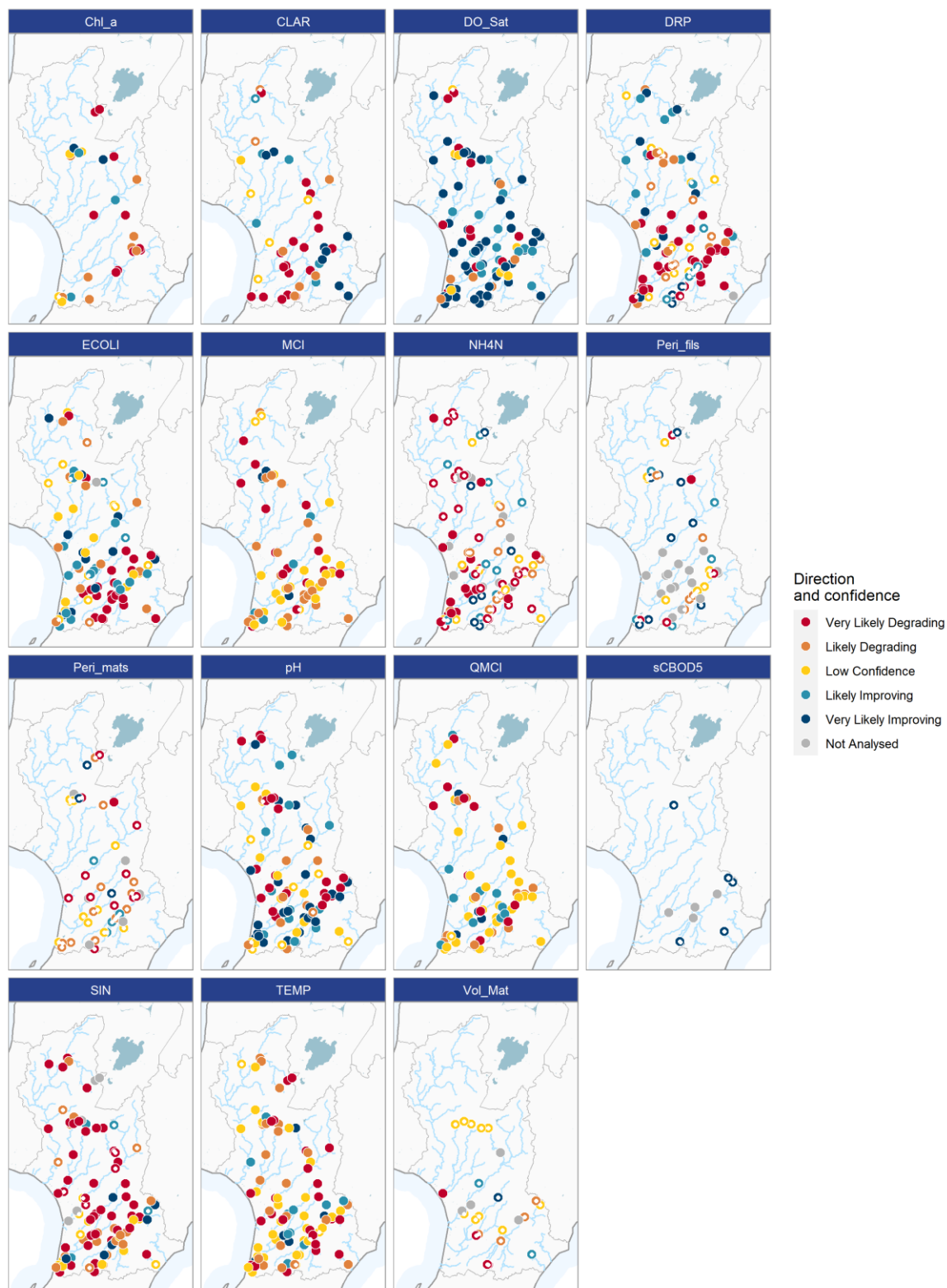


Figure 15: Map of river SoE sites classified by 10 year trend confidence and direction. Confidence and direction is expressed categorically based on the levels defined in Table 3. Sites with a Sen Slope of zero are indicated with a white dot.

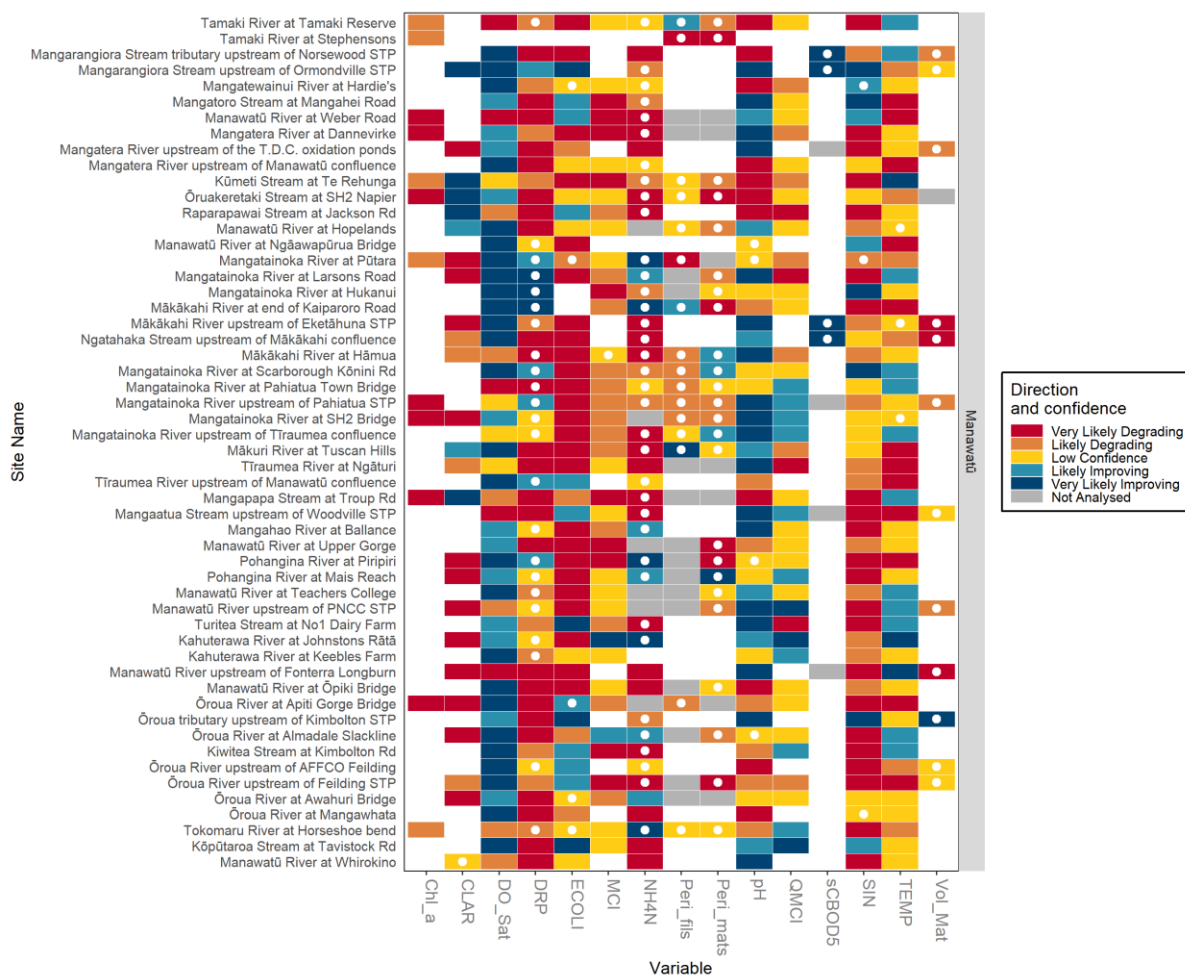


Figure 16: Assessed 10-year raw water quality trend at SoE sites in the Manawātū FMU classified by trend confidence and direction. Confidence and direction is expressed categorically based on the levels defined in Table 3. Sites with a Sen Slope of zero are indicated with a white dot.

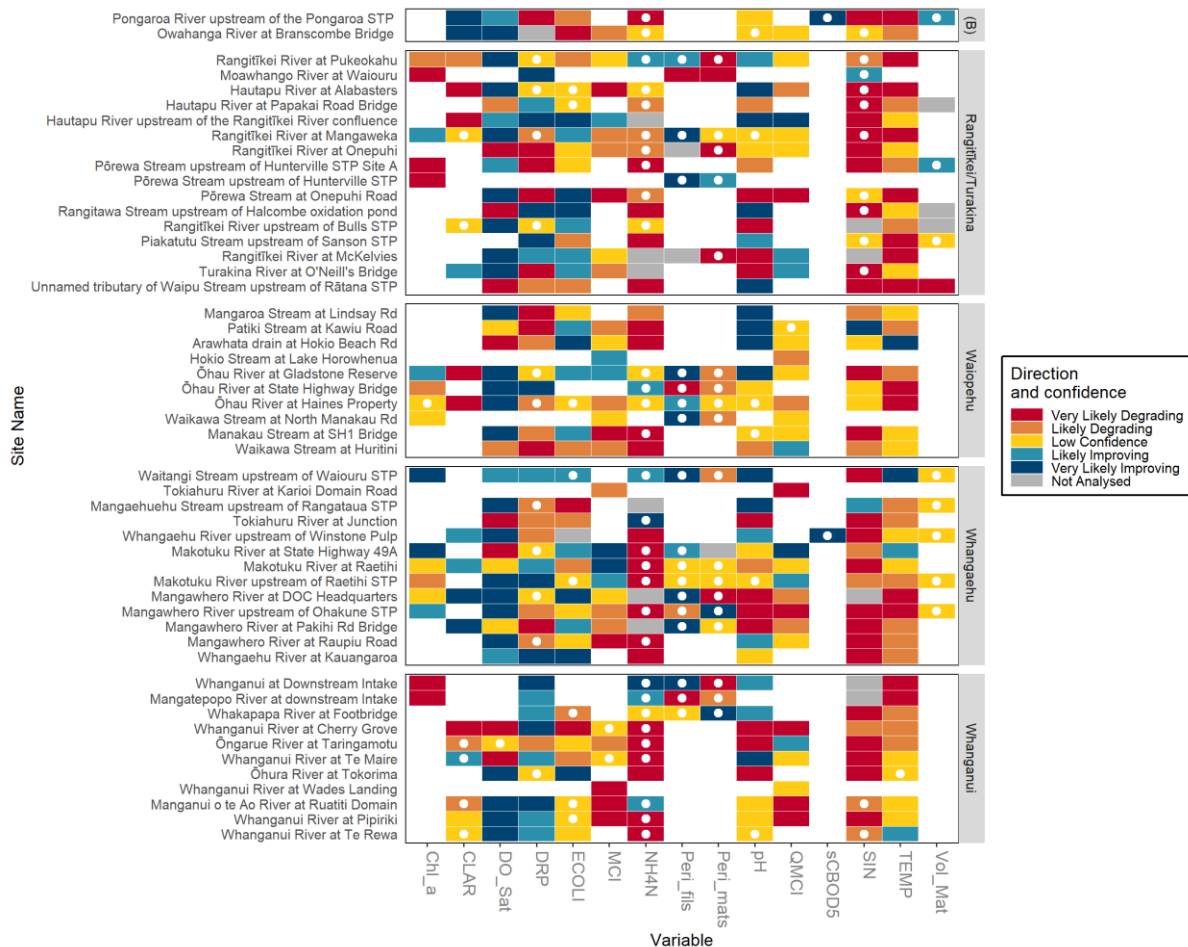


Figure 17: Assessed 10-year raw water quality trend at SoE sites outside of the Manawātū FMU classified by trend confidence and direction. Confidence and direction is expressed categorically based on the levels defined in Table 3. Sites with a Sen Slope of zero are indicated with a white dot.

#### 5.1.1.2 20 year trends

The LAWA categorical description for the raw (with high censor filter) trends for the river SoE sites for the 20 year trend period is mapped in Figure 18 and shown in a summary table Figure 19.



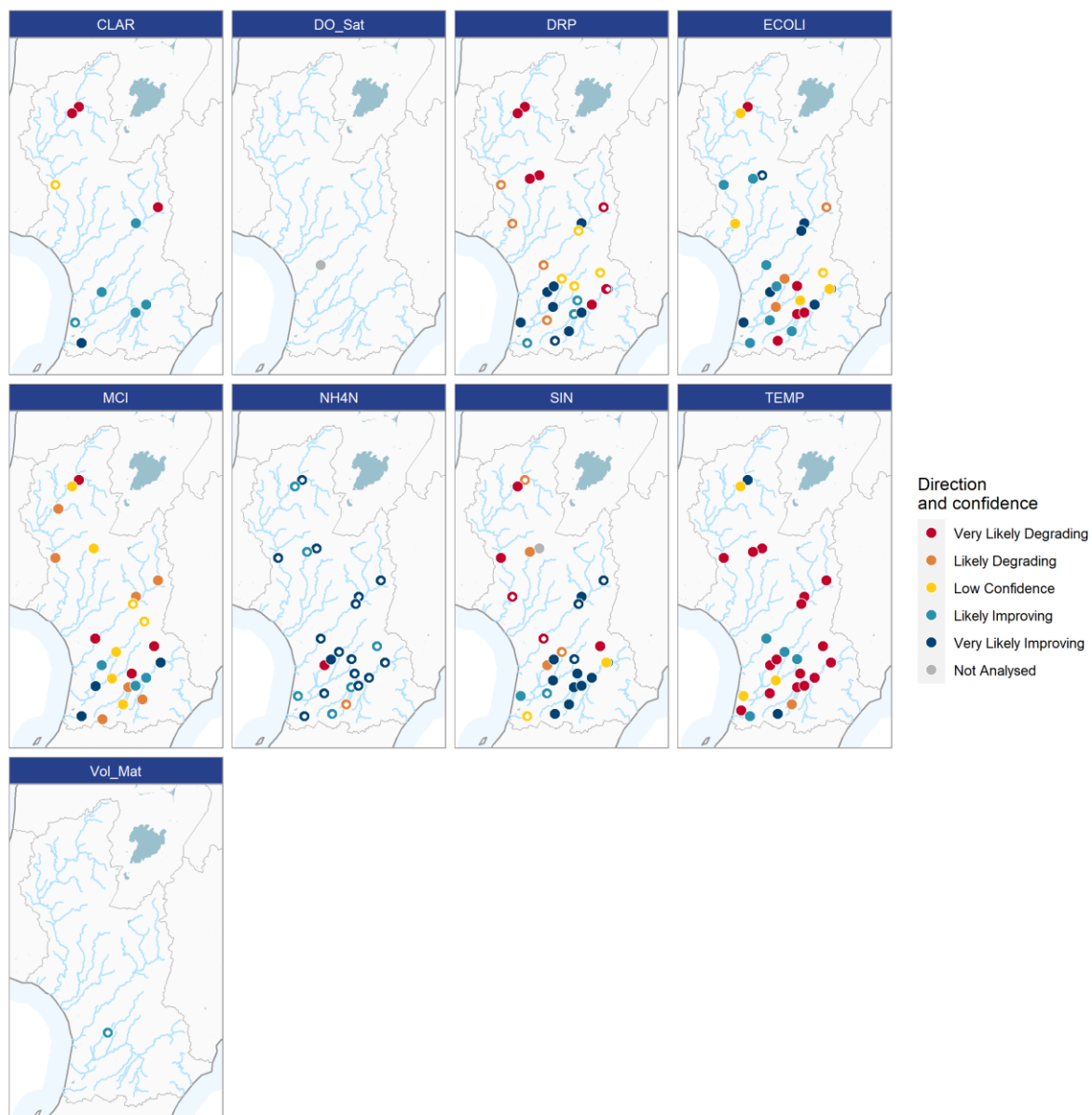


Figure 18: Map of river SoE sites classified by 20 year trend confidence and direction. Confidence and direction is expressed categorically based on the levels defined in Table 3. Sites with a Sen Slope of zero are indicated with a white dot.

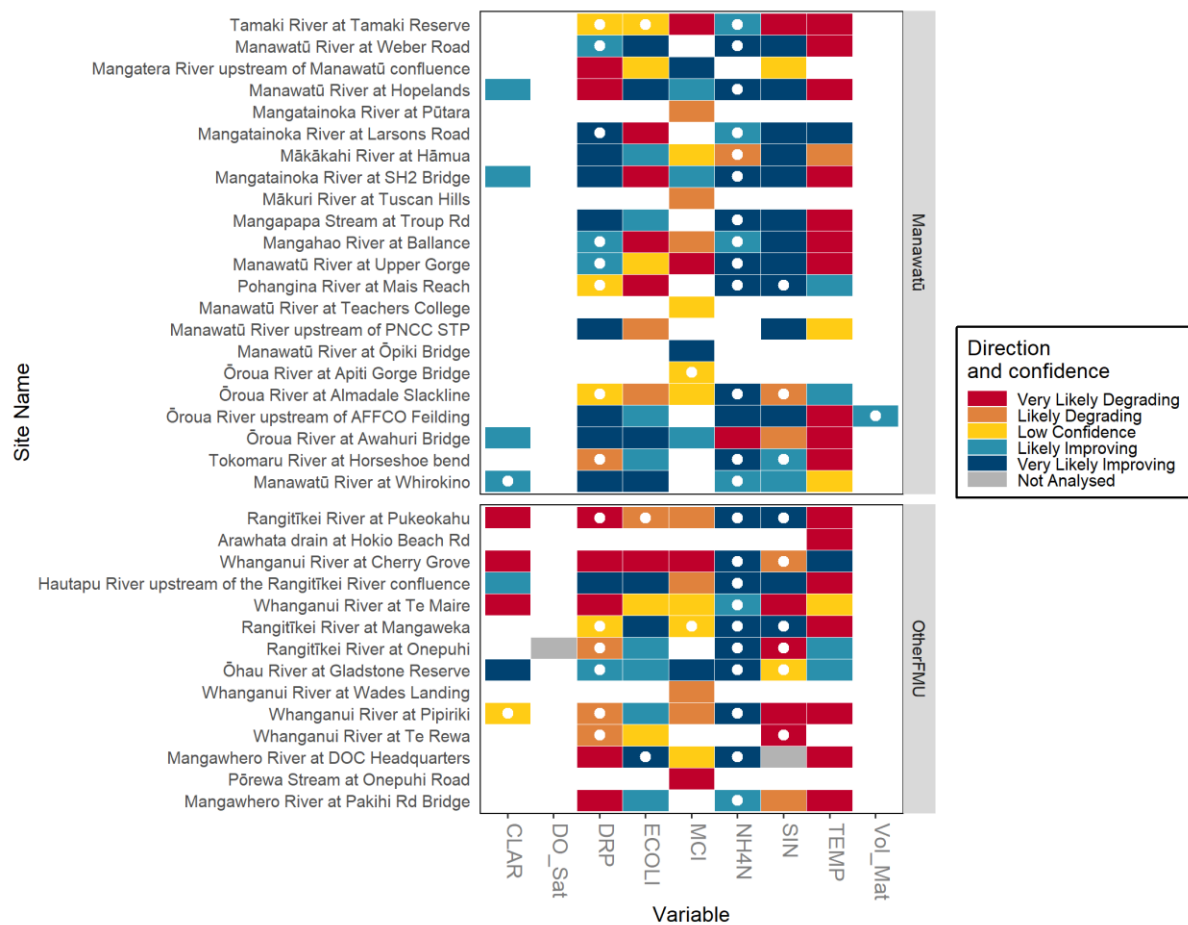


Figure 19: Assessed 20-year raw water quality trend at SoE sites classified by trend confidence and direction. Confidence and direction is expressed categorically based on the levels defined in Table 3. Sites with a Sen Slope of zero are indicated with a white dot.

#### 5.1.1.3 30 year trends

The LAWA categorical description for the raw (with high censor filter) trends for the river SoE sites for the 30 year trend period is mapped in Figure 20 and shown in a summary table in Figure 21.

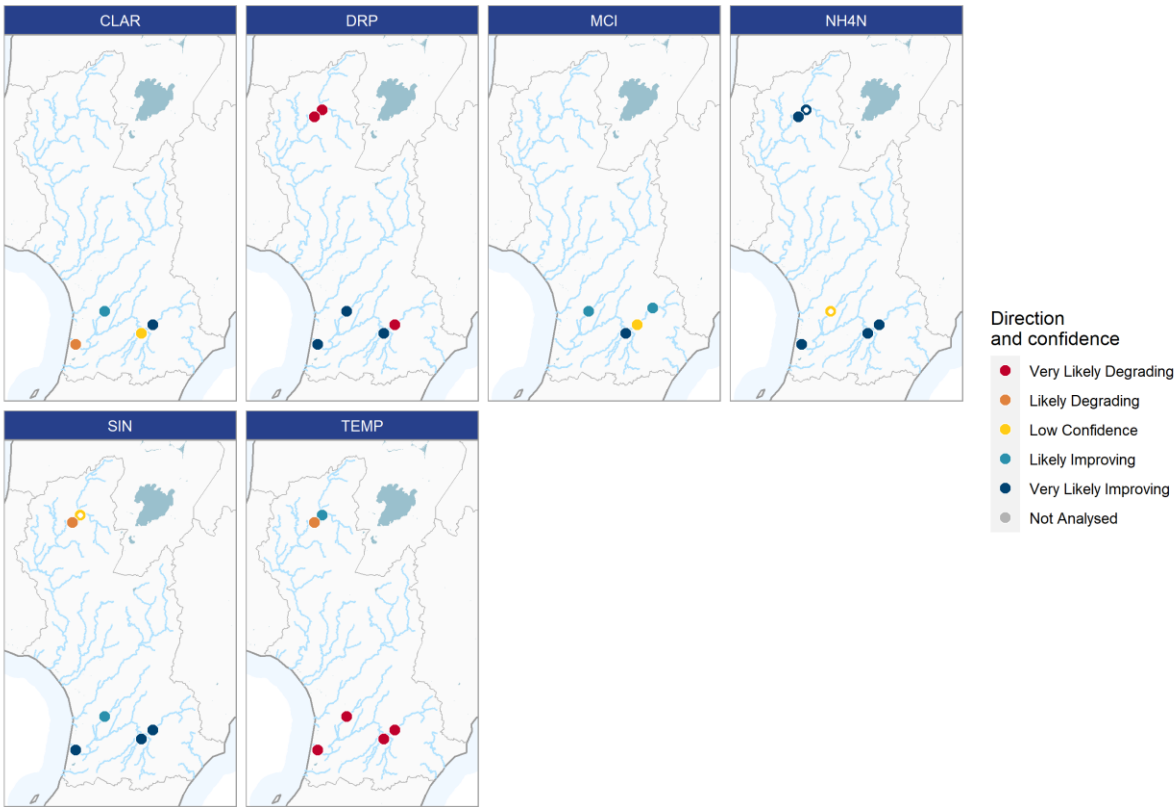


Figure 20: Map of river SoE sites classified by 30 year trend confidence and direction. Confidence and direction is expressed categorically based on the levels defined in Table 3. Sites with a Sen Slope of zero are indicated with a white dot.

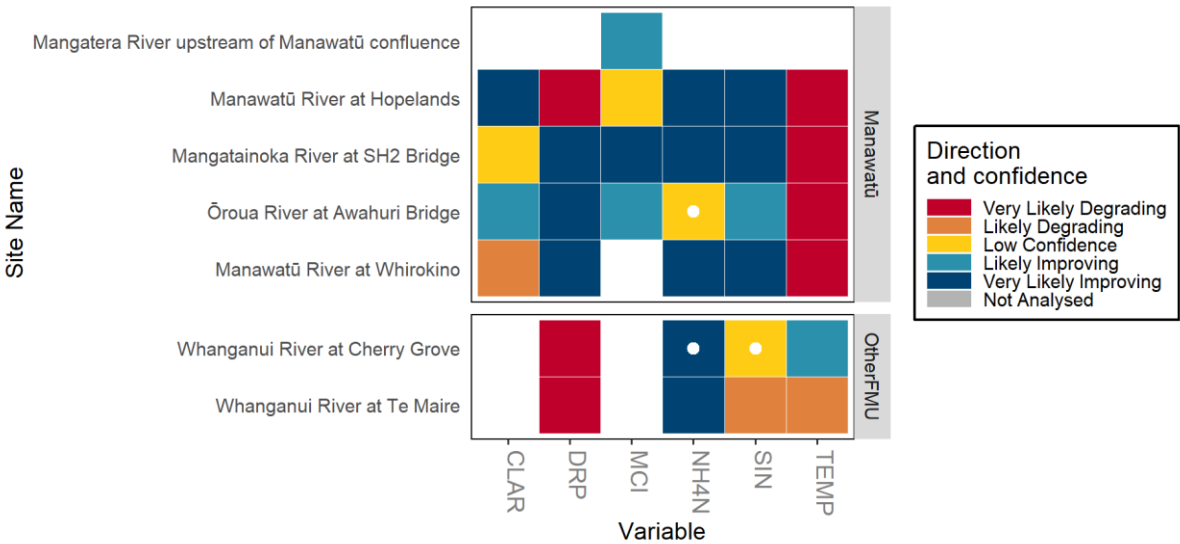


Figure 21: Assessed 30-year raw water quality trend at SoE sites classified by trend confidence and direction. Confidence and direction is expressed categorically based on the levels defined in Table 3. Sites with a Sen Slope of zero are indicated with a white dot.

#### 5.1.1.4 Aggregate trends

Figure 22 and Figure 23 show colour coded bar charts representing the proportions of SoE sites with improving and degrading water quality trends based on the categories defined in Table 3 for the 10- and 20-year trend periods, respectively. Blue colours indicate sites with improving trends, and red-orange colours indicate sites with degrading trends. Interpretation of these plots should also take into account that there were variable numbers of sites included in the different time periods (see Table 4).

For the 10 year trends, seven of the 15 water quality variables had more than half of sites classed as “likely degrading” or “Very likely degrading” (Chl\_a, CLAR, DRP, MCI, NH4N, Peri\_mats, SIN), whereas only two variables had more than half of sites classes as “likley improving” or “very likley improving” (DO\_Sat, sCBOD5).

For the 20 year trends, only one of the seven water quality variables had more than half of sites classed as “likely degrading” or “Very likely degrading” (TEMP), whereas four variables had more than half of sites classes as “likely improving” or “very likely improving” (CLAR, ECOLI, NH4N, SIN). While the 20-year aggregate trends appear to paint a better picture of the aggregate trends in the region, it is noted that there are fewer sites included in the 20 year trend assessment (Table 4).

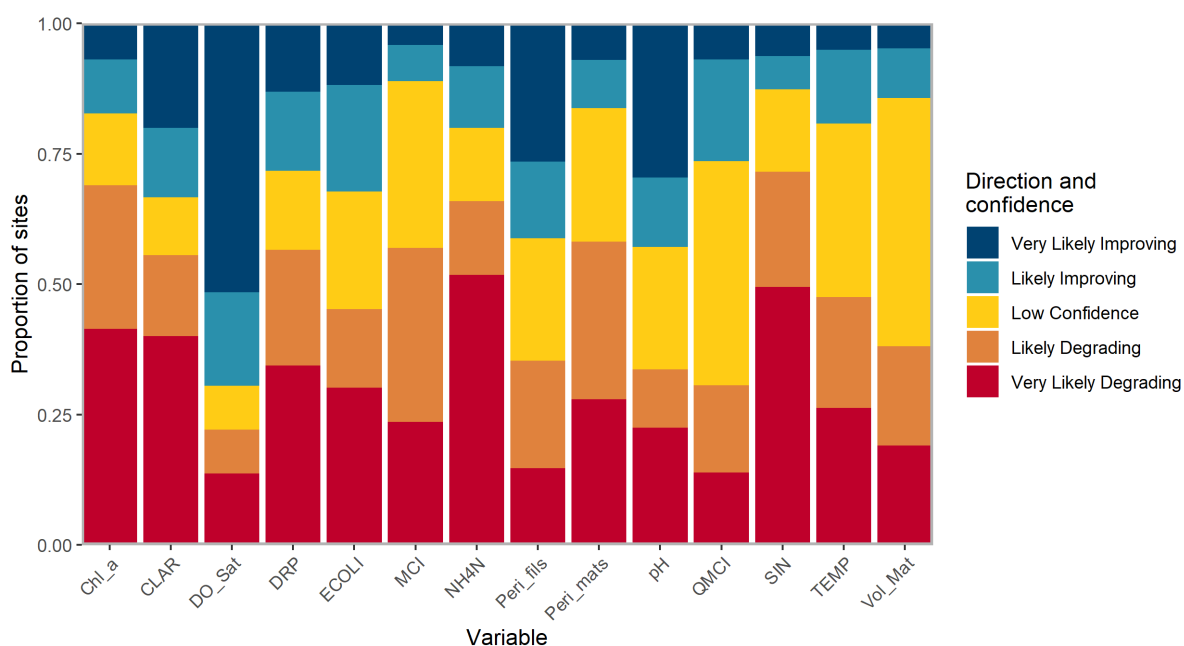


Figure 22. Summary plot representing the proportion of SoE river sites each categorical level of confidence and direction for 10-year time period trends. The plot shows the proportion of sites in each of the trend direction and confidence categories defined in Table 3.

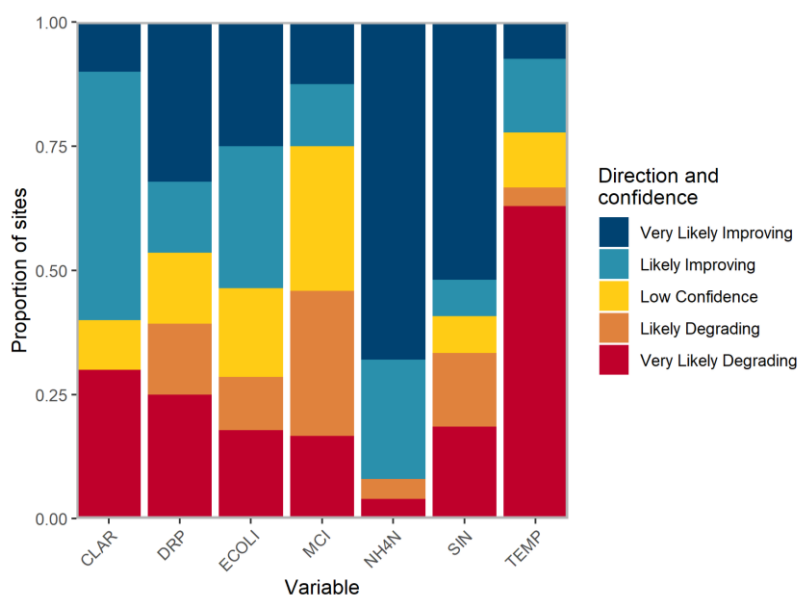


Figure 23. Summary plot representing the proportion of SoE river sites each categorical level of confidence and direction for 20-year time period trends. The plot shows the proportion of sites in each of the trend direction and confidence categories defined in Table 3.

### 5.1.2 Impact sites

Following the application of the filtering rules described in section 3.2.1, the total number of impact sites that were included in the analyses was reduced from that shown in Table 1. A summary of the site numbers that were included in the final impact site trend assessments is presented in Table 5. There were no impact sites that met the minimum data requirements for 20 of 30 year trends.

Table 5. River water quality variables and impact site numbers for which 10-year trends were analysed by this study.

| Variable  | Number of sites | Number of sites that complied with filtering rules for 10 year trends |
|-----------|-----------------|-----------------------------------------------------------------------|
| Chl_a     | 9               | 5                                                                     |
| CLAR      | 27              | 9                                                                     |
| DO_Sat    | 27              | 27                                                                    |
| DRP       | 27              | 27                                                                    |
| ECOLI     | 27              | 27                                                                    |
| MCI       | 7               | 7                                                                     |
| NH4N      | 27              | 27                                                                    |
| Peri_fils | 10              | 8                                                                     |
| Peri_mats | 10              | 8                                                                     |
| pH        | 27              | 27                                                                    |
| QMCI      | 7               | 7                                                                     |

|         |    |    |
|---------|----|----|
| sCBOD5  | 28 | 10 |
| SIN     | 27 | 27 |
| TEMP    | 27 | 27 |
| Vol_Mat | 28 | 26 |

#### 5.1.2.1 10 year trends

The LAWA categorical description for the raw (with high censor filter) trends for the river impact sites for the 10 year trend period are mapped in Figure 24 and shown in a summary table in Figure 25.

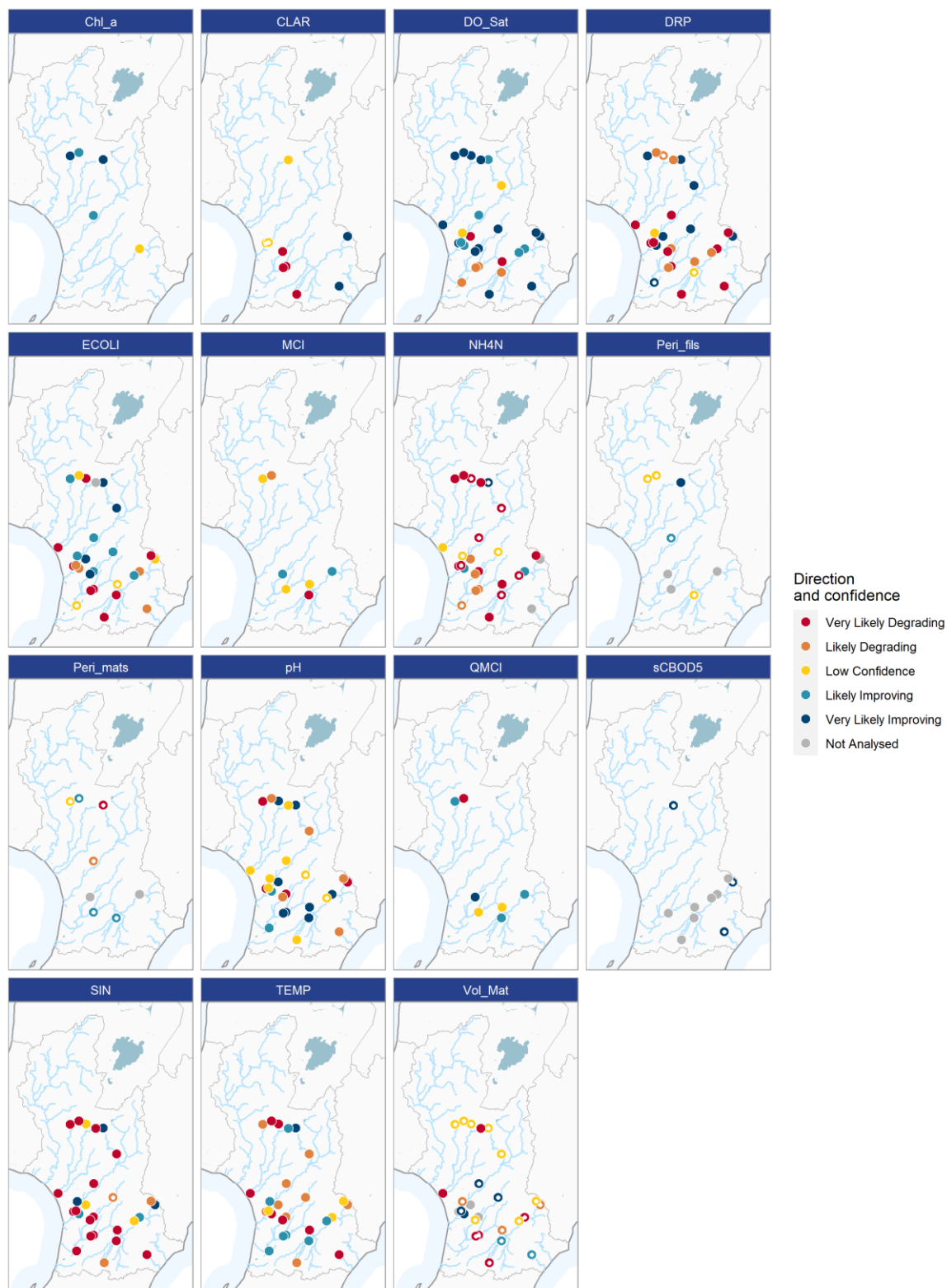


Figure 24: Map of river impact sites classified by 10 year trend confidence and direction. Confidence and direction is expressed categorically based on the levels defined in Table 3. Sites with a Sen Slope of zero are indicated with a white dot.

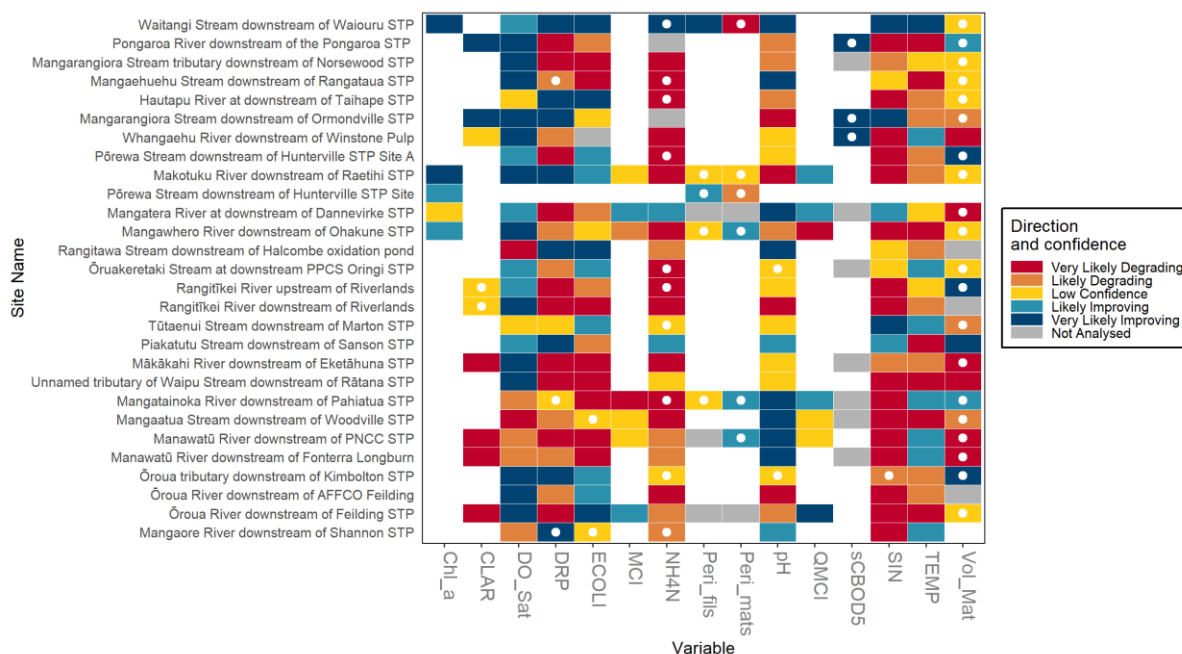


Figure 25: Assessed 10-year raw water quality trend at impact sites classified by trend confidence and direction. Confidence and direction is expressed categorically based on the levels defined in Table 3. Sites with a Sen Slope of zero are indicated with a white dot.

#### 5.1.2.2 Aggregate trends

Figure 26 shows colour coded bar charts representing the proportions of impact sites with improving and degrading water quality trends based on the categories defined in Table 3 for the 10-year trend period. Four of the eight water quality variables had more than half of sites classed as “likely degrading” or “Very likely degrading” (DRP, NH<sub>4</sub>N, SIN, TEMP), whereas only one variable had more than half of sites classes as “likely improving” or “very likely improving” (DO\_Sat).



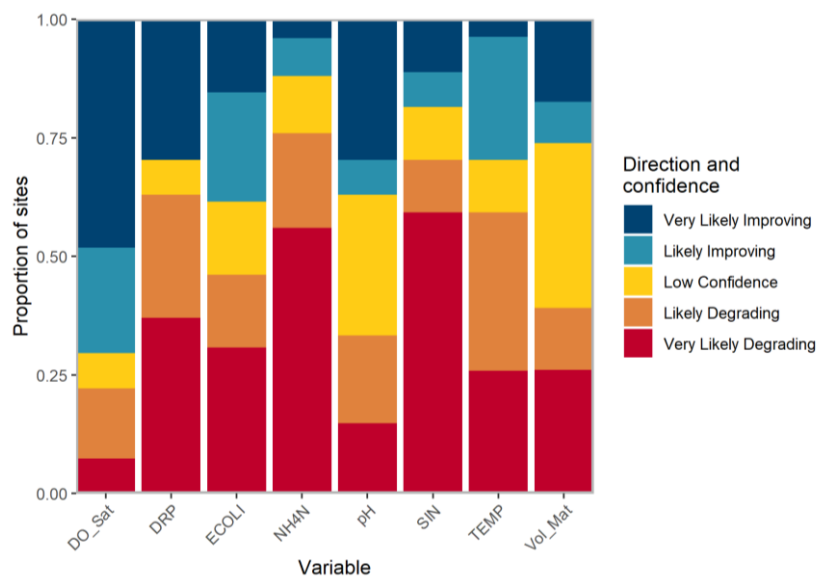


Figure 26. Summary plot representing the proportion of impact sites each categorical level of confidence and direction for 10-year time period trends. The plot shows the proportion of sites in each of the trend direction and confidence categories defined in Table 3.

### 5.1.3 Discharge sites

Following the application of the filtering rules described in section 3.2.1, the total number of discharge sites that were included in the analyses was reduced from that shown in Table 1. A summary of the site numbers that were included in the final discharge site trend assessments is presented in Table 6. There were no discharge sites that met the minimum data requirements for 30 year trends.

Table 6. River water quality variables and discharge site numbers for which 10- and 20-year trends were analysed by this study.

| Variable | Number of sites | Number of sites that complied with filtering rules |          |
|----------|-----------------|----------------------------------------------------|----------|
|          |                 | 10 years                                           | 20 years |
| DRP      | 34              | 23                                                 | 2        |
| ECOLI    | 34              | 24                                                 | 2        |
| NH4N     | 34              | 21                                                 | 1        |
| sCBOD5   | 34              | 23                                                 | 0        |
| SIN      | 34              | 23                                                 | 2        |
| Vol_Mat  | 34              | 24                                                 | 2        |

#### 5.1.3.1 10 year trends

The LAWA categorical description for the raw (with high censor filter) trends for the river discharge sites for the 10 year trend period are mapped in Figure 27 and shown in a summary table in Figure 28.

