Southland lakes: Classification, attributes and state assessment

Values and Objectives Technical Report

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Executive Summary

Environment Southland and Te Ao Marama (TAMI) have, through their People Water and Land programme, embarked on a community-involved process to further develop the approach to managing land and water in the region. This has included community engagement to support the development of community values and freshwater objectives, and the formation of Regional Forum to help develop limits and both regulatory and non-regulatory methods to achieve them.

The purpose of this report is to contribute to the process of developing draft freshwater objectives for consideration by Environment Southland's Council and the Te Ao Marama board. This report is one of a number of supplementary reports and memos that contribute to the report titled: *Developing Draft Freshwater Objectives for Southland* (Norton and Wilson, 2019) and: *Current Environmental State and the "Gap" to Draft Freshwater Objectives for Southland* (Norton et. al., 2019).

This report explains:

- The rationale for the **lake classification** proposed to be used in developing freshwater objectives in Southland:
- A description of the **lake attributes** proposed to be used for numeric freshwater objectives, to support the values of 'Human Health for Recreation' and 'Ecosystem Health', along with the associated attribute state option tables; and,
- A summary of the tabulation of data used to **assess attribute state** for 2010, 2016 and 2019 (current state).

Once the process for establishing freshwater objectives for Southland has been completed, it is recommended that a review of the Southland lake monitoring programme be undertaken to ensure it aligns with any changes in approach to the management of land and water in the region.

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1 Introduction

Environment Southland and Te Ao Marama (TAMI) have, through their People, Water and Land – Te Mana o te Tangata, te Wai, te Whenua programme, embarked on a community-involved process to further develop the approach to managing land and water in the region. This has included community engagement to support the development of community values and freshwater objectives, and the formation of Regional Forum to help develop limits and both regulatory and non-regulatory methods to achieve them.

The People, Water and Land programme has three workstreams, one of which is 'Values and Objectives'. The objective of this workstream is to raise awareness of freshwater and to determine the community's values and freshwater objectives in accordance with the requirements of the National Policy Statement for Freshwater Management[1] (NSPFM). The outputs from this workstream are key components for the other two workstreams: the 'Regional Forum' workstream which is a community group providing Council and Te Ao Marama board members on methods and timeframes to achieve the communities' aspirations for freshwater, and the 'Action on the Ground' workstream whose goal is to enable and support change at the farm-to-catchment scale.

This report is part of a package of work being prepared through the Values and Objectives workstream. Specifically, this report is part of supplementary material that has been produced to contribute to the reports titled: *Developing Draft Freshwater Objectives for Southland* (Norton and Wilson, 2019) and: *Current Environmental State and the "Gap" to Draft Freshwater Objectives for Southland* (Norton et al., 2019).

1.1 Report purpose

The purpose of this report is to describe the technical basis for the lake components used in Norton and Wilson (2019) and Norton et al., (2019). This work covers three key areas:

1. **Lake classification:** The rationale and description of the lake classes proposed to be used in developing freshwater objectives in Southland.

2. **Attributes:** In addition to specifying national compulsory attributes, the NPS-FM requires councils to develop attributes appropriate for their region to use when setting freshwater objectives. This report describes how lake attributes have been selected to help describe the values of 'human health for recreation' and 'ecosystem health' (see Wilson et. al., 2019)[2], and how attribute state option tables have been developed to support the setting of freshwater objectives for Southland lakes (see Norton and Wilson, 2019).

3. **Assessing attribute state**: The NPS-FM requires regional councils to 'maintain or improve' water quality in their regions. Therefore, as part of the process for developing draft freshwater objectives, an assessment of attribute state was required. This report explains the data used and how it has been tabulated to inform attribute state for three time periods: 2010, 2016 and 2019 (current state) (see Norton et. al., 2019).

[1] The NPS-FM was first released in 2011 and amended in 2014 and 2017. Unless otherwise stated, this report refers to the 2017 version of the NPS-FM. The NPS-FM was further amended in 2020, after this report was first prepared.

[2] The attributes used in this report are likely to support additional values, such as threatened species and mahinga kai (both introduced as national compulsory values in the NPS-FM 2020), however attribute applicability to other values, and additional attributes that may be required to support other values, have not been considered in this report. This may be part of further work considering the implications of the NPS-FM 2020 to the Values and Objectives package prepared under the NPS-FM 2017.

1.1 Where this report fits in the process

This report is part of supplementary material that has been prepared for two key reports in the 'Values and Objectives' workstream in the People, Water and Land programme:

- Lake classification, lake attributes and attribute state tables were used in the *Developing Draft Freshwater Objectives for Southland* report (Norton and Wilson, 2019) and;
- Assessment of attribute state for three time periods were used in the *Current Environmental State and the "Gap" to Draft Freshwater Objectives for Southland* report (Norton et. al., 2019).

It is noted that these reports in turn were used in the third iteration of the draft freshwater objectives, where the above community workstream was woven together with the iwi values and objectives work, to derive a combined set of draft freshwater objectives that provide for hauora, the health and well-being of waterbodies in Southland Murihiku (hauora being a requirement of Te Mana o te Wai in the NPS-FM) (Bartlett et. al., 2020).

2 Lake classification

2.1 Existing lake classes in regional plans

The Regional Water Plan for Southland (2010) introduced surface water body classes with associated water quality standards that were taken through largely unchanged into the proposed Southland Water and Land Plan (pSWLP)[3]. The classes identified for Southland lakes are:

- Natural State;
- Mataura 3 (from the Water Conservation (Mataura River) Order 1997);
- Lowland/Coastal Lakes and Wetlands;
- Hill Lakes and Wetlands; and,
- Mountain Lakes and Wetlands.

A summary of how the current lake classes have been defined and issues that have arisen with these classes are presented in

Table 1.

[3] Unless otherwise stated, the pSWLP referred to in this report is the Decisions version, 4th April 2018.

Table 1: Summary of current regional plan lake classes and issues

Current lake class definition	Issues with lake class definition
Natural state	
The glossary in the pSWLP defines natural state as: <u>Natural state waters (for water quality purposes)</u> *Waters within:* *(a) areas defined as National Park managed under the National Parks Act 1980 (including land for the time being administered as if it was a national park pursuant to any statute or written agreement with the owners); and* *(b) public conservation land managed under the Conservation Act 1987 and the Reserves Act 1977 as detailed in Table 1 "Natural State Waters outside National Parks" in Appendix I "Natural State Waters outside National Parks" of this Plan.*	**Issue:** The class includes some locations, such as Lake George/Uruwera, that despite the lake being within a conservation area it is not in a 'natural' state because the catchment area is not within conservation area and therefore there has been historical and current land use change that has impacted the lake. For some attributes Lake George/Uruwera is considered degraded due to modified catchment land use and historical sediment infilling. *Recommendation:* Lake George/Uruwera should be included in Lowland shallow lake class. The natural state rule should include lake and lake catchment area. **Issue:** The class does not include some locations in Fiordland that would be in a catchment with no development and would likely fit into a 'natural' state classification. *Recommendation:* Capture these areas in the objectives set for the Fiordland and Islands FMU. **Issue:** Islands in Foveaux Strait are not in the current mapped classification which include some lake and estuary systems e.g. Ruapuke Island has Waitokariro Lagoon and Tauatemaku Lagoon these lakes are not classified on FENZ. *Recommendation:* Include these islands in the updated GIS mapping of lakes and include these lakes and estuaries in the Fiordland and Islands FMU.
Mataura 3	
The Water Conservation (Mataura River) Order 1997 was established to provide for outstanding fisheries and angling amenity features throughout much of the Mataura and Waikaia River catchments. It establishes water quality standards for three surface water classes that apply to all surface water bodies in the specified catchment areas. Lakes are included in the Mataura 3 class which covers the majority of the Order area (Mataura 1 and Mataura 2 classes are associated with point source discharges).	**Issue:** The Mataura 3 classification is not based on the physical characteristics of lakes (mixing and depth) that would influence water quality and the attributes included in the water quality standards are set for rivers and are not directly applicable to lakes. *Recommendation:* Lakes within this area should be classified into appropriate lake types that are based on both elevation and mixing condition and lake specific attributes should be selected.

Current lake class definition	Issues with lake class definition
Lowland/Coastal Lakes and Wetlands	
There is no readily available documentation on how this class was defined or mapped. From the limited information available, it has been assumed that the lowland classification is based on the source flow for rivers in the REC classification system. i.e. >50% of rain occurs <400m based on the source flow. The addition of wetlands to this class occurred during the submissions and council decision part of the plan process.	**Issue:** The class does not account for brackish lakes and lagoons which behave differently to other lakes in the class. *Recommendation:* Adopt new lake class for brackish lakes and lagoons, which is inclusive of Intermittently Closed and Open Lake and Lagoon (ICOLLs). **Issue:** The classification is based on geographical location and does not adequately differentiate on the basis of physical characteristics (e.g. mixing) which can have a significant influence on water quality and ecology in lakes. *Recommendation:* Adopt new lake classes that differentiate lakes according to water quality and ecological susceptibility (e.g. by elevation and mixing conditions) using the approach taken in the development of attributes for the NPS-FM (see section 2.2 in this report). **Issue:** Wetlands do not behave in the same way as lakes and therefore should not be included in the lakes classification. *Recommendation:* Wetlands should be defined in their own class with their own attributes.
Hill Lakes and Wetlands	
There is no readily available documentation on how this class was defined or mapped. From the limited information available it has been assumed that the hill classification is based on the source flow for rivers in the REC system. i.e. >50% of rain occurs between 400 and 1000m based on source flow. The addition of wetlands to this class occurred during the submissions and council decision part of the plan process (as above).	**Issue:** The classification is based on geographical location and does not adequately differentiate on the basis of physical characteristics (e.g. mixing) which can have a significant influence on water quality and ecology in lakes. *Recommendation:* Adopt new lake classes that differentiates lakes according to water quality and ecological susceptibility (e.g. by elevation and mixing conditions) using the approach taken in the development of attributes for the NPS-FM (see section 2.2 in this report). **Issue:** Wetlands do not behave in the same way as lakes and therefore should not be included in the lakes classification. *Recommendation:* Wetlands should be defined in their own class with their own attributes.

Current lake class definition	Issues with lake class definition
Mountain Lakes and Wetlands	
There is no readily available documentation on how this class was defined or mapped. From the limited information available it has been assumed that the Mountain classification is based on the source flow for rivers in the REC classification system. i.e. >50% of rain occurs >1000m based on the source flow. The addition of wetlands to this class occurred during the submissions and council decision part of the plan process (as above).	**Issue:** The classification is based on geographical location and does not adequately differentiate on the basis of physical characteristics (e.g. mixing) which can have a significant influence on water quality and ecology in lakes. *Recommendation:* Adopt new lake classes that differentiates lakes according to water quality and ecological susceptibility (e.g. by elevation and mixing conditions) using the approach taken in the development of attributes for the NPS-FM (see section 2.2 in this report). **Issue:** Wetlands do not behave in the same way as lakes and therefore should not be included in the lakes classification. *Recommendation:* Wetlands should be defined in their own class with their own attributes.

2.2 Proposed lake classes

Five lake classes are proposed to replace the existing ones described in section 2.1, for the purposes of setting freshwater objectives:

- Natural State;
- Lowland Shallow Lakes;
- Upland Shallow Lakes;
- Brackish Lakes and Lagoons; and,
- Deep Lakes.

2.2.1 Natural State

The Natural State class has been through several planning and decisions processes and as a result, it is not recommended that this classification is modified. However, it is recommended for this classification to be applied to lakes, the lake and its catchment area must comply with the natural state (water quality) definition of National Park or Conservation land (see Glossary in pSWLP).

The natural state water quality definition implies that the waterbody is under reference conditions and that the natural quality of the water should not be altered. Schallenberg (2019) defined New Zealand reference lakes as those with combined high ecological integrity[4] in lake catchments with more than 90% native vegetation cover. This study analysed data from several New Zealand lakes and highlighted the importance of considering both the lake itself and the lake catchment.

Currently, there are Natural State lakes identified in the pSWLP whose catchment area contains considerably less than 90% native vegetation cover, and includes modified and developed land. For example, Lake George/Uruwera is identified as 'Natural State Waters outside National Parks' (see Appendix I in pSWLP) due to government purpose reserve land around the lake, but excludes tributaries flowing into Lake George. Only the lake itself is within conservation land while the lake catchment area is modified and supports intensive land use. As a result, the lake is in a declining state and cannot be considered representative of an unimpacted system. It is recommended that the mapping of the natural state lakes class be redone using the existing criteria, but expanded to apply to the lake catchment area in addition to the lake itself, and that this includes Lake George/Uruwera being reclassified as a Lowland Shallow Lake.

2.2.2 Lowland Shallow Lakes

Shallow freshwater lakes are polymictic meaning the water column is vertically mixed throughout the year and they are generally less than <15m in depth[5] (Schallenberg, 2019; Verburg, 2012). Some shallow freshwater lakes can briefly show weak stratification events, however for the most part of the year they exhibit vertical mixing. Because the water column is well mixed there is a strong interaction between sediment processes and the water column. The shallow depths also result in large temperature ranges over a seasonal cycle and warming during the summer months which can lead to increased productivity within the system.

Shallow freshwater lakes in good condition generally exhibit good clarity because they are dominated by aquatic macrophytes, however wind driven mixing can lead to resuspension of the sediments and turbid waters (Schallenberg, 2019).

[4] Ecological integrity: includes four key components that define a healthy lake ecosystem. Nativeness, Pristineness, Diversity and Resilience (Schallenberg, 2019)

[5] 15m depth refers to the maximum lake depth that is recorded in FENZ, unless it the lake depth is known.

Shallow lakes defined as lowland are below 300m elevation (Verburg 2012), in general lower elevations catchments are more developed and therefore lakes in this category are more likely to be under pressure.

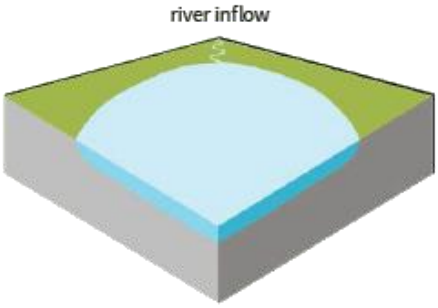


Figure 1: Conceptual diagram of a Lowland Shallow Lake

2.2.3 Upland Shallow Lakes

Upland Shallow Lakes have the same mixing characteristics as Lowland Shallow Lakes (see section 2.2.2) and are located above 300m elevation (Verburg, 2012). The higher elevations mean these lakes are generally less developed and therefore lakes in this category are likely to be under less pressure from intensive land use practices. Upland lakes are subject to differing rainfall patterns, lower temperatures and differing humidity to Lowland Shallow Lakes.

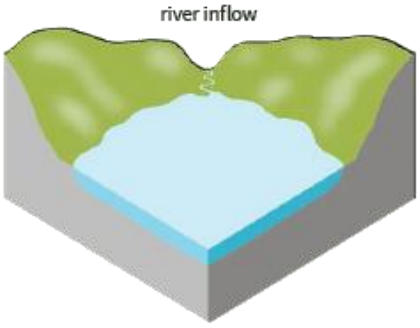


Figure 2: Conceptual diagram of an Upland Shallow Lake.

2.2.4 Brackish Lakes and Lagoons

Brackish Lakes and Lagoons are influenced by the marine environment, either directly through tidal exchange or indirectly. These systems are influenced by the marine environment through not only salinity but also lake level, flushing, mixing and stratification. Brackish waters are waters that fit within the salinity range 0.5 to 30‰ and are defined in Hume et al., (2016) as water that is in between fresh (< 0.5‰) and seawater (30 - 50‰).

Some Brackish Lakes and Lagoons can experience long periods of mouth closure, which reduces dilution from seawater and increases the residence time of the lake. During this time the salinity decreases and the residence time increases resulting in increased susceptibility to nutrient retention and eutrophication. Under these conditions excess phytoplankton growth and reduced macrophyte growth are characteristic eutrophication symptoms. When lakes remain open for extended periods of time, these lakes behave more like estuaries and prolonged periods of high salinity can put pressure

on freshwater species including aquatic plants. These systems can vary between marine and close to freshwater salinities; a co-limiting situation between N and P is expected.

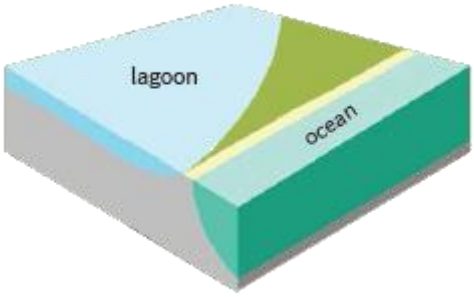


Figure 3: Conceptual diagram of a Brackish Lake or Lagoon.

2.2.5 Deep Lakes

Deep Lakes undergo seasonal stratification, this type of stratification is persistent and results in two distinct layers; a surface layer (epilimnion) and the bottom layer (hypolimnion) the stratification is caused by a temperature differential between the surface and bottom layer known as the thermocline. Deep seasonally stratified lakes have zones of productivity and decomposition within the water column and sediment (Schallenberg, 2019). There is reduced interaction between the sediment and surface waters within these deep lakes because they are separated by light, temperature and density gradients (Schallenberg, 2019).

In Southland temperature stratification generally occurs in the summer months, when the surface waters are warmed leading to a vertical density gradient. In autumn when the lake cools it induces vertical mixing or turnover of the surface and bottom waters. The coupling between benthic and pelagic processes is weaker in deep lakes than in shallow lakes and therefore for management purposes deep lakes are considered separately to shallow and brackish lakes.

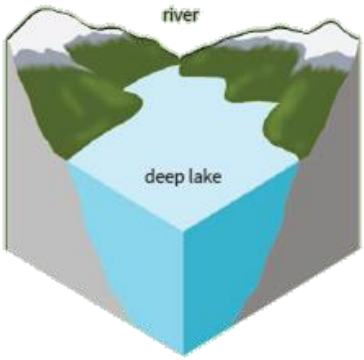


Figure 4: Conceptual diagram of a Deep Lake.

2.3 Rational for proposed lake classes

There is limited information on how the current lake classes were developed for the RWPS and pSWLP. It is assumed that the river and stream classification system (REC; which is relatively well documented) was used as the primary basis for deriving the current lake[6] classes (i.e. mountain, hill and lowland lakes). The REC uses rainfall within elevation ranges to classify lakes into three categories; mountain,

[6] It is recommended that wetlands be separated from the lakes classification because these systems function differently and therefore require different attributes and freshwater objectives. As such, wetlands are not discussed in this report.

hill and lowland. This classification approach is based on geographical location and does not adequately differentiate on the basis of physical characteristics (e.g. mixing) which can have a significant influence on water quality and ecology in lakes. Hence, a new classification system has been proposed as described in section 2.2.

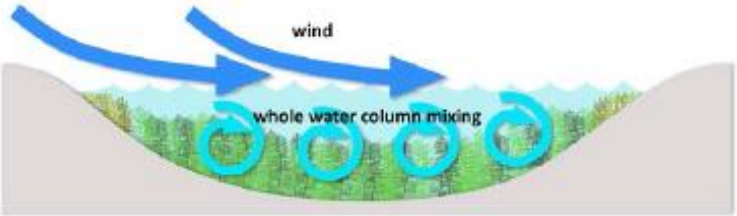
The Freshwater Ecosystems New Zealand (FENZ) geo-database (Leathwick et al., 2010) provides spatial layers and supporting information on New Zealand's rivers, stream, lakes and wetlands. It encompasses data from a wide range of sources but in principal classifies waterbodies based on their physical environment and biological character. The supporting information for lakes includes characteristics on lake depth, elevation, residence time, volume and geomorphic type. In the Department of Conservation (DOC) FENZ geo-database there are over 900 lakes in the Southland region that are larger than one hectare (ha). The majority of those lakes are freshwater lakes, however, there are some coastal lagoon systems that are influenced by the marine environment through mouth openings/ closures or other tidal influences such as water level and salinity changes. These lakes have different characteristics that influence water quality and as such, a separate class 'brackish lakes' class has been proposed (see section 2.2.4).

Geomorphic type is also an important feature to consider in classifying lakes. Seven geomorphic lake types have been identified in Southland based on the information compiled in the FENZ geo-database (Leathwick et al., 2010). These types include glacial, riverine, shoreline (coastal), landslide, peat, aeolian and dam. Geomorphic type needs to be considered when classifying lakes because different geomorphic types can lead to different physical, chemical and biological conditions. For example, peat lakes are formed through the build-up of partially rotted plant material in wet environments. The peat soils in these areas can have a significant effect on the physical, chemical and biological nature of the lake, for example lower pH in the water column when compared to other geomorphic types. It has been acknowledged that peat lakes may not fit within the attribute criteria developed for the proposed lake classification (see section 3). There are a small number of peat lakes in Southland that are outside of the Natural State lake type and it is proposed that for these systems, an exception be included for attributes which would naturally fall outside the criteria by including the following footnote: "*unless caused by natural perturbations.*"

It was noted by the 'Report of the National Objectives Framework Reference Group' (2012) that: *"In general, the effects of natural processes on water quality should be covered in the water body classification systems..."* This means it is important to categorise lakes based on the natural processes that would influence water quality such as mixing characteristics. Verburg (2012) considered lake size as a key characteristic that effects water quality and hence it was the focus of the expert science panel in their development of the National Objectives Framework for lakes in the NPS-FM. Lake size including lake area, depth and residence time, was explored using monitoring data that was nationally available at the time. It was identified in this work that lake depth was the most important size factor because it directly influenced the lakes mixing regime (Figure 5). As such, lakes were classed into two categories polymictic and stratified. By default, lakes deeper than 15 metres were considered stratified and those less than 15 metres polymictic. There were some exceptions to this rule for example, Lake Rotorua is 45m deep and is polymictic. Hence, if the mixing condition is known it should be classified in the appropriate mixing class irrespective of depth.

