Review of the status of freshwater quality in Taranaki

Technical Report 2014–103

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Executive summary

Under Section 65 of the *Resource Management Act 1991* (RMA), a regional council may prepare a regional plan to assist it to deliver any of the functions of a regional council described in Section 30 of the RMA. Under Section 67, a regional plan may state [(2)(a)] *the issues that the plan seeks to address; and…(c) the principal reasons for adopting the policies and methods; and (d) the environmental results expected from the policies and methods;…*

A freshwater plan (the *Regional Fresh Water Plan for Taranaki*, or RFWP) has been in effect in Taranaki since October 2001. The Taranaki Regional Council (the Council) is currently undertaking a statutory review of the RFWP. This review is being undertaken against a background of a national conversation around water quality (including its state and trends in its state) in New Zealand. This conversation has focused primarily on perceptions of deteriorating water quality due to increases in concentrations of nitrogen and to a lesser extent of bacteriological degradation, and of the primary solution being regulatory intervention in land use (particularly targeting intensive pastoral farming).

The Council considers it critical that in regard to the review of the RFWP, the regional community is well-informed as to the state and nature of and trends in the quality of surface water in Taranaki, and understands the significant variations in surface water from region to region (and hence the scale and significance of water quality issues). This review sets out information on the state of our streams and rivers, including an evaluation of suitability for use in the light of various guidelines and statutory standards; it provides information on trends in the various parameters that are used to measure aspects of water quality and suitability for use (values); and it discusses the present and anticipated future drivers of in-stream health including the likely effects of proposed interventions/ methods of implementation of policies for enhancing water quality.

This information then provides the context within which to evaluate any justification for measures that could be introduced within the new RFWP.

The information this review draws upon is taken from the Council's 'state of the environment' (SEM) programmes, which have been in place for 18 years and have been delivered (including data interpretation) according to recognised 'good practice' techniques and with external review. Sites are variously assessed using measures of ecological health, physicochemical state, suitability for recreational use (bacteriology), and periphyton cover. This review also incorporates the date from 3 sites monitored for physicochemical measurements by the National Institute for Water and Atmospheric Sciences (NIWA) for a longer period. One of the NIWA sites is also monitored independently by the Council, for mutual quality control purposes.

Because this review is being implemented within the context of the Council's review of the current RFWP, trend analysis discussed herein has encompassed the more recent of the SEM water quality data, as this period is the more relevant to consideration of the effectiveness of current policies and their implementation.

Any new policy intervention should be well-grounded in evidence and science that informs the understanding of the current situation and explores the justification for ('is a change in policy actually needed? On what basis is that statement made?') and the likely or unlikely effectiveness ('will it achieve the desired outcome in full or only in part') and efficiency ('what is the cost of the proposed intervention against the benefit?') of each potential intervention.

The scientific and evidential basis should reflect the Taranaki context (while noting that there may also be national obligations that must be honoured eg National Policy Statements or National Environmental Standards, under the Resource Management Act 1991). The latest and best relevant information should be brought to bear, and incorporated constructively into the new policy.

The values to be given effect to through any accomplishment, improvement, or progress to be gained through any new policy should reflect those held by the Taranaki community.

The policy should be framed in a way that facilitates innovative and holistic solutions ('best net environmental outcomes?') rather than be siloed from other programmes and instruments.

Policy should build on what is already happening regionally (not necessarily what is happening elsewhere) and on what is needed or justified regionally (not necessarily on what has been found to be necessary elsewhere).

With regard to the current **state of Taranaki's surface waters**, this review shows that the state of Taranaki's streams and rivers is already very good by assessment against guidelines and statutory requirements. When compared with the National Objectives Framework (NOF) established through the *National Policy Statement for Freshwater Management 2014* (NPS-FW), by far the greatest number of attribute measurements at each site already fall into the 'A' NOF category, with most of the remainder falling into a 'B' category. There is a single 'C' result and no 'D' result: that is, there is no attribute at any site that falls below the compulsory bottom lines established within the NOF.

Before the NOF was released, the Council had in preparation for the review of its RFWP commissioned NIWA to develop regionally appropriate guidelines for water quality to provide for a range of potential uses of surface water. These guidelines cover a greater number of parameters/attributes than does the NOF. As with the NOF criteria, results for almost all attributes at almost all sites already fully satisfy these criteria. In a few isolated cases the majority of but not every result already meet the criteria; there is one site where only a minority of results currently meet the stock drinking water/ human secondary recreational use guideline; and DRP is higher than desired at some sites. In this latter instance it should be noted that monitoring of periphyton (algae layers on the stream bed) in the region demonstrates that national guidelines for periphyton are satisfied everywhere even under the most extreme conditions, except on rare occasion at one or two sites. That is, even when DRP levels are higher than guideline values this is not leading to adverse environmental outcomes within the region.

Other than at three freshwater bathing sites where environmental forensic investigations using DNA have identified seagulls, pukekos, and ducks as major sources of faecal contamination, more than 99% of freshwater samples collected each summer in the Council's recreational surveys meet the national bathing guideline.

The Council makes extensive use of the Macroinvertebrate Community Index (MCI) as a measure of the health of in-stream ecology. Macroinvertebrate communities (tiny animals including insects, crustaceans, molluscs, worms, and leeches) are assessed for their presence and abundance, and this data is transformed into a quantitative index. There are no national guidelines for MCIs, as values change significantly down a catchment as stream morphology, hydrology, and meteorology change with altitude and distance from source. The Council makes use of comparisons of MCI values at any point in any catchment, with calculated ‘expected values’ based on reference sites of a similar nature across the region. This work shows that there are a few, spatially limited, areas in the region where MCI values are lower than those that could be expected (and hence there is opportunity for targeted interventions to achieve enhancements in in-stream health), but that otherwise MCI values across the region are generally already in the appropriate range.

In summary, this review shows that the existing water quality in Taranaki is already very high when evaluated against guidelines/ standards relating to various purposes for which water could be utilised. There is no statutory, environmental, or value driver that justifies interventions that would carry a high cost to the region or to a sector within the region.

In summary, this review shows that the emphasis upon using ecological measures to assess stream health that is at the heart of monitoring practice in Taranaki is consistent with current monitoring innovation internationally. The monitoring programmes implemented by the Taranaki Regional Council have been repeatedly subject to independent review and audit, and found to be fit for purpose.

The existing water quality in Taranaki is found to already be very high when evaluated against guidelines and standards (whether national and international) relating to various values and purposes for which water could be utilised. The accomplishments and improvements already established within the region have created a good framework for modification by any further policy extension.

There is thus no statutory, environmental, or value driver that justifies interventions that would carry a high cost to the region or to a sector within the region. Any new policy should be designed to enhance and build on what is already a good picture.

With regard to the **current trends in Taranaki’s surface waters**, this review shows that clear improvements are occurring across the region in most measures of water quality. Ecological health is widely regarded by water management agencies as the primary measure of freshwater quality, using indices based on macroinvertebrate communities (see above). Data from 57 key sites shows that in the most recent surveys reported, 21 recorded their best-ever macroinvertebrate score. Rigorous statistical analysis shows that 21 sites are demonstrating an ‘almost certain’ positive trend and 9 further sites are demonstrating a ‘very likely’ positive trend. No sites are demonstrating evidence of deterioration at an equivalent statistical level.

Assessments of trends in periphyton cover show an improvement in measures of mat coverage and strand coverage that is statistically meaningful at three (mats) or seven (strands) sites, respectively, and otherwise no evidence of change in the two measures at all remaining sites.

Assessment of trends in physicochemical parameters shows that in recent years, almost universally results are demonstrating an almost certain improvement, a very likely improvement, or at the very least no evidence of a change. Only one site (out of 13) shows deterioration in some of its measures. Notably, a number of sites are now showing reductions (improvements) in the concentrations of nutrients (the various forms of nitrogen and phosphorus) present in the water column. Trend analyses across both long term (19 years) and recent (the last 7 years) records show that total nitrogen is significantly reducing at a majority of the sites monitored and has not increased and is not increasing at any site. Across all 13 sites, 12 of the measurements of one or other of the various forms of nitrogen (ammonia, total nitrogen, and nitrate) are showing significant recent improvement, and only one measurement (of ammonia in the upper Waingongoro) that is showing a recent deterioration.

In summary, this review shows that the region is not facing a crisis of deteriorating water quality. Indicators of in-stream ecological health and of pressures upon water quality are moving in the desired direction. As an overall trend, water quality is currently being enhanced in the region (15% of measurements showing significant improvement, 80% showing no evidence of a trend, and 5 % showing a deterioration, over the last 7 years). Therefore, measures to halt and reverse regional trends are not required; instead, it is a matter of considering what new measures (if any) are appropriate to further foster the current direction of travel.

With regard to **drivers of in-stream health and water quality**, this review notes that first of all it is important for the regional community to be aware that (i) nitrogen is not the key determinant of in-stream ecology (periphyton and macrophytes) in Taranaki streams in any case. Rather, phosphorus is recognised as the limiting nutrient- that is, the extent of periphyton growth, including any excessive growth, will be determined by the availability of phosphorus. Thus, measures that focus on reducing nitrogen inputs would be mis-placed, and conversely, measures that reduce phosphate loadings would have much more direct benefit; (ii) secondly, excessive nutrients (if indeed they were to be present) do not of themselves actually lead to adverse environmental consequences. The relationship between nutrients within a waterway and the ecological health of that waterway is neither linear nor straightforward. A number of other environmental factors must also simultaneously be present before periphyton proliferate. In particular, the duration of low, warm, and slow flows in the presence of strong sunlight is a controlling factor. An independent national study found that the Taranaki region is essentially the least susceptible region in New Zealand for excessive periphyton to occur, because of the frequency of rainfall events even during summer (this is not about total rainfall, but the return interval between the rainfall events that result in flushing effects in rivers). This prognosis is borne out by the actual observations of periphyton made during monitoring at critical times (see above).

The Council is proposing two significant new measures for introduction in the next RFWP: the region-wide diversion of dairy shed effluent from discharge to water, to discharge to land as a general rule, and the completion of the current riparian exclusion and planting programmes across the region’s ring plain. Currently about half the region’s dairy farms discharge to water, although the proportion is gradually reducing; the Council considers that this can be accelerated and discharge to land made the regulatory rule. This would effectively eliminate one of the two major sources of organic, bacteriological, and nutrient loadings to Taranaki’s waterways.

