BEFORE THE ENVIRONMENT COURT
I MUA I TE KOOTI TAIAO O AOTEAROA

UNDER	the Resource Management 1991
IN THE MATTER	of of appeals under Clause 14 of the First Schedule of the Act
BETWEEN	**TRANSPOWER NEW ZEALAND LIMITED** (ENV-2018-CHC-26)
	FONTERRA CO-OPERATIVE GROUP (ENV-2018-CHC-27)
	HORTICULTURE NEW ZEALAND (ENV-2018-CHC-28)
	ARATIATIA LIVESTOCK LIMITED (ENV-2018-CHC-29)
	WILKINS FARMING CO (ENV-2018-CHC-30)

(Continued next page)

STATEMENT OF EVIDENCE OF ROGER HODSON ON BEHALF OF THE SOUTHLAND REGIONAL COUNCIL
14 December 2018

Judicial Officer: Judge Borthwick and Judge Hassan

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(ENV-2018-CHC-31)

DAIRYNZ LIMITED
(ENV-2018-CHC-32)

H W RICHARDSON GROUP
(ENV-2018-CHC-33)

BEEF + LAMB NEW ZEALAND
(ENV-2018-CHC-34 & 35)

DIRECTOR-GENERAL OF CONSERVATION
(ENV-2018-CHC-36)

SOUTHLAND FISH AND GAME COUNCIL
(ENV-2018-CHC-37)

MERIDIAN ENERGY LIMITED Act 1991
(ENV-2018-CHC-38)

ALLIANCE GROUP LIMITED
(ENV-2018-CHC-39)

FEDERATED FARMERS OF NEW ZEALAND
(ENV-2018-CHC-40)

HERITAGE NEW ZEALAND POUHERE TAONGA
(ENV-2018-CHC-41)

STONEY CREEK STATION LIMITED
(ENV-2018-CHC-42)

THE TERRACES LIMITED
(ENV-2018-CHC-43)

CAMPBELL'S BLOCK LIMITED
(ENV-2018-CHC-44)

ROBERT GRANT
(ENV-2018-CHC-45)

SOUTHWOOD EXPORT LIMITED, SOUTHLAND PLANTATION FOREST COMPANY OF NZ, SOUTHWOOD EXPORT LIMITED
(ENV-2018-CHC-46)

TE RUNANGA O NGAI TAHU, HOKONUI RUNAKA, WAIHOPAI RUNAKA, TE RUNANGA O AWARUA & TE RUNANGA O ORAKA APARIMA
(ENV-2018-CHC-47)

PETER CHARTRES
(ENV-2018-CHC-48)

RAYONIER NEW ZEALAND LIMITED
(ENV-2018-CHC-49)

ROYAL FOREST AND BIRD PROTECTION SOCIETY OF NEW ZEALAND
(ENV-2018-CHC-50)

Appellants

AND **SOUTHLAND REGIONAL COUNCIL**

Respondent

Introduction

1 My full name is Roger John William Hodson.

2 I am an Environmental Scientist – Surface Water Quality at the Southland Regional Council (**Council**).

3 I have worked as an Environmental Scientist – Surface Water Quality since November of 2012. Prior to this I worked for 3 years as an Environmental Technical Officer – Living Streams for the Council.

4 I hold a Bachelor of Applied Science with a major in Environmental Management, with 1st Class Honours from the University of Otago.

5 My work for the Council includes: technical input to the proposed Southland Water and Land Plan (**pSWLP**) development process, running the Southland Regional State of Environment river water quality and ecosystem health monitoring programs, as well as reporting to the Council and community on those same programs. I am, and have been involved, in national working groups to contribute to the development of National Environmental Monitoring Standards, for discrete river water quality sampling, and periphyton monitoring protocols.

6 My involvement in the pSWLP to date has included: technical input to the pSWLP development process; updated state and trend analysis of Council data sets; presentation of evidence to the pSWLP hearing and response to commissioners' questions.

7 I have been asked by the Council to prepare evidence for these proceedings.

Code of Conduct

8 I confirm that I have read the Code of Conduct for expert witnesses as contained in the Environment Court Practice Note 2014. I have complied with the Code of Conduct when preparing my written statement of evidence, and will do so when I give oral evidence.

9 The data, information, facts and assumptions I have considered in forming my opinions are set out in my evidence. The reasons for the opinions expressed are also set out in my evidence.

10 Other than where I state I am relying on the evidence of another person, my evidence is within my area of expertise. I have not omitted to

consider material facts known to me that might alter or detract from the opinions that I express.

Scope

11 I have been asked by the Council to provide evidence in relation to the state of the environment in Southland, specifically relating to rivers and streams. My evidence addresses:

(a) An overview of surface water bodies in the Southland Region;

(b) Contaminants affecting water quality;

(c) River and stream State of Environment monitoring;

(d) Current state of and trends in surface water quality and freshwater ecosystem health with respect to:

(i) Ecosystem health:

(1) Macroinvertebrates;

(2) Periphyton;

(3) Nitrate Nitrite Nitrogen (**NNN**);

(4) Ammonia; and

(5) Dissolved reactive phosphorus;

(ii) Human health:

(1) E.coli; and

(2) Toxic algae.

12 In preparing this evidence, I have read and considered a number of documents, which are referenced throughout my evidence, and a complete list of references is set out at the end of my evidence (after the Appendices).

Executive Summary - state and water quality trends in rivers and streams

13 Data and reports[1] published from the Council's State of Environment (**SoE**) monitoring networks data sets show several consistent themes:

(a) Non-point source agricultural inputs, such as leaching and runoff, are the main source of nutrient contaminants in Southland's rivers;

(b) There is elevated microbial contamination in lowland rivers and streams, resulting in a high risk to human health;

(c) A spatial pattern of elevated concentrations of NNN[2] concentration:

(i) With concentration increasing from headwaters downstream in the four main catchments; and

(ii) Elevated concentrations in small catchments with higher proportions of developed land and/or Old Mataura, Central Plains and Oxidising physiographic zones vulnerable to the loss of nitrate nitrite nitrogen;

(d) NNN trends for the 17 year time period from January 2000 to December 2016 illustrate deteriorating concentrations at 15 of 34 and 4 of 6 sites with sufficient data, operated by the Council and NIWA respectively, and improvements in concentration at 2 of 34, and 1 of 6 sites operated by the Council and NIWA respectively, with trends at the balance of sites being indeterminate;

(e) Nuisance growths of benthic periphyton in the lower Mataura, Aparima and Waiau Rivers and several other lowland streams; and

(f) Macroinvertebrate community health standards are not met at about 20% of sites.

Overview of surface water bodies in the Southland Region

14 Southland is New Zealand's southernmost region and includes much of Murihiku (the southern part of the South Island). The region (including

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1 Including: Environment Southland, (2000); Environment Southland and Te Ao Marama Incorporated (2010); Snelder et al. (2014); Environment Southland (2016(b)); Kitto and Hodson (2016); Hodson et al (2017).

2 As set out in my evidence below, NNN is the concentration of nitrogen that is present in the form of Nitrite (NO_2^-) and Nitrate (NO_3^-), and is referred by Land Air Water Aotearoa as Total Oxidised Nitrogen.

Rakiura/Stewart Island and other offshore islands) has a total land area of 3.2 million hectares.

15 Over half (approximately 59%) of the region is covered by indigenous vegetation (including alpine areas where there may be little vegetative cover). Fiordland and Stewart Island comprise 42.3% of the region.

16 Approximately 38% of the region's land area is developed. The developed areas have been extensively modified with the clearance of native forests and vegetation, the drainage of wetlands and lowland soils, the introduction of improved pasture, and the straightening of the rivers. The remaining 3% of the region's 'land' area is accounted for by surface water bodies.

17 Southland contains a large amount of freshwater, both as surface water and groundwater. The region has six of New Zealand's 25 largest lakes (as measured by surface area), including Lakes Te Anau, Manapōuri, and Hauroko (which are also New Zealand's three deepest lakes). The Waiau, Aparima, Ōreti, and the Mataura Rivers are the four main rivers draining areas of developed land. Together the catchments of these four rivers drain 1.85 million hectares or 62% of the Southland mainland. Numerous other rivers and streams drain the remaining land area directly to the coast, including Waituna Creek, Waimatuku Stream, and the Waikawa, Waihopai, and Pourakino Rivers.[3]

18 In lowland Southland, the pre human wetland extent has been estimated to have been 450,985 hectares[4]. Wetlands have been drained using extensive networks of open surface as well as tile and mole drains for the development of agriculture. The draining of wetlands has increased pressure on the environment by making more land available for agricultural, while reducing the environment's natural capacity to attenuate nutrient losses from this land. The installation of tile and mole drains has created direct channels (or pathways) for losses of nutrients to enter surface water, bypassing some natural processes. The drainage of wetlands, and lowland soils more generally, has changed the regional hydrology across lowland areas so that there is comparatively little time

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3 Moran et al 2017.

4 Ausseil A-G.E., Gerbeaux P., Chadderton W.L., Stephens T., Brown D., and Leathwick J. 2008: Wetland ecosystems of national importance for biodiversity: criteria, methods, and candidate list of nationally important inland wetlands. Landcare Research Contract Report LC0708/158. Prepared for the Department of Conservation.

for substances, such as nutrients, to be attenuated (e.g. taken up by plants or transformed to other forms) before they reach waterways.

19 In addition, shallow groundwater aquifers exchange groundwater to surface water relatively quickly. Approximately 47% of all of the water in Southland streams is groundwater from shallow groundwater aquifers (the mean base flow index for Southland is around 0.47). However, it is highly variable across the region, with lowland streams having a much higher proportion of groundwater than alpine streams.[5]

20 The consequences of the quick exchange between groundwater and surface water is that there is often limited natural water storage in areas of developed land, and nutrient losses move through the landscape rapidly (i.e. there are short lag times). Accordingly, the modification of Southland's lowland hydrology favours the rapid transport of nutrients, sediment, and microbes to waterways, reducing the time for natural processes to attenuate these substances before reaching waterbodies.

21 The region's freshwater flows into numerous estuaries before entering Foveaux Strait, or the enclosed waters of Fordland and into the Southern Ocean. There are four basic types of estuaries: tidal lagoons (e.g. New River Estuary), tidal rivers (e.g. Waimatuku), coastal embayments (e.g. Bluff Harbour) and fiords (e.g. Milford Sound). In Southland, tidal lagoon estuaries dominate within the developed river catchments and they contain high levels of biodiversity and tend to retain loads of nutrients and fine sediments. Some tidal lagoons and tidal river estuaries have mouths that intermittently close and open (e.g. Waituna Lagoon).

22 A map set out in **Appendix 1** depicts the Southland region, including the major surface water bodies (rivers, lakes, and estuaries), as well as the State Highways, and Invercargill City, and towns.

23 Under the National Policy Statement for Freshwater Management (**NPSFM**, (2014)) Council divided the region spatially into five Freshwater Management Units (**FMUs**). The FMUs are the geographical areas where community processes will occur. They are larger than their name sake waterbodies as they incorporate adjacent watersheds draining directly to the coast. Limits on the use of freshwater in each

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5 Rissmann et al., (2012); Liquid Earth (2011)).

FMU will be based on the community's objectives for water, including ecosystem health and human health. Running from West to East, Southland's five FMUs are: Fiordland and Islands; Waiau; Aparima; Ōreti; and Mataura. The five FMUs are illustrated on the map in **Appendix 1**.

Contaminants affecting water quality

24 The main contaminants impacting Southland's freshwater quality are nutrients (nitrogen and phosphorus), fine sediment, and disease-causing micro-organisms (referred to as microbes[6]).

25 Elevated nutrient concentrations can drive nuisance plant growth and be toxic to aquatic organisms and have negative health effects for humans.