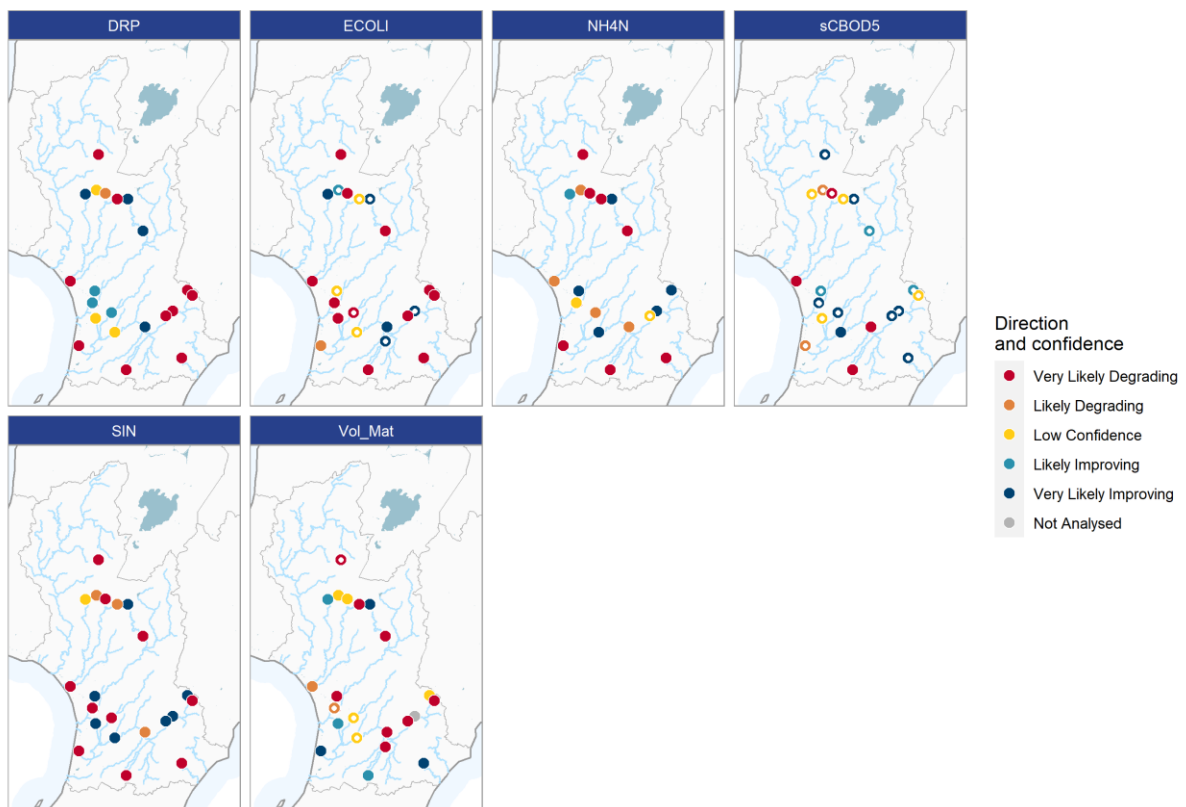


Figure 27: Map of river discharge sites classified by 10 year trend confidence and direction. Confidence and direction is expressed categorically based on the levels defined in Table 3. Sites with a Sen Slope of zero are indicated with a white dot.

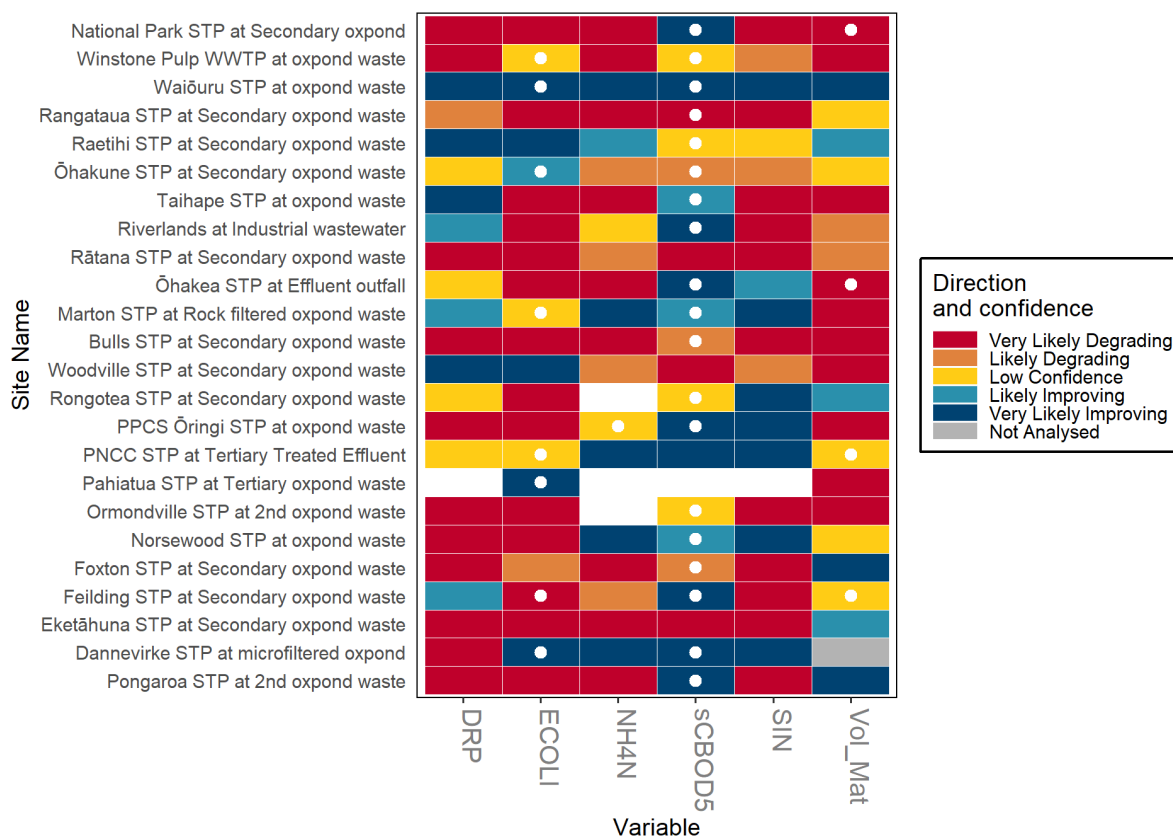


Figure 28: Assessed 10-year raw water quality trend at discharge sites classified by trend confidence and direction. Confidence and direction is expressed categorically based on the levels defined in Table 3. Sites with a Sen Slope of zero are indicated with a white dot.

#### 5.1.3.2 20 year trends

The LAWA categorical description for the raw (with high censor filter) trends for the river discharge sites for the 20 year trend period are mapped in Figure 29 and shown in a summary table in Figure 30.

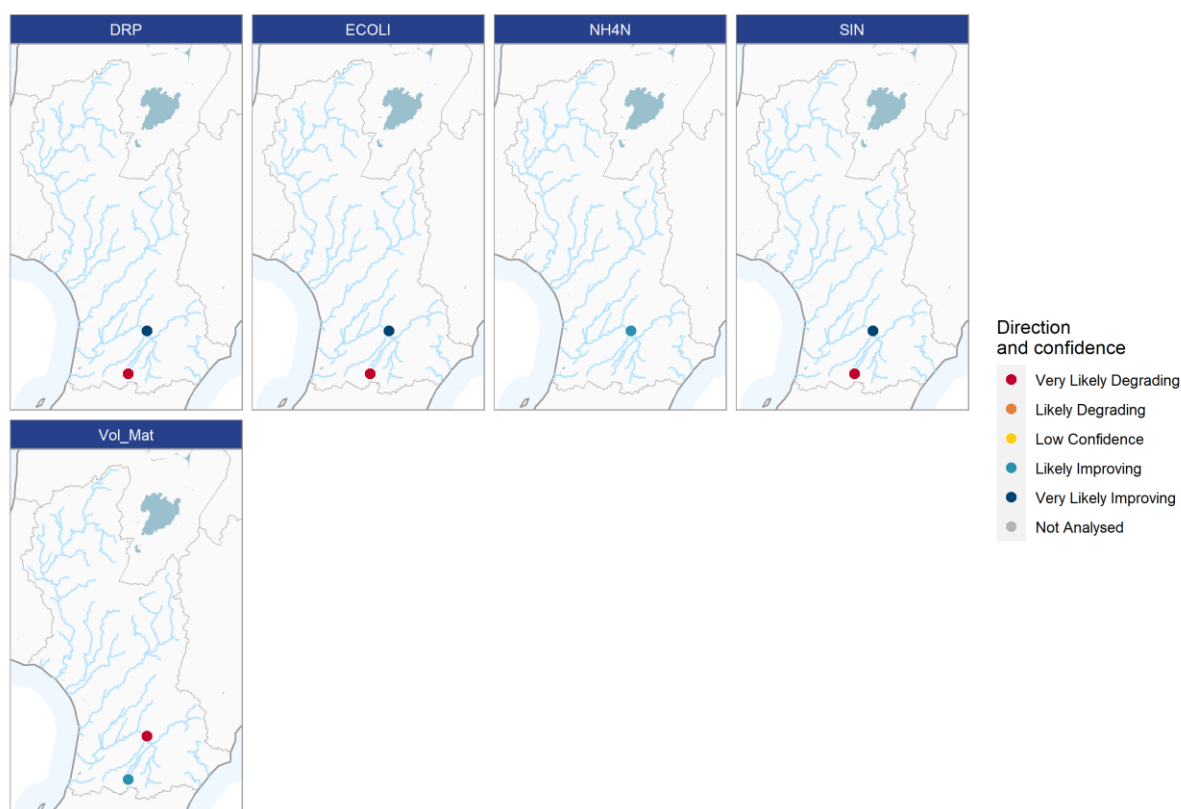


Figure 29: Map of river discharge sites classified by 20 year trend confidence and direction. Confidence and direction is expressed categorically based on the levels defined in Table 3. Sites with a Sen Slope of zero are indicated with a white dot.

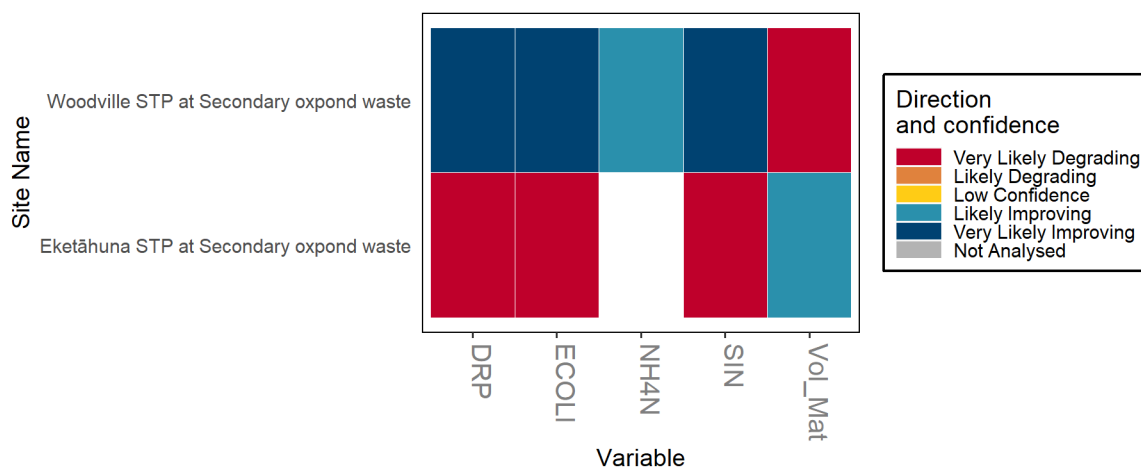


Figure 30: Assessed 20-year raw water quality trend at discharge sites classified by trend confidence and direction. Confidence and direction is expressed categorically based on the levels defined in Table 3. Sites with a Sen Slope of zero are indicated with a white dot.

### 5.1.3.3 Aggregate trends

Figure 31 shows colour coded bar charts representing the proportions of discharge sites with improving and degrading water quality trends based on the categories defined in Table 3 for the 10-year trend period. All but one of the variables (sCBOD5) had more than half of sites classed as “likley degrading” or “Very likley degrading” (DRP, ECOLI, NH4N, SIN, Vol\_Mat).

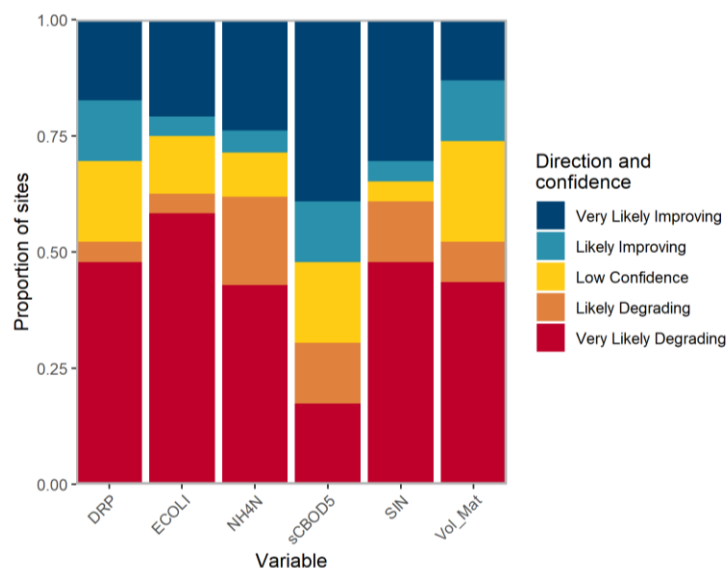


Figure 31. Summary plot representing the proportion of discharge sites each categorical level of confidence and direction for 10-year time period trends. The plot shows the proportion of sites in each of the trend direction and confidence categories defined in Table 3.

## 5.2 Lakes

Following the application of the filtering rules described in section 3.2.1, the total number of lake sites that were included in the analyses was reduced from that shown in Table 1. A summary of the site numbers that were included in the final lake site trend assessments is presented in Figure 9. There were no lake sites that met the minimum data requirements for 20 or 30 year trends.

Table 7. Lake water quality variables and lake site numbers for which 10-year trends were analysed by this study.

| Variable | Number of sites | Number of sites that complied with filtering rules for 10 year trends |
|----------|-----------------|-----------------------------------------------------------------------|
| Chl_a    | 15              | 4                                                                     |
| ECOLI    | 15              | 3                                                                     |
| NH4N     | 15              | 4                                                                     |
| TN       | 15              | 4                                                                     |
| TP       | 15              | 4                                                                     |

The LAWA categorical description for the raw (with high censor filter) trends for the lake sites for the 10 year trend period are shown in a summary table in Figure 32. Across the four sites there was a dominance of degrading trends for Chl\_a, and a dominance for improving trends for the remaining variables (ECOLI, NH4N, TN, TP).

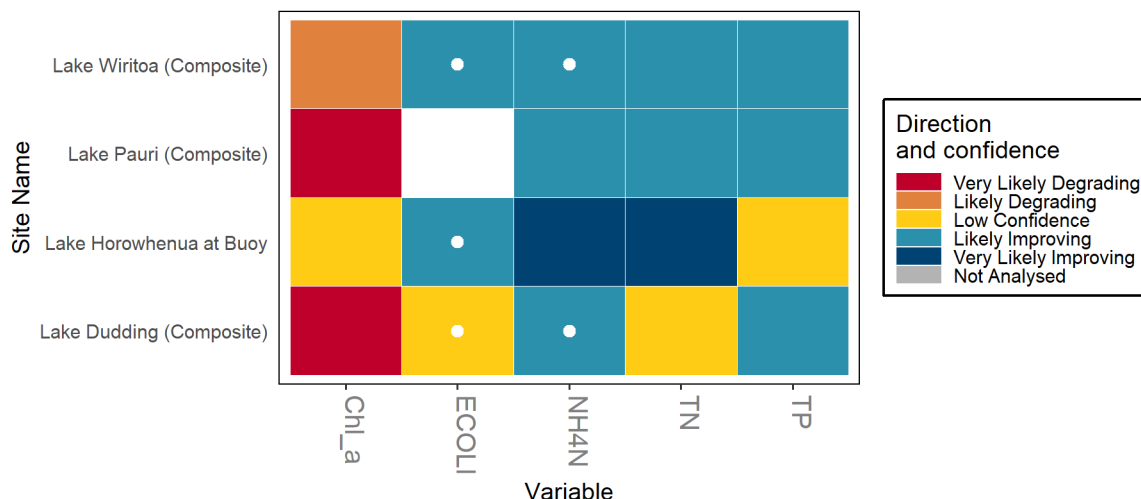


Figure 32: Assessed 10-year raw water quality trend at lake sites classified by trend confidence and direction. Confidence and direction is expressed categorically based on the levels defined in Table 3. Sites with a Sen Slope of zero are indicated with a white dot.

### 5.3 Estuary

Following the application of the filtering rules described in section 3.2.1, the total number of estuary sites that were included in the analyses was reduced from that shown in Table 1. A summary of the site numbers that were included in the final estuary site trend assessments is presented in Table 8. There were no estuary sites that met the minimum data requirements for 20 or 30 year trends.

Table 8. Estuary water quality variables and estuary site numbers for which 10-year trends were analysed by this study.

| Variable | Number of sites | Number of sites that complied with filtering rules for 10 year trends |
|----------|-----------------|-----------------------------------------------------------------------|
| Chl_a    | 6               | 4                                                                     |
| DO_Sat   | 7               | 6                                                                     |
| DRP      | 7               | 6                                                                     |
| ECOLI    | 7               | 6                                                                     |
| NH4N     | 7               | 6                                                                     |
| pH       | 1               | 1                                                                     |
| SIN      | 7               | 3                                                                     |
| TEMP     | 7               | 6                                                                     |

The LAWA categorical description for the raw (with high censor filter) trends for the estuary sites for the 10 year trend period are shown in a summary table in Figure 33. All six sites had very likely degrading trends for NH<sub>4</sub>N, and a dominance for improving trends for Chl<sub>a</sub> and DO<sub>Sat</sub>. Mōwhānau Stream at Footbridge showed very likely degrading trends for four of the six variables evaluated at the site.

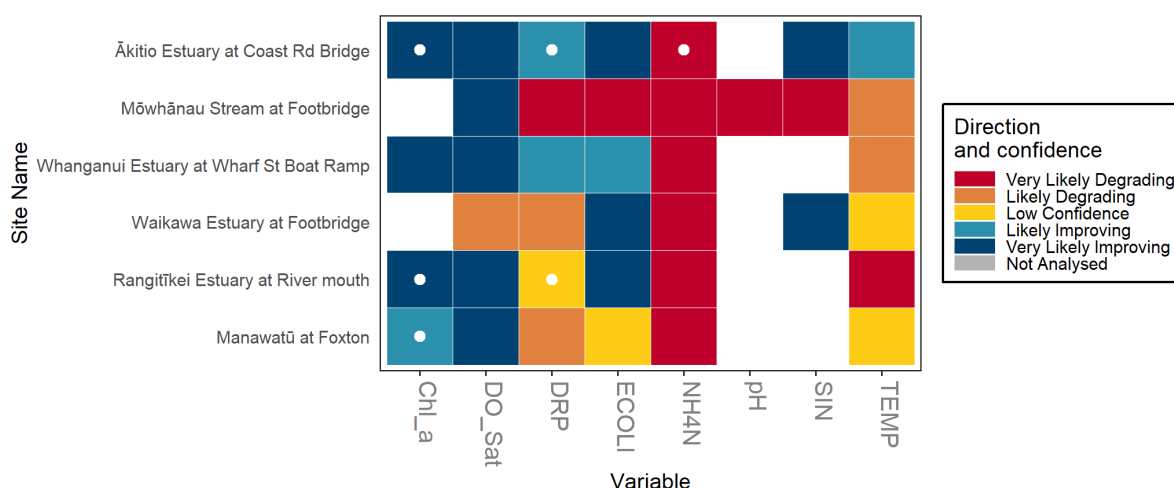


Figure 33: Assessed 10-year raw water quality trend at estuary sites classified by trend confidence and direction. Confidence and direction is expressed categorically based on the levels defined in Table 3. Sites with a Sen Slope of zero are indicated with a white dot.

## 5.4 Coastal

Following the application of the filtering rules described in section 3.2.1, the total number of coastal sites that were included in the analyses was reduced from that shown in Table 1. A summary of the site numbers that were included in the final coastal site trend assessments is presented in Table 9. There were no coastal sites that met the minimum data requirements for 20 or 30 year trends.

Table 9. Coastal water quality variables and coastal site numbers for which 10-year trends were analysed by this study.

| Variable          | Number of sites | Number of sites that complied with filtering rules for 10 year trends |
|-------------------|-----------------|-----------------------------------------------------------------------|
| Chl <sub>a</sub>  | 4               | 4                                                                     |
| NH <sub>4</sub> N | 4               | 3                                                                     |
| TN                | 4               | 4                                                                     |
| TP                | 4               | 4                                                                     |

The LAWA categorical description for the raw (with high censor filter) trends for the coastal sites for the 10 year trend period are shown in a summary table in Figure 32. Across the four sites there was a dominance of degrading trends for TN, and a dominance for improving trends for Chl<sub>a</sub> and NH<sub>4</sub>N.

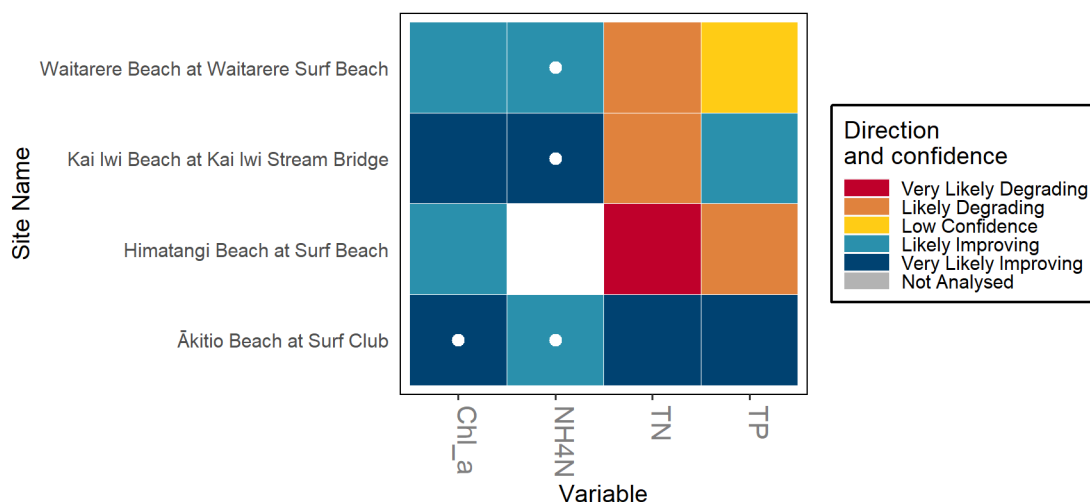


Figure 34: Assessed 10-year raw water quality trend at coastal sites classified by trend confidence and direction. Confidence and direction is expressed categorically based on the levels defined in Table 3. Sites with a Sen Slope of zero are indicated with a white dot.

## 6 Comparison of state and trends

The relevance of trends and identification of appropriate management actions is dependent on many factors, including the current state and the direction and magnitude of the trends. Figure 35 to Figure 39 show the distribution of 10-year Sen slopes for each variable separated by One Plan grades (evaluated for the most recent 5 years) for SoE, impact, lake, estuary and coastal sites. Note, in some cases the state target did not have a corresponding trend calculated (i.e., maximum ammoniacal-N, *E. coli* bathing); in these cases, the Sen slopes shown in the figures represent the trends evaluated for all data for the corresponding variable. The same data are presented in Appendix D but shown as scatter plots with the continuous compliance statistic (e.g., median NH4-N) on the x-axis and annual Sen slope with on the y-axis, including the 90% confidence intervals for the Sen slopes.

### 6.1 Rivers

Sites of all grades were associated with both improving and degrading trends for both SoE and impact sites. The largest degrading trends were associated with sites with poor state grades, almost uniformly across all variables. For the *E. coli* grades, the largest improving trends were also associated with sites with the lowest state grades. For the NH4N grades, the largest degrading trends were associated with sites that had passing grades. The site with the worst state for Periphyton Mats (Moawhango at Waiouru), also had the largest degrading trends (by over and order of magnitude), with a Sen slope of 3% cover per year.



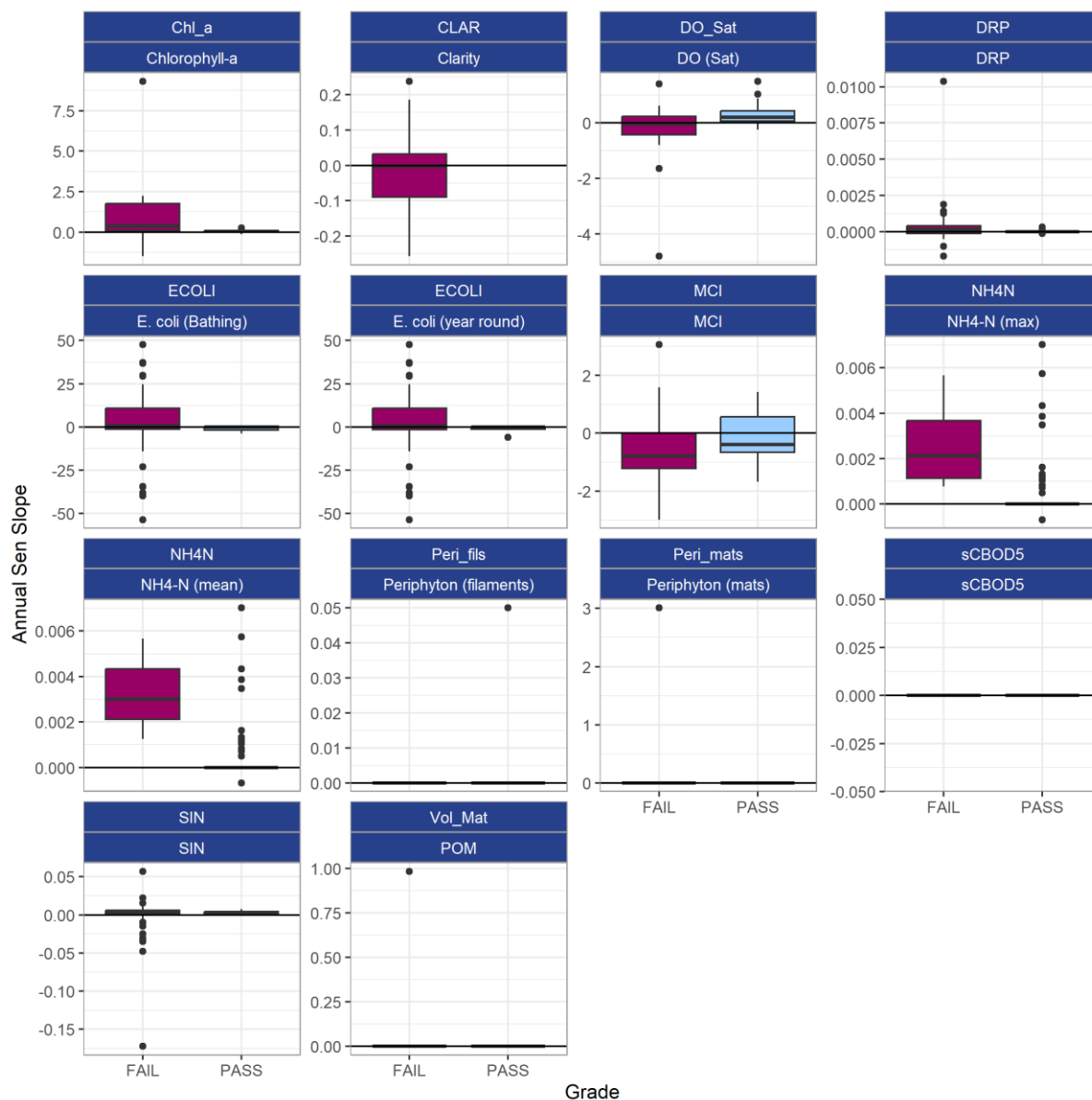


Figure 35: Box and whisker plot showing distribution of 10-year trend magnitudes (Sen slopes) for river SoE sites categorised by their (5-year) One Plan grades. Note, for CLAR, DO\_Sat and MCI negative Sen Slopes indicate degradation; for other variables negative Sen slopes indicate improvement. The first row of plot labels is the trend variable, and the second row is the One Plan target name.

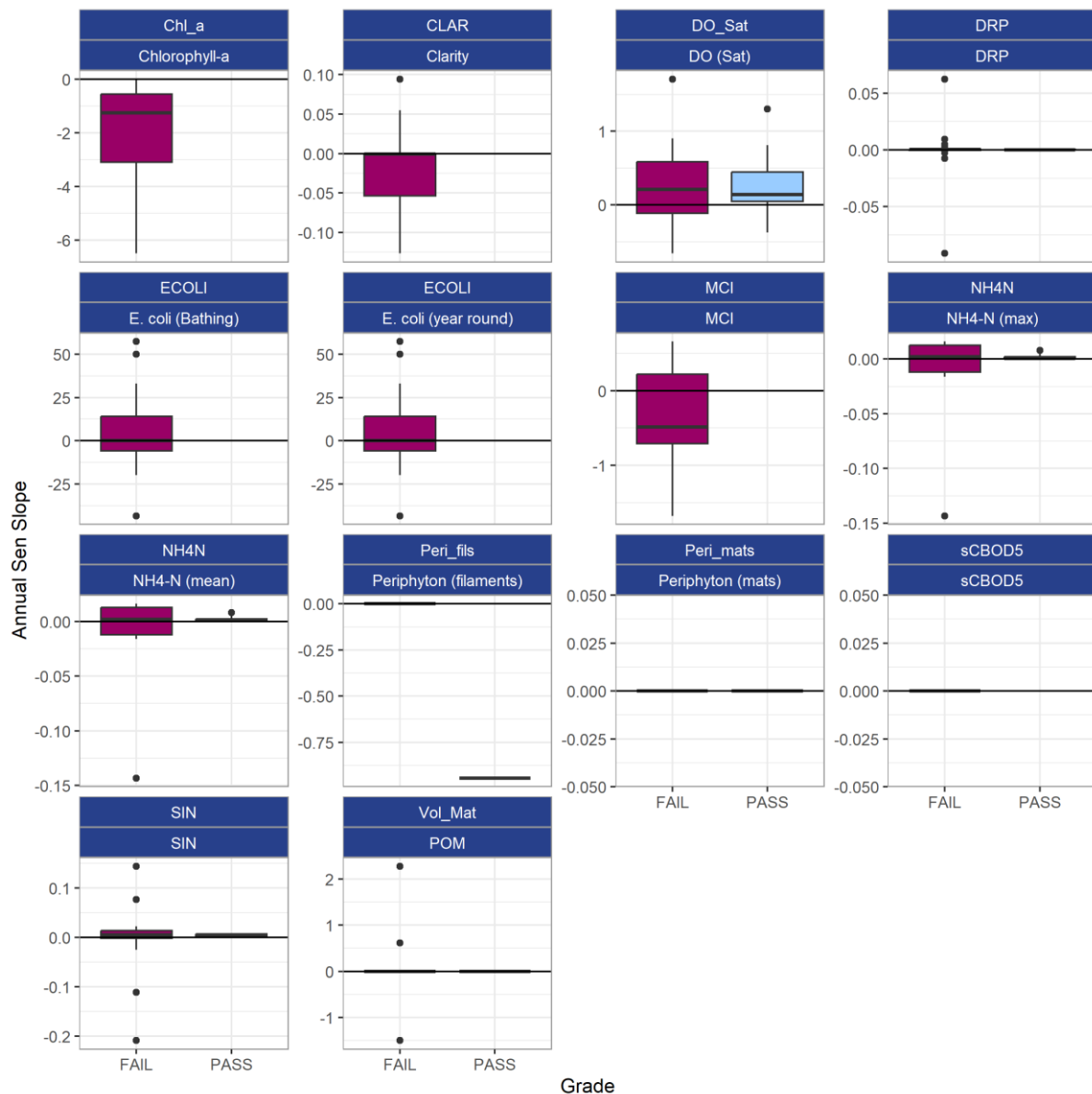


Figure 36: Box and whisker plot showing distribution of 10-year trend magnitudes (Sen slopes) for river impact sites categorised by their (5-year) One Plan grades. Note, for CLAR, DO\_Sat and MCI negative Sen Slopes indicate degradation; for other variables negative Sen slopes indicate improvement. The first row of plot labels is the trend variable and the second row is the One Plan target name.

## 6.2 Lakes

The largest degrading trends in Lakes were associated with poor state grades, almost uniformly across all variables. For the *E. coli* trends, all sites had Sen slopes of zero, i.e., trend slopes could not be quantified given the detection limit and precision of the monitoring. All sites are failing to meet the chlorophyll-a One Plan targets, and with the exception of Lake Horowhenua at Buoy, the site trends indicate further degradation. In contrast, for TP and TN, although sites are uniformly failing the One Plan targets, three out of four sites had improving trends.

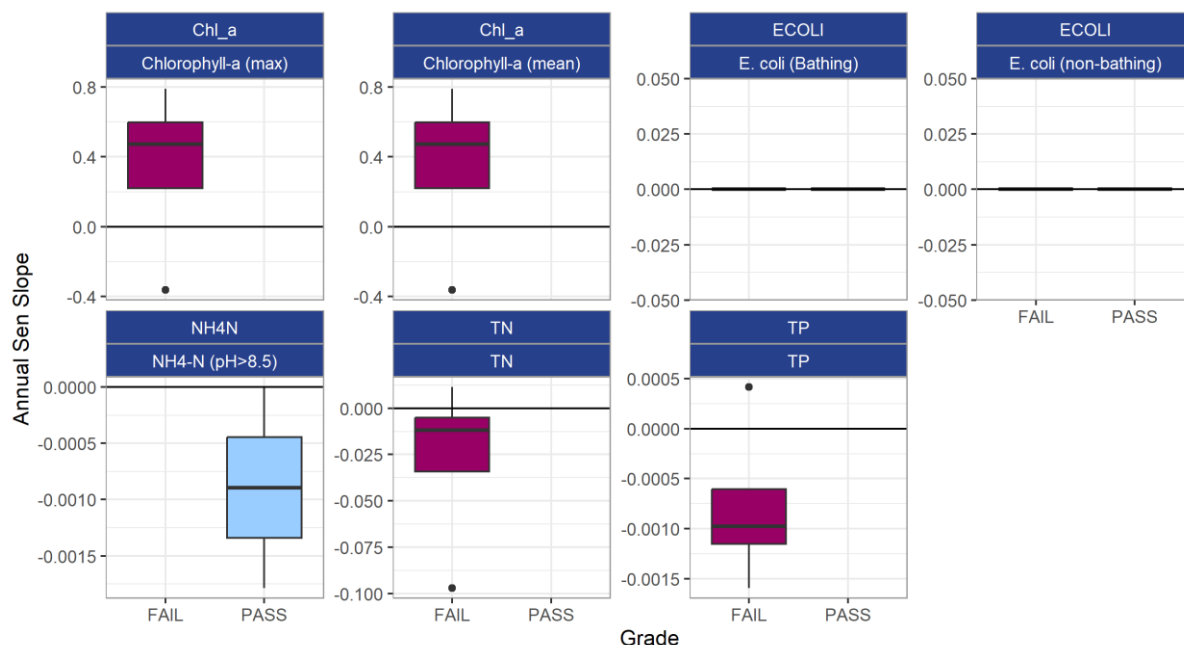


Figure 37: Box and whisker plot showing distribution of 10-year trend magnitudes (Sen slopes) for lake sites categorised by their (5-year) One Plan grades. The first row of plot labels is the trend variable and the second row is the One Plan target name.

### 6.3 Estuary

For DRP, TEMP and NH4N there was a pattern of increasing degrading trends with larger compliance statistic values (i.e., poorer water quality state, Appendix D, Figure 110). Improvements in DO\_Sat were greatest for sites that had failed the One Plan target. Although all sites failed the One Plan *E. coli* targets, all but one site (Mōwhānau stream at Footbridge) had an improving trend in *E. coli*.

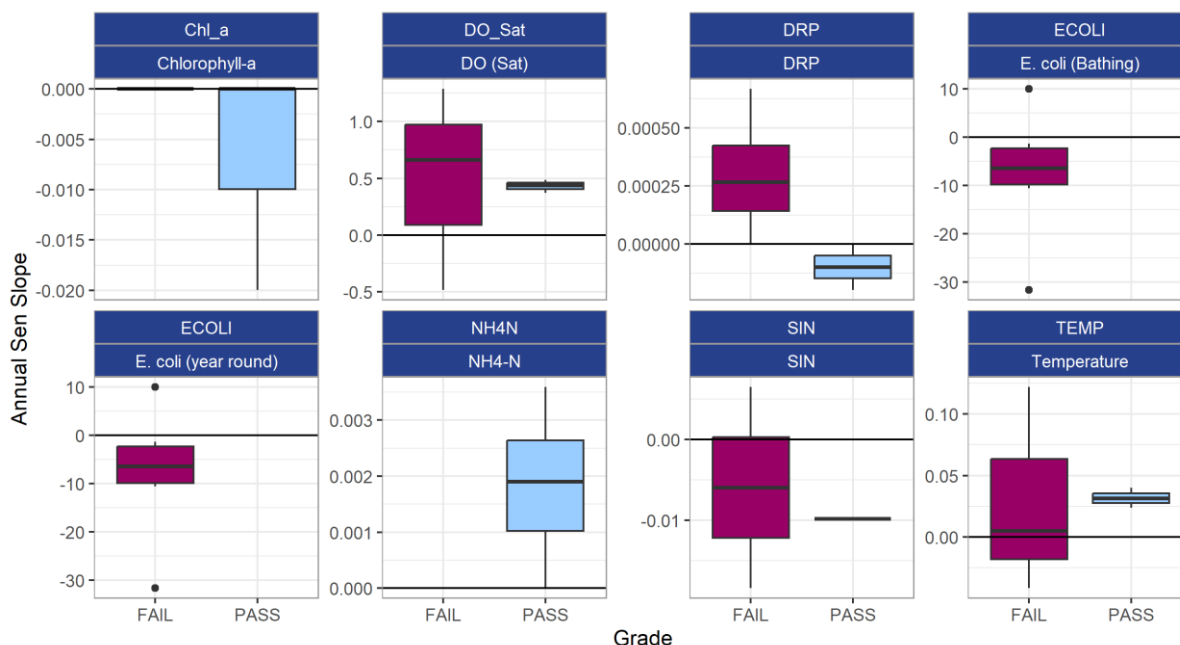


Figure 38: Box and whisker plot showing distribution of 10-year trend magnitudes (Sen slopes) for estuary sites categorised by their (5-year) One Plan grades. Note, for DO\_Sat negative Sen Slopes indicate degradation; for other variables negative Sen slopes indicate improvement. The first row of plot labels is the trend variable and the second row is the One Plan target name.

## 6.4 Coastal

Trends in Chl\_a at coastal sites indicate improvement, both for sites that have passed and failed the One Plan Chlorophyll-a target. For TN and TP there is a pattern of increasing magnitude of degrading trends with poorer water quality state (Figure 39 and Appendix D: Figure 112).

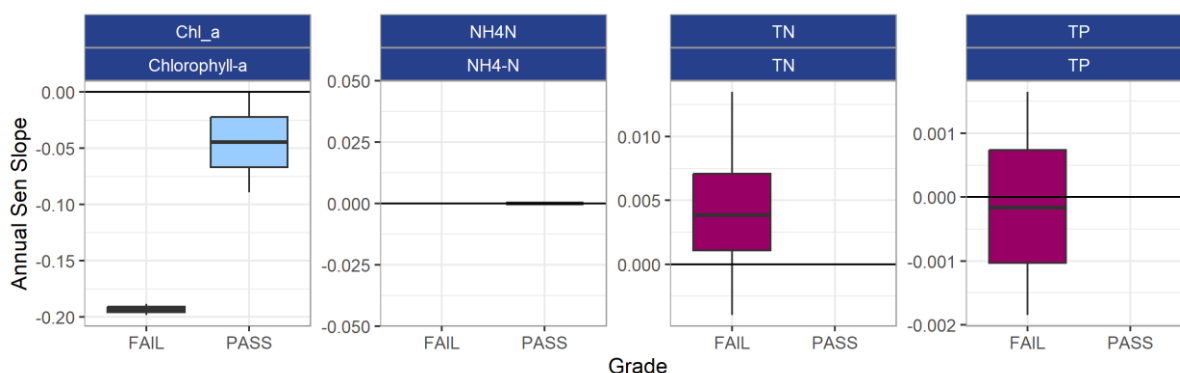


Figure 39: Box and whisker plot showing distribution of 10-year trend magnitudes (Sen slopes) for coastal sites categorised by their (5-year) One Plan grades. The first row of plot labels is the trend variable and the second row is the One Plan target name.

## 7 Summary

### 7.1 Water quality state

The most obvious pattern associated with the assessment of water quality state was that for many variables the individual sites almost uniformly passed or failed One Plan criteria. A majority of river sites failed the Horizons One Plan criteria for dissolved reactive phosphorus (DRP), macroinvertebrate community index (MCI), *E. coli* and clarity. Conversely, almost all sites passed the One Plan criteria for ammoniacal-N (NH<sub>4</sub>-N), periphyton (mats) and dissolved oxygen (sat). There were similar numbers of State of Environment sites passing and failing the One Plan criteria for chlorophyll-a, particulate organic matter (POM), periphyton (filaments) and soluble inorganic nitrogen (SIN). Generally, these patterns in grades were similar for the impact sites. A majority of discharge sites failed the One Plan criteria for change in pH, and percent reduction in clarity. Conversely, most discharge sites passed the change in temperature criterion.

All lakes sites failed the total nitrogen (TN) criterion, and only Lake Koiitiata passed the chlorophyll-a and total phosphorus (TP) criteria. Grades varied across the region for the *E. coli* (bathing) criteria. For estuary sites, all sites failed *E. coli* criteria and passed NH<sub>4</sub>-N criteria and for coastal sites, all sites based the NH<sub>4</sub>-N criteria and failed the TN, TP and enterococci (bathing) criteria.

There are no immediately obvious geographic patterns associated with the variation in grades, however this does not mean that there are not associations with, for example, river size or catchment land cover..

### 7.2 Water quality trends

Water quality trends for the 10 year period were assessed for up to 100 (of 112) river SoE sites, 27 (of 27) river impact sites, 24 (of 34) discharge sites, 4 (of 15) lake sites, 6 (of 7) estuary sites and 4 (of 4) coastal sites. Water quality trends for the 20 year period were assessed at up to 28 (of 112) river SoE sites and 2 (of 34) discharge sites. There were insufficient data to calculate 20 year trends at any Lake, Estuary, Coastal or river impact sites. Water quality trends for the 30 year period were also calculated for up to 6 river SoE sites. The difference in numbers of sites between time periods reflects the significant expansion of Horizon Regional Council's river monitoring network over the period 2007-2010, and the lake monitoring network in recent years.

For the 10 year period and river SoE site trends, seven of the 15 water quality variables had more than half of sites categorised as "likely degrading" or "Very likely degrading" (chlorophyll a, visual clarity, DRP, MCI, NH<sub>4</sub>-N, percent cover of mat algae and SIN), whereas only two variables had more than half of sites classes as "likely improving" or "very likely improving" (DO\_Sat, sCBOD5). In previous trend assessments (and over the 20 year trend period) NH<sub>4</sub>-N was dominated by improving trends. However, the majority of the NH<sub>4</sub>-N trends are evaluated as having a Sen slope of zero (i.e., below the rate of detection given by the detection limit and time period).