The second measure would see elimination of overland flow (runoff) from diffuse sources of contamination, such as eroding soil, fertiliser, and animal wastes, on pastoral land, and the consequences of animals entering or damaging the banks of streams (soil erosion and the direct deposition of animal wastes). Because phosphate binds to soil, prevention of soil loss and soil transport into streams has a major added benefit of reduced phosphate transport. Overseas studies reviewed within this report indicate that riparian control can reduce sediment, phosphate, and bacteriological loadings from diffuse pollution runoff by up to 80%. It is recognised that riparian plantings are less effective at reducing nitrogen transport into streams (because nitrogen is generally transported in dissolved form via groundwater rather than surface runoff), but this qualification needs to be placed within the context that in-stream nitrogen concentrations are already reducing, the diversion of dairy shed effluent will of itself significantly further reduce nitrogen loadings on waterways, and nitrogen is of less significance environmentally in Taranaki than in some other regions. The Council will continue to encourage (rather than require) the adoption of other good farming practices such as the use of balanced nutrient budgets based on both nutrient modelling and also on soil/pasture sampling, the avoidance of heavy stocking of saturated pastures near streams, maintaining soil nutrient levels at optimal instead of at excessive concentrations, and matching fertiliser application to times and degree of greatest demand (precision fertilisation). Given the scale of the anticipated benefits of the proposed measures, it is difficult to see how harsher or more punitive regulatory measures to reduce nutrient loadings can be justified against incremental gains that might be made..

In terms of future trends within the dairying industry, much has been made of intensification of land use (conversion to dairying or to higher stocking rates on existing pasture) within the context of the conversation around national water quality. This review notes an investigation of the issue by the Parliamentary Commissioner for the Environment (PCE). As discussed in more detail further in this review, the PCE found that it was the conversion of land previously used for purposes such as extensive agriculture or forestry, to intensive dairying (usually involving irrigation) that was the root driver of a deterioration of water quality (as measured by nutrient concentrations). Her concern focused on nitrogen and not on phosphorus (it was noted that riparian control is effective at abating phosphorus), because it was seen as a trigger of excessive periphyton. The study noted that eliminating effluent discharges to water would reduce nitrogen losses to water by about 20%. The PCE assessment for Taranaki was that the area of land dedicated to intensive dairying since 1996 had in fact reduced by about 7%; while an increase by 2020 was predicted through modelling, the magnitude of this predicted increase in absolute terms above the 1996 level was less than 3%. The PCE report presented modelling that suggested nitrogen loadings to Taranaki's waterways had increased 4% 1996-2008, and can be expected to increase another 5% by 2020.

However, monitoring shows that in actual fact concentrations of total nitrogen in the region's waterways have actually reduced overall throughout 1996- 2014, when loadings had supposedly increased according to the modelling; and over the last seven years- when the area of dairying was increasing again-nitrogen concentrations are continuing to reduce on a regional perspective, with no increase in total nitrogen at any site during this period. Thus, any imperative for a proactive intervention that anticipates a future major issue around increasing nutrients in the region's waterways is not supported upon close examination. The modelling undertaken for the PCE report indicates that Taranaki is unlikely to see a major expansion of intensive dairying into catchments that hitherto were not exposed to this land use; and in addition, monitoring to date shows that the modelled outcomes are conservative- that is, they present a picture that is more pessimistic than is borne out in realisation. The work by NIWA establishes that the levels of nitrogen and phosphorus in streams in Taranaki (even in 2009) were not high by national comparison. Concerns, interventions, and actions elsewhere do not transfer directly to Taranaki.

The mid and lower catchment reaches of rivers in Taranaki are shown to be phosphate-limited: that is, actions to reduce the levels of periphyton in Taranaki's rivers (if action is needed) by reducing levels of nutrient would be more effective if they focus on phosphorus over nitrogen. However, given the frequency and nature of flushing events within Taranaki's hydrological systems, Taranaki is simply not vulnerable to extended periods of excessive periphyton. Once flow patterns (return periods for flushing events) are taken into account, the picture of susceptibility to excessive periphyton biomass. The imperative to reduce nutrient concentration has less application in Taranaki than elsewhere.

NIWA's nationwide data validates this analysis. Sites in Taranaki meet national criteria and are amongst the better sites nationally.

Fertiliser loadings and soil concentrations of phosphorus have largely remained stable over the last two decades but in-stream concentrations are showing some indications of stabilization and reductions since 2004.

Nitrogen loadings onto pasture have increased markedly, but in-stream nitrogen concentrations have remained stable and more recently (since 2006) have begun reducing.

Riparian management is shown to have multiple benefits for the aquatic environment –

- reduced loadings not only of nutrients, but of sediment (found by USEPA to be more critical as a pressure on water quality than nutrients are), organic content, and bacteria;
- enriched in-stream and stream-bank habitat, thus supporting more diverse and abundant communities;
- shading that reduces light and lowers in-stream temperature;
- greater food supply via leaf litter and woody debris;
- reduced run-off flow velocities

Riparian management has been shown to be amongst the most cost-effective and effective in absolute terms as a means of promoting stream health.

The diversion of treated dairy shed effluent from water under all but the most exceptional of circumstances will further reduce current nutrient loadings within the region. As with riparian management, this action has benefits not only for reduction of nutrient loadings, but also for reduced turbidity, suspended solids, organic loadings, and bacteriological impacts.

Given that:-

- lag times on the ring plain of Taranaki are quite short (less than 5 years) due to free-draining soil and shallow aquifers and the intensive stream network; and that
- groundwater across the region is showing if anything a slight overall decrease in levels of nitrate nitrogen during the last decade, despite increasing applications of broadcast artificial nitrogen fertiliser; and that
- the median concentrations of nitrate-nitrogen in shallow groundwater across the region are very low, and if anything are gradually reducing, despite the increase in applications of broadcast nitrogenous fertiliser; and that
- on a site by site basis improvements in stream ecological condition have been found to be independent of trends in nutrient concentrations at the same site (data not shown); and that
- macroinvertebrate conditions at a substantial number of sites were showing a marked improvement even when the overall pattern of nutrient concentrations in waterways was unchanging or still deteriorating at a substantial proportion of sites; and that
- the year by year increase in the number of sites showing a marked improvement in their macroinvertebrate condition is displaying a similar trajectory to the year by year increase in the extent of riparian fencing and planting; and that
- an accelerating number of stream sites are showing improvements in ecological condition that are both meaningful changes and are statistically significant, at the same time that riparian fencing and planting are accelerating on a regional basis:-

it is postulated that the current primary driver for the significant improvements in ecological condition of the Taranaki region's waterways is the implementation of the regional riparian programme. It is considered that a continuation and acceleration of this programme, in association with measures to reduce effluent discharges from farm pond system, will have demonstrable and widespread benefits.

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1. Introduction

1.1 Purpose of this review

1.1.1 Introduction

A freshwater plan (the *Regional Fresh Water Plan for Taranaki*, or RFWP) has been in effect in Taranaki since October 2001. The Taranaki Regional Council (the Council) is currently undertaking a statutory review of the RFWP, in accordance with Section 66 of the RMA. This review is being undertaken against a background of a national conversation around water quality (including its state and trends in its state) in New Zealand. This conversation has focused primarily on perceptions of deteriorating water quality due to increases in concentrations of nitrogen and to a lesser extent of bacteriological degradation, and of the primary solution being regulatory intervention in land use (particularly targeting intensive pastoral farming).

The Council considers it critical that in regard to the review of the RFWP, the regional community is well-informed as to the state and nature of and trends in the quality of surface water in Taranaki, and understands the significant variations in surface water from region to region (and hence the scale and significance of water quality issues). This review sets out information on the state of our streams and rivers, including an evaluation of suitability for use in the light of various guidelines and statutory standards; it provides information on trends in the various parameters that are used to measure aspects of water quality and suitability for use (values); and it discusses the present and anticipated future drivers of in-stream health including the likely effects of proposed interventions/ methods of implementation of policies for enhancing water quality.

This information thus provides the context within which to evaluate any justification for measures that could be introduced within the new RFWP.

1.1.2 Study of nutrient management options for RFWP

As part of the review of the *Regional Freshwater Plan for Taranaki*, the Taranaki Regional Council (the Council) is examining options for maintaining and enhancing water quality through improved nutrient management on land where dairy farming occurs. This examination needs to be to a level that satisfies the recently amended Section 32 of the Resource Management Act 1991 (RMA). This examination includes consideration as to whether nutrient management measures are necessary, and the relative costs and benefits of options for nutrient management.

The Council is preparing an *Economic Costs & Benefits Report* with the purpose of investigating and providing a report assessing the economic costs and benefits of including different nutrient management options for dairy farming into a reviewed Taranaki Regional Freshwater Plan. The *Economic Costs & Benefits Report* will then form the basis of a Section 32 Evaluation Report of the objectives and policies adopted in the reviewed Taranaki Regional Freshwater.

The Council has identified three alternative policy options as context for the *Economic Costs & Benefits Report,* as follows:-

Option One – ***Status Quo***

This option involves continuation of the voluntary Riparian Management Programme which involves the following initiatives:

- Eventual completion across an anticipated 90% of the region of existing voluntary fencing of waterways
- Eventual completion across an anticipated 90% of the region of existing voluntary planting of waterways
- On-going liaison and support
- Encourage the existing trend of increasing disposal of farm dairy effluent to land
- Encourage good management practices (GMP) on dairy farms (including feed pads and nutrient budgeting)
- Control the application of farm dairy effluent onto or into land not exceeding 200kg N/ha/yr and with separation zones between application areas and waterways

Option Two – ***On-farm Mitigation***

This option involves the regulating the effects of land uses by:

- Making fencing and riparian management mandatory for all waterways through intensive pastoral land use
- Requiring timely full completion of the Riparian Management Programme
- Requiring land disposal of dairy farm effluent in all except exceptional circumstances
- Encourage good management practices (GMP) on dairy farms (including feed pads and nutrient budgeting)
- All by 2020

Option Three – Nutrient Cap plus other on-farm mitigation

This option involves a scenario for setting nutrient caps e.g.:

- Set a nitrogen baseline- for example, of either 48 kg N/ha/year or 30 kg N/ha/year (defined as the discharge of nitrogen below root zone as modelled by OVERSEER expressed in kg/ha/yr) and any activity (i.e. any farm) that causes the nitrogen baseline to be exceeded is a discretionary or even non-complying activity. (nb The figures of 48 and 30 kg N/ha/year were chosen as indicative numbers for the sake of providing a starting point for this examination, and must not be taken as signalling a developed and defensible land use limitation already decided upon by the Council).