26 Nuisance aquatic algal growth, and excessive macrophyte (aquatic plant) growth in turn, can drive high instream plant biomass and can result in changes to pH, and dissolved oxygen, a process termed eutrophication. Typical responses can range from losses of plant, invertebrate and fish biodiversity, shifts in plant species composition and relative abundance, and increased algal productivity.

27 Within my evidence the term "nutrients" includes the plant available forms of nitrogen and phosphorous. For clarity, the various forms are explained below.

Nitrogen

28 Nitrogen can be present in an aquatic environment in a variety of forms and oxidation states. Both the oxidized and reduced inorganic nitrogen species (being Nitrite (NO_2^-), Nitrate (NO_3^-), ammonium (NH_4^+), ammonia (NH_3)) and organic nitrogen fractions (being dissolved organic nitrogen (DON) and particulate organic nitrogen (PON)) are commonly found in all freshwater, estuarine, and coastal waters.

29 Nitrate, nitrite, ammonium, and DON are directly available for plant uptake, supporting production in both the algal and higher plant communities.

30 Hereafter the forms of nitrogen discussed are:

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6 *Escherichia coli (E.coli*) levels are used as an indicator of the risk to human health.

(a) The form of nitrogen I refer to is Nitrate Nitrite Nitrogen (**NNN**). NNN is the concentration of nitrogen that is present in the form of Nitrite (NO_2^-) and Nitrate (NO_3^-), and is referred by Land Air Water Aotearoa (**LAWA**) as Total Oxidised Nitrogen (**TON**);

(b) Ammoniacal Nitrogen, which includes two forms of nitrogen: ammonia (NH_3) and ammonium (NH_4^+).

31 NNN is the measure of nitrate the Council has historically tested and recorded in surface water environments. NNN is used as it provides the longest duration of consistent records for trend analysis and nitrite concentrations are typically a very small proportion of NNN in oxidised surface water environments.[7]

Phosphorus

32 Dissolved reactive phosphorus (**DRP**), is the form of phosphorus immediately available to support algae and plant growth. As set out above, elevated DRP can drive nuisance plant growth.

33 DRP generally enters freshwater bodies via quick flow pathways eg in soil zone drainage waters, or runoff.

Fine sediment

34 Fine sediment is a pervasive contaminant in freshwater environments in and of itself. It alters the physical condition of stream habitat, by filling in the interstitial[8] spaces and smothering benthic surfaces, altering macroinvertebrate community composition. It can alter stream chemistry and act as a source of nutrients to drive eutrophication. It also makes waterbodies less attractive and less safe for recreation.

Microbes

35 Freshwater in Southland is commonly used for recreational activities, such as swimming and boating. Poor water quality can have negative effects on human health, as well as lost opportunities for recreation and commercial use of water.

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7 This is because NNN is nitrate-nitrogen plus nitrite-nitrogen. However, nitrite-nitrogen is a very small portion (if present at all) of NNN. Therefore, it is considered to be appropriate to make comparisons of NNN against the NOF nitrate-nitrogen toxicity attribute in the NOF.

8 The spaces between stream bed substrates

36 Risk to human health from recreational activities is usually associated with illness from exposure to microbial contamination or toxic algal blooms[9]. *Escherichia coli* (***E.coli***) levels are used as an indicator of the risk from microbial contamination sourced from faecal material.

River and stream State of Environment monitoring

37 The Council uses State of the Environment (**SOE**) monitoring programmes to assess the state of the environment and to track long-term environmental trends. SOE networks are designed to be broadly representative of the region. However, a majority of Southland SOE sites are located in areas developed for agricultural or residential land use, despite approximately 50% of Southland's land area occurring in national parks (which is generally undeveloped). Reference sites in undeveloped areas are under-represented due to difficulties in accessing remote areas and a historical tendency towards monitoring developed areas to assess the effectiveness of resource management.

38 Monitoring water quality state and trend involves measuring the physical properties of water: temperature; and visual clarity; and the chemical characteristics, such as: nutrients; pH; and dissolved oxygen levels at monthly frequency in surface waters.

39 Ecological health monitoring aims to understand spatial and temporal patterns in ecosystem health and how freshwater environments respond to contaminant stressors, such as elevated nutrient and sediment levels. On a monthly frequency (when practicable) the amount of benthic periphyton[10] growing on the bottom of a river bed is observed. Once a year during the summer period the number and type of macroinvertebrates, including small aquatic animals such as insect larvae, worms and snails[11], are used to assess 'Ecosystem health'.

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9 The NPSFM 2014, provides a framework for assessing the risk posed to human health from recreation using e.coli. In river environments, interim national guidelines are available to assess the risk to human health from benthic algae mats (MFE and MOH, 2009).

10 Called benthic periphyton. 'Benthic' refers to the bottom surface of a water body, such as a river or lake bed. 'Periphyton' refers to the complex mixture of algae, cyanobacteria, microbes, and detritus that forms a slime layer, which attaches to submerged surfaces in most aquatic ecosystems. Although benthic periphyton is an important source of food for many aquatic animals, excessive growth can reduce habitat quality and indicate high nutrient and or sediment levels.

11 Called macro-invertebrates. Defined as animals without a back-bone or spine that can be caught by using a 500µm net or sieve (i.e. visible to the naked eye without using a

40 For the purpose of describing the current state of the environment in Southland, the Council and National Institute for Water and Atmospheric Research (**NIWA**) SOE monitoring data, from Southland, is considered against the values and water quality attributes in the NPSFM or the standards in the operative Regional Water Plan (**RWP**) for Southland. The NPSFM requires the Council to assess a number of compulsory attributes of "Ecosystem Health" and "Human Health".

Current state and trend

41 This section presents the results of assessments of the state and trend (where relevant) of indicators of ecosystem and human health from Councils SoE monitoring data sets. Results are presented as they relate to the two compulsory objectives of the NPSFM:

(a) Ecosystem Health; and

(b) Human Health.

Ecosystem Health – state and trend background

42 The ecosystem health section of my evidence summarises the Council indicators used to assess ecosystem health in rivers and streams.

43 The Council's SOE reporting for rivers includes a number of indicators of ecosystem health: macroinvertebrates, benthic periphyton, NNN, ammoniacal nitrogen, and DRP. These nutrients are the most readily available to drive instream algal and macrophyte growth, which can adversely affect ecosystem health.

44 To assess current state, the Council and NIWA SOE monitoring data is considered against respective values and water quality attributes in the NPSFM or standards in the RWP and ANZECC 2000 Guidelines[12].

45 Trend analysis presented in this section is sourced from three references: Hodson and Akbaripasand 2016[13]; Hodson et al, 2017[14]; Land Air Water Aotearoa (**LAWA**)[15].

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microscope). Macro-invertebrates are sensitive to changes in their environment and are good indicators of environmental change such as increased contaminant levels.

12 Australian and New Zealand Environment and conservation Council. 2000. Australia and New Zealand guidelines for fresh and marine water quality. Townsville: Environment Australia

13 Hodson, R. and Akbaripasand, A., 2016. *State and Trends in Freshwater Macroinvertebrate Community Health in Southland.* New Zealand Fresh Water

46 Differences between the methods employed in each of the references referred to above make it difficult to make direct comparisons between the results of each. Site numbers and which specific sites are included may differ between analyses. This is as a result of different time periods being considered, variations in minimum data requirements for site inclusion, and changing approaches to the level of confidence required to determine trend.

47 Hodson and Akbaripasnad 2016 considered trends to be to be ‘strongly significant’ where certainty was 95-100% and to be ‘significant’ where certainty was 90-95%.

48 Hodson et al, 2017 required 95% or greater certainty, to determine a trend direction. Sites with less than a 95% certainty were classified as ‘indeterminate’.

49 LAWA 2018 applied a 5-category approach to determine trends. Where certainty was 90-100% a trend was determined to be ‘very likely improving’ or ‘very likely deteriorating’. Where certainty was 67-90% a trend was determined to be ‘likely’. Where confidence was less than 67% the trend was considered to be ‘indeterminate’. As a result of the use of lower levels of certainty, the proportion of sites with indeterminate trend direction for a given parameter is generally reduced.

50 In general, trend analysis from longer time periods are more robust than from shorter time periods. This is because longer time periods typically include a large number of data points and are therefore less likely to be influenced by short term variations in climate or other factors.

51 I discuss below the current state and trend for the following indicators of ecosystem health: macroinvertebrates, benthic periphyton, NNN, ammoniacal nitrogen, and DRP.

Conference Proceedings, Invercargill. http://www.es.govt.nz/Document%20Library/Presentations/Science%20Conference%20Posters%202016/State%20and%20Trends%20in%20Freshwater%20Macroinvertebrate%20Community%20Health%20in%20Southland.pdf

[14] Hodson R., Dare J., Merg M., Couldrey, M. (2017), Water Quality in Southland: Current State and Trends. Environment Southland publication No: 2017-04.

[15] www.lawa.org.nz

Macroinvertebrates – state

52 Macroinvertebrates provide an important food source to fish and birds. They provide a good indicator of ecosystem health due to their limited range of movement and life-cycles which expose them to ambient and seasonally variable water quality conditions. Some taxa are more sensitive to contaminants than others.

53 The Macroinvertebrate Community Index (**MCI**) is a tool for assessing water quality. Different macroinvertebrate taxa are assigned a tolerance score based on their tolerance to contaminants. The index is then calculated by summing the scores for all species present at a site.

54 A higher MCI score generally indicates a healthier stream. Generally, MCI scores range from >150 (very good water quality) to as low as 20 (very poor water quality). National guidelines are commonly used to interpret MCI scores.[16]

55 The RWP and pSWLP include spatially differentiated standards for MCI scores. From higher standards in Mountains areas to lower standards in Lowland Soft Bed areas. The MCI standards in order from highest to lowest are Mountains, Hill, Lowland Hard Bed, Lakes and Spring Fed, Lowland Soft Bed (see Table 1).

Table 1 - RWP and pSWLP	
MCI standards for Southland RWP management unit	**Standard**
Natural state	NA
Mountains	120
Hill	100
Lowland Hard Bed	90
Lakes	90
Spring Fed	90
Lowland Soft Bed	80

56 Snelder et al[17] (2014), found a high level of non-compliance with RWP standards for MCI in Lowland hard Bed and Spring Fed sites.

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16 Stark and Maxted 2007.

17 Snelder, T., Fraser, C., Hodson,R., Ward, N., Rissmann, C., Hicks, A., 2014. *Regional Scale Stratification of Southland's Water Quality – Guidance for Water and Land Management.* Prepared for southland regional council by Aqualinc Research Limited, Report No: C13055/22, March 2014.

57 The national MCI quality classification of poor (defined as MCI <80) is exceeded at 7 out of 52 sites included in Environment Southland[18] (2016b) and Kitto and Hodson[19], (2016). Sites with both MCI data and water quality were included in these publications.[20] All sites with adequate data are discussed in Hodson and Akbaripasand (2016).[21]

58 Consideration of the state of the MCI in Southland for all sites with adequate data during the time period 2010 – 2014, shows that RWP standards for MCI are not met at about 23% (19 of 81) sites in Southland[22]. This is illustrated on the maps in **Appendix 2**(**a and b**)[23].

Macroinvertebrates - trend

59 For the time period 1996 to 2014, 26% (19 of 72) of the Council's monitored sites had strongly significant deteriorating macroinvertebrate community index score trends. 3% (2 of 72) of sites were considered to have significant deteriorating trends. A trend direction was unable to be determined with confidence for 71 % (51 of 72) of sites. No sites showed improving trends[24]. This is illustrated on the map in **Appendix 2(c)**.

