**IN THE ENVIRONMENT COURT**

**UNDER** the Resource Management Act 1991

**AND**

**IN THE MATTER** appeals under clause 14(1) of Schedule 1 of the Act in respect of Proposed Southland Water and Land Plan

**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 on next page)*

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# STATEMENT OF PRIMARY EVIDENCE OF JUSTIN ALLAN KITTO ON BEHALF OF FONTERRA CO-OPERATIVE GROUP LTD AND DAIRYNZ LTD

**15 MARCH 2019**

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**GORE DISTRICT COUNCIL, SOUTHLAND DISTRICT COUNCIL & INVERCARGILL DISTRICT COUNCIL** (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*

## 1. EXECUTIVE SUMMARY

1.1 This water quality evidence addresses the current trend and state of water quality in Southland; explains the need for the use of the term 'overall' when making water quality state and trend assessments; and provides commentary on the appropriateness of using nitrogen and phosphorus limits for managing ecosystem health.

1.2 There has been growth in the dairy industry in Southland over the last two decades. Despite this dairy growth, the ten-year trend analysis period reported by Land, Air, Water Aotearoa (**LAWA**) has identified variable trend directions for different parameters and between different Freshwater Management Units (**FMUs**). When considered in totality, 44% of trend tests had improving trends while 30% had worsening trends. The balance of 26% of trend tests had indeterminate trends.

1.3 Assessment of the state of water quality revealed that there were no exceedances of the periphyton national bottom line using measured data. My evidence has not reported on macroinvertebrates as I agree with the statements made by Mr Hodson. Mr Hodson stated that while there is not an attribute for macroinvertebrate communities in the National Objectives Framework, the National Policy Statement for Freshwater Management (**NPSFM**) does require regional councils to investigate the cause of macroinvertebrate community index (**MCI**) scores being less than 80. There are sites that do fail this score and additional sites that fail prescribed outcomes in Southland. There is also a widespread bacteria (*E.Coli*) issue that impacts on recreational values.

1.4 The trend and state results demonstrate that there are localised hotspots of poor ecosystem health and degrading water quality for some measures. But, in my opinion, there is not a widespread pattern of degraded ecosystem health metrics or degrading water quality.

1.5 Given the complexity of monitoring and reporting on water quality, data can sometimes display contradictory and conflicting results. This necessitates an 'overall' assessment of water quality by water quality experts.

1.6 Dr Russell Death has proposed nutrients limits to manage for ecosystem health, which is represented by macroinvertebrate community index scores. I do have concerns about the justification for the management of nutrients given that nutrients (except at very high concentrations of nitrogen) have not been reported to have direct effects on macroinvertebrate communities. Additionally, there is clear evidence that there can be multiple stressors and drivers of macroinvertebrate community scores and the focus on nutrients alone is simplistic and risks only managing some of the direct stress on macroinvertebrate scores, which might or might not be the major source of stress.

1.7 It is my view that the proposed Southland Water and Land Plan's (**pSWLP**) 'holding the line' approach is appropriate to manage water quality risks pending Environment Southland's limit setting process being implemented. This will allow for a subsequent, more detailed process to identify appropriate objectives and limits based on a more comprehensive, site by site assessment of the local conditions.

## 2. INTRODUCTION

2.1 My full name is Justin Allan Kitto

2.2 I have been a Water Quality Scientist for DairyNZ for over six years. Prior to this, I was an Environmental Scientist (Water Quality) at Otago Regional Council. I hold a Master of Environmental Science (Freshwater Ecology) (Hons) from the University of Canterbury. I am also a member of the New Zealand Freshwater Sciences Society.

2.3 In both of these positions I have been responsible for examining pressure-state-trend-response of water quality for a variety of catchments and regions. My recent experience in Southland includes analyzing water quality data, involvement in Environment Southland's water quality science research program and being heavily engaged with farmer-led catchment groups throughout Southland, explaining agricultural effects on water quality, the state and trend of freshwater environments, and advising on water quality monitoring programs. I have also provided support to dairy farmers on riparian, wetland and land management.