As part of preparing the *Economic Costs & Benefits Report* the Council is seeking the preparation of supplementary reports on four focus areas:

- Dairy Farm practices and management
- Nutrient management tools/models and practices
- Surface water quality
- Agricultural economics

This report covers the third bullet point above- surface water quality in Taranaki.

1.1.3 Structure of this report

Section 1 of this report is a background section, setting out the statutory context of a regional plan review and describing the information accessed for the review of freshwater quality, its status, trends, and drivers.

Section 2 focuses on details of the state of freshwater in Taranaki, drawing on 18 years of data, and then placing this data in the context of various national and regional standards and guidelines. In other words, section 2 covers the question: what are our waterways like? And are they good or bad?

Section 3 considers trends in the parameters that the Council uses to measure fresh water state and quality- are things getting better or worse?

Section 4 considers broader questions around what really matters in water management, what might the future look like, and what would be effective and efficient if we wish to enhance Taranaki's waterways further?

1.1.4 The Resource Management Act 1991 and a Regional Fresh Water Plan for Taranaki

Under Section 65 of the *Resource Management Act 1991* (RMA), a regional council may prepare a regional plan to assist it to deliver any of the functions of a regional council described in Section 30 of the RMA. Under Section 67, a regional plan may state [(2)(a)] *the issues that the plan seeks to address; and…(c) the principal reasons for adopting the policies and methods; and (d) the environmental results expected from the policies and methods;…*

The Council's 'Regional Freshwater Plan for Taranaki' (October 2001) states as two of its objectives for the regional community, 'to maintain and enhance the quality of the surface water resources of Taranaki by avoiding, remedying or mitigating the adverse effects of contaminants discharged to land and water from point-sources.... and diffuse sources' (Objectives 6.2.1 and 6.3.1). In doing so, the Council and community seek to provide for the values associated with surface water, and to ensure the maintenance of aquatic ecosystems (Environmental Results Anticipated ER1).

In order to ascertain the successful adoption and application or otherwise of the Council's policies and methods of implementation, the Council conducts 'state of the environment' (SEM) monitoring to obtain up to date robust information for parameters that characterise the region's environment and resources. The results and findings of the SEM programme for the region's freshwater systems can be interrogated to determine trends and changes in trends in the quality of the region's freshwater resources, alongside the information on the current 'state' of the region's in-stream ecological health parameters that SEM generates. With SEM established in 1995, the database is now extensive enough to allow regular robust statistical trend analysis, conducted according to recognised methodologies, for such reviews.

This review of water quality draws out implications of scientific data about the state of, drivers of, and trends in the quality of Taranaki's streams and rivers.

1.1.5 The regional information that informs this review

The information this review draws upon is taken from the Council's 'state of the environment' (SEM) programmes, which have been in place for 18 years and have been delivered (including data interpretation) according to recognised 'good practice' techniques and with external review. Sites are variously assessed using measures of ecological health, physicochemical state, suitability for recreational use (bacteriology), and periphyton cover. This review also incorporates the date from 3 sites monitored for physicochemical measurements by the National Institute for Water and Atmospheric Sciences (NIWA) for a longer period. One of the NIWA sites is also monitored independently by the Council, for mutual quality control purposes.

1.1.6 Key points

Any new policy intervention should be well-grounded in evidence and science that informs the understanding of the current situation and explores the justification for ('is a change in policy actually needed? On what basis is that statement made?') and the likely or unlikely effectiveness ('will it achieve the desired outcome in full or only in part') and efficiency ('what is the cost of the proposed intervention against the benefit?') of each potential intervention.

The scientific and evidential basis should reflect the Taranaki context (while noting that there may also be national obligations that must be honoured eg National Policy Statements or National Environmental Standards, under the Resource Management Act 1991). The latest and best relevant information should be brought to bear, and incorporated constructively into the new policy.

The values to be given effect to through any accomplishment, improvement, or progress to be gained through any new policy should reflect those held by the Taranaki community.

The policy should be framed in a way that facilitates innovative and holistic solutions ('best net environmental outcomes?') rather than be siloed from other programmes and instruments.

Policy should build on what is already happening regionally (not necessarily what is happening elsewhere) and on what is needed or justified regionally (not necessarily on what has been found to be necessary elsewhere).

2. The state of our streams and guideline values

2.1 Water

2.1.1 Measures of quality - international

The primary indicator used by the Environmental Protection Agency of the USA to assess the state of its small streams and rivers, is to take account of the condition of the benthic macroinvertebrates (aquatic insects, crustaceans, worms and molluscs) at each location[1] . The EPA notes that *'macroinvertebrates are key organisms that reflect the quality of their environment and respond to human disturbance in fairly predictable ways...given the wide geographical distribution of macroinvertebrates, as well as their abundance and link to fish and other aquatic vertebrates, these organisms serve as excellent indicators of the quality of flowing waters and the human stressors that affect these systems...'*. The EPA uses a 'Macroinvertebrate Index' that is very similar in concept to the Macroinvertebrate Community Index used by the Taranaki Regional Council for more than 25 years. This approach incorporates factors such as the taxonomic richness (different types of organism groups), composition (relative abundances of different taxa), diversity, groups displaying differing habitat requirements, and tolerance to pollution, to provide an Index value for the aquatic community at each site.

The USEPA has found [2] that the physico-chemical factor posing the biggest risk to in-stream communities is the extent of streambed sedimentation. While high concentrations of both phosphorus and nitrogen were also risk factors, the EPA noted that because these often occurred together, it was impossible to separate out the relative effect of each. The EPA found other risk factors were the loss of riparian vegetative cover, the degree of streambank disturbance, and any loss of diversity of in-stream habitats.

The EPA report described these as factors that increased risk, not as factors that inevitably caused degradation.

Similar methods are used throughout the European Community[3] and in other environmental jurisdictions throughout the world. The European Commission notes *'While prior European legislation considered chemical contamination in water, the directive* [ie the Water Framework Directive] *provides a major innovation by addressing aquatic ecosystems as well. Monitoring will now assess the health of ecosystems'.*[4] *'The directive defines "good ecological and chemical status" in terms of low levels of chemical pollution as well as a healthy ecosystem. The second criterion- good ecological status- is an innovative step for EU water legislation . To achieve good ecological status, Member States will have to address the factors harming water ecosystems.* [5]

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[1] *Wadeable streams assessment: a collaborative survey of the nation's streams*, United States Environmental Protection Agency May 2006)

[2] see ref 1.

[3] see for example *UKTAG River Assessments Methods Benthic Invertebrate Fauna: River invertebrate classification tool (RICT)*, Water Framework Directive - United Kingdom Technical Advisory Group December 2008

4 *Water Note 6: Monitoring programmes: taking the pulse of Europe's waters* European Commission July 2009

5 *Water Note 2: Cleaning up Europe's waters: identifying and assessing surface water bodies at risk* European Commission March 2008

The UK Technical Advisory Group on the Water Framework Directive ('the UK TAG')[6] has recently released a report on environmental standards to protect river ecology[7]. That report includes two significant statements.

1. The UK TAG report notes: '*… the use of standards to take important decisions about the control of eutrophication has in the past required an indication of actual or potential biological impact in addition to the failure of a nutrient threshold...we propose that a similar approach is used for the Water Framework Directive*' (page 31). In other words, assumptions about the consequences of failure to comply with nutrient standards must be validated by ecological studies before water management decisions are taken. Nutrient criteria of themselves should not be used in a regulatory setting in respect of stream health.
2. The UK TAG report also notes: '*although nitrogen may have a role in the eutrophication in some types of freshwaters, we consider the general understanding of this to be insufficient at present for it to be used as a basis for setting standards or conditions. The possibility is too strong that the statistical associations produced by these methods would represent correlation between nitrogen and phosphorus (and other factors), and not the standards for nitrogen that are truly needed to protect the biology. For these reasons no standards for nitrogen are proposed in this report*.' (page 31). That is, the best science to date can still not quantify the cause-and-effect link between eutrophication and elevated nitrogen. Meaningful or valid nitrogen limits for ecological protection can't yet be established, in the view of the TAG.

The UKTAG has since continued its work on appropriate criteria for maintaining good or high quality ecological status of water bodies throughout the UK, as required under the EU's Water Framework Directive. Updated biological and phosphorus standards were released in 2013. The UKTAG notes that the use of the ecological status classes helps identify where environmental improvement may be needed and where improvement efforts have been successful.[8]

The phosphorus standards are intended to help in managing environmental risks- the likely tolerance limits to phosphorus of each biological status class. In announcing updated phosphorus standards for rivers[9], the UKTAG noted that the review was necessitated because the existing phosphorus standards were producing a high number of mismatches between the phosphorus classifications and the ecological condition classifications. That is, the phosphorus standards were not indicating whether or not the river was likely to be able to accommodate additional phosphorus inputs without significant risk of adverse ecological effects; or alternatively, whether the existing ecological condition was being driven in part by the concentration of phosphate.

The UKTAG stresses that the link between phosphorus and biology comes through as '*a fuzzy equation*'.[10] In its 2008 report the UKTAG stressed '*the classification for phosphorus* ***has not been regarded as suitable for regulatory purposes*** *because of*

6 A working group of experts drawn from multiple agencies within the UK, including the various environment protection agencies

7 *UK environmental standards and conditions (Phase 1) Final report April 2008.*

8 Pg 3, *Final recommendations on new and updated biological standards* UKTAG September 2013

9 *Updated recommendations on phosphorus standards for rivers- River basin Management (2015-2012) Final report* UKTAG August 2013

10 Para 4.2, ibid

uncertainties over cause and effect. Classification has been used to monitor general changes over time…When managing nutrients, it has been the norm to require that biological impacts and enhanced nutrient levels ***must be observed prior to improvement action being taken****.*[11]

Crucially, the UKTAG notes 'B*ecause of the uncertainty in the relationship between phosphorus and biological response, UKTAG continues to recommend that* ***expensive action to reduce phosphorus concentrations at a site should be considered only where there is supporting evidence of adverse biological impacts.'*** [12]

The UKTAG goes on to caution: *The relationship between phosphorus and biological quality in the data used to develop the regression model is highly variable- there is a lot of scatter in the data. As a result,* ***a regression model cannot produce standards that correspond perfectly to every site's biological status class boundaries****. The biology at a significant proportion of sites will be more affected by phosphorus than indicated by the standards. At others it will be significantly less affected.…Part of the reason for this is the inevitable statistical errors in the summary statistics of phosphorus and biology used in setting up the regression equation used to derive the standards. However, UKTAG considers the major reason to be that* ***biological response to phosphorus is affected by other factors as well as those represented by a site's alkalinity and altitude. For example, shade, river flow, river bed composition, grazing and the effects of other plant nutrients such as nitrates or the presence of other pressures*** *could all influence the biological response to phosphorus'*.[13]

The EPA of Victoria, Australia, notes *Traditional water quality monitoring involves measuring physical and chemical aspects of water. Common measurements include pH, salinity, turbidity, nutrient levels and the amount of dissolved oxygen in the water. These measures are used because they provide a 'snapshot' of environmental conditions at the moment the samples were taken.*

EPA has moved towards a more holistic approach to environmental assessment in rivers and streams, which incorporates biological indicators of ecosystem health. The great value in directly monitoring the biological community is that it responds to all types of disturbances and toxicants, which can be assessed from relatively infrequent sampling of the community (for example twice a year). The nature of the biological community reflects the net effect of all environmental factors, including cumulative impacts over a period of weeks, months or years.[14]

2.1.2 Measuring quality regionally

The *Regional Fresh Water Plan for Taranaki (2001)* [now under review] contains objectives to manage the state of the region's surface freshwater. Objective 6.2.1 requires the Council and region 'to maintain and enhance the quality of the surface water resources of Taranaki by avoiding, remedying or mitigating the adverse effects of contaminants discharged to land and water from point sources', while Objective 6.3.1 is an equivalent objective for diffuse sources of contaminants.