60 The LAWA 2018 trend analysis of MCI for the 10-year time period 2008 – December 2017 indicates that of the 36 sites were assessed, 4 (11%) were very likely to be degrading, 8 (22%) were likely to be degrading, 14 (38%) were indeterminate, 7 (19%) were likely to be improving and 3 (8%) were very likely to be improving (see **Appendix 14**).

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18 Environment Southland, 2016(b), *Water Quality in Southland,* *http://www.es.govt.nz/Document%20Library/Factsheets/Other%20factsheets/Water%20Quality%20in%20Southland%20web.pdf*

19 Kitto, J. and Hodson, R.J.W. 2016, Water quality state and trends for southland. Dairy New Zealand Poster. 2016 New Zealand Fresh Water Conference Proceedings, Invercargill.

20 Accordingly, the publication presents a limited spatial extent (some sites not illustrated) because they are not coincidental to location of water quality data.

21 Hodson, R. and Akbaripasand, A., 2016. *State and Trends in Freshwater Macroinvertebrate Community Health in Southland.* New Zealand Fresh Water Conference Proceedings, Invercargill at paragraph 48.

22 To enable a comprehensive regional analysis the Mataura 1, 2 & 3 water bodies were considered against the equivalent RWP management unit MCI standards, eg Mountain, Hill, Lowland Hard Bed, Lowland Soft Bed, or Spring Fed.

23 Hodson, R. and Akbaripasand, A., 2016. *State and Trends in Freshwater Macroinvertebrate Community Health in Southland.* New Zealand Fresh Water Conference Proceedings, Invercargill. http://www.es.govt.nz/Document%20Library/Presentations/Science%20Conference%20Posters%202016/State%20and%20Trends%20in%20Freshwater%20Macroinvertebrate%20Community%20Health%20in%20Southland.pdf

24 Hodson and Akbaripasand (2016).

Periphyton – state

61 In river and stream environments, periphyton most commonly grows on bottom (benthic) substrates as either ‘mats’ or long filaments. Periphyton is an important source of food for invertebrates, which in turn provide food for fish and birds. However, high or nuisance levels of periphyton put stress on aquatic ecosystems by smothering habitat, altering invertebrate communities and driving adverse fluctuations in dissolved oxygen and pH. High levels of periphyton can also alter water colour, odour and the physical nature of the river bed, having a negative impact on aesthetic and human uses of a river.

62 The NPSFM National Objectives Framework (**NOF**) sets a national bottom line for benthic periphyton cover, of 200 mg/m^2, and allows for frequency of exceedance to be used in the assessment. One exceedance per year (1 month in 12 is approximately 8% of the time) is allowed for, and two exceedances per year in productive classes[25].

63 In 2014[26] annual frequency summer monitoring data was used to develop predictive models of periphyton cover in Southland rivers. Results indicated that breaches of the national bottom line were likely to occur in the lower reaches of the main stem of the Mataura River and tributaries of the Aparima, Oreti, Waimatuku and Makarewa Rivers.

64 Subsequent assessments by the Council and Dairy New Zealand scientists[27] showed that eight sites were unlikely to meet the national bottom line for periphyton. This is illustrated in **Appendix 3** and in Table 2.

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25 Productive Class is defined in the NPSFM as the combination of REC “Dry” Climate categories (i.e. Warm-Dry (WD) and Cool-Dry (CD)) and REC Geology categories that have naturally high levels of nutrient enrichment due to their catchment geology (i.e. Soft-Sedimentary (SS), Volcanic Acidic (VA) and Volcanic Basic (VB)).

26 Snelder, T., Fraser, C., Hoson,R., Ward, N., Rissman, C., Hicks, A., 2014. *Regional Scale Stratification of Southland’s Water Quality – Guidance for Water and Land Management.* Prepared for southland regional council by Aqualinc Research Limited, Report No: C13055/22, March 2014.

27 Kitto, J. and Hodson, R.J.W. 2016, Water quality state and trends for southland. Dairy New Zealand Poster. 2016 New Zealand Fresh Water Conference Proceedings, Invercargill.

Table 2: Sites not likely to meet the national bottom line for periphyton based on Kitto and Hodson (2016) and Environment Southland (2016b)
Site Name
Mataura River at Seaward Downs
Mataura River 200 m ds Mataura Bridge
Waimea River at Mandeville
Waikaka Stream at Gore
Aparima River at Thornbury
Otautau Stream at Otautau Tuatapere Highway
Winton Stream at Lochiel
Makarewa River at Wallacetown

65 In 2018, Council used up to 3 years (December 2014 – December 2017) of monthly benthic chlorophyll a data from 30 sites, from 27 different rivers and streams, to provide a revised assessment of the state of periphyton in Southland.

66 The data set included observations of periphyton as: benthic chlorophyll-a; Ash Free Dry Matter (AFDM biomass); percentage cover of long filamentous algae; percentage cover of diatom and cyanobacteria algae, collected at monthly frequency, with missing data for some months. Monthly frequency data was assessed against the National Objectives Framework in the NPSFM, RWP and pSWLP standards for periphyton[28].

67 Hodson and De Silva (2018) analysed monthly frequency (December 2014 – December 2017) benthic chlorophyll-a data collected in run habitat[29] from 30 sites. The approach used the site mean to estimate the level of benthic chlorophyll-a exceeded one or two months per year using the exponential distribution. The exponential distribution is described by a single parameter, the measured site mean chlorophyll-a. By setting the probability of exceedance to 1/12 or 2/12, the exponential distribution can be used to estimate the 92nd or 83rd percentile concentration for assessment against the NOF attribute for benthic chlorophyll-a.

68 The analysis illustrated that all sites (30 sites within 27 different streams and rivers) are likely to be within the NOF band range of A – C. While

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28 Hodson and De Silva (2018) Assessing the State of Periphyton in outland Streams and Rivers. Environment Southland Publication No 2018-19.

29 Being the mesohabitat where observations are made.

none of the sites fell into band D (i.e., below the national bottom line), seven sites (23%) had a 95% upper prediction interval value in the D band, Table 3. All 30 sites are illustrated in **Appendix 4**. Sites with upper 95% prediction interval higher than the D band are considered to be at risk of failing to meet the NOF.

Table 3: Monthly monitoring sites with a risk of failing to meet national bottom line for periphyton when 95% upper prediction interval is considered
Site Name
Lill Burn at Lill Burn-Monowai Road
Aparima River at Thornbury
Mataura River at Mataura Island Bridge
Longridge Stream at Sandstone
Waituna Creek at Marshall Road
Dipton Stream at South Hillend-Dipton Road
Waiau River at Tuatapere

69 Hodson and De Silva (2018) analysis of the AFDM biomass data from 19 monthly monitoring sites demonstrated that 68% (13 of 19) comply with respective AFDM biomass standards defined in the pSWLP (2018)[30],[31]. This is illustrated on the map in **Appendix 5**.

70 Hodson and De Silva (2018) analysis of percentage cover of periphyton from 19 monthly monitoring sites demonstrated that 21% of sites were compliant with both long filamentous and diatom/mat periphyton standards defined in the pSWLP (2018) [32], [33]. This is illustrated on the map in **Appendix 6**.

Periphyton - trend

71 Trends in periphyton cover are not able to be assessed. There is insufficient data available.

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30 19 sites have been included here as the lowland soft bed and lake fed management units do not apply AFDM biomass standards.

31 While the pSWLP does not apply AFDM biomass standard to surface water bodies classified as Mataura 1,2 or 3, the authors have applied the equivalent River Environment Classification to sites which would have been classified as lowland hard bed, Hill or Mountain.

32 19 sites have been included here as the lowland soft bed and lake fed management units do not apply AFDM biomass standards.

33 While the pSWLP does not apply AFDM biomass standard to surface water bodies classified as Mataura 1,2 or 3, the authors have applied the equivalent River Environment Classification to sites which would have been classified as lowland hard bed, Hill or Mountain.

NNN – state

72 NNN is an important and naturally occurring nutrient in aquatic environments. It supports primary productivity[34] of algae and macrophyte. In excess, NNN can drive undesirable levels of primary productivity e.g. nuisance periphyton, and at high concentrations becomes toxic to aquatic animals and cause adverse health effects in humans.

73 Southland currently meets the national bottom line for nitrate toxicity at all surface water monitoring sites. Of 55 sites 29 sites are classified in the NOF A band, 17 in the B band and 9 in the C band[35]. However, increasing trends for nitrate in groundwater and surface water suggest that for some locations there is a risk of not meeting this bottom line in the future (**Appendix 7**).

74 Assessment of NNN concentration illustrates that at 38 of 55 sites median NNN concentrations are greater than the respective ANZECC 2000 guideline (**Appendix 8**). Of the sites classified as upland, 12 of 22 have a NNN concentration above and the other 10 have a concentration below the upland ANZECC 2000 guideline. Seven of 33 Lowland sites have a median NNN concentration below the lowland guideline, and 26 sites are above the ANZECC 2000 guideline[36].

NNN - trend

75 Trend analysis for the time period January 2000 to December 2016 illustrates a deterioration in NNN levels in the main stem and some tributaries of the Waiau, Oreti, Mataura and Pourakino Rivers.

76 For sites with sufficient data for the time period 2000 to 2016, NNN levels increased at 15 of 34 sites monitored by the Council and 4 of 6 sites monitored by NIWA. Improvements (i.e. decreases of NNN concentration) were detected at 2 of 24 and 1 of 6 sites operated by the Council and NIWA respectively. Trends for remaining sites, which had

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34 Primary production is the production of chemical energy in organic compounds by living organisms, it principally occurs through photosynthesis.

35 Hodson R., Dare J., Merg M., Couldrey, M. (2017), Water Quality in Southland: Current State and Trends. Environment Southland publication No: 2017-04.

36 Hodson R., Dare J., Merg M., Couldrey, M. (2017), Water Quality in Southland: Current State and Trends. Environment Southland publication No: 2017-04.

sufficient data for analysis, were indeterminate Hodson et al. (2017). A summary table is contained in **Appendix 11**.

77 Trend analysis for the shorter time period January 2007 to December 2016 illustrates an improvement in NNN at 12 of 49 sites. Deteriorations were detected at 5 of 49 and trend direction was indeterminate at the remaining 32 sites. A summary table is contained in **Appendix 12**.

78 Of the 55 sites monitored by the Council, with sufficient data for analysis, trend analysis for the five-year period January 2012 to December 2016, illustrated improving trends in concentration (i.e. decreases) at 9 of 55, deteriorating trends (i.e. increases) in concentration were detected at 2 of 55 sites, and trends direction was indeterminate for 38 of 55 sites. Trend direction was indeterminate for sites operated by NIWA, Hodson et al., (2017). A summary table is contained in **Appendix 13**.

79 Land Air Water Aotearoa (**LAWA, 2018**) analysis of 10-year trend for the time period ending December 2017 shows that NNN is to be very likely to be improving at 20 of 49 sites, likely to be improving at 7 of 49 sites, indeterminate at 8 of 49, likely to be degrading at 6 of 49 and very likely to be degrading at 8 of 49. A summary table of the LAWA 2018 analysis is contained in **Appendix 14**.

80 The LAWA 2018 5-year trend analysis for the time period ending December 2017 shows that in NNN to be very likely to be improving at 14 of 51 sites, likely to be improving at 12 of 51 sites, indeterminate at 12 of 51, likely to be degrading at 8 of 51 sites and very likely to be degrading at 5 of 51 sites. A summary table of the LAWA analysis is contained in **Appendix 14**.

Ammonia – state

81 Southland currently meets the National Objectives Framework (NOF) national bottom line for ammonia toxicity at all surface water monitoring sites. Of the 55 monitored sites, 31 are in the NOF A band, 20 are in the B band and four are in the C band[37].