2.4 My relevant experience also involves the provision of technical work to support the development of Proposed Plan Change 6A to the Otago Regional Plan: Water and providing technical evidence on water quality matters for the pSWLP and Plan Changes 3 and 5 to the Canterbury Land and Water Regional Plan. I was also on a water quality working group for the Waimakariri Zone in Canterbury examining the water quality effects of different policy scenarios.

2.5 In preparing this evidence I have read and am familiar with the pSWLP, the Council Officers' Section 42A reports as well as the evidence in chief of: Mr Roger Hodson; Mr Ewen Rodway; Mr Nicolas Ward; Dr Russell Death and; Ms Kathryn McArthur.

## 3. BACKGROUND

### Code of conduct

3.1 I have read the Environment Court's Code of Conduct for Expert Witnesses and I agree to comply with it. My qualifications as an expert have been set out above and my evidence in this statement is within my areas of expertise. I have not omitted to consider material facts known to me that might alter or detract from the opinions which I express.

3.2 I acknowledge that I am an employee of DairyNZ, which is a party to this proceeding, and I may not be considered to be independent simply because of that employee status. Notwithstanding that, I can confirm that I have prepared and present this evidence in all other respects as an independent expert and in compliance with the Code of Conduct.

### Scope of evidence

3.3 I have been asked to provide specific comments and opinions relating to:

(a) A current assessment of state of, and trends for, river water quality

(b) The use of the term "Overall" in assessing water quality

(c) The drivers of macroinvertebrate health and their use as limits

## 4. ASSESSMENT OF STATE AND TREND OF RIVER WATER QUALITY

### Trend

4.1 This section provides an assessment of trend direction in Southland. For my evidence I have focused on the ten-year trend analysis from LAWA (January 2008 - December 2017).

4.2 Despite focusing my evidence on the ten-year LAWA trend, I do agree with the trend summary provided by Mr Hodson. The reason I have chosen to focus on the ten-year LAWA analysis as opposed to the trend analysis from Hodson et al (2017) is because, for the three time periods considered by Hodson et al (2017), 'indeterminate' was the most frequent categorisation for all parameters for all three time periods. Only for the period 2000-2016 could increasing or decreasing trends be detected for nitrogen and phosphorus measures respectively. The concern being, especially for the shorter periods, that meaningful assessments of trend are not possible, as such a high proportion of sites could not have a trend confidently detected.

4.3 The reason for such a frequent occurrence of indeterminate trends in Hodson et al (2017) can be attributed to reliance of a 95 percent confidence interval. The use of 95th confidence interval was common practice in trend analysis. However, recently a new method has been developed whereby lower levels of confidence are accepted (Snelder and Fraser, 2018). This approach has been used by the Canterbury and Wellington Regional Councils for trend analysis as well as in the LAWA analysis. The benefit of this updated approach is it accepts trend directions with lower levels of confidence (but still at least 66% confident).

4.4 Therefore, it is my view that the method used in the LAWA data is more nuanced and can help make better interpretations of trend direction from the available data.

4.5 In my evidence I have not referred to the five-year data period from the LAWA analysis. It is my view that with short term periods of trend analysis, there is the risk that the period coincides with wet or dry periods which can influence trend direction. In Appendix 1, I have summarized the ten-year LAWA trends and broken these results down into the Freshwater Management Units (**FMU's**) defined by Environment Southland. In summary, I found:

(a) In the Waiau FMU, improving trends were more frequent than other trend categories for clarity, total phosphorus (**TP**), ammonical nitrogen (**$NH_4$-N**) and Escherichia coli (***E.coli***). Worsening trends were more common for total nitrogen (**TN**). For dissolved reactive phosphorus (**DRP**) there were just as many sites worsening as sites with indeterminate trends. For total oxidised nitrogen (**TON**), there were just as many improving sites as indeterminate sites.

(b) In the Aparima FMU, improving trends were more frequent for clarity, DRP, TP and TN, TON and *E.coli*. There were worsening trends for DRP, TN, TON and *E.coli*, but less frequent than improving trends. Sites were evenly split between improving and indeterminate for $NH_4$-N.

(c) In the Oreti FMU improving trends were more frequent than worsening trends for TP, TN and TON. Clarity has more sites with indeterminate trends, followed by worsening trends. *E.coli* was broadly split equally between the three categories. NH4-N and DRP had more worsening trends than improving trends.