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[11] Pp32-33, *Final recommendations on new and updated biological standards* UKTAG September 2013

[12] Para 6.6, *Updated recommendations on phosphorus standards for rivers- River basin Management (2015-2012) Final report*

[13] Paras 7.1, 7.2, ibid

[14] http://www.epa.vic.gov.au/water/Rivers/rivers.asp

In Section 10.3 of the Plan, the Council commits to continued monitoring, research and investigations related to fresh water quality, to provide information on the state of freshwater in the region and the effectiveness of the Plan.

In doing so, the Council and community seek to provide for the values associated with surface water, and to ensure the maintenance of aquatic ecosystems (Environmental Results Anticipated ER1).

In order to ascertain the successful adoption and application or otherwise of the Council's policies and methods of implementation, the Council conducts 'state of the environment' (SEM) monitoring to obtain up to date robust information for parameters that characterise the region's environment and resources. Programmes cover the ecological health of the region's waterways, the presence or otherwise of excessive periphyton as a measure of aesthetic and ecological quality, and the concentrations and measurements of a range of parameters that characterise their physico-chemical state and their suitability for a range of uses and values. The results and findings of the SEM programme for the region's freshwater systems can be interrogated to determine trends and changes in trends in the quality of the region's freshwater resources, alongside the information on the current 'state' of the region's in-stream ecological health parameters that SEM generates. With SEM established in 1995, the database is now extensive enough to allow regular robust statistical trend analysis, conducted according to recognised methodologies, for such reviews.

The programmes have been subject to invited external audit and review, and to a comprehensive audit by the Office of the Auditor-General. NIWA reviewed the Council's methodologies and protocols as part of the latter audit. In addition, the Council implements ongoing quality assurance and quality control measures to ensure the integrity and reliability of its work. In this way timely and reliable feedback on the quality and health of the region's streams and the effectiveness of water quality management in the region can be generated and utilised.

2.1.3 Current quality and the National Objectives Framework

On 4 July 2014 the government released the NPS-FM 2014.

The NPS-FM 2014 came into effect on 1 August 2014 and replaced the *National Policy Statement for Freshwater Management 2011* (NPS-FM 2011).

The NPS-FM 2014 contains key elements of change from the NPS-FM 2011 including implementing the National Objectives Framework (NOF), which sets national bottom lines and attribute states (categories) relating to the quality of fresh water in terms of ecosystem health and secondary contact. These objectives are intended to meet community and tangata whenua values, and to have a uniform demonstration across the country of attainment or otherwise of water quality that provides for these values. That is, it is mandatory that water quality management provides for these values (uses) of water by ensuring that water quality is of at least the national bottom line (i.e. within the 'C' category). The NOF also enables communities to get a sense of how good their water is, and to set objectives or goals for water quality to be of a state higher than the minimum acceptable quality as specified within the NOF. The attributes (measures or parameters) together with the criteria for each band are set out in Table 1.

It should be noted that the NPS-FW requires not only that water must be of at least the minimum standard (national bottom line); it requires also that existing water quality must be maintained or enhanced. There is no scope to provide for a 'pollute down to' approach.

Table 1 National Objectives Framework attributes and criteria

Attribute and value	Nitrate Ecosystem health		Ammonia Ecosystem health		Dissolved oxygen Ecosystem health		E.coli Recreation
Attribute state criteria	Annual median	Annual 95th percentile	Annual median	Annual 95th percentile	7 day mean min	1 day min	Annual median
A	< 1.0	< 1.5	< 0.03	< 0.05	> 8.0	> 7.5	< 260
B	1.0-2.4	1.5-3.5	0.03-0.24	0.05-0.40	7.0-8.0	5.0-7.5	260-540
C	2.4-6.9	3.5-9.8	0.24-1.30	0.40-2.20	5.0-7.0	4.0-5.0	540-1000
D (*below national bottom line*)	> 6.9	> 9.8	> 1.30	> 2.20	< 5.0	< 4.0	> 1000

The water quality of the rivers and streams of Taranaki as measured at state of the environment sites in accordance with the NPS-FW is presented numerically in Table 2, and in terms of NOF attribute state in Tables 3 and 4.

Table 2 Water quality in Taranaki for the period July 2007-June 2014 (assessed as per NOF methodology)

Site code	Site	Nitrate		Ammonia		Dissolved oxygen		E.coli
		Annual median	Annual 95th percentile	Annual median	Annual maximum	7 day mean min	1 day min	Annual median
MGH000950	T	0.038	0.196	0.008	0.033	9.8	7.9	110
MKW000300	T	0.118	0.438	0.005	0.015	10.1	9	255
MRK000420	T	0.683	1.014	0.024	0.104	9.6	8.1	905
PAT000200	T	0.019	0.039	0.003	0.02	10.3	9.1	19.5
PAT000360	T	0.907	1.124	0.037	0.135	10.5	9.2	150
PNH000200	T	0.009	0.079	0.005	0.013	10.0	9	120
PNH000900	T	0.625	1.665	0.023	0.376	9.9	8.8	430
STY000300	T	0.019	0.049	0.0015	0.008	10.4	9.4	4.5
WGG000500	T	0.999	1.606	0.013	1.72	10.3	9.3	135
WGG000900*	T,N	1.486	2.19	0.025	0.142	10.1	8.4	170
WKH000500	T	0.054	0.208	0.004	0.021	10.5	9.2	140
WA1	N	0.156	0.487	0.008	0.021	9.8	8.3	58
WA2	N	0.036	0.163	0.005	0.018	10.1	8.8	77
WA3*	T,N	1.538	2.242	0.025	0.243	10.2	9	99

*Note: WA3 (NIWA site code) = WGG000900 (TRC site code). The site is sampled independently and at a separate time each month by the Council and by NIWA.
T = TRC SEM site, N= NIWA national network site
WA1 = Waitara at Bertrand Rd, WA2 = Manganui at SH3, WA3 = Waingongoro at SH45

Table 3 Water quality in Taranaki (July 2007-June 2014) classified according to NOF criteria

Site code	Site	Nitrate		Ammonia		Dissolved oxygen		E. coli
		Annual median	Annual 95th percentile	Annual median	Annual maximum	7 day mean min	1 day min	Annual median
MGH000950	T	A	A	A	A	A	A	A
MKW000300	T	A	A	A	A	A	A	A
MRK000420	T	A	A	A	B	A	A	C
PAT000200	T	A	A	A	A	A	A	A
PAT000360	T	A	A	B	B	A	A	A
PNH000200	T	A	A	A	A	A	A	A
PNH000900	T	A	B	A	B	A	A	A
STY000300	T	A	A	A	A	A	A	B
WGG000500	T	A	B	A	C	A	A	A
WGG000900*	T,N	B	B	A	B	A	A	A
WKH000500	T	A	A	A	A	A	A	A
WA1	N	A	A	A	B	A	A	A
WA2	N	A	A	A	A	A	A	A
WA3*	T,N	B	B	A	B	A	A	A

*Note: WA3 (NIWA site code) = WGG000900 (TRC site code). The site is sampled independently and at a separate time each month by the Council and by NIWA.
T = TRC SEM site, N= NIWA national network site
WA1 = Waitara at Bertrand Rd, WA2 = Manganui at SH3, WA3 = Waingongoro at SH45

Table 4 Water quality compliance with NOF bottom lines in Taranaki

Site code	Site	Nitrate		Ammonia		Dissolved oxygen		E. coli
		Annual median	Annual 95th percentile	Annual median	Annual maximum	7 day mean min	1 day min	Annual median
Limit		<6.9 gm^{-3}	<9.8 gm^{-3}	<1.3 gm^{-3}	<2.2 gm^{-3}	<5.0 gm^{-3}	<4.0 gm^{-3}	<1000/100ml
MGH000950	T	☺	☺	☺	☺	☺	☺	☺
MKW000300	T	☺	☺	☺	☺	☺	☺	☺
MRK000420	T	☺	☺	☺	☺	☺	☺	☺
PAT000200	T	☺	☺	☺	☺	☺	☺	☺
PAT000360	T	☺	☺	☺	☺	☺	☺	☺
PNH000200	T	☺	☺	☺	☺	☺	☺	☺
PNH000900	T	☺	☺	☺	☺	☺	☺	☺
STY000300	T	☺	☺	☺	☺	☺	☺	☺
WGG000500	T	☺	☺	☺	☺	☺	☺	☺
WGG000900	T,N	☺	☺	☺	☺	☺	☺	☺
WKH000500	T	☺	☺	☺	☺	☺	☺	☺
WA1	N	☺	☺	☺	☺	☺	☺	☺
WA2	N	☺	☺	☺	☺	☺	☺	☺
WA3	T,N	☺	☺	☺	☺	☺	☺	☺

Key:

☺ All results meet national bottom limit

☹ Results exceed the national bottom limit

With regard to the current **state of Taranaki's surface waters**, this review shows that the state of Taranaki's streams and rivers is already very good by assessment against statutory requirements. When compared with the National Objectives Framework (NOF) established through the *National Policy Statement for Freshwater Management 2014* (NPS-FW), by far the greatest number of attribute measurements at each site already fall into the 'A' NOF category (80%), the top category for classification, with most of the remainder falling into a 'B' category (19%). There is a single 'C' result, and no 'D' result: that is, there is no attribute at any site that falls below the compulsory bottom lines established within the NOF, and 99% of results are in the top two categories.