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37 Hodson R., Dare J., Merg M., Couldrey, M. (2017), Water Quality in Southland: Current State and Trends. Environment Southland publication No: 2017-04.

82 Assessment of ammonia concentrations against the ANZECC 2000 guideline illustrates 7 of 54 sites have median concentrations greater than the relevant upland or lowland ANZECC 2000 guideline[38].

Ammoniacal nitrogen - trend

83 Trend analysis for the time period January 2000 to December 2016 illustrates that of 13 sites with sufficient data for analysis, 8 have an improvement in concentration, and one site has a deteriorating trend in concentration. For the remaining four sites the trend is indeterminate[39]. A summary table is contained in **Appendix 11**.

84 Trend analysis for the time period January 2007 to December 2016 illustrates an improvement at nine of 11 sites with sufficient data for analysis. For the remaining two sites the trend direction is indeterminate[40]. A summary table is contained in **Appendix 12**.

85 Trend analysis for the five-year period January 2012 – December 2016 illustrates three of 18 sites with sufficient data for analysis have an improving trend in concentration. For the remaining 15 sites the trend is indeterminate[41]. A summary table is contained in **Appendix 13**.

86 LAWA, 2018 analysis of the 10-year trend for the time period ending December 2017, shows that of 32 sites assessed, 5 were very likely degrading, 5 likely degrading, 8 indeterminate, 4 likely improving, and 10 very likely improving. A summary table is contained in **Appendix 14**.

87 The LAWA 2018 5-year trend analysis for the time period ending December 2017 shows that of 26 sites assessed, 1 was very likely to be degrading, 10 were likely to be degrading, 7 were indeterminate, 3 were likely to be improving and 5 were very likely to be improving. A summary table is contained in **Appendix 15**.

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38 Hodson R., Dare J., Merg M., Couldrey, M. (2017), Water Quality in Southland: Current State and Trends. Environment Southland publication No: 2017-04.

39 Hodson R., Dare J., Merg M., Couldrey, M. (2017), Water Quality in Southland: Current State and Trends. Environment Southland publication No: 2017-04.

40 Hodson R., Dare J., Merg M., Couldrey, M. (2017), Water Quality in Southland: Current State and Trends. Environment Southland publication No: 2017-04.

41 Hodson R., Dare J., Merg M., Couldrey, M. (2017), Water Quality in Southland: Current State and Trends. Environment Southland publication No: 2017-04.

Dissolved reactive phosphorus - state

88 Assessment of DRP concentrations illustrates that at 25 of 55 sites, median DRP concentrations are less than the respective ANZECC 2000 guideline, and 27 sites were above the guideline. Of the sites classified as upland, four of 19 sites have a DRP concentration above and 15 sites have a concentration below the upland ANZECC 2000 guideline. 10 of 33 lowland sites had a median DRP concentration below the lowland guideline, and 23 sites are above the ANZECC 2000 guideline (**Appendix 9**) [42].

Dissolved reactive phosphorus – Trend

89 Trend analysis for the time period January 2000 to December 2016 shows that 11 of 20 sites with sufficient data for analysis have a decreasing trend in DRP concentration. For the remaining nine sites the trend direction was indeterminate[43]. See the summary table in **Appendix 11**.

90 Trend analysis for the time period January 2007 to December 2016 illustrates improvements in DRP concentration at 3 of 35 sites assessed, deterioration at 7, and at 25 sites the trend direction was indeterminate[44]. See the summary table in **Appendix 12**.

91 DRP trend analysis for the five-year period January 2012 to December 2016 illustrates that of 38 sites assessed, one was improving, 3 were deteriorating and 34 were indeterminate[45], See the summary table in **Appendix 13**.

92 LAWA, 2018 analysis of the 10-year DRP trend for the time period ending December 2017 showed that of 42 sites assessed, 9 were very likely degrading, 7 were likely degrading, 12 were indeterminate, 6 likely improving and 8 very likely improving, See the summary table in **Appendix 14**.

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42 Hodson R., Dare J., Merg M., Couldrey, M. (2017), Water Quality in Southland: Current State and Trends. Environment Southland publication No: 2017-04.

43 Hodson R., Dare J., Merg M., Couldrey, M. (2017), Water Quality in Southland: Current State and Trends. Environment Sotuhland publication No: 2017-04.

44 Hodson R., Dare J., Merg M., Couldrey, M. (2017), Water Quality in Southland: Current State and Trends. Environment Southland publication No: 2017-04.

45 Hodson R., Dare J., Merg M., Couldrey, M. (2017), Water Quality in Southland: Current State and Trends. Environment Southland publication No: 2017-04.

93 The LAWA 2018 5-year DRP trend analysis, for the time period ending December 2017, shows that of 41 sites assessed, 3 were very likely degrading, 5 likely degrading, 14 indeterminate, 9 likely improving, and 10 very likely improving. See the summary table in **Appendix 14**.

Human Health

94 Freshwater in Southland is commonly used for recreational activities, such as swimming and boating, and for drinking water supplies to both reticulated networks and individual households. Poor water quality can have negative effects on human health, as well as lost opportunities for recreation and commercial use of water.

95 Risk to human health from recreational activities is usually associated with illness from exposure to microbial contamination or toxic algal blooms[46]. *Escherichia coli (E.coli*) levels are used as an indicator of the risk from microbial contamination sourced from faecal material[47].

96 I discuss below the current state and trend for the following indicators of human health: E.coli and toxic algae.

E.coli - state

97 Six popular river bathing sites (primary contact recreation) have been identified for Southland in the RWP. However, none of the six meet the standard for bathing waters, they all have a "Very Poor" Suitability for Recreation Grading (**SFRG**)[48].

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46 The NPSFM provides a framework for assessing the risk posed to human health from recreation in lake environments from planktonic algae. In river environments, interim national guidelines are available to assess the risk to human health from benthic algae mats (MFE and MOH, 2009).

47 Standards for *E.coli* levels that can be used to interpret the risk to human health from recreational contact with the water can be found in: The Regional Water Plan for Southland (ES, 2010), proposed Southland Water and Land Plan (ES, 2016a), Microbiological water quality guidelines for marine and freshwater recreational areas (MfE and MoH, 2009) and the National Policy Statement for Freshwater Management (MFE, 2014).

48 Larkin, G., 2013, Recreational Waters of Southland. http://www.es.govt.nz/Document%20Library/Research%20and%20reports/Coastal%20reports/Recreational%20Waters%20of%20Southland/recreational_waters_technical_report_2013_final.pdf

Table 3 Popular bathing sites monitored by Council and corresponding human health risk grading.
NOTE: * indicates sites that are explicitly identified as Popular Bathing Sites in Appendix K of the RWP (ES, 2010).

Site Name	**ES RWP 2010 *E.*coli/100 ml compliance (5 year median (Hazen) from (Larken 2013)**	**SFRG (Larken 2013)**
Oreti River at Winton Bridge *	993	Very Poor
Oreti River at Wallacetown Bridge *	1764	Very Poor
Mataura River at Gore Bridge *	3289	Very Poor
Aparima River at Thornbury Bridge *	7270	Very Poor
Waiau River at Tuatapere Bridge *	3228	Very Poor
Waikaia River at Waikaia Bridge *	4050	Very Poor
Waikaia River u/s Piano Flat	1091	Poor
Mataura River at Riversdale	3540	Very Poor
Mararoa River at South Mavora Lake	21	Very Good
Lake Te Anau at Boat Harbour Beach	221	Very Good
Lake Manapōuri at Frazers Beach	28	Very Good

98 In 2017 the NPSFM was amended. The amendment changed the way the compulsory value of human health is to be assessed. There was a move away from the use of ‘primary’ and ‘secondary’ contact recreation, each with different attribute tables, to a single attribute ‘swimmability’. The revised attribute contains five gradings from A to E, defined by relative risk of infection. Appendix 6 of the NPSFM 2017 sets out a national target for swimmability, which is to increase proportions of

specified rivers in the A, B and C bands to at least 80% by 2030 and 90% by 2040[49].

99 The 2018 LAWA revision included an assessment of *E.coli* against the NPSFM (as amended in 2017) swimmability criteria. For Southland, 40 sites had adequate data during the 5-year (January 2013 to December 2017) period. Of those, 4 (10%) were in the A band, 2 (5%) in the B band, 10 (25%) in the D band and 24 (60%) in the E band.

E.coli – trend

100 Trend analysis for the time period January 2000 to December 2016, illustrates that four of 40 sites with sufficient data for analysis, have an increasing trend in *E.coli* concentration. Three sites have a decreasing *E.coli* concentration, and for the remaining 33 sites the trend direction was unable to be confidently determined. See the summary table in **Appendix 11**.

101 Trend analysis for the time period January 2007 to December 2016, illustrates improvements in *E.coli* concentration at two of 54 sites assessed, deterioration at five, and at 26 sites the trend direction was indeterminate. See summary table in **Appendix 12**.

102 Trend analysis for the five-year period January 2012 to December 2016, illustrates that deteriorations in *E.coli* concentration were observed at 3 of 54 sites assessed and that the trend was indeterminate at 51 sites. See summary table in **Appendix 13**.

103 LAWA (LAWA, 2018) analysis of 10-year *E.coli* trend for the time period ending December 2017 shows that of 52 sites assessed, 8 were very likely degrading, 5 were likely degrading, 19 indeterminate, 11 likely improving and 9 very likely improving. See summary table in **Appendix 14**.

104 The LAWA 2018 5-year *E.coli* trend analysis for the time period ending December 2017 shows that of 53 sites analysed, 7 were very likely degrading 18 likely degrading, 16 indeterminate, 10 likely improving and 2 very likely improving. See summary table in **Appendix 14**.

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49 New Zealand Government (2017). National Policy Statement for Freshwater Management 2014 updated August 2017 to incorporate amendments from the National Policy Statement for Freshwater amendment Order 2017.

Toxic algae

105 Toxic algae, such as cyanobacteria (blue green algae), in rivers and streams can also impact suitability for recreation. For example, under certain conditions[50] some periphyton can produce toxins that can be harmful to humans, stock and pets.

106 The Ministry for the Environment (**MFE**) and Ministry of Health (**MOH**) (2009) provide interim guidelines, for the percentage cover of benthic cyanobacteria mats in rivers as an alert framework. When percentage cover is greater than 20% and less than 50%, notification is to be provided to the Public Health Unit, and consideration given to increasing the frequency of observation and testing for toxin presence. When percentage cover is greater than 50%, notification is to be made to both the Public Health Unit and the public.

107 Relatively little published information is available on the frequency or duration of benthic cyanobacteria blooms in Southland Rivers.

108 Benthic Cyanobacteria (often *Phormidium* species) proliferations have been observed in the main stem and some tributaries of the four main river systems in Southland; Waiau, Aparima, Oreti, Waikaia and Mataura.

109 Heath and Wood[51] (2010) found that over a summer survey, five out of five sites had high abundances of Phormidium mat cover for at least several weeks during the summer.

110 McAllister et.al.[52] (2016) published a review article on the cyanobacteria species Phormidium. **Appendix 10** illustrates the rivers in Southland that have experienced Phormidium proliferations (greater than 20% coverage). Furthermore, McAlister et al. (2016) identify concentrations of toxins in the Oreti and Waikaia Rivers as the highest observed nationally.

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50 For example, when they 'bloom' or are under 'stress'.

51 Heath, M.W. and Wood. S.A. 2010, Benthic Cyanobacteria and Anatoxin-a and Homanatoixn-a Concentrations in Five Southland Rivers.Cawthron Report No. 1841. http://www.es.govt.nz/Document%20Library/Research%20and%20reports/Surface%20water%20quality%20reports/southland-cyanobacteria-report-2010.pdf

52 McAllister, T.G., Wood, S.A., and Hawes, I. 2016, The rise of toxic benthic Phormidium proliferations: A review of their taxonomy, distribution, toxin content and factors regulating prevalence and increased severity. Harmfull algae, vol. 55, 282-294.