(d) In the Mataura FMU, improving trends were more frequent for TP, $NH_4$-H, TN and TON than worsening (but only just for TN). Clarity had more sites worsening than improving as did DRP and *E.coli*.

4.6 For macroinvertebrate community index (MCI) scores, fewer sites were able to be analysed using the LAWA method than the approach used by Hodson and Akbaripassand (2017). Nevertheless, in the Waiau FMU, most sites had indeterminate trends, but 25% of sites were worsening. In the Aparima FMU, only one site was analysed and the trend was indeterminate. In the Oreti FMU, half of sites were improving, but a quarter were worsening. In the Mataura FMU, 21% of sites were improving and 43% of sites were worsening.

4.7 In my assessment of trend results for the ten-year period ending December 2017, there are variable trend directions reported across sites and within sites. Specifically, for all trend tests completed for all parameters at all sites, 44% of tests had improving trends while 30% of trend tests had worsening trends. Accordingly, I do not agree that paragraph 32 of Ms McArthur's evidence, which reports that degrading ten-year water quality trends were common, presents the full picture; a more accurate summary would be that while degrading trends are common (at 30%), there are a greater percentage of trends (44%) that are improving.

**State**

4.8 Mr Hodson has provided a summary of the state of water quality against attributes from the NOF, standards in the Southland Regional Water Plan and ANZEEC (2000) guidelines. I agree with his statements, in particular with respect to periphyton and macroinvertebrate community index (MCI) results and only wish to add the following comments to provide additional context.

4.9 To aid comparisons of NNN and DRP, Mr Hodson has compared Southland monitoring data to ANZECC guideline values. It is important to note that the ANZECC guideline values are based on 80$^{th}$ percentile values from low or non-impacted (by human activities) upland and lowland rivers from NIWA's river water quality monitoring network. Because these guideline values are based on monitored data at a small selection of low or non-impacted sites and not tested against ecological data to identify ecological tipping points, they should not to be used as limits that imply degraded ecosystem health if they are exceeded.

4.10 Monthly periphyton data for three years collected between December 2014 and December 2017 was collected at 30 sites. Analysis of this data demonstrated that none of the sites have failed the national bottom line (D-band) for the periphyton attribute prescribed in the NOF. Modelling of this measured data indicates a possibility that the D-band would have been breached at seven sites. However, the conditions that occurred between December 2014 and December 2017, did not allow for the proliferation of algae (Hodson and de Silva, 2018). This comment also reinforces the point that ANZECC guidelines are just guidelines, not limits, as, despite the ANZECC guidelines being exceeded during the period of periphyton sampling, there were no periphyton blooms that a D-band reflects.

4.11 Ms McArthur has also provided commentary on the quartile bandings of the five-year median for different parameters (paragraphs 25 to 29) based on the rank of Southland's water quality sites with other, similar sites (based on elevation and land cover classifications) throughout New Zealand. Dividing sites into quartiles as a method of assessing state is not helpful as it does not account for natural variables (for example, volcanic geology with naturally enriched phosphorus soils), nor does it assess the current state of water quality against effects-based thresholds. I therefore, do not agree that the way Ms McArthur has presented her data through dividing sites into quarterlies is appropriate.

**Assessment of state and trend of water quality in Southland**

4.12 When the LAWA trend results described above are considered in totality, there has been degradation in water quality attributes for 30% of all trend tests completed. However, there were improving trends for 44% of trend tests completed (water chemistry and MCI scores included).

4.13 The state results have demonstrated that while there is the risk that periphyton may exceed the national bottom line, the results from sampling conducted between December 2014 and December 2017 have shown that there are no sites with periphyton blooms despite the ambient water quality conditions at that time. However, when MCI scores are considered, 23% of sites do not comply with the MCI standards prescribed in the operative Southland Regional Water Plan.

4.14 Based on this information and in the absence of community defined outcomes for water quality, it is my opinion, that while there has been worsening trends and some sites do not meet prescribed outcomes for MCI, there is not a wide-scale pattern of degraded and degrading water quality (with respect to ecosystem health) at the regional scale.

4.15 The exception to this assessment is human health, specifically *E.coli* results which demonstrate that there is a wide-spread *E.coli* problem, especially in lowland rivers.