2.1.4 Current quality and regional guidelines

Before the NOF was released, the Council had in preparation for the review of its RFWP commissioned NIWA to develop regionally appropriate guidelines for water quality to provide for a range of potential uses of surface water. These guidelines cover a greater number of parameters/attributes than does the NOF, to address a range of potential uses and values of Taranaki's surface water, and not just the two compulsory values of the NPS-FW, which are ecosystem health and recreation. The Council's guidelines address aesthetic, additional recreational, stock water supply, avoidance of undesirable in-stream growths, and municipal water supply values. Some of the parameters directly relate to suitability of water for various purposes and values. In other cases (especially the nutrients), they will indicate a potential contributing pressure upon a desired state or value, but not necessarily an actual change in that state or value itself.

The Council's guideline values are described in Table 5, and the current extent of compliance with these guidelines is set out in Tables 6 and 7.

Table 5 Guideline criteria for water quality in Taranaki[15]

Note that these criteria are to be applied when flows are at or below the median.

Variable	Value	Metric	Comment
DRP	0.009 mg/L 0.026 mg/L	80th percentile of results	Reference sites at higher altitude Low altitude sites in developed catchments
TP	0.034 mg/L	median	General
NH_4-N (total ammoniacal N)	0.90 mg/L 0.30 mg/L	80th percentile of results	All sites where pH≤8 At sites where pH>8
Nitrate	0.295 mg/L 1.5 mg/L 3.5 mg/L	annual mean 95th percentile 95th percentile	Where periphyton blooms occur Reference sites at higher altitude Low altitude sites in developed catchments (Hickey 2013)
Temperature	20°C	Averaged over the five (5) hottest days (from inspection of a continuous temperature record).	Provisional NOF standard for waters categorised as having minor-moderate thermal stress as a result of incomplete shade
Dissolved oxygen	At least 80% saturated	80th percentile	General
Turbidity	10 NTU	80th percentile	General
Black disc water clarity	0.8 m	80th percentile	General
E. coli	1000/100ml	median	General

15 *Developing water quality limits for Taranaki Regional Council*, NIWA September 2014

Table 6 Water quality in Taranaki, July 2007-June 2014 (assessed according to Council guidelines)

Variable	Site	BDisc	CBOD	DRP	*E.coli*	DO%	NO3	NH4	TN	TP	NO3
Metric		80th pc	80th pc	80th pc	Median	80th pc	95th pc	80th pc	Max.	Median	Max.
Value		>1.4	<2	<0.026	<1000	>80%	<3.5	<0.9	<25	<0.034	<11.3
MGH000950	T	0.91	0.7	0.008	110	108	0.196	0.017	0.72	0.014	0.357
MKW000300	T	2.26	0.6	0.032	255	100	0.438	0.009	0.64	0.034	0.517
MRK000420	T	1.39	1.1	0.012	905	99	1.014	0.041	1.58	0.022	1.097
PAT000200	T	4.04	0.25	0.029	19.5	100	0.039	0.005	0.41	0.028	0.057
PAT000360	T	1.45	1.4	0.083	150	115	1.124	0.054	1.82	0.071	1.49
PNH000200	T	1.96	0.25	0.038	120	103	0.079	0.006	0.20	0.037	0.089
PNH000900	T	1.42	1.2	0.084	430	101	1.665	0.065	2.08	0.088	1.697
STY000300	T	2.88	0.25	0.024	4.5	102	0.049	0.002	0.12	0.024	0.109
WGG000500	T	1.48	0.9	0.037	135	108	1.606	0.029	3.22	0.039	1.736
WGG000900*	T,N	1.28	1.2	0.086	170	108	2.19	0.046	3.08	0.094	2.658
WKH000500	T	2.64	0.6	0.043	140	103	0.208	0.008	0.37	0.039	0.289
WA1	N	0.75	-	0.006	58	107	0.487	0.012	0.78	0.021	0.666
WA2	N	3.72	-	0.012	77	101	0.163	0.007	0.24	0.015	0.202
WA3*	T, N	1.3	-	0.073	99	111	2.242	0.035	2.69	0.092	2.511

*Note: WA3 (NIWA site code) = WGG000900 (TRC site code). The site is sampled independently and at a separate time each month by the Council and by NIWA.

T = TRC SEM site, N= NIWA national network site

WA1 = Waitara at Bertrand Rd, WA2 = Manganui at SH3, WA3 = Waingongoro at SH45

Table 7 Water quality in Taranaki: compliance with guidelines for various usages (values)

WA1 = Waitara at Bertrand Rd, WA2 = Manganui at SH3, WA3 = Waingongoro at SH45

Usage	Site	Aesthetics		Avoiding excessive algae	Stock water	Aquatic ecosystems			Irrigation		Drinking water
Metric		BDisc	CBODf	DRP	*E.coli*	DO%	NO3	NH4	TN	TP	NO3
Value		>1.4	<2	<0.026	<1000	>80%	<3.5	<0.9	<25	<0.034	<11.3
MGH000950	T	🙂	😃	😃	😃	😃	😃	😃	😃	😃	😃
MKW000300	T	😃	😃	🙂	😃	😃	😃	😃	😃	😃	😃
MRK000420	T	🙂	😃	😃	😃	😃	😃	😃	😃	😃	😃
PAT000200	T	😃	😃	🙂	😃	😃	😃	😃	😃	😃	😃
PAT000360	T	😃	😃	😐	😃	😃	😃	😃	😃	🙂	😃
PNH000200	T	😃	😃	😐	😃	😃	😃	😃	😃	🙂	😃
PNH000900	T	😃	😃	😐	😃	😃	😃	😃	😃	🙂	😃
STY000300	T	😃	😃	😃	😃	😃	😃	😃	😃	😃	😃
WGG000500	T	😃	😃	🙂	😃	😃	😃	😃	😃	🙂	😃
WGG000900	T,N	🙂	😃	●	😃	😃	😃	😃	😃	●	😃
WKH000500	T	😃	😃	😐	😃	😃	😃	😃	😃	🙂	😃
WA1	N	🙂	-	😃	😃	😃	😃	😃	😃	😃	😃
WA2	N	😃	-	😃	😃	😃	😃	😃	😃	😃	😃
WA3	T, N	🙂	-	😐	😃	😃	😃	😃	😃	●	😃

Key :

😃 Guideline fully met

🙂 Majority of results (more than half but less than the stipulated metric) meet guideline

😐 Minority of results meet usage guidelines

☹ No results meet usage guidelines

WA3 (NIWA identification) is the same site as WGG000900 (TRC identification)

As with the NOF criteria, results for most attributes at almost all sites (ie 84% of all results) already fully satisfy the criteria specifically developed for the Council by NIWA. For some parameters, the majority of individual results at each site already meet the criterion, but not enough to deem that the criterion is satisfied at all times. DRP and TP, indicators of pressure upon elements of in-stream health, are higher than desirable at some sites (but refer Section 2.1.1 for relevant discussion). For this latter parameter it should be noted that monitoring of periphyton (algae layers on the stream bed) in the region demonstrates that national guidelines for periphyton are satisfied everywhere even under the most extreme conditions, except at a couple of sites (see next section). That is, even when phosphate levels are higher than guideline values, this is not leading to adverse environmental outcomes.

2.1.5 Current quality and United Kingdom classifications (Water Framework Directive)

Reference is made in Section 2.1.1 above to the water body classification system used by the United Kingdom to implement the Water Framework Directive of the EU. Caution should be applied when reviewing water quality criteria derived from ecosystems elsewhere and interpreting New Zealand data in the light of those criteria. However, it is informative to have some sense of how regional water quality compares in broad terms which that found elsewhere. The UKTAG has established physico-chemical criteria that reflect ecological state, as best as can be determined given the current state of scientific knowledge and as best found in correlation studies- that is, ecosystems of ‘x’ state most commonly have physico-chemical water quality of ‘y’ condition. (It must be recognised that correlation does not imply causation, and that the UKTAG cautions against any use of their criteria as some sort of standard or as some sort of justification for intervention). With these caveats in mind, it can be noted that the UKTAG has established classifications for dissolved oxygen, biochemical oxygen demand, ammonia, and dissolved reactive phosphorus. Each of these has criteria for a water body to be assigned into one of the classifications of ‘high’, ‘good’, ‘moderate’, or ‘poor’ water quality. The UK has a target that all water bodies should reach at least the ‘good’ category in due course; currently less than half (47%) meet both the biological and the phosphorus criteria for at least a ‘good’ classification

Of note: all of Taranaki’s environmental monitoring results for dissolved oxygen fall into the UKTAG ‘high’ grading.

All of Taranaki’s environmental monitoring results for biochemical oxygen demand fall into the UKTAG ‘high’ grading.

All of Taranaki’s environmental monitoring results for ammonia fall into the UKTAG ‘high’ grading.

29% of Taranaki’s environmental monitoring results for dissolved reactive phosphorus fall into the UKTAG ‘high’ grading, and 43% of Taranaki’s environmental monitoring results for dissolved reactive phosphorus fall into the UKTAG ‘good’ grading. 28% of Taranaki’s environmental monitoring results for dissolved reactive phosphorus fall into the UKTAG ‘moderate’ grading, but these all sit in the best 15% of the ‘moderate’ range- that is, they sit just outside the ‘good’ classification.

2.1.6 The current quality of ecological health

The Council makes extensive use of the Macroinvertebrate Index (MCI) as a measure of the health of in-stream ecology. Macroinvertebrate communities (tiny animals including insects, crustaceans, molluscs, worms, and leeches) are assessed for their presence and abundance, and this data is transformed into a quantitative index. There are no national guidelines for MCIs, as values change significantly down a catchment as stream morphology, hydrology, and meteorology change with altitude and distance from source. In 2009, the Council compared actual MCI values at any point in any catchment, with calculated 'expected values' based on reference sites of a similar nature across the region[16]. This work showed that at the time, MCI values were as good as or better than could typically be expected across two-thirds of the ring plain; and conversely, at that time sites across around one-third (34.7%) of the ring plain were observed to have median MCI values lower than those that could be found under optimal conditions,. Hence there was opportunity for targeted interventions to achieve enhancements in in-stream health. The results of the 2009 study are depicted in Figure 1 below.