Shallow lake

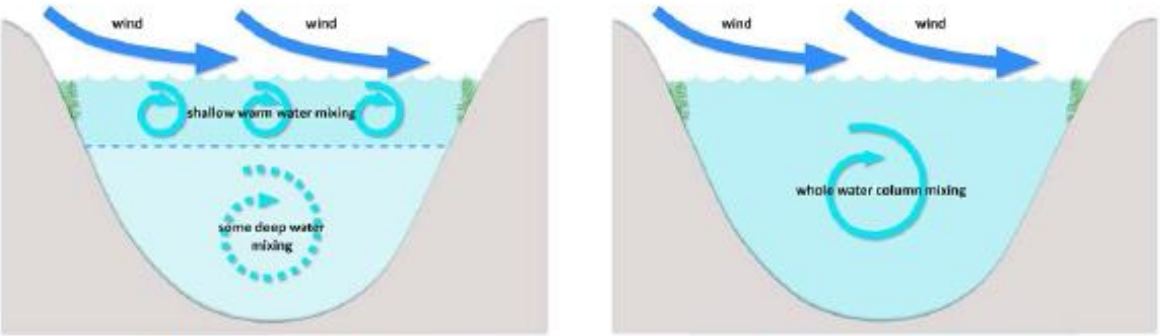
Nutrients mix vertically within a lake or lagoon in different ways depending on depth. Shallow lakes and lagoons have a water column that is relatively well mixed and even in temperature, resulting in nutrients being distributed throughout the lake. When nutrient levels are high this can fuel the excessive growth of aquatic plants or microalgae across the whole lake.



Shallow lake with well mixed water column

Deep lake

In contrast, deep lakes can behave differently. During the warmer months deep lakes tend to have a layer of warm water sitting on top of cooler deeper water. This separation can change the way in which nutrients are cycled in the two layers. In the cooler months the temperature of the surface water drops and is similar to the cooler deeper water. This drop in surface water temperature causes the water column to mix creating an even temperature in the water column.



Deep lake - summer, stratification

Deep lake - winter, no stratification

Figure 5: Conceptual diagram of stratification and mixing dynamics in a well-mix shallow lake and a seasonally stratified deep lake.

[Source: Environment Southland Lakes Factsheet]

2.3.1 Shallow Lakes (Upland and Lowland)

Shallow lakes have been separated into two classes rather than the four current classes in the pSWLP (see Table 2). In summary, the depth cut off for 'shallow' is set at 15m as discussed in section 2.3 and the elevation cut off between upland and lowland was determined to be 300 metres based on work that supported the development of the NPS-FM "Classification and objective bands for monitored lakes" (Verburg, 2012).

Table 2: Existing and proposed Upland Shallow Lake and Lowland Shallow Lake classes

pSWLP class	Definition ('Source of Flow' in REC)
Lowland/coastal lakes	>50% of rain occurs <400m elevation
Hill lakes	>50% of rain occurs between 400 and 1,000m elevation
Mountain lakes	>50% of rain occurs >1,000m elevation
Mataura 3	Part of the Mataura protected waters (defined in Conservation Order)

Proposed class	Definition (Mixing and elevation)
Lowland shallow lakes	<15m deep and <300m elevation
Upland shallow lakes	<15m deep and >300m elevation

Shallow lakes were separated into two categories Lowland and Upland Shallow Lakes because climatic conditions and catchment development are generally different in these regions. Upland Shallow Lakes are subject to differing rainfall patterns, lower temperatures and differing humidity. Lowland Shallow Lakes generally have lower ecosystem health and habitat quality compared to upland sites because they are impacted by multiple stressors such as water quality degradation from diffuse discharges from urban and agricultural catchments, habitat degradation, and contaminated groundwater (Environment Canterbury Targets Review Report). The separation of shallow lakes into two classes will also allow different objectives to be set for these lake types.

The literature presents several different elevation cut offs used for separating lowland and upland freshwater environments:

- The elevation cut off proposed here, 300m, is derived from the 'Classification and objective bands for monitored lakes' (Verburg, 2012). This elevation was used to classify lakes in the development of attributes for the NPS-FM;
- In contrast, Environment Canterbury has separated high country and lowland lakes using an elevation cut off of 400m reported in Table 1 of Norton and Snelder (2003). This is closely aligned with the river environment classification system that uses the criteria of > 50% annual rainfall in the upstream catchment below 400m a.s.l (Snelder and Biggs, 2002).;
- In an assessment of water quality in New Zealand Rivers Larned et al., (2016) classified river lowland monitoring sites within a catchment elevation below 350m a.s.l. It was highlighted in that study that high intensity agriculture and urban land cover accounts for ~60% of the land cover below 350m a.s.l in New Zealand (LCDB3); and,
- The Australian and New Zealand Guidelines for Fresh and Marine Water Quality classify 'lowland' river monitoring sites <150m above sea level and >150m as upland.

It is possible that when we work through the objectives and attributes that these two shallow lake classes (upland and lowland) will be grouped, however this will be assessed more thoroughly after the lake classes have been applied. The classification for the NPS-FM process resulted in grouping these lakes based on their mixing state (polymictic), however it is reasonable to examine these lake types separately and if similar thresholds are determined they can be grouped at a later date. The final elevation criteria for separating lowland and upland lakes in the Southland region will need to be explored further when going through the final lake type classification, it is possible the final elevation cut off of 300m may differ from the current proposed elevation criteria.

2.3.2 Brackish Lakes and Lagoons

At present Brackish Lakes and Lagoons are grouped with freshwater lakes in the pSWLP Lowland/Coastal Lake classification. The current classification system does not account for the influence of the marine environment on the physical, chemical and biological nature of these lakes. For example, Waituna Lagoon is a brackish lagoon system that is prone to mouth closures or openings for prolonged periods of time. This opening regime can alter the residence time, salinity and tidal influence of this system which can influence human and ecosystem health attributes. Currently Waituna Lagoon and a similar system, Lake Brunton, are classified as Lowland/Coastal Lakes. Objectives set for Lowland/Coastal Lakes or the new proposed Lowland Shallow Lakes class (see section 2.2.2) will not be suitable for brackish systems.

Previously, the Estuary Trophic Index (ETI) classified systems such as Waituna Lagoon and Lake Brunton as Intermittently Closed/ Open Lake and Lagoon (ICOLLs). However, Hume et al., (2016) suggested that these terms be treated with caution outside of Australia, where this classification was first developed, because New Zealand conditions are different. Furthermore, the ICOLL classification does not include other brackish systems such as Te Waewae (Waiau) Lagoon, a hāpua type system. Te Waewae (Waiau) Lagoon is a lagoon connected to Te Waewae (Waiau) Estuary (see classification in Ward and Roberts, 2020) and experiences changes in water level due to tidal fluctuations and higher than freshwater salinity >0.5‰ (salinity in Te Waewae (Waiau) Lagoon measured in state of the environment monitoring up to 5‰).

The Brackish Lakes and Lagoons classification will include both traditional ICOLL systems and Te Waewae (Waiau) Lagoon because they are both influenced by the marine environment to some degree through salinity, tidal water level changes, flushing, mixing and stratification. When setting objectives for systems that open to the sea there will need to be some consideration around state of the system under both open and closed conditions, there is already some guidance for the total nitrogen and total phosphorus attributes in the NPS-FM on how to apply attributes to open and closed conditions for these lagoon types.

2.3.3 Deep Lakes

At present Deep Lakes are covered in the Hill and Mountain Lake classification in the pSWLP and grouped with shallow lakes systems. Deep lakes go through annual stratification and mixing events which affects the fundamental functioning of the lake (Schallenberg, 2019). In comparison to shallow lakes there is reduced interaction between the sediment and surface waters because they are separated by light, temperature and density gradients (Schallenberg, 2019). Because of this stratification regime these lakes behave very differently to shallow lakes and should be classed accordingly, this is consistent with the approach taken in the development of lake types for the NPS-FM “Classification and objective bands for monitored lakes” (Verburg, 2012). Deep Lakes were not separated into the subcategories of lowland and upland.

2.4 Mapping the proposed lake classes

The lakes classification system proposed in this report for the objective setting process is simplified and based on mixing dynamics and salinity status as described in section 2.2 and 2.3. The FENZ classification system for lakes was not used due to its complexity. However, the supporting information in the FENZ geo-database such as depth and elevation were used to support the classification and mapping of Southland lakes.

The proposed lakes classes are based on depth (mixing characteristics), elevation (land use and climate conditions) and salinity:

- Natural State is defined in the pSWLP, the application of natural state should include the lake and its catchment;
- Lowland Shallow lakes are defined as lakes < 15m and <300m surface elevation. These lakes are generally polymictic (well-mixed);
- Upland Shallow lakes are defined as lakes <15m and >300m surface elevation. These lakes are generally polymictic (well-mixed);
- Brackish lakes >0.5‰ salinity and are influenced by the sea; and,
- Deep lakes >15m and exhibit seasonal stratification.

Using the above classification criteria lakes were mapped in GIS using the Lakes layer in the FENZ (Freshwater Environments New Zealand) geo-database. The lakes in the FENZ geodatabase were reclassified based on the proposed lake types (natural state, shallow lowland lake, shallow upland lake, deep lake and brackish lake) using the supporting information in the FENZ spatial layer (e.g. lake depth and elevation) and additional information from other sources. Significantly more lakes have been captured in this mapping exercise in comparison to the current lakes layer used for the pSWLP (Figure 6).

The surface elevation listed in the FENZ attribute table does not accurately reflect the surface elevation of the lake. In instances where elevation was not available or it was close to the 300m elevation cut off, the most recent 8m contour digital elevation model[7] for Southland was used to estimate elevation. Lakes were classified based on lake depth (recorded in the FENZ database) and elevation. Information on how the lakes were classified is recorded in the attribute table in the GIS layer. In instances where lake depth was not available in the FENZ database, lakes were classified manually based upon expert judgement and comparison with similar lakes in close proximity. Where a manual classification was required a description is provided in the GIS layer attribute table and will need to be ground truthed in future to confirm the lake type. Most lakes that required manual classification were in the Fiordland and Islands FMU, many of which will likely be classified within the 'natural state' lake type. Additional descriptors such as "lake type", "surface elevation" (calculated from the DEM), "FMU" and "final lake type" taking into account the natural state overlay were recorded.

Brackish Lakes and Lagoons were manually classified based on salinity information (where available), morphology and geographical location. These criteria superseded the underlying Lowland Shallow Lake classification to be reclassified as Brackish Lakes and Lagoons.

Additionally, lakes not captured in the FENZ database were mapped manually by drawing a polygon around the lake margins, identified from a recent aerial imagery. Examples include:

- Te Waewae (Waiau) Lagoon which was separated into two parts: the eastern end a brackish lagoon and the western end an estuarine system because it is more heavily influenced by salinity and tides. The lagoon polygon was taken from the 2008 Coastal Risk layer (Robertson and Stevens, 2008) and manually included in the lakes layer. To apply attributes to the waterbodies the western lagoon is named Te Waewae Lagoon and is classified as a Brackish Lake and Lagoon. The eastern estuarine section is described as the Waiau Estuary and classified as a Tidal River Estuary (see Ward and Roberts 2020). The margin separating the two

[7] Note: Lk Elev in the FENZ geodatabase doesn't appear to be surface elevation so should not be used in the classification.

waterbodies is defined by the “narrows” a small narrow channel between the estuary and the lagoon.

- Ruapuke Island needed to be included in the watershed polygons and the two Brackish Lake and Lagoons systems (potentially ICOLLS) were included in the lake classification process.

The wetlands layer was overlaid on the lakes layer and any wetlands that were also classified as lakes were removed from the lakes classification.

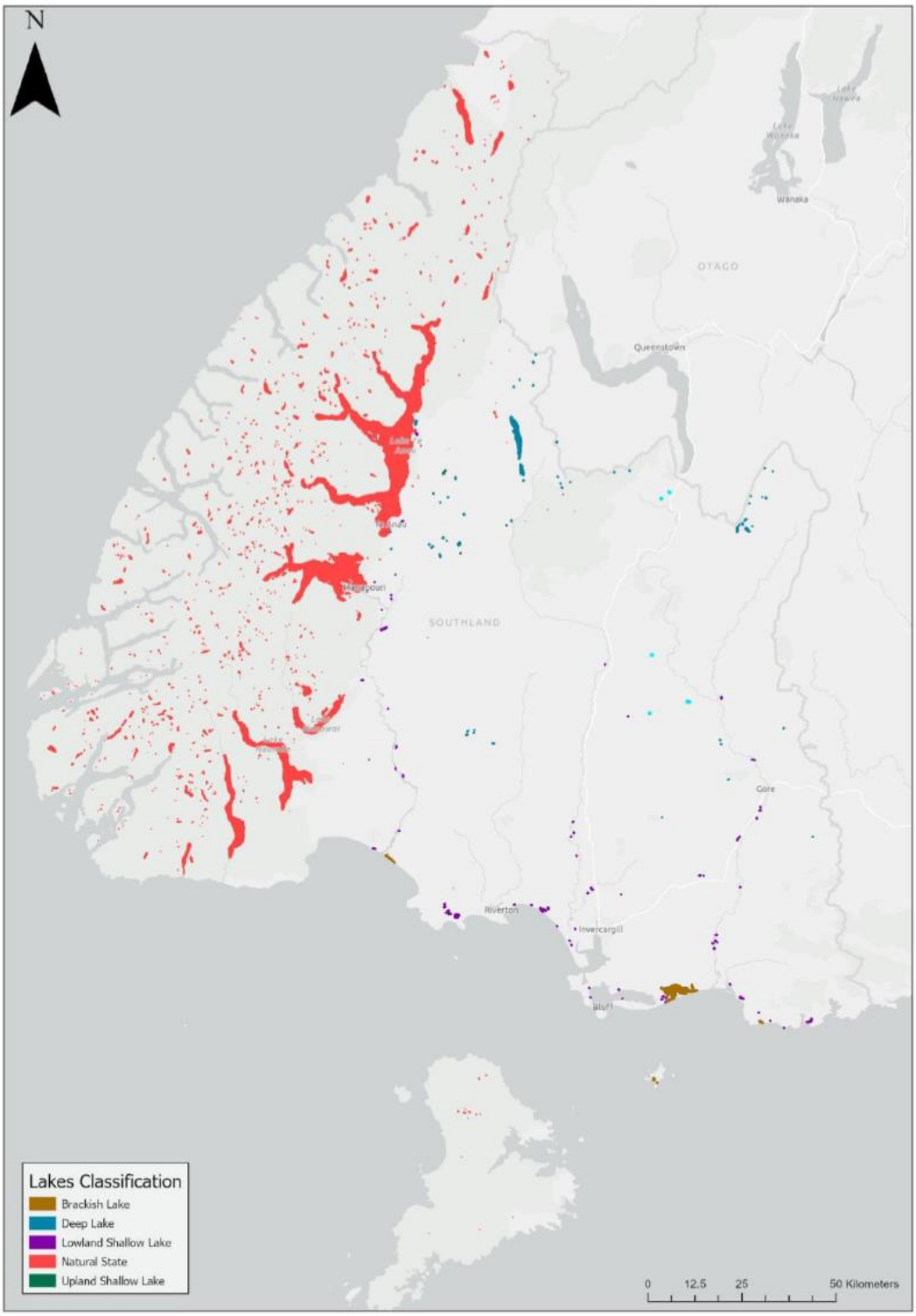


Figure 6: Map of proposed lake classes for the Southland region.

3 Lake attributes

The NPS-FM sets compulsory attributes with attribute states which aim to support a nationally consistent approach to the setting of freshwater objectives in relation to the national values in Appendix 1 in the NPS-FM (MfE, 2017). The compulsory attributes are intended to:

- *"prevent unnecessary cost and duplication that would be caused by councils independently developing and testing their own technical information*
- *allow local discussions to focus on community values and the impacts of decisions, rather than on debating the validity of the science and the technical detail of how a value is measured."* (MfE, 2017)

The NPS-FM makes it clear that the compulsory attributes are not an exhaustive list. Councils are required to develop additional attributes relating to the compulsory values ('ecosystem health' and 'human health for recreation') and attributes relating to non-compulsory values (Appendix 1 in NPS-FM and any additional values derived through local processes). The national compulsory attributes for the value of 'ecosystem health' are:

- Phytoplankton
- Total nitrogen
- Total phosphorus
- Ammonia (toxicity)

And the compulsory attributes for the value of 'human health for recreation' are:

- *Escherichia coli* (*E. coli*)
- Cyanobacteria

The compulsory attribute state option tables in Appendix 2 of the NPS-FM include national bottom lines. A national bottom line represents the minimum acceptable state of a waterbody in New Zealand. Where the current state is worse than the national bottom line the council is required to implement management actions that will improve current state. Generally, national bottom lines are set where an ecosystem is moderately impacted and at high risk of a regime shift which could lead to a more persistent state of degradation which can be difficult to reverse.

This section describes how additional (i.e. non-compulsory) attributes have been selected for use in developing draft freshwater objectives for lakes in the Southland region. Furthermore, other attributes that are considered important for describing ecosystem health and human health but are not suitable for use as freshwater objectives, have also been proposed as supporting indicators that should continue to be monitored.

The additional attributes proposed for the value of 'ecosystem health' for Southland lakes are:

- Trophic level index (TLI)
- Nitrate (toxicity)
- Dissolved oxygen[8]
- Trophic state (LakeSPI)

[8] This attribute been included as it was proposed as a new national compulsory attribute in the draft NPS-FM released as part of the Essential Freshwater Package in September 2019.

- Macrophyte cover
- Fish
- Riparian habitat
- Marginal habitat

The supporting indicators proposed for continued monitoring are[9]:

- Secchi depth (clarity)
- Water temperature
- pH
- Electrical conductivity
- Turbidity
- Dissolved nutrients (dissolved reactive phosphorus, nitrate, nitrite)
- Sedimentation rate
- Sediment quality
- Water level
- Residence time
- Emerging contaminants

A summary of the attributes and how they link to values and management is summarised in Table 3.

[9] Supporting indicators could be included as attributes in a narrative freshwater objective, however further research is needed before using these indicators to develop numeric freshwater objective. The supporting indicators are not described in detail in this report.

Table 3: Description of lake attributes, the value they represent and links to management. Reliance on lake type and available data is also presented.

Attribute	See section	Value	Description	Links to management	Lake type dependant?	Southland data[1]
National compulsory attributes (NPS-FM, 2017)						
Phytoplankton	3.1.1	Ecosystem health (trophic state)	Phytoplankton (chl-*a*) is a primary food source at the base of the food web (fed on by zooplankton then macroinvertebrates and fish). Excess phytoplankton growth indicates high nutrient status. Prolonged excess phytoplankton growth can lead to light limitation and die-back of aquatic macrophytes and low water column oxygen. A shift to a phytoplankton dominated state from a macrophyte dominated state is considered a regime shift and represents a system with poor ecosystem health.	Nutrient loading from upstream sources increase nutrient concentrations in a lake. This can lead to excess phytoplankton growth when nutrients are in excess and light is not a limiting factor. Sediment loading and high turbidity can temporarily limit light.	No	Yes – currently monthly monitoring
Total phosphorus	3.1.2	Ecosystem health (trophic state)	Phosphorus is an essential nutrient for primary production (plant growth) including both phytoplankton and macrophytes. Excess phosphorus can lead to increased phytoplankton and/or macrophyte growth creating unfavourable conditions for aquatic life (e.g. low oxygen, light limitation etc). High phosphorus concentrations can occur in clear water state (e.g. lots of macrophytes) however this still represents a system under pressure and at potential risk of a regime shift.	Phosphorus loading from upstream sources including diffuse and point sources will determine phosphorus concentration in the lake. If the phosphorus load exceeds phosphorus attenuation in the lake this can lead to excess phytoplankton growth. Sediment loading (e.g. total phosphorus) can also have an influence on in lake concentrations and sediment deposition can influence internal nutrient loading. When water column oxygen conditions decrease phosphorus can be released rapidly from the sediment. Oxygen status is linked to high organic loading (internal or catchment) and mixing condition.	No	Yes – currently monthly monitoring
Total nitrogen	3.1.3	Ecosystem health (trophic state)	Nitrogen is an essential nutrient for primary production or plant growth including both phytoplankton and macrophytes. Excess nitrogen can lead to increased phytoplankton and/or macrophyte growth creating unfavourable conditions for aquatic life (e.g. low oxygen, light limitation etc). High nitrogen concentrations can occur in clear water state (e.g. lots of macrophytes) however this still represents a system under pressure and at potential risk of a regime shift.	Nitrogen loading from upstream sources including diffuse and point sources will determine nitrogen concentration in the lake. If nitrogen load exceeds nitrogen attenuation in the lake this can lead to excess phytoplankton growth. Sediment loading (e.g. total nitrogen) can also have an influence on in lake concentrations and internal nutrient loading.	Yes (mixing condition e.g. different bandings presented for deep vs shallow lakes)	Yes – currently monthly monitoring
Ammonia (toxicity)	3.1.4	Ecosystem health (toxicity)	Ammonia is an essential nutrient for primary production but in high concentrations it can be toxic to macroinvertebrates and fish. More sensitive species that live in lakes with good ecosystem health will be susceptible to toxicity at lower concentrations than more tolerant species. The attribute is based on the threshold effect concentration and the number of species that will be impacted by toxicity at each banding level.	Ammonia makes up part of the dissolved nitrogen loading from upstream sources including diffuse and point sources. High concentrations of ammonia are generally linked to point source discharges or low oxygen status of the water column. Oxygen status is linked to high organic loading (internal or catchment) and mixing condition.	No	Yes – currently monthly monitoring
Escherichia coli (*E. coli*)	3.1.5	Human health for recreation	*E. coli* is a faecal indicator. *E. coli* concentration does not identify faecal origin (e.g. human, cow, sheep, bird) but rather gives an indication that faecal contamination is present in the waterway and the risk of associated disease-causing microorganisms such as virus, bacteria and protozoa. *E. coli* is an indicator for human health and is based on the level of risk of infection through ingestion of water during recreational activities.	Elevated *E. coli* levels can be primarily attributed to upstream sources of *E. coli* within the catchment. Exceptions include waterfowl and direct point source discharges.	No	Yes – currently monthly monitoring
Cyanobacteria	3.1.6	Human health for recreation	Cyanobacteria is a form of photosynthetic bacteria. Some forms of cyanobacteria can produce toxins which can be harmful to both humans and animals. Like phytoplankton, cyanobacteria often blooms when	Excess cyanobacteria growth or blooms are generally linked to high in lake concentrations of nutrients. Nutrient loading from upstream sources including diffuse and point sources will determine nutrient concentration	No	Yes – currently monthly monitoring