111 Proliferations of benthic cyanobacteria mats have been publicly notified during the summer period of several years (Kelly 2017[53], ICC 2015[54]). During the 1998/99 summer, dog deaths were recorded from the Mataura River (Hamill, 2001[55]).

DATED this 14th day of December 2018

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Roger Hodson

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53 Kelly, R. 2017, *Toxic algae found in Southland River.* The Southland Times, January 11 2017. http://www.stuff.co.nz/southland-times/news/88231454/toxic-algae-found-in-southland-river

54 Invercargill City Council (ICC), 2015, Algae warning for Southlanders. 15 January 2015, http://icc.govt.nz/algae-warning-southlanders/

55 Hamill, K.D. 2001. Toxicity in benthic freshwater cyanobacteria (blue-green algae): First observations in New Zealand. *New Zealand Journal of Marine and Freshwater Research*, 35: 1057-1059.

Appendix 1

Map of Southland Region – including major surface water bodies

environment SOUTHLAND REGIONAL COUNCIL Te Taiao Tonga

Southland
New Zealand

Date: 5/12/2018

State Highways	Fiordland and Islands
Rivers	Mataura
Vegetation	Oreti
Fresh Water Management Units	Waiau
Aparima	

N

1:800,000

DISCLAIMER
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DATA SOURCE: ES GIS 2018

Appendix 2

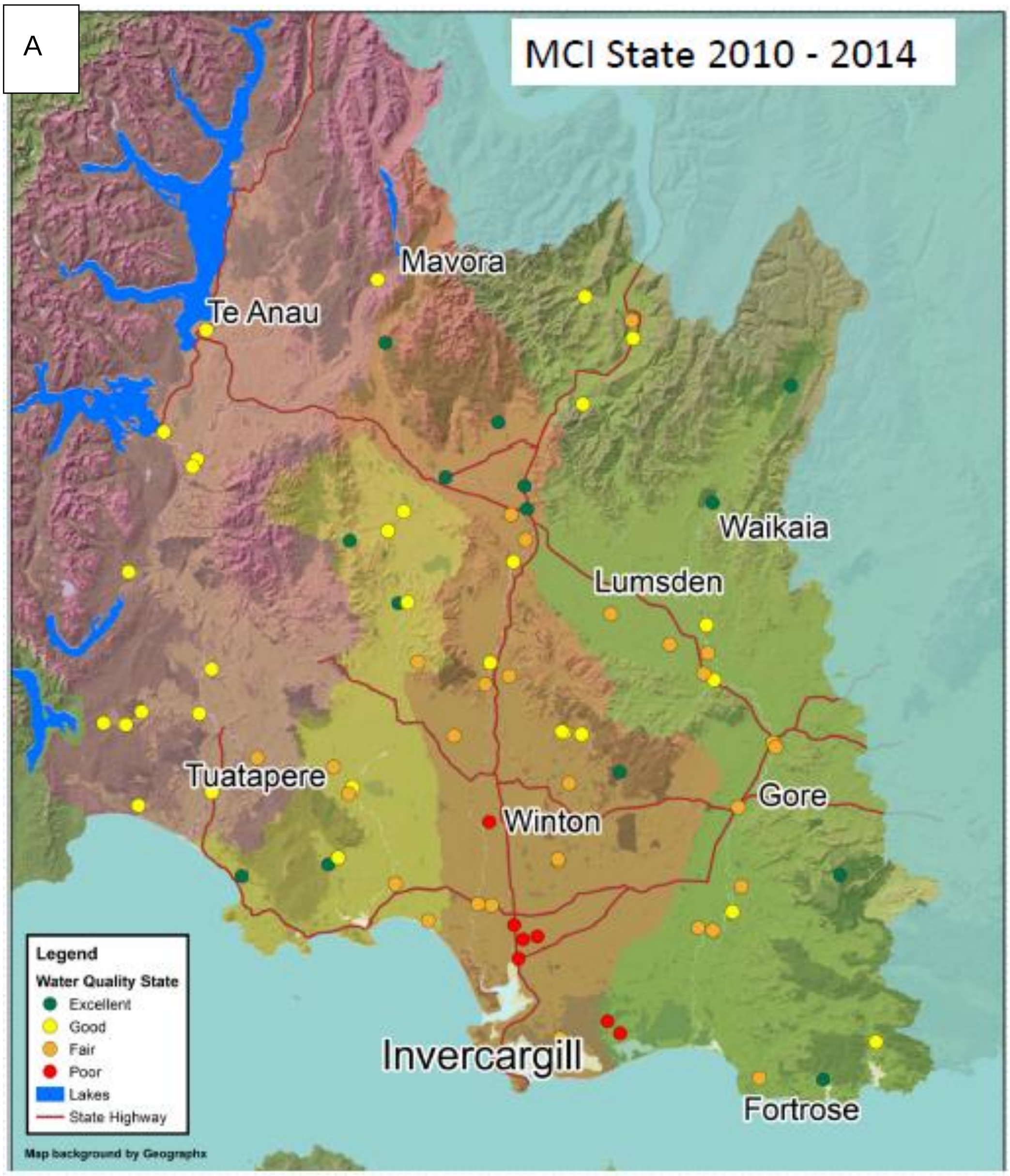
State of Macroinvertebrates in context of:

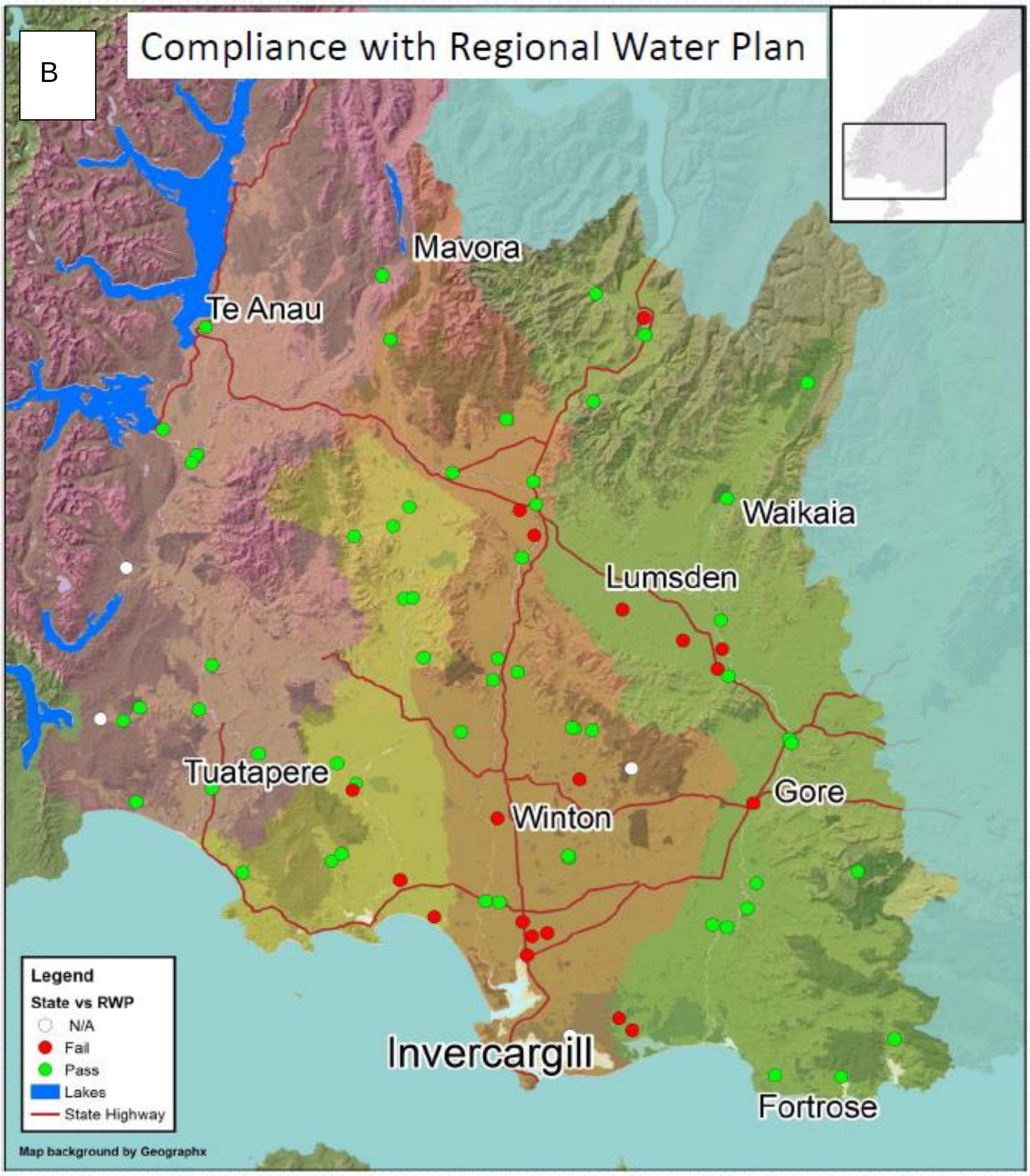
a) Stark and Maxted 2007

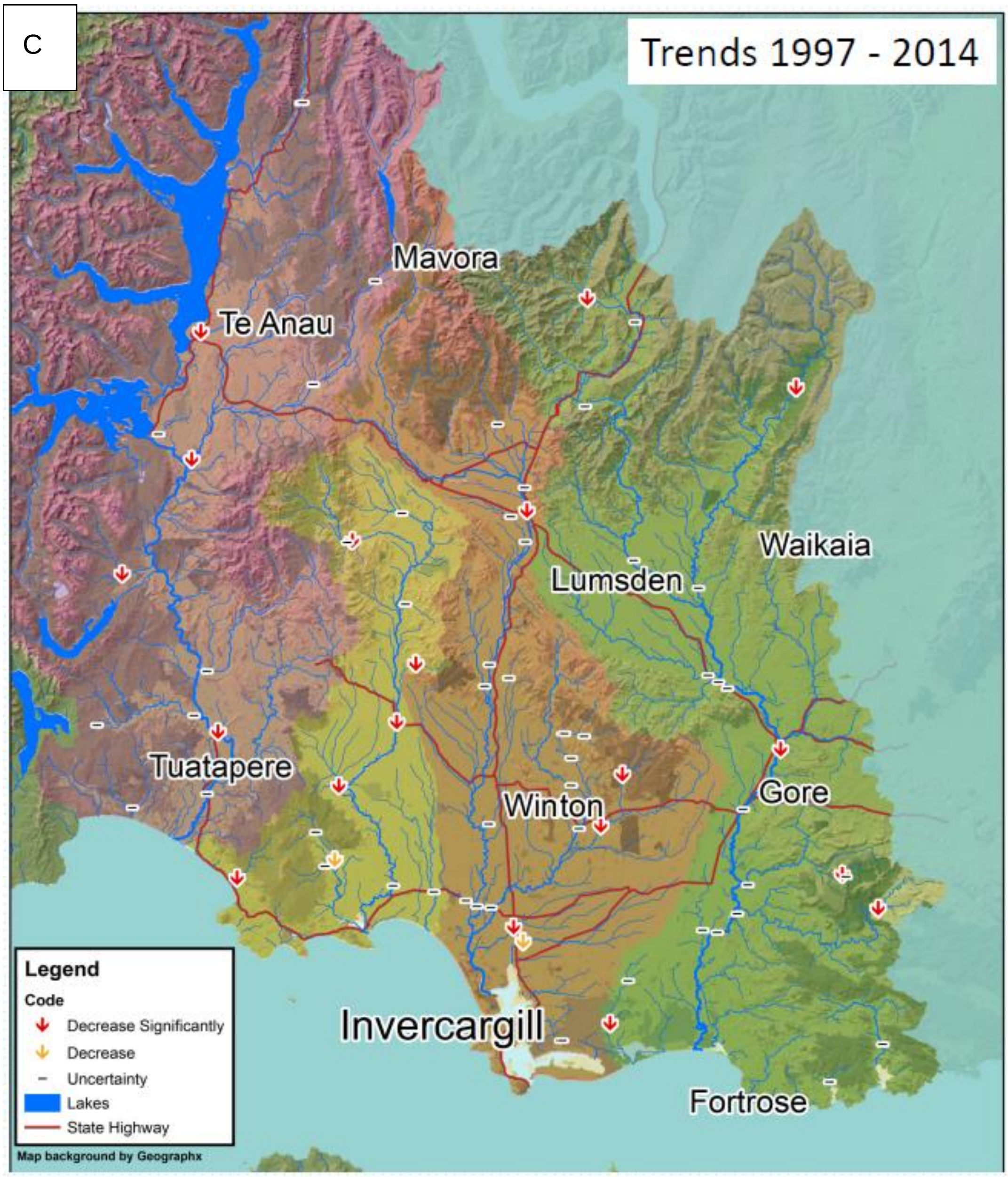
b) Regional Water Plan standards

c) Trend in Macroinvertebrates

Adapted from: Hodson and Akbaripasand (2016). Available online from: *https://www.es.govt.nz/Document%20Library/Presentations/Science%20Conference%20Posters%202016/State%20and%20Trends%20in%20Freshwater%20Macroinvertebrate%20Community%20Health%20in%20Southland.pdf*


A
MCI State 2010 - 2014
Mavora
Te Anau
Waikaia
Lumsden
Tuatapere
Gore
Winton
Invercargill
Fortrose
Legend
Water Quality State
Excellent
Good
Fair
Poor
Lakes
State Highway
Map background by Geographx

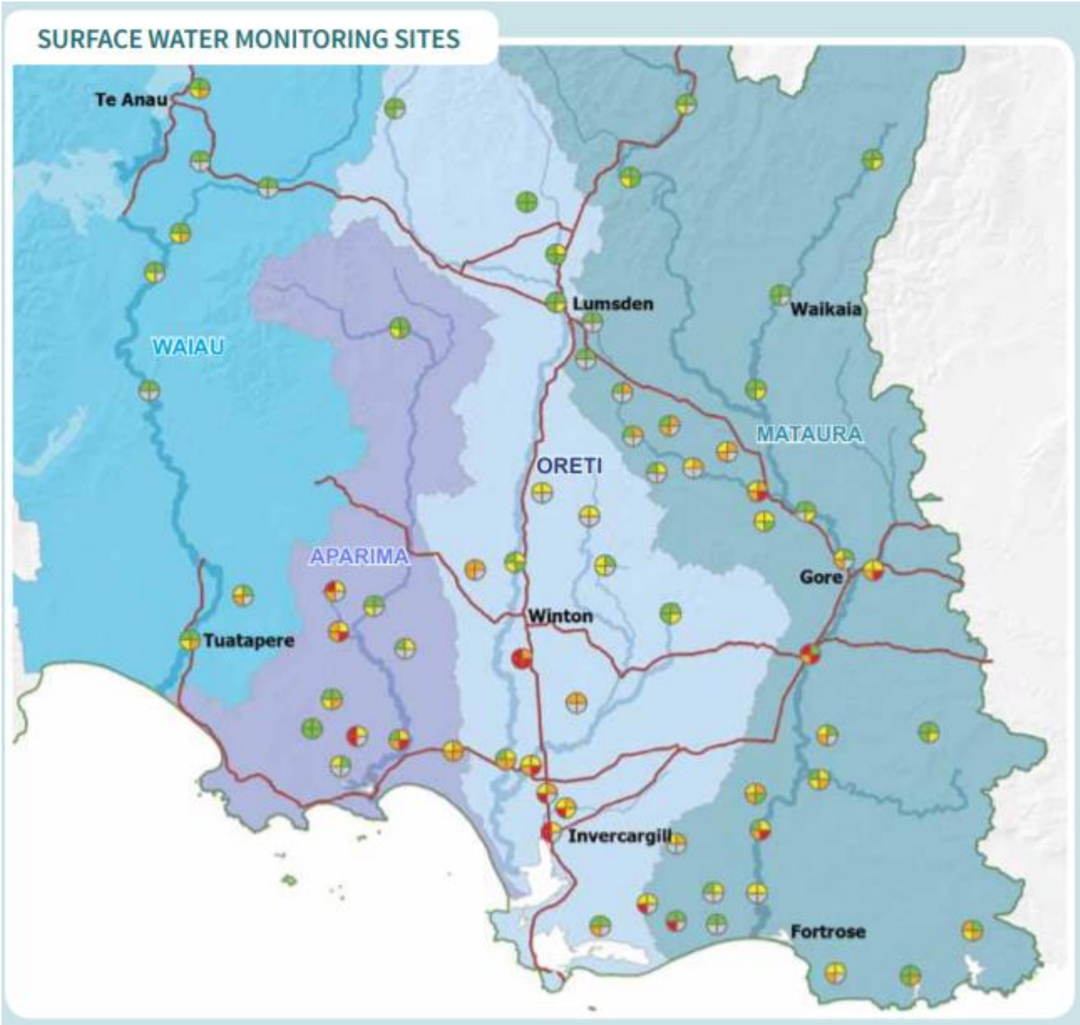

B
Compliance with Regional Water Plan
Mavora
Te Anau
Waikaia
Lumsden
Tuatapere
Gore
Winton
Invercargill
Fortrose
Legend
State vs RWP
N/A
Fail
Pass
Lakes
State Highway
Map background by Geographx


C
Trends 1997 - 2014
Mavora
Te Anau
Waikaia
Lumsden
Tuatapere
Winton
Gore
Invercargill
Fortrose
Legend
Code
Decrease Significantly
Decrease
Uncertainty
Lakes
State Highway
Map background by Geographx

Appendix 3

Water Quality in Southland. The bottom right quadrant illustrates periphyton state.

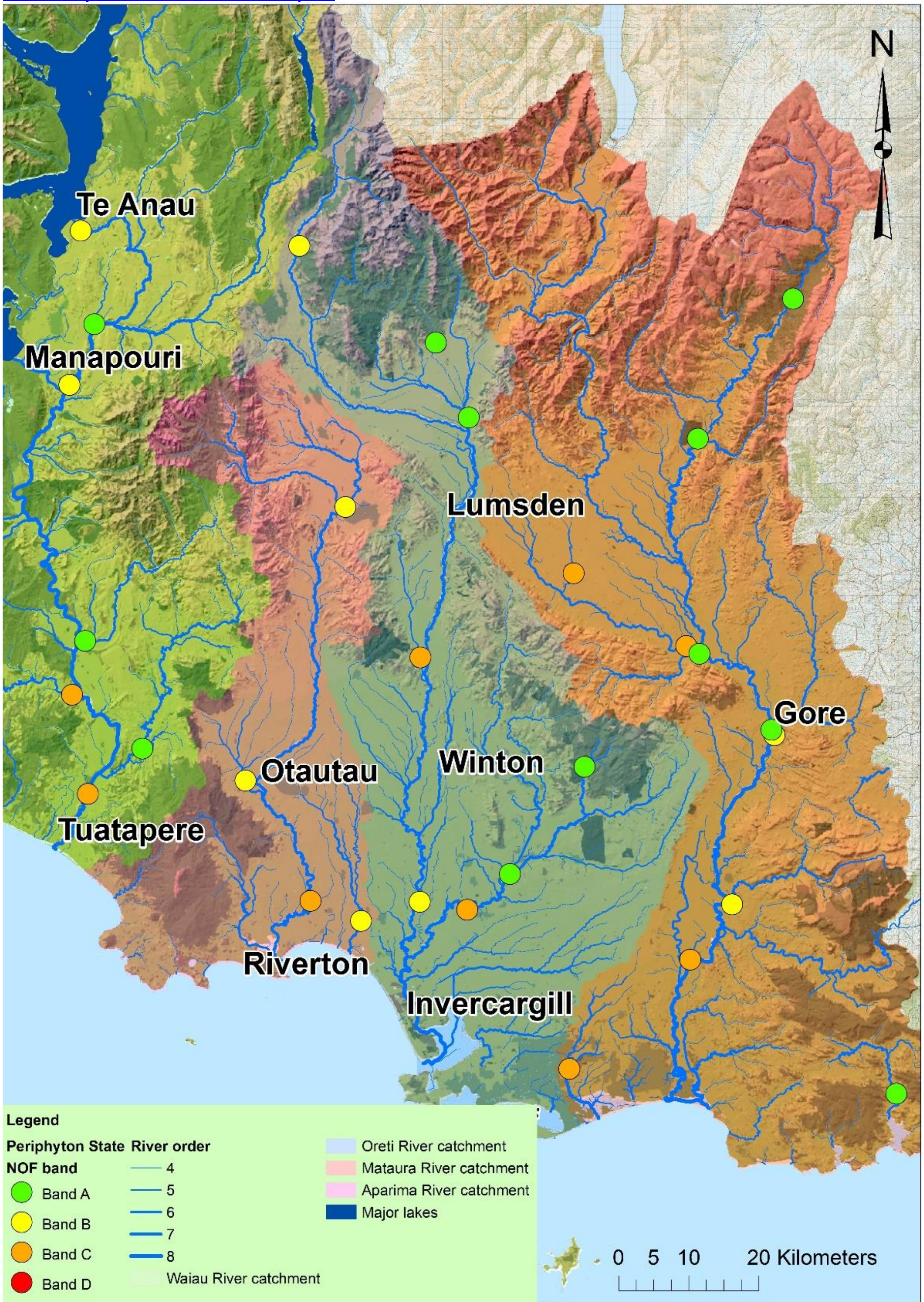
From: Environment Southland (2016b) and Kitto and Hodson (2016) . available online at:
https://www.es.govt.nz/Document%20Library/Factsheets/Other%20factsheets/Water%20Quality%20in%20Southland%20web.pdf