However, comparison of the reference data used in the study described above (Figure 1) with the latest results as reported by the Council[17] and as partially illustrated in Figure 2, highlights that the situation has already changed significantly since then for the better. The areas of lowest scores in 2009 ('poor') are now by and large in a higher category ('fair'); whereas in 2009, 14.7% of sites were graded 'poor', the latest report shows that now only 7% of sites fall into this category. The number of sites in the 'very good' or 'excellent' categories has risen from 13.6 to 20% over the same period.

In 2009, sites across 34.7% of the ring plain were observed to have MCI scores one health class lower than predicted; by 2013 this percentage had fallen to just 4%. In 2009 6.5% of sites were observed to have MCI scores either one or two classes above predicted scores based on their altitude; by 2013 this percentage had risen to 11%.

Thus the current situation in respect of in-stream health measurements and expectations is significantly different from and better than depicted in 2009.

2.1.7 Current state of periphyton

Periphyton is the algae or 'slime' that can be seen from time to time in rivers and streams, especially during extended periods of low flows and warm temperatures. It plays a fundamental role within the stream ecosystem by absorbing nutrients and converting them into biomass which is then used as a food source for invertebrates, and subsequently native fish and birds. Nuisance periphyton, in the form of either prolific thick mats or long filaments of algae can cause streams to become un-inviting for recreation and/or have adverse impacts on stream ecology.

This freshwater nuisance periphyton programme has been designed to monitor the presence and distribution of 'nuisance' algae in Taranaki streams and rivers which may

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[16] *Relationships between MCI, site altitude, and distance from source for Taranaki ring plain streams*, Stark Environmental Report 2009-01, January 2009.

[17] *Freshwater Macroinvertebrate Fauna Biological Monitoring Programme Annual State of the Environment Monitoring Report 2012-2013 Technical Report 2013-48,* February 2014

affect the instream values of these streams i.e., aesthetic values (contact recreation and landscape values), biodiversity values, and those values linked to Maori culture and tradition.

The New Zealand Periphyton Guidelines, established by the Ministry for the Environment (Biggs, 200), provide a reference at which point growths of periphyton exceed the recreational guideline. This point is exceeded when at least 30% of the bed is covered by filamentous algae and/or at least 60% of the bed is covered by thick mats of algae.

Council staff survey 21 sites for evidence of periphyton twice each year, under 'worst case' conditions- that is, following extended periods of calm, warm, bight, and dry weather, so that river conditions are most conducive to proliferation of periphyton in the region's waterways.

During the 2010-2012 period (the latest period available for reporting[18]), a total of 154 individual periphyton surveys were conducted across the 21 sites. Across the entire reporting period, there was a single exceedance of the MfE periphyton guidelines. At the monitoring site at the mouth of the Kapoaiaia Stream, excessive filamentous algae were found. The percentage of mats at the same site on the same occasion was well within the guideline. The Kapoaiaia Stream drains through agricultural land and has relatively poor riparian vegetation, meaning it is exposed to a high degree of sunlight, warmth, light, and nutrient runoff. A mid-catchment site on the same stream was found to have some periphyton (but not exceeding either guideline) on the same occasion.

The next two sites at which periphyton cover was generally found to be more extensive than for the remainder of sites, are both very exposed, wide, and shallow reaches, without riparian shading (see Photo 1).

Photo 1 Mangaehu River periphyton monitoring site

18 *Freshwater Periphyton Monitoring Programme (Periphyton monitoring in relation to amenity values) State of Environment Monitoring Report 2010-2012 Technical Report 2013-20*, Taranaki Regional Council, in prep

As a general observation, sites lower in catchments were found to have discernably more periphyton cover than sites upstream. On the other hand, a number of sites even in lower catchments were repeatedly found to have no or little measurable periphyton.

The compliance rate for meeting the MfE periphyton guidelines, under 'worst-case' conditions for periphyton proliferation, is currently 99.4%.

2.1.8 Current quality and recreational use

Other than at three freshwater bathing sites where environmental forensic investigations using DNA have identified seagulls, pukekos, and ducks as major sources of faecal contamination, more than 99% of freshwater samples collected each summer in the Council's recreational surveys meet the national bathing guideline.

2.1.9 Current quality: key points

In summary, this review shows that the emphasis upon using ecological measures to assess stream health that is at the heart of monitoring practice in Taranaki is consistent with current monitoring innovation internationally.
The monitoring programmes implemented by the Taranaki Regional Council have been repeatedly subject to independent review and audit, and found to be fit for purpose.

The existing water quality in Taranaki is found to already be very high when evaluated against guidelines and standards (whether national and international) relating to various values and purposes for which water could be utilised. The accomplishments and improvements already established within the region have created a good framework for modification by any further policy extension.

There is thus no statutory, environmental, or value driver that justifies interventions that would carry a high cost to the region or to a sector within the region. Any new policy should be designed to enhance and build on what is already a good picture.

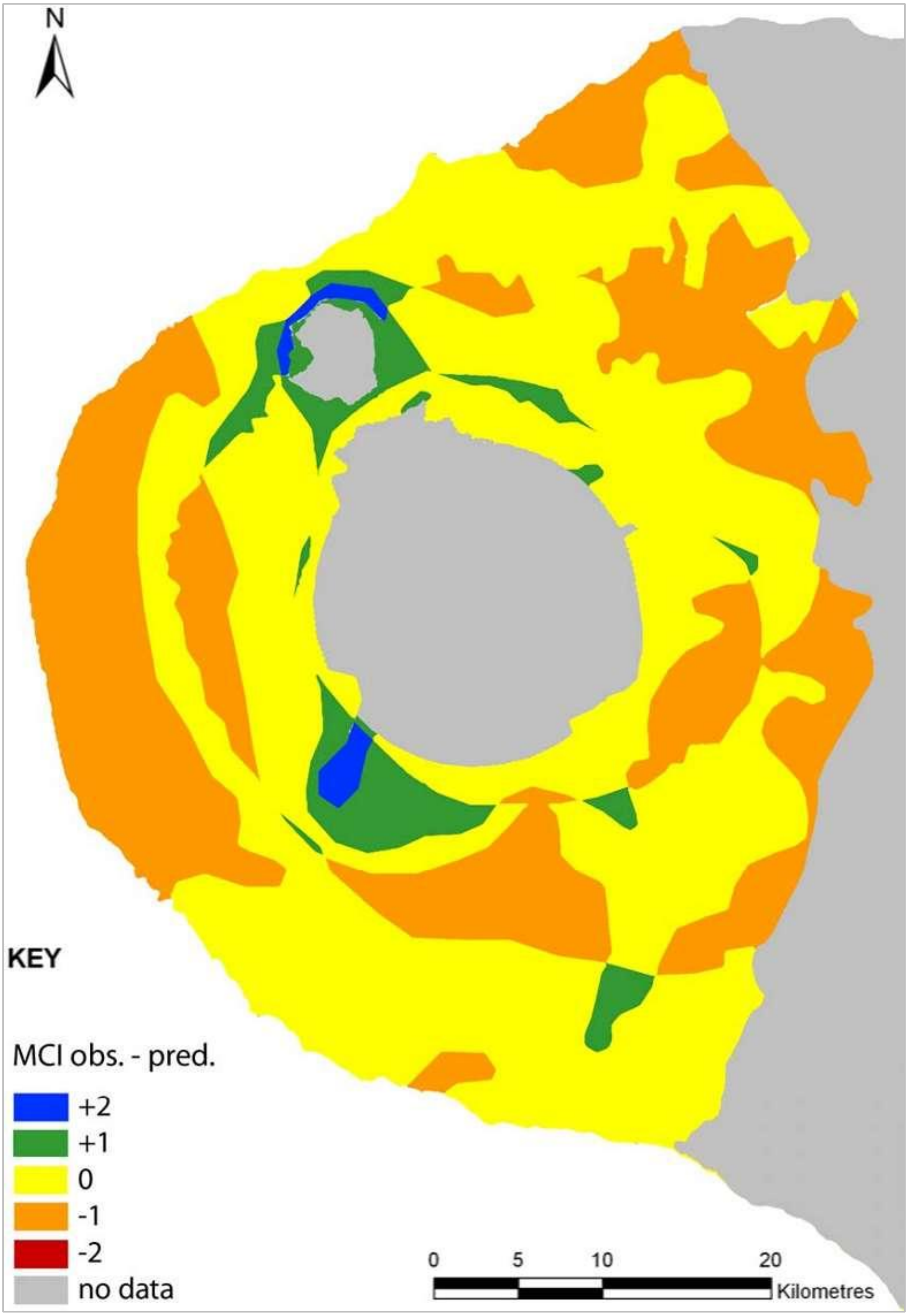

Figure 1 2009 Map of Taranaki ring plain showing the prevailing differences between observed and predicted MCI values. In the key '0' means that observed and predicted stream health classes were the same and '+2' means that the observed quality class was two classes higher than predicted (e.g. Excellent vs good).