Attribute	See section	Value	Description	Links to management	Lake type dependant?	Southland data[1]
			nutrients and light conditions are not limiting. The attribute is based on risk to human health through ingestion during recreational activities.	in the lake and the amount of primary productivity within the lake. Sediment loading and high turbidity can temporarily limit light limitation.		
Proposed Southland attributes						
Trophic level index (TLI)	3.2.1	Ecosystem health (trophic state)	Trophic level index (TLI) gives an indication of overall trophic state and was proposed by Burns and Bryers (2000). TLI4 comprises of four key attributes TN, TP, chlorophyll-*a* and secchi depth (TLI3 can be used alternatively when secchi depth is not measured). Trophic state refers to the production of algae, epiphytes and macrophytes in a lake.	Nitrogen loading from upstream sources including diffuse and point sources will determine TN, TP, Chl-*a* and secchi depth in the lake. If nutrient load exceeds nutrient attenuation in the lake this can lead to excess phytoplankton growth and chl-*a*. Sediment loading (e.g. total nitrogen) can also have an influence on in lake concentrations and internal nutrient loading.	No	Yes – currently monthly monitoring
Macrophyte cover	3.2.2	Ecosystem health (trophic state)	Aquatic macrophytes are important features in lakes because they regulate water quality and phytoplankton growth but also provide habitat for fish and macroinvertebrates. % Macrophyte cover takes into account the functional ecosystem service that macrophytes provide (e.g. uptake of nutrients, improvement in water clarity and habitat provision) rather than whether the species of macrophyte is native or invasive.	Macrophyte growth and cover can be linked to nutrient loads entering the lake. High nutrient loading can lead to increased phytoplankton growth which can result in light limitation and reduction in macrophyte cover. Loss of macrophyte cover can lead to a 'regime shift' where a system becomes phytoplankton dominated and is at risk of algal blooms.	Yes, only applicable to shallow and brackish lakes requires further development for deep lakes.	Limited, historical data for some lakes up to 2019 not planned currently for future monitoring.
Trophic state (LakeSPI)	3.2.3	Ecosystem health (aquatic life)	Lake SPI (Lake submerged plant indicators) is a method for characterising ecological health of a lake based on the amount of native and invasive macrophyte species present in the lake. The key assumption of the LakeSPI method are that native plant species and high plant diversity represents healthier lakes or better lake conditions (Burton et al., 2015).	There is a relationship between LakeSPI and land cover for NZ lakes. LakeSPI decreased with increasing % pastoral land cover and increased with increasing percentage alpine or native cover (Verburg, 2010). It was postulated that the relationship between LakeSPI score and land cover may be partly related to "nutrient enrichment and other pollutant stressors (notably fine sediment) from pasture, and human activities as a vector for invasive aquatic weed transfer".	No	Limited, historical data available up to 2014 not planned currently for future monitoring
Dissolved oxygen	3.2.4	Ecosystem health (water quality)	Dissolved oxygen is essential for the survival of fish and other organisms in aquatic ecosystems. It also plays an important role in regulating redox condition in the water column and sediment which in turn influences nutrient cycling pathways. Low bottom water oxygen can lead to the release of nutrients from the sediment which can lead to a large internal loading of TN and TP. Recommended as a supporting monitoring attribute rather than as a proposed Southland numeric freshwater objective.	Oxygen condition in a lake can be related to two main mechanisms: (1) Stratification (2) Oxygen consumption. Excess oxygen consumption is related to increased nutrient processing, excess phytoplankton growth and decomposition of plant material. Increased oxygen consumption (respiration) is linked to increased productivity which can be caused by excess nutrient loading from upstream sources.	Yes Bottom oxygen (shallow and brackish lakes) Hypolimnetic (deep lakes)	Limited, appropriate methodology would need to be included into the current monitoring program.
Nitrate (toxicity)	3.2.5	Ecosystem health (toxicity)	The nitrate toxicity attribute was developed based on the toxicity of nitrate to sensitive species, the bandings were set at concentrations below acute toxicity levels. Nitrate toxicity occurs at levels that would have detrimental impacts to ecosystem health. This attribute would be most suitable for point source discharges to lakes.	Nitrate makes up part of the dissolved nitrogen loading from upstream sources including diffuse and point sources. High concentrations of nitrate are generally linked to point source discharges.	No	Yes – currently monthly monitoring
Fish	3.4.3	Ecosystem health (aquatic life)	Fish are an important part of a lakes ecological integrity and can play an important role in the regulation of the food web. Many native species of New Zealand fish (e.g. tuna, inanga, kōkopu) use lakes as refuge for part of	Trophic state (TN, TP, Chl-*a*) and macrophytes can also play an important role in determining whether a lake is suitable for fish survival which is strongly linked to upstream nutrient loads.	TBA (dependent on narrative	Limited to one study in shallow lakes in 2013.

Attribute	See section	Value	Description	Links to management	Lake type dependant?	Southland data[1]
			their lifecycle. Introduced species of fish such as trout and perch can disrupt the balance of the food web in a lake system. Proposed as a narrative freshwater objective.	Connectivity between upstream, lakes and downstream to coast is important for migratory species. Management of introduced species to lakes is important particularly for lakes without introduced species at present.	attribute developed)	
Lake margin habitat	3.4.1	Ecosystem health (habitat)	Lake margin habitat refers to the 200m terrestrial margin surrounding the lake. Lake margin habitat can provide a buffer around lakes to capture and process nutrients and provide habitat for wildlife. Proposed as a narrative freshwater objective.	Catchment land use type, particularly within the 200m margin of a lake, is important to determine whether lake margin habitat can provide a buffer to nutrient and sediment run off from the immediate catchment.	No (dependent on narrative attribute developed)	Limited, historical data not planned currently for future monitoring.
Aquatic margin habitat	3.4.2	Ecosystem health (habitat)	Aquatic marginal habitat refers to the aquatic-terrestrial margin surrounding the lake. Aquatic-terrestrial margin habitat (e.g. tussock, rushland, raupō) Proposed as a narrative freshwater objective.	Catchment land use type is important to determine whether aquatic marginal habitat can provide a buffer to nutrient and sediment run off from the immediate catchment.	Yes (dependent on narrative attribute developed and available habitat)	Limited, historical data not planned currently for future monitoring.

[1] Statement true at date of writing, April 2020.

3.1 Compulsory attributes for New Zealand lakes

3.1.1 Phytoplankton

The phytoplankton attribute is a compulsory attribute from the NPS-FM and supports the values of ecosystem health (trophic state), human health for recreation, mahinga kai and fishing (

Table 4). Phytoplankton measured as chlorophyll-*a* does not necessarily represent a lake under nutrient stress, particularly when the lake is macrophyte dominated therefore it is important that this attribute is considered with the other two compulsory attributes TN and TP (Howard-Williams et al., 2013).

For Southland an 'A+ banding' is proposed for phytoplankton based on the microtrophic lake type presented in Table 1.4 of Burns and Bryers (2000). To achieve a five band system, the two lowest and the two highest lake trophic states were grouped to make the A band and the D band, respectively. Separating the A band in the NPS-FM compulsory attribute into A and A+ will accommodate for lakes that are already at the top of the A band. For lakes currently in an A+ state, a shift from the top to the bottom of the existing A band would be a significant shift in state and potentially irreversible. The natural reference conditions proposed in Schallenberg (2019) for New Zealand deep lakes was 0.3 µg L^{-1} within the A+ banding range.

Table 4: Attribute state option table for phytoplankton

Value	Ecosystem health	
Freshwater body type	Lakes	
Attribute group	National compulsory attribute	
Attribute name	Phytoplankton	
Attribute unit	mg chl-*a*/m^3	
Attribute band and description	**Numeric attribute state**	
	Annual median	Annual maximum
A+* Close to natural reference conditions.	≤0.8	≤4
A Lake ecological communities are healthy and resilient, similar to natural reference conditions.	≤2	≤10
B Lake ecological communities are slightly impacted by additional algal and/or plant growth arising from nutrient levels that are elevated above natural reference conditions.	>2 and ≤5	>10 and ≤25
C Lake ecological communities are moderately impacted by additional algal and plant growth arising from nutrient levels that are elevated well above natural reference conditions. Reduced water clarity is likely to affect habitat available for native macrophytes.	>5 and ≤12	>25 and ≤60
National bottom line	**12**	**60**
D Lake ecological communities have undergone or are at high risk of a regime shift to a persistent, degraded state (without native macrophyte / seagrass cover), due to impacts of elevated nutrients leading to excessive algal and/or plant growth, as well as from losing oxygen in bottom waters of deep lakes.	>12	>60

*The A+ band has been proposed for Southland and is not part of the National Objectives Framework in the NPS-FM.

Recommended minimum data requirements are 3 years of monthly sampling (n=36).

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

3.1.2 Total phosphorus

Total phosphorus is a compulsory attribute from the NPS-FM (2014) and supports the values of ecosystem health (trophic state), mahinga kai, habitat and fishing (Table 5). The original attribute table in the NPS-FM was derived from Table 1.4 in Burns and Bryers (2000). To achieve a five band system, the two lowest and the two highest lake trophic states were grouped to make the A band and the D band, respectively. The A+ banding is recommended for total phosphorus from Table 1.4 in Burns and Bryers (2000) based on the microtrophic lake type.

Table 5: Attribute state option table for total phosphorus

Value	Ecosystem health
Freshwater body type	Lakes
Attribute group	National compulsory attribute
Attribute name	Total phosphorus
Attribute unit	mg/m^3
Attribute band and description	**Numeric attribute state**
	Annual median
A+* Close to natural reference conditions.	≤4
A Lake ecological communities are healthy and resilient, similar to natural reference conditions.	≤10
B Lake ecological communities are slightly impacted by additional algal and plant growth arising from nutrient levels that are elevated above natural reference conditions.	>10 and ≤20
C Lake ecological communities are moderately impacted by additional algal and plant growth arising from nutrient levels that are elevated well above natural reference conditions.	>20 and ≤50
National bottom line	**50**
D Lake ecological communities have undergone or are at high risk of a regime shift to a persistent, degraded state (without native macrophyte/seagrass cover), due to impacts of elevated nutrients leading to excessive algal and/or plant growth, as well as from losing oxygen in bottom waters of deep lakes.	>50

*The A+ band has been proposed for Southland and is not part of the National Objectives Framework in the NPS-FM.

Recommended minimum data requirements are 3 years of monthly sampling (n=36).

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

3.1.3 Total nitrogen

Total nitrogen is a compulsory attribute from the NPS-FM (2014) and supports the values of ecosystem health (trophic state), mahinga kai, habitat and fishing. As discussed for the phytoplankton attribute an A+ banding is also proposed for total nitrogen (

Table 6). The bandings presented in the NPS-FM are conservative for stratified and brackish lakes, as such the values for the microtrophic lake type from Table 1.4 in Burns and Bryers (2000) are proposed for the A+ banding. Because the guidelines presented in Burns and Bryers (2000) are based on the annual average, it is proposed that the median value be rounded from 73 mg/m^3 to 80mg/m^3 which is consistent with the rounding of the other NOF bandings that were originally derived from Table 1.4 in Burns and Bryers (2000). Less conservative bandings have been proposed for polymictic lakes and as such the A+ banding will be based on the oligotrophic lake type in the Table 1.4 Burns and Bryers (2000). This is supported by Hamill et al., (2014).

Table 6: Attribute state option table for total nitrogen

Value	Ecosystem health	
Freshwater body type	Lakes	
Attribute group	National compulsory attribute	
Attribute name	Total nitrogen	
Attribute unit	mg/m^3 (milligrams per cubic metre)	
Attribute band and description	**Numeric attribute state**	
	Annual median	Annual median
	Seasonally Stratified & Brackish	Polymictic
A+* Close to natural reference conditions.	≤80	≤160
A Lake ecological communities are healthy and resilient, similar to natural reference conditions.	≤160	≤300
B Lake ecological communities are slightly impacted by additional algal and/or plant growth arising from nutrient levels that are elevated above natural reference conditions.	>160 and ≤350	>300 and ≤500
C Lake ecological communities are moderately impacted by additional algal and plant growth arising from nutrient levels that are elevated well above natural reference conditions. Reduced water clarity is likely to affect habitat available for native macrophytes.	>350 and ≤750	>500 and ≤800
National bottom line	**750**	**800**
D Lake ecological communities have undergone or are at high risk of a regime shift to a persistent, degraded state (without native macrophyte / seagrass cover), due to impacts of elevated nutrients leading to excessive algal and/or plant growth, as well as from losing oxygen in bottom waters of deep lakes.	>750	>800

*The A+ band has been proposed for Southland and is not part of the National Objectives Framework in the NPS-FM.

Recommended minimum data requirements are 3 years of monthly sampling (n=36). For lakes and lagoons that are intermittently open to the sea, monitoring data should be analysed separately for closed periods and open periods.

3.1.4 Ammonia (toxicity)

Ammonia (toxicity) is a compulsory attribute from the NPS-FM and supports the values of ecosystem health (toxicity), fishing and mahinga kai. No additional A+ banding is recommended for the ammonia (toxicity) attribute because > 99% of all species are protected under the A-band. The ammonia toxicity bands were developed based on the toxicity of ammonia to sensitive species, the bandings were set at concentrations below acute toxicity levels. Information on the derivation of the ammonia toxicity attribute is summarised in Hickey et al., (2014), its applicability in the Auckland region is discussed in Hickey et al., (2016).

Table 7: Attribute state option table for ammonia (toxicity)

Value	Ecosystem health	
Freshwater body type	Lakes and rivers	
Attribute group	National compulsory attribute	
Attribute name	Ammonia toxicity	
Attribute unit	mg NH_4-N/L (milligrams ammoniacal-nitrogen per litre)	
Attribute band and description	**Numeric attribute state**	
	Annual median	Annual maximum
A 99% species protection level: No observed effect on any species tested.	≤0.03	≤0.05
B 95% species protection level: Starts impacting occasionally on the 5% most sensitive species.	>0.03 and ≤0.24	>0.05 and ≤0.40
C 80% species protection level: Starts impacting regularly on the 20% most sensitive species (reduced survival of most sensitive species).	>0.24 and ≤1.30	>0.40 and ≤2.20
National bottom line	**1.30**	**2.20**
D Starts approaching acute impact level (i.e. risk of death) for sensitive species	>1.30	>2.20
Based on pH 8 and temperature of 20°C and recommended minimum data requirements of 3 years of monthly sampling (n=36). Where a sample is missed the state may be determined over a longer time period. Compliance with the numerical attribute states should be undertaken after pH adjustment		

3.1.5 *Escherichia coli* (*E. coli*)

E. coli is a compulsory attribute from the NPS-FM and supports the values of human health for recreation and mahinga kai. The *E. coli* attribute defines an *E. coli* concentration where the population is at risk of *Campylobacter* infection through ingestion of water during recreational activities. Risk bands from A to E are presented in the NPS-FM. No change is recommended for the *E. coli* attribute.

Table 8: Attribute state option table for *E. coli*

Value	Human health for recreation			
Freshwater body type	Lakes and rivers			
Attribute group	National compulsory attribute			
Attribute name	*Escherichia coli* (*E. coli*)			
Attribute unit	*E. coli*/100 mL (number of *E. coli* per hundred millimetres)			
Attribute band and description	**Numeric attribute state**			
	% exceedances over 540 cfu/100 mL	% exceedances over 260 cfu/100 mL	Median concentration (cfu/100 mL)	95th percentile of *E. coli*/100 mL
A For at least half the time, the estimated risk is <1 in 1,000 (<0.1% risk). The predicted average infection risk is 1%*.	<5%	<20%	≤130	≤540
B For at least half the time, the estimated risk is <1 in 1,000 (<0.1% risk). The predicted average infection risk is 2%*.	5 to 10%	20 to 30%	≤130	≤1,000
C For at least half the time, the estimated risk is <1 in 1,000 (<0.1% risk). The predicted average infection risk is 3%*.	10 to 20%	20 to 34%	≤130	≤1,200
D 20 to 30% of the time the estimated risk is ≥50 in 1,000 (>5% risk). The predicted average infection risk is >3%*.	20 to 30%	>34%	>130	>1,200
E For more than 30% of the time the estimate risk is ≥50 in 1,000 (>5% risk). The predicted average infection risk is 7%*.	>30%	>50%	>260	>1,200

* The predicted average infection risk is the overall average infection to swimmers based on a random exposure on a random day, ignoring any possibility of not swimming during high flows or when a surveillance advisory is in place (assuming that the *E. coli* concentration follows a lognormal distribution). Actual risk will generally be less if a person does not swim during high flows.

[1] Attribute state should be determined by using a minimum of 60 samples over a maximum of 5 years, collected on a regular basis regardless of weather and flow conditions. However, where a sample has been missed due to adverse weather or error, attribute state may be determined using samples over a longer timeframe.

[2] Attribute state must be determined by satisfying all numeric attribute states.

Recommended minimum data requirements are 5 years of monthly sampling (n=60). Where a sample is missed the state may be determined over a longer time period.

3.1.6 Cyanobacteria

Cyanobacteria is a compulsory attribute from the NPS-FM and supports the values of human health for recreation and mahinga kai. No additional A+ banding is recommended for cyanobacteria attribute because the A band already covers exposure close to natural conditions. The planktonic cyanobacteria guidelines were developed in 2013 through the cyanobacteria expert group for MfE the findings are summarised in Wood et al., (2013) and Wood et al., (2014). Biovolume is not available for all cyanobacteria identified and will require further research for this attribute to apply to all cyanobacteria species.

Table 9: Attribute state option table for cyanobacteria

Value	Ecosystem health
Freshwater body type	Lakes and lake-fed rivers
Attribute group	National compulsory attribute
Attribute name	Cyanobacteria (planktonic)
Attribute unit	Biovolume – mm^3/L (cubic millimetres per litre)
Attribute band and description	**Numeric attribute state**
	80th percentile
A Risk exposure from cyanobacteria is no different to that in natural conditions (from any contact with fresh water).	≤0.5 mm^3/L biovolume equivalent for the combined total of all cyanobacteria
B Low risk of health effects from exposure to cyanobacteria (from any contact with fresh water).	>0.5 and ≤1.0 mm^3/L biovolume equivalent for the combined total of all cyanobacteria
C Moderate risk of health effects from exposure to cyanobacteria (from any contact with freshwater).	>1.0 and ≤1.8 mm^3/L biovolume equivalent of potentially toxic cyanobacteria OR >1.0 and ≤10 mm^3/L total biovolume of all cyanobacteria
National bottom line	**1.8 mm^3/L biovolume equivalent of potentially toxic cyanobacteria OR** **10 mm^3/L total biovolume of all cyanobacteria**
D High health risks (e.g. respiratory, irrigation and allergy symptoms) exist from exposure to cyanobacteria (from any contact with fresh water).	>1.8 mm^3/L biovolume equivalent of potentially toxic cyanobacteria OR >10 mm^3/L total biovolume of all cyanobacteria
Recommended data requirements are 30 samples over 3 years with a minimum requirement of 12 samples over 3 years.	

3.2 Proposed Southland attributes for numeric freshwater objectives

3.2.1 Trophic level index

Trophic level index (TLI) gives an indication of overall trophic state and was proposed by Burns and Bryers (2000). TLI4 comprises of four key attributes total nitrogen, total phosphorus, chlorophyll-*a* and secchi depth (TLI3 can be used alternatively when secchi depth is not measured). Trophic state refers to the production of algae, epiphytes and macrophytes in a lake. The TLI is calculated based on annual means and there is some guidance that suggests it should be calculated on a minimum of two years' worth of water quality data to account for natural variability (Burns and Bryers, 2000), this length of time was chosen because there can be a rapid change in the trophic state of a lake that could be missed over a longer time scale. A time period of three years is recommended to align with other attributes and remove the influence of short term climate variability. As stated for phytoplankton, total nitrogen and total phosphorus an A+ banding is proposed based on the microtrophic values in Burns and Bryers (2000). The TLI has been used at both Bay of Plenty and Environment Canterbury as an attribute for a numeric freshwater objective.

Table 10: Proposed attribute state option table for trophic level index

Value	Ecosystem health
Freshwater body type	Lakes
Attribute group	Southland attribute
Attribute name	Trophic Level Index (TLI)
Attribute unit	TLI score (as either TLI3 or TLI4[1])
Attribute band and description	**Numeric attribute state**
	Mean TLI score
A+ Microtrophic: The lake is clear with very low levels of nutrients and algae. *Reference conditions.*	≤2
A Oligotrophic: The lake is clear with low levels of nutrients and algae. *Lake ecological communities are healthy and resilient, similar to natural reference conditions.*	≤3
B Mesotrophic: The lake has moderate levels of nutrients and algae. *Lake ecological communities are slightly impacted by additional algal and/or plant growth arising from nutrient levels that are elevated above natural reference conditions.*	>3 and ≤4
C Eutrophic: The lake is green and murky, with high amounts of nutrients and algae. *Lake ecological communities are moderately impacted by additional algal and plant growth arising from nutrient levels that are elevated well above natural reference conditions.*	>4 and ≤5
Proposed minimum acceptable state	**5**
D Supertrophic: The lake is saturated in nutrients, excess algae and poor water clarity. *Lake ecological communities have undergone or are at high risk of a regime shift to a persistent, degraded state, (without native macrophytes/ seagrass cover) due to impacts of elevated nutrients leading to excessive algal and/or plant growth, as well as from losing oxygen in bottom waters of deep lakes.*	>5

[1] TLI3 is used in preference to TLI4 when there are no reliable clarity measures e.g. where a mixture of horizontal and vertical secchi depth is used.
Recommended minimum data requirements are 3 years of monthly sampling.