### 7.3 Relationships between state and trends

For river and lake sites the trends with the largest rates of degradation trends were associated with sites with poor state grades, almost uniformly across all variables. For *E. coli*, the largest improving trend rates were at sites that had failed the One Plan *E. coli* criteria. At estuary sites, all but one site that failed the One Plan *E. coli* criteria had improving trends for *E. coli*. At both

lakes and estuaries there was a pattern of larger degrading trend rates with larger (worse) water quality (based on compliance statistics). Trends in chlorophyll-a at coastal sites indicate improvement, both for sites that have passed and failed the One Plan chlorophyll-a criterion.

## Acknowledgements

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## References

- Helsel, D. R. (2012). Reporting Limits. In *Statistics for censored environmental data using Minitab and R* (Second, Vol. 77, pp. 22–36). John Wiley & Sons.
- Helsel, D. R., Hirsch, R. M., Ryberg, K. R., Archfield, S. A., & Gilroy, E. J. (2020). *Statistical methods in water resources* (Report No. 4-A3) (p. 484). Reston, VA.  
<https://doi.org/10.3133/tm4A3>
- Horizons Regional Council. (2014). One Plan. Retrieved January 5, 2018, from  
<http://www.horizons.govt.nz/data/one-plan>
- Larned, S., Snelder, T., Unwin, M., McBride, G., Verburg, P., & McMillan, H. (2015). Analysis of water quality in New Zealand lakes and rivers. *Prepared for the Ministry for the Environment. Wellington: Ministry for the Environment.*
- Larned, S., Whitehead, A., Fraser, C. E., Snelder, T., & Yang, J. (2018). *Water quality state and trends in New Zealand rivers. Analyses of national-scale data ending in 2017* (Prepared for Ministry for the Environment No. 2018347CH) (p. 71). NIWA. Retrieved from <https://www.mfe.govt.nz/sites/default/files/media/Fresh%20water/spatial-modelling-of-river-water-quality-state.pdf>
- McBride, G. B. (2005). *Using statistical methods for water quality management: issues, problems and solutions* (Vol. 19). John Wiley & Sons.
- Ministry for Environment, & Ministry of Health. (2003). *Microbiological water quality guidelines for marine and freshwater recreational areas* (No. ME Number: 474). Ministry for the Environment. Retrieved from  
<https://www.mfe.govt.nz/sites/default/files/microbiological-quality-jun03.pdf>
- R Core Team. (2023). R: A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing. Retrieved from <https://www.R-project.org/>.
- Snelder, T., & Fraser, C. (2021). *The LWP-Trends Library; v2102 November 2021* (p. 35). LWP Ltd Report.
- Snelder, T., Fraser, C., & Whitehead, A. (2022). Continuous measures of confidence in direction of environmental trends at site and other spatial scales. *Environmental Challenges*, *In press*, 1–11.



## Appendix A Site specific One Plan criteria

Table 10: Site specific One Plan criteria for river (SoE and Impact) sites

| Site Name                                                 | Chlorophyll-a | POM | DRP   | SIN   | DO (Sat) | MCI | MH4-N (mean) | NH4-N (mean) | Clarity | E. coli (bathing) | E. coli (year round) | Periphyton (mats) | Periphyton (filaments) | SCBOD5 |
|-----------------------------------------------------------|---------------|-----|-------|-------|----------|-----|--------------|--------------|---------|-------------------|----------------------|-------------------|------------------------|--------|
| Arawhata drain at Hokio Beach Rd                          | 200           | 5   | 0.015 | 0.167 | 60       | 100 | 0.4          | 2.1          | 2.5     | 260               | 550                  | 60                | 30                     | 2      |
| Hautapu River at Alabasters                               | 120           | 5   | 0.01  | 0.11  | 80       | 120 | 0.4          | 2.1          | 3       | 260               | 550                  | 60                | 30                     | 1.5    |
| Hautapu River at downstream of Taihape STP                | 120           | 5   | 0.01  | 0.11  | 70       | 100 | 0.4          | 2.1          | 2       | 260               | 550                  | 60                | 30                     | 2      |
| Hautapu River at Papakai Road Bridge                      | 120           | 5   | 0.01  | 0.11  | 70       | 100 | 0.4          | 2.1          | 2       | 260               | 550                  | 60                | 30                     | 2      |
| Hautapu River upstream of the Rangitikei River confluence | 120           | 5   | 0.01  | 0.11  | 70       | 100 | 0.4          | 2.1          | 2       | 260               | 550                  | 60                | 30                     | 2      |
| Hokio Stream at Lake Horowhenua                           | 200           | 5   | 0.015 | 0.167 | 60       | 100 | 0.4          | 2.1          | 2.5     | 260               | 550                  | 60                | 30                     | 2      |
| Kahuterawa River at Johnstons Rātā                        | 50            | 5   | 0.006 | 0.07  | 80       | 120 | 0.32         | 1.7          | 3       | 260               | 550                  | 60                | 30                     | 1.5    |
| Kahuterawa River at Keebles Farm                          | 50            | 5   | 0.006 | 0.07  | 80       | 120 | 0.32         | 1.7          | 3       | 260               | 550                  | 60                | 30                     | 1.5    |
| Kai Iwi Stream at Handley Road                            | 200           | 5   | 0.015 | 0.167 | 70       | 100 | 0.4          | 2.1          | 1.6     | 260               | 550                  | 60                | 30                     | 2      |
| Kaikōkopu Stream at Himatangi Beach                       | 200           | 5   | 0.015 | 0.167 | 60       | 100 | 0.4          | 2.1          | 2.5     | 260               | 550                  | 60                | 30                     | 2      |
| Kaitoke Stream at Vector Gas Line                         | 200           | 5   | 0.015 | 0.167 | 60       | 100 | 0.4          | 2.1          | 2.5     | 260               | 550                  | 60                | 30                     | 2      |
| Kiwitea Stream at Kimbolton Rd                            | 120           | 5   | 0.01  | 0.167 | 70       | 120 | 0.4          | 2.1          | 2.5     | 260               | 550                  | 60                | 30                     | 2      |
| Koitiata Stream at Beamish Rd                             | 200           | 5   | 0.015 | 0.167 | 60       | 100 | 0.4          | 2.1          | 2.5     | 260               | 550                  | 60                | 30                     | 2      |
| Kōpūtaroa Stream at Tavistock Rd                          | 200           | 5   | 0.015 | 0.444 | 60       | 100 | 0.4          | 2.1          | 2.5     | 260               | 550                  | 60                | 30                     | 2      |
| Kuku Stream at N. Johnstone Farm Bridge                   | 120           | 5   | 0.01  | 0.11  | 70       | 100 | 0.4          | 2.1          | 2.5     | 260               | 550                  | 60                | 30                     | 2      |
| Kūmeti Stream at Te Rehunga                               | 50            | 5   | 0.006 | 0.07  | 80       | 120 | 0.32         | 1.7          | 3       | 260               | 550                  | 60                | 30                     | 1.5    |

| Site Name                                      | Chlorophyll-a | POM | DRP   | SIN   | DO (Sat) | MCI | MH4-N (mean) | NH4-N (mean) | Clarity | E. coli (bathing) | E. coli (year round) | Periphyton (mats) | Periphyton (filaments) | SCBOD5 |
|------------------------------------------------|---------------|-----|-------|-------|----------|-----|--------------|--------------|---------|-------------------|----------------------|-------------------|------------------------|--------|
| Mangaroa Stream at Lindsay Rd                  | 200           | 5   | 0.015 | 0.167 | 60       | 100 | 0.4          | 2.1          | 2.5     | 260               | 550                  | 60                | 30                     | 2      |
| Makahika Stream above Ōhau Confluence          | 50            | 5   | 0.006 | 0.07  | 80       | 120 | 0.32         | 1.7          | 3       | 260               | 550                  | 60                | 30                     | 1.5    |
| Mākākahi River downstream of Eketāhuna STP     | 120           | 5   | 0.01  | 0.444 | 80       | 120 | 0.4          | 2.1          | 3       | 260               | 550                  | 60                | 30                     | 1.5    |
| Mākākahi River at end of Kaiparoro Road        | 120           | 5   | 0.01  | 0.444 | 80       | 120 | 0.4          | 2.1          | 3       | 260               | 550                  | 60                | 30                     | 1.5    |
| Mākākahi River at Hāmua                        | 120           | 5   | 0.01  | 0.444 | 80       | 120 | 0.4          | 2.1          | 3       | 260               | 550                  | 60                | 30                     | 1.5    |
| Mākākahi River upstream of Eketāhuna STP       | 120           | 5   | 0.01  | 0.444 | 80       | 120 | 0.4          | 2.1          | 3       | 260               | 550                  | 60                | 30                     | 1.5    |
| Makaretu Stream above Ōhau Confluence          | 50            | 5   | 0.006 | 0.07  | 80       | 120 | 0.32         | 1.7          | 3       | 260               | 550                  | 60                | 30                     | 1.5    |
| Makomako Road drain at Lake Horowhenua         | 200           | 5   | 0.015 | 0.167 | 60       | 100 | 0.4          | 2.1          | 2.5     | 260               | 550                  | 60                | 30                     | 2      |
| Makorokio Stream at Tirohanga Station          | 120           | 5   | 0.01  | 0.11  | 70       | 100 | 0.4          | 2.1          | 2.5     | 260               | 550                  | 60                | 30                     | 2      |
| Makotuku River upstream of Raetihi STP         | 50            | 5   | 0.006 | 0.07  | 80       | 120 | 0.32         | 1.7          | 3       | 260               | 550                  | 60                | 30                     | 1.5    |
| Makotuku River downstream of Raetihi STP       | 50            | 5   | 0.006 | 0.07  | 80       | 120 | 0.32         | 1.7          | 3       | 260               | 550                  | 60                | 30                     | 1.5    |
| Makotuku River at Raetihi                      | 50            | 5   | 0.006 | 0.07  | 80       | 120 | 0.32         | 1.7          | 3       | 260               | 550                  | 60                | 30                     | 1.5    |
| Makotuku River at State Highway 49A            | 50            | 5   | 0.006 | 0.07  | 80       | 120 | 0.32         | 1.7          | 3       | 260               | 550                  | 60                | 30                     | 1.5    |
| Mākuri River at Tuscan Hills                   | 120           | 5   | 0.01  | 0.11  | 80       | 120 | 0.4          | 2.1          | 3       | 260               | 550                  | 60                | 30                     | 1.5    |
| Manakau Stream at Cemetery                     | 120           | 5   | 0.01  | 0.167 | 70       | 100 | 0.4          | 2.1          | 2.1     | 260               | 550                  | 60                | 30                     | 2      |
| Manakau Stream at SH1 Bridge                   | 120           | 5   | 0.01  | 0.167 | 70       | 100 | 0.4          | 2.1          | 2.5     | 260               | 550                  | 60                | 30                     | 2      |
| Manawatū River downstream of PNCC STP          | 120           | 5   | 0.01  | 0.444 | 70       | 100 | 0.4          | 2.1          | 2.5     | 260               | 550                  | 60                | 30                     | 2      |
| Manawatū River downstream of Fonterra Longburn | 120           | 5   | 0.01  | 0.444 | 70       | 100 | 0.4          | 2.1          | 2.5     | 260               | 550                  | 60                | 30                     | 2      |
| Manawatū River at Hopelands                    | 120           | 5   | 0.01  | 0.444 | 80       | 120 | 0.4          | 2.1          | 3       | 260               | 550                  | 60                | 30                     | 1.5    |

| Site Name                                          | Chlorophyll-a | POM | DRP   | SIN   | DO (Sat) | MCI | MH4-N (mean) | NH4-N (mean) | Clarity | E. coli (bathing) | E. coli (year round) | Periphyton (mats) | Periphyton (filaments) | SCBOD5 |
|----------------------------------------------------|---------------|-----|-------|-------|----------|-----|--------------|--------------|---------|-------------------|----------------------|-------------------|------------------------|--------|
| Manawatū River at Ngāawapūrua Bridge               | 120           | 5   | 0.01  | 0.444 | 80       | 120 | 0.4          | 2.1          | 3       | 260               | 550                  | 60                | 30                     | 1.5    |
| Manawatū River at Ōpiki Bridge                     | 120           | 5   | 0.01  | 0.444 | 70       | 100 | 0.4          | 2.1          | 2.5     | 260               | 550                  | 60                | 30                     | 2      |
| Manawatū River at Teachers College                 | 120           | 5   | 0.01  | 0.444 | 70       | 100 | 0.4          | 2.1          | 2.5     | 260               | 550                  | 60                | 30                     | 2      |
| Manawatū River upstream of PNCC STP                | 120           | 5   | 0.01  | 0.444 | 70       | 100 | 0.4          | 2.1          | 2.5     | 260               | 550                  | 60                | 30                     | 2      |
| Manawatū River at Upper Gorge                      | 120           | 5   | 0.01  | 0.444 | 70       | 100 | 0.4          | 2.1          | 2.5     | 260               | 550                  | 60                | 30                     | 2      |
| Manawatū River upstream of Fonterra Longburn       | 120           | 5   | 0.01  | 0.444 | 70       | 100 | 0.4          | 2.1          | 2.5     | 260               | 550                  | 60                | 30                     | 2      |
| Manawatū River at Weber Road                       | 120           | 5   | 0.01  | 0.167 | 80       | 120 | 0.4          | 2.1          | 3       | 260               | 550                  | 60                | 30                     | 1.5    |
| Manawatū River at Whirokino                        | 200           | 5   | 0.015 | 0.444 | 70       | 100 | 0.4          | 2.1          | 2.5     | 260               | 550                  | 60                | 30                     | 2      |
| Mangaatua Stream downstream of Woodville STP       | 120           | 5   | 0.01  | 0.444 | 70       | 100 | 0.4          | 2.1          | 2.5     | 260               | 550                  | 60                | 30                     | 2      |
| Mangaatua Stream upstream of Woodville STP         | 120           | 5   | 0.01  | 0.444 | 70       | 100 | 0.4          | 2.1          | 2.5     | 260               | 550                  | 60                | 30                     | 2      |
| Mangaehuehu Stream downstream of Rangataua STP     | 50            | 5   | 0.006 | 0.07  | 80       | 120 | 0.32         | 1.7          | 3       | 260               | 550                  | 60                | 30                     | 1.5    |
| Mangaehuehu Stream upstream of Rangataua STP       | 50            | 5   | 0.006 | 0.07  | 80       | 120 | 0.32         | 1.7          | 3       | 260               | 550                  | 60                | 30                     | 1.5    |
| Mangahao River at Ballance                         | 50            | 5   | 0.006 | 0.167 | 80       | 120 | 0.32         | 1.7          | 3       | 260               | 550                  | 60                | 30                     | 1.5    |
| Manganui o te Ao River at Ruatiti Domain           | 120           | 5   | 0.01  | 0.11  | 80       | 120 | 0.32         | 1.7          | 3.4     | 260               | 550                  | 60                | 30                     | 1.5    |
| Mangaore River downstream of Shannon STP           | 120           | 5   | 0.01  | 0.167 | 70       | 100 | 0.4          | 2.1          | 2.5     | 260               | 550                  | 60                | 30                     | 2      |
| Mangaore River upstream of Shannon STP             | 120           | 5   | 0.01  | 0.167 | 70       | 100 | 0.4          | 2.1          | 2.5     | 260               | 550                  | 60                | 30                     | 2      |
| Mangapapa Stream at Troup Rd                       | 120           | 5   | 0.01  | 0.444 | 70       | 100 | 0.4          | 2.1          | 2.5     | 260               | 550                  | 60                | 30                     | 2      |
| Mangarangiora Stream downstream of Ormondville STP | 120           | 5   | 0.01  | 0.167 | 80       | 120 | 0.4          | 2.1          | 3       | 260               | 550                  | 60                | 30                     | 1.5    |

| Site Name                                                  | Chlorophyll-a | POM | DRP   | SIN   | DO (Sat) | MCI | MH4-N (mean) | NH4-N (mean) | Clarity | E. coli (bathing) | E. coli (year round) | Periphyton (mats) | Periphyton (filaments) | SCBOD5 |
|------------------------------------------------------------|---------------|-----|-------|-------|----------|-----|--------------|--------------|---------|-------------------|----------------------|-------------------|------------------------|--------|
| Mangarangiora Stream upstream of Ormondville STP           | 120           | 5   | 0.01  | 0.167 | 80       | 120 | 0.4          | 2.1          | 3       | 260               | 550                  | 60                | 30                     | 1.5    |
| Mangarangiora Stream tributary downstream of Norsewood STP | 120           | 5   | 0.01  | 0.167 | 80       | 120 | 0.4          | 2.1          | 3       | 260               | 550                  | 60                | 30                     | 1.5    |
| Mangarangiora Stream tributary upstream of Norsewood STP   | 120           | 5   | 0.01  | 0.167 | 80       | 120 | 0.4          | 2.1          | 3       | 260               | 550                  | 60                | 30                     | 1.5    |
| Mangatainoka River at SH2 Bridge                           | 120           | 5   | 0.01  | 0.444 | 80       | 120 | 0.4          | 2.1          | 3       | 260               | 550                  | 60                | 30                     | 1.5    |
| Mangatainoka River downstream of Pahiatua STP              | 120           | 5   | 0.01  | 0.444 | 80       | 120 | 0.4          | 2.1          | 3       | 260               | 550                  | 60                | 30                     | 1.5    |
| Mangatainoka River at Hukanui                              | 120           | 5   | 0.01  | 0.444 | 80       | 120 | 0.4          | 2.1          | 3       | 260               | 550                  | 60                | 30                     | 1.5    |
| Mangatainoka River at Larsons Road                         | 50            | 5   | 0.006 | 0.07  | 80       | 120 | 0.32         | 1.7          | 3       | 260               | 550                  | 60                | 30                     | 1.5    |
| Mangatainoka River at Pahiatua Town Bridge                 | 120           | 5   | 0.01  | 0.444 | 80       | 120 | 0.4          | 2.1          | 3       | 260               | 550                  | 60                | 30                     | 1.5    |
| Mangatainoka River at Pūtara                               | 50            | 5   | 0.006 | 0.07  | 80       | 120 | 0.32         | 1.7          | 3       | 260               | 550                  | 60                | 30                     | 1.5    |
| Mangatainoka River at Scarborough Kōnini Rd                | 120           | 5   | 0.01  | 0.444 | 80       | 120 | 0.4          | 2.1          | 3       | 260               | 550                  | 60                | 30                     | 1.5    |
| Mangatainoka River upstream of Pahiatua STP                | 120           | 5   | 0.01  | 0.444 | 80       | 120 | 0.4          | 2.1          | 3       | 260               | 550                  | 60                | 30                     | 1.5    |
| Mangatainoka River upstream of Tīraumea confluence         | 120           | 5   | 0.01  | 0.444 | 80       | 120 | 0.4          | 2.1          | 3       | 260               | 550                  | 60                | 30                     | 1.5    |
| Mangatepopo River at downstream Intake                     | 50            | 5   | 0.006 | 0.07  | 80       | 120 | 0.32         | 1.7          | 3       | 260               | 550                  | 60                | 30                     | 1.5    |
| Mangatera River at downstream of Dannevirke STP            | 120           | 5   | 0.01  | 0.444 | 70       | 100 | 0.4          | 2.1          | 2.5     | 260               | 550                  | 60                | 30                     | 2      |
| Mangatera River at Dannevirke                              | 120           | 5   | 0.01  | 0.444 | 70       | 100 | 0.4          | 2.1          | 2.5     | 260               | 550                  | 60                | 30                     | 2      |
| Mangatera River upstream of Manawatū confluence            | 120           | 5   | 0.01  | 0.444 | 70       | 100 | 0.4          | 2.1          | 2.5     | 260               | 550                  | 60                | 30                     | 2      |
| Mangatera River upstream of the T.D.C. oxidation ponds     | 120           | 5   | 0.01  | 0.444 | 70       | 100 | 0.4          | 2.1          | 2.5     | 260               | 550                  | 60                | 30                     | 2      |

| Site Name                                        | Chlorophyll-a | POM | DRP   | SIN   | DO (Sat) | MCI | MH4-N (mean) | NH4-N (mean) | Clarity | E. coli (bathing) | E. coli (year round) | Periphyton (mats) | Periphyton (filaments) | SCBOD5 |
|--------------------------------------------------|---------------|-----|-------|-------|----------|-----|--------------|--------------|---------|-------------------|----------------------|-------------------|------------------------|--------|
| Mangatewainui River at Hardie's                  | 120           | 5   | 0.01  | 0.167 | 80       | 120 | 0.4          | 2.1          | 3       | 260               | 550                  | 60                | 30                     | 1.5    |
| Mangatoro Stream at Mangahei Road                | 120           | 5   | 0.01  | 0.11  | 80       | 120 | 0.4          | 2.1          | 3       | 260               | 550                  | 60                | 30                     | 1.5    |
| Mangawhero River downstream of Ohakune STP       | 50            | 5   | 0.006 | 0.07  | 80       | 120 | 0.32         | 1.7          | 3       | 260               | 550                  | 60                | 30                     | 1.5    |
| Mangawhero River at DOC Headquarters             | 50            | 5   | 0.006 | 0.07  | 80       | 120 | 0.32         | 1.7          | 3       | 260               | 550                  | 60                | 30                     | 1.5    |
| Mangawhero River at Pakihi Rd Bridge             | 50            | 5   | 0.006 | 0.07  | 80       | 120 | 0.32         | 1.7          | 3       | 260               | 550                  | 60                | 30                     | 1.5    |
| Mangawhero River at Raupiu Road                  | 120           | 5   | 0.01  | 0.11  | 70       | 100 | 0.4          | 2.1          | 2       | 260               | 550                  | 60                | 30                     | 2      |
| Mangawhero River upstream of Ohakune STP         | 50            | 5   | 0.006 | 0.07  | 80       | 120 | 0.32         | 1.7          | 3       | 260               | 550                  | 60                | 30                     | 1.5    |
| Moawhango River at Waiouru                       | 50            | 5   | 0.006 | 0.07  | 80       | 120 | 0.32         | 1.7          | 3       | 260               | 550                  | 60                | 30                     | 1.5    |
| Ngatahaka Stream upstream of Mākākahi confluence | 120           | 5   | 0.01  | 0.444 | 80       | 120 | 0.4          | 2.1          | 3       | 260               | 550                  | 60                | 30                     | 1.5    |
| Ōhau River at Gladstone Reserve                  | 50            | 5   | 0.006 | 0.07  | 80       | 120 | 0.32         | 1.7          | 3       | 260               | 550                  | 60                | 30                     | 1.5    |
| Ōhau River at Haines Property                    | 120           | 5   | 0.01  | 0.11  | 70       | 100 | 0.4          | 2.1          | 2.5     | 260               | 550                  | 60                | 30                     | 2      |
| Ōhau River at State Highway Bridge               | 120           | 5   | 0.01  | 0.11  | 70       | 100 | 0.4          | 2.1          | 2.5     | 260               | 550                  | 60                | 30                     | 2      |
| Ōhau River upstream of Makahika confluence       | 50            | 5   | 0.006 | 0.07  | 80       | 120 | 0.32         | 1.7          | 3       | 260               | 550                  | 60                | 30                     | 1.5    |
| Ōhura River at Tokorima                          | 200           | 5   | 0.015 | 0.167 | 70       | 100 | 0.4          | 2.1          | 1.6     | 260               | 550                  | 60                | 30                     | 2      |
| Ōngarue River at Taringamotu                     | 120           | 5   | 0.01  | 0.11  | 80       | 100 | 0.4          | 2.1          | 2.5     | 260               | 550                  | 60                | 30                     | 1.5    |
| Ōroua River at Almadale Slackline                | 120           | 5   | 0.01  | 0.167 | 70       | 100 | 0.4          | 2.1          | 2.5     | 260               | 550                  | 60                | 30                     | 2      |
| Ōroua River at Apiti Gorge Bridge                | 120           | 5   | 0.01  | 0.167 | 70       | 100 | 0.4          | 2.1          | 2.5     | 260               | 550                  | 60                | 30                     | 2      |
| Ōroua River at Awahuri Bridge                    | 120           | 5   | 0.01  | 0.444 | 70       | 100 | 0.4          | 2.1          | 2.5     | 260               | 550                  | 60                | 30                     | 2      |
| Ōroua River downstream of AFFCO Feilding         | 120           | 5   | 0.01  | 0.444 | 70       | 100 | 0.4          | 2.1          | 2.5     | 260               | 550                  | 60                | 30                     | 2      |

| Site Name                                          | Chlorophyll-a | POM | DRP   | SIN   | DO (Sat) | MCI | MH4-N (mean) | NH4-N (mean) | Clarity | E. coli (bathing) | E. coli (year round) | Periphyton (mats) | Periphyton (filaments) | SCOD5 |
|----------------------------------------------------|---------------|-----|-------|-------|----------|-----|--------------|--------------|---------|-------------------|----------------------|-------------------|------------------------|-------|
| Ōroua River downstream of Feilding STP             | 120           | 5   | 0.01  | 0.444 | 70       | 100 | 0.4          | 2.1          | 2.5     | 260               | 550                  | 60                | 30                     | 2     |
| Ōroua River at Mangawhata                          | 200           | 5   | 0.015 | 0.444 | 70       | 100 | 0.4          | 2.1          | 2.5     | 260               | 550                  | 60                | 30                     | 2     |
| Ōroua River upstream of AFFCO Feilding             | 120           | 5   | 0.01  | 0.444 | 70       | 100 | 0.4          | 2.1          | 2.5     | 260               | 550                  | 60                | 30                     | 2     |
| Ōroua River upstream of Feilding STP               | 120           | 5   | 0.01  | 0.444 | 70       | 100 | 0.4          | 2.1          | 2.5     | 260               | 550                  | 60                | 30                     | 2     |
| Ōroua tributary upstream of Kimbolton STP          | 120           | 5   | 0.01  | 0.167 | 70       | 100 | 0.4          | 2.1          | 2.5     | 260               | 550                  | 60                | 30                     | 2     |
| Ōroua tributary downstream of Kimbolton STP        | 120           | 5   | 0.01  | 0.167 | 70       | 100 | 0.4          | 2.1          | 2.5     | 260               | 550                  | 60                | 30                     | 2     |
| Ōruakeretaki Stream at downstream PPCS Oringi STP  | 120           | 5   | 0.01  | 0.444 | 70       | 100 | 0.4          | 2.1          | 2.5     | 260               | 550                  | 60                | 30                     | 2     |
| Ōruakeretaki Stream at SH2 Napier                  | 120           | 5   | 0.01  | 0.444 | 70       | 100 | 0.4          | 2.1          | 2.5     | 260               | 550                  | 60                | 30                     | 2     |
| Owahanga River at Branscombe Bridge                | 200           | 5   | 0.015 | 0.167 | 70       | 100 | 0.4          | 2.1          | 1.6     | 260               | 550                  | 60                | 30                     | 2     |
| Patiki Stream at Kawi Road                         | 200           | 5   | 0.015 | 0.167 | 60       | 100 | 0.4          | 2.1          | 2.5     | 260               | 550                  | 60                | 30                     | 2     |
| Piakatutu Stream downstream of Sanson STP          | 120           | 5   | 0.01  | 0.11  | 70       | 100 | 0.4          | 2.1          | 2.5     | 260               | 550                  | 60                | 30                     | 2     |
| Piakatutu Stream upstream of Sanson STP            | 120           | 5   | 0.01  | 0.11  | 70       | 100 | 0.4          | 2.1          | 2.5     | 260               | 550                  | 60                | 30                     | 2     |
| Pohangina River at Mais Reach                      | 120           | 5   | 0.01  | 0.11  | 70       | 100 | 0.4          | 2.1          | 2.5     | 260               | 550                  | 60                | 30                     | 2     |
| Pohangina River at Piripiri                        | 120           | 5   | 0.006 | 0.07  | 80       | 120 | 0.32         | 1.7          | 3       | 260               | 550                  | 60                | 30                     | 1.5   |
| Pongaroa River downstream of the Pongaroa STP      | 200           | 5   | 0.015 | 0.167 | 70       | 100 | 0.4          | 2.1          | 1.6     | 260               | 550                  | 60                | 30                     | 2     |
| Pongaroa River upstream of the Pongaroa STP        | 200           | 5   | 0.015 | 0.167 | 70       | 100 | 0.4          | 2.1          | 1.6     | 260               | 550                  | 60                | 30                     | 2     |
| Pōrewa Stream downstream of Hunterville STP Site   | 120           | 5   | 0.01  | 0.11  | 70       | 100 | 0.4          | 2.1          | 1.6     | 260               | 550                  | 60                | 30                     | 2     |
| Pōrewa Stream downstream of Hunterville STP Site A | 120           | 5   | 0.01  | 0.11  | 70       | 100 | 0.4          | 2.1          | 1.6     | 260               | 550                  | 60                | 30                     | 2     |
| Pōrewa Stream at Onepuhi Road                      | 120           | 5   | 0.006 | 0.07  | 70       | 120 | 0.32         | 1.7          | 3       | 260               | 550                  | 60                | 30                     | 2     |

| Site Name                                              | Chlorophyll-a | POM | DRP   | SIN   | DO (Sat) | MCI | MH4-N (mean) | NH4-N (mean) | Clarity | E. coli (bathing) | E. coli (year round) | Periphyton (mats) | Periphyton (filaments) | SCBOD5 |
|--------------------------------------------------------|---------------|-----|-------|-------|----------|-----|--------------|--------------|---------|-------------------|----------------------|-------------------|------------------------|--------|
| Pōrewa Stream upstream of Hunterville STP              | 120           | 5   | 0.01  | 0.11  | 70       | 100 | 0.4          | 2.1          | 1.6     | 260               | 550                  | 60                | 30                     | 2      |
| Pōrewa Stream upstream of Hunterville STP Site A       | 120           | 5   | 0.01  | 0.11  | 70       | 100 | 0.4          | 2.1          | 1.6     | 260               | 550                  | 60                | 30                     | 2      |
| Rangitawa Stream downstream of Halcombe oxidation pond | 120           | 5   | 0.01  | 0.11  | 70       | 100 | 0.4          | 2.1          | 2.5     | 260               | 550                  | 60                | 30                     | 2      |
| Rangitawa Stream upstream of Halcombe oxidation pond   | 120           | 5   | 0.01  | 0.11  | 70       | 100 | 0.4          | 2.1          | 2.5     | 260               | 550                  | 60                | 30                     | 2      |
| Rangitikei River downstream of Riverlands              | 120           | 5   | 0.01  | 0.11  | 70       | 100 | 0.4          | 2.1          | 2.5     | 260               | 550                  | 60                | 30                     | 2      |
| Rangitikei River at Mangaweka                          | 120           | 5   | 0.01  | 0.11  | 80       | 120 | 0.32         | 1.7          | 3.4     | 260               | 550                  | 60                | 30                     | 1.5    |
| Rangitikei River at McKelvies                          | 120           | 5   | 0.01  | 0.11  | 70       | 100 | 0.4          | 2.1          | 2.5     | 260               | 550                  | 60                | 30                     | 2      |
| Rangitikei River at Onepuhi                            | 120           | 5   | 0.01  | 0.11  | 80       | 120 | 0.4          | 2.1          | 3       | 260               | 550                  | 60                | 30                     | 1.5    |
| Rangitikei River at Pukeokahu                          | 50            | 5   | 0.006 | 0.07  | 80       | 120 | 0.32         | 1.7          | 3.4     | 260               | 550                  | 60                | 30                     | 1.5    |
| Rangitikei River upstream of Bulls STP                 | 120           | 5   | 0.01  | 0.11  | 70       | 100 | 0.4          | 2.1          | 2.5     | 260               | 550                  | 60                | 30                     | 2      |
| Rangitikei River upstream of Riverlands                | 120           | 5   | 0.01  | 0.11  | 70       | 100 | 0.4          | 2.1          | 2.5     | 260               | 550                  | 60                | 30                     | 2      |
| Raparapawai Stream at Jackson Rd                       | 120           | 5   | 0.01  | 0.444 | 70       | 100 | 0.4          | 2.1          | 2.5     | 260               | 550                  | 60                | 30                     | 2      |
| Tamaki River at Stephensons                            | 120           | 5   | 0.01  | 0.444 | 70       | 100 | 0.4          | 2.1          | 2.5     | 260               | 550                  | 60                | 30                     | 2      |
| Tamaki River at Tamaki Reserve                         | 50            | 5   | 0.006 | 0.07  | 80       | 120 | 0.32         | 1.7          | 3       | 260               | 550                  | 60                | 30                     | 1.5    |
| Tīraumea River at Ngāturi                              | 120           | 5   | 0.01  | 0.444 | 70       | 100 | 0.4          | 2.1          | 2       | 260               | 550                  | 60                | 30                     | 2      |
| Tīraumea River upstream of Manawatū confluence         | 120           | 5   | 0.01  | 0.444 | 70       | 100 | 0.4          | 2.1          | 2       | 260               | 550                  | 60                | 30                     | 2      |
| Tokiahuru River at Junction                            | 50            | 5   | 0.006 | 0.07  | 80       | 120 | 0.32         | 1.7          | 3       | 260               | 550                  | 60                | 30                     | 1.5    |
| Tokiahuru River at Karioi Domain Road                  | 50            | 5   | 0.006 | 0.07  | 80       | 120 | 0.32         | 1.7          | 3       | 260               | 550                  |                   |                        | 1.5    |
| Tokomaru River at Horseshoe bend                       | 50            | 5   | 0.006 | 0.07  | 80       | 120 | 0.32         | 1.7          | 3       | 260               | 550                  | 60                | 30                     | 1.5    |

| Site Name                                                  | Chlorophyll-a | POM | DRP   | SIN   | DO (Sat) | MCI | MH4-N (mean) | NH4-N (mean) | Clarity | E. coli (bathing) | E. coli (year round) | Periphyton (mats) | Periphyton (filaments) | SCBOD5 |
|------------------------------------------------------------|---------------|-----|-------|-------|----------|-----|--------------|--------------|---------|-------------------|----------------------|-------------------|------------------------|--------|
| Turakina River at O'Neill's Bridge                         | 200           | 5   | 0.015 | 0.167 | 70       | 100 | 0.4          | 2.1          | 1.6     | 260               | 550                  | 60                | 30                     | 2      |
| Turitea Stream at No1 Dairy Farm                           | 50            | 5   | 0.006 | 0.07  | 80       | 120 | 0.32         | 1.7          | 3       | 260               | 550                  | 60                | 30                     | 1.5    |
| Tūtaenui Stream downstream of Marton STP                   | 200           | 5   | 0.01  | 0.11  | 60       | 100 | 0.4          | 2.1          | 2.5     | 260               | 550                  | 60                | 30                     | 2      |
| Tūtaenui Stream upstream of Marton STP                     | 200           | 5   | 0.01  | 0.11  | 60       | 100 | 0.4          | 2.1          | 2.5     | 260               | 550                  | 60                | 30                     | 2      |
| Unnamed tributary of Waipu Stream downstream of Rātana STP | 200           | 5   | 0.015 | 0.167 | 60       | 100 | 0.4          | 2.1          | 2.5     | 260               | 550                  | 60                | 30                     | 2      |
| Unnamed tributary of Waipu Stream upstream of Rātana STP   | 200           | 5   | 0.015 | 0.167 | 60       | 100 | 0.4          | 2.1          | 2.5     | 260               | 550                  | 60                | 30                     | 2      |
| Waikawa Stream at Huritini                                 | 120           | 5   | 0.01  | 0.167 | 70       | 100 | 0.4          | 2.1          | 2.5     | 260               | 550                  | 60                | 30                     | 2      |
| Waikawa Stream at North Manakau Rd                         | 120           | 5   | 0.01  | 0.167 | 70       | 100 | 0.4          | 2.1          | 2.5     | 260               | 550                  | 60                | 30                     | 2      |
| Waikawa Stream upstream of Manakau confluence*             | 120           | 5   | 0.01  | 0.167 | 70       | 100 | 0.4          | 2.1          | 2.5     | 260               | 550                  | 60                | 30                     | 2      |
| Waitangi Stream downstream of Waiouru STP                  | 120           | 5   | 0.01  | 0.11  | 80       | 100 | 0.4          | 2.1          | 2.5     | 260               | 550                  | 60                | 30                     | 1.5    |
| Waitangi Stream upstream of Waiouru STP                    | 120           | 5   | 0.01  | 0.11  | 80       | 100 | 0.4          | 2.1          | 2.5     | 260               | 550                  | 60                | 30                     | 1.5    |
| Whakapapa River at Footbridge                              | 50            | 5   | 0.006 | 0.07  | 80       | 120 | 0.32         | 1.7          | 3       | 260               | 550                  | 60                | 30                     | 1.5    |
| Whangaehu River downstream of Winstone Pulp                | 50            | 5   | 0.006 | 0.07  | 80       | 120 | 0.32         | 1.7          | 3       | 260               | 550                  | 60                | 30                     | 1.5    |
| Whangaehu River at Kauangaroa                              | 120           | 5   | 0.01  | 0.11  | 70       | 100 | 0.4          | 2.1          | 2       | 260               | 550                  | 60                | 30                     | 2      |
| Whangaehu River upstream of Winstone Pulp                  | 50            | 5   | 0.006 | 0.07  | 80       | 120 | 0.32         | 1.7          | 3       | 260               | 550                  | 60                | 30                     | 1.5    |
| Whanganui River at Cherry Grove                            | 120           | 5   | 0.01  | 0.11  | 80       | 100 | 0.4          | 2.1          | 2.5     | 260               | 550                  | 60                | 30                     | 1.5    |
| Whanganui at Downstream Intake                             | 50            | 5   | 0.006 | 0.07  | 80       | 120 | 0.32         | 1.7          | 3       | 260               | 550                  | 60                | 30                     | 1.5    |
| Whanganui River at Pipiriki                                | 120           | 5   | 0.01  | 0.11  | 70       | 100 | 0.4          | 2.1          | 2       | 260               | 550                  | 60                | 30                     | 2      |
| Whanganui River at Te Maire                                | 120           | 5   | 0.01  | 0.11  | 80       | 100 | 0.4          | 2.1          | 2.5     | 260               | 550                  | 60                | 30                     | 1.5    |



| Site Name                            | Chlorophyll-a | POM | DRP   | SIN   | DO (Sat) | MCI | MH4-N (mean) | NH4-N (mean) | Clarity | E. coli (bathing) | E. coli (year round) | Periphyton (mats) | Periphyton (filaments) | SCBOD5 |
|--------------------------------------|---------------|-----|-------|-------|----------|-----|--------------|--------------|---------|-------------------|----------------------|-------------------|------------------------|--------|
| Whanganui River at Te Rewa           | 120           | 5   | 0.01  | 0.11  | 70       | 100 | 0.4          | 2.1          | 2       | 260               | 550                  | 60                | 30                     | 2      |
| Whanganui River at Wades Landing     | 120           | 5   | 0.01  | 0.11  | 80       | 100 | 0.4          | 2.1          | 2.5     | 260               | 550                  | 60                | 30                     | 1.5    |
| Whitebait Creek at Edinburgh Terrace | 200           | 5   | 0.015 | 0.444 | 70       | 100 | 0.4          | 2.1          | 2.5     | 260               | 550                  | 60                | 30                     | 2      |

Table 11: Site specific One Plan criteria for river discharge sites

| Site Name                                 | pH (change) | Temperature (change) | Clarity (change) | QMCI (change) |
|-------------------------------------------|-------------|----------------------|------------------|---------------|
| Pongaroa STP at 2nd oxpond waste          | 0.5         | 3                    | 30               | 20            |
| AFFCO Fielding at Industrial Waste water  | 0.5         | 3                    | 30               | 20            |
| Dannevirke STP at microfiltered oxpond    | 0.5         | 3                    | 30               | 20            |
| DB Breweries at Industrial wastewater     | 0.5         | 3                    | 20               | 20            |
| Eketāhuna STP at Secondary oxpond waste   | 0.5         | 3                    | 20               | 20            |
| Feilding STP at Secondary oxpond waste    | 0.5         | 3                    | 30               | 20            |
| Foxton STP at Secondary oxpond waste      | 0.5         | 3                    | 30               | 20            |
| Kimbolton STP at oxpond waste             | 0.5         | 3                    | 30               | 20            |
| Norsewood STP at oxpond waste             | 0.5         | 3                    | 20               | 20            |
| Ormondville STP at 2nd oxpond waste       | 0.5         | 3                    | 20               | 20            |
| Pahiatua STP at Tertiary oxpond waste     | 0.5         | 3                    | 20               | 20            |
| PNCC STP at Tertiary Treated Effluent     | 0.5         | 3                    | 30               | 20            |
| PPCS Ōringi STP at oxpond waste           | 0.5         | 3                    | 30               | 20            |
| Rongotea STP at Secondary oxpond waste    | 0.5         | 3                    | 30               | 20            |
| Shannon STP at oxpond waste               | 0.5         | 3                    | 30               | 20            |
| Tokomaru at oxpond waste                  | 0.5         | 3                    | 30               | 20            |
| Woodville STP at Secondary oxpond waste   | 0.5         | 3                    | 30               | 20            |
| Bulls STP at Secondary oxpond waste       | 0.5         | 3                    | 30               | 20            |
| Halcombe at Secondary oxpond              | 0.5         | 3                    | 30               | 20            |
| Huntermville STP at Microfiltration Plant | 0.5         | 3                    | 30               | 20            |
| Huntermville STP at Secondary oxpond      | 0.5         | 3                    | 30               | 20            |
| Marton STP at Rock filtered oxpond waste  | 0.5         | 3                    | 30               | 20            |
| Ōhakea STP at Effluent outfall            | 0.5         | 3                    | 30               | 20            |
| Rātana STP at Secondary oxpond waste      | 0.5         | 3                    | 30               | 20            |
| Riverlands at Industrial wastewater       | 0.5         | 3                    | 30               | 20            |
| Sanson STP at Secondary oxpond waste      | 0.5         | 3                    | 30               | 20            |
| Taihape STP at oxpond waste               | 0.5         | 3                    | 30               | 20            |
| Ōhakune STP at Secondary oxpond waste     | 0.5         | 2                    | 20               | 20            |
| Raetihi STP at Secondary oxpond waste     | 0.5         | 2                    | 20               | 20            |
| Rangataua STP at Secondary oxpond waste   | 0.5         | 2                    | 20               | 20            |
| Waiōuru STP at oxpond waste               | 0.5         | 2                    | 30               | 20            |
| Winstone Pulp WWTP at oxpond waste        | 0.5         | 2                    | 20               | 20            |
| National Park STP at Secondary oxpond     | 0.5         | 2                    | 20               | 20            |
| Taumarunui STP at Tertiary treated waste  | 0.5         | 2                    | 30               | 20            |