4.16 With the above assessment of water quality, and understanding that:

(a) Rule 20(d) of the pSWLP requires all dairy conversions to apply for consent, and the following is required as part of that consent application:

(i) A Farm Environment plan (FEP) must be prepared and implemented

(ii) An assessment must show no increase in N, P, sediment and microbial contaminants as a result of the conversion

(iii) A mitigation plan must accompany the application;

(b) Dairy farm conversions appeared to have plateaued (Appendix 3);

(c) Groundwater lag times are estimated to be around ten years for most of Southland (Rodway, 2019 and references therein);

it is my view that once the lag time periods are realised, the likelihood of an increase in receiving environment concentrations due to existing land use intensification (the 'lag to come') will have lessened considerably (especially for nitrogen which is the contaminant that would most likely experience a lag) and the receiving environment should move to a steady state. It is possible that with the requirements for increased buffer widths and FEPs requiring the uptake of good management practice, that concentrations associated with run-off (sediment, phosphorus and bacteria) could further reduce.

4.17 With my assessment of water quality above, and with the understanding that Environment Southland is in the early stages of starting a limit setting process, it is my opinion that the 'holding the line' approach proposed in the pSWLP is sufficient to maintain overall water quality while more detailed assessments of water quality limits and the site specific drivers is undertaken in the limit setting process. Given some of the necessary information is not currently available to define the site-specific drivers of ecosystem health, there is the risk that management responses will be ineffective or poorly targeted. Therefore, site-specific drivers of ecosystem health should be identified during the limit setting process when values and objectives are identified.

## 5. DISCUSSION OF 'OVERALL' WATER QUALITY

5.1 I note that there has been considerable debate about the term "overall" (sometimes referred to as 'unders and overs') (Land and Water Forum, 2014; Parliamentary Commissioner for the Environment, 2015). This term has often been debated in the context of one site or sites degrading while another site or sites improve whereby these sites can be seen to 'balance out' to represent the 'overall' maintenance of water quality.

5.2 To help with the interpretation of ‘overall’ I understand that when the NPSFM was first released, it interpreted overall water quality as applying to the regional scale. The 2017 amendments to the NPSFM reduced this term’s spatial scale from regional to the FMU scale. Further, it is my understanding based on the evidence of Mr Willis, that additional guidance provided in respect of the NPSFM states that overall water quality is maintained when an attribute state is within the same attribute state band as existing water quality (or, where the attribute is not in Appendix 2 (and therefore has no predetermined bands) where the value(s) it is being set for will be no worse off.

5.3 Further to this, it is my opinion, that the use of the term ‘overall’ is appropriate and necessary given the complexities associated with monitoring and reporting water quality data. For example, when water quality experts review water quality information, there is often a large record of data (but equally, an absence of data). This could include physical data (e.g., temperature data, habitat data), chemical data (e.g., nutrients), biological data (e.g. periphyton, fish), hydrological data, land-use information and catchment specific details such as geology. This data is often highly variable in both space and time with different trend directions which are responding to climatic variation, land-use change, land-management change or natural disturbances. With all of this information, water quality experts will need to review this data and consider the land-use change that has occurred (and which could occur) as well as the relevant receiving environments, to determine if the water body in question is of acceptable or unacceptable ecosystem health and if the water body is getting better or worse in response to human activities. An example of this from my evidence is where I have noted that 44% of all trend tests had improving trends while 30% had worsening trends. This illustrates that there are often mixed and contradictory trends within and between attributes and monitoring stations.

5.4 These assessments often have the added challenge of ecosystem health being impaired by multiple stressors where the stressors are additive and interactive, and effects are not fully understood, nor their tipping points defined. Therefore, by using the word “overall”, experts have the ability to consider all information as opposed to relying on one single metric to describe water quality.

## 6. THE DRIVERS OF MACROINVERTEBRATE COMMUNITIES AND THEIR USE AS LIMITS

6.1 Macroinvertebrate monitoring has been used for decades in New Zealand and is considered useful for assessing ecosystem health in wadable rivers. This is reflected in recent additions to the NPSFM whereby regional councils are required to examine the causes for macroinvertebrate community indices (**MCI**) that are less than 80, or where a declining trend has been established (Policy CB3, NPSFM).