3.2.2 Macrophytes

Aquatic macrophytes are important features in lakes because they regulate water quality and phytoplankton growth but also provide habitat for fish and macroinvertebrates. The loss of macrophyte cover can lead to a 'regime shift' where a system becomes phytoplankton dominated and is at risk of algal blooms. The current proposed attribute is to account for all macrophytes and does not discriminate between native and invasive species because it more accurately reflects the ecosystem services that it provides (Hamill et al., 2014). Two macrophyte attributes are proposed

because the percentage macrophyte cover attribute encapsulates the ecosystem service that all macrophytes provide with respect to habitat and water quality, whilst Lake SPI alternatively focuses on nativeness.

The proposed macrophyte bandings for intermittently closed and open lakes or lagoons in addition to brackish lagoons and the reasoning behind the bandings is described in Hamill et al., (2014). In addition to brackish lakes and lagoons it is proposed that this attribute is also applied to upland and lowland shallow lakes. Kelly et al., (2016) examined bandings for percentage native macrophyte cover in shallow lakes for Southland, the bandings from this study are similar to those proposed by Hamill et al., (2014) and therefore it is suggested that this attribute cover both shallow lakes and brackish lakes and lagoons. Additional research is required to determine whether these bandings can be applied to deep lakes. Further development of this attribute will be required to clarify the term "available habitat" and a consistent approach and methodology will need to be developed to apply this attribute.

Table 11: Proposed attribute state option table for macrophytes

Value	Ecosystem health
Freshwater body type	Lakes
Attribute group	Southland attribute
Attribute name	Macrophytes
Attribute unit	% cover (percentage cover of available habitat)
Attribute band and description	**Numeric attribute state**
	% cover of available habitat (Shallow and brackish lakes)
A Macrophyte communities are healthy and resilient, similar to natural conditions.	≥70%
B Macrophyte and ecological communities are slightly impacted from natural conditions.	≥50 and <70%
C Ecological communities are moderately impacted from natural conditions.	≥20 and <50%
Proposed minimum acceptable state	**20**
D Ecological communities significantly impacted by reduced macrophyte over due to loss of habitat, food sources and less sediment stabilisation. Macrophytes have limited ability to buffer nutrient loads and there is a high risk of a regime shift to a persistent, degraded state.	<20%
Numeric attribute state to be based on a survey during the period of likely maximum annual biomass. Available habitat to be determined based on morphological, hydrological and substrate conditions. Some clarity will need to be developed around the term "available habitat" and a consistent method specified.	

3.2.3 Trophic state (LakeSPI)

Two macrophyte attributes are proposed for Southland lakes:

- Macrophyte cover (section 3.2.2) represents the functional ecosystem service that macrophytes provide in the processing of nutrients and improving water clarity in lakes. It does not discriminate between invasive or native species, the macrophyte cover attribute is more representative of the influence of macrophytes on water quality and inherent ecosystem health; and,
- LakeSPI Index represents biodiversity and ecological values by taking into consideration native and invasive macrophyte species present within a lake. A key assumption of the LakeSPI method and the link to ecosystem health is that native plant species and high plant diversity represents healthier lakes or better lake conditions (Burton et al., 2015).

As a result, both attributes have been proposed for Southland because whilst macrophyte cover and LakeSPI both represent 'ecosystem health' they represent different facets of ecosystem health; the functional role of macrophytes in nutrient cycling and water clarity and biodiversity and ecological values, respectively.

Lake SPI (Lake submerged plant indicators) is a method for characterising ecological health of a lake based on the amount of native and invasive macrophyte species present in the lake. The key assumption of the LakeSPI method are that native plant species and high plant diversity represents healthier lakes or better lake conditions (Burton et al., 2015). This principal is also discussed in Schallenberg (2019) in which nativeness is considered an important component of ecological integrity and subsequent lake health. Highlighting that non-native species are known to negatively impact on the ecology of lakes. There are several other factors that influence a lakes ecological integrity and Lake SPI is only one component of this, other indices (e.g. fish) require further development.

Verberg et al., (2010), in a report for MfE, demonstrated a relationship between LakeSPI and land cover for New Zealand lakes. LakeSPI score decreased with increasing percentage pastoral land cover and increased with increasing percentage alpine or native cover. The lowest (poorest) LakeSPI scores were recorded for lakes in catchments with dominant pastoral land cover. It was postulated that the relationship between LakeSPI score and land cover may be partly related to "nutrient enrichment and other pollutant stressors (notably fine sediment) from pasture, and human activities as a vector for invasive aquatic weed transfer".

Two LakeSPI attributes are proposed for Southland, it should be decided through the regional forum process which is the most suitable going forward. The first is LakeSPI index (%) which provides an overall score for lake macrophytes taking into account native and invasive species. The second attribute is proposed in the amendments to the NPS-FM (2019)[10] which provides the individual scores for nativeness and invasiveness and may be more appropriate to set specific ecological targets around acceptable limits of invasiveness. The LakeSPI methodology includes the collection of all Lake SPI indices. A decision will be required to identify which LakeSPI attribute is most appropriate for Southland (overall score or nativeness and invasiveness), the decision should consider how the attribute will be used (e.g. manage invasiveness and maintain nativeness or as overall indicator of ecological integrity).

The LakeSPI score is presented as a percentage of the lakes maximum scoring potential, higher percentage values indicate good ecosystem health and water quality. The bandings for the LakeSPI index (%) are based on NIWA's bandings outlined in the Southland report Burton et al., (2015),

[10] At the time of writing, this attribute proposed in the NPS-FM (amended 2019) was still under consultation.

Environment Canterbury have directly applied these bandings for the LakeSPI attribute to set objectives for the lakes in the Canterbury region. The Bay of Plenty Regional Council have taken an alternative approach and proposed bandings based on the % reduction in the LakeSPI score, if this is to be applied to Southland it would require further investigation into the current dataset and applicability to the region will need to be investigated, this is also potentially more useful as a tool to monitor a plans effectiveness to meet the attribute LakeSPI score than to be put forward as an attribute itself.

Table 12: Proposed attribute state option table for trophic state (LakeSPI)

Value	Ecosystem health
Freshwater body type	Lakes
Attribute group	Southland attribute
Attribute name	Trophic state (LakeSPI)
Attribute unit	LakeSPI Index (%)
Attribute band and description	**Numeric attribute state**
	Lake SPI Index (%)
A+ Excellent ecological health and high value.	≥90
A High ecological health.	≥75 and <90
B Good ecological health.	≥50 and <75
C Moderate ecological health.	≥20 and <50
Proposed minimum acceptable state	**20**
D Poor ecological health or non-vegetated (0%)	<20
Numeric attribute state to be calculated annually following the method described in Clayton J, and Edwards T. 2006. *LakeSPI: A method for monitoring ecological condition in New Zealand Lakes.* User Manual Version 2. Hamilton, New Zealand: National Institute of Water & Atmospheric Research Ltd.	

Two additional LakeSPI attributes are proposed in the 2019 proposed changes to the NPS-FM. These attributes capture the native state and invasive impact experienced by a lake with respect to aquatic macrophytes. These attributes take into consideration the native values of plant species within a lake.

Table 13: Proposed attribute state option table for submerged plants (natives)

Value	Ecosystem health
Freshwater Body Type	Lakes
Attribute	Submerged plants (natives)
Attribute Unit	LakeSPI (native condition index)
Attribute band and description	**Numeric Attribute State**
	Lake SPI Native Index (%)
A Excellent ecological condition. Native submerged plant communities are almost completely intact.	>75
B High ecological condition. Native submerged plant communities are largely intact.	>50 and ≤75
C Moderate ecological condition. Native submerged plant communities are moderately impacted.	≥20% and ≤50
Proposed national bottom line	**20**
D Poor ecological condition. Native submerged plant communities are largely degraded or absent.	<20
Monitoring to be conducted at least once every three years, following the method described in Clayton J, and Edwards T. 2006. *LakeSPI: A method for monitoring ecological condition in New Zealand Lakes.* User Manual Version 2. Hamilton, New Zealand: National Institute of Water & Atmospheric Research Ltd p57. Scores are reported as a percentage of maximum potential score (%) of the Native Condition Index, and lakes in a devegetated state receive scores of 0.	

Table 14: Proposed attribute state option table for submerged plants (invasive species)

Value	Ecosystem health
Freshwater Body Type	Lakes
Attribute	Submerged plants (invasive species)
Attribute Unit	LakeSPI (invasive impact index)
Attribute band and description	**Numeric Attribute State**
	Lake SPI Invasive Impact Index (%)
A No invasive plants present in the lake. Native plant communities remain intact.	0
B Invasive plants having only a minor impact on native vegetation. Invasive plants will be patchy in nature co-existing with native vegetation. Often major weed species not present or in early stages of invasion.	>1 and ≤25
C Invasive plants having a moderate to high impact on native vegetation. Native plant communities likely displaces by invasive wee beds particularly in the 2 – 8 m depth range.	>25 and ≤90
Proposed national bottom line	**90**
D Tall dense weed beds exclude native vegetation and dominate entire depth range of plant growth. Species concerned likely hornwort and Egeria.	>90
Numeric attribute state to be calculated annually following the method described in Clayton J, and Edwards T. 2006. *LakeSPI: A method for monitoring ecological condition in New Zealand Lakes.* User Manual Version 2. Hamilton, New Zealand: National Institute of Water & Atmospheric Research Ltd p57.	

3.2.4 Dissolved oxygen

Dissolved oxygen is essential for the survival of fish and other organisms in aquatic ecosystems. It also plays an important role in regulating redox condition in the water column and sediment which in turn influences nutrient cycling pathways. For example, oxic conditions in the bottom water results in oxygenated lakes sediments which is important for the binding of phosphorus. If oxygen becomes depleted in the lake bottom waters and the surface sediments this would result in the release of phosphorus from the sediment into the water column leading to an internal nutrient loading. Similarly, nitrogen cycling pathways are regulated by oxygen concentration.

Oxygen concentration is controlled by parameters such as salinity, temperature and pressure in addition to wind driven aeration (particularly in shallow lakes), mixing and consumption (respiration) and production (photosynthesis) processes. In general, when these processes are balanced oxygen concentration will be in the A banding, however if there is a high amount of nutrients and subsequent respiration this can lead to lower oxygen concentrations and poorer ecosystem health outcomes. Two

attributes for oxygen in lakes are proposed in the draft NPS-FM (2019); mid-hypolimnetic dissolved oxygen in deep lakes[11] and lake bottom dissolved oxygen[12].

Table 15: Proposed NPS-FM (2019) attribute state option table for mid-hypolimnetic dissolved oxygen

Value	Ecosystem health
Freshwater Body Type	Lakes
Attribute	Dissolved oxygen (mid-hypolimnetic)
Attribute Unit	Milligrams per litre (mg/l)
Attribute band and description	**Numeric Attribute State**
A No stress caused to any fish species by low dissolved oxygen.	≥7.5
B Minor stress on sensitive fish seeking thermal refuge in the hypolimnion. Minor risk of reduced abundance of sensitive fish and macroinvertebrate species.	≥5.0 and <7.5
C Moderate stress on sensitive fish seeking thermal refuge in the hypolimnion. Risk of sensitive fish species being lost.	≥4.0 and <5.0
Proposed national bottom line	**4.0**
D Significant stress on a range of fish species seeking thermal refuge in the hypolimnion. Likelihood of local extensions of fish species and loss of ecological integrity.	<4.0
Numeric attribute state to be measured using either continuous monitoring sensors or discrete DO profiles.	

[11] Mid-hypolimnetic oxygen reflects the effect of oxygen has on fish species in stratified lakes, classified as Deep Lakes in Southland.

[12] Dissolved oxygen on the lake bottom is an ecosystem health attribute that reflects the effect oxygen concentration has on the nutrient exchange between the sediment and water column

Table 16: Proposed NPS-FM (2019) attribute state option table for lake bottom dissolved oxygen

Value	Ecosystem health
Freshwater Body Type	Lakes
Attribute	Dissolved oxygen (lake bottom)
Attribute Unit	Milligrams per litre (mg/l)
Attribute band and description	**Numeric Attribute State**
A No risk from bottom dissolved oxygen of biogeochemical conditions causing nutrient release from sediments.	≥7.5
B Minimal risk from bottom dissolved oxygen of biogeochemical conditions causing nutrient release from sediments.	≥2.0 and <7.5
C Risk from bottom dissolved oxygen of biogeochemical conditions causing nutrient release from sediments.	≥0.5 and <2.0
Proposed national bottom line	**0.5**
D Likelihood risk from bottom dissolved oxygen of biogeochemical conditions resulting in nutrient release from sediments.	<0.5
To be measured less than 1 metre above sediment surface at the deepest part of the lake suing either continuous monitoring sensors or discrete DO profiles.	

3.2.5 Nitrate (toxicity)

Nitrate (toxicity) supports the values of ecosystem health (toxicity), fishing and mahinga kai. No additional A+ banding is recommended for nitrate (toxicity) because effects are unlikely to be observed in the A band additional protection is not required. The nitrate toxicity bands were developed based on the toxicity of nitrate to sensitive species, the bandings were set at concentrations below acute toxicity levels. Information on the derivation of the nitrate toxicity attribute is summarised in Hickey et al., (2013) initially the attribute was proposed as a compulsory attribute for both lakes and rivers and was based on some lake species. The concentrations represented in the table are less stringent from an ecosystem health perspective and detrimental ecological effects will likely be observed before toxicity levels are reached. However, a nitrate toxicity attribute may be useful for point source discharges to lakes.

Table 17: Proposed attribute state option table for nitrate (toxicity)

Value	Ecosystem health	
Freshwater body type	Lakes	
Attribute group	Southland attribute	
Attribute name	Nitrate toxicity	
Attribute unit	mg NO_3-N/L (milligrams nitrate-nitrogen per litre)	
Attribute band and description	**Numeric attribute state**	
	Annual median	Annual 95th percentile
A High conservation value system. Unlikely to be effects even on sensitive species.	≤1.0	≤1.5
B Some growth effect on up to 5% of species.	>1.0 and ≤2.4	>1.5 and ≤3.5
C Some growth effects on up to 20% of species (mainly sensitive species such as fish). No acute effects.	>2.4 and ≤6.9	>3.5 and ≤9.8
Proposed minimum acceptable state	**6.9**	**9.8**
D Impacts on growth of multiple species, and starts approaching acute impact level (i.e. risk of death) for sensitive species at high concentrations.	>6.9	>9.8
Recommended minimum data requirements are 3 years of monthly sampling (n=36).		

3.3 Additional attributes in existing regional plans

There are several attributes that are applicable to lakes specified in Appendix E of the Proposed Southland Water and Land Plan (Decisions Version, 4 April 2018) (pSWLP) and they are listed in Table 18. These attributes apply to all lake classes.

Table 18: Additional attributes for lakes specified in the proposed Southland Water and Land Plan (Appendix E)

Attribute	Plan water quality standard
Odour	There shall be no objectionable or offensive odour present.
Bacterial or fungal growths	There shall be no bacterial or fungal slime* growths visible to the naked eye, including within discharge mixing zones.
Edible species	Edible species such as fish and shellfish shall not be rendered unsuitable for human consumption by the presence of contaminants.

*It is recommended that the word "slime" be removed from the description of bacterial and fungal growths. This is unnecessarily descriptive and precludes other fungal and bacterial morphologies that could be problematic. An example of this issue in its practical application for compliance has already been observed.

3.4 Proposed Southland attributes for narrative freshwater objectives

3.4.1 Lake margin habitat

Requires further development before lake margin habitat is considered for a numeric freshwater objective, currently appropriate to include as a narrative attribute.

Lake margin habitat refers to the terrestrial margin surrounding the lake, Environment Southland currently report on the land use and terrestrial vegetation in the 200m terrestrial margin for shallow lakes. The terrestrial vegetation surrounding a lake can provide an important buffer, through the uptake of soil and shallow groundwater nutrients before they are transported to the lake. Removal of vegetation and conversion of land to pasture can reduce the effectiveness of this margin. Furthermore, vegetated terrestrial margins can provide important corridors for the movement of indigenous wildlife.

At present there are no numeric thresholds set for lake margin habitat, however it is a contributing factor the lake health and therefore is a good candidate for a narrative attribute.

3.4.2 Aquatic marginal habitat

Requires further development before aquatic marginal vegetation is considered for a numeric freshwater objective, currently appropriate to include as a narrative attribute.

Aquatic marginal habitat refers to the aquatic margin (e.g. tussockland, rushland, or raupō) surrounding a lake. Fringing aquatic vegetation (e.g. wetland type plants such as raupō) play an important role in the removal of nutrients creating a buffer zone before nutrients are transported to the main body of the lake (Gibbs and Hickey 2012). They take up majority of the nutrients through their root systems and are important for stripping nutrients from groundwater (Gibbs and Hickey 2012). While senesce of plants occur during winter which will lead to the release of some nutrients, aquatic marginal vegetation provides an important nutrient uptake mechanism during summer periods when phytoplankton blooms are likely to occur. Furthermore, phytoplankton blooms wash up on the shoreline of lakes and become trapped in marginal vegetation, the decomposition of phytoplankton in these areas can provide further nutrients for aquatic margin plants (Gibbs and Hickey)

Existing aquatic marginal habitat is important because it maintains a balance within the lake ecosystem and contributes to annual nutrient cycling providing a buffer for nutrients in groundwater and direct run off from the catchment. However, at present there are no numeric thresholds set for aquatic marginal vegetation therefore it is currently appropriate to include as a narrative attribute only.

3.4.3 Native fish

Requires further development before native fish is considered for a numeric freshwater objective, currently appropriate to include as a narrative attribute in the interim.

No fish attribute is proposed for numeric freshwater objectives. An appropriate index has not been developed and established for lakes (e.g. a lake equivalent to IBI in rivers and streams). As such, it is recommended native fish are included as an attribute for narrative freshwater objectives rather than as a numeric freshwater, until further work is completed at a national level.

The fish attribute state option table proposed (Table 19) is based on the Greater Wellington Regional Council native fish attribute for rivers and streams and it requires further investigation to determine whether it is applicable to Southland lakes. Kelly et al., (2016) used percentage native species which was a comparison of the number of native species identified in the collection of all native and non-native fish, however, it was determined that percentage native species was not a good indicator of ecological integrity in all lakes.

The fish attribute state option table needs further development but should include whether there are introduced species present and if there are important species that should be protected such as giant kōkopu and inanga that are currently classified as in decline.

Table 19: Proposed narrative attribute state option table for native fish

Value	Ecosystem health
Freshwater body type	Lakes
Attribute group	Southland attribute
Attribute name	Native fish
Attribute unit	
Attribute band and description	**Numeric attribute state**
A Fish community is typical of undisturbed or reference conditions.	None proposed
B All expected reference conditions species are present but populations may be under a low level of stress from, for example, habitat disturbance, toxicants or organic pollutants, phytoplankton blooms or oxygen stress.	None proposed
C Most expected reference conditions species are present but populations may be under a low level of stress from, for example, habitat disturbance, toxicants or organic pollutants, phytoplankton blooms or oxygen stress.	None proposed
Proposed minimum acceptable state	
D Fish community shows large changes with loss of species that would be expected under reference conditions for the lake type. Reflects significant levels of disturbance and degradation.	None proposed

3.5 Existing freshwater objectives for lake attributes

The NPS-FM does not allow freshwater objectives to be set below the national bottom line (D/C band boundary)[13]. Similarly, for proposed regional attributes (e.g. trophic level index, macrophytes, trophic state (LakeSPI), dissolved oxygen and nitrate (toxicity)), a minimum acceptable state has been

[13] Unless caused by natural perturbations.

proposed at the C/D band boundary based on literature. The proposed minimum acceptable state represents the point where lake health is at risk of a regime shift[14] which could potentially be irreversible.

Freshwater objectives must be set above the national bottom line, therefore, the default option range for setting a freshwater objective ranges from A (or A+) to C band. Deciding on where to set a freshwater objective within this range is a value-based decision that needs to be made by decision-makers, and can vary for each attribute and each lake class.

The pSWLP (along with its predecessor, the Regional Freshwater Plan for Southland, 2010) already set receiving water quality standards for some lake attributes. For example, Appendix E of the pSWLP specifies water quality standards for phytoplankton, ammonia toxicity and *E. coli*. These water quality standards use a lake type classification system described in Section 2.1, and shown in Table 20. In order to use these water quality standards to refine the option range for setting freshwater objectives, expert judgement was required to translate the pSWLP lake classes to those proposed in this report (Section 2.2). For example:

- The pSWLP water quality standards associated with the lake class of 'Lowland/Coastal Lakes' objectives were adapted to the 'Shallow Lowland Lakes' and 'Brackish Lakes and Lagoons' classes proposed in this report;
- The pSWLP water quality standards for 'Mountain Lakes' were more conservative and representative of the 'Deep Lakes' class proposed in this report; and,
- The 'Upland Shallow Lakes' class proposed in this report could be represented by both the pSWLP 'Hill' and 'Mountain' lake types so both have been used, with the 'Hill Lakes' class representing the minimum banding.

Table 20: Lake water quality standards in Appendix E in the pSWLP (Decisions version, April 2018). The colours represent the associated proposed attribute state option band where A = blue, B = green, C = yellow and D = red.