Table 12: Site specific One Plan criteria for lake sites

| Site Name                | Chlorophyll-a<br>(mean) | Chlorophyll-a<br>(max) | TP   | TN   | NH4-N (ph>8.5) | Clarity | E. coli (Bathing) | E. coli (non-bathing) |
|--------------------------|-------------------------|------------------------|------|------|----------------|---------|-------------------|-----------------------|
| Lake Alice               | 8                       | 30                     | 0.03 | 0.49 | 0.4            | 0.8     | 250               | 550                   |
| Lake Dudding (Composite) | 5                       | 15                     | 0.02 | 0.37 | 0.4            | 2.8     | 250               | 550                   |
| Lake Heaton              | 8                       | 30                     | 0.03 | 0.49 | 0.4            | 0.8     | 250               | 550                   |
| Lake Herbert             | 8                       | 30                     | 0.03 | 0.49 | 0.4            | 0.8     | 250               | 550                   |
| Lake Koitiata            | 8                       | 30                     | 0.03 | 0.49 | 0.4            | 0.8     | 250               | 550                   |
| Lake Koputara            | 8                       | 30                     | 0.03 | 0.49 | 0.4            | 0.8     | 250               | 550                   |
| Lake Waipū               | 5                       | 15                     | 0.02 | 0.37 | 0.4            | 2.8     | 250               | 550                   |
| Lake William             | 8                       | 30                     | 0.03 | 0.49 | 0.4            | 0.8     | 250               | 550                   |
| Omanuka Lagoon           | 8                       | 30                     | 0.03 | 0.49 | 0.4            | 0.8     | 250               | 550                   |
| Pukepuke Lagoon          | 8                       | 30                     | 0.03 | 0.49 | 0.4            | 0.8     | 250               | 550                   |
| Lake Horowhenua at Buoy  | 8                       | 30                     | 0.03 | 0.49 | 0.4            | 0.8     | 250               | 550                   |
| Lake Kohata              | 8                       | 30                     | 0.03 | 0.49 | 0.4            | 0.8     | 250               | 550                   |
| Lake Pauri (Composite)   | 5                       | 15                     | 0.02 | 0.37 | 0.4            | 2.8     | 250               | 550                   |
| Lake Westmere            | 8                       | 30                     | 0.03 | 0.49 | 0.4            | 0.8     | 250               | 550                   |
| Lake Wairua (Composite)  | 5                       | 15                     | 0.02 | 0.37 | 0.4            | 2.8     | 250               | 550                   |

Table 13: Site specific One Plan criteria for estuary sites

| Site Name                               | Chlorophyll-a | Temperature | DO (Sat) | DRP   | SIN   | NH4-N | E. coli (Bathing) | E. coli (year round) | Clarity |
|-----------------------------------------|---------------|-------------|----------|-------|-------|-------|-------------------|----------------------|---------|
| Ākitio Estuary at Coast Rd Bridge       | 4             | 22          | 70       | 0.015 | 0.167 | 0.4   | 260               | 550                  | 1.2     |
| Mōwhānau Stream at Footbridge           | 4             | 24          | 70       | 0.015 | 0.167 | 0.4   | 260               | 550                  | 1.2     |
| Manawatū at Foxton                      | 4             | 24          | 70       | 0.015 | 0.444 | 0.4   | 260               | 550                  | 1.2     |
| Rangitīkei Estuary at River mouth       | 4             | 24          | 70       | 0.015 | 0.167 | 0.4   | 260               | 550                  | 1.2     |
| Ōhau at Estuary                         | 4             | 22          | 70       | 0.01  | 0.11  | 0.4   | 260               | 550                  | 1.2     |
| Waikawa Estuary at Footbridge           | 4             | 22          | 70       | 0.01  | 0.167 | 0.4   | 260               | 550                  | 1.2     |
| Whanganui Estuary at Wharf St Boat Ramp | 4             | 24          | 70       | 0.015 | 0.167 | 0.4   | 260               | 550                  | 1.2     |

Table 14: Site specific One Plan criteria for coastal sites

| Site Name                               | Chlorophyll-a | TP   | TN   | NH4-N | Enterococci (bathing) | Enterococci (non-bathing) | Faecal Coliforms (median) | Faecal Coliforms (q90) |
|-----------------------------------------|---------------|------|------|-------|-----------------------|---------------------------|---------------------------|------------------------|
| Ākitio Beach at Surf Club               | 3             | 0.01 | 0.06 | 0.06  | 140                   | 280                       | 14                        | 43                     |
| Himatangi Beach at Surf Beach           | 3             | 0.01 | 0.06 | 0.06  | 140                   | 280                       | 14                        | 43                     |
| Kai Iwi Beach at Kai Iwi Stream Bridge  | 3             | 0.01 | 0.06 | 0.06  | 140                   | 280                       | 14                        | 43                     |
| Waitarere Beach at Waitarere Surf Beach | 3             | 0.01 | 0.06 | 0.06  | 140                   | 280                       | 14                        | 43                     |

## Appendix B Monitoring site supplementary information

Table 15: Summary of discharge sites and associated up and downstream monitoring sites

| Site Name                                | Relevant Impact Site                                       | Relevant SOE Site                                        | Relevant Impact Site MCI         | Relevant SOE Site MCI                  |
|------------------------------------------|------------------------------------------------------------|----------------------------------------------------------|----------------------------------|----------------------------------------|
| Pongaroa STP at 2nd oxpond waste         | Pongaroa River downstream of the Pongaroa STP              | Pongaroa River upstream of the Pongaroa STP              |                                  |                                        |
| AFFCO Feilding at Industrial Waste water | Ōroua River downstream of AFFCO Feilding                   | Ōroua River upstream of AFFCO Feilding                   |                                  |                                        |
| Dannevirke STP at microfiltered oxpond   | Mangatera River at downstream of Dannevirke STP            | Mangatera River upstream of the T.D.C. oxidation ponds   | Mangatera at d/s Dannevirke STP  | Mangatera at u/s T.D.C. Ox Ponds       |
| DB Breweries at Industrial wastewater    | Mangatainoka River at SH2 Bridge                           | Mangatainoka River at SH2 Bridge                         | Mangatainoka at d/s DB Breweries | Mangatainoka at Brewery - S.H.2 Bridge |
| Eketāhuna STP at Secondary oxpond waste  | Mākāhahi River downstream of Eketāhuna STP                 | Mākāhahi River upstream of Eketāhuna STP                 | Mākāhahi at d/s Eketāhuna STP    | Mākāhahi at u/s Eketāhuna STP          |
| Feilding STP at Secondary oxpond waste   | Ōroua River downstream of Feilding STP                     | Ōroua River upstream of Feilding STP                     | Ōroua at d/s Feilding STP        | Ōroua at U/S Feilding STP              |
| Foxton STP at Secondary oxpond waste     | NA                                                         | NA                                                       |                                  |                                        |
| Kimbolton STP at oxpond waste            | Ōroua tributary downstream of Kimbolton STP                | Ōroua tributary upstream of Kimbolton STP                |                                  |                                        |
| Norsewood STP at oxpond waste            | Mangarangiora Stream tributary downstream of Norsewood STP | Mangarangiora Stream tributary upstream of Norsewood STP |                                  |                                        |
| Ormondville STP at 2nd oxpond waste      | Mangarangiora Stream downstream of Ormondville STP         | Mangarangiora Stream upstream of Ormondville STP         |                                  |                                        |
| Pahiatua STP at Tertiary oxpond waste    | Mangatainoka River downstream of Pahiatua STP              | Mangatainoka River upstream of Pahiatua STP              | Mangatainoka at d/s Pahiatua STP | Mangatainoka at u/s Pahiatua STP       |
| PNCC STP at Tertiary Treated Effluent    | Manawatū River downstream of PNCC STP                      | Manawatū River upstream of PNCC STP                      | Manawatū at d/s PNCC STP         | Manawatū at u/s PNCC STP               |
| PPCS Ōringi STP at oxpond waste          | Ōruakeretaki Stream at downstream PPCS Ōringi STP          | Ōruakeretaki Stream at SH2 Napier                        |                                  |                                        |
| Rongotea STP at Secondary oxpond waste   | NA                                                         | NA                                                       |                                  |                                        |
| Shannon STP at oxpond waste              | Mangaore River downstream of Shannon STP                   | Mangaore River upstream of Shannon STP                   |                                  |                                        |
| Tokomaru at oxpond waste                 | NA                                                         | NA                                                       |                                  |                                        |
| Woodville STP at Secondary oxpond waste  | Mangaatua Stream downstream of Woodville STP               | Mangaatua Stream upstream of Woodville STP               | Mangaatua at d/s Woodville STP   | Mangaatua at u/s Woodville STP         |

|                                           |                                                            |                                                          |                                |                                 |
|-------------------------------------------|------------------------------------------------------------|----------------------------------------------------------|--------------------------------|---------------------------------|
| Bulls STP at Secondary oxpond waste       | Rangitikei River upstream of Riverlands                    | Rangitikei River upstream of Bulls STP                   |                                |                                 |
| Halcombe at Secondary oxpond              | Rangitawa Stream downstream of Halcombe oxidation pond     | Rangitawa Stream upstream of Halcombe oxidation pond     |                                |                                 |
| Huntermville STP at Microfiltration Plant | Pōrewa Stream downstream of Huntermville STP Site A        | Pōrewa Stream upstream of Huntermville STP Site A        | Pōrewa at d/s Huntermville STP | Pōrewa at u/s Huntermville STP  |
| Huntermville STP at Secondary oxpond      | Pōrewa Stream downstream of Huntermville STP Site A        | Pōrewa Stream upstream of Huntermville STP               | Pōrewa at d/s Huntermville STP |                                 |
| Marton STP at Rock filtered oxpond waste  | Tūtaenui Stream downstream of Marton STP                   | Tūtaenui Stream upstream of Marton STP                   |                                | Tūtaenui Stream at Curls Bridge |
| Ōhakea STP at Effluent outfall            | NA                                                         | NA                                                       |                                |                                 |
| Rātana STP at Secondary oxpond waste      | Unnamed tributary of Waipu Stream downstream of Rātana STP | Unnamed tributary of Waipu Stream upstream of Rātana STP |                                |                                 |
| Riverlands at Industrial wastewater       | Rangitikei River downstream of Riverlands                  | Rangitikei River upstream of Riverlands                  |                                |                                 |
| Sanson STP at Secondary oxpond waste      | Piakatutu Stream downstream of Sanson STP                  | Piakatutu Stream upstream of Sanson STP                  |                                |                                 |
| Taihapa STP at oxpond waste               | Hautapu River at downstream of Taihapa STP                 | Hautapu River at Papakai Road Bridge                     |                                | Hautapu at Alabasters           |
| Ōhakune STP at Secondary oxpond waste     | Mangawhero River downstream of Ōhakune STP                 | Mangawhero River upstream of Ōhakune STP                 | Mangawhero at d/s Ōhakune STP  | Mangawhero at u/s Ōhakune STP   |
| Raetihi STP at Secondary oxpond waste     | Makotuku River downstream of Raetihi STP                   | Makotuku River upstream of Raetihi STP                   | Makotuku at d/s Raetihi STP    | Makotuku at Above Sewage Plant  |
| Rangataua STP at Secondary oxpond waste   | Mangaehuehu Stream downstream of Rangataua STP             | Mangaehuehu Stream upstream of Rangataua STP             |                                |                                 |
| Waiōuru STP at oxpond waste               | Waitangi Stream downstream of Waiōuru STP                  | Waitangi Stream upstream of Waiōuru STP                  | Waitangi at d/s Waiōuru STP    | Waitangi at u/s Waiōuru STP     |
| Winstone Pulp WWTP at oxpond waste        | Whangaehu River downstream of Winstone Pulp                | Whangaehu River upstream of Winstone Pulp                |                                |                                 |
| National Park STP at Secondary oxpond     | NA                                                         | NA                                                       |                                |                                 |
| Taumarunui STP at Tertiary treated waste  | Whanganui River at Cherry Grove                            | Whanganui River at Te Rewa                               |                                |                                 |

## Appendix C State with time

This appendix presents the results of the rolling state assessments, as described in section 3.1.3. Rolling state assessments are only shown for sites that had sufficient data to calculate rolling grades for five assessment periods (each of which is 5 years in duration).

### C1 River SoE sites

#### C1.1 Chlorophyll-a

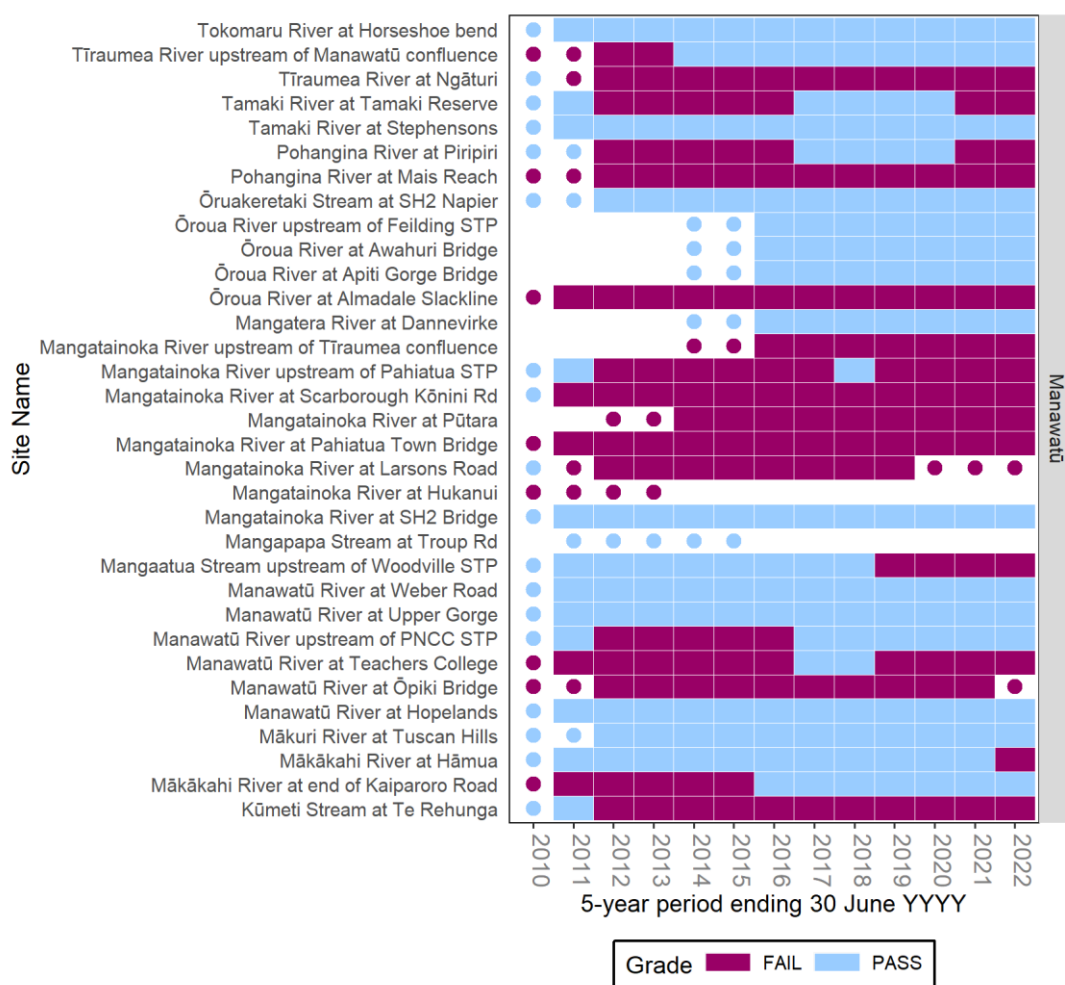


Figure 40: Rolling state assessment for One Plan river chlorophyll-a target for sites in the Manawatu FMU Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

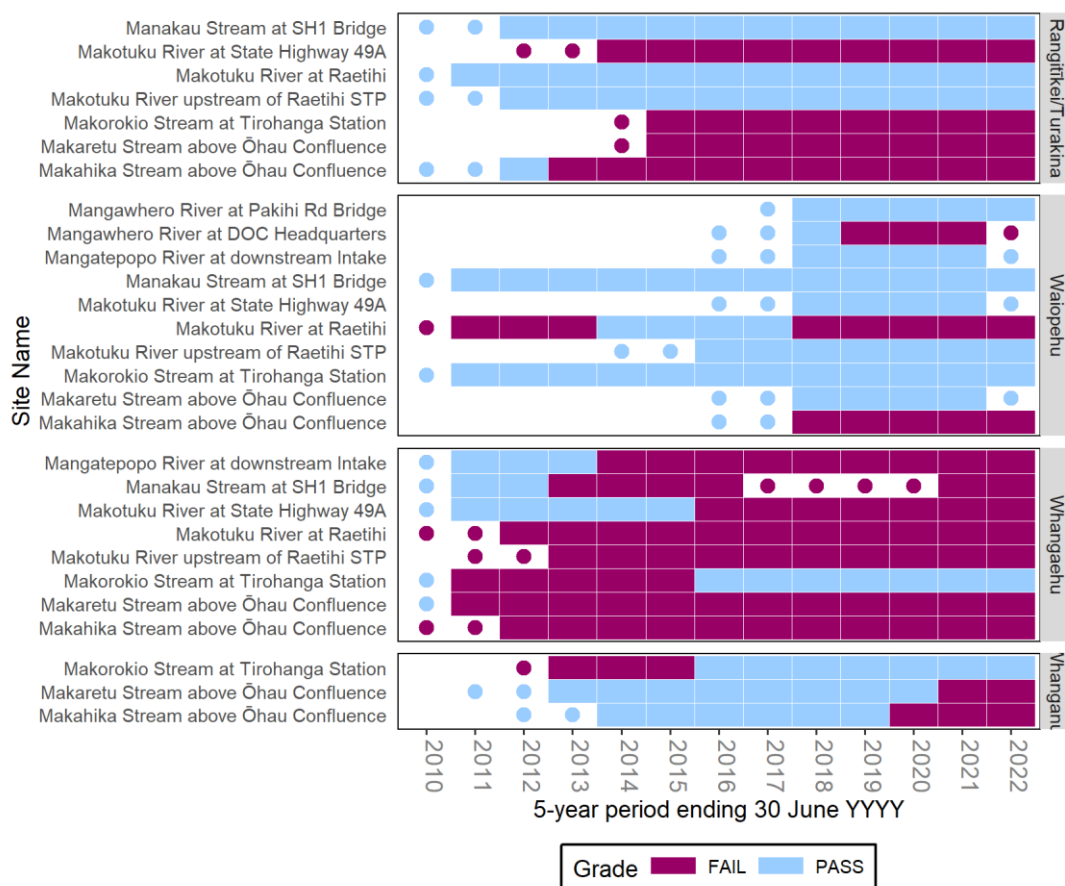


Figure 41: Rolling state assessment for One Plan river chlorophyll-a target for sites outside of the Manawatu FMU Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.



## C1.2 Clarity

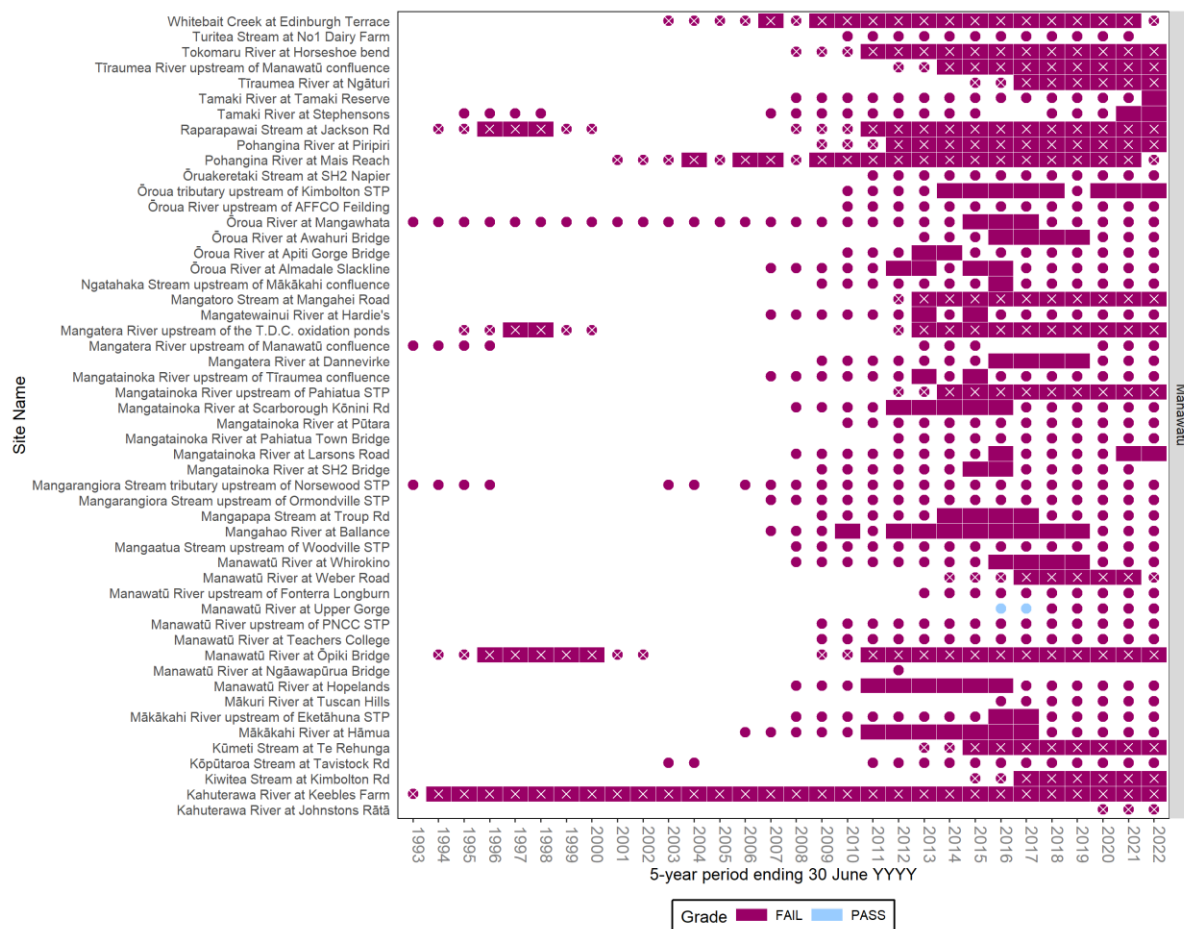


Figure 42: Rolling state assessment for One Plan river clarity target for sites in the Manawatu FMU Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades. White crosses indicate grades were evaluated without accounting for the flow requirements for the target.

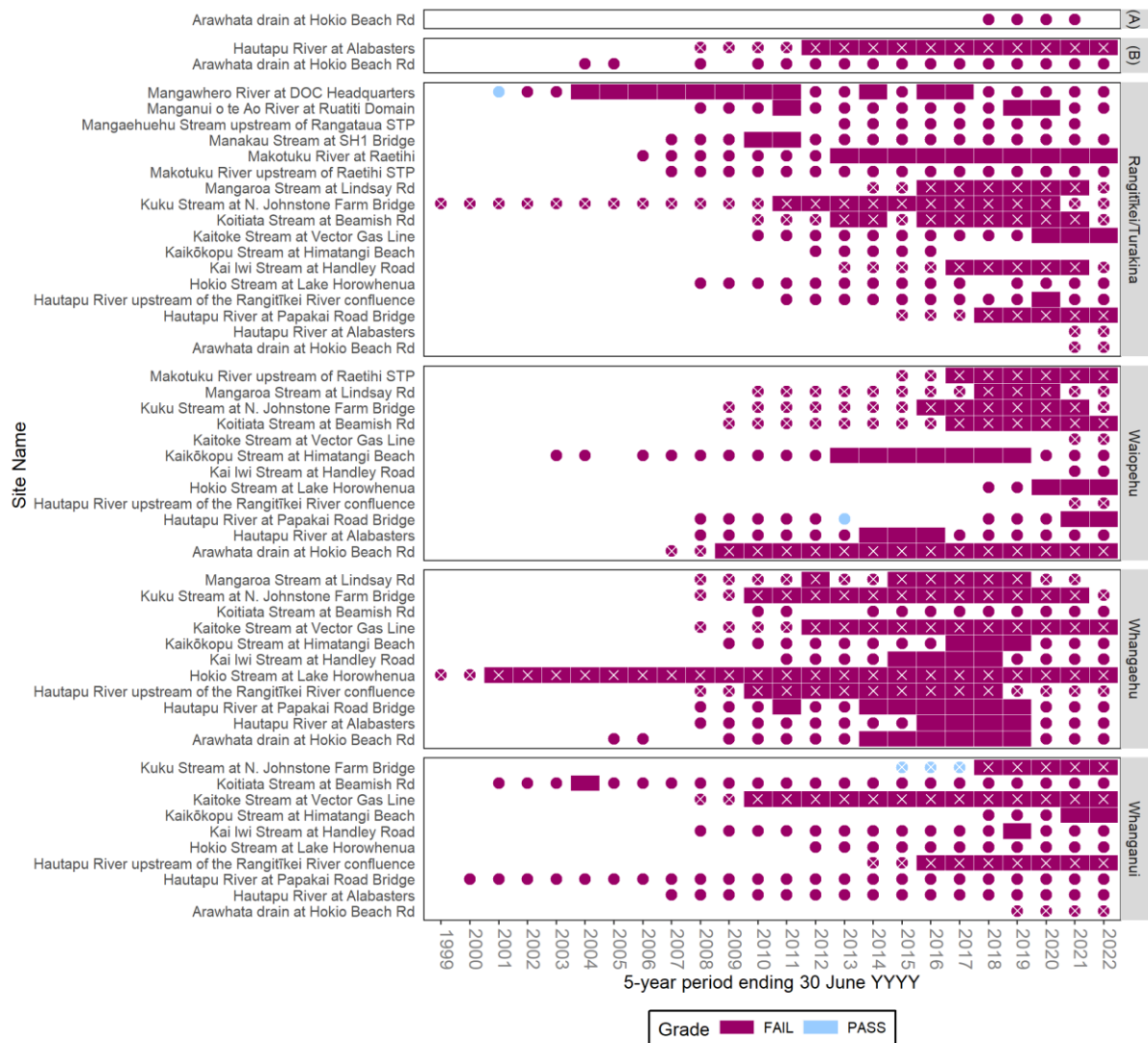


Figure 43: Rolling state assessment for One Plan river clarity target for sites outside of the Manawatu FMU Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades. White crosses indicate grades were evaluated without accounting for the flow requirements for the target.

### C1.3 DO (Sat)

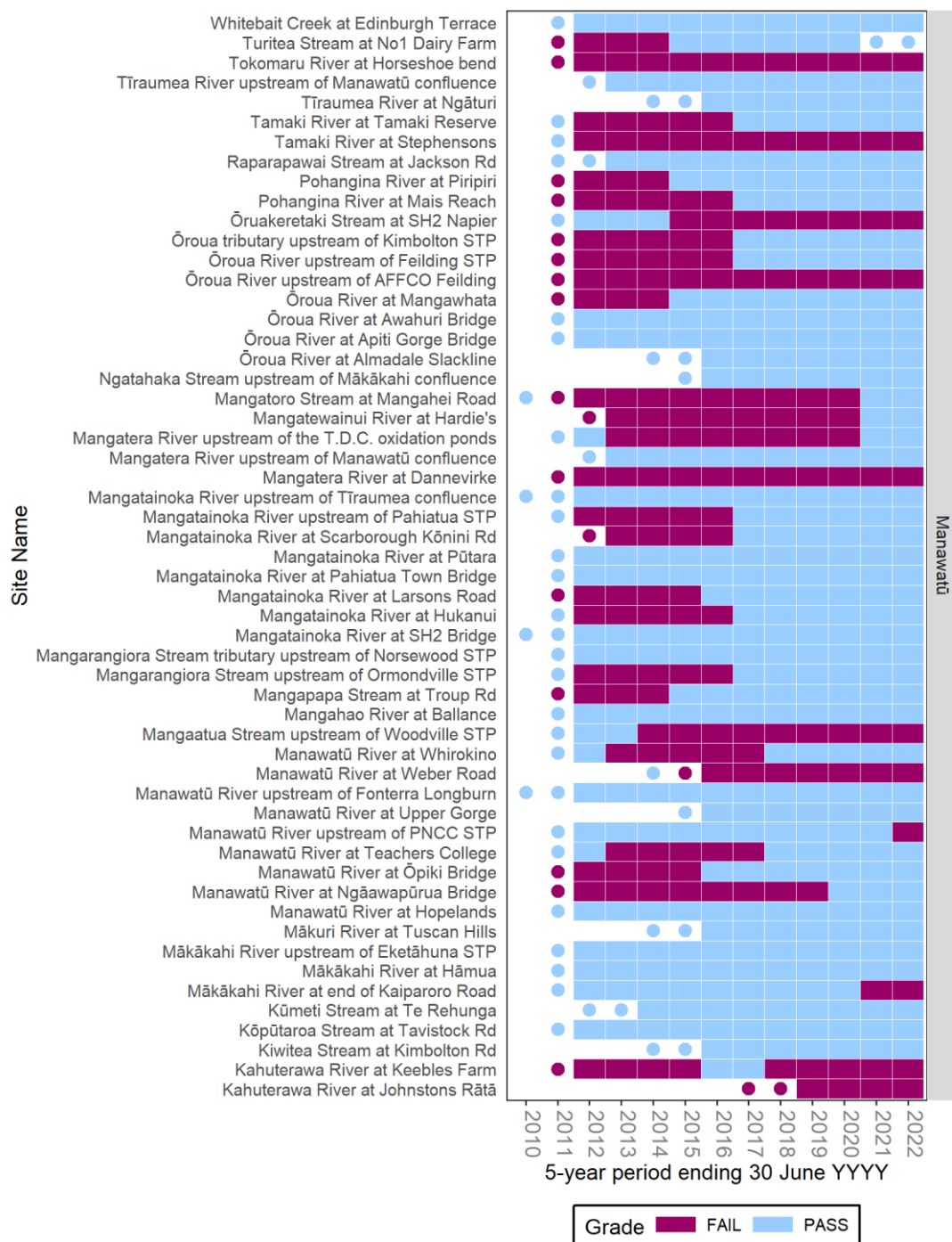


Figure 44: Rolling state assessment for One Plan river DO (sat) target for sites in the Manawatu FMU Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

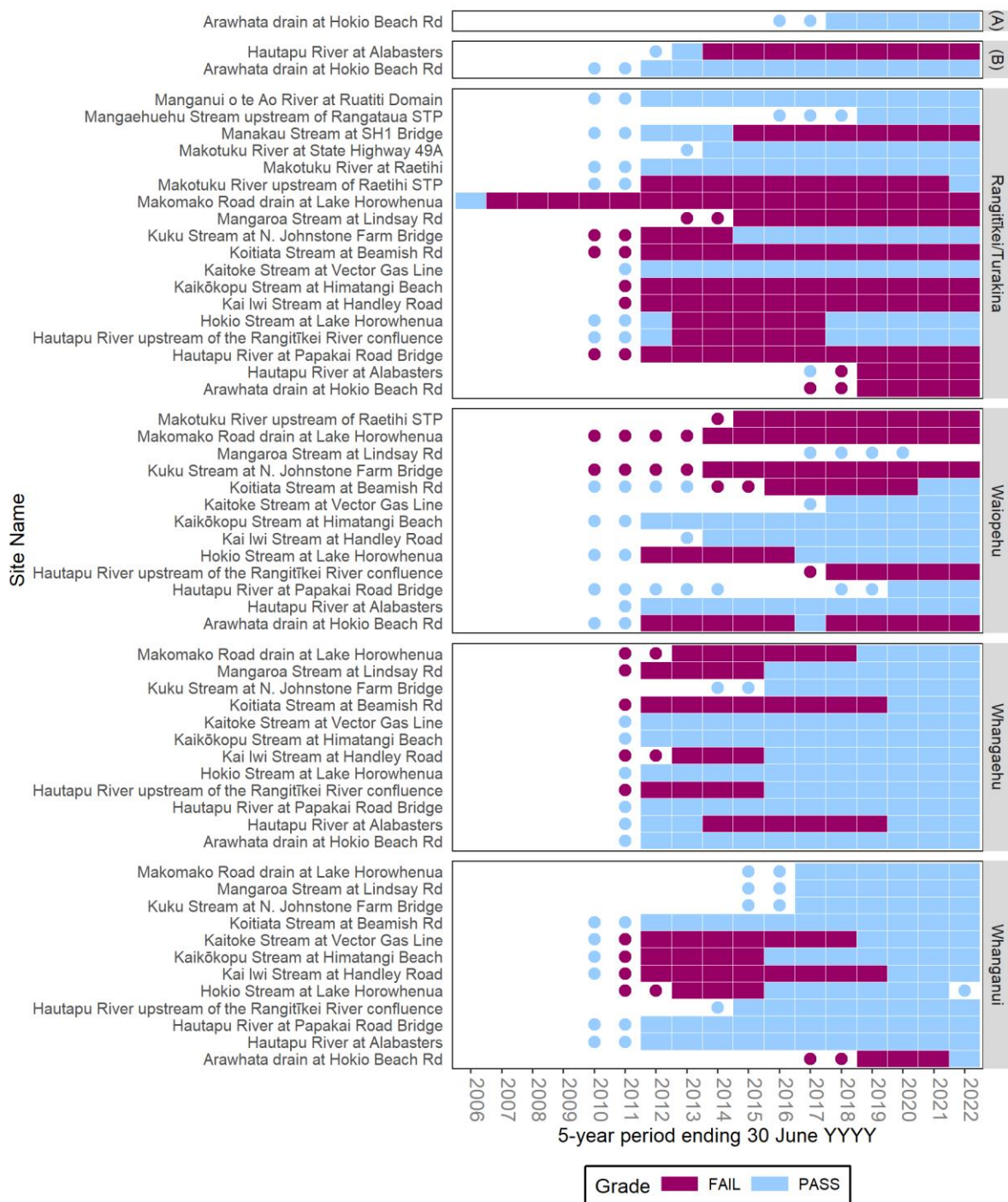


Figure 45: Rolling state assessment for One Plan river DO (sat) target for sites outside of the Manawatu FMU Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.



## C1.4 DRP

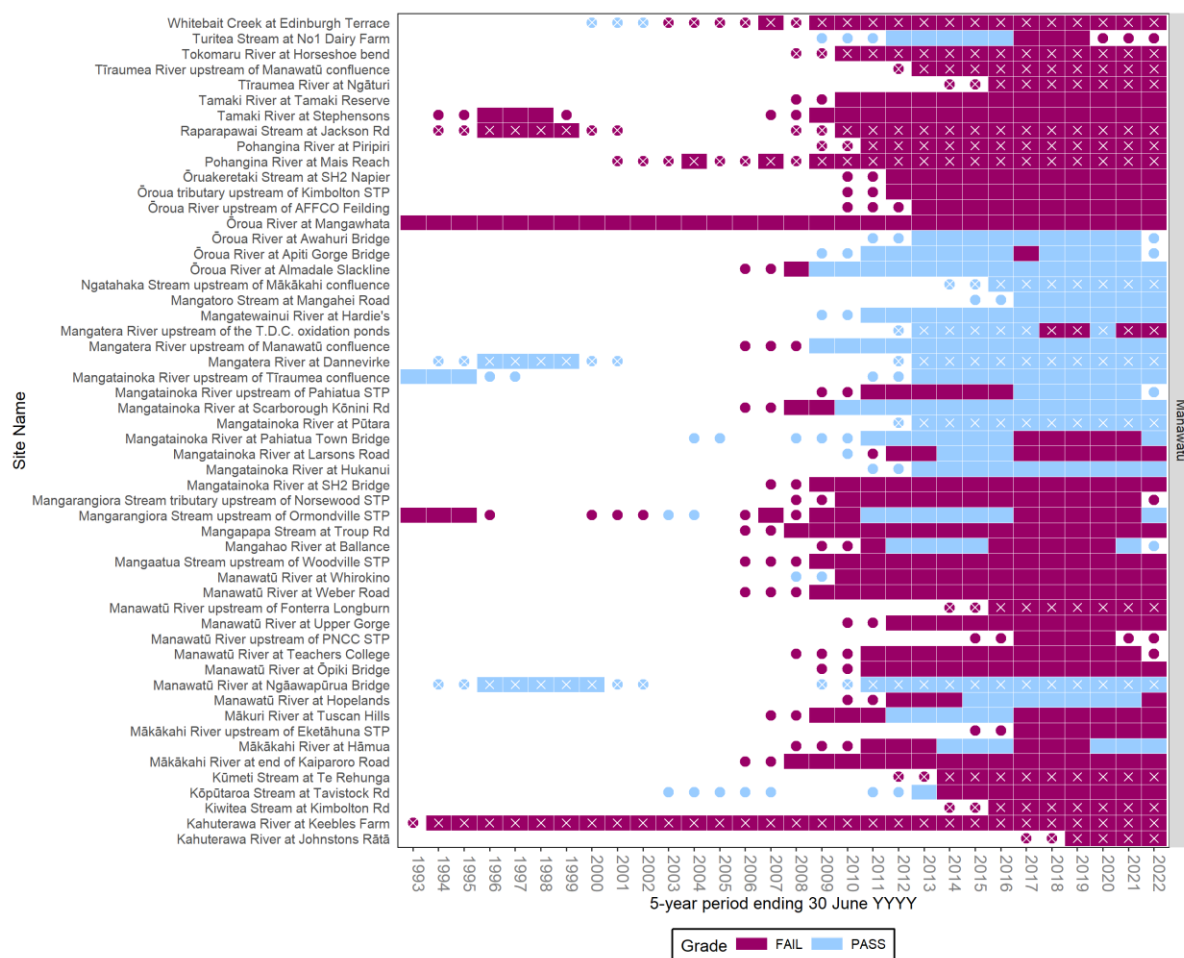


Figure 46: Rolling state assessment for One Plan river DRP target for sites in the Manawatu FMU Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades. White crosses indicate grades were evaluated without accounting for the flow requirements for the target.

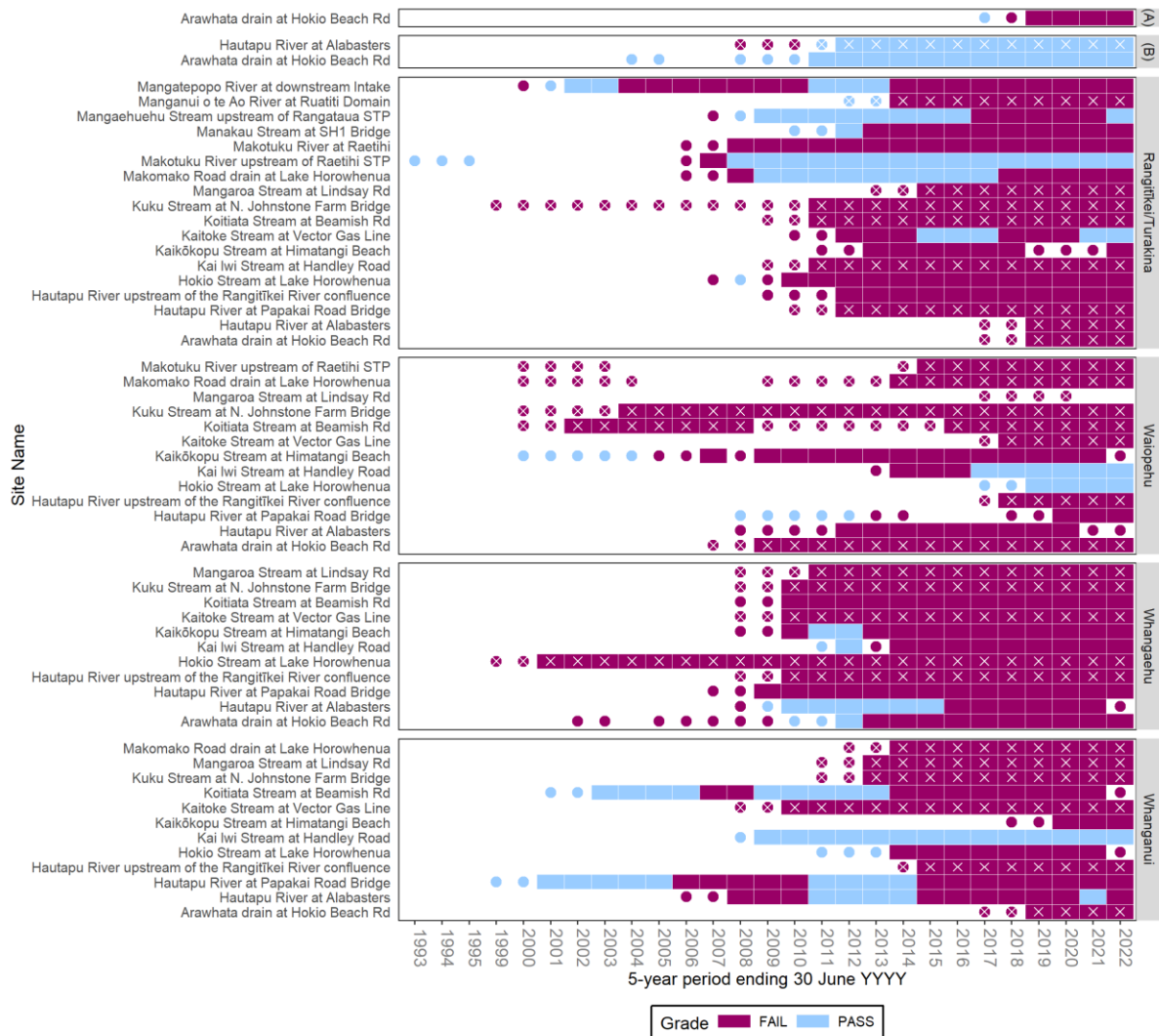


Figure 47: Rolling state assessment for One Plan river DRP target for sites outside of the Manawatu FMU Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades. White crosses indicate grades were evaluated without accounting for the flow requirements for the target.