6.2 Macroinvertebrate community composition and abundance is influenced by a variety of factors which have been examined in numerous New Zealand studies (e.g. Quinn et al. 1997; Young and Collier, 2009). These factors include:

(a) the removal of riparian vegetation, which can change food webs, increase water temperature and the amount of light reaching a stream thus promoting plant growth - macrophytes or periphyton (Quinn et al 1997; Davies-Colley and Quinn, 1998; Parkyn, 2004) as well as reducing complex habitat (Parkyn, 2004; Quinn and McKergow, 2007);

(b) increased sediment inputs which can reduce benthic habitat availability (Matthaei et al. 2010; Greenwood et al. 2011; Burdon et al. 2013);

(c) increased nutrient availability (nitrogen, ammonia, phosphorus) which can promote plant growth (Biggs, 2000) and, in situations where nutrient concentrations are high, have toxic effects (Hickey, 2013).

6.3 Many of these factors can and do have cascading or additive effects on the ecosystem. This is best shown in Appendix 2.

6.4 In his Evidence in Chief, Dr Death has recommended instream nitrogen and phosphorus concentration criteria that are required to manage for different macroinvertebrate community index (**MCI**) thresholds. Dr Death has also recommended increases in MCI scores for some river types. I have read the manuscript that Dr Death has co-authored and has presented as evidence to support his proposed instream nutrient criteria. I have several concerns with the approach used. These include the following:

(a) The authors have used four lines of evidence to explore nitrate ($NO_3$-N) and dissolved reactive phosphorus (DRP) loss relationships with MCI scores. Two of these are modelled data while the remaining two are based on measured data. The modelled data identified that the percent heavy pasture cover and percent indigenous forest cover were, relatively speaking, the strongest predictors of MCI and nitrate data. This result is unsurprising as it is expected that as the percent cover of native forest reduces and is replaced by agricultural cover that nitrate concentrations increases. In addition, it is not surprising that MCI scores reduce given that, as land is converted from native cover to agricultural cover, a range of changes occur (as described in paragraph 6.2 of my evidence) which will subsequently impact on MCI scores.

(b) Therefore, the risk with Dr Death's analysis is that it simplifies all the known drivers of degraded MCI scores to two predictors ($NO_3$-N and DRP) that do not have direct effects on MCI scores.

(c) This point is especially pertinent given that Clapcott et al (2017) has concluded that nutrients are most likely to affect macroinvertebrates via growths of periphyton rather than directly. The only direct effect of nutrients on macroinvertebrates (specifically nitrate and ammonia) will be at high concentrations (Hickey, 2013).

(d) While I am unaware of any New Zealand study that has compared the effects of river engineering and drain clearing on macroinvertebrates, it is acknowledged that this activity can affect instream ecosystems (e.g. Brooker, 1985; Young et al. 2004; Allibone and Dare, 2014). In Southland, much of the river network has been heavily modified and frequently maintained to provide for flood and drainage management. This engineering and management include the straightening of rivers, removal/spraying of macrophytes, removal of wooden debris and sediment to the point of creating homogeneous rivers (Brooker, 1985). Consequently, many rivers and streams are now highly modified and support fewer features of benefit to macroinvertebrate communities including organic debris (leaf packs) habitat, complex and diverse benthic habitat and run/ riffle/ pool sequences (e.g. Scealy et al. 2007). In my opinion, this river modification and management will be causing some of the degradation in MCI scores in Southland.

## 7. CONCLUSION

7.1 My evidence has identified that while there are increasing trends for some water quality measures, there is not a widespread issue of degrading water quality for the ten-year data recorded and presented by LAWA. This is demonstrated by 44% of trend tests improving and 30% worsening.

7.2 My evidence, and the evidence of Mr Hodson, has identified that there are some sites not meeting MCI outcomes as currently prescribed. However, there is no evidence of wide-spread and degraded water quality (and ecosystem health) in rivers with respect to the national bottom lines for toxicity or periphyton or those where attribute states are outside of the NPSFM (e.g. MCI). Nevertheless, there is a wide spread bacteria issue presenting a risk to recreational activities.

7.3 This evidence highlights the need for the word 'overall' to be maintained within the planning framework to allow for water quality experts to make assessments of water quality based on the range of data and the complexities and conflicts within that data.