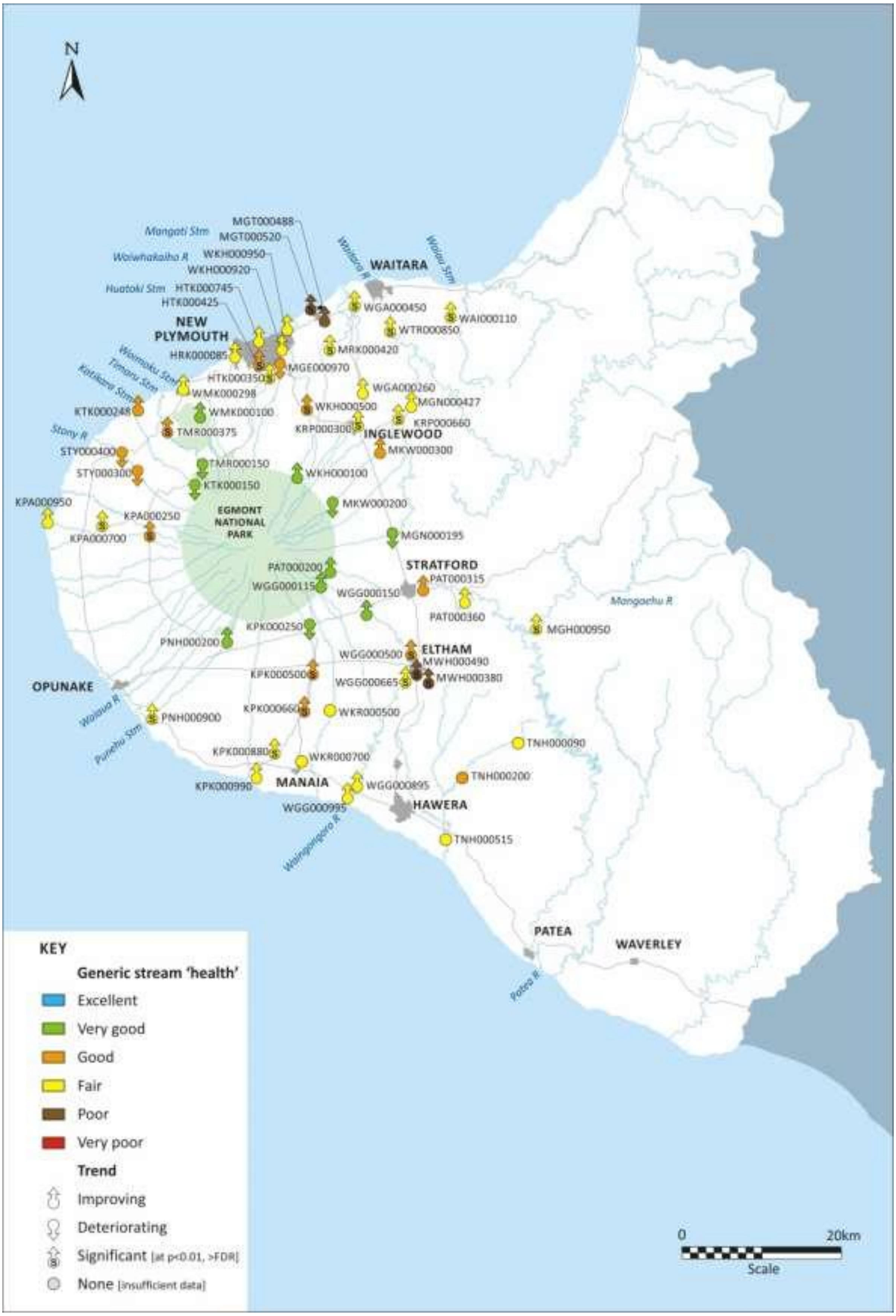

Figure 2 Generic stream health (based on median MCI over 1995-2013) and all trends in biological quality (regardless of statistical significance) for SEM sites

3. Trends in water quality

3.1 Trends in ecological condition

3.1.1 Macroinvertebrate index

In terms of MCI, the specific measure of the health of in-stream ecological communities, the latest results available to the Council show that in 2013-2014, MCI scores were generally higher than typical, especially in the spring surveys (overall 5 MCI units higher than the long-term medians), but even in summer under drier low flow conditions (3.1 MCI units higher than medians), at the 57 representative sites used by the Council for SEM purposes. Two of the sites scored their highest MCI values ever, while one site produced a new minimum score. Median scores (19 year record) have now increased at 20 sites as a result of incorporating the scores from the latest 2 surveys, while median scores reduced slightly at 2 sites.

As is typical, summer scores were lower overall than spring scores, but the seasonal difference was very slight in 2013-2014.

Changes in the indicative and statistically significant trends are summarised in Table 8 and Figures 3 and 4.

The updated trend analysis shows that at 44 of the 57 sites (77%), MCI scores are improving. This is the same result as last year. Furthermore, the number of sites showing improvement continues to increase over the long term, rather than plateau as might generally be expected. In trend analysis to 2011, 40 sites were showing improvement; in trend analysis to 2012, the number increased to 42 sites, and in the last two years 44 sites have been showing an improving trend across the 19 years.

Table 8 Progressive changes in significant and highly significant trends in MCI scores (57 sites)

Year	Number of sites with +ve, very sig trend (p<0.01, FDR)	Number of sites with +ve, sig trend (p<0.05 but not highly sig)	Total number of sites with positive trends of any significance	Number of sites with negative trend of any significance	Sites with positive	Sites with negative
1995-2014	21	9	**30**	0	44	8
1995-2013	21	5	**26**	0	44	8
1995-2012	15	10	**25**	1	42	10
1995-2011	9	14	**23**	0	40	12
1995-2010	7	11	**18**	0	40	12
1995-2009	7	9	**16**	0	38	14
1995-2008	5	8	**13**	0	38	13

Eight sites are showing signs of deterioration. The number of sites showing deterioration continues to reduce- in trend analysis to 2014, 8 sites were showing deterioration, down from 10 in 2012 and 12 in 2011. That is, the proportion of sites in the region showing a trend of improvement continues to exceed the proportion of sites showing declines, in an ever-increasing ratio (the ratio is now at 5.5:1, up from 2.9:1 in 2008).

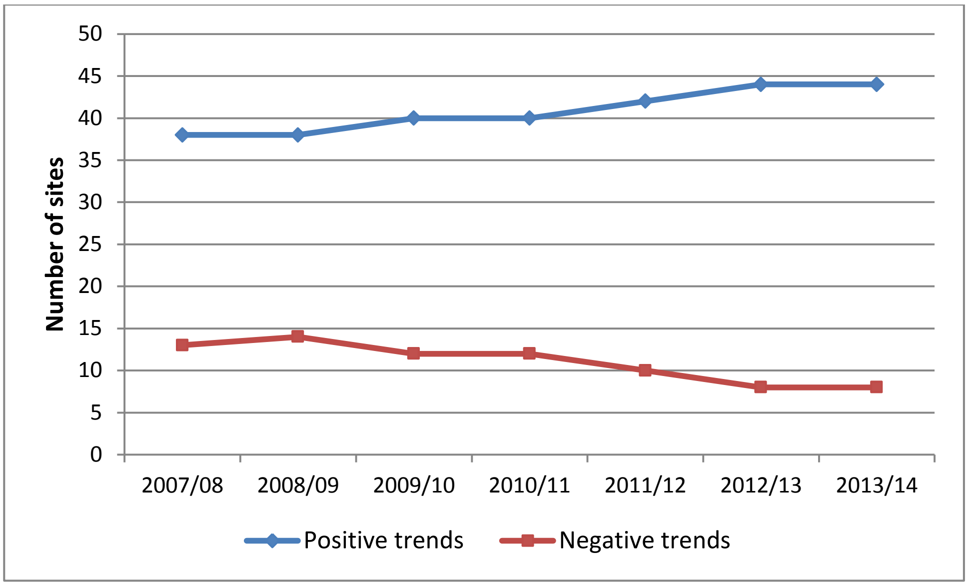

Figure 3 Number of sites each year showing respective directions of a potential trend- either improvement (blue) or deterioration (red)- in ecological condition when MCI data is collated from 1995 to year to date.

Applying more rigorous statistical evaluation of trend data ('how sure are we that what we are seeing is a real trend, not just an apparent one?'), there are now 21 sites with a positive and very significant trend across 1995-2014. This is up from 15 sites with a positive statistically very significant trend across 1995-2012, and 9 sites for the data 1995-2011. There are further 9 sites with a positive and significant trend, giving 30 sites now in either of the two positive categories showing strong or very strong improving trends. This compares with 10 such sites (giving 25 altogether) for 1995-2012, and 14 sites for the data 1995-2011, giving 23 sites altogether to June 2011. Going back to the first trend analysis undertaken by the Council (for the years1995-2007), it found 'only' 5 sites showing a very strong improvement (so there are now 4 times as many in this category as there were 6 years ago), with another 8 sites showing strong improvement- a total of 13 sites showing strong or very strong improving trends in at the time (now 30, or more than twice as many).

In the report covering 1995-2012, there was one site with a significant, but not strongly significant, negative trend. The site in question is in the upper Manganui River above Stratford, and the cause is most likely to be headwater erosion events that had occurred recently. With the inclusion of more recent survey results, this intermittent negative trend has disappeared.

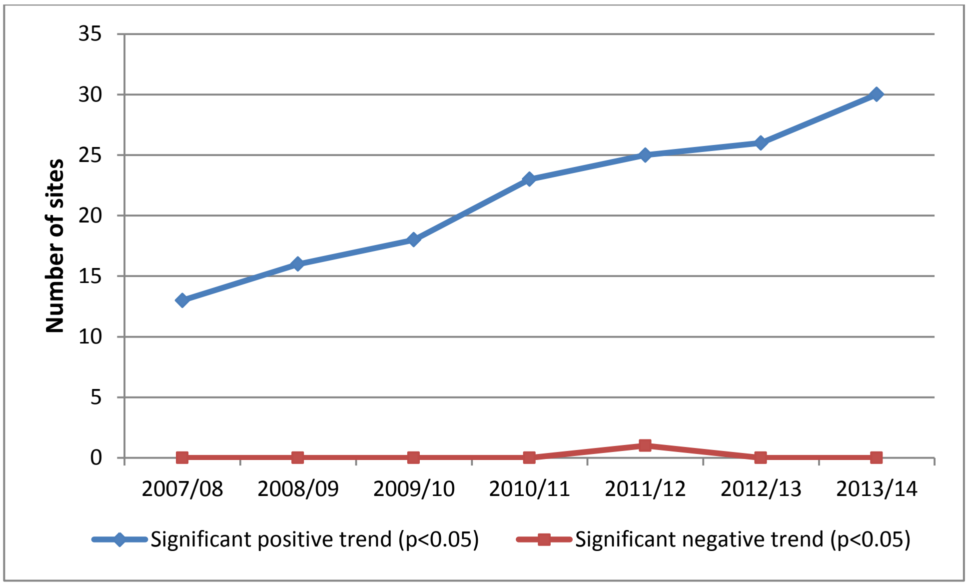

Figure 4 Shows the number of sites each year found to show a statistically significant ($p<0.05$) improvement (blue) or deterioration (red) in ecological condition when trends are calculated from 1995 to year to date. Only sites where the change is also ecologically meaningful are included.

There are no ecological monitoring sites in Taranaki showing either a significant or a highly significant negative trend.

In terms of the question 'what is the state of the ecological health of our streams?', predictive scores have been developed for ringplain sites that are based on either the altitude of each site, or its distance below the National Park boundary. The predictive modelling indicates for each site what the MCI 'should' be, if the site were as good as could be reasonably achieved based on best equivalent scores. A summary for all results for the 2013-2014 year is provided below, by percentage allocation into 'significantly lower', 'no significant difference', or 'significantly higher' scores than expected.