## C1.5 E. coli (bathing)

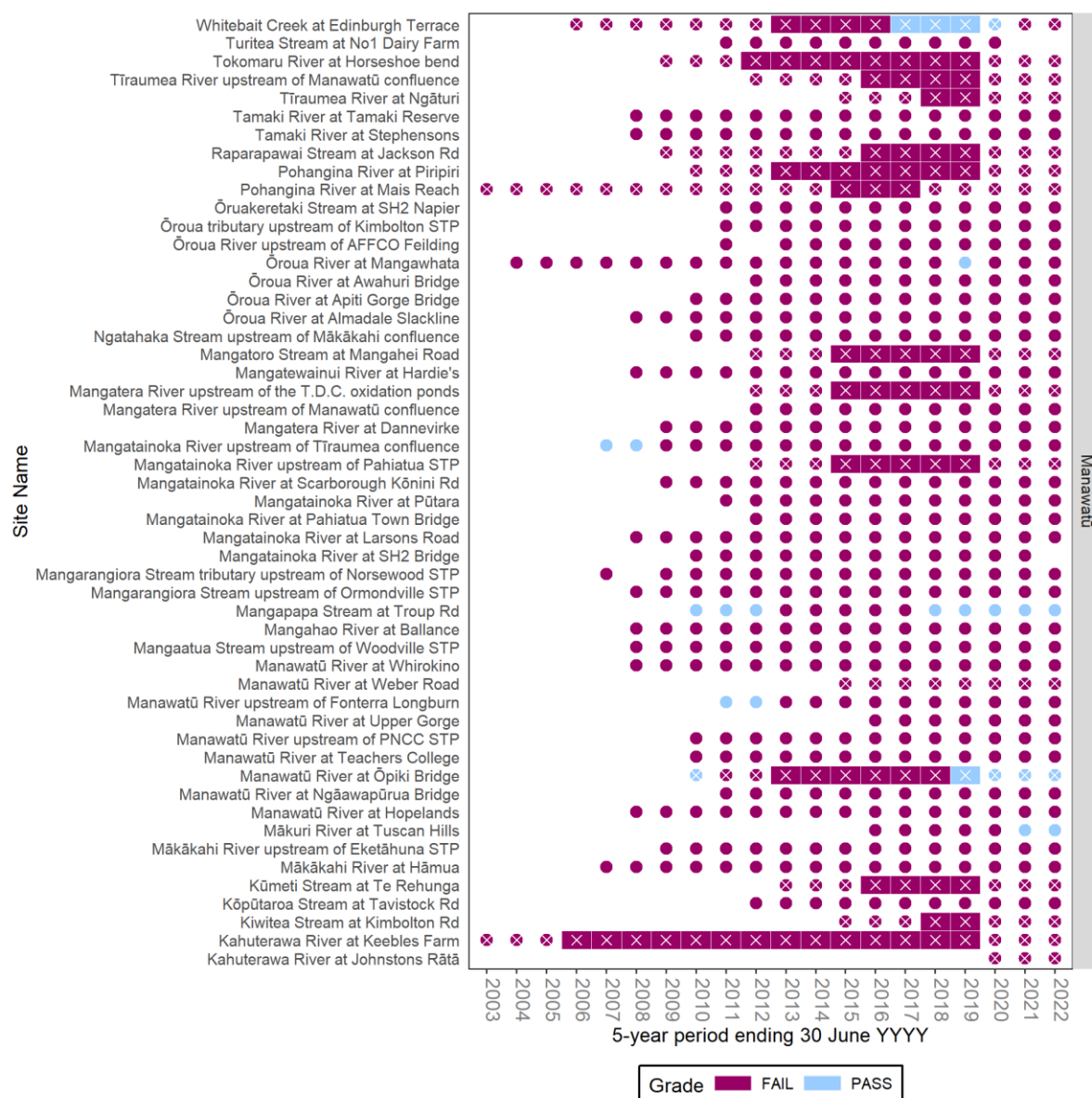


Figure 48: Rolling state assessment for One Plan river E. coli (bathing) target for sites in the Manawatu FMU Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades. White crosses indicate grades were evaluated without accounting for the flow requirements for the target.

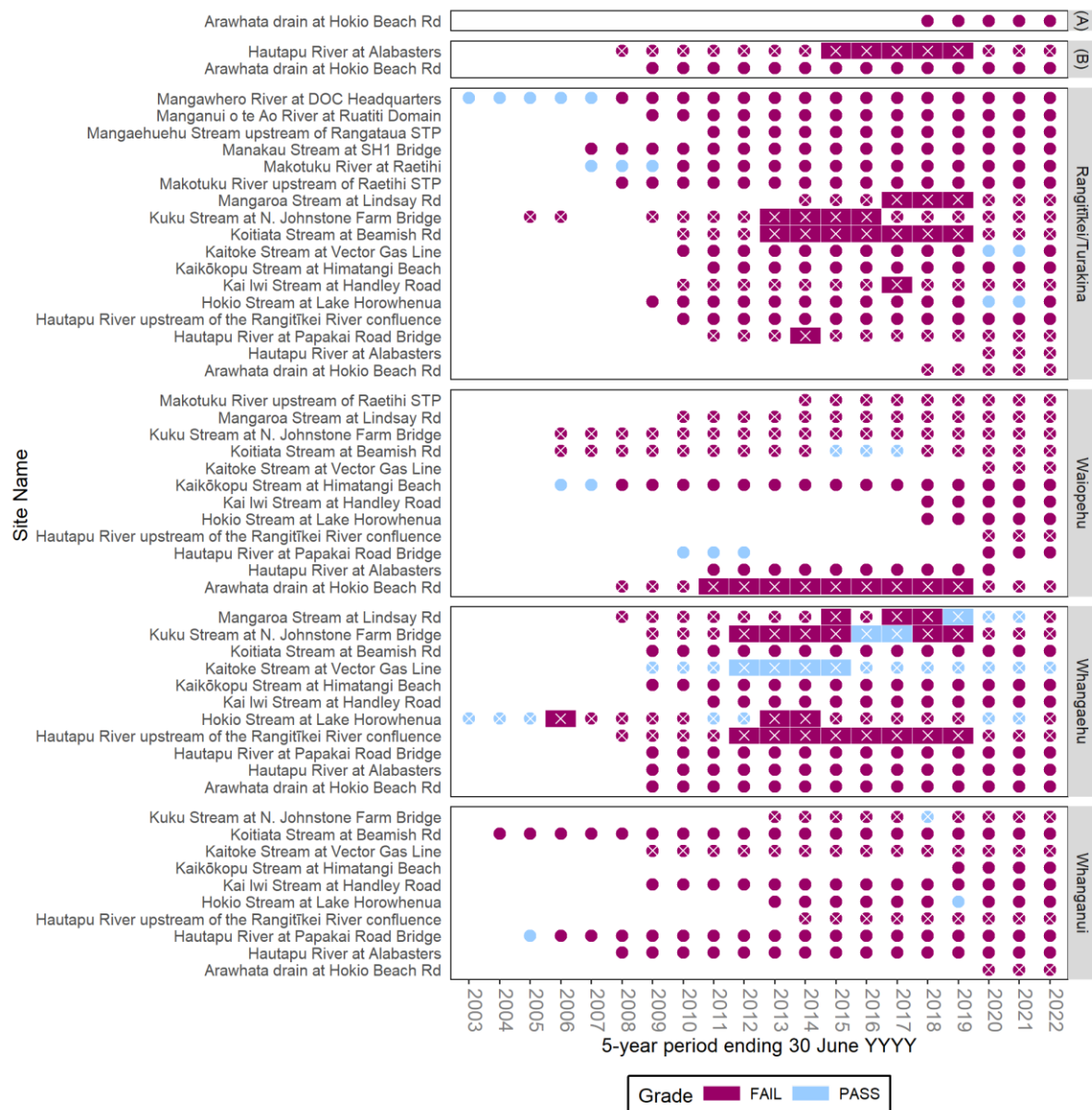


Figure 49: Rolling state assessment for One Plan river *E. coli* (bathing) target for sites outside of the Manawatu FMU Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades. White crosses indicate grades were evaluated without accounting for the flow requirements for the target.



## C1.6 E. coli (year round)

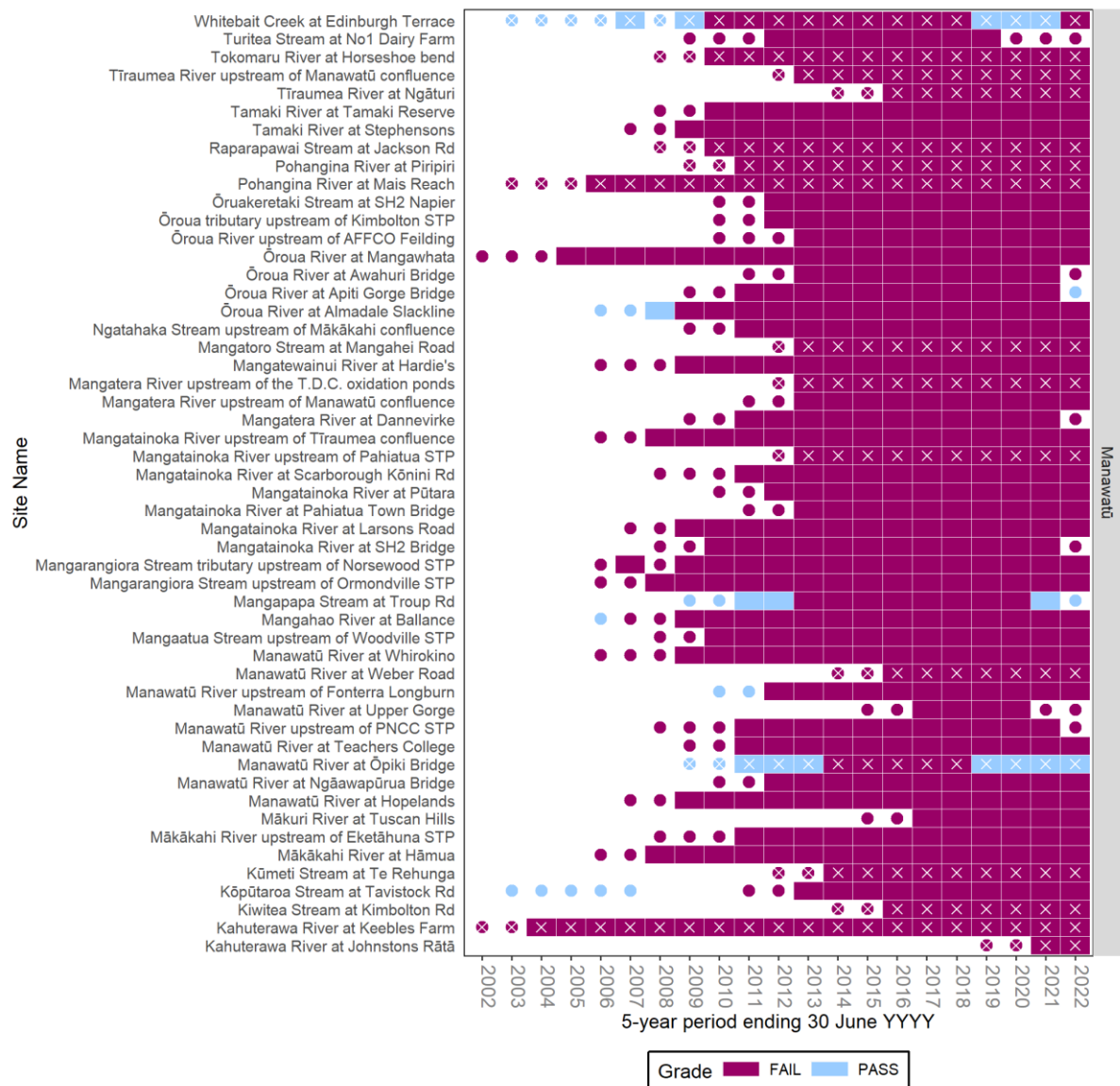


Figure 50: Rolling state assessment for One Plan river E. coli (year round) target for sites in the Manawatu FMU Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades. White crosses indicate grades were evaluated without accounting for the flow requirements for the target.

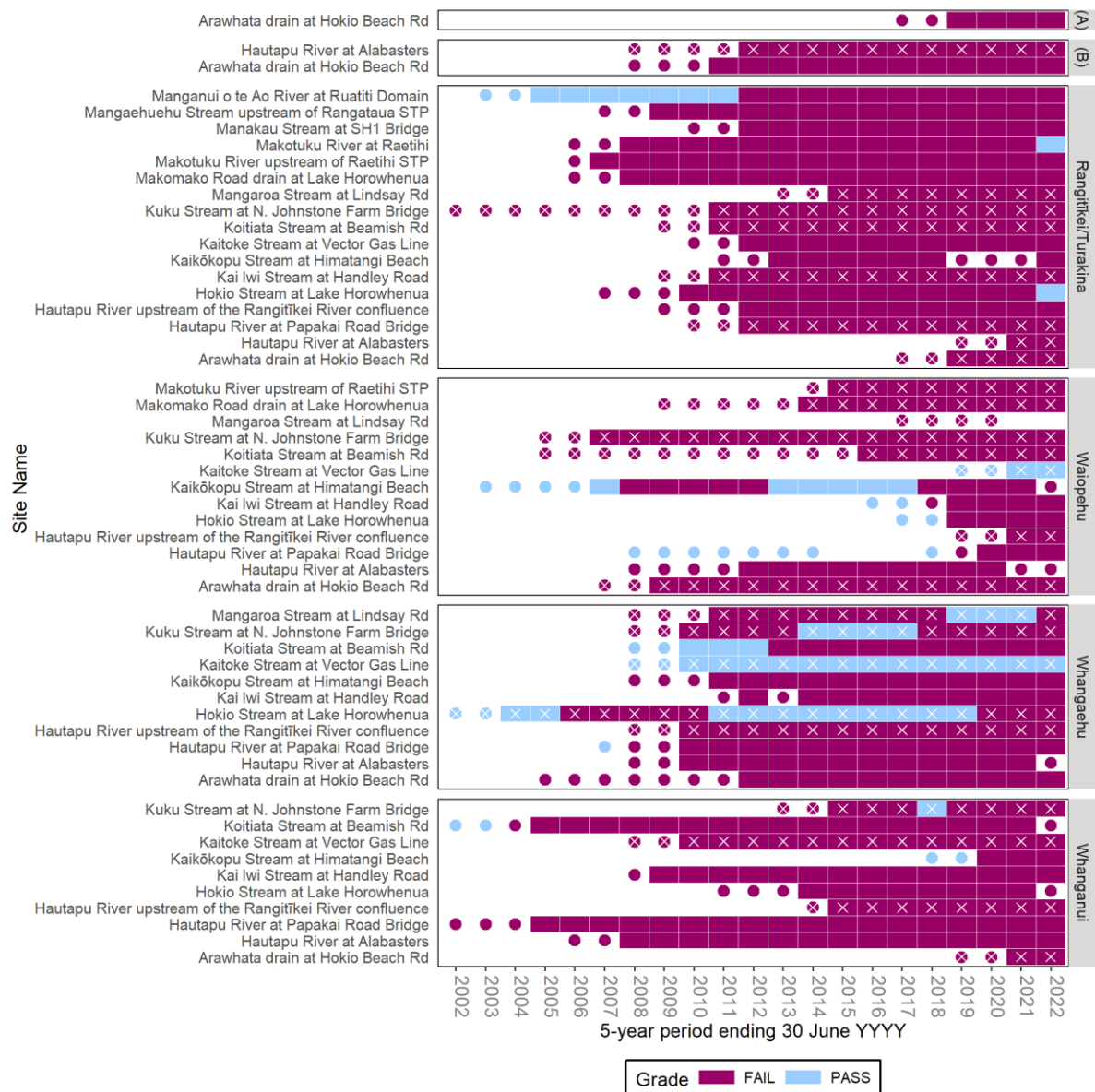


Figure 51: Rolling state assessment for One Plan river *E. coli* (year round) target for sites outside of the Manawatu FMU Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades. White crosses indicate grades were evaluated without accounting for the flow requirements for the target.

## C1.7 MCI

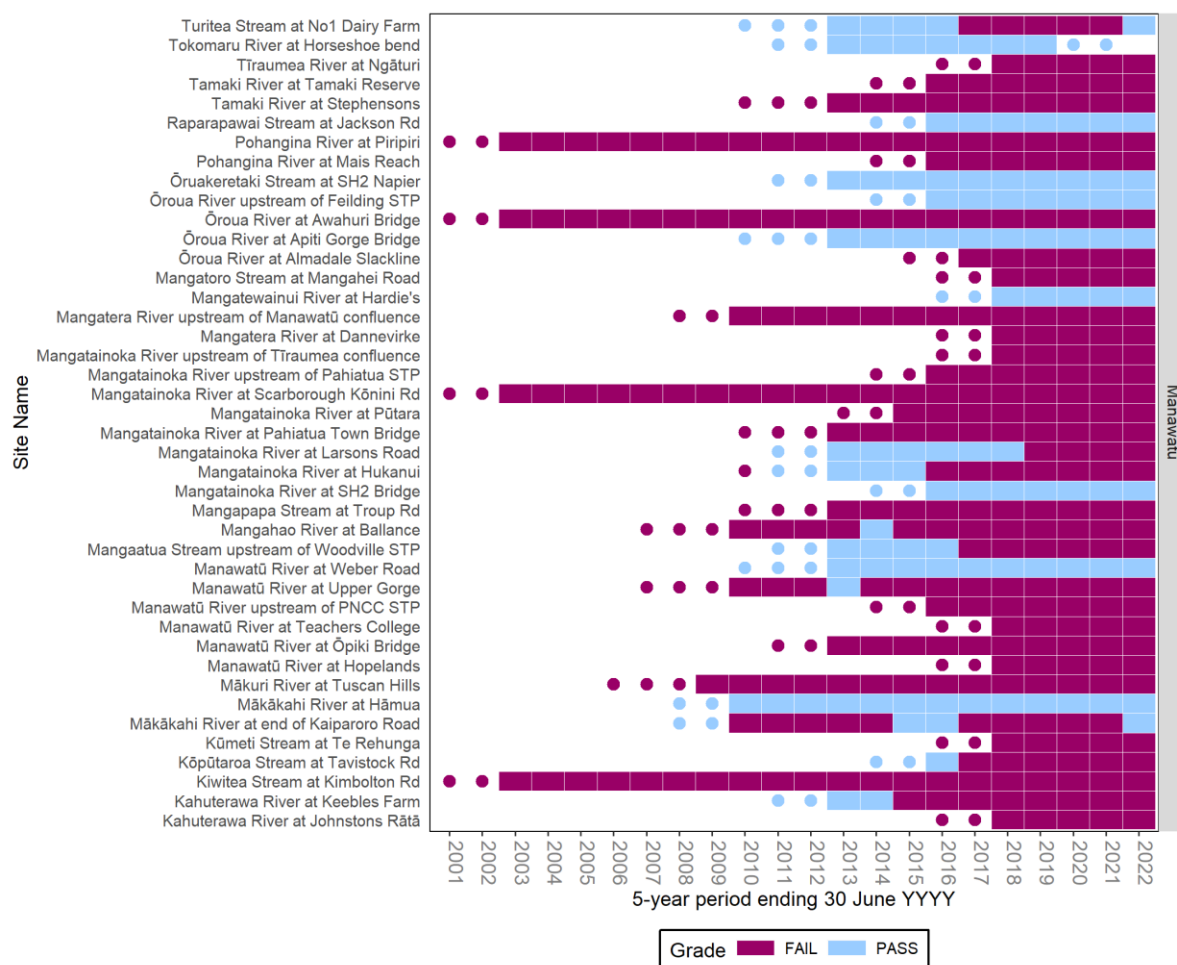


Figure 52: Rolling state assessment for One Plan river MCI target for sites in the Manawatu FMU Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

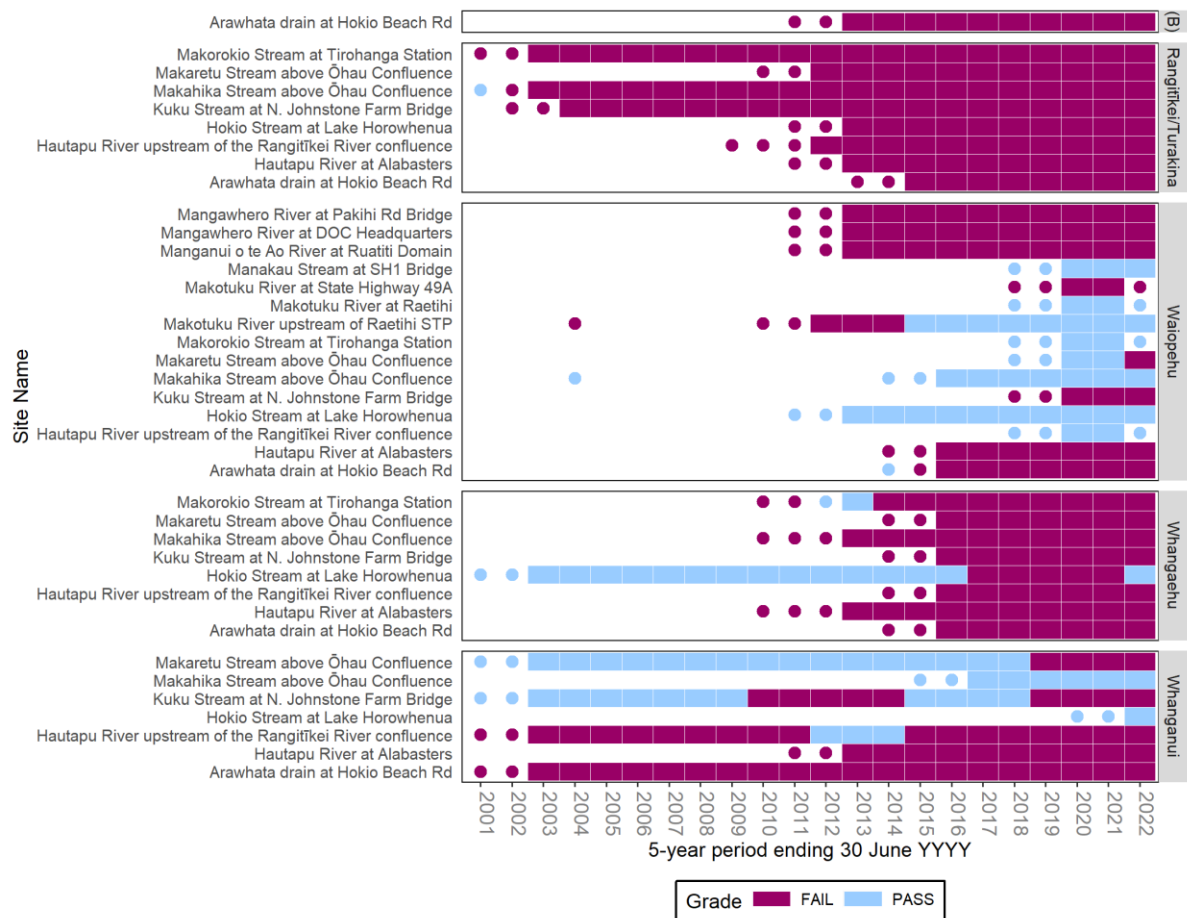


Figure 53: Rolling state assessment for One Plan river MCI target for sites outside of the Manawatu FMU Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

## C1.8 NH4-N (max)

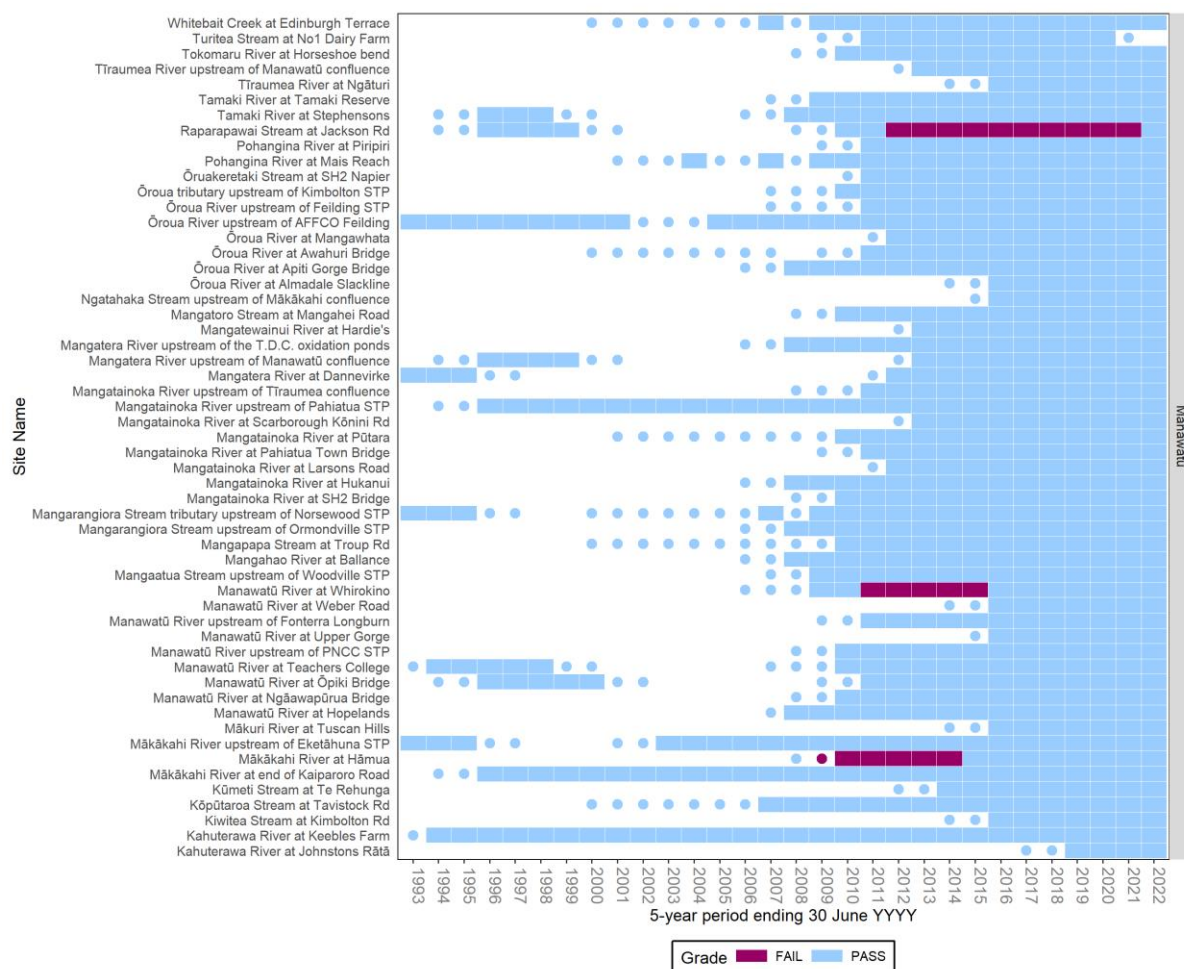


Figure 54: Rolling state assessment for One Plan river NH4-N (max) target for sites in the Manawatu FMU Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

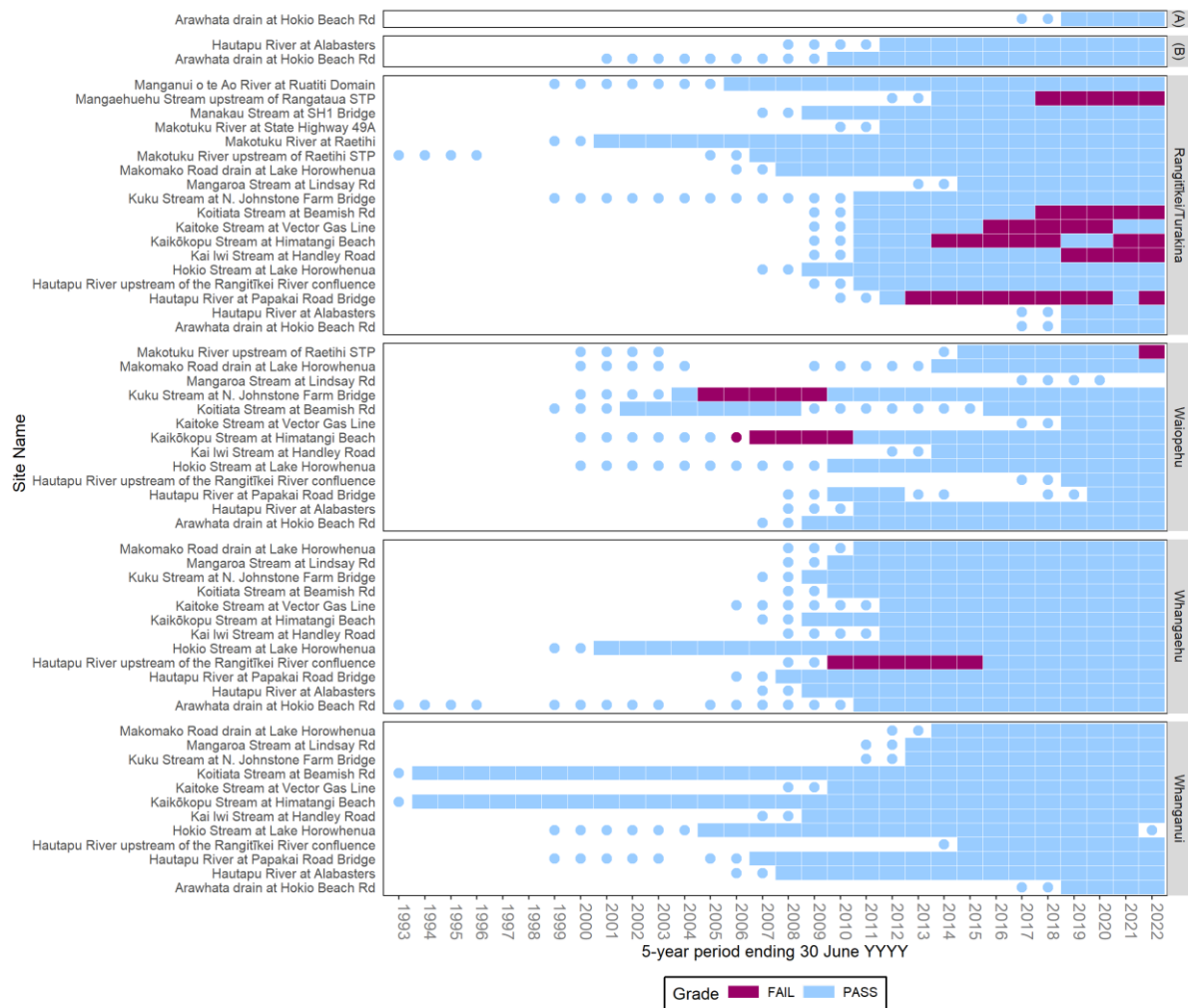


Figure 55: Rolling state assessment for One Plan river NH4-N (max) target for sites outside of the Manawatu FMU Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.



## C1.9 NH4-N (mean)

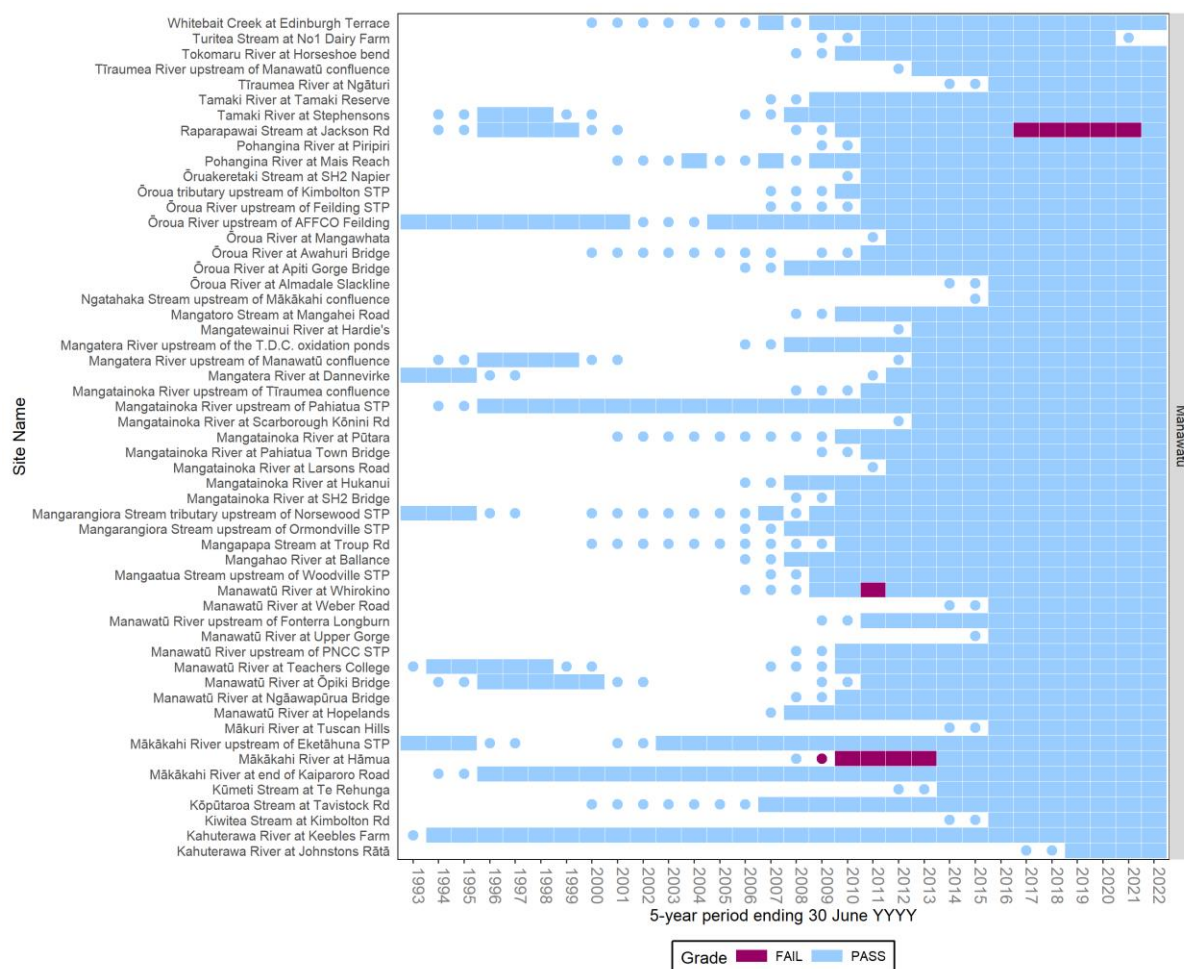


Figure 56: Rolling state assessment for One Plan river NH4-N (mean) target for sites in the Manawatu FMU Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

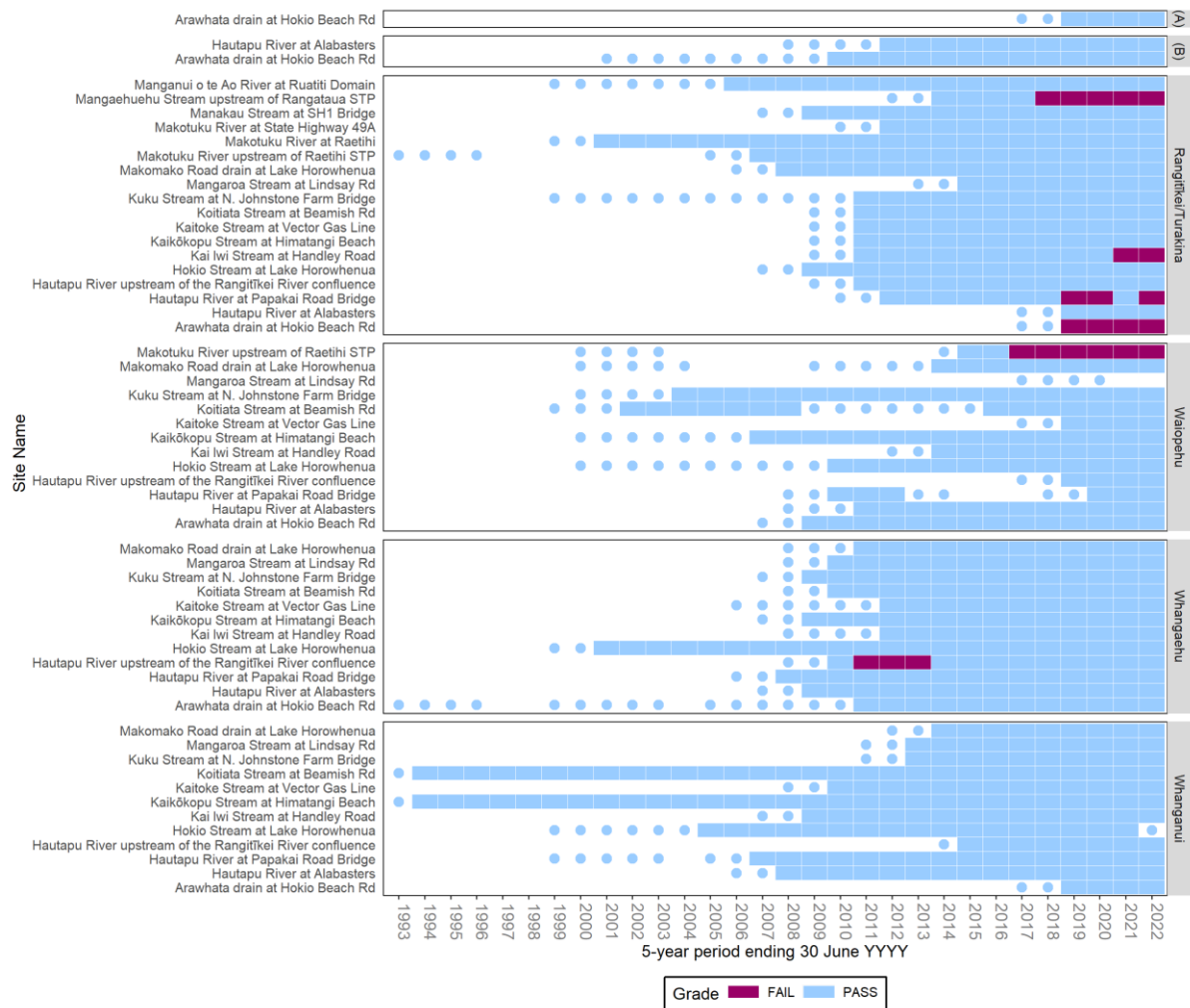


Figure 57: Rolling state assessment for One Plan river NH4-N (mean) target for sites outside of the Manawatu FMU. Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.