7.4 I am concerned that the rationale for Dr Death's MCI and $NO_3$-N and DRP limits relies on the assumption that NO3-N and DRP have direct impacts on MCI scores which my evidence disagrees with. This raises reliability issues with respect to Dr Death's proposed limits.

7.5 With this evidence in mind, it is my opinion that the pSWLP's 'holding the line' approach is appropriate to manage water quality risks while a more detailed FMU limit setting process is implemented. Such a process should be able to identify more appropriate objectives and limits based on a more detailed, site by site assessment of the local conditions.

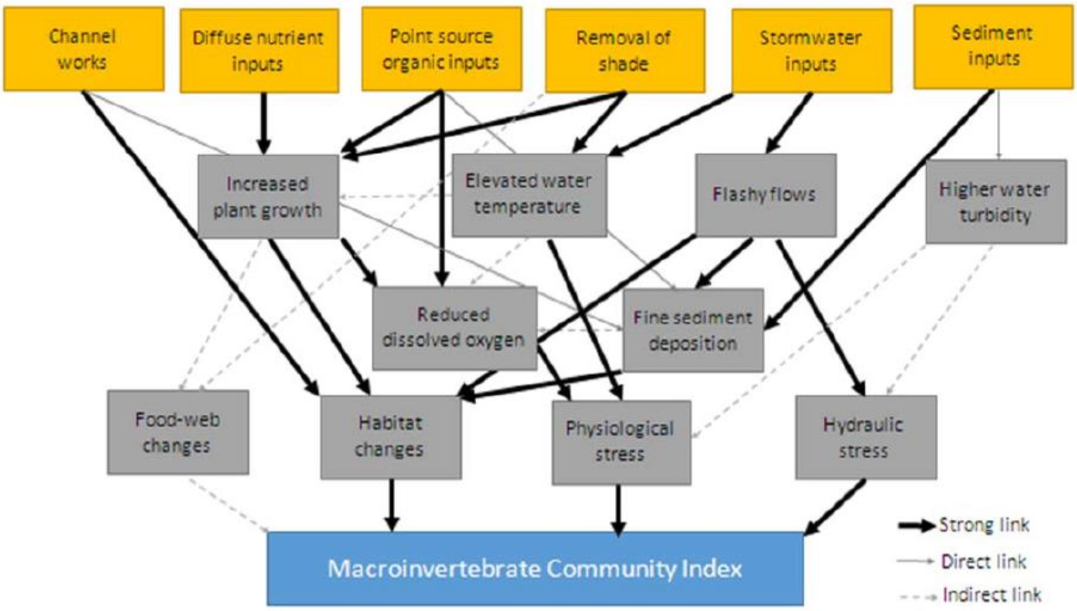
Justin Kitto
15 March 2019

**Appendix 1:** Summary of trend results of water chemistry and macroinvertebrate community index for the period January 2008- December 2017. Adapted from LAWA 2018 (accessed 6 March 2019).