Attribute	Lowland/ Coastal Lakes	Hill Lakes	Mountain Lakes
Ecosystem health			
Phytoplankton (chl-*a* mg/m^3)	<5	<5	<2
Ammonia (toxicity) (mg/L)[1]	<0.9	<0.9	<0.32
Human health for recreation			
Faecal coliforms (CFU/100mL)	<1,000	<130	<130
E. coli (*E. coli*/100mL) converted[2]	<860	<110	<110
E. coli (*E. coli*/100mL) at popular bathing sites	<130		

[1] Ammonia toxicity standardised to pH 8 at 20°C

[2] A conversion factor was used to convert Faecal Coliforms to an *E. coli* concentration. Data up to June 2019 from Southland lakes and lagoons was used to derive the linear relationship Faecal Coliforms = 1.1642(*E. coli*), R^2 = 0.95. Conversion factor: 100 Faecal Coliforms = 86 *E. coli*.

The option range for setting freshwater objectives has been adjusted to incorporate the water quality standards in Table 20 as the new minimum option as shown in Table 21. The Natural State lake class

[14] A regime shift occurs when a lake shifts from a clear water macrophyte dominated state to a phytoplankton dominated state which results in the loss of macrophytes, reduces clarity and threatens fish and other organisms.

has a water quality requirement of “no change” and therefore freshwater objective options are not presented for this lake type.

Table 21: Option range for setting numeric freshwater objectives for Southland lakes incorporating water quality standards in the pSWLP. Coloured cells show where the minimum option is set in the pSWLP.

Attribute	Natural state	Lowland shallow lakes	Upland shallow lakes	Deep lakes	Brackish lakes and lagoons	Reference source
National compulsory attributes						
Phytoplankton (Chl-*a* mg/m^3)	No change	B	A to B	A	B	NPS-FM (2017)
Total phosphorus (mg/L)		A+ to C	A+ to C	A+ to C	A+ to C	NPS-FM (2017)
Total nitrogen (mg/L)		A+ to C	A+ to C	A+ to C	A+ to C	NPS-FM (2017)
Ammonia (toxicity) (mg/L)		C	B to C	B	C	NPS-FM (2017)
Cyanobacteria (biovolume mm^3/L)		A to C	A to C	A to C	A to C	NPS-FM (2017)
E. coli (*E. coli*/100mL)		B	A	A	B	NPS-FM (2017)
Proposed Southland attributes for numeric freshwater objectives						
E. coli at popular bathing sites		A	A	A	A	pSWLP
Trophic level index (TLI)	No change	A+ to C	A+ to C	A+ to C	A+ to C	Hamill et al (2014), Kelly et al (2016)
Macrophytes (% cover)		A to C	A to C	A to C	A to C	NIWA and EBoP
Submerged plants (nativeness)		A to C	A to C	A to C	A to C	Draft NPS-FM (2019)
Submerged plants (invasive species)		A to C	A to C	A to C	A to C	Draft NPS-FM (2019)
Dissolved oxygen (lake bottom)		A to C	A to C	A to C	A to C	Draft NPS-FM (2019)
Dissolved oxygen (mid-hypolimnetic)		A to C	A to C	A to C	A to C	Draft NPS-FM (2019)
Nitrate (toxicity) (mg/L)		A to C	A to C	A to C	A to C	Hickey et al (2013)
Proposed Southland attributes for narrative freshwater objectives						
Fish	No change	Narrative freshwater objective to be developed				
Lake margin habitat						
Aquatic marginal habitat						
Additional current attributes from the pSWLP						
Odour	No change	There shall be no objectionable or offensive odour present.				pSWLP
Bacterial or fungal growths		There shall be no bacterial or fungal slime growths visible to the naked eye, including within discharge mixing zones.				pSWLP
Edible species		Edible species such as fish and shellfish shall not be rendered unsuitable for human consumption by the presence of contaminants.				pSWLP

4 Attribute state assessment for Southland lakes

The NPS-FM (2017) requires water quality to be 'maintained or improved'. Therefore, knowledge of current state is required in order to ensure no deterioration occurs. This section describes how the state assessment of the proposed attributes was undertaken. This assessment was used to inform the *Current Environmental State and the "Gap" to Draft Freshwater Objectives for Southland* report (Norton et. al., 2019) where the draft freshwater objectives were refined to include the 'maintain or improve' requirement of the NPS-FM.

4.1 Assessment methodology

The analysis of attribute state incorporates assessment of four spatial scales (site within a lake, a lake, and by lake class) using three time periods (2010, 2016 and 'present' or 2019)[15]. Hydrological years (hereafter referred to as years)[16] were used unless a different time period has been specified. Unless otherwise stated, three preceding years for each time period (e.g. 2007/08 to 2019/10 for '2010', 2013/14 to 2015/16 for '2016' and 2016/17 to 2018/19 for '2019') were used to account for any climate variability that would not be accounted for using a one-year dataset.

Not all attributes have been able to be assessed for at timescale and spatial scale for reasons including:

- Lake Vincent, The Reservoir, Lake George were not monitored pre-2015;
- Waiau Lagoon monitoring programme began in late 2016;
- There was a gap in the monitoring data because monitoring was halted due to budget constraints in the glacial lakes programme between 2014 and 2017;
- Lakes that are currently not covered in the water quality monitoring programme (Lake Brunton, Mavora Lakes and Lake Hauroko) have previously been assessed for macrophyte cover and Lake SPI, these have been included in the presentation of state for the "lake" level of analysis;
- Lake Sheila, Lake Calder and Lake Brunton were assessed in 2012 in a study by Cawthron to provide an indicative state. The report values have been shown in the proceeding section however these do not meet the minimum statistical requirement for the attribute; and,
- For some attributes the analysis was not undertaken by Environment Southland and the data presented is directly from an existing monitoring report (e.g. Lake SPI and macrophyte cover). In these instances, the data may not directly align with the proposed baseline years 2010, 2016 and 2019, in which case the closest time period was used. Data sources are identified in the following sections.

Data was analysed using Time Trends (v.6.30, 2017) for metrics such as mean, median, 95th percentile, maximum and minimum. Microsoft Excel (2016) was used where additional analysis was required such as the % exceedances for *E. coli* or basic plotting.

Where numerical values were below the limit of detection a general rule was applied; the below detect was replaced with a numerical value equivalent to a half fraction of the detection limit. Studies have shown that the application of this rule is not suitable for trend analysis (Helsel, 2006), however the purpose of this report was not to assess trends but to report on state for two baseline years (2010 and 2016) and current state (2019). The statistical analyses were applied to attribute state bandings, in all

[15] Hydrological year is defined as July 1 to June 30 inclusive.
[16] Summary statistics for key parameters are presented in Appendix 2

cases non-detect values lie within the A banding before applying the half fraction rule and therefore is unlikely to misrepresent the true state of the lake it is currently presented.

If multiple statistical tests are required to determine the attribute state (e.g. annual median and annual maximum are required for phytoplankton), then the poorest attribute state band was applied and reflects the final attribute state. Where the attribute state was calculated for a lagoon system that is periodically open and closed to the coast, the statistic has been calculated separately for 'open' and 'closed' periods and both states are presented. It is recommended that a precautionary approach be taken for these types of systems and 'closed' conditions should be preferentially used to determine attribute state because this is when the lagoon is most vulnerable. Where the preferred statistics could not be met, this is outlined in Appendix 1.

4.1.1 Spatial scales

Sites within a lake

Where appropriate for the attribute, individual sites within a lake were analysed for state in 2010, 2016 and 2019 using the preferred statistic outlined in Table 22. In some instances, the frequency of sampling did not meet the minimum statistical requirement for the attribute, in which case state is reported as a best estimate and should be treated as having much higher uncertainty. State has been tabulated for the assessment three periods (2010, 2016 and 2019) along with the percent change needed to meet the minimum requirement of the draft freshwater objective (see Norton and Wilson, 2019), referred to as the 'gap'. Where no draft freshwater objective has been identified, the percent change as not been recorded.

Lake

Lake data was screened for site sets within a lake, where all lake sites were not monitored on a given date the date was removed from the analysis to prevent bias toward a particular lake site. The attribute statistics was applied to the grouped data to determine state for each attribute. This approach was used for all 'Ecosystem Health' attributes. Because the 'Human Health' attributes (e.g. *E. coli*) are associated with a risk to human health, a precautionary approach was taken and the individual site with the poorest grading within the lake was reported. Sites were not grouped for analysis of the 'Human Health' attributes because grouping poor sites with better sites will misrepresent the risk to human health. Note attributes such as macrophyte cover and Lake SPI are only reported for the 'Lake' spatial scale because these attributes are not applicable to individual sites. State has been tabulated for the baseline period (2010 and 2016) and current (2019) in addition to the percent reduction needed to meet the minimum requirement of the draft FWO, known as the 'gap'. Where no draft FWO has been reported the percent reduction as not been presented.

Lake class

Lake class did not require additional analyses, the lake sites were grouped into appropriate classes and the data reported. The lakes programme is small compared to the river network and therefore box and whisker plots were not a suitable representation of the data, instead the graphical representation of the data represents the numerical value used for the assessment at the site level against the attribute banding. The table includes the proportion of sites within each banding for all lake types, including natural state, for 2010, 2016 and 2019. Furthermore, the proportion of sites where, one, two and three state improvement would be needed to meet the FWO is presented.

Figure 7: Example of the different spatial scales used in the lake attribute state assessment

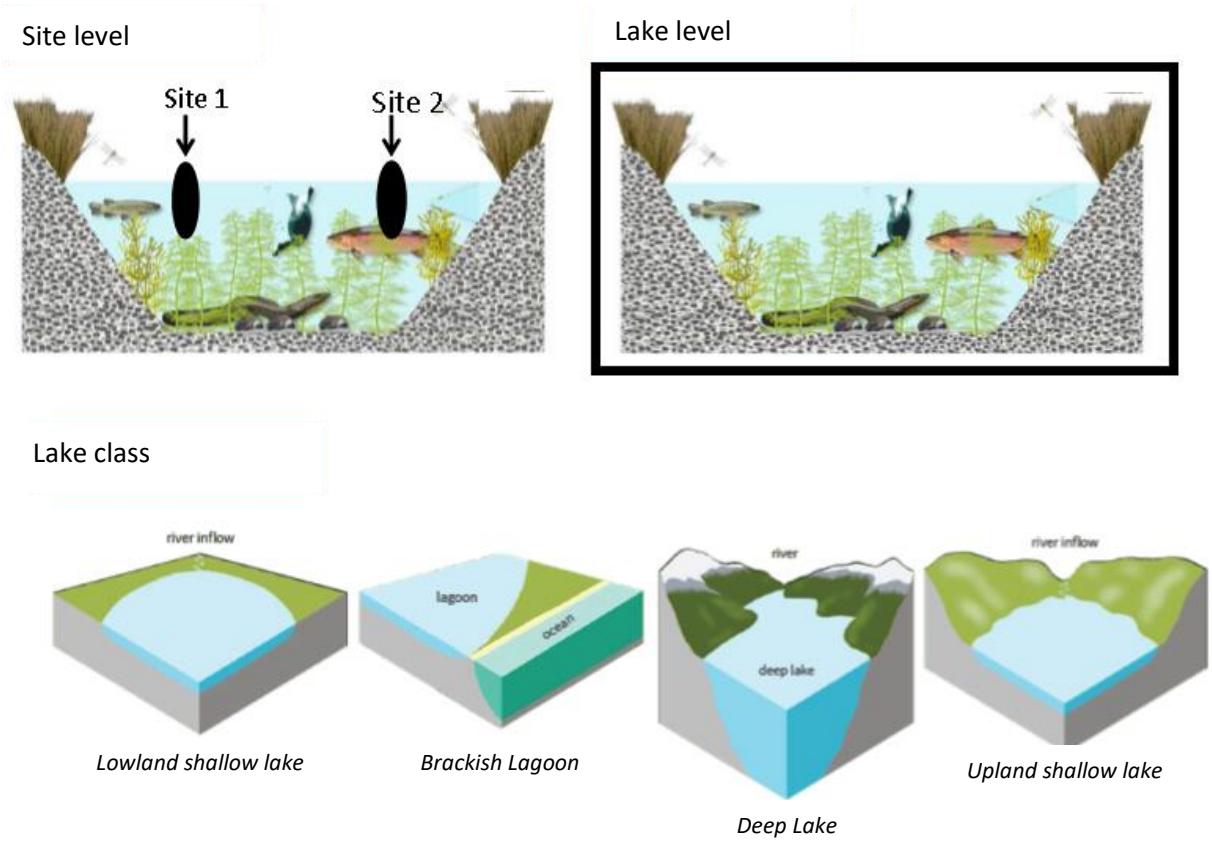


Table 22: Minimum statistical requirements for lake attributes accounted for in the analysis of state.

Attribute	Assessment statistics	Minimum data requirements[1]	Additional assessment criteria
National compulsory attribute			
Phytoplankton	• Annual median • Annual maximum	3 years of monthly sampling, n = 36	Lakes and Lagoons intermittently open to the sea, data is analysed separately for open/ closed periods.
Total phosphorus	• Annual median	3 years of monthly sampling, n = 36	Lakes and Lagoons intermittently open to the sea, data is analysed separately for open/ closed periods.
Total nitrogen	• Annual median	3 years of monthly sampling, n = 36	Assessment must consider whether the lake is seasonally stratified or polymictic. Brackish lakes are grouped with seasonally stratified lakes. Lakes and Lagoons intermittently open to the sea, data is analysed separately for open/ closed periods.
Ammonia (toxicity)	• Annual median • Annual maximum	3 years of monthly sampling, n = 36	Lakes and Lagoons intermittently open to the sea, data is analysed separately for open/ closed periods.
E. coli	• Median • 95th percentile • % exceedances over 540 *E. coli*/100mL • % exceedances over 260 *E. coli*/ 100mL	5 years of monthly sampling, n = 60[4]	Lakes and Lagoons intermittently open to the sea, data is analysed separately for open/ closed periods.
Cyanobacteria	• 80th percentile	3 years of monthly sampling, n = 36.	Lakes and Lagoons intermittently open to the sea, data is analysed separately for open/ closed periods. NPS-FM recommends 30 samples over 3 years with a minimum of 12 samples over 3 years accepted.

Attribute	Assessment statistics	Minimum data requirements[1]	Additional assessment criteria
Proposed Southland attribute			
Tropic state level (TLI)	• Annual mean **TLI3 = 1/3 (TLc + TLp + TLn)** Chlorophyll (TLc) = 2.22 + 2.54log[Chla] TP (TLp) = 0.218 + 2.92log[TP] TN (TLn) = -3.61 + 3.01log[TN]	3 years of monthly sampling, n = 36.	Lakes and Lagoons intermittently open to the sea, data is analysed separately for open/ closed periods. Each parameter TLc, TLp, TLn and then TLI3 is calculated separately per sampling data before the mean TLI3 is calculated. TLI4 was not used because secchi depth was not always available.
Nitrate (toxicity)	• Annual median • 95th percentile	3 years of monthly sampling, n = 36	Lakes and Lagoons intermittently open to the sea, data is analysed separately for open/ closed periods.
Dissolved oxygen (lake bottom)	• Annual minimum	3 years of monthly sampling, n = 36	Lakes and Lagoons intermittently open to the sea, data is analysed separately for open/ closed periods. Attribute only applies to shallow and brackish lakes.
Dissolved oxygen (mid-hypolimnetic)	• Annual minimum	3 years of monthly sampling, n = 36	Attribute only applies to seasonally stratified lakes.
Macrophytes[2]	• Total % cover of available habitat	Assessment based on the likely maximum annual biomass in a one-year period. Attribute applies to the available macrophyte habitat determined by morphological, hydrological and substrate conditions.	The total percent cover is weighted with % cover across the polygon and the coverage across the whole lake. E.g. **Total % cover = Sum(% cover x polygon area)/ total area of available habitat x 100** Sum(% cover x polygon area): % cover is estimated across lake transects that represent particular areas of the lake, these are extrapolated to the whole polygon area. Polygons are summed to represent the total available habitat within the lake.

Attribute	Assessment statistics	Minimum data requirements[1]	Additional assessment criteria
Tropic level (LakeSPI)[3]	• Lake SPI Score (%) • % reduction in score • Native Condition Index (%) • Invasive Impact Index (%)	Assessment based on the likely maximum annual biomass in a one year period.	Numeric attribute state to be calculated annually following the method described in Clayton and Edwards (2006).

[1] Where the preferred statistics could not be met the conditions are presented in Appendix 1.
[2] The overall grade has been assigned for macrophyte cover by referring to available monitoring reports in the years the assessments have been made. These do not always align with the assessment years (2010, 2016 and 2019) in which case the available data has been assigned to the closest year. No consideration is needed for open and closed periods in brackish lakes and lagoons because a single score is reported for the survey. Plant indicators are long term indicators and will not respond rapidly to changing conditions.
[3] The overall grade has been assigned for LakeSPI by referring to NIWA Lake Submerged Plant Indicators Database (https://lakespi.niwa.co.nz/). No consideration is needed for open and closed periods in brackish lakes and lagoons because a single score is reported for the survey. Plant indicators are long term indicators and will not respond rapidly to changing conditions.
[4] The NPS-FM (2017) recommends a minimum of 60 samples over 5 years, however, where a sample is missed the state may be determined over a longer timeframe.

4.1.2 Location of monitored Southland lakes

The analysis of attribute state was undertaken using Environment Southland long-term (state of the environment) monitoring data. The lake sites within this program are shown in Figure 8. Multiple sites are monitored in each lake and are presented as site level spatial scale.

Historically investigations and limited monitoring has occurred in other lakes across the region. Where this information is available, it has been used in the analysis, however the uncertainty with this data is much higher as the limited data available do not meet the minimum statistical requirements outlined in Table 22.

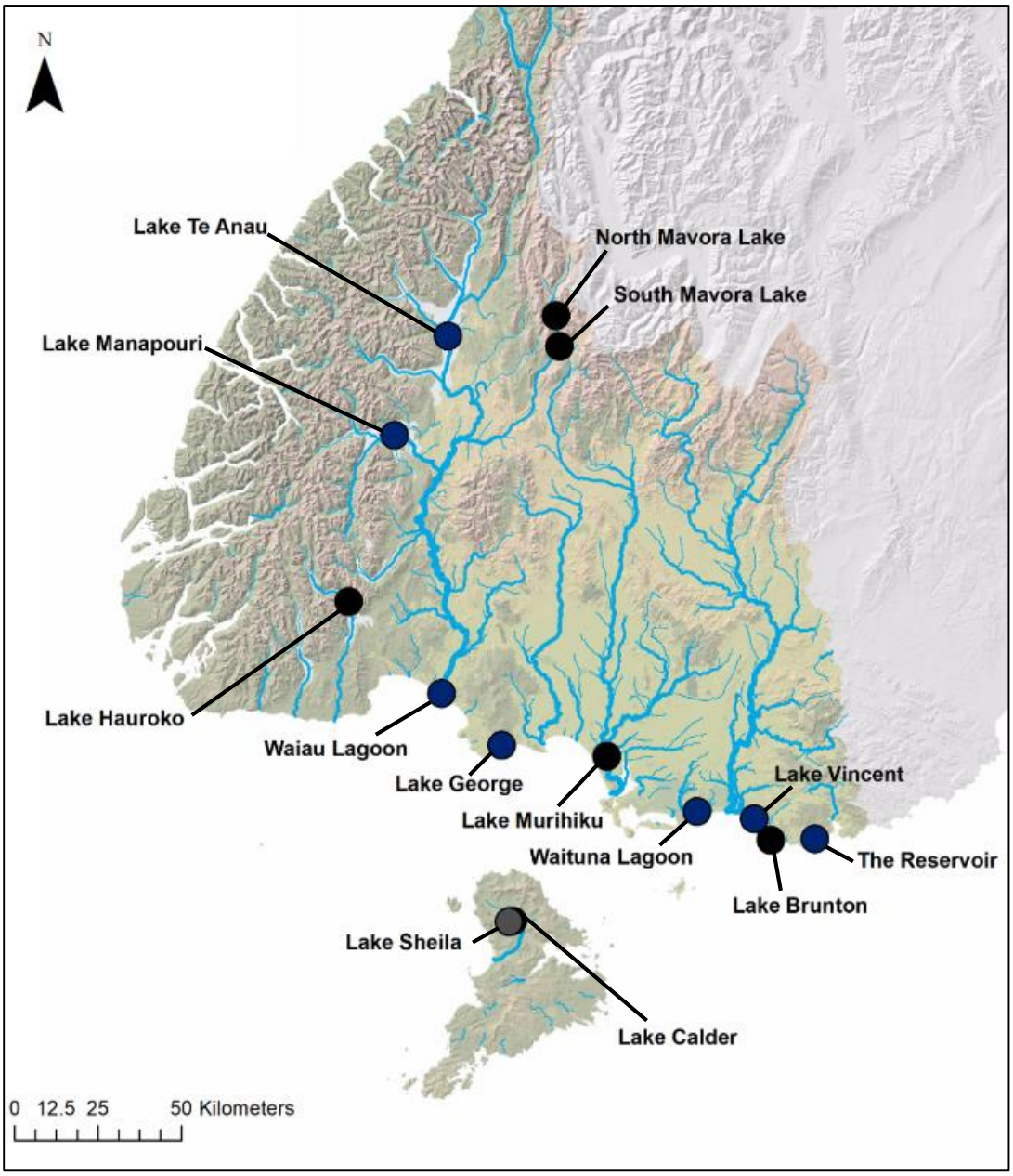


Figure 8: Lakes monitored in Southland. Note: the blue dots represent lakes in the current long-term (state of the environment) lake monitoring programme while black/grey dots represent lakes with historical data.