## C1.10 Periphyton (filaments)

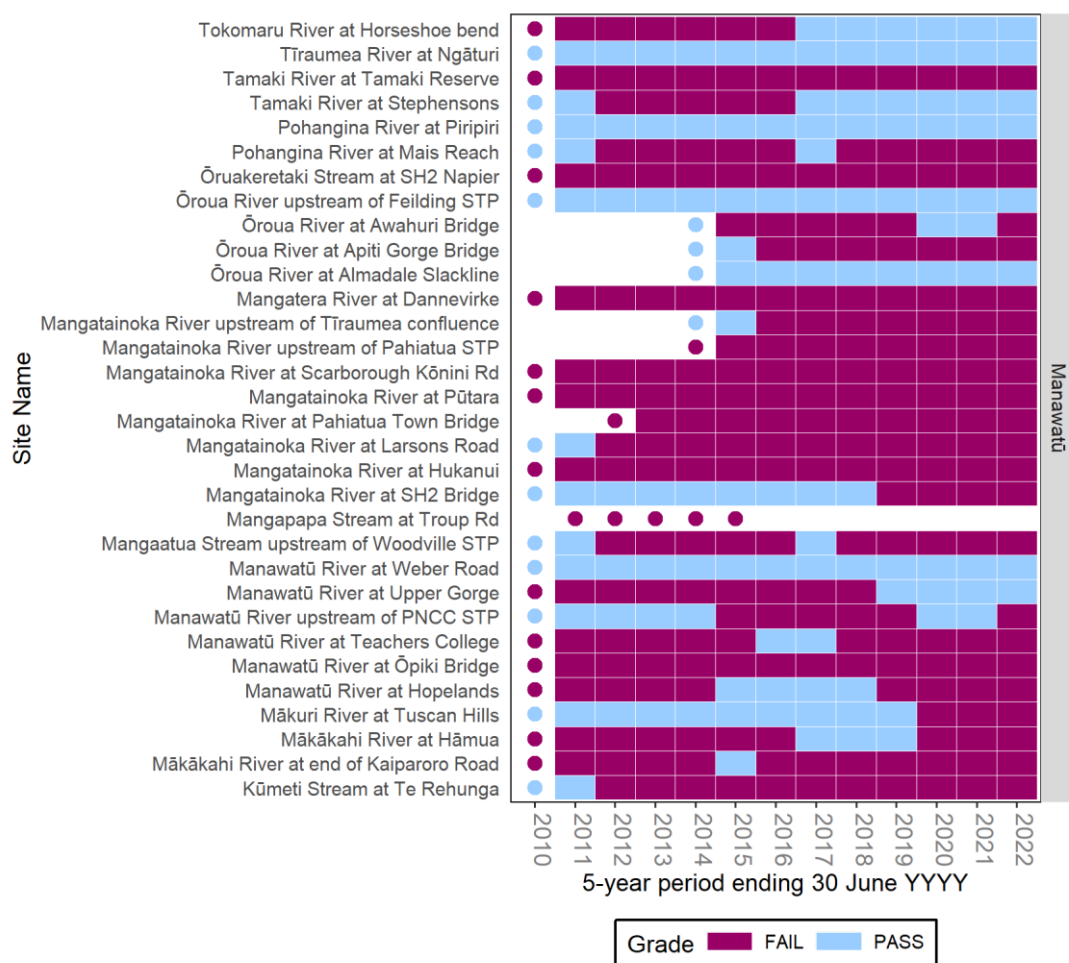


Figure 58: Rolling state assessment for One Plan river Periphyton (filaments) target for sites in the Manawatu FMU Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

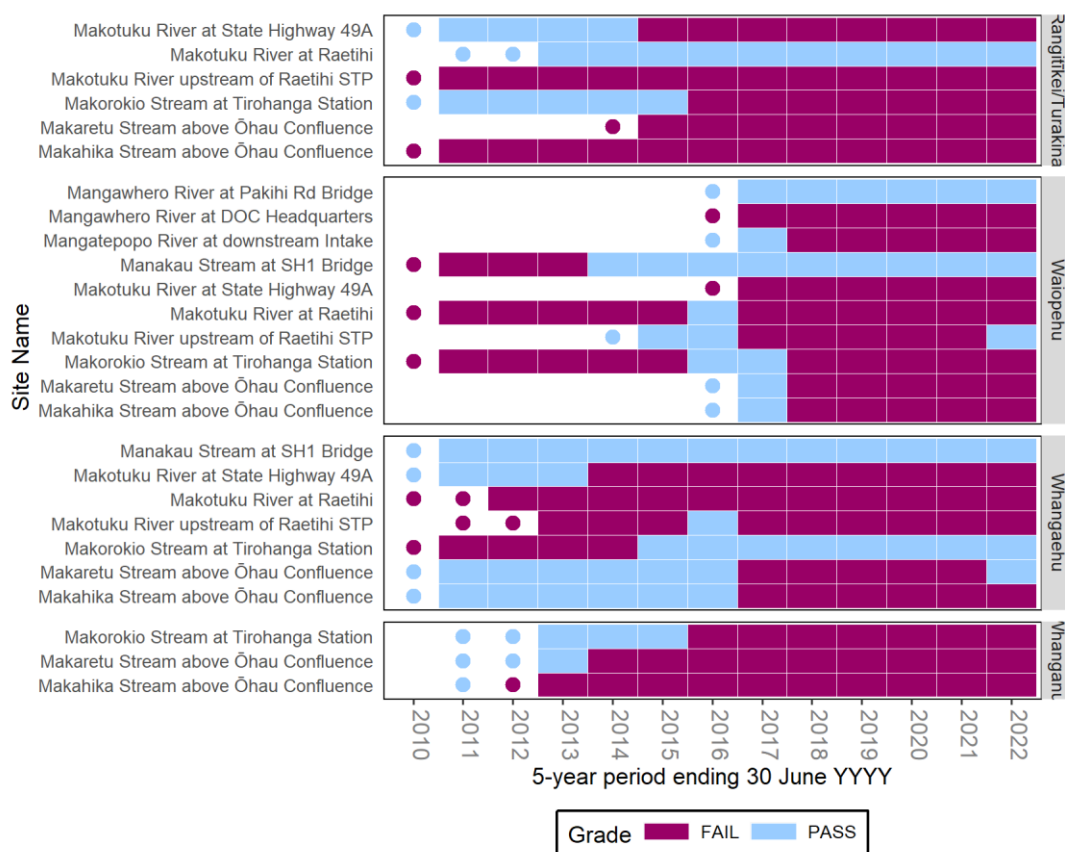


Figure 59: Rolling state assessment for One Plan river Periphyton (filaments) target for sites outside of the Manawatu FMU Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

## C1.11 Periphyton (mats)

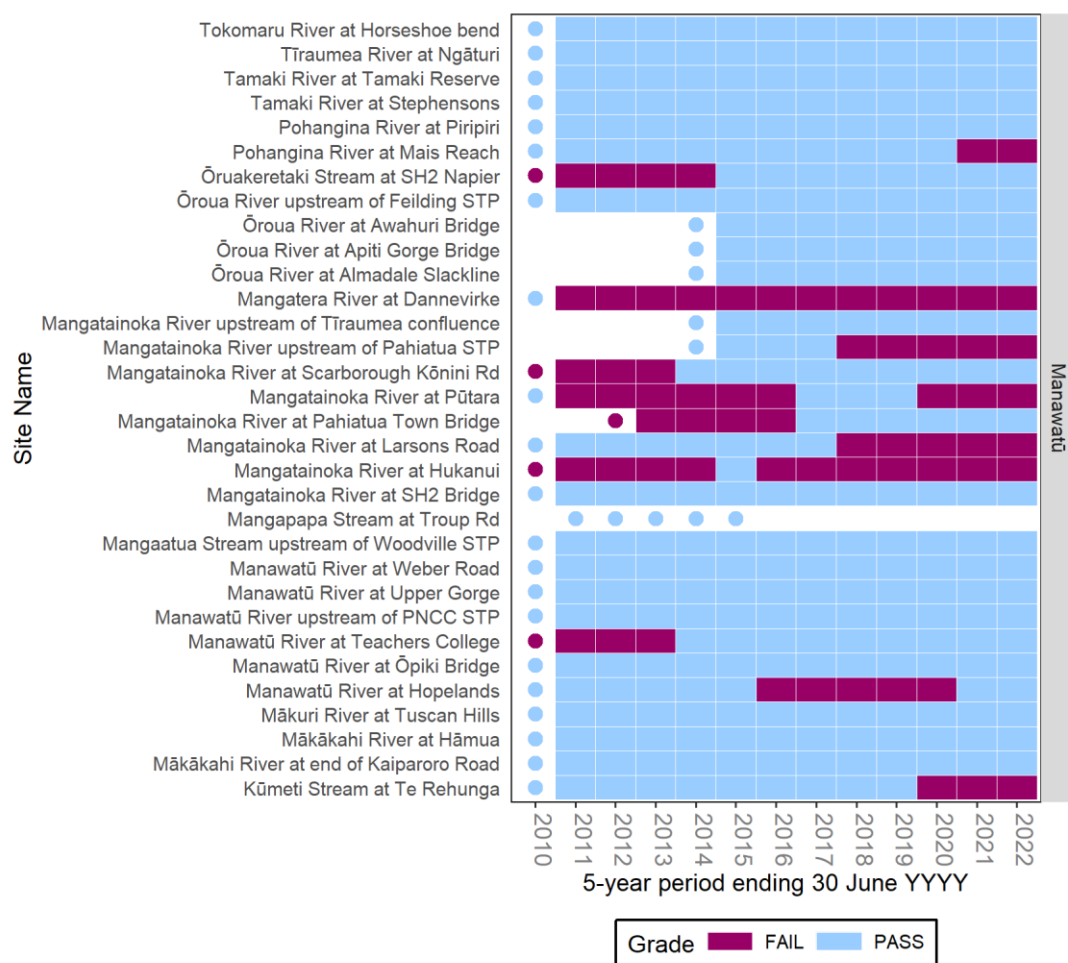


Figure 60: Rolling state assessment for One Plan river Periphyton (mats) target for sites in the Manawatu FMU Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

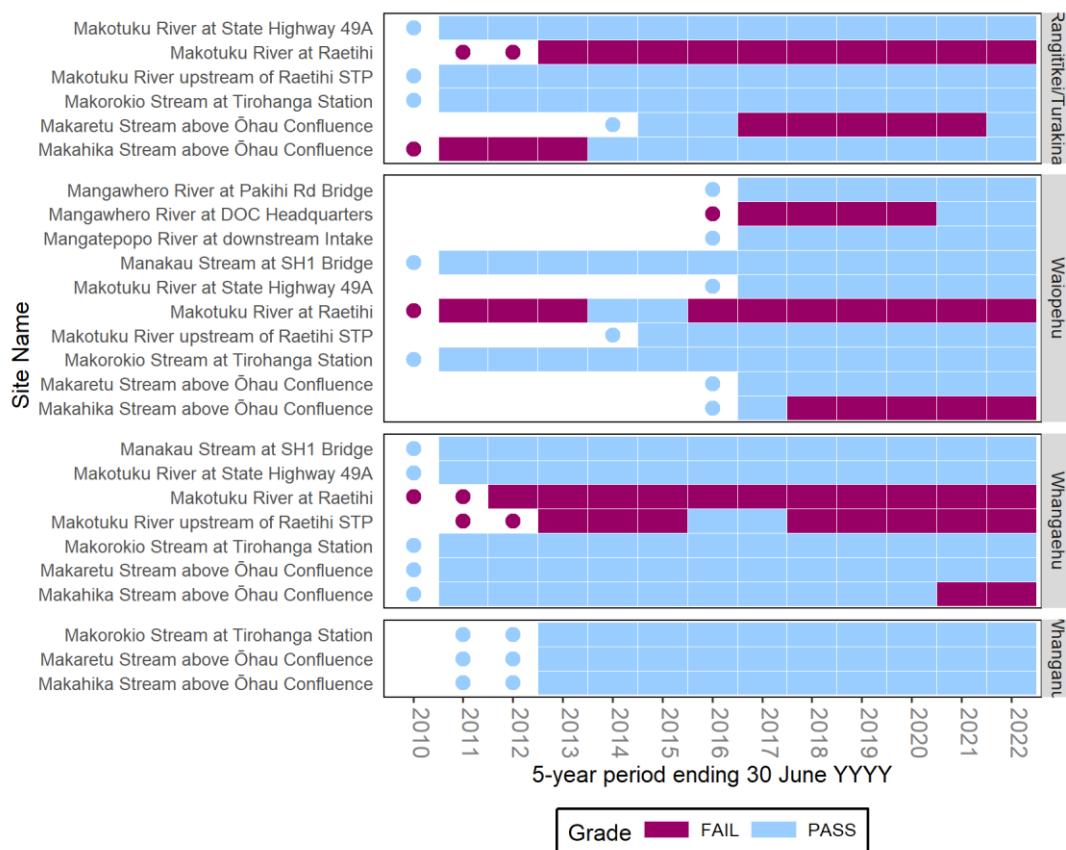


Figure 61: Rolling state assessment for One Plan river Periphyton (mats) target for sites outside of the Manawatu FMU Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

## C1.12 POM

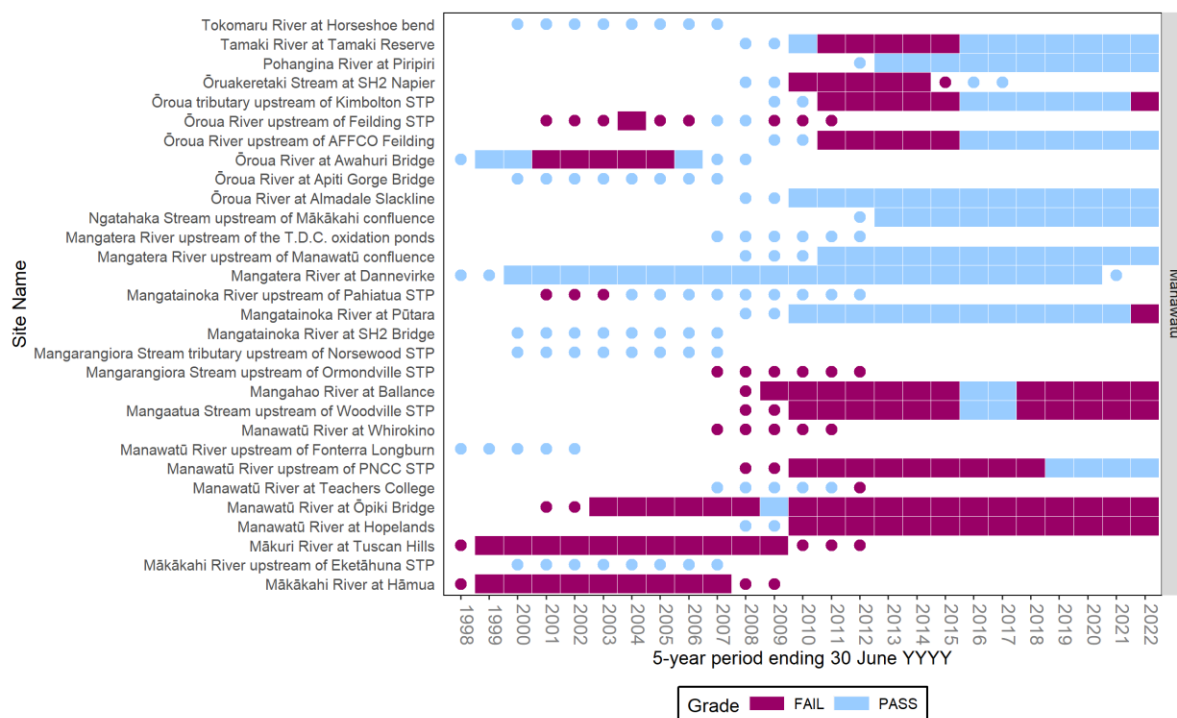


Figure 62: Rolling state assessment for One Plan river POM target for sites in the Manawatu FMU Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

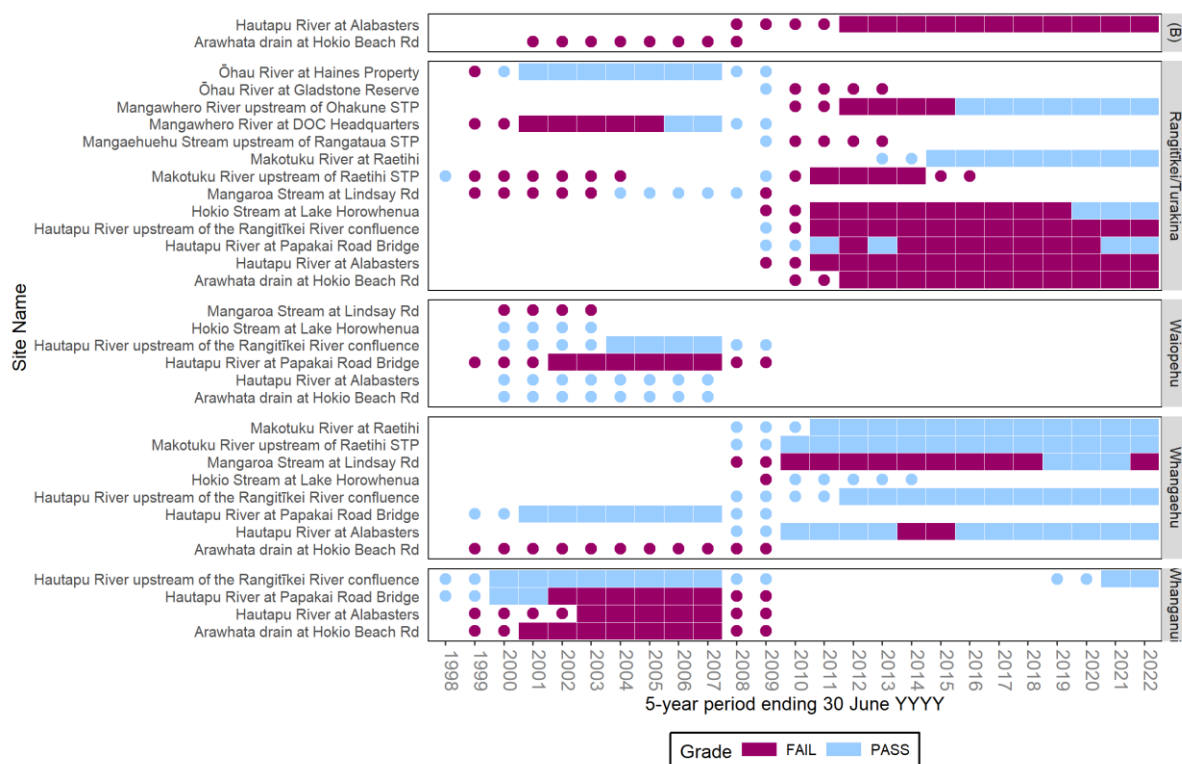


Figure 63: Rolling state assessment for One Plan river POM target for sites outside of the Manawatu FMU Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

## C1.13 sCBOB5

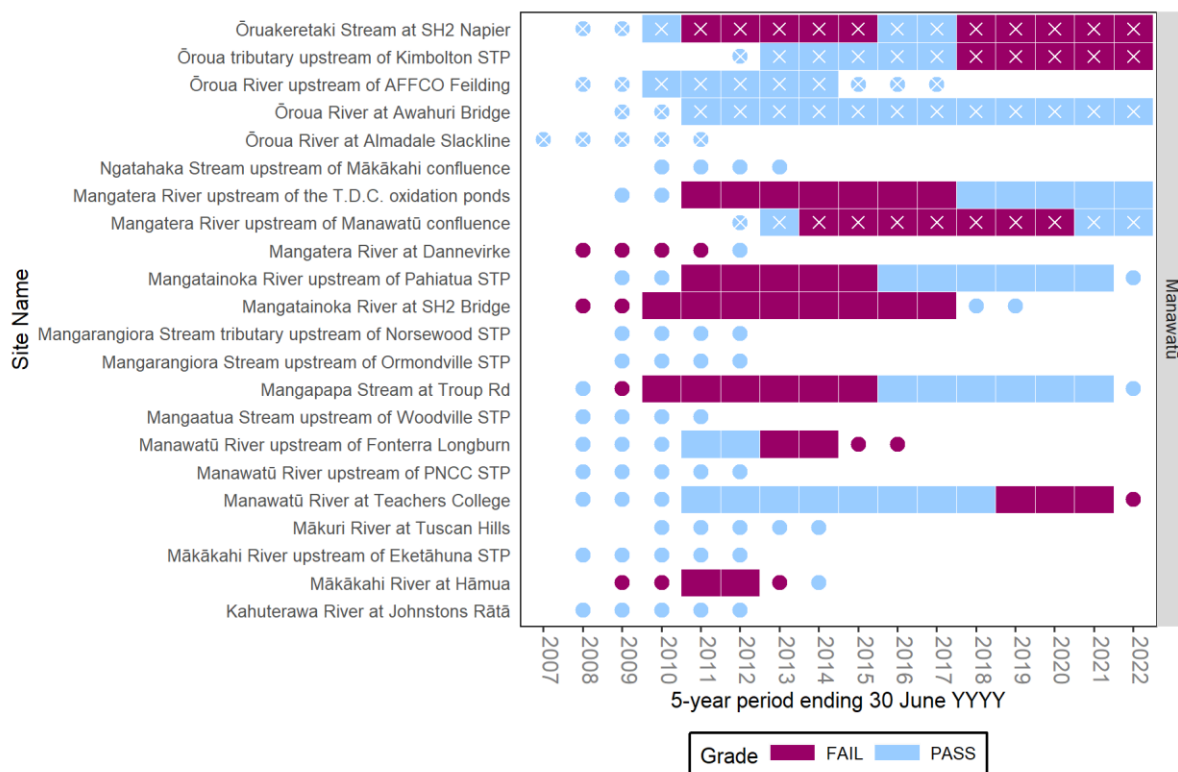


Figure 64: Rolling state assessment for One Plan river sCBOD5 target for sites in the Manawatu FMU Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades. White crosses indicate grades were evaluated without accounting for the flow requirements for the target.

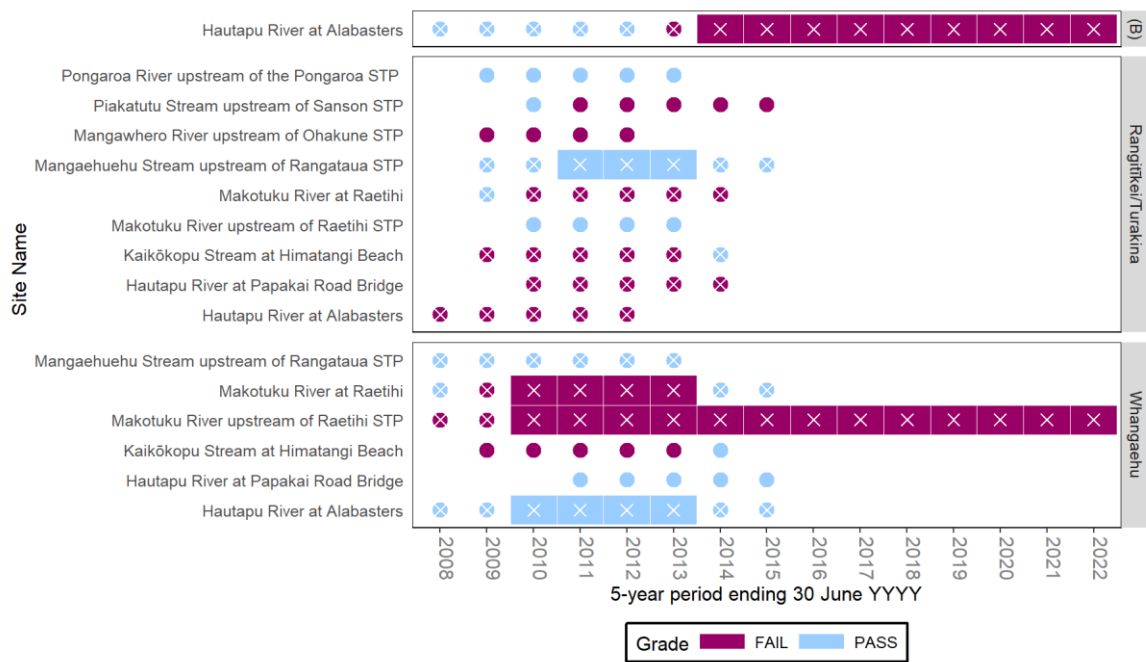


Figure 65: Rolling state assessment for One Plan river sCBOD5 target for sites in the Manawatu FMU Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades. White crosses indicate grades were evaluated without accounting for the flow requirements for the target.



## C1.14 SIN

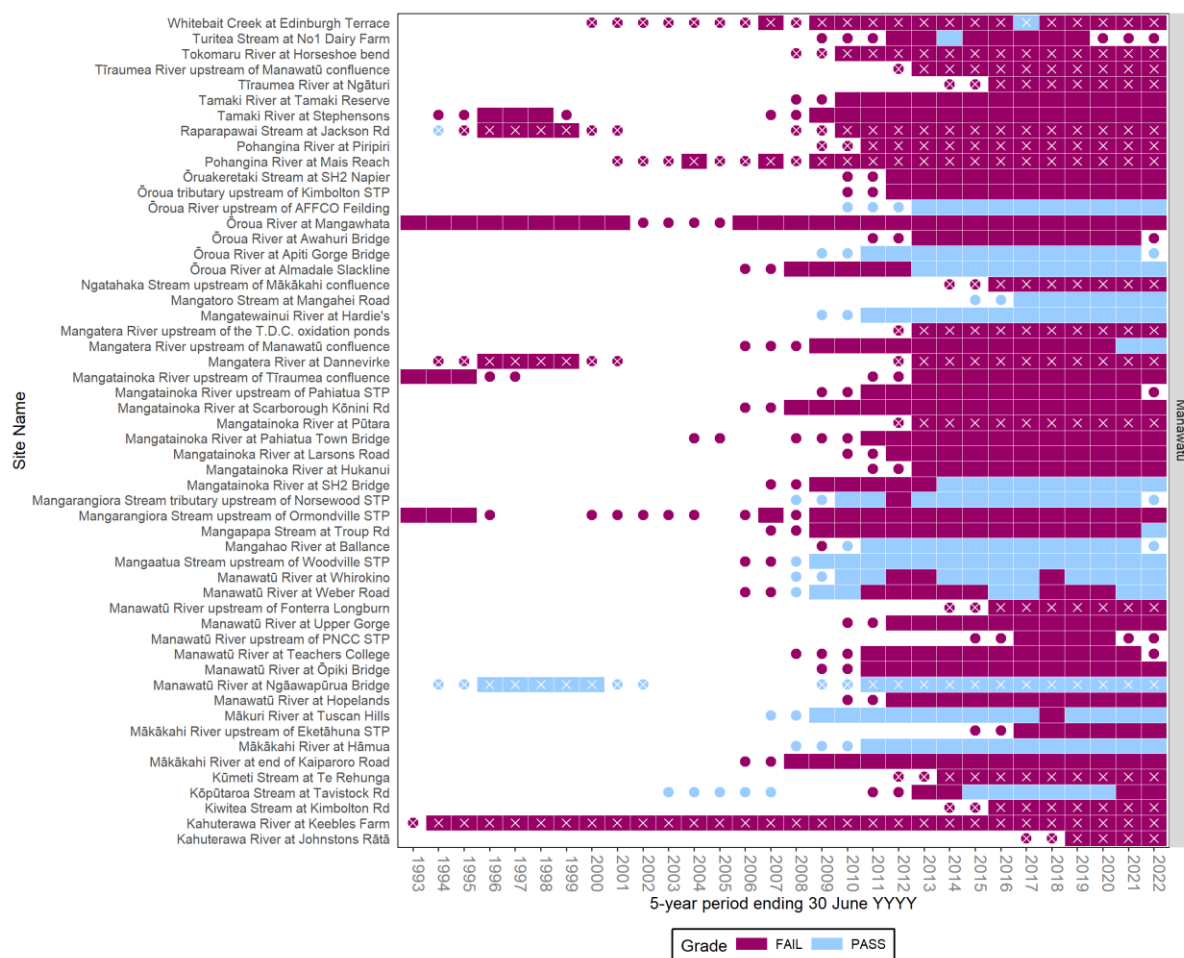


Figure 66: Rolling state assessment for One Plan river SIN target for sites in the Manawatu FMU Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades. White crosses indicate grades were evaluated without accounting for the flow requirements for the target.

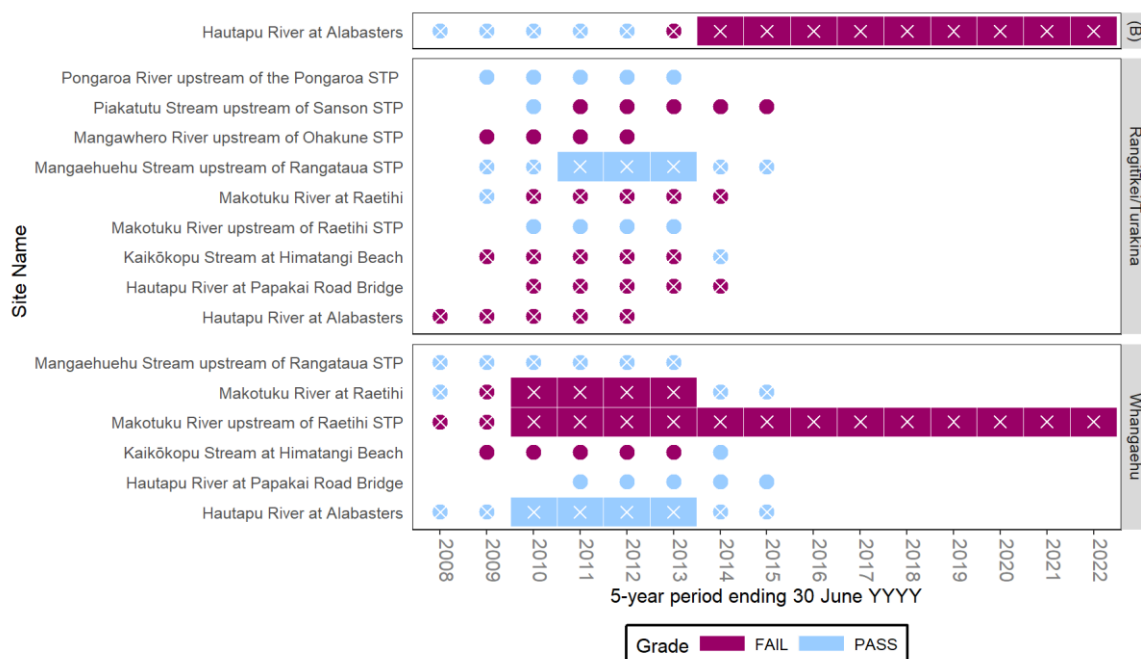


Figure 67: Rolling state assessment for One Plan river SIN target for sites outside of the Manawatu FMU Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades. White crosses indicate grades were evaluated without accounting for the flow requirements for the target.

## C2 River impact sites

### C2.1 Chlorophyll-a

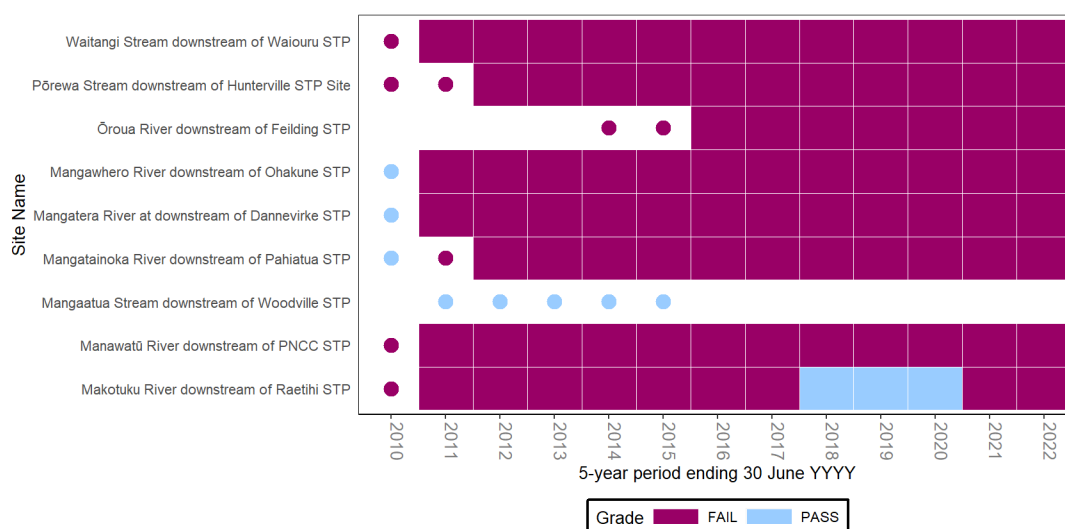


Figure 68: Rolling state assessment for One Plan river chlorophyll-a target for impact sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours

indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

## C2.2 Clarity

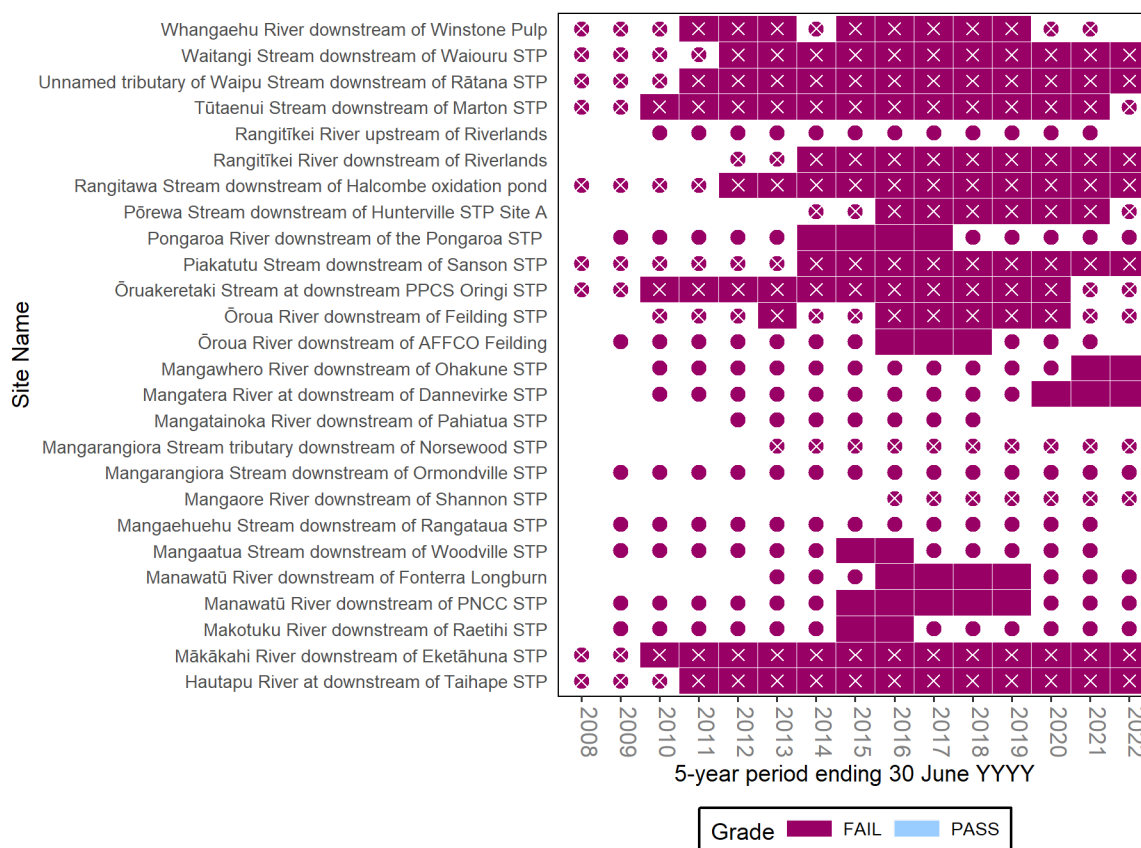


Figure 69: Rolling state assessment for One Plan river clarity target for impact sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades. White crosses indicate grades were evaluated without accounting for the flow requirements for the target.

### C2.3 DO (Sat)

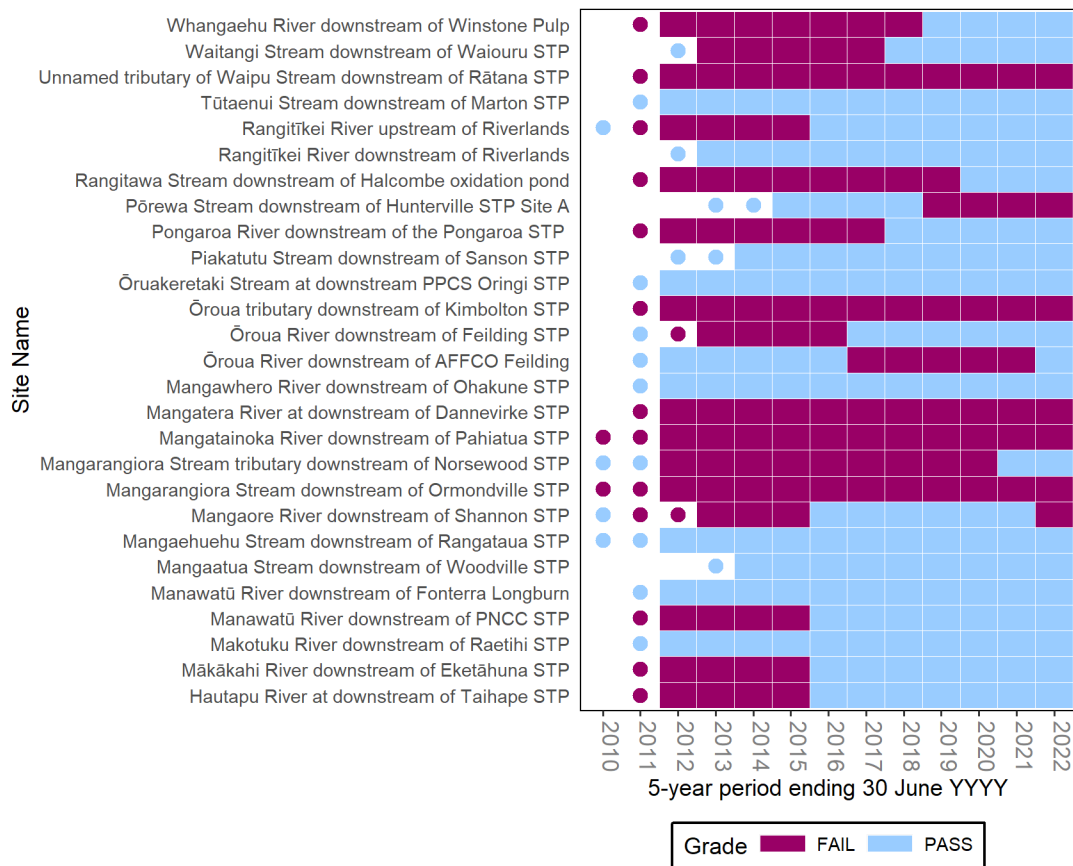


Figure 70: Rolling state assessment for One Plan river DO (sat) target for impact sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

## C2.4 DRP

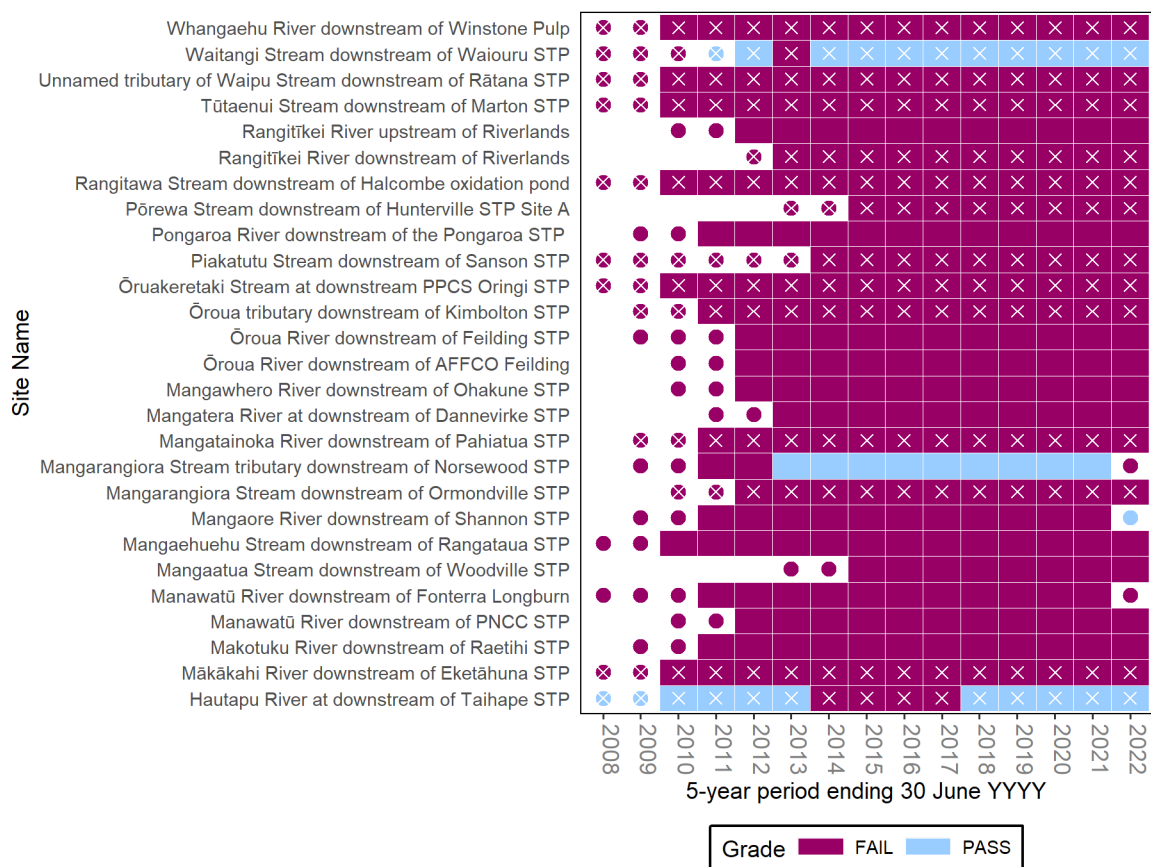


Figure 71: Rolling state assessment for One Plan river DRP target for impact sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades. White crosses indicate grades were evaluated without accounting for the flow requirements for the target.

## C2.5 E. coli (bathing)

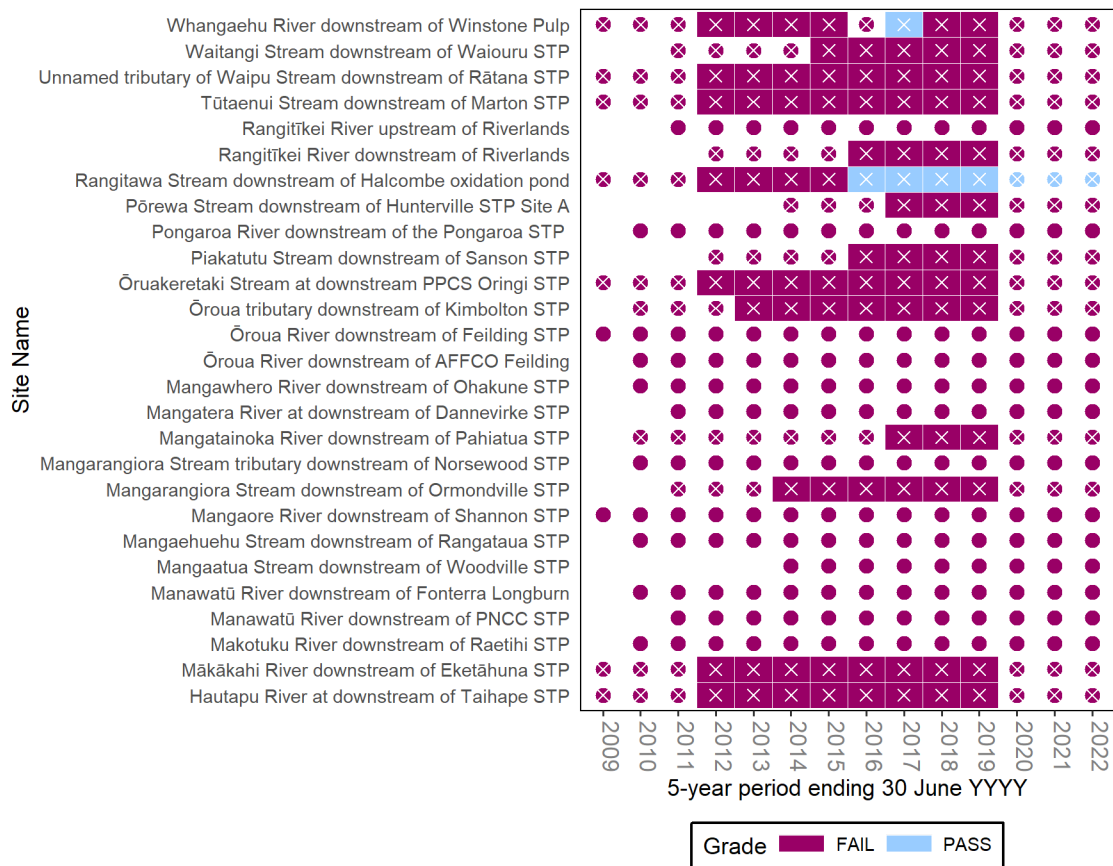


Figure 72: Rolling state assessment for One Plan river E. coli (bathing) target for impact sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades. White crosses indicate grades were evaluated without accounting for the flow requirements for the target.

## C2.6 E. coli (year round)

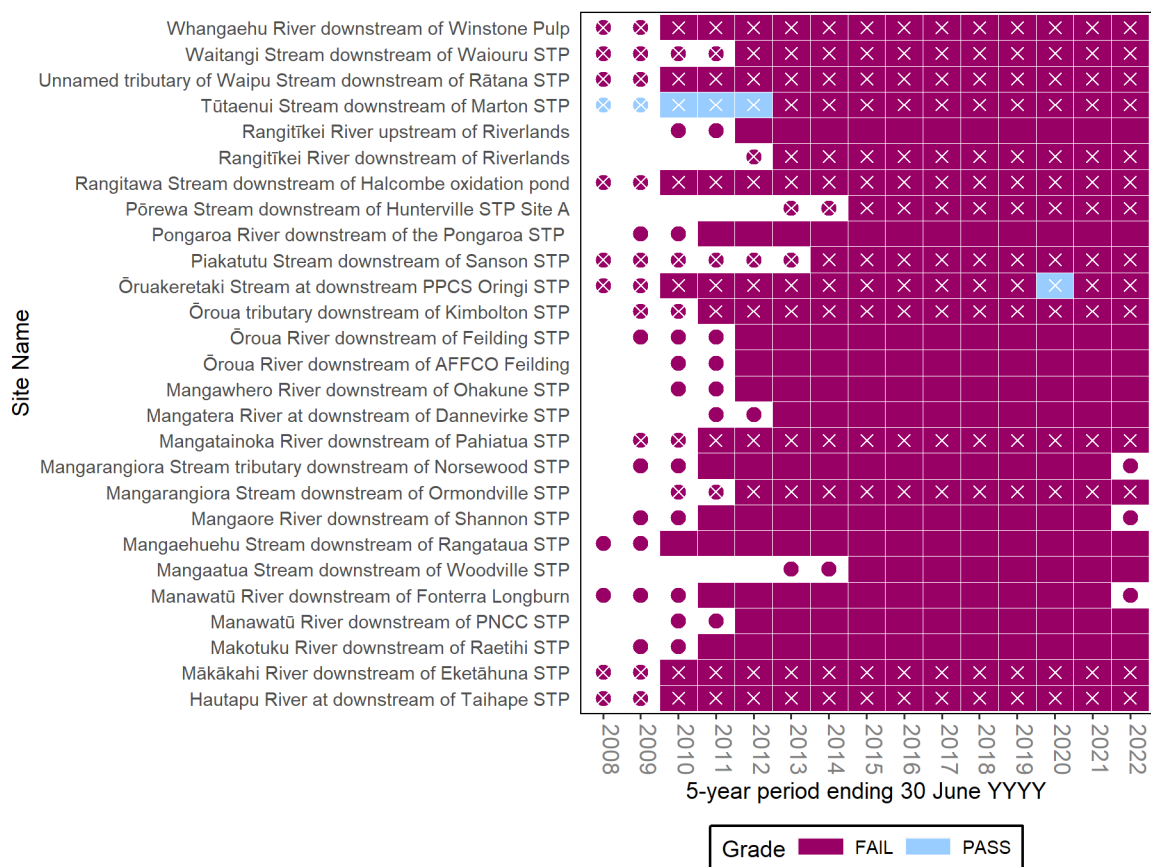


Figure 73: Rolling state assessment for One Plan river E. coli (year round) target for impact sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades. White crosses indicate grades were evaluated without accounting for the flow requirements for the target.