Season	Spring 2013			Summer 2014		
Actual vs Prediction	> 10 units lower	± 10 units	> 10 units higher	> 10 units lower	± 10 units	> 10 units higher
Altitude	4	64	32	6	60	34
Distance	5	63	32	5	71	24

This analysis shows that in the 2013-2014 year, about one-third of all sites had MCI scores that were much better than could have been reasonably anticipated based on typical quality for equivalent sites, and only a very small percentage of sites (found in short, small ringplain streams) had MCI scores that were much worse than is usually the case.

Thus, the findings of the macroinvertebrate monitoring programme demonstrate that the Council and regional community are meeting the Long Term Plan (LTP) target, to maintain and enhance water quality in the region, and this is becoming even more evident as each year goes by. Most of the improving sites are located in mid to lower/mid-catchment reaches; significant improvement at the lowest sites is unlikely to be detected until habitat improvement occurs and drivers of cumulative adverse effects are reduced throughout each upstream catchment.

3.1.2 Periphyton cover

With a decade record of monitoring the degree of periphyton cover at indicator sites, it has been possible to undertake trend analysis.

In respect of thick mats, across the 21 sites, there is an equal split between sites where there are indications of an increasing trend, and sites indicating a decreasing trend. However, when a more rigorous test of statistical significance is applied, the situation changes - 3 sites are found to have reducing levels of periphyton mats, and none are showing a significant increase. When an even more rigorous statistical test is applied (FDR adjustment), there are no statistically significant trends in mat cover percentage. It should be noted that with many sites having very low levels of mat cover in any case, it is mathematically difficult to establish certainty if a reduction is occurring.

In respect of filamentous strands of periphyton, a stronger pattern is emerging. Of the 21 sites, 17 are displaying indications of reductions in filamentous growth, with 2 showing an indication of an increase. The trend of a reduction was found to be statistically significant at 7 of the 21 sites, and was found to be highly significant at 2 sites.

Six of the rivers monitored- the Kapoaiaia, the Mangaehu, the Stony, the Waiwhakaiho, the Waiongana, and the Waingongoro - showed indications of reductions in filamentous growths (albeit at varying degrees of statistical robustness) at all sites throughout their length. Two of these rivers, the Mangaehu and the Kapoaiaia, are the catchments that currently present the highest levels of periphyton growth in survey results.

In terms of looking for some correlation between trends in periphyton cover data with physicochemical parameter trends, the following may be noted:-

- the Mangaehu and the Waiwhakaiho rivers are showing indications of increases in mat cover (although still at low levels), yet both are showing reductions in concentrations of total nitrogen;
- likewise, the lowest Waingongoro River site has had a long term and very significant reduction in almost all measures of nutrients, yet shows indications of an increase in periphyton mats;
- the sites with the strongest reductions in nutrients are not necessarily showing equivalent strong reductions in either filamentous periphyton or in periphyton mats.

3.2 Trends in physico-chemical conditions

In order to ascertain the successful adoption and application or otherwise of the Council's policies and methods of implementation, the Council conducts 'state of the environment' (SEM) monitoring to obtain and report up to date robust information for parameters that characterise the region's environment and resources. The results and findings of the SEM programme for the region's freshwater systems can be interrogated to determine trends and changes in trends in the quality of freshwater's physicochemical parameters, alongside the information on the current 'state' of the region's freshwater resources that SEM generates. With SEM established in 1995, the database is now extensive enough to allow regular robust trend analysis, conducted according to nationally recognised methodologies, for such reviews. The Council determines trends on both a recent (the last seven years) and a long-term (all data back to 1995) basis. Because this review is seeking to evaluate the effectiveness of the current RFWP, the more recent trends are most relevant for consideration. However, both trend periods are discussed for each parameter below.

The latest results (to 2014) show marked improvements in water quality across all parameters and across the region over the last seven years. In particular, current trends (and hence, current water quality) are demonstrably better than they were even 6 years ago, when trend analysis of recent data was undertaken for the first time. The trends 6 years ago (2003-2009) showed 25% of parameters were deteriorating and 3% were improving as of that time; now, in the most up to date trend analysis (2007-2014), only 5% of parameters show deterioration, and 15% are showing improvement. That is, improvements now outnumber deteriorations by 3 to 1 whereas only 6 years ago deteriorations outnumbered improvements 8 to 1 (while still being only 25% of all results i.e. most water quality parameters were showing no trend or were improving).

In terms of specific measure of water quality, **BOD (a measure of organic contamination)** is improving at one site, deteriorating at another, and showing no trend otherwise, whereas even 6 years ago 6 out of 10 sites were showing deteriorating levels at the time. The pattern of deterioration in the recent past has now been eliminated.

Over the long term, BOD showed no trend for most sites, with deterioration at a few.

Most results for **bacteriological parameters** show regional stability over both the longer term and also more recently. Over the long term, three sites had been showing deterioration in either one or both of the two bacteriological measures.

Markers of **aesthetic water quality** (suspended solids, clarity) show no trend from a regional perspective, except for improvement at a few. The long term trend analysis shows that 3 of 13 sites had been showing a very significant loss of clarity. (In previous long-term trend analysis, 4 sites had shown loss of clarity; one of these sites has shown recent recovery so that its clarity is now as good as ever measured previously). Over the more recent period, two sites are now showing marked improvement in clarity and no site is now showing deterioration in any measure of aesthetic quality. Even 6 years ago, two sites were showing current deterioration, with none showing any trends of improvement.

While over the long-term record there were increases in either or both of dissolved reactive **phosphate** and total phosphate at about half the sites, this previous trend of deterioration has been halted. In 2009 the analysis of recent data showed 37% of phosphate measures were deteriorating; this figure has now reduced to just 5% (and at one site only).

Likewise, in the light of the current conversation at national level propounding that **nitrogen** concentrations are deteriorating (getting higher) in surface waterways, it is interesting to note that concentrations of total nitrogen have in fact either reduced (at 54% of sites) or remained stable (at 46% of sites) over the long term. That is, there has been no increase in the total amount of nitrogen going down Taranaki's streams, in the long term, at any of the sites monitored. Only a few sites have shown an increase over the long term in any of the specific nitrogen forms that are monitored, and nitrate levels have shown a reduction at more sites (3) than increase (2) over the long-term record.

Over recent years, 5 sites have demonstrated a reduction in nitrate, and none an increase.

Across all three nitrogen species (nitrate, ammonia, and total nitrogen), there is now a single site showing an increase in one nitrogen species (ammonia) at the present time. Five sites are displaying a reduction in nitrate, and none an increase. Three upper catchment sites and two lower catchment sites show stability (no evidence of a trend) across all nitrogen species measured, while 6 of the remaining 7 (all in mid or lower catchment locations) are showing improvements (reductions) in one or more species. 28% of all measurements of the various nitrogen species are now showing a trend of significant reduction - just 6 years ago only 5% of the measures of the various nitrogen species were getting better.

Overall, on a regional basis previous deteriorations in nitrate and ammonia and clarity have now been arrested and reversed, previous declines in reactive and total phosphate have been arrested, trends of improvements in total nitrogen and faecal coliforms continue, past limited deterioration in enterococci has been reversed, and BOD and suspended solids remain stable.

3.3 Discussion of results of trend analysis

With regard to the **current trends in Taranaki's surface waters**, this review shows that widespread improvements are occurring across the region in most measures of water quality. Ecological health is widely regarded by water management agencies as the primary measure of freshwater quality, using indices based on macroinvertebrate communities (see above). Data from 57 key sites shows that in the most recent surveys reported, 2 recorded their best-ever macroinvertebrate score. Rigorous statistical analysis shows that 21 sites are demonstrating an 'almost certain' positive trend and 9 further sites are demonstrating a 'very likely' positive trend. No sites are demonstrating evidence of deterioration at an equivalent statistical level.

Assessments of trends in periphyton cover show an improvement in the results obtained from measures of mat coverage and strand coverage at two sites, and otherwise no evidence of change in the two measures at all remaining sites.

Assessment of trends in physicochemical parameters shows that in recent years, almost universally results are demonstrating an almost certain improvement, a very likely improvement, or at the very least no evidence of a change. Only one site (out of 13) shows deterioration in some of its measures of nutrient species. Notably, most sites are now showing reductions (improvements) in the concentrations of nutrients (the various forms of nitrogen and phosphorus) present in the water column. Trend analyses across both long term (19 years) and recent (the last 7 years) records show that total nitrogen is significantly reducing at a majority of the sites monitored and has not increased and is not increasing at any site. Across all 13 sites, 12 of the measurements of one or other of the various forms of nitrogen (ammonia, total nitrogen, and nitrate) are showing significant recent improvement, and only one measurement (of ammonia in the upper Waingongoro) that is showing a recent deterioration.

In summary, this review shows that the region is not facing a crisis of deteriorating water quality. Indicators of in-stream ecological health and of pressures upon water quality are moving in the desired direction. As an overall trend, water quality is currently being enhanced in the region (15% of measurements showing significant improvement, 80% showing no trend, and 5 % showing a deterioration, over the last 7 years). Therefore, measures to halt and reverse regional trends are not required; instead, it is a matter of considering what new measures (if any) are appropriate to further foster the current direction of travel.

3.4 Trends in water quality in Taranaki: key points

Ecological health is widely regarded by water management agencies as the primary measure of freshwater quality, using indices based on macroinvertebrate communities. There is a clear and widespread pattern of improvement in the ecological condition of Taranaki's rivers and streams, across the region. The improvements are most pronounced at mid-catchment sites, but are increasingly discernible at lower catchment sites as well. That is, current policies and the actions by the regional community already have indicators moving in the right direction.

Assessments of trends in periphyton cover show either an improvement in measures of mat coverage and strand coverage that is statistically meaningful or no evidence of change.

Assessment of trends in physicochemical parameters shows that in recent years, almost universally (one site is the exception) nutrient measures are demonstrating an almost certain improvement, a very likely improvement, or at the very least no evidence of a change. No site has shown an increase in nitrate in recent years.

Over the long term there has been either a reduction in the concentration of total nitrogen (the majority of sites) or at the very least no evidence of a change. Most sites have shown no change in the concentration of nitrate in recent years; the number of sites where there has been an increase in nitrate is matched by the number of sites where there has been a decrease.

The region is not seeing the increases in nitrate or nitrogen found where there is widespread conversion from extensive land uses (such as forestry or sheep and beef cattle grazing) to intensive land uses (such as dairying or horticulture). Interventions targeting this concern lack justification in Taranaki.

4. Drivers of stream health and quality

4.1 National studies of periphyton