Appendix 4

Periphyton state in Southland from December 2014 – December 2017

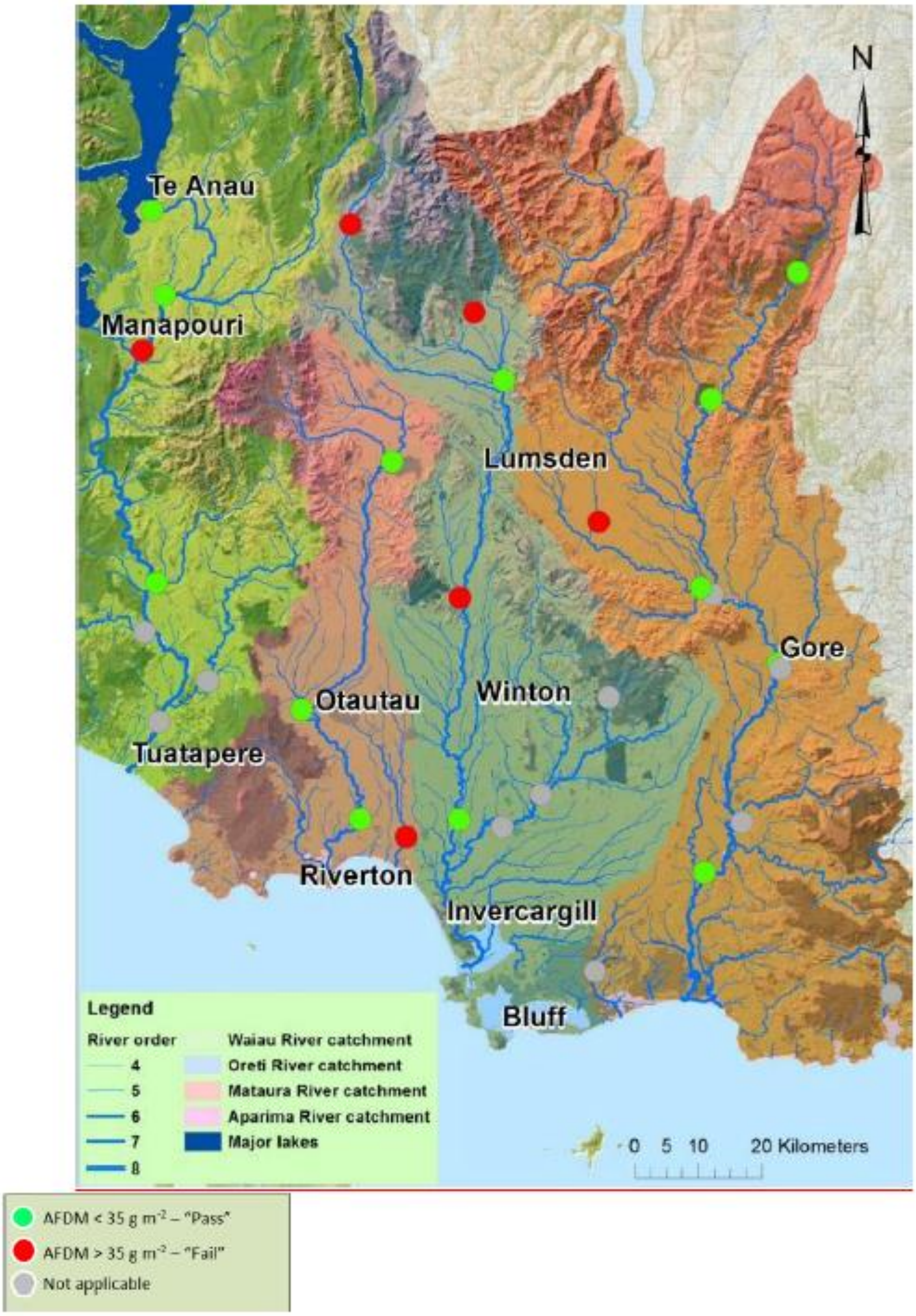
Adapted from Hodson and DeSilva 2018. Available online at: https://www.es.govt.nz/Document%20Library/Research%20and%20reports/Various%20reports/Science%20reports/Science%20reports%20September%202018/Technical%20Report%20-%20Periphyton%20state%20in%20Southland%20-%20September%202018.pdf



Appendix 5

Ash Free Dry Matter (AFDM) compliance with RWP standards

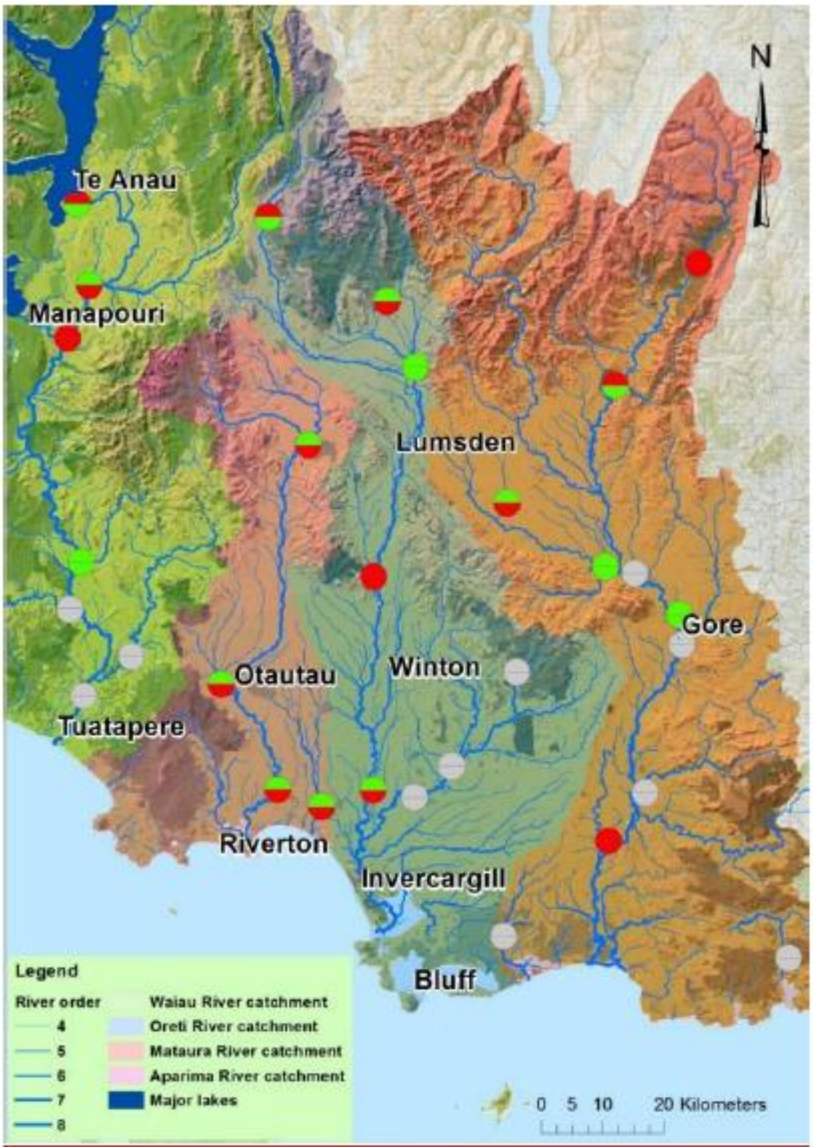
Adapted from Hodson and DeSilva 2018



Appendix 6

Periphyton compliance with RWP standards

Adapted from Hodson and DeSilva 2018

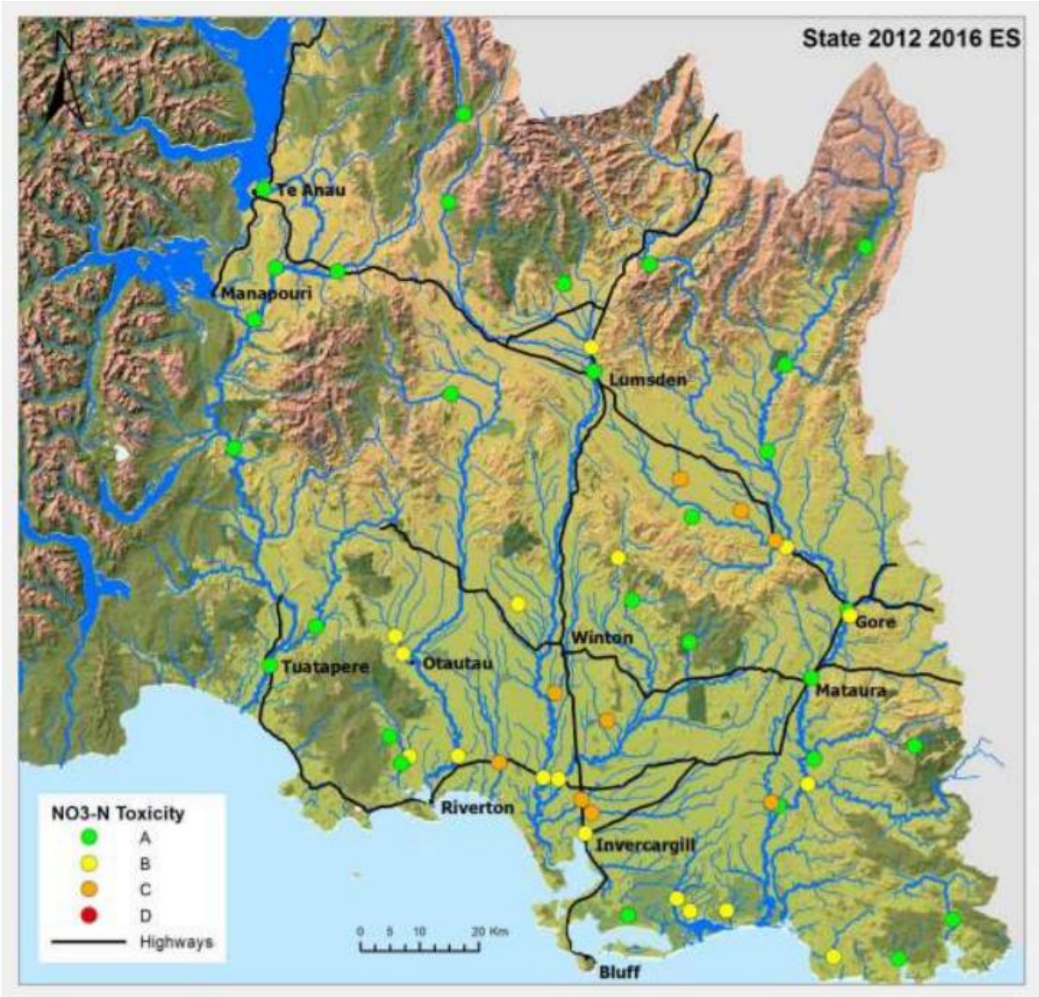


Diatoms and cyanobacteria (> 0.3cm thick) <
Diatoms and cyanobacteria (> 0.3cm thick) >
Filamentous algae (> 2 cm long) < 30% - "Pass"
Filamentous algae (> 2 cm long) > 30% - "Fail"
Not applicable

Appendix 7

Nitrate nitrite nitrogen toxicity assessed against the NOF

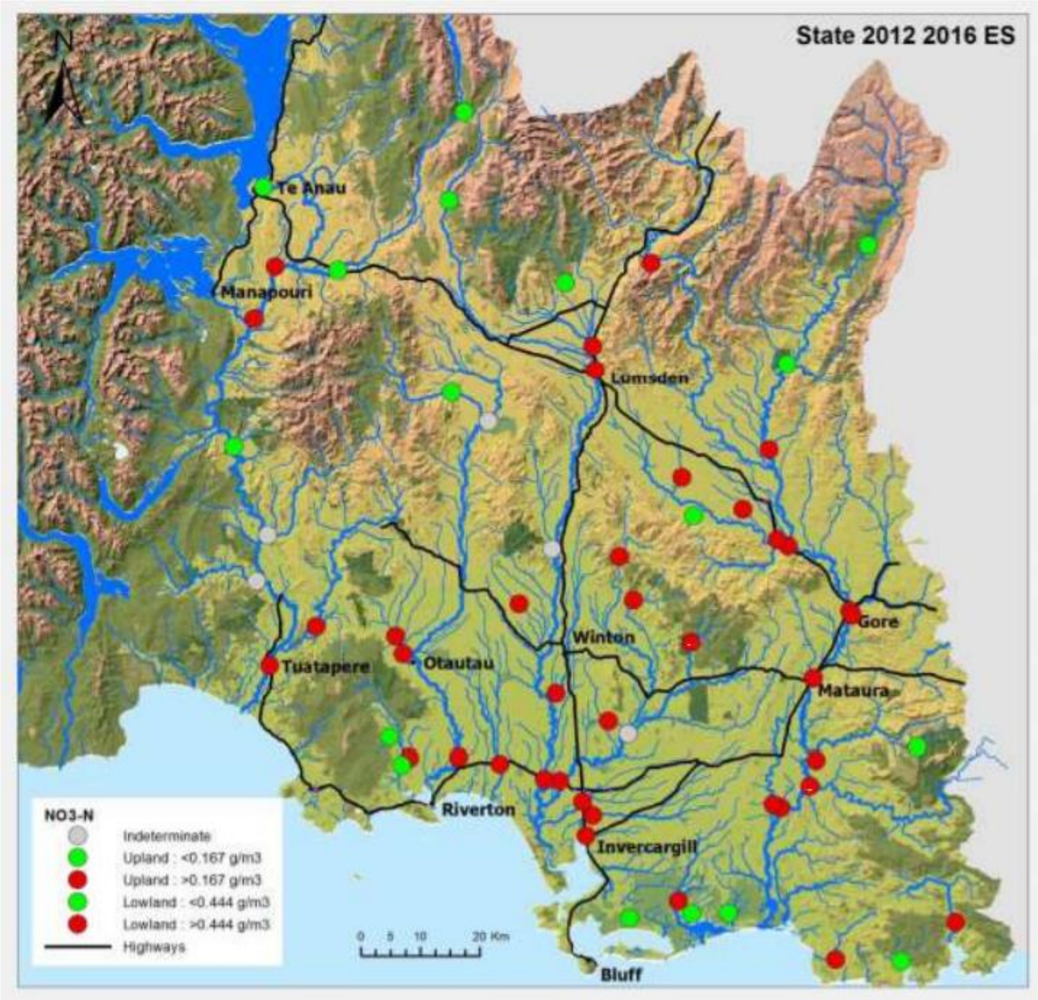
Adapted from Hodson et al 2017. Available online at: https://www.es.govt.nz/Document%20Library/Research%20and%20reports/Various%20reports/Science%20reports/Water%20Quality%20in%20Southland%20-%20Current%20State%20and%20Trends%20-%20April%202017.pdf