C2.7 MCI

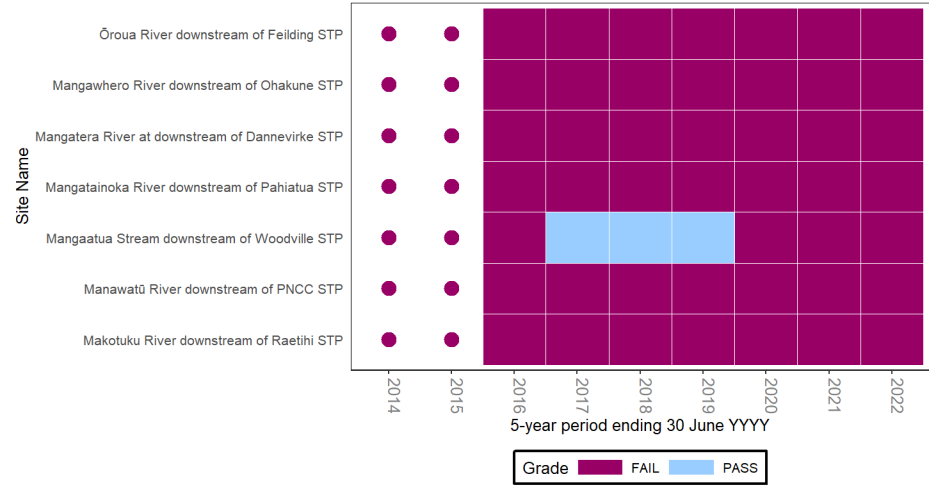


Figure 74: Rolling state assessment for One Plan river MCI target for impact sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.



## C2.8 NH<sub>4</sub>-N (max)

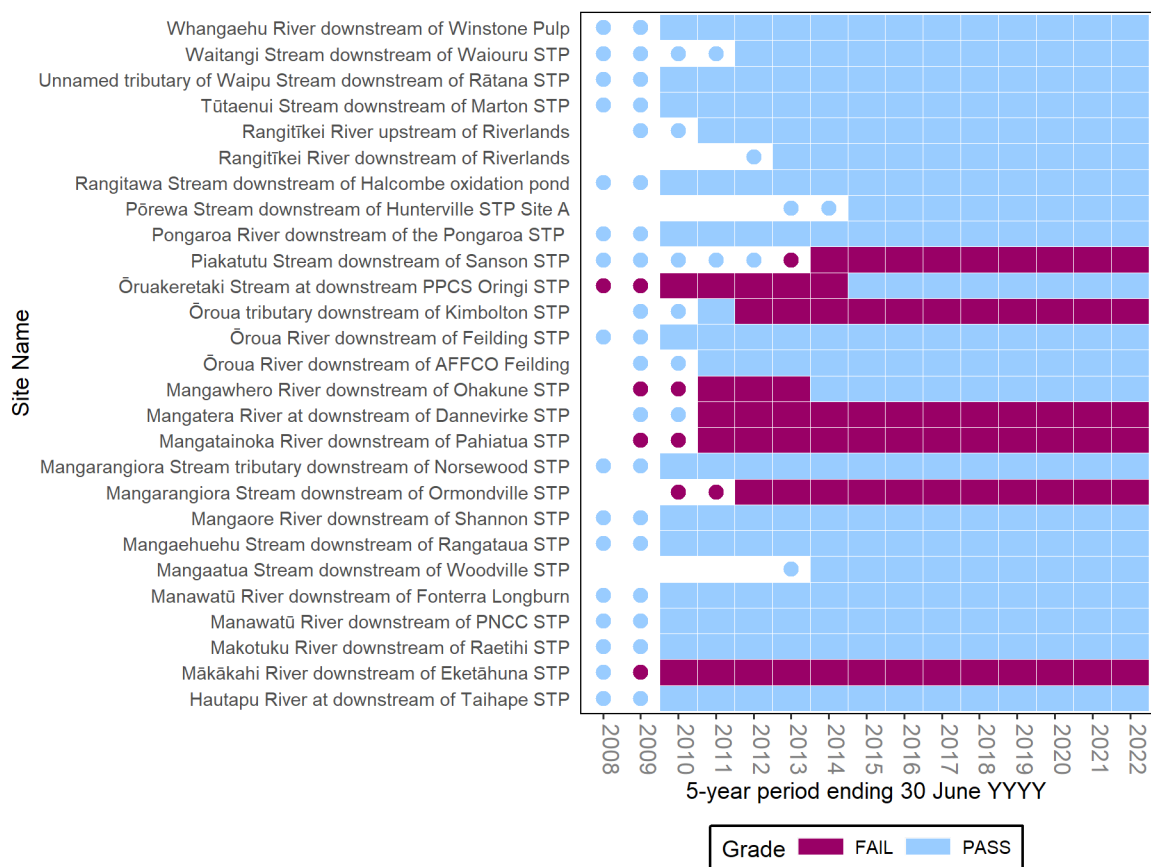


Figure 75: Rolling state assessment for One Plan river NH<sub>4</sub>N (max) target for impact sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

## C2.9 NH4-N (mean)

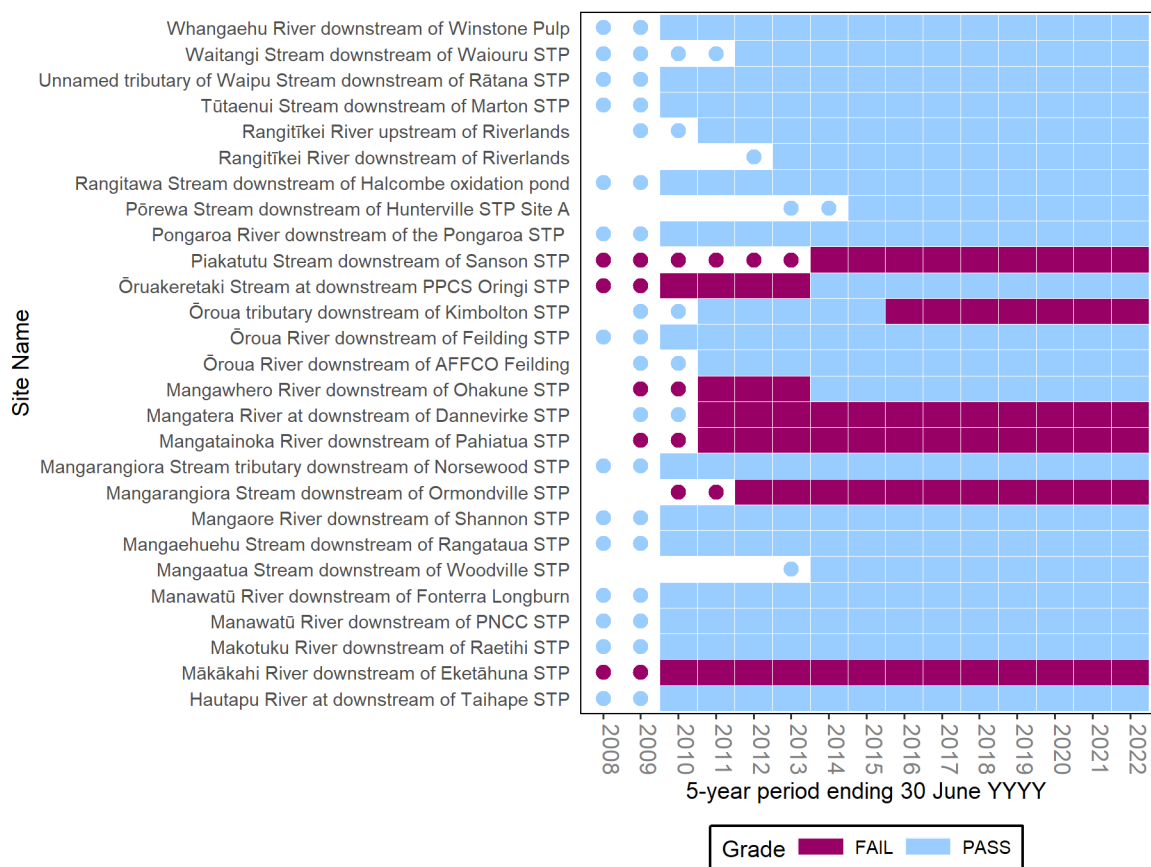


Figure 76: Rolling state assessment for One Plan river NH4N (mean) target for impact sites. Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

## C2.10 Periphyton (filaments)

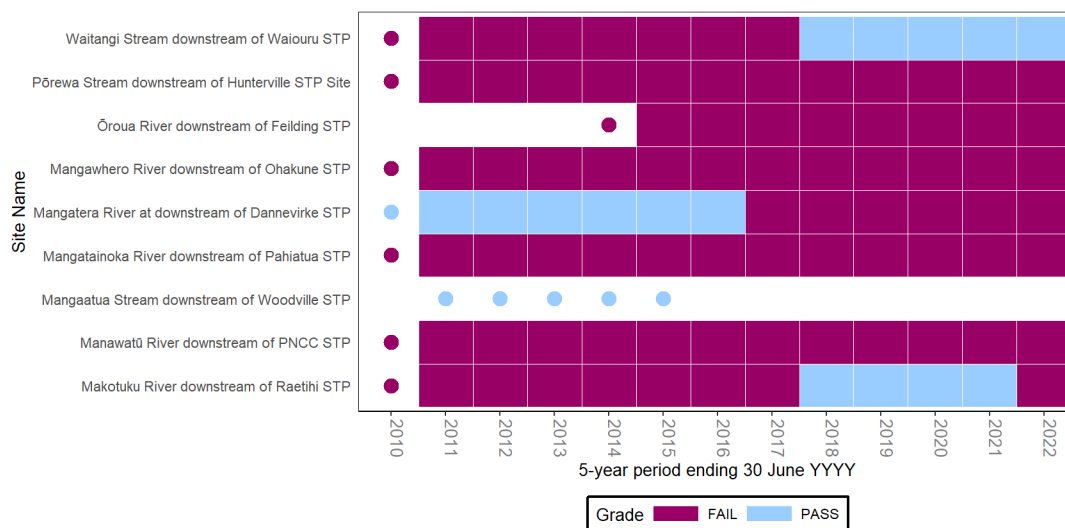


Figure 77: Rolling state assessment for One Plan river Periphyton (filaments) target for impact sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

## C2.11 Periphyton (mats)

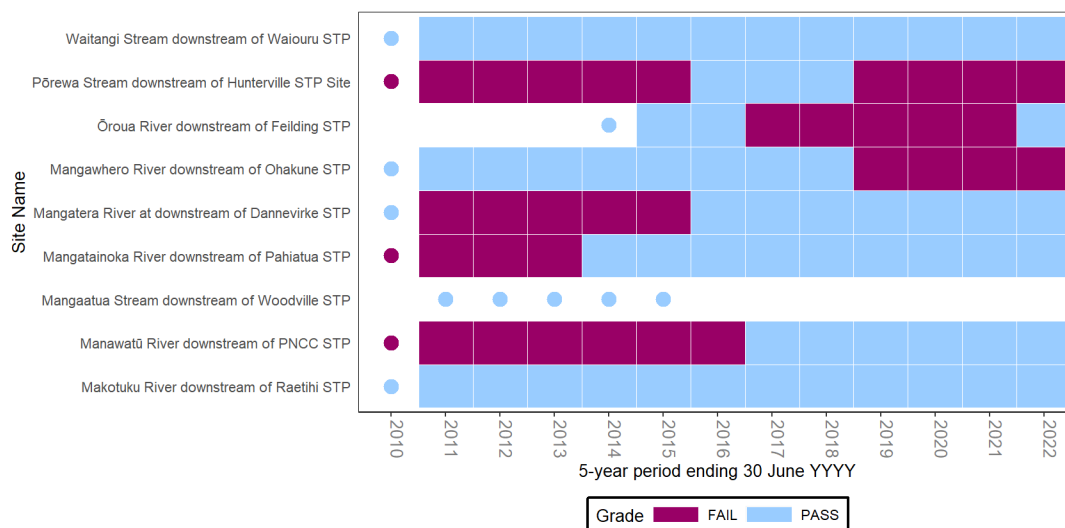


Figure 78: Rolling state assessment for One Plan river Periphyton (mats) target for impact sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

## C2.12 POM

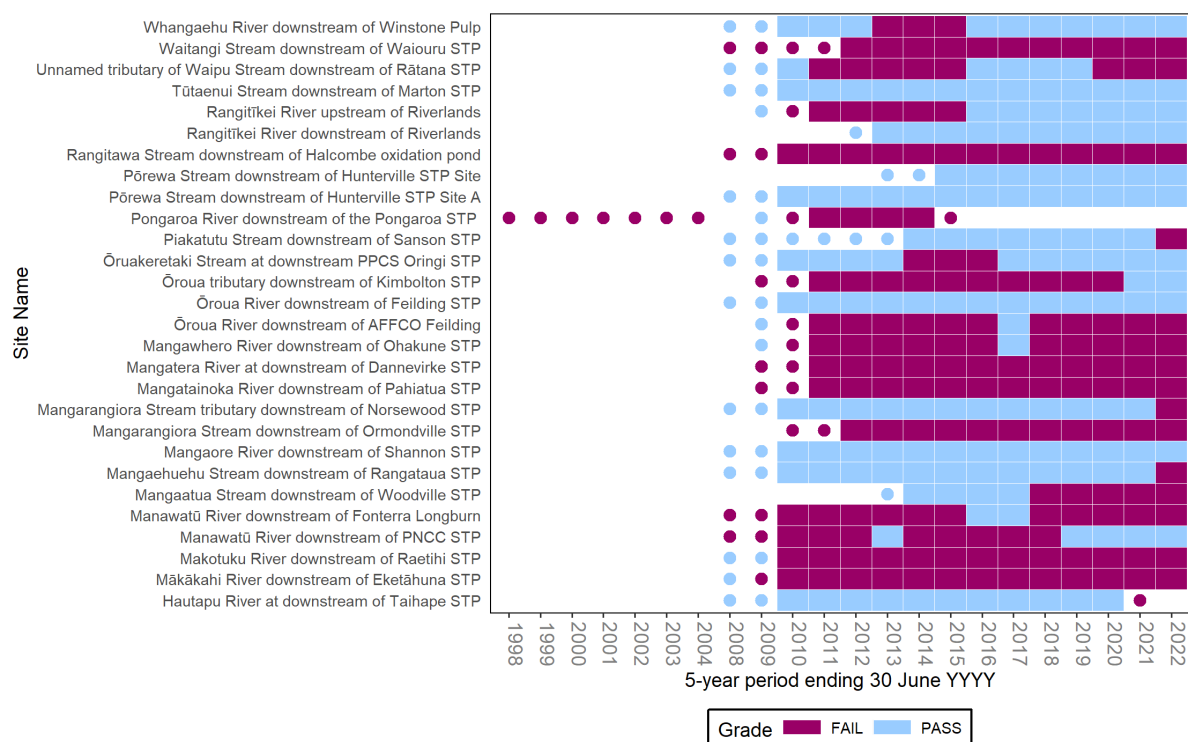


Figure 79: Rolling state assessment for One Plan river POM target for impact sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

## C2.13 sCBOB5

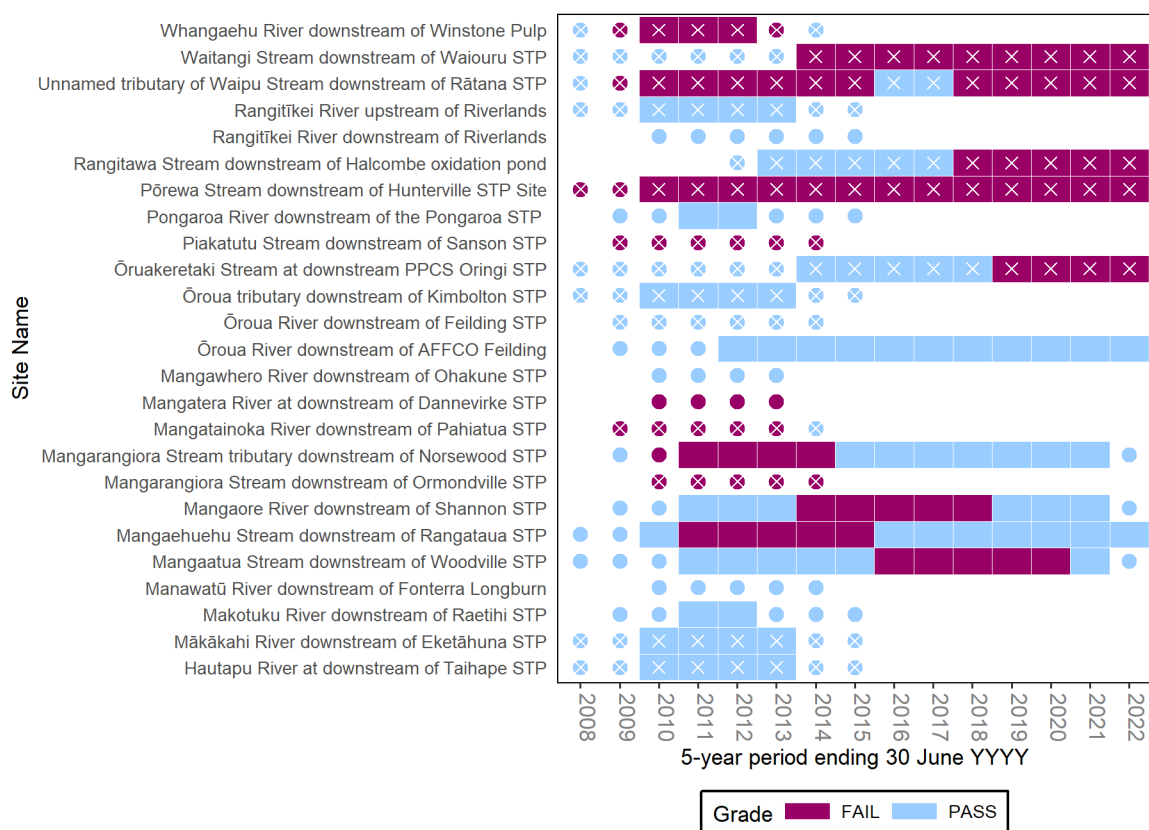


Figure 80: Rolling state assessment for One Plan river sCBOD5 target for impact sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades. White crosses indicate grades were evaluated without accounting for the flow requirements for the target.

## C2.14 SIN

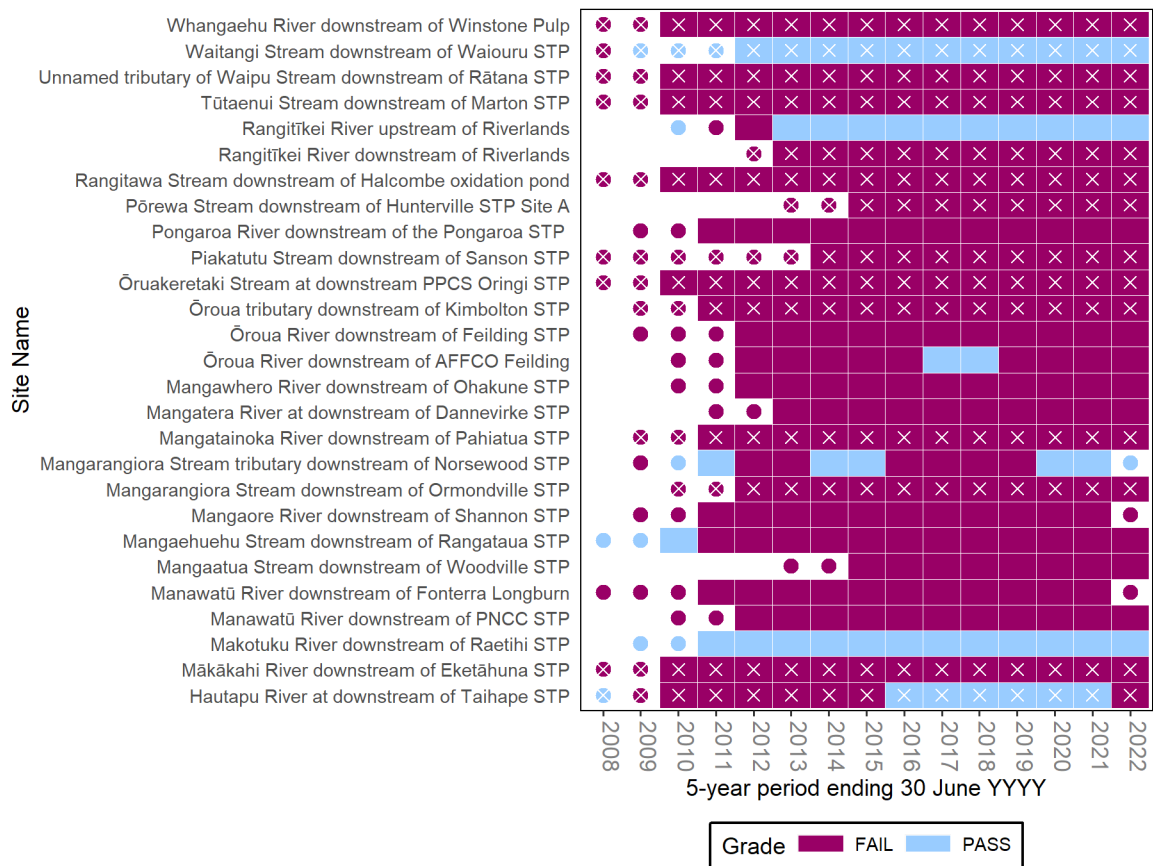


Figure 81: Rolling state assessment for One Plan river SIN target for impact sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades. White crosses indicate grades were evaluated without accounting for the flow requirements for the target.

## C3 River discharge sites

### C3.1 pH (change)

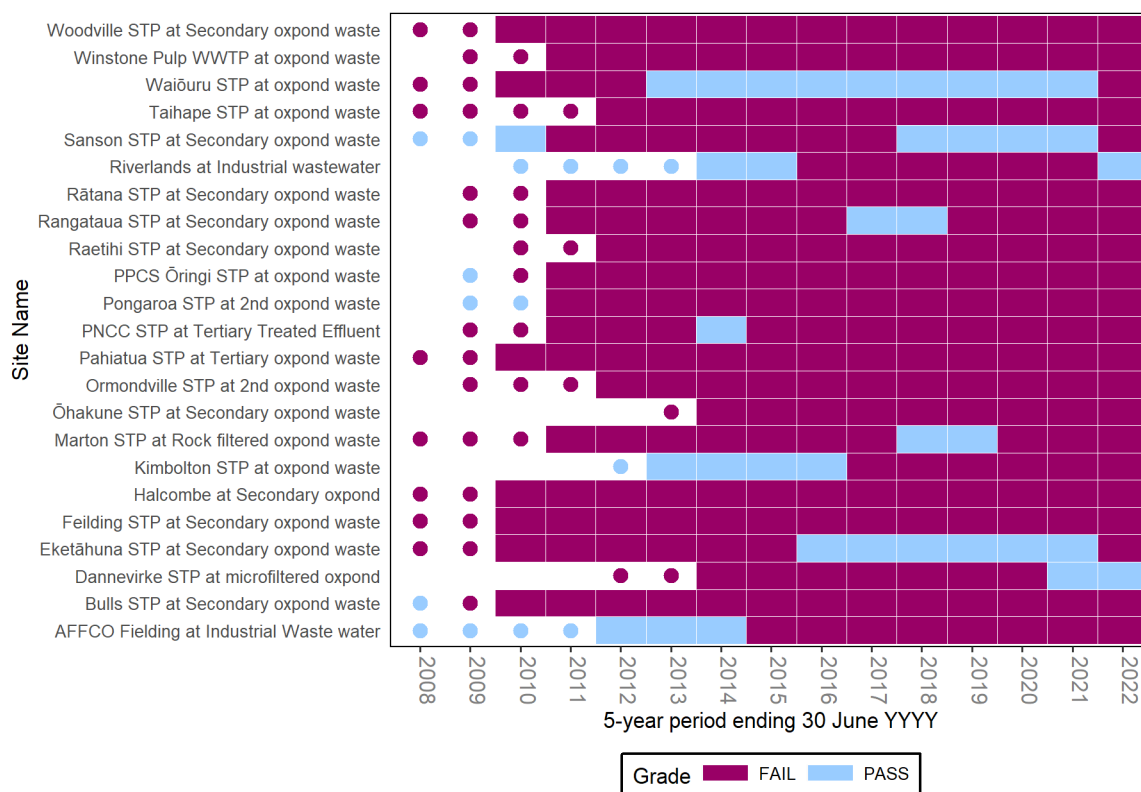


Figure 82: Rolling state assessment for One Plan river pH (change) target for discharge sites. Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

### C3.2 Temperature (change)

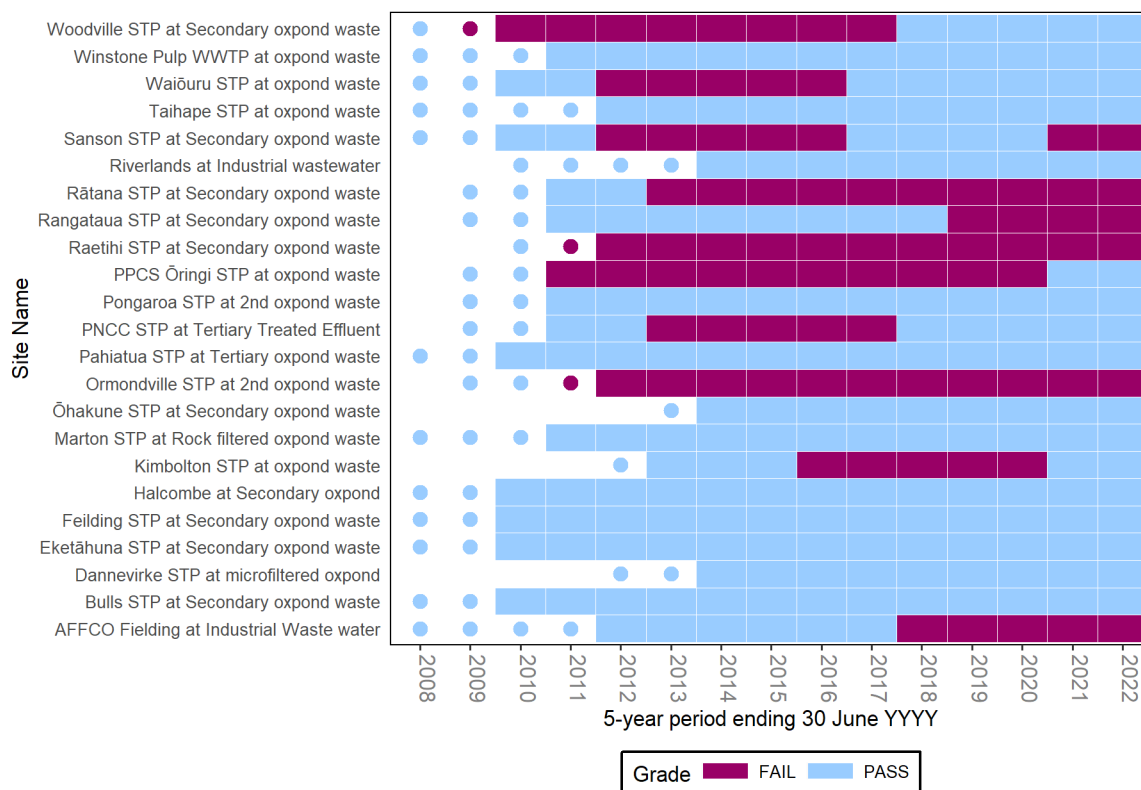


Figure 83: Rolling state assessment for One Plan river temperature (change) target for discharge sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.



### C3.3 Clarity (change)

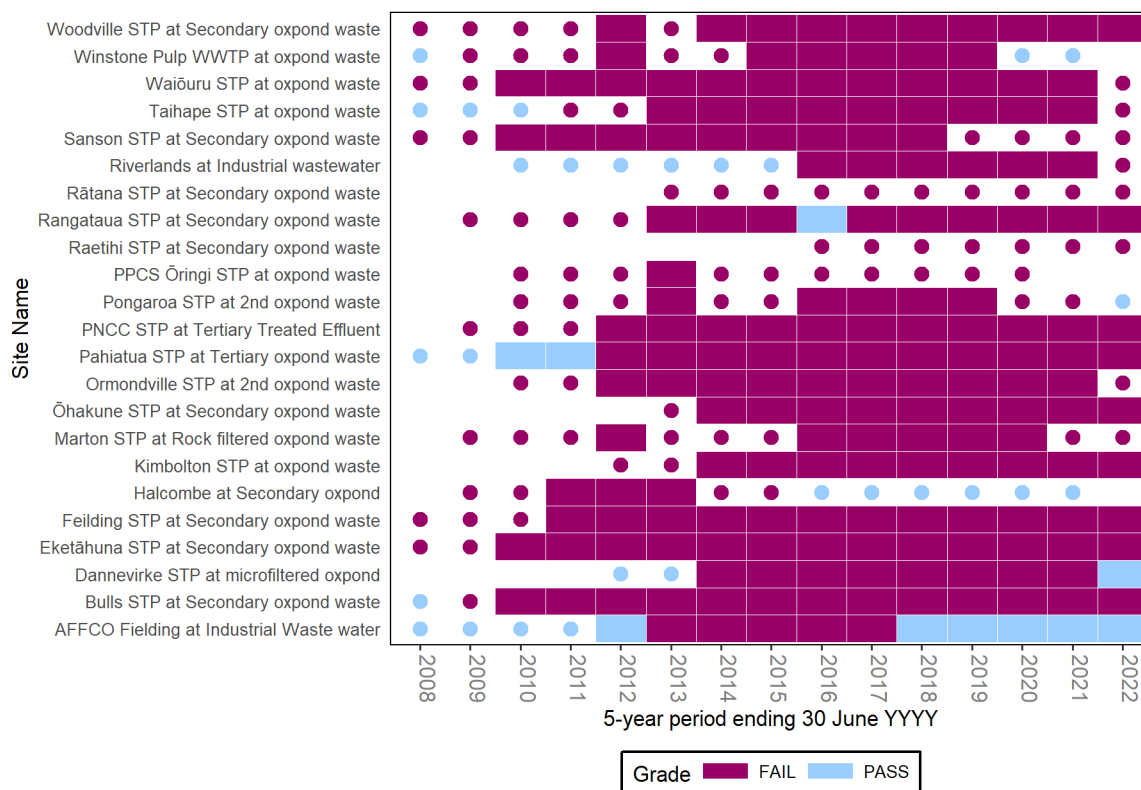
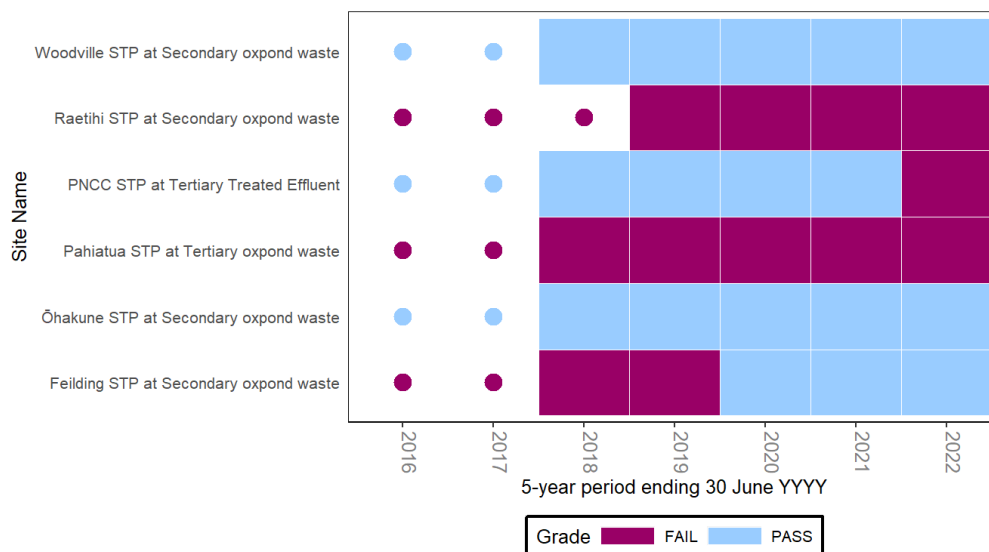


Figure 84: Rolling state assessment for One Plan river clarity (change) target for discharge sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

### C3.4 QMCI (change)



*Figure 85: Rolling state assessment for One Plan river QMCI (change) target for discharge sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.*

## C4 Lakes

### C4.1 Chlorophyll-a (mean)

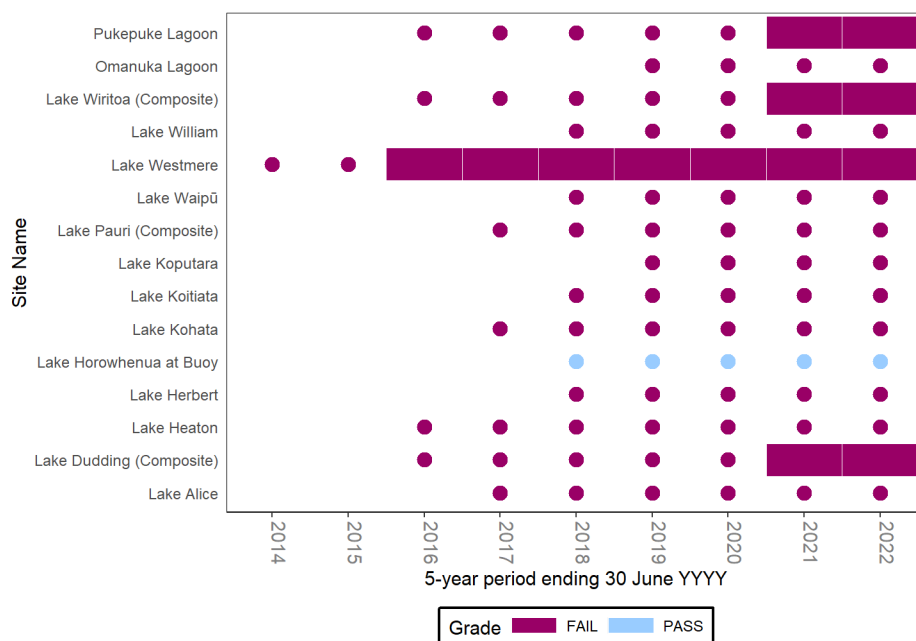


Figure 86: Rolling state assessment for One Plan chlorophyll-a (mean) target for lake sites. Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

## C4.2 Chlorophyll-a (max)

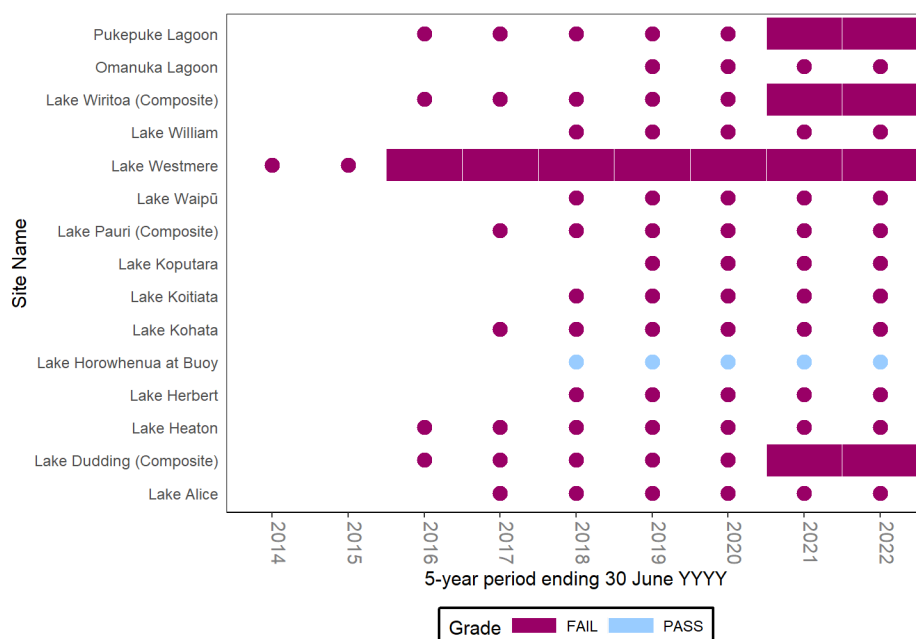


Figure 87: Rolling state assessment for One Plan chlorophyll-a (meax) target for lake sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

## C4.3 Clarity

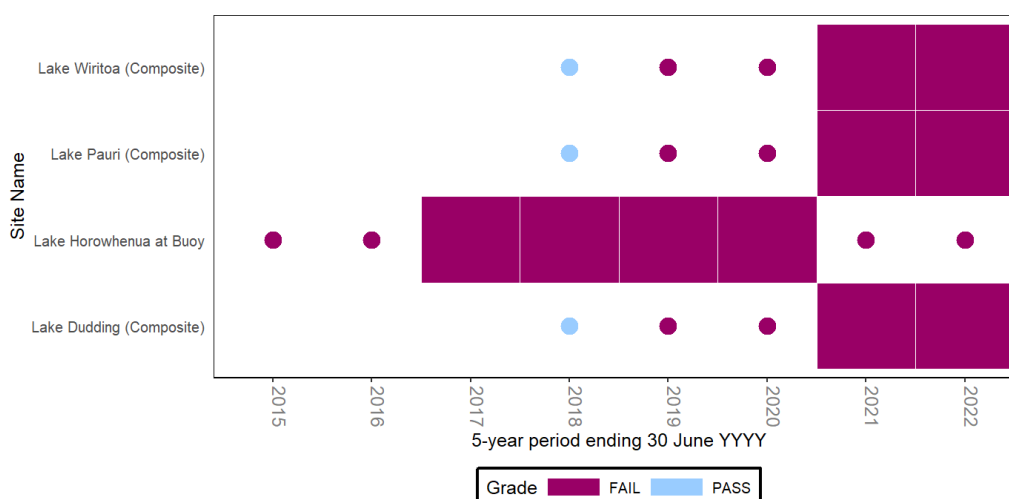


Figure 88: Rolling state assessment for One Plan clarity target for lake sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

#### C4.4 E. coli (bathing)

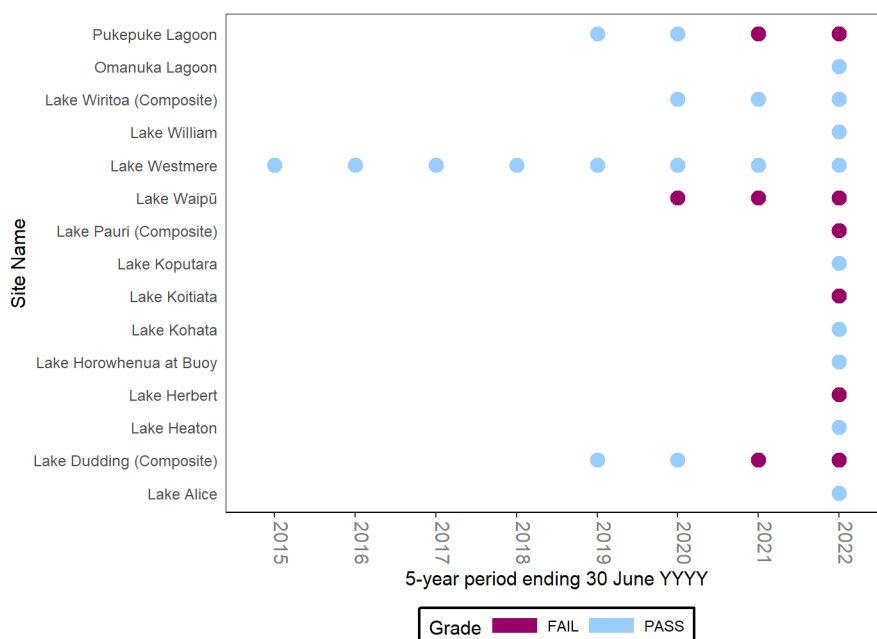


Figure 89: Rolling state assessment for One Plan E. coli (bathing) target for lake sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

#### C4.5 E. coli (non-bathing)

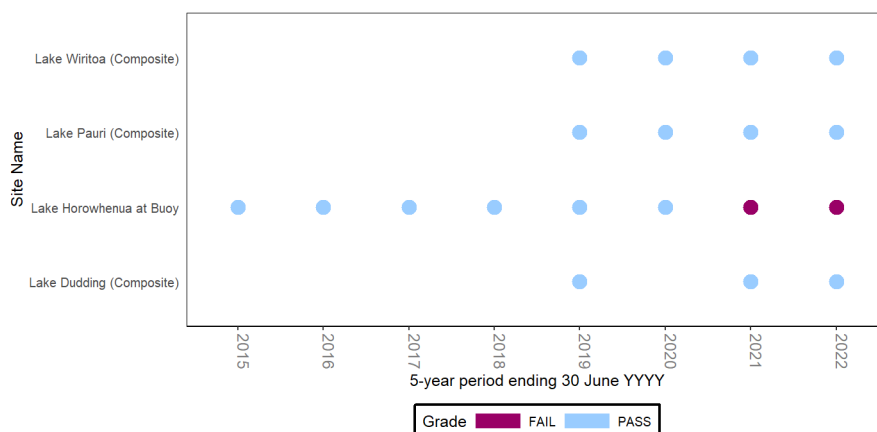


Figure 90: Rolling state assessment for One Plan E. coli (non-bathing) target for lake sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

## C4.6 TN

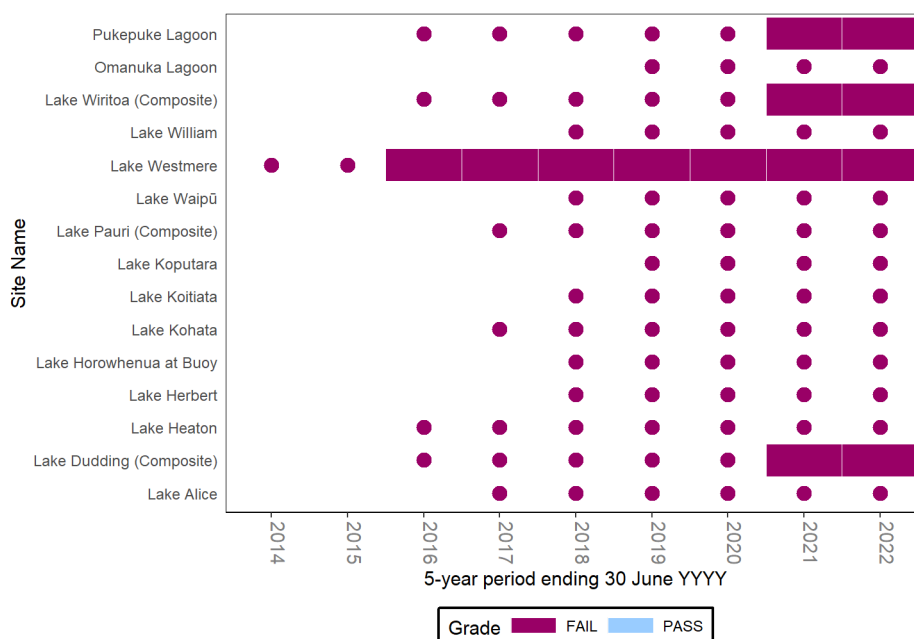


Figure 91: Rolling state assessment for One Plan TN target for lake sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

## C4.7 TP

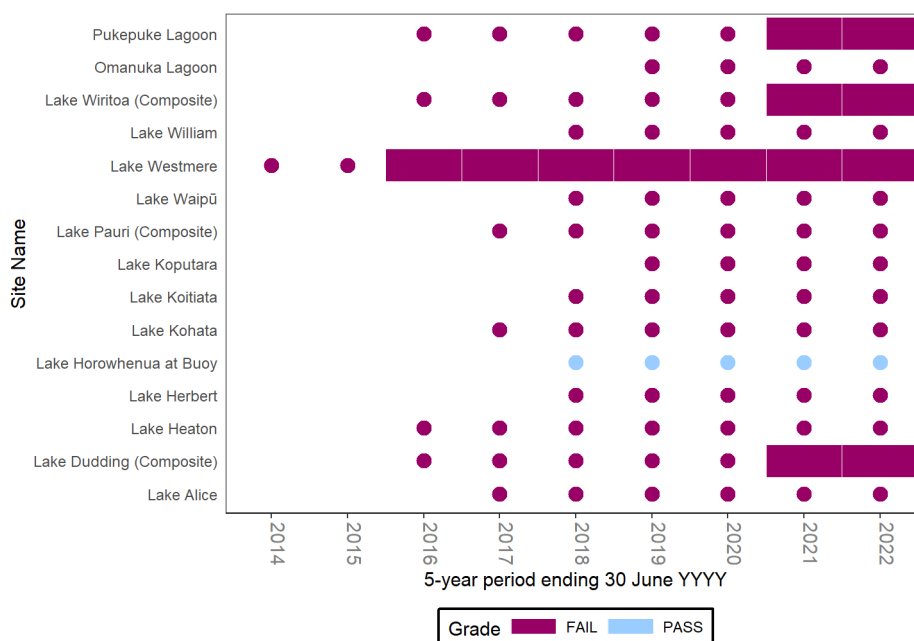


Figure 92: Rolling state assessment for One Plan TP target for lake sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

## C5 Estuary

### C5.1 Chlorophyll-a

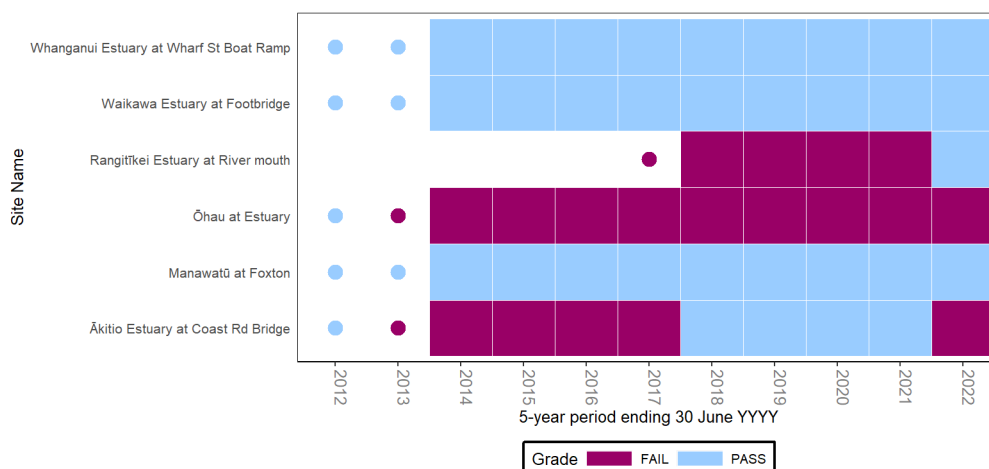


Figure 93: Rolling state assessment for One Plan chlorophyll-a target for estuary sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

### C5.2 Clarity

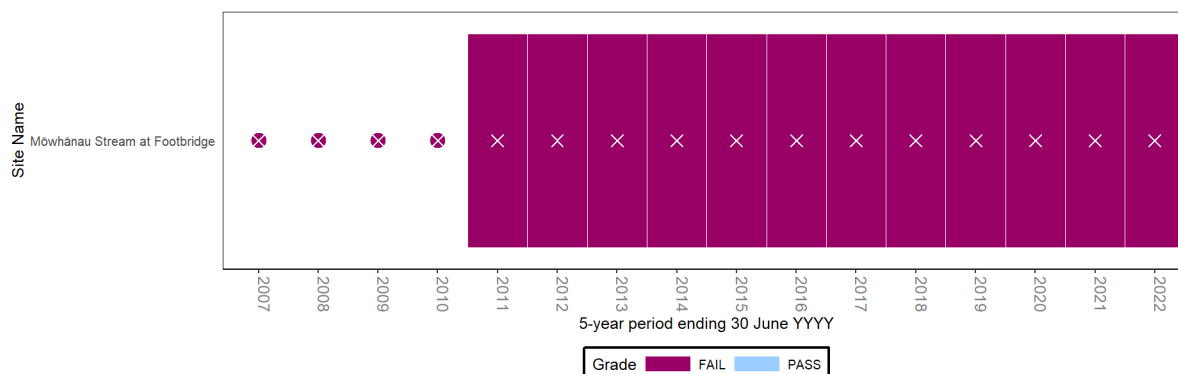


Figure 94: Rolling state assessment for One Plan clarity target for estuary sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades. White crosses indicate grades were evaluated without accounting for the flow requirements for the target.