4.2 Attribute state results – by sites

Table 23 to 27 provide results for the attribute state assessment for sites within lakes for the three assessment periods (2010, 2016 and 2019), along with the reduction required to achieve the draft freshwater objective described in Table 21. Refinement of the draft freshwater objectives to incorporate the 'maintain or improve' criteria from the NPS-FM using the state assessment below is provided in Norton et al., 2019.

Table 23: Phytoplankton (Chlorophyll-*a*) and trophic state (TLI3) attribute state bands by monitoring sites for 2010 ('10'), 2016 ('16') and 2019 ('19').

Class	FMU	Site	Phytoplankton										TLI3						
			Draft FWO	State			%↓ needed (median)			%↓ needed (maximum)			Obj	State			%↓ needed (mean)		
				10	16	19	10	16	19	10	16	19		10	16	19	10	16	19
Upland Shallow Lake	NA	NA	A	NA			NA			NA			Not set	NA			NA		
Lowland Shallow Lake	Aparima	Lake George NE	B	ND	B	D	ND	0	0	ND	0	72		ND	C	C	NA		
Lowland Shallow Lake	Aparima	Lake George SW	B		B	D		0	0		0	72			C	C			
Lowland Shallow Lake	Mataura	Lake Vincent Centre	B		B	B		0	0		0	0			C	C			
Lowland Shallow Lake	Mataura	Lake Vincent North	B		B	B		0	0		0	0			C	C			
Lowland Shallow Lake	Mataura	The Reservoir Centre	B		D	C		71	44		19	0			C	C			
Lowland Shallow Lake	Mataura	The Reservoir West	B		D	C		67	44		11	0			C	C			
Brackish Lake or Lagoon	Waiau	Waiau Lagoon Middle	B		ND	B		ND	0		ND	0			ND	C			
Brackish Lake or Lagoon	Waiau	Waiau Lagoon Monitoring Station	B		ND	B		ND	0		ND	0			ND	C			
Brackish Lake or Lagoon	Waiau	Waiau Lagoon opp boat ramp	B		ND	C		ND	0		ND	4			ND	B			
Brackish Lake or Lagoon	Mataura	Waituna Lagoon East - CLOSED	B	B	B	B	0	0	0	0	0	0		C	C	C			
Brackish Lake or Lagoon	Mataura	Waituna Lagoon East - OPEN	B	ND	B	A	ND	0	0	ND	0	0		ND	B	C			
Brackish Lake or Lagoon	Mataura	Waituna Lagoon South - CLOSED	B	C	C	C	0	0	0	26	4	32		C	C	C			
Brackish Lake or Lagoon	Mataura	Waituna Lagoon South - OPEN	B	ND	B	B	ND	0	0	ND	0	0		ND	C	B			
Brackish Lake or Lagoon	Mataura	Waituna Lagoon Centre - CLOSED	B	C	C	C	0	0	0	31	7	11		C	C	C			
Brackish Lake or Lagoon	Mataura	Waituna Lagoon Centre - OPEN	B	ND	B	A	ND	0	0	ND	0	0		ND	B	B			
Brackish Lake or Lagoon	Mataura	Waituna Lagoon West - CLOSED	B	D	C	C	0	0	0	79	11	31		C	C	C			
Brackish Lake or Lagoon	Mataura	Waituna Lagoon West - OPEN	B	ND	A	C	ND	0	0	0	0	7		ND	B	B			
Deep Lake (Natural State)	Waiau	Lake Te Anau Blue Gum Point	A	A	ND	A	No change needed			No change needed				A+	ND	A+			
Deep Lake (Natural State)	Waiau	Lake Te Anau South Fiord	A	A		A+								A+		A+			
Deep Lake (Natural State)	Waiau	Lake Manapouri Stony Point	A	A		A+								A+		A+			
Deep Lake (Natural State)	Waiau	Lake Manapouri Frazers Beach	A	A		A+								A		A+			
Deep Lake (Natural State)	Waiau	Lake Manapouri Pomona Island	A	A		A+								A+		A+			

Table 24: Total phosphorus and total nitrogen attribute state bands by monitoring sites for 2010 ('10'), 2016 ('16') and 2019 ('19').

Class	FMU	Site	Total Phosphorus							Total Nitrogen						
			Draft FWO	State			%↓ needed (median)			Draft FWO	State			%↓ needed (median)		
				10	16	19	10	16	19		10	16	19	10	16	19
Upland Shallow Lake	NA	NA	Not set	NA			NA			Not set	NA			NA		
Lowland Shallow Lake	Aparima	Lake George NE		ND	C	C					ND	B	C			
Lowland Shallow Lake	Aparima	Lake George SW			C	C						C	C			
Lowland Shallow Lake	Mataura	Lake Vincent Centre			C	C						D	C			
Lowland Shallow Lake	Mataura	Lake Vincent North			C	B						D	C			
Lowland Shallow Lake	Mataura	The Reservoir Centre			C	C						C	C			
Lowland Shallow Lake	Mataura	The Reservoir West			C	C						C	C			
Brackish Lake or Lagoon	Waiau	Waiau Lagoon Middle			ND	C						ND	C			
Brackish Lake or Lagoon	Waiau	Waiau Lagoon Monitoring Station			ND	C						ND	C			
Brackish Lake or Lagoon	Waiau	Waiau Lagoon opp boat ramp			ND	C						ND	C			
Brackish Lake or Lagoon	Mataura	Waituna Lagoon East - CLOSED		C	C	C					D	D	D			
Brackish Lake or Lagoon	Mataura	Waituna Lagoon East - OPEN		ND	C	C					ND	C	D			
Brackish Lake or Lagoon	Mataura	Waituna Lagoon South - CLOSED		C	C	C					C	D	D			
Brackish Lake or Lagoon	Mataura	Waituna Lagoon South - OPEN		ND	B	B					ND	B	B			
Brackish Lake or Lagoon	Mataura	Waituna Lagoon Centre - CLOSED		C	C	C					D	D	D			
Brackish Lake or Lagoon	Mataura	Waituna Lagoon Centre - OPEN		ND	C	B					ND	B	C			
Brackish Lake or Lagoon	Mataura	Waituna Lagoon West - CLOSED		C	C	C					D	D	D			
Brackish Lake or Lagoon	Mataura	Waituna Lagoon West - OPEN		ND	C	C					ND	C	C			
Deep Lake (Natural State)	Waiau	Lake Te Anau Blue Gum Point		A+	ND	A+					A+	ND	A			
Deep Lake (Natural State)	Waiau	Lake Te Anau South Fiord		A+		A+					A+		A			
Deep Lake (Natural State)	Waiau	Lake Manapouri Stony Point		A+		A+					A+		A			
Deep Lake (Natural State)	Waiau	Lake Manapouri Frazers Beach		A		A+					A+		A			
Deep Lake (Natural State)	Waiau	Lake Manapouri Pomona Island		A+		A+					A+		A			

Table 25: Ammonia (toxicity) and nitrate (toxicity) attribute state bands by monitoring sites for 2010 ('10'), 2016 ('16') and 2019 ('19').

Class	FMU	Site	Nitrate[17]										Ammonia									
			Draft FWO	State			%↓ needed (median)			%↓ needed (95th %ile)			Draft FWO	State			%↓ needed (median)			%↓ needed (maximum)		
				10	16	19	10	16	19	10	16	19		10	16	19	10	16	19	10	16	19
Upland Shallow Lake	NA	NA	Not set	NA			NA			NA			B	NA			NA			NA		
Lowland Shallow Lake	Aparima	Lake George NE			A	A							C		A	A		0	0		0	0
Lowland Shallow Lake	Aparima	Lake George SW			A	A							C		A	A		0	0		0	0
Lowland Shallow Lake	Mataura	Lake Vincent Centre			A	A							C		B	A		0	0		0	0
Lowland Shallow Lake	Mataura	Lake Vincent North			A	A							C		B	A		0	0		0	0
Lowland Shallow Lake	Mataura	The Reservoir Centre		ND	A	A							C	ND	A	A	ND	0	0	ND	0	0
Lowland Shallow Lake	Mataura	The Reservoir West			A	A							C		A	A		0	0		0	0
Brackish Lake or Lagoon	Waiau	Waiau Lagoon Middle			ND	A							C		ND	B		ND	0		ND	0
Brackish Lake or Lagoon	Waiau	Waiau Lagoon Monitoring Station			ND	A							C		ND	B		ND	0		ND	0
Brackish Lake or Lagoon	Waiau	Waiau Lagoon opp boat ramp			ND	A							C		ND	A		ND	0		ND	0
Brackish Lake or Lagoon	Mataura	Waituna Lagoon East - CLOSED		B	A	A							C	B	A	A	0	0	0	0	0	0
Brackish Lake or Lagoon	Mataura	Waituna Lagoon East - OPEN		ND	B	A							C	ND	B	A	ND	0	0	ND	0	0
Brackish Lake or Lagoon	Mataura	Waituna Lagoon South - CLOSED		B	A	A							C	B	A	A	0	0	0	0	0	0
Brackish Lake or Lagoon	Mataura	Waituna Lagoon South - OPEN		ND	A	A							C	ND	A	A	ND	0	0	ND	0	0
Brackish Lake or Lagoon	Mataura	Waituna Lagoon Centre - CLOSED		B	A	A							C	B	A	A	0	0	0	0	0	0
Brackish Lake or Lagoon	Mataura	Waituna Lagoon Centre - OPEN		ND	B	A							C	ND	B	A	ND	0	0	ND	0	0
Brackish Lake or Lagoon	Mataura	Waituna Lagoon West - CLOSED		B	A	A							C	B	A	B	0	0	0	0	0	0
Brackish Lake or Lagoon	Mataura	Waituna Lagoon West - OPEN		ND	B	B							C	ND	B	B	ND	0	0	ND	0	0
Deep Lake (Natural State)	Waiau	Lake Te Anau Blue Gum Point		A		A							B	A		A	0		0	0		0
Deep Lake (Natural State)	Waiau	Lake Te Anau South Fiord		A		A							B	A		A	0		0	0		0
Deep Lake (Natural State)	Waiau	Lake Manapouri Stony Point		A	ND	A							B	A	ND	A	0	ND	0	0	ND	0
Deep Lake (Natural State)	Waiau	Lake Manapouri Frazers Beach		A		A							B	A		A	0		0	0		0
Deep Lake (Natural State)	Waiau	Lake Manapouri Pomona Island		A		A							B	A		A	0		0	0		0

[17] For Waituna Lagoon, Lake Te Anau and Lake Manapouri NOx (Nitrate + Nitrite) was used to make the assessment because nitrate alone was not measured pre-2015. This was carried through all the analysis years for consistency. At these sites nitrate makes up ~99% of the NOx on average.

Table 26: Dissolved oxygen (lake bottom) and dissolved oxygen (mid-hypolimnetic) attribute state bands by monitoring sites for 2010 ('10'), 2016 ('16') and 2019 ('19').

Class	FMU	Site	Lake Bottom Dissolved Oxygen							Mid-Hypolimnetic Dissolved Oxygen						
			Draft FWO	State			%↓ needed (minimum)			Draft FWO	State			%↓ needed (minimum)		
				10	16	19	10	16	19		10	16	19	10	16	19
Upland Shallow Lake	NA	NA	Not set	NA			NA			Not set	NA			NA		
Lowland Shallow Lake	Aparima	Lake George NE		ND	A	A					NA	NA	NA			
Lowland Shallow Lake	Aparima	Lake George SW			A	A										
Lowland Shallow Lake	Mataura	Lake Vincent Centre			A	A										
Lowland Shallow Lake	Mataura	Lake Vincent North			A	A										
Lowland Shallow Lake	Mataura	The Reservoir Centre			A	A										
Lowland Shallow Lake	Mataura	The Reservoir West			A	B										
Brackish Lake or Lagoon	Waiau	Waiau Lagoon Middle			ND	B										
Brackish Lake or Lagoon	Waiau	Waiau Lagoon Monitoring Station			ND	A										
Brackish Lake or Lagoon	Waiau	Waiau Lagoon opp boat ramp			ND	A										
Brackish Lake or Lagoon	Mataura	Waituna Lagoon East - CLOSED			A	ND										
Brackish Lake or Lagoon	Mataura	Waituna Lagoon East - OPEN			B	ND										
Brackish Lake or Lagoon	Mataura	Waituna Lagoon South - CLOSED			A	ND										
Brackish Lake or Lagoon	Mataura	Waituna Lagoon South - OPEN			A	ND										
Brackish Lake or Lagoon	Mataura	Waituna Lagoon Centre - CLOSED			A	A										
Brackish Lake or Lagoon	Mataura	Waituna Lagoon Centre - OPEN			A	A										
Brackish Lake or Lagoon	Mataura	Waituna Lagoon West - CLOSED			A	ND										
Brackish Lake or Lagoon	Mataura	Waituna Lagoon West - OPEN			A	ND										
Deep Lake (Natural State)	Waiau	Lake Te Anau Blue Gum Point			ND	ND						ND				
Deep Lake (Natural State)	Waiau	Lake Te Anau South Fiord														
Deep Lake (Natural State)	Waiau	Lake Manapouri Stony Point														
Deep Lake (Natural State)	Waiau	Lake Manapouri Frazers Beach														
Deep Lake (Natural State)	Waiau	Lake Manapouri Pomona Island														

Table 27: *E. coli* and cyanobacteria attribute state bands by monitoring sites for 2010 ('10'), 2016 ('16') and 2019 ('19').

Class	FMU	Site	*E. coli*[18]															Cyanobacteria[19]							
			Draft FWO	State			%↓ needed (median)			%↓ needed (95th %ile)			%↓ needed exceedances >260			%↓ needed exceedances >540			Draft FWO	State			%↓ needed (maximum)		
				10	16	19	10	16	19	10	16	19	10	16	19	10	16	19		10	16	19	10	16	19
Upland Shallow Lake	NA	NA	A	NA			NA												Not set	NA			NA		
Lowland Shallow Lake	Aparima	Lake George NE	B	ND	ND	A	ND	ND	0	ND	ND	0	ND	ND	0	ND	ND	0	Not set	ND	ND	-	NA		
Lowland Shallow Lake	Aparima	Lake George SW	B			D			7			0			0			0				-			
Lowland Shallow Lake	Mataura	Lake Vincent Centre	B			A			0			0			0			0				-			
Lowland Shallow Lake	Mataura	Lake Vincent North	B			A			0			0			0			0				-			
Lowland Shallow Lake	Mataura	The Reservoir Centre	B			A			0			0			0			0				-			
Lowland Shallow Lake	Mataura	The Reservoir West	B			A			0			0			0			0				-			
Brackish Lake or Lagoon	Waiau	Waiau Lagoon Middle	B			D			0			56			0			0				-			
Brackish Lake or Lagoon	Waiau	Waiau Lagoon Monitoring Station	B			D			0			55			0			0				A			
Brackish Lake or Lagoon	Waiau	Waiau Lagoon opp boat ramp	B			D			0			32			0			0				-			
Brackish Lake or Lagoon	Mataura	Waituna Lagoon East - CLOSED	B			A			0			0			0			0				-			
Brackish Lake or Lagoon	Mataura	Waituna Lagoon East - OPEN	B			A			0			0			0			0				-			
Brackish Lake or Lagoon	Mataura	Waituna Lagoon South - CLOSED	B			A			0			0			0			0				-			
Brackish Lake or Lagoon	Mataura	Waituna Lagoon South - OPEN	B			A			0			0			0			0				-			
Brackish Lake or Lagoon	Mataura	Waituna Lagoon Centre - CLOSED	B			B			0			0			0			0				C			
Brackish Lake or Lagoon	Mataura	Waituna Lagoon Centre - OPEN	B			A			0			0			0			0				-			
Brackish Lake or Lagoon	Mataura	Waituna Lagoon West - CLOSED	B			A			0			0			0			0				-			
Brackish Lake or Lagoon	Mataura	Waituna Lagoon West - OPEN	B			A			0			0			0			0				-			
Deep Lake (Natural State)	Waiau	Lake Te Anau Blue Gum Point	A			ND			ND			ND			ND			ND				A			
Deep Lake (Natural State)	Waiau	Lake Te Anau South Fiord	A																			-			
Deep Lake (Natural State)	Waiau	Lake Manapouri Stony Point	A																			A			
Deep Lake (Natural State)	Waiau	Lake Manapouri Frazers Beach	A																			-			
Deep Lake (Natural State)	Waiau	Lake Manapouri Pomona Island	A																			-			

[18] *E. coli* samples for Lake Manapouri and Lake Te Anau are only collected at one bathing beach site most impacted by human activity. This is reported in the lake level analysis.

[19] Shallow lakes data has been collected since late 2016 however for cyanobacteria the samples are mixed into composite samples so the data for these systems are reported in the lake level.

4.3 Attribute state results – by lakes

Table 28 to 36 provide results for the attribute state assessment at the lake scale for the three assessment periods (2010, 2016 and 2019), along with the reduction required to achieve the draft freshwater objective described in Table 21. Refinement of the draft freshwater objectives to incorporate the 'maintain or improve' criteria from the NPS-FM using the state assessment below is provided in Norton et al., 2019.

Table 28: Phytoplankton (Chlorophyll-*a*) and trophic state (TLI3) attribute state bands by lakes for 2010 ('10'), 2016 ('16') and 2019 ('19'). Red text shows attribute state has been estimated from a limited survey.

Class	FMU	Site	Phytoplankton										TLI3						
			Draft FWO	State			%↓ needed (median)			%↓ needed (maximum)			Draft FWO	State			%↓ needed (mean)		
				10	16	19	10	16	19	10	16	19		10	16	19	10	16	19
Upland Shallow Lake	NA	NA	A	NA			NA			NA			Not set	NA			NA		
Lowland Shallow Lake	Aparima	Lake George	B	ND	B	D	ND	0	0	ND	0	72		ND	C	C	NA		
Lowland Shallow Lake	Mataura	Lake Vincent	B		B	B		0	0		0	0			C	C			
Lowland Shallow Lake	Mataura	The Reservoir	B		D	C		69	44		19	0			C	C			
Brackish Lake or Lagoon	Waiau	Waiau Lagoon	B		ND	C		ND	0		ND	4			ND	C			
Brackish Lake or Lagoon	Mataura	Waituna Lagoon - CLOSED	B	D	C	C	0	0	0	79	11	32		C	C	C			
Brackish Lake or Lagoon	Mataura	Waituna Lagoon - OPEN	B	ND	C	C	ND	0	0	ND	0	7		ND	B	B			
Deep Lake (Natural State)	Waiau	Lake Te Anau	A	A	ND	A+	0	ND	0	0	ND	0		A+	ND	A+			
Deep Lake (Natural State)	Waiau	Lake Manapouri	A	A	ND	A+	0	ND	0	0	ND	0		A+	ND	A+			
Lowland Shallow Lake	Fiordland & Islands	Lake Sheila[20]	B	A	ND		0	ND		0	ND			A	NA		NA		
Lowland Shallow Lake	Fiordland & Islands	Lake Calder[20]	B	A			0			0				A					
Brackish Lake or Lagoon	Mataura	Lake Brunton[20]	B	A			0			0				B					

[20] Data from Schallenberg and Kelly (2012): Ecological condition of six shallow Southland lakes. This is an indicative state based on the data in the report, the minimum statistical requirement has not been met.

Table 29: Total phosphorus and total nitrogen attribute state bands by lakes for 2010 ('10'), 2016 ('16') and 2019 ('19'). Red text shows attribute state has been estimated from a limited survey.

Class	FMU	Site	Total Phosphorus							Total Nitrogen						
			Draft FWO	State			%↓ needed (median)			Draft FWO	State			%↓ needed (median)		
				10	16	19	10	16	19		10	16	19	10	16	19
Upland Shallow Lake	NA	NA	Not set	NA			NA			Not set	NA			NA		
Lowland Shallow Lake	Aparima	Lake George			C	C						C	C			
Lowland Shallow Lake	Mataura	Lake Vincent			C	C						D	C			
Lowland Shallow Lake	Mataura	The Reservoir			C	C						C	C			
Brackish Lake or Lagoon	Waiau	Waiau Lagoon			ND	C						ND	C			
Brackish Lake or Lagoon	Mataura	Waituna Lagoon - CLOSED		C	C	C					D	D	D			
Brackish Lake or Lagoon	Mataura	Waituna Lagoon - OPEN		ND	C	C					ND	C	C			
Deep Lake (Natural State)	Waiau	Lake Te Anau		A+	ND	A+					A+	ND	A			
Deep Lake (Natural State)	Waiau	Lake Manapouri		A+	ND	A+					A+	ND	A			
Lowland Shallow Lake	Fiordland and Islands	Lake Sheila[21]		A	ND		NA				A	ND		NA		
Lowland Shallow Lake	Fiordland and Islands	Lake Calder[21]		A							A					
Brackish Lake or Lagoon	Mataura	Lake Brunton[21]		C							C					

[21]Data from Schallenberg and Kelly (2012) Ecological condition of six shallow Southland lakes. This is an indicative state based on the data in the report, the minimum statistical requirement has not been met.

Table 30: Ammonia (toxicity) and nitrate (toxicity) attribute state bands by lakes for 2010 ('10'), 2016 ('16') and 2019 ('19'). Red text shows attribute state has been estimated from a limited survey.