Appendix 8

Nitrate nitrite nitrogen concentrations assessed against ANZECC 2000 guidelines.

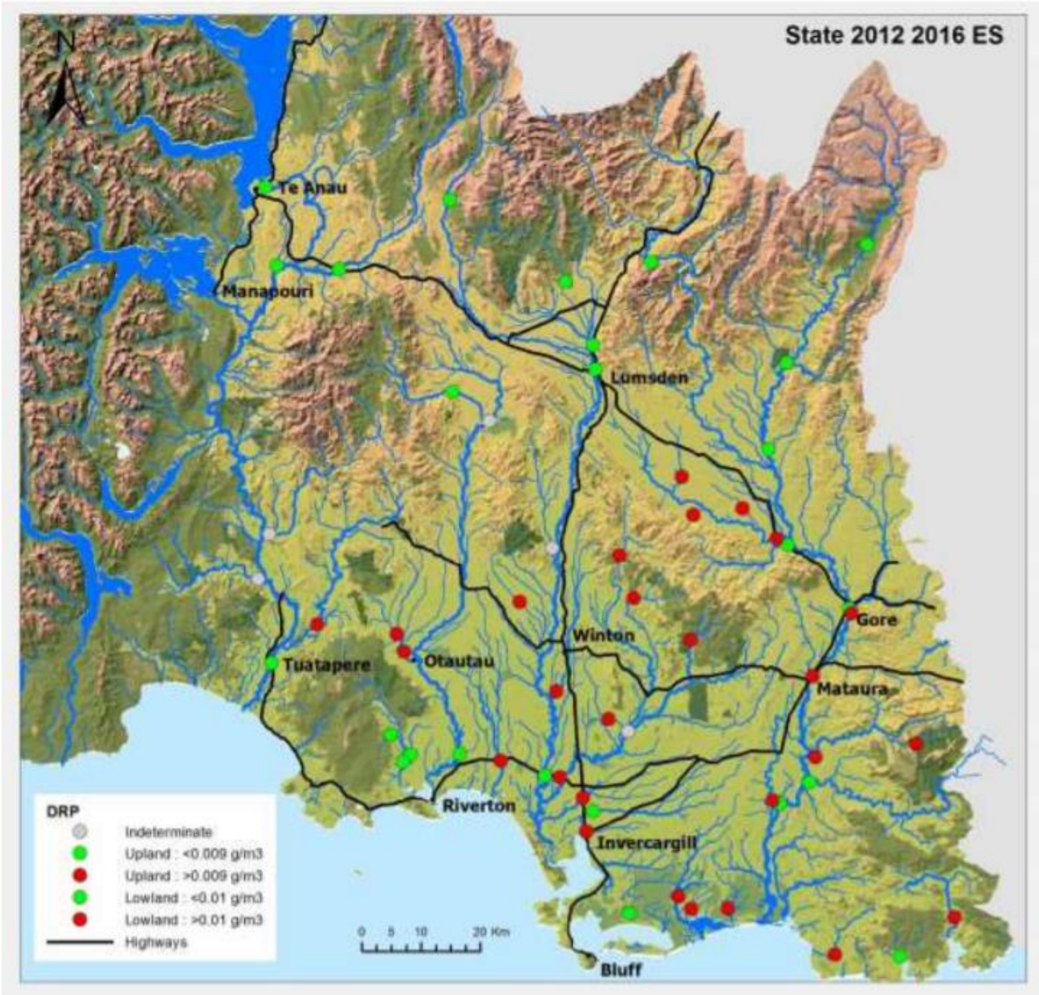
Adapted from Hodson et al 2017. Available online at:
https://www.es.govt.nz/Document%20Library/Research%20and%20reports/Various%20reports/Science%20reports/Water%20Quality%20in%20Southland%20-%20Current%20State%20and%20Trends%20-%20April%202017.pdf



Appendix 9

Dissolved reactive phosphorus state assessed against ANZECC 2000 guidelines.

Adapted from Hodson et al 2017. Available online at:
https://www.es.govt.nz/Document%20Library/Research%20and%20reports/Various%20reports/Science%20reports/Water%20Quality%20in%20Southland%20-%20Current%20State%20and%20Trends%20-%20April%202017.pdf



Appendix 10

Southland Rivers where one (or more) sites have experienced Phormidium proliferations (greater than 20% coverage) on one (or more) occasion since 2009.

Adapted from McAllister et al., 2016.

Appendix 11

Summary of Environment Southland 2000 – 2017 trend analysis

Variable	Clarity	*E.coli*	NNN	TN	NH4	ON	DRP	TP
Number sites analysed	29	40	35	34	13	29	20	21
Indeterminate	19	33	18	22	4	24	9	12
Decrease	5	3	2	1	8	1	11	9
Increase	5	4	15	11	1	4	0	0

Appendix 12

Summary of Environment Southland 2007 – 2017 trend analysis

Variable	Clarity	*E.Coli*	NNN	TN	NH4	ON	DRP	TP
Number sites analysed	35	54	49	46	11	46	35	40
Indeterminate	26	47	32	33	2	33	25	24
Decrease	9	2	12	3	9	0	3	14
Increase	0	5	5	10	0	13	7	2

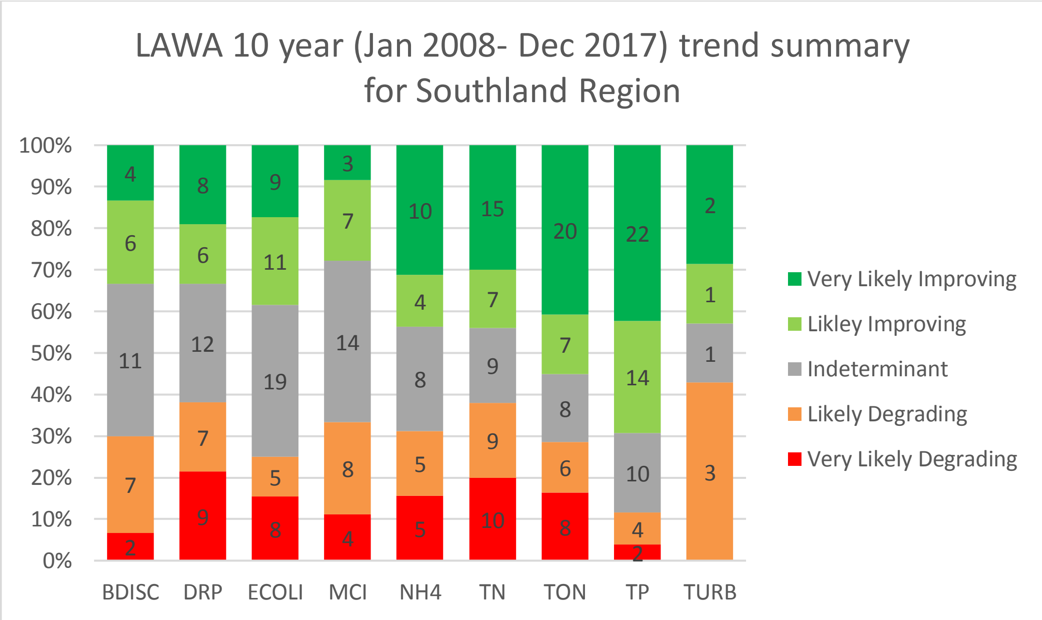
Appendix 13

Summary of Environment Southland 2012 – 2017 trend analysis

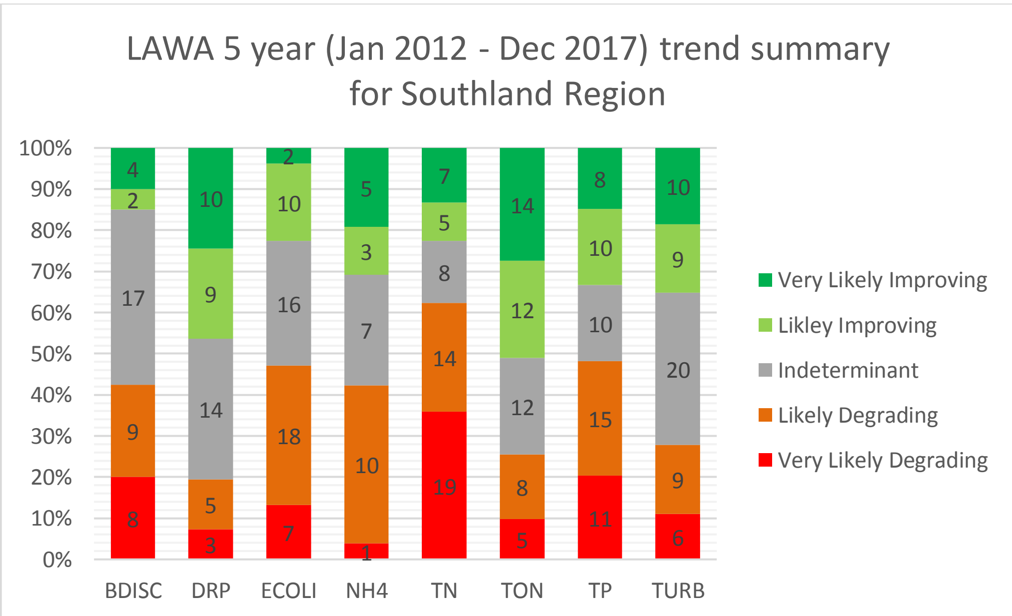
Variable	Clarity	*E.Coli*	NNN	TN	NH_4	ON	DRP	TP
Number sites analysed	32	54	49	46	18	46	38	45
Indeterminate	25	51	38	39	15	37	34	44
Decrease	7	0	9	7	3	0	1	0
Increase	0	3	2	0	0	9	3	1

Appendix 14

Summary of Trend analysis presented on LAWA 2018. Adapted from: www.lawa.org.nz



Certainty of trend	Description
90-100%	Very Likely Improving
67-90%	Likely Improving
<67%	Indeterminate
67-90%	Likely Degrading
90-100%	Very Likely degrading



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