### C5.3 DO (Sat)

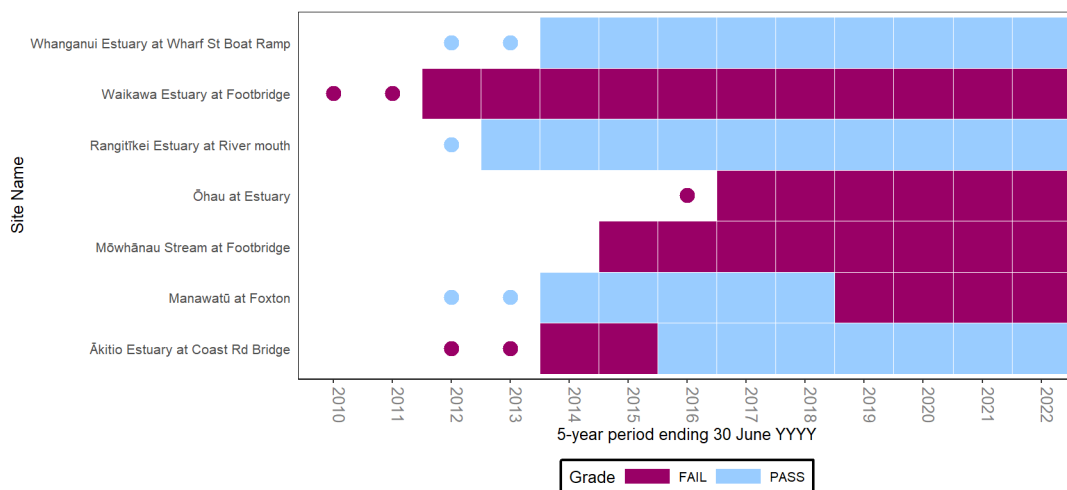


Figure 95: Rolling state assessment for One Plan DO (Sat) target for estuary sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

### C5.4 DRP

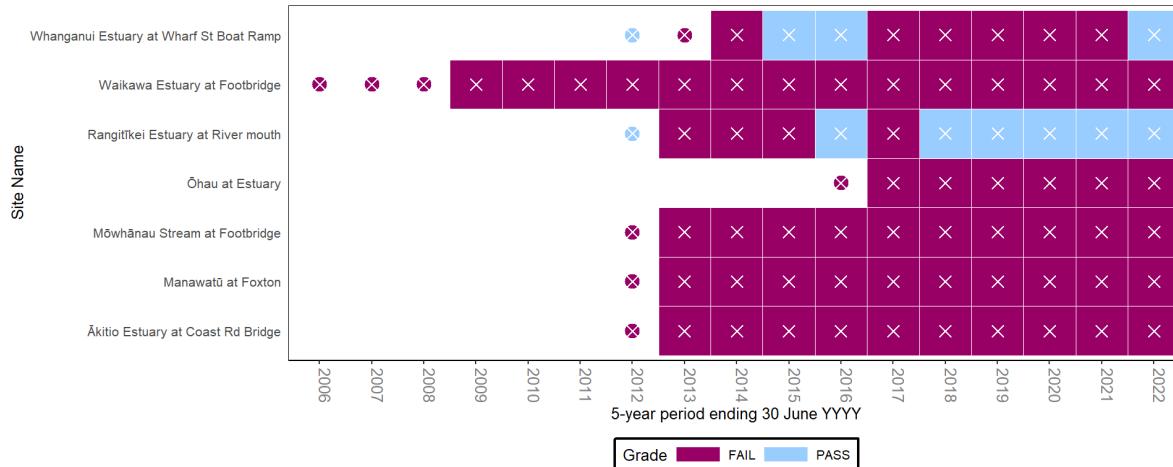


Figure 96: Rolling state assessment for One Plan DRP target for estuary sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades. White crosses indicate grades were evaluated without accounting for the flow requirements for the target.



## C5.5 E. coli (bathing)

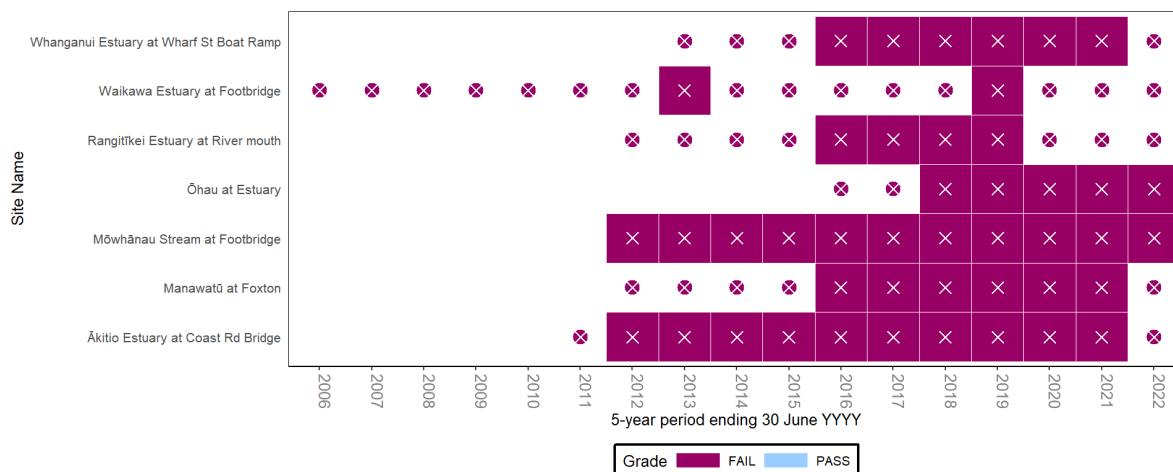


Figure 97: Rolling state assessment for One Plan E. coli (bathing) target for estuary sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades. White crosses indicate grades were evaluated without accounting for the flow requirements for the target.

## C5.6 E. coli (year round)

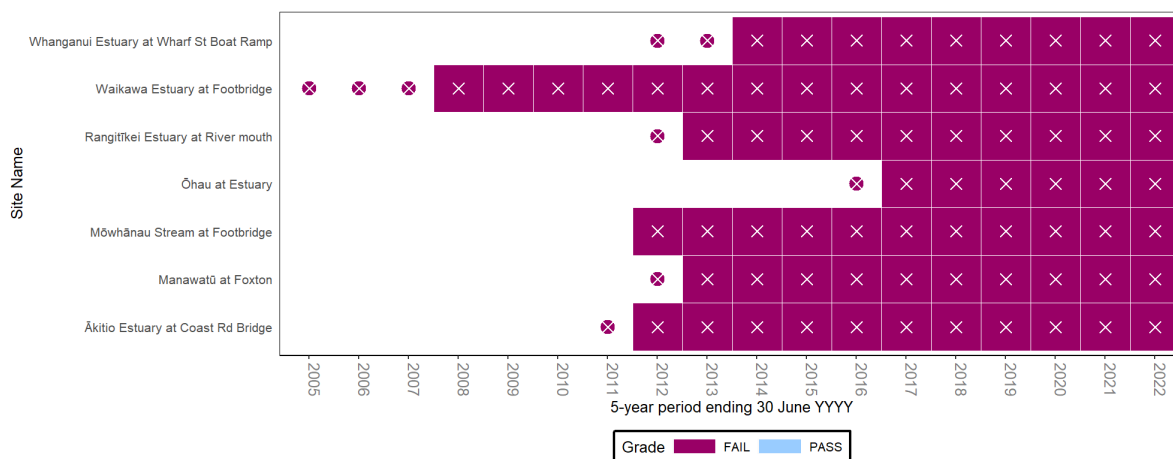


Figure 98: Rolling state assessment for One Plan E. coli (year round) target for estuary sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades. White crosses indicate grades were evaluated without accounting for the flow requirements for the target.

## C5.7 NH4-N

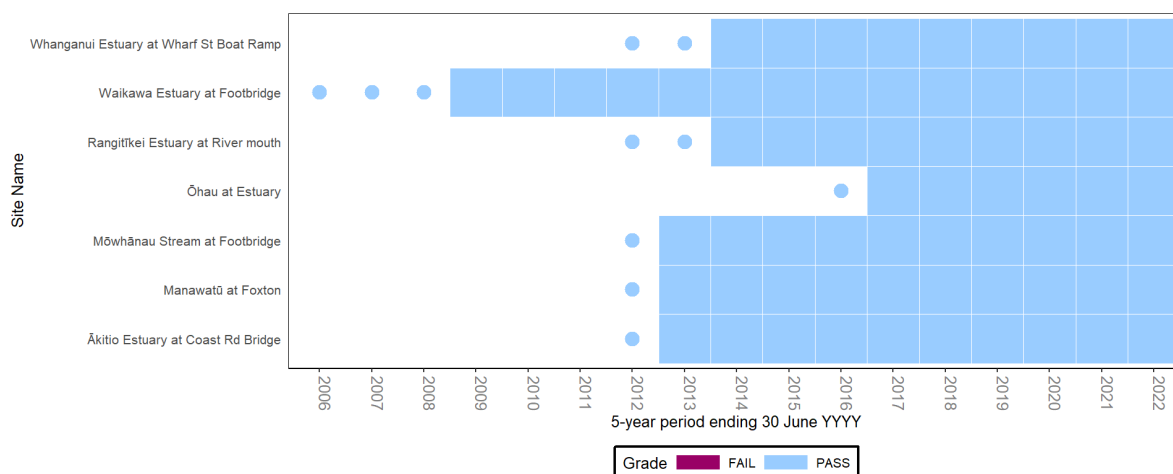


Figure 99: Rolling state assessment for One Plan NH4-N target for estuary sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

## C5.8 SIN

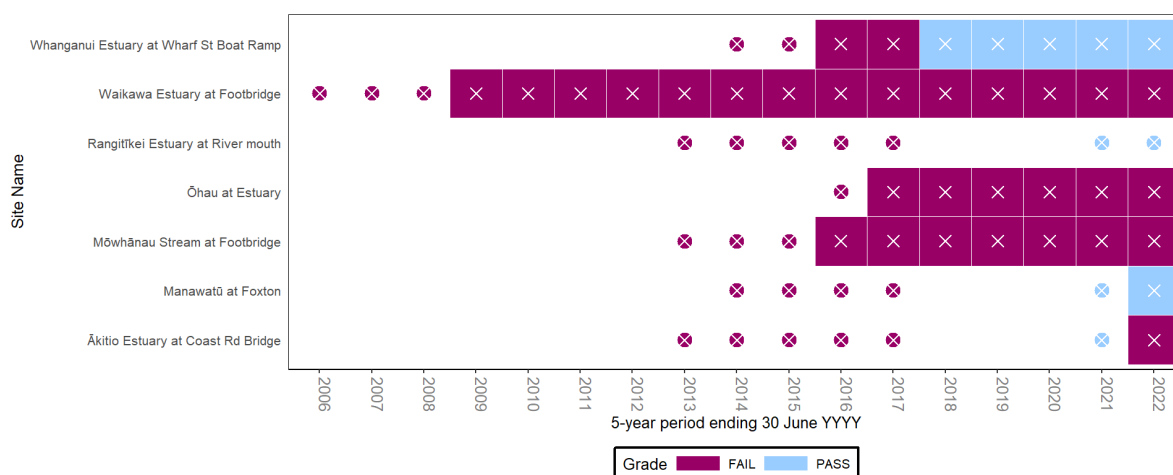


Figure 100: Rolling state assessment for One Plan SIN target for estuary sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades. White crosses indicate grades were evaluated without accounting for the flow requirements for the target.

## C5.9 Temperature

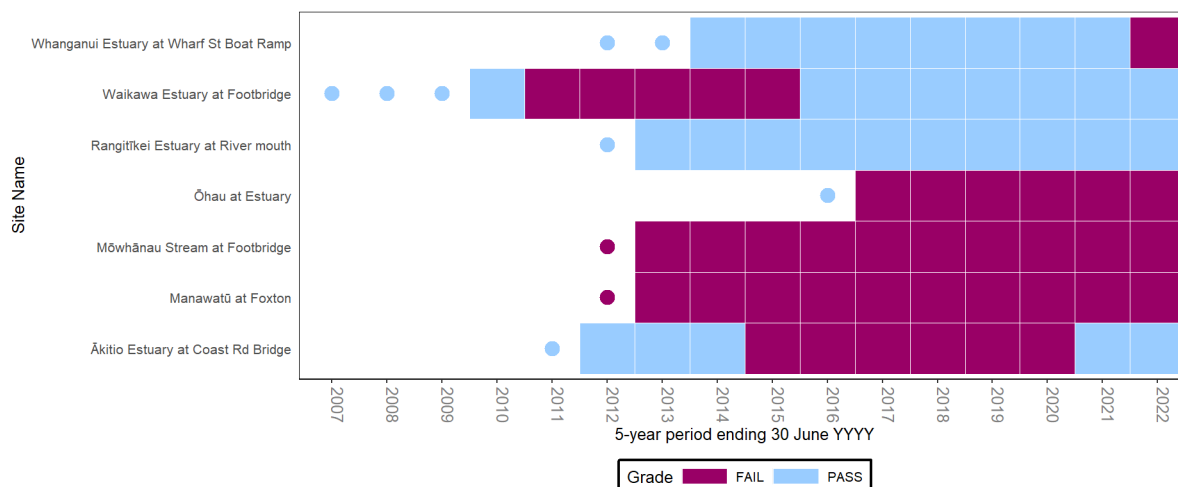


Figure 101: Rolling state assessment for One Plan temperature target for estuary sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

## C6 Coastal

### C6.1 Chlorophyll-a

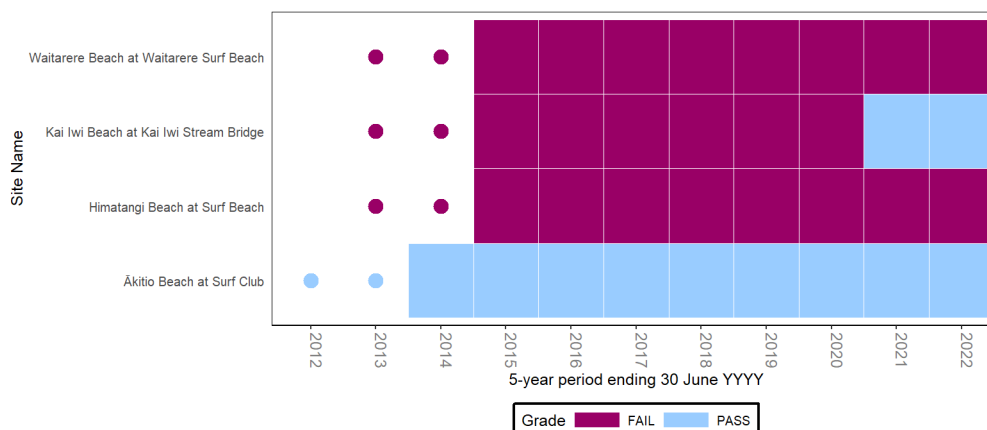


Figure 102: Rolling state assessment for One Plan chlorophyll-a target for coastal sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

## C6.2 Faecal coliforms (median)

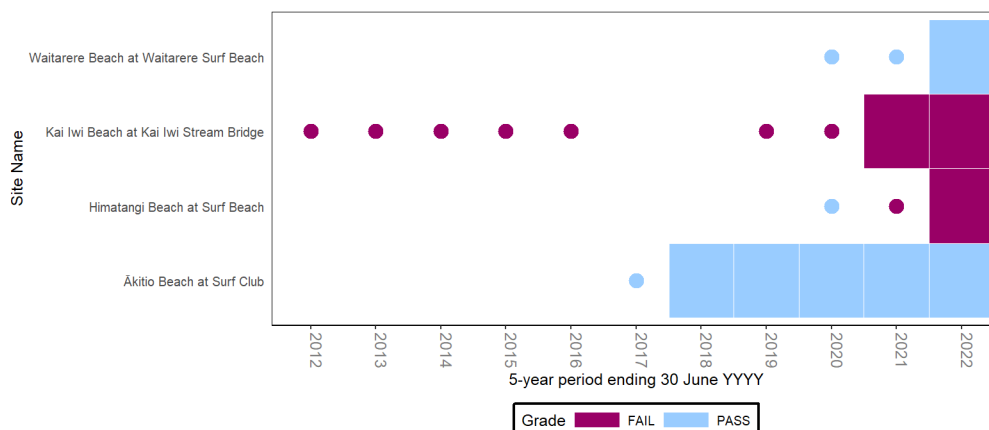


Figure 103: Rolling state assessment for One Plan faecal coliforms (median) target for coastal sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

## C6.3 Faecal coliforms (q90)

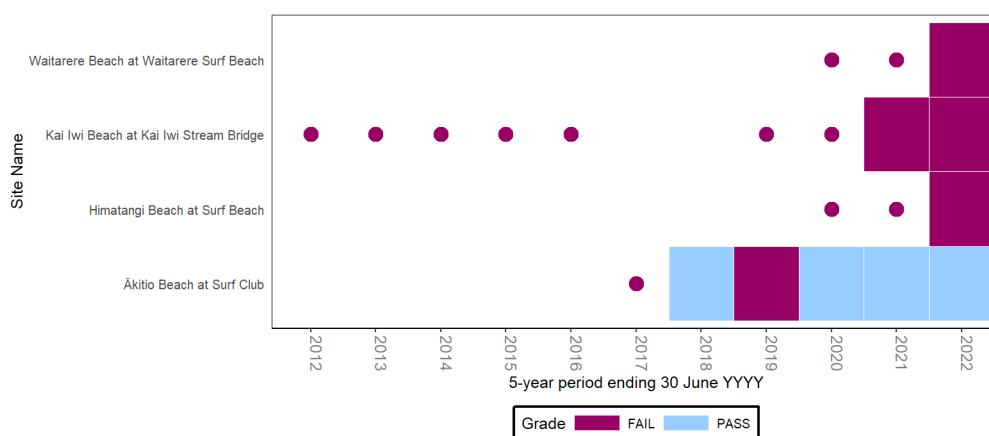


Figure 104: Rolling state assessment for One Plan faecal coliforms (q90) target for coastal sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

## C6.4 NH4-N

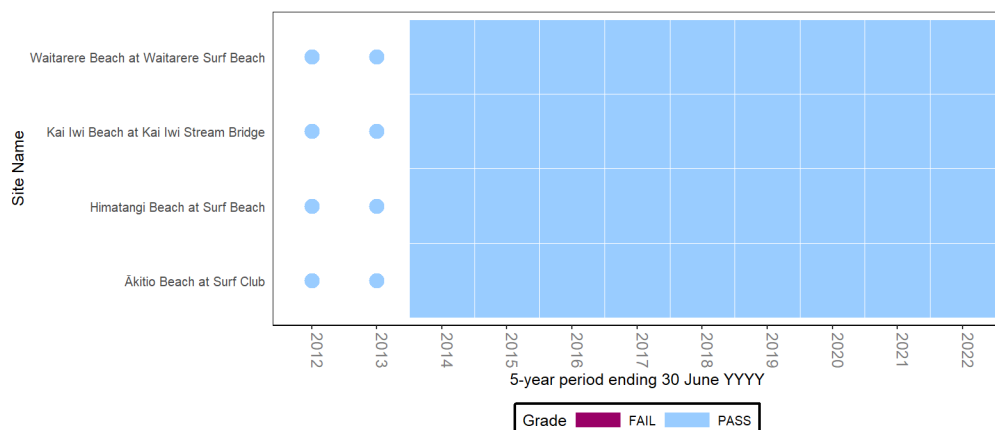


Figure 105: Rolling state assessment for One Plan NH4-N target for coastal sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

## C6.5 TN

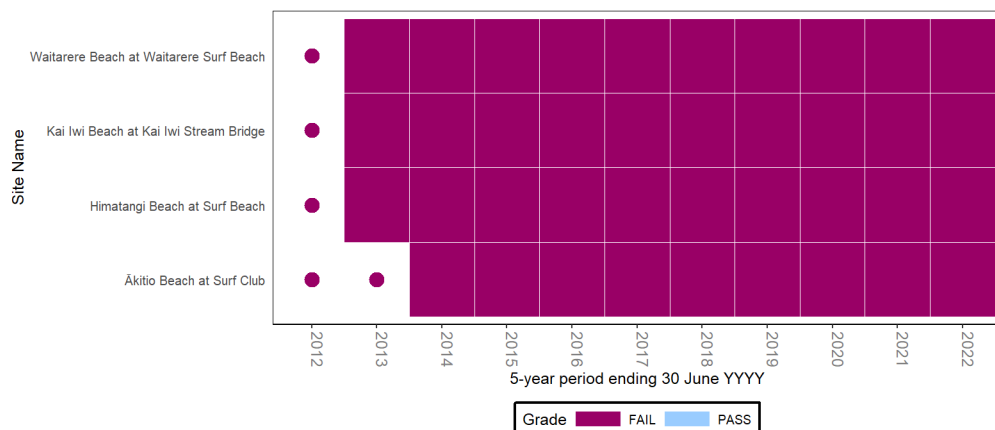
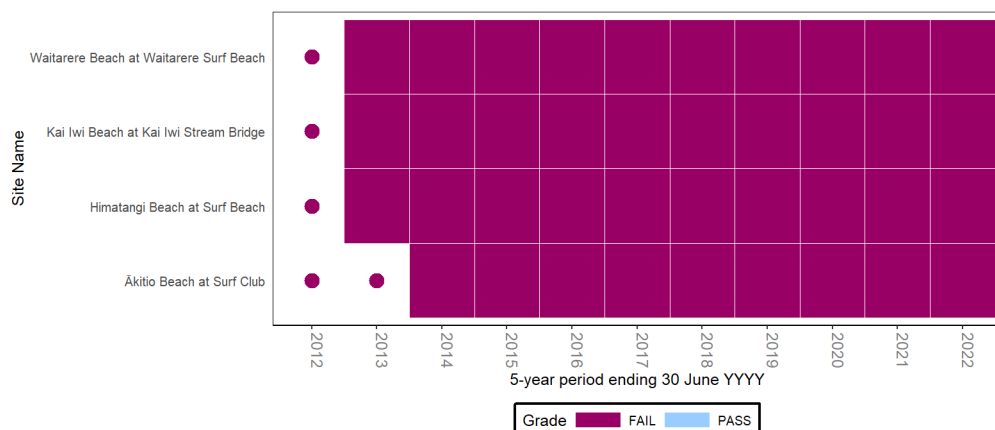


Figure 106: Rolling state assessment for One Plan TN target for coastal sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.

## C6.6 TP



*Figure 107: Rolling state assessment for One Plan TP target for coastal sites Y-axis provides the end year of the 5-year state assessment (ending on 30 June). Colours indicate state grade for each site. Coloured circles indicate interim grades for sites. No colour indicates that there were no observations, or fewer than required to define interim grades.*

## Appendix D Scatter plots of state versus trend

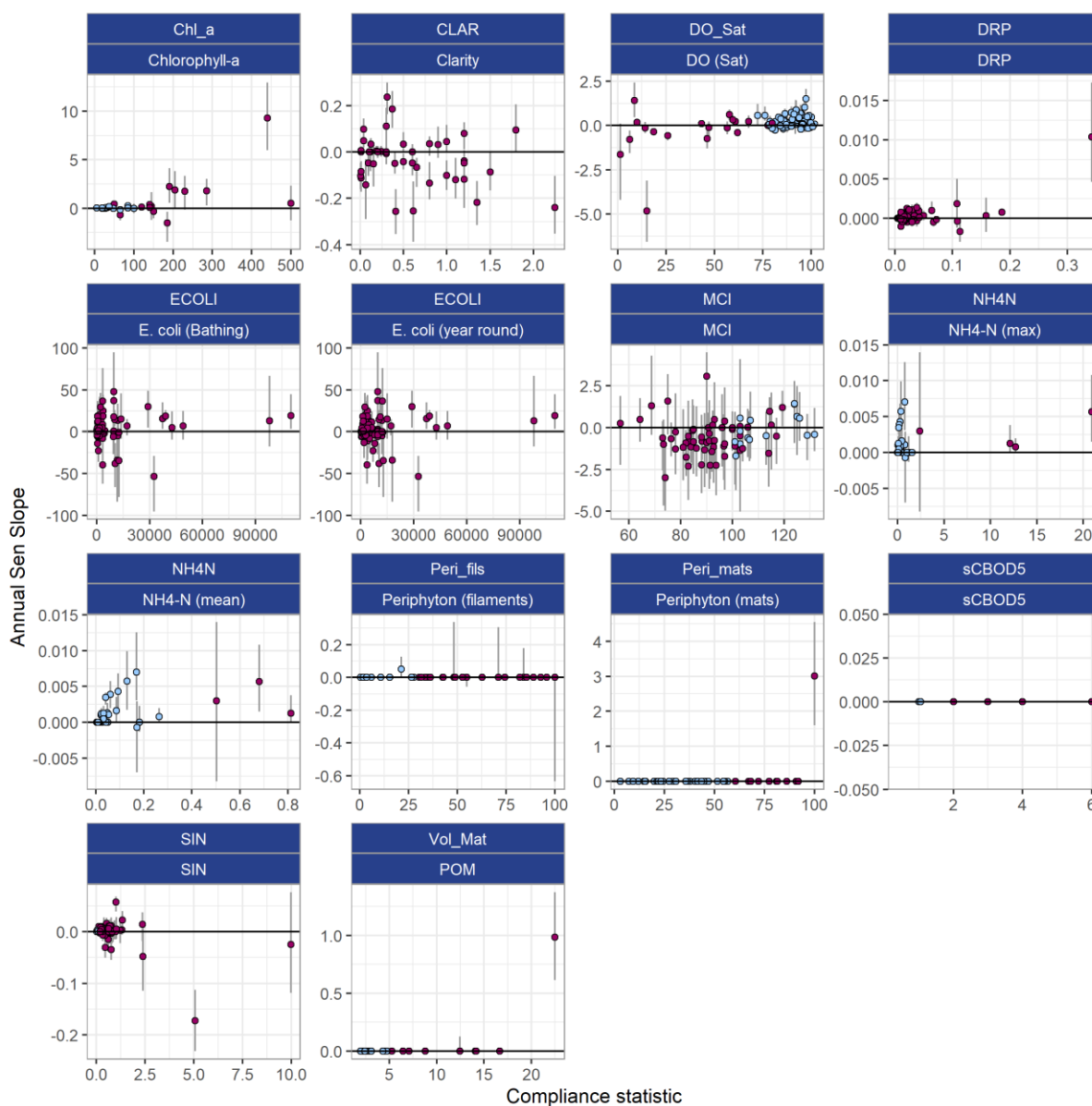


Figure 108: Scatter plot showing state versus 10-year trend magnitudes (Sen slopes), with 90% confidence intervals at river SoE sites. Points are coloured based on One Plan grades (maroon = FAIL, blue=PASS).

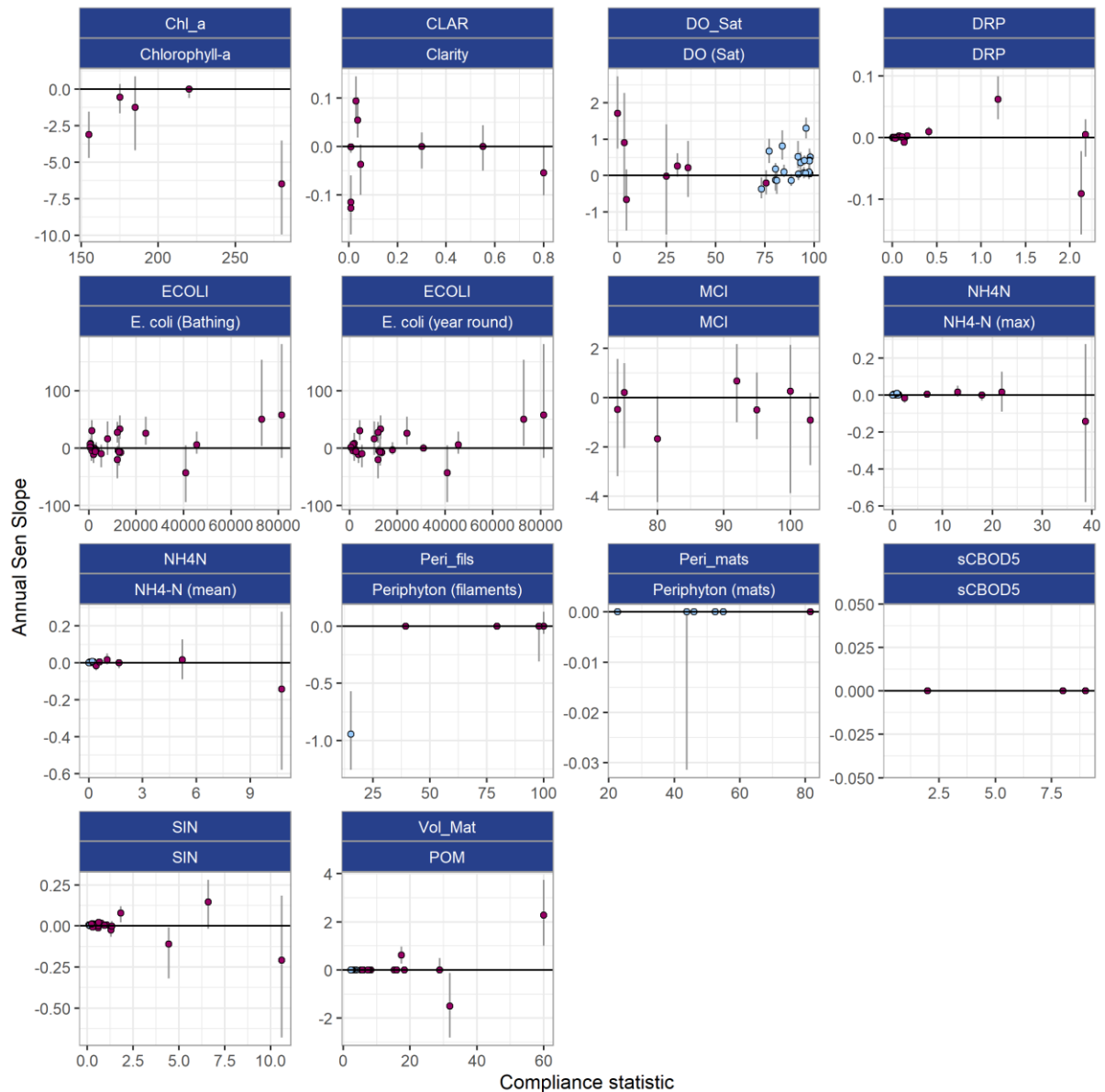


Figure 109: Scatter plot showing state versus 10-year trend magnitudes (Sen slopes), with 90% confidence intervals at river impact sites. Points are coloured based on One Plan grades (maroon = FAIL, blue=PASS).



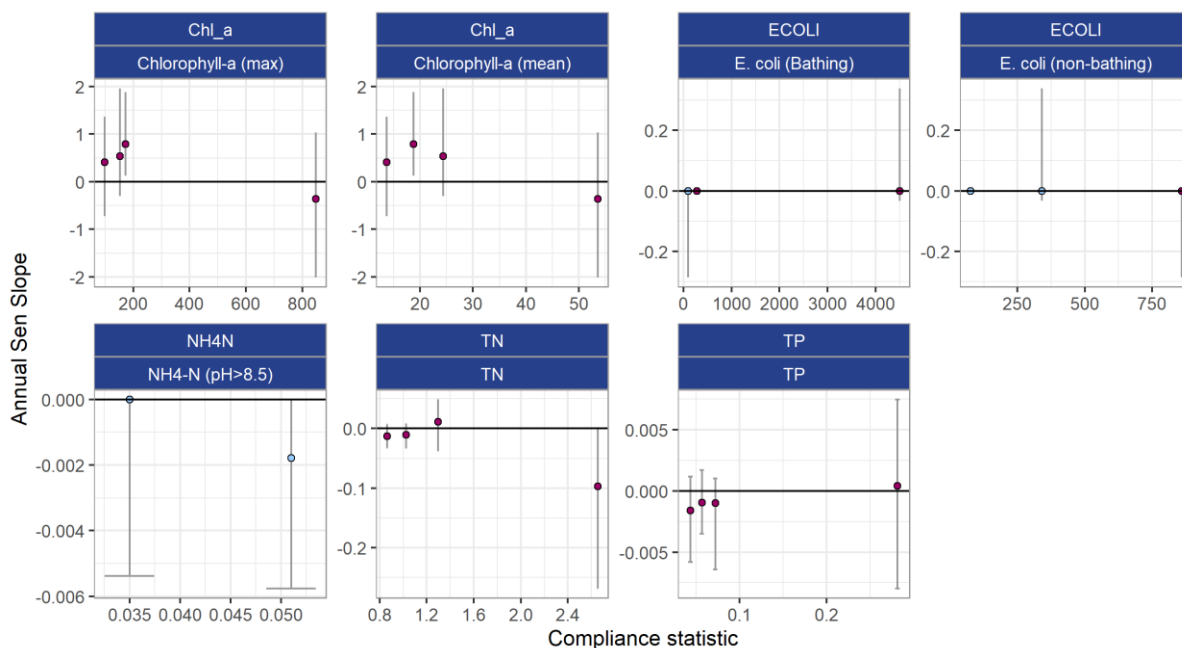


Figure 110: Scatter plot showing state versus 10-year trend magnitudes (Sen slopes), with 90% confidence intervals at lake sites. Points are coloured based on One Plan grades (maroon = FAIL, blue=PASS).

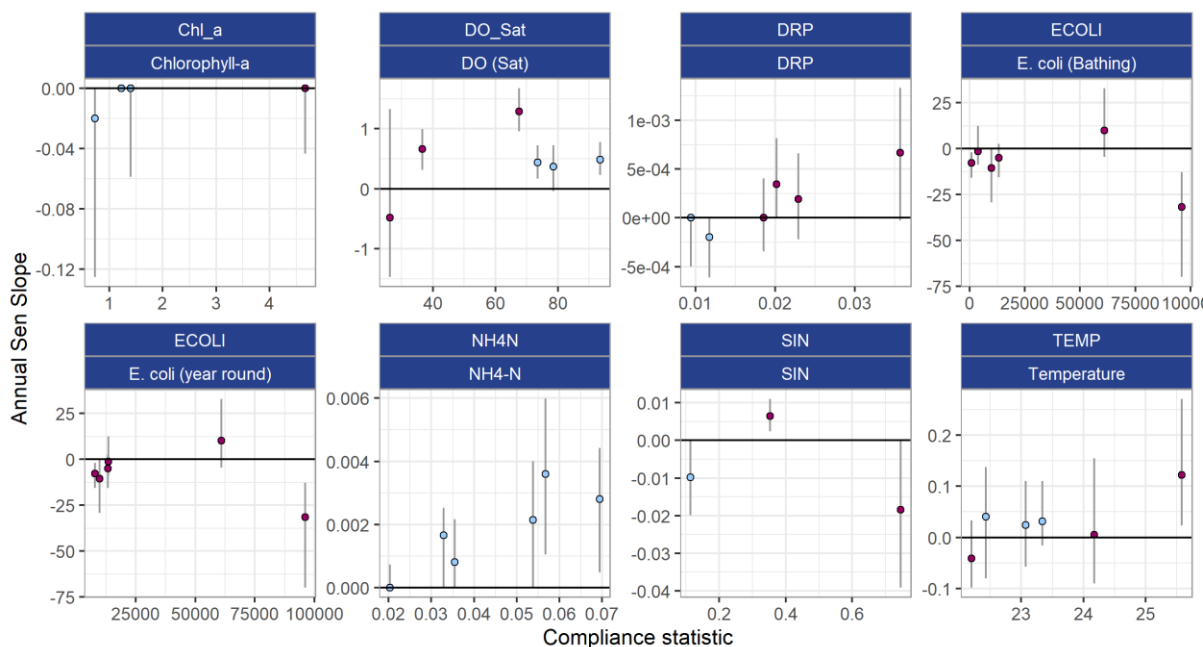


Figure 111: Scatter plot showing state versus 10-year trend magnitudes (Sen slopes), with 90% confidence intervals at estuary sites. Points are coloured based on One Plan grades (maroon = FAIL, blue=PASS).

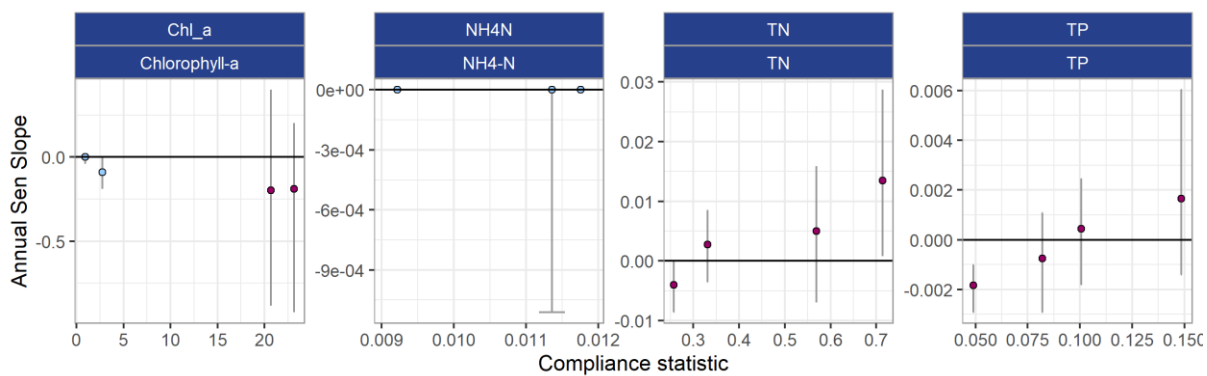


Figure 112: Scatter plot showing state versus 10-year trend magnitudes (Sen slopes), with 90% confidence intervals at coastal sites. Points are coloured based on One Plan grades (maroon = FAIL, blue=PASS).



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