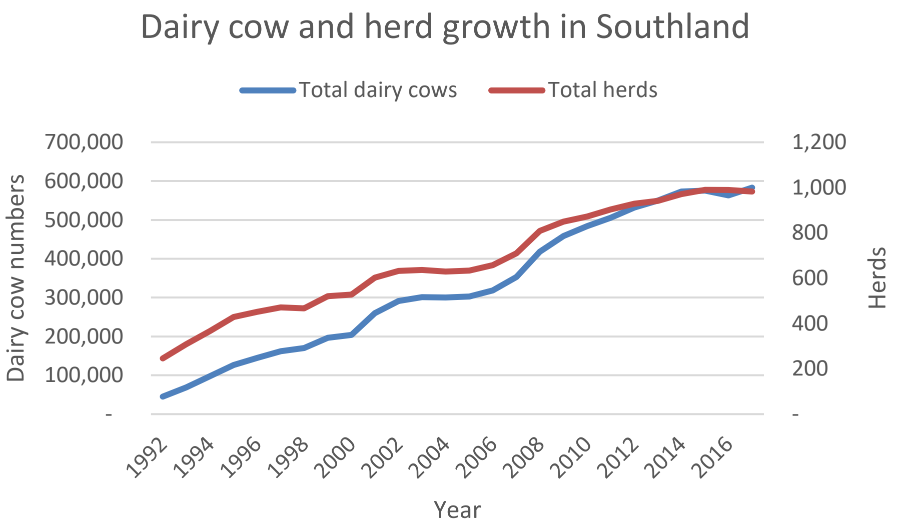
| **Freshwater Management Unit** | | **Clarity** | **Turbidity** | **Dissolved reactive phosphorus** | **Total phosphorus** | **Ammonical nitrogen** | **Total nitrogen** | **Total oxidised nitrogen** | ***E.coli*** | **Macroinvertebrate community index** |
|---|---|---|---|---|---|---|---|---|---|---|
| **Waiau** | Total sites | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 |
| | Total sites analysed | 6 | 1 | 2 | 8 | 4 | 8 | 7 | 6 | 4 |
| | Improving | 3 | | 0 | 4 | 2 | 0 | 3 | 4 | 0 |
| | Worsening | 1 | 1 | 1 | 2 | 1 | 5 | 3 | 2 | 1 |
| | Indeterminate | 2 | | 1 | 2 | 1 | 3 | 1 | | 3 |
| | % improving | 50 | 0 | 0 | 50 | 50 | 0 | 43 | 67 | 0 |
| | % worsening | 17 | 100 | 50 | 25 | 25 | 63 | 43 | 33 | 25 |
| | % indeterminate | 33 | 0 | 50 | 25 | 25 | 38 | 14 | 0 | 75 |
| **Aparima** | Total sites | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 |
| | Total sites analysed | 3 | 2 | 7 | 8 | 4 | 7 | 7 | 8 | 1 |
| | Improving | 3 | 2 | 3 | 8 | 2 | 4 | 4 | 6 | 0 |
| | Worsening | 0 | 0 | 2 | 0 | 0 | 3 | 2 | 2 | 0 |
| | Indeterminate | 0 | 0 | 2 | 0 | 2 | | 1 | 0 | 1 |
| | % improving | 100 | 100 | 43 | 100 | 50 | 57 | 57 | 75 | 0 |
| | % worsening | 0 | 0 | 29 | 0 | 0 | 43 | 29 | 25 | 0 |
| | % indeterminate | 0 | 0 | 29 | 0 | 50 | 0 | 14 | 0 | 100 |
| **Oreti** | Total sites | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 |
| | Total sites analysed | 8 | 1 | 12 | 15 | 10 | 14 | 13 | 17 | 8 |
| | Improving | 1 | 0 | 4 | 7 | 4 | 9 | 8 | 6 | 4 |
| | Worsening | 3 | 0 | 5 | 3 | 5 | 3 | 3 | 5 | 2 |
| | Indeterminate | 4 | 1 | 3 | 5 | 1 | 2 | 2 | 6 | 2 |
| | % improving | 13 | 0 | 33 | 47 | 40 | 64 | 62 | 35 | 50 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | % worsening | 38 | 0 | 42 | 20 | 50 | 21 | 23 | 29 | 25 |
| | % indeterminate | 50 | 100 | 25 | 33 | 10 | 14 | 15 | 35 | 25 |
| **Mataura** | Total sites | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 |
| | Total sites analysed | 13 | 3 | 21 | 21 | 14 | 21 | 22 | 20 | 14 |
| | Improving | 3 | 1 | 7 | 17 | 6 | 9 | 11 | 3 | 3 |
| | Worsening | 5 | 2 | 8 | 1 | 4 | 8 | 6 | 7 | 6 |
| | Indeterminate | 5 | 0 | 6 | 3 | 4 | 4 | 5 | 10 | 5 |
| | % improving | 23 | 33 | 33 | 81 | 43 | 43 | 50 | 15 | 21 |
| | % worsening | 38 | 67 | 38 | 5 | 29 | 38 | 27 | 35 | 43 |
| | % indeterminate | 38 | 0 | 29 | 14 | 29 | 19 | 23 | 50 | 36 |

**Appendix 2:** Conceptual model of causal linkages between anthropogenic impacts and the macroinvertebrate community index from Collier et al. (2014).



**Appendix 3:** The growth or dairy cow and her numbers in Southland (New Zealand Dairy Statistics, 2018).



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