Class	FMU	Site	Nitrate										Ammonia									
			Draft FWO	State			%↓ needed (median)			%↓ needed (95th %ile)			Draft FWO	State			%↓ needed (median)			%↓ needed (maximum)		
				10	16	19	10	16	19	10	16	19		10	16	19	10	16	19	10	16	19
Upland Shallow Lake	NA	NA	Not set	NA			NA			NA			B	NA			NA			NA		
Lowland Shallow Lake	Aparima	Lake George		ND	A	A	NA			NA			C	ND	A	A	ND	0	0	ND	0	0
Lowland Shallow Lake	Mataura	Lake Vincent			A	A							C		B	A		0	0		0	0
Lowland Shallow Lake	Mataura	The Reservoir			A	A							C		A	A		0	0		0	0
Brackish Lake or Lagoon	Waiau	Waiau Lagoon			ND	A							C		A	B		ND	0		ND	0
Brackish Lake or Lagoon	Mataura	Waituna Lagoon - CLOSED		B	B	B							C	B	A	B	0	0	0	0	0	0
Brackish Lake or Lagoon	Mataura	Waituna Lagoon - OPEN		ND	B	C							C	ND	B	B	ND	0	0	ND	0	0
Deep Lake (Natural State)	Waiau	Lake Te Anau		A	ND	A							B	A	ND	A	0	ND	0	0	ND	0
Deep Lake (Natural State)	Waiau	Lake Manapouri		A	ND	A							B	A	ND	A	0	ND	0	0	ND	0
Lowland Shallow Lake	Fiordland & Islands	Lake Sheila[22]		A	ND		NA			NA			C	A	ND		0	ND		0	ND	
Lowland Shallow Lake	Fiordland & Islands	Lake Calder[22]		A									C	A			0			0		
Brackish Lake or Lagoon	Mataura	Lake Brunton[22]		A									C	A			0			0		

[22] Data from Schallenberg and Kelly (2012): Ecological condition of six shallow Southland lakes. This is an indicative state based on the data in the report, the minimum statistical requirement has not been met.

Table 31: Dissolved oxygen (lake bottom) and dissolved oxygen (mid-hypolimnetic) attribute state bands by lakes for 2010 ('10'), 2016 ('16') and 2019 ('19').

Class	FMU	Site	Lake Bottom Dissolved Oxygen							Mid-Hypolimnetic Dissolved Oxygen						
			Draft FWO	State			%↓ needed (minimum)			Draft FWO	State			%↓ needed (minimum)		
				10	16	19	10	16	19		10	16	19	10	16	19
Upland Shallow Lake	NA	NA	Not set	NA			NA			Not set	NA			NA		
Lowland Shallow Lake	Aparima	Lake George			A	A					NA	NA	NA			
Lowland Shallow Lake	Mataura	Lake Vincent			A	A										
Lowland Shallow Lake	Mataura	The Reservoir			A	B										
Brackish Lake or Lagoon	Waiau	Waiau Lagoon			ND	B										
Brackish Lake or Lagoon	Mataura	Waituna Lagoon - CLOSED		A	A	A										
Brackish Lake or Lagoon	Mataura	Waituna Lagoon - OPEN		ND	B	A										
Deep Lake (Natural State)	Waiau	Lake Te Anau		ND	ND	ND						ND				
Deep Lake (Natural State)	Waiau	Lake Manapouri		ND	ND	ND						ND				

Table 32: *E. coli* and cyanobacteria attribute state bands by lakes for 2010 ('10'), 2016 ('16') and 2019 ('19').

Class	FMU	Site	*E. coli*																Cyanobacteria						
			Draft FWO	State			%↓ needed (median)			%↓ needed (95th %ile)			%↓ needed (% exceedances >260)			%↓ needed (% exceedances >540)			Draft FWO	State			%↓ needed (maximum)		
				10	16	19	10	16	19	10	16	19	10	16	19	10	16	19		10	16	19	10	16	19
Upland Shallow Lake	NA	NA	A	NA			NA												Not set	NA			NA		
Lowland Shallow Lake	Aparima	Lake George	B	ND	ND	D	ND	ND	7	ND	ND	0	ND	ND	0	ND	ND	0		ND	ND	A	NA		
Lowland Shallow Lake	Mataura	Lake Vincent	B			A			0			0			0			0				ND			
Lowland Shallow Lake	Mataura	The Reservoir	B			A			0			0			0			0				A			
Brackish Lake or Lagoon	Waiau	Waiau Lagoon	B			D			56			0			0			0				A			
Brackish Lake or Lagoon	Mataura	Waituna Lagoon - CLOSED	B			B			0			0			0			0				C			
Brackish Lake or Lagoon	Mataura	Waituna Lagoon - OPEN	B			A			0			0			0			0				ND			
Deep Lake (Natural State)	Waiau	Lake Te Anau	A	A	A	A	0	0	0	0	0	0	0	0	0	0	0	0				A			
Deep Lake (Natural State)	Waiau	Lake Manapouri	A	A	A	A	0	0	0	0	0	0	0	0	0	0	0	0				A			

Table 33: Tropic state (LakeSPI) attribute state bands by lakes for 2010 ('10'), 2016 ('16') and 2019 ('19').

Class	FMU	Site	LakeSPI Score[23]						
			Draft FWO	State			%↓ needed (LakeSPI Score)		
				10	16	19	10	16	19
Upland Shallow Lake	NA	NA	Not set	ND	ND	ND	NA		
Lowland Shallow Lake	Aparima	Lake George			A+				
Lowland Shallow Lake	Mataura	Lake Vincent			B				
Lowland Shallow Lake	Mataura	The Reservoir			B				
Brackish Lake or Lagoon	Waiau	Waiau Lagoon			ND				
Brackish Lake or Lagoon	Mataura	Waituna Lagoon			ND				
Deep Lake (Natural State)	Waiau	Lake Te Anau		B	C				
Deep Lake (Natural State)	Waiau	Lake Manapouri		C	C				
Deep Lake	Waiau	North Mavora Lake		B	ND				
Deep Lake	Waiau	South Mavora Lake		B	ND				
Deep Lake (Natural State)	Fiordland & Islands	Lake Hauroko		B	B				

[23] Data sourced from NIWA Lake Submerged Plant Indicators Database (https://lakespi.niwa.co.nz/)

Table 34: Submerged plants (nativeness) and submerged plants (invasive species) attribute state bands by lakes for 2010 ('10'), 2016 ('16') and 2019 ('19').

Class	FMU	Site	LakeSPI Native Condition Index[24]							Lake SPI Invasive Impact Index							
			Draft FWO	State			%↓ needed (Native Index)			Draft FWO	State			%↓ needed (Invasive Index)		
				10	16	19	10	16	19		10	16	19	10	16	19
Upland Shallow Lake	NA	NA	Not set	ND	ND	ND	NA			Not set	ND	ND	ND	ND		
Lowland Shallow Lake	Aparima	Lake George			A							A				
Lowland Shallow Lake	Mataura	Lake Vincent			B							C				
Lowland Shallow Lake	Mataura	The Reservoir			B							B				
Brackish Lake or Lagoon	Waiau	Waiau Lagoon			ND							ND				
Brackish Lake or Lagoon	Mataura	Waituna Lagoon			ND							ND				
Deep Lake	Natural State	Lake Te Anau		C	C						B	C				
Deep Lake	Natural State	Lake Manapouri		C	C						C	C				
Deep Lake	Waiau	North Mavora Lake		B	ND						C	ND				
Deep Lake	Waiau	South Mavora Lake		B	ND						C	ND				
Deep Lake	Fiordland & Islands	Lake Hauroko		C	C						B	B				

[24] Data sourced from NIWA Lake Submerged Plant Indicators Database (https://lakespi.niwa.co.nz/)

Table 35: Macrophytes (% cover) attribute state bands by lakes for 2010 ('10'), 2016 ('16') and 2019 ('19').

Class	FMU	Site	Macrophyte Cover						
			Draft FWO	State			%↓ needed (%cover)		
				10	16	19	10	16	19
Upland Shallow Lake	NA	NA	Not set	ND	ND	ND	NA		
Lowland Shallow Lake	Aparima	Lake George			C	C			
Lowland Shallow Lake	Mataura	Lake Vincent			A	A			
Lowland Shallow Lake	Mataura	The Reservoir			C	C			
Brackish Lake or Lagoon	Waiau	Waiau Lagoon		C	ND	A			
Brackish Lake or Lagoon	Mataura	Waituna Lagoon [25]		B	B	B			
Brackish Lake or Lagoon	Mataura	Lake Brunton		D	D	D			
Lowland Shallow Lake (Natural State)	Fiordland & Islands	Lake Sheila[26]		B	ND				
Lowland Shallow Lake (Natural State)	Fiordland & Islands	Lake Calder[26]		C					
Lowland Shallow Lake	Ōreti	Lake Murihiku		ND	C	ND			

[25] Waituna Lagoon macrophyte state is based on average % cover rather than weighted % cover. These will need to be updated at a later date, however the average % cover provides an indicative state.

[26] Data from Schallenberg and Kelly (2012) Ecological condition of six shallow Southland lakes. The data reported here is an indicative state because the survey was not extensive only 5 transects were used to calculate % cover and likely underestimate the true state. These have not been reported through to Lake Type and FMU.

Table 36: Fish attribute state bands by lakes for 2013.

Class	FMU	Site	Draft FWO	Fish						
				State 2013						
				Perch (Introduced)	Trout (Introduced)	Longfin Eel	Shortfin Eel	Giant Kokopu	Inanga	Narrative State[27]
Upland Shallow Lake	NA	NA	Not set	ND						
Deep Lake	NA	NA		ND						
Lowland Shallow Lake	Aparima	Lake George		Yes	Yes	Yes	Yes	No	Yes	D
Lowland Shallow Lake	Mataura	The Reservoir		No	No	Yes	Yes	Yes	No	B
Lowland Shallow Lake	Mataura	Lake Vincent		Yes	No	Yes	Yes	Yes	No	C
Lowland Shallow Lake (Natural State)	Fiordland & Islands	Lake Sheila[28]		No	No	Yes	No	Yes	Yes	A
Lowland Shallow Lake	Ōreti	Lake Murihiku		Yes	No	Yes	Yes	No	No	D

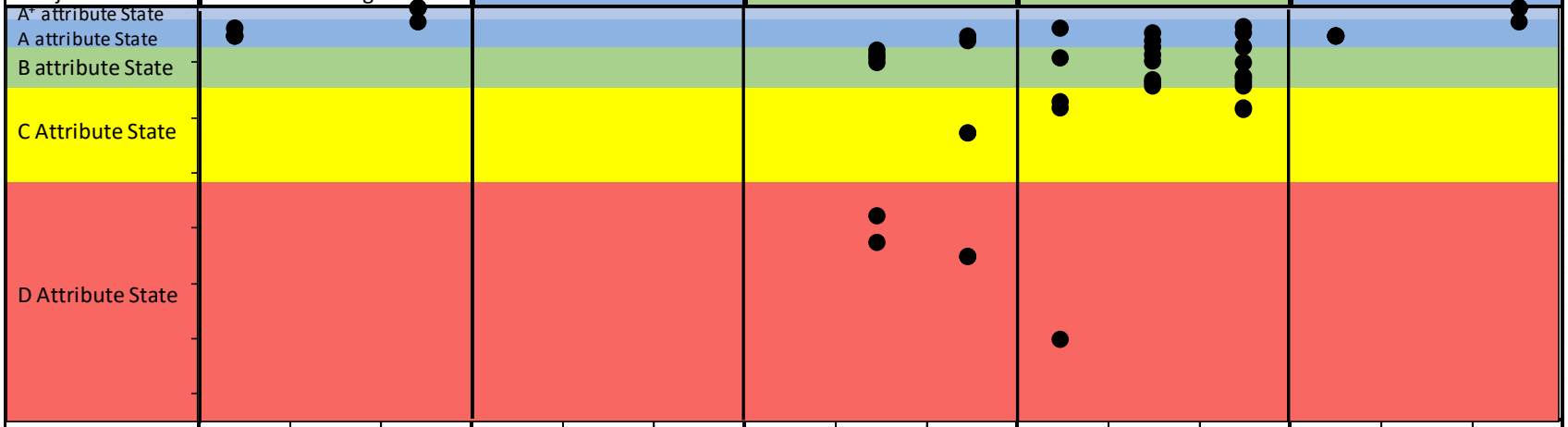
4.4 Attribute state results – by lake classes

[27] An appropriate narrative state needs developed for Southland the current assessment was based on the Greater Wellington Fish narrative attribute taking into consideration invasive species and important species to protect e.g. Giant Kokopu and Inanga

[28] Data from Hicks (2013) Fish surveys in non-wadeable systems and Schallenberg and Kelly (2012) Ecological condition of six shallow Southland lakes. The data reported here is an indicative of the fish community at these two time periods.

Table 37 to 49 provide results for the attribute state assessment at the lake class scale for the three assessment periods (2010, 2016 and 2019), along with the reduction required to achieve the draft freshwater objective described in Table 21. Refinement of the draft freshwater objectives to incorporate the 'maintain or improve' criteria from the NPS-FM using the state assessment below is provided in Norton et al., 2019.

Table 37: Phytoplankton attribute state bands by lake class and the level of improvement required to meet the draft freshwater objective.

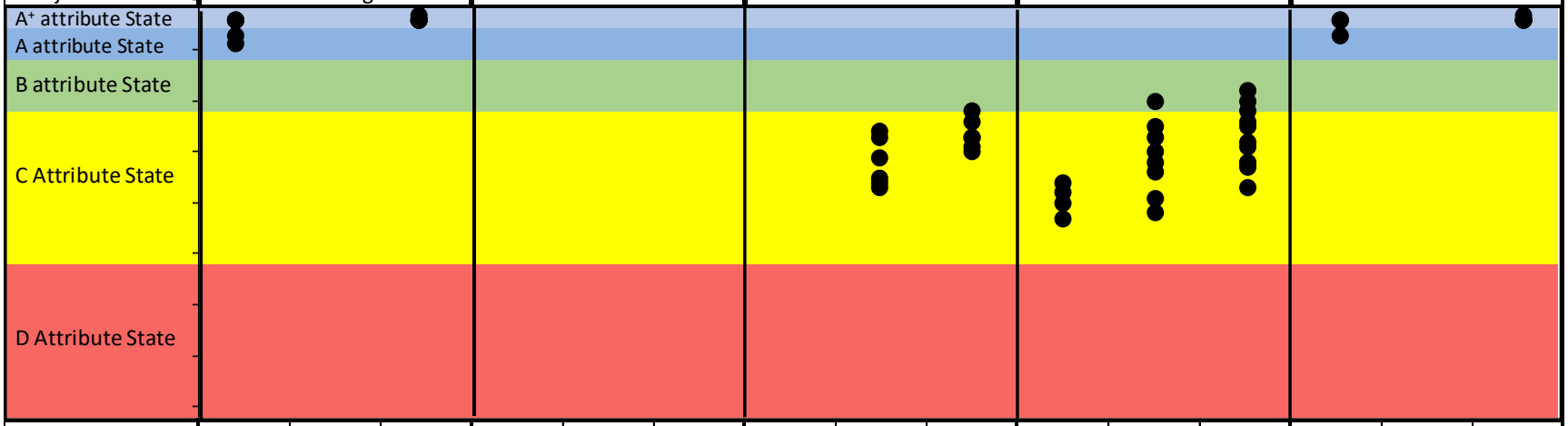


Class	Natural State Lakes			Upland Shallow Lakes			Lowland Shallow Lakes			Brackish Lakes & Lakes			Deep Lakes		
Objective state	No change			A			B			B			A		
Baseline year	2010	2016	2019	2010	2016	2019	2010	2016	2019	2010	2016	2019	2010	2016	2019
Sites in A+ state	0	ND	4 (80%)	ND			ND	0	0	0	0	0	0	ND	4 (80%)
Sites in A state	7 (100%)		1 (20%)					0	0	1 (20%)	1 (10%)	2 (18%)	5 (100%)		1 (20%)
Sites in B state	0		0					4 (66%)	2 (33%)	1 (20%)	4 (50%)	4 (36%)	0		0
Sites in C state	0		0					0	2 (33%)	2 (40%)	3 (40%)	5 (45%)	0		0
Sites in D state	0		0					2 (33%)	2 (33%)	1 (20%)	0	0	0		0
Maintain	*Note: the deep glacial lakes are reported in both natural state and deep lakes. In 2010 natural state also includes Lake Sheila and Calder on Stewart Island*			NA			ND	4	2	2	5	6	5	ND	5
Improve 1 state								0	2	2	3	5	0		0
Improve 2 states								2	2	1	0	0	0		0
Improve 3 states								0	0	0	0	0	0		0

Table 38: Trophic level index (TLI3) attribute state bands by lake class. No draft freshwater objective has been set for this attribute.

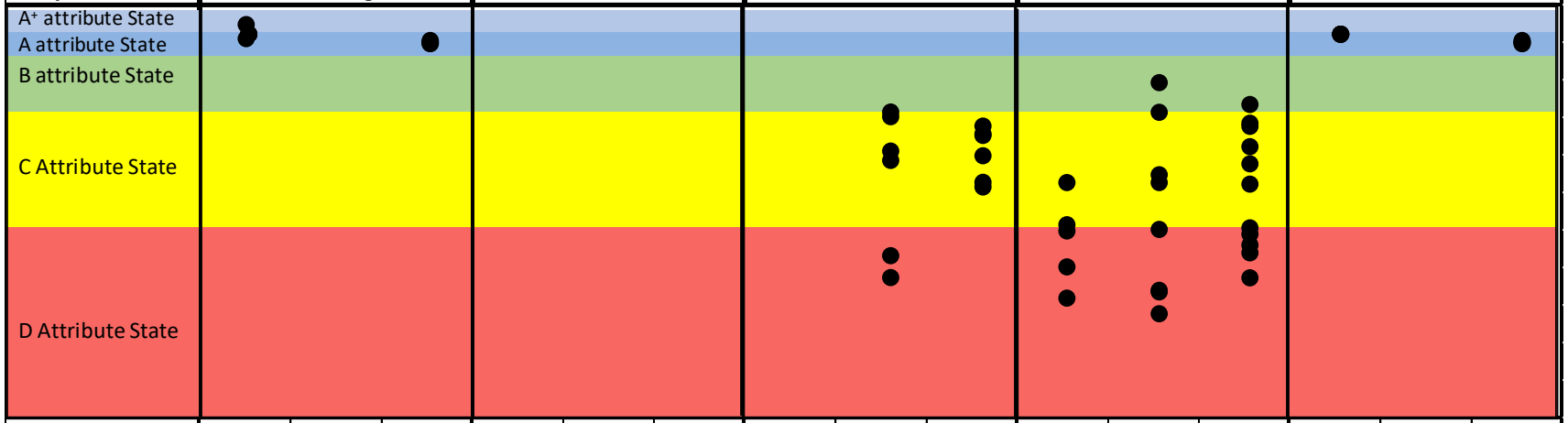
Class	Natural State Lakes			Upland Shallow Lakes			Lowland Shallow Lakes			Brackish Lakes & Lakes			Deep Lakes		
Objective state	No change			NA			NA			NA			NA		
A+ attribute State															
A attribute State															
B attribute State															
C Attribute State															
D Attribute State															
Baseline year	2010	2016	2019	2010	2016	2019	2010	2016	2019	2010	2016	2019	2010	2016	2019
Sites in A+ state	4 (57%)	ND	5 (100%)	ND			ND	0	0	0	0	0	4 (80%)	ND	5 (100%)
Sites in A state	3 (43%)		0					0	0	0	0	0	1 (20%)		0
Sites in B state	0		0					0	0	1 (20%)	3 (37%)	4 (37%)	0		0
Sites in C state	0		0					6 (100%)	6 (100%)	4 (80%)	5 (63%)	7 (63%)	0		0
Sites in D state	0		0					0	0	0	0	0	0		0
Maintain	*Note: the deep glacial lakes are reported in both natural state and deep lakes. In 2010 natural state also includes Lake Sheila and Calder on Stewart Island*			NA			NA			NA			NA		
Improve 1 state															
Improve 2 states															
Improve 3 states															

Table 39: Total phosphorus attribute state bands by lake class. No draft freshwater objective has been set for this attribute.



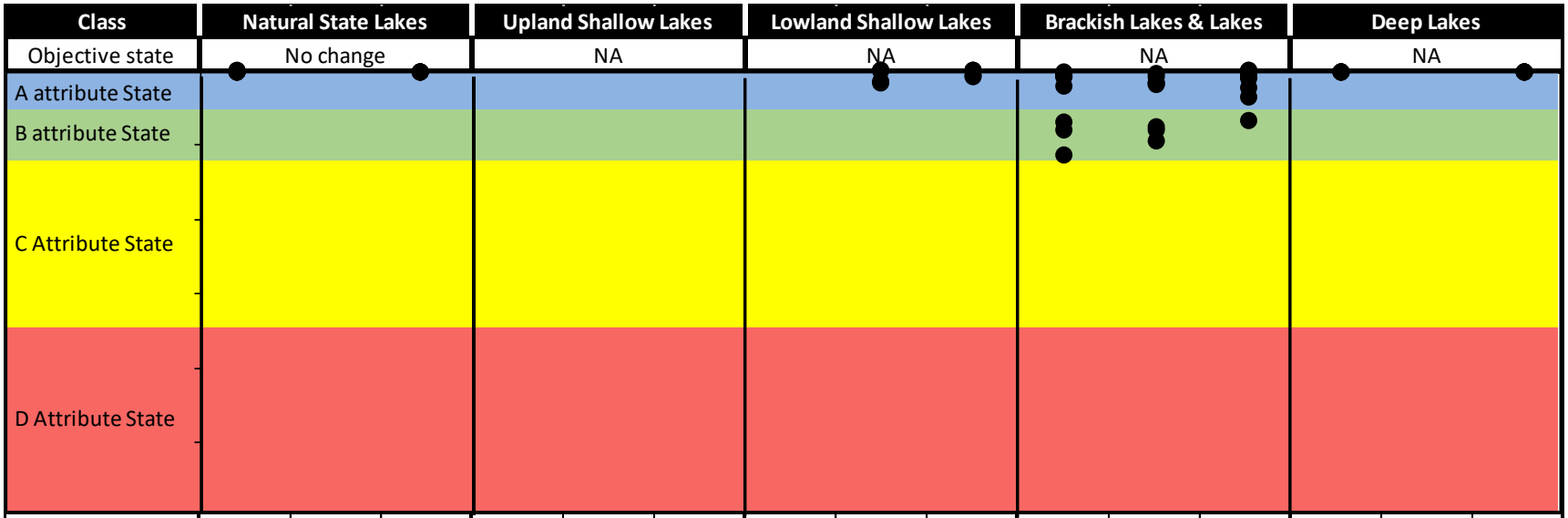
Class	Natural State Lakes			Upland Shallow Lakes			Lowland Shallow Lakes			Brackish Lakes & Lakes			Deep Lakes		
Objective state	No change			NA			NA			NA			NA		
Baseline year	2010	2016	2019	2010	2016	2019	2010	2016	2019	2010	2016	2019	2010	2016	2019
Sites in A+ state	5 (72%)	ND	5 (100%)	ND			ND	0	0	0	0	0	4 (80%)	ND	5 (100%)
Sites in A state	2 (28%)		0					0	0	0	0	0	1 (20%)		0
Sites in B state	0		0					0	1 (17%)	0	1 (12%)	2 (18%)	0		0
Sites in C state	0		0					6 (100%)	5 (83%)	5 (100%)	7 (88%)	9 (82%)	0		0
Sites in D state	0		0					0	0	0	0	0	0		0
Maintain	*Note: the deep glacial lakes are reported in both natural state and deep lakes. In 2010 natural state also includes Lake Sheila and Calder on Stewart Island*			NA			NA			NA			NA		
Improve 1 state															
Improve 2 states															
Improve 3 states															

Table 40: Total nitrogen attribute state bands by lake class[29]. No draft freshwater objective has been set for this attribute.



Class	Natural State Lakes			Upland Shallow Lakes			Lowland Shallow Lakes			Brackish Lakes & Lakes			Deep Lakes		
Objective state	No change			NA			NA			NA			NA		
Baseline year	2010	2016	2019	2010	2016	2019	2010	2016	2019	2010	2016	2019	2010	2016	2019
Sites in A+ state	5 (72%)	ND	0	ND			ND	0	0	0	0	0	5 (100%)	ND	0
Sites in A state	2 (28%)		5 (100%)					0	0	0	0	0	0		5 (100%)
Sites in B state	0		0					1 (17%)	0	0	2 (25%)	1 (10%)	0		0
Sites in C state	0		0					3 (50%)	6 (100%)	2 (40%)	2 (25%)	5 (45%)	0		0
Sites in D state	0		0					2 (33%)	0	3 (60%)	4 (50%)	5 (45%)	0		0
Maintain	*Note: the deep glacial lakes are reported in both natural state and deep lakes. In 2010 natural state also includes Lake Sheila and Calder on Stewart Island*			NA			NA			NA			NA		
Improve 1 state															
Improve 2 states															
Improve 3 states															

Table 41: Nitrate (toxicity) attribute state bands by lake class[30]. No draft freshwater objective has been set for this attribute.



Baseline year	2010	2016	2019	2010	2016	2019	2010	2016	2019	2010	2016	2019	2010	2016	2019
Sites in A state	7 (100%)	ND	5 (100%)	ND			ND	6 (100%)	6 (100%)	1 (20%)	5 (63%)	10 (91%)	5 (100%)	ND	5 (100%)
Sites in B state	0		0					0	0	4 (80%)	3 (37%)	1 (9%)	0		0
Sites in C state	0		0					0	0	0	0	0	0		0
Sites in D state	0		0					0	0	0	0	0	0		0
Maintain	*Note: the deep glacial lakes are reported in both natural state and deep lakes. In 2010 natural state also includes Lake Sheila and Calder on Stewart Island*			NA			NA			NA			NA		
Improve 1 state															
Improve 2 states															
Improve 3 states															

[30] The data for brackish lakes and lagoon is spread across the B to D bandings. The higher bandings, in general, are related to Waituna Lagoon under conditions where it is closed to the sea.

Table 42: Ammonia (toxicity) attribute state bands by lake class and the level of improvement required to meet the draft freshwater objective[31].

Class	Natural State Lakes			Upland Shallow Lakes			Lowland Shallow Lakes			Brackish Lakes & Lakes			Deep Lakes		
Objective state	No change			B			C			C			B		
A attribute State															
B attribute State															
C Attribute State															
D Attribute State															
Baseline year	2010	2016	2019	2010	2016	2019	2010	2016	2019	2010	2016	2019	2010	2016	2019
Sites in A state	7 (100%)	ND	5 (100%)	ND				6 (100%)	6 (100%)	1 (20%)	5 (63%)	7 (64%)	5 (100%)	ND	5 (100%)
Sites in B state	0		0					0	0	4 (80%)	3 (37%)	4 (36%)	0		0
Sites in C state	0		0					0	0	0	0	0	0		0
Sites in D state	0		0					0	0	0	0	0	0		0
Maintain	*Note: the deep glacial lakes are reported in both natural state and deep lakes. In 2010 natural state also includes Lake Sheila and Calder on Stewart Island*			NA			NA	6	6	5	8	11	5	NA	5
Improve 1 state								0	0	0	0	0	0		0
Improve 2 states								0	0	0	0	0	0		0
Improve 3 states								0	0	0	0	0	0		0

Table 43: Dissolved oxygen (lake bottom) attribute state bands by lake class. No draft freshwater objective has been set for this attribute.

Class	Natural State Lakes			Upland Shallow Lakes			Lowland Shallow Lakes			Brackish Lakes & Lakes			Deep Lakes		
Objective state	No change			NA			NA			NA			NA		
A attribute State															
B attribute State															
C Attribute State															
D Attribute State															
Baseline year	2010	2016	2019	2010	2016	2019	2010	2016	2019	2010	2016	2019	2010	2016	2019
Sites in A state	ND			ND			ND	6 (100%)	5 (80%)	ND	7 (87%)	4 (80%)	ND		
Sites in B state								0	1 (20%)		1 (13%)	1 (20%)			
Sites in C state								0	0		0	0			
Sites in D state								0	0		0	0			
Maintain	NA			NA			NA			NA			NA		
Improve 1 state															
Improve 2 states															
Improve 3 states															

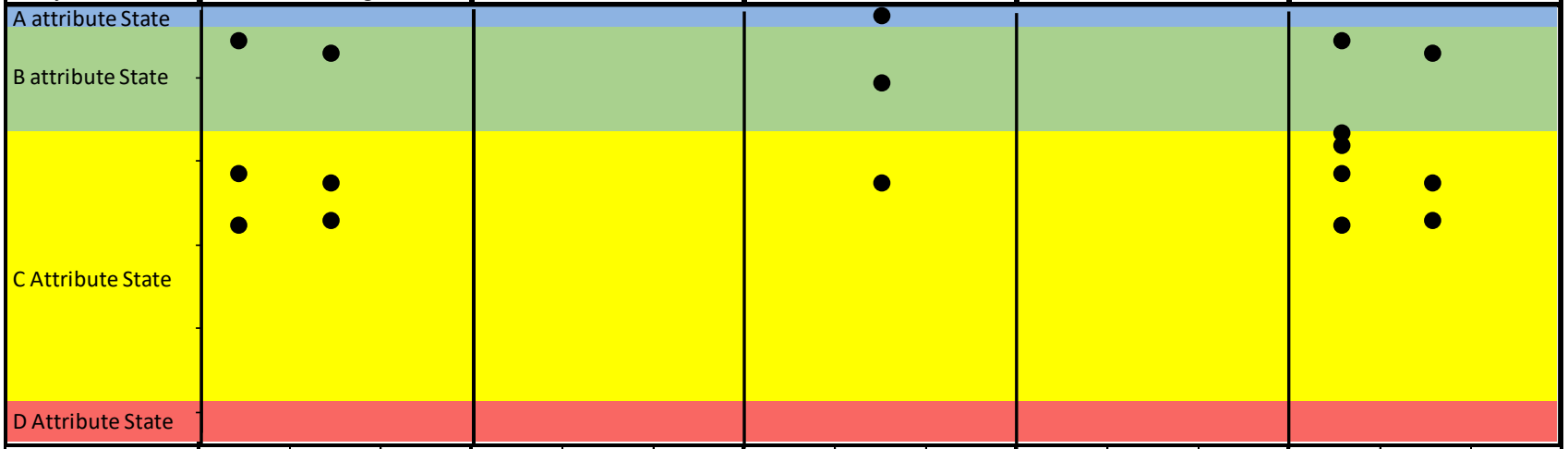
Table 44: Trophic state (LakeSPI) attribute state bands by lake class. No draft freshwater objective has been set for this attribute.

Class	Natural State Lakes			Upland Shallow Lakes			Lowland Shallow Lakes			Brackish Lakes & Lakes			Deep Lakes		
Objective state	No change			NA			NA			NA			NA		
A+ attribute State															
A attribute State															
B Attribute State															
C Attribute State															
D Attribute State															
Baseline year	2010	2016	2019	2010	2016	2019	2010	2016	2019	2010	2016	2019	2010	2016	2019
Sites in A^{+} state	0	0	ND	ND			ND	1 (33%)	ND	ND			0	0	ND
Sites in A state	0	0						0					0	0	
Sites in B state	2 (67%)	1 (33%)						2 (33%)					4 (80%)	1 (33%)	
Sites in C state	1 (33%)	2 (67%)						0					1 (20%)	2 (67%)	
Sites in D state	0	0						0					0	0	
Maintain	*Note: the deep glacial lakes are reported in both natural state and deep lakes. In 2010 natural state also includes Lake Sheila and Calder on Stewart Island*			NA			NA			NA			NA		
Improve 1 state															
Improve 2 states															
Improve 3 states															

Table 45: Submerged plants (nativeness) attribute state bands by lake class. No draft freshwater objective has been set for this attribute.

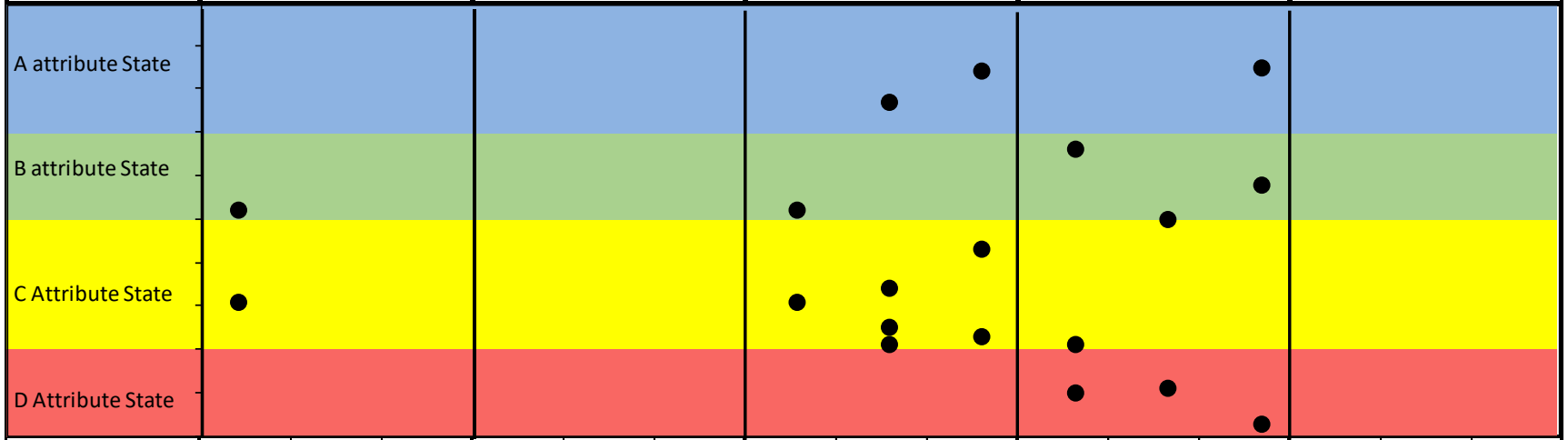
Class	Natural State Lakes			Upland Shallow Lakes			Lowland Shallow Lakes			Brackish Lakes & Lakes			Deep Lakes		
Objective state	No change			NA			NA			NA			NA		
A attribute State															
B attribute State															
C Attribute State															
D Attribute State															
Baseline year	2010	2016	2019	2010	2016	2019	2010	2016	2019	2010	2016	2019	2010	2016	2019
Sites in A state	0	0	ND	ND			ND	1 (33%)	ND	ND			0	0	ND
Sites in B state	0	0						2 (67%)					2 (40%)	0	
Sites in C state	3 (100%)	3 (100%)						0					3 (60%)	3 (100%)	
Sites in D state	0	0						0					0	0	
Maintain	*Note: the deep glacial lakes are reported in both natural state and deep lakes. In 2010 natural state also includes Lake Sheila and Calder on Stewart Island*			NA			NA			NA			NA		
Improve 1 state															
Improve 2 states															
Improve 3 states															

Table 46: Submerged plants (invasive species) attribute state bands by lake class. No draft freshwater objective has been set for this attribute.



Class	Natural State Lakes			Upland Shallow Lakes			Lowland Shallow Lakes			Brackish Lakes & Lakes			Deep Lakes		
Objective state	No change			NA			NA			NA			NA		
Baseline year	2010	2016	2019	2010	2016	2019	2010	2016	2019	2010	2016	2019	2010	2016	2019
Sites in A state	0	0	ND	ND			ND	1 (33%)	ND	ND			0	0	ND
Sites in B state	2 (67%)	1 (33%)						1 (33%)					2 (40%)	1 (33%)	
Sites in C state	1 (33%)	2 (67%)						1 (33%)					3 (60%)	2 (67%)	
Sites in D state	0	0						0					0	0	
Maintain	*Note: the deep glacial lakes are reported in both natural state and deep lakes. In 2010 natural state also includes Lake Sheila and Calder on Stewart Island*			NA			NA			NA			NA		
Improve 1 state															
Improve 2 states															
Improve 3 states															

Table 47: Macrophytes attribute state bands by lake class. No draft freshwater objective has been set for this attribute.



Class	Natural State Lakes			Upland Shallow Lakes			Lowland Shallow Lakes			Brackish Lakes & Lakes			Deep Lakes		
Objective state	No change			NA			NA			NA			NA		
Baseline year	2010	2016	2019	2010	2016	2019	2010	2016	2019	2010	2016	2019	2010	2016	2019
Sites in A state	0	ND	ND	ND			0	1 (25%)	1 (33%)	0	0	1 (33%)	ND		
Sites in B state	1 (50%)						1 (50%)	0	0	1 (33%)	1 (33%)	1 (33%)			
Sites in C state	1 (50%)						1 (50%)	3 ('75%)	2 (67%)	1 (33%)	0	0			
Sites in D state	0						0	0	0	1 (33%)	1 (33%)	1 (33%)			
Maintain	*Note: the deep glacial lakes are reported in both natural state and deep lakes. In 2010 natural state also includes Lake Sheila and Calder on Stewart Island*			NA			NA			NA			NA		
Improve 1 state															
Improve 2 states															
Improve 3 states															

Table 48: *E. coli* attribute state bands by lake class and the level of improvement required to meet the draft freshwater objective[32].

Class	Natural State Lakes			Upland Shallow Lakes			Lowland Shallow Lakes			Brackish Lakes & Lakes			Deep Lakes		
Objective state	No change			A			B			B			A		
A attribute State															
B attribute State															
C Attribute State															
D Attribute State															
E Attribute State															
Baseline year	2010	2016	2019	2010	2016	2019	2010	2016	2019	2010	2016	2019	2010	2016	2019
Sites in A state	2 (100%)	2 (100%)	2 (100%)	ND			ND	ND	5 (80%)	ND	ND	7 (64%)	2 (100%)	2 (100%)	2 (100%)
Sites in B state	0	0	0						0			1 (9%)	0	0	0
Sites in C state	0	0	0						0			0	0	0	0
Sites in D state	0	0	0						1 (20%)			3 (27%)	0	0	0
Sites in E state	0	0	0						0			0	0	0	0
Maintain	*Note: the deep glacial lakes are reported in both natural state and deep lakes. In 2010 natural state also includes Lake Sheila and Calder on Stewart Island*			NA			ND	ND	5	ND	ND	8	2	2	2
Improve 1 state									0			0	0	0	0
Improve 2 states									1			3	0	0	0
Improve 3 states									0			0	0	0	0

[32] Note: the *E. coli* state is determined by 4 statistics the graphs represents the relative position in the banding and has been scaled to provide a visual representation of state, the state was determine on the poorest statistic as shown in Table 22.

Table 49: Cyanobacteria attribute state bands by lake class. No draft freshwater objective has been set for this attribute.

Class	Natural State Lakes			Upland Shallow Lakes			Lowland Shallow Lakes			Brackish Lakes & Lakes			Deep Lakes		
Objective state	No change			NA			NA			NA			NA		
A attribute state	Not applicable														
B attribute state															
C attribute state															
D attribute state															
Baseline year	2010	2016	2019	2010	2016	2019	2010	2016	2019	2010	2016	2019	2010	2016	2019
Sites in A state	ND	ND	2 (100%)	ND			ND	ND	2 (100%)	ND	ND	1 (50%)	ND	ND	2 (100%)
Sites in B state			0						0			0			0
Sites in C state			0						0			1 (50%)			0
Sites in D state			0						0			0			0
Maintain	NA			NA			NA			NA			NA		
Improve 1 state															
Improve 2 states															
Improve 3 states															

5 Summary and recommendations

The purpose of this report is to contribute to the process of developing draft freshwater objectives for consideration by Environment Southland's Council and the Te Ao Marama board. This report is one of a number of supplementary reports and memos that contribute to the report titled: *Developing Draft Freshwater Objectives for Southland* (Norton and Wilson, 2019) and: *Current Environmental State and the "Gap" to Draft Freshwater Objectives for Southland* (Norton et. al., 2019).

This report explains:

- The rationale for the **lake classification** proposed to be used in developing freshwater objectives in Southland:
- A description of the **lake attributes** proposed to be used for numeric freshwater objectives, to support the values of 'Human Health for Recreation' and 'Ecosystem Health', along with the associated attribute state option tables; and,
- A summary of the tabulation of data used to **assess attribute state** for 2010, 2016 and 2019 (current state).

The recommendations for each of these are described in further detail in the following sections.

5.1 Recommended lake classification

The Regional Water Plan for Southland (2010) introduced surface water body classes with associated water quality standards that were taken through largely unchanged into the pSWLP. The classes identified for Southland lakes are:

- Natural state;
- Mataura 3 (from the Water Conservation (Mataura River) Order 1997);
- Lowland/Coastal Lakes and Wetlands;
- Hill Lakes and Wetlands; and,
- Mountain Lakes and Wetlands.

A number of issues were identified with this classification (see Table 1). A key issue is that these lake classes are not based on the physical characteristics of lakes (mixing and depth) that would influence water quality and the attributes included in the water quality standards in the pSWLP are set for rivers and are not directly applicable to lakes. It is therefore recommended that the lake classes are amended to the following, based on their physical characteristics:

- Natural state;
- Lowland shallow lakes;
- Upland shallow lakes;
- Brackish lakes and lagoons; and,
- Deep lakes.

5.2 Recommended lake attributes

The NPS-FM (2017) sets out a number of compulsory attributes and requires regional councils to develop additional attributes relevant to their region and local values. Table 50 provides a summary of the attributes proposed for Southland lakes, developed for the two national compulsory values of ecosystem health and human health for recreation. While the attributes proposed are only attributed to 2 of the 20 community values identified in Wilson et al., (2019), these attributes will, to some degree, reflect many of the other values identified including mahinga kai. Numeric and/or narrative attribute state option tables have been developed for each of these attributes.

Table 50: Summary of proposed lake attributes for Southland's freshwater objectives.

Ecosystem health	Human health for recreation
National compulsory attributes	
Phytoplankton	*Escherichia coli* (*E. coli*)
Total phosphorus	Cyanobacteria
Total nitrogen	
Ammonia (toxicity)	
Proposed Southland attributes for numeric freshwater objectives	
Trophic level index	*Escherichia coli* (*E. coli*) at popular bathing sites
Macrophytes	
Dissolved oxygen (lake bottom)*	
Dissolved oxygen (mid-hypolimnetic)*	
Nitrate (toxicity)	
Trophic state (LakeSPI)	
Submerged plants (nativeness)*	
Submerged plants (invasive species)*	
Additional attributes existing in regional plans	
Odour	
Bacterial or fungal growths	
Edible species	
Proposed Southland attributes for narrative freshwater objectives	
Lake margin habitat	
Aquatic marginal habitat	
Native fish	

*These attributes have been included because they are recommended as new attributes for the National Objectives Framework in the draft NPS-FM (2019).

Where water quality standards for these attributes exist in the pSWLP, they have been used to set a draft freshwater objective.

5.3 Attribute state assessment

The NPS-FM (2017) requires water quality to be 'maintained or improved'. Therefore, knowledge of current state is required in order to ensure no deterioration occurs. An assessment of attribute state was undertaken for each attribute for three time periods (2010, 2016 and 2019) with data being assessed at three spatial scales (sites within lakes, lakes and lake classes). The results from the attribute state assessment have been used to inform the *Current Environmental State and the "Gap" to Draft Freshwater Objectives for Southland* report (Norton et. al., 2019) where the draft freshwater

objectives were refined to include the 'maintain or improve' requirement of the NPS-FM. Further commentary on the lake attribute state results are provided in this report.

5.4 Other recommendations

Once the process for establishing freshwater objectives for Southland has been completed, it is recommended that a review of the Southland lake monitoring programme be undertaken to ensure it aligns with any changes in approach to the management of land and water in the region.

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Appendix 1

Data analysis output for lakes including grading and graphs for each attribute can be found within Environment Southland's document management system at: Southland Lakes Data Analysis State and Gap Report Oct_2019 (A550425)

Comparison of whether the data analysis met the statistical criteria outlined in **Error! Reference source not found.** 22. Denoted by 'TRUE' if the condition was met and 'FALSE' if the condition was not met can be found within Environment Southland's document management system at: Statistical Criteria for State and Gap Analysis - Lakes Oct_2019 (A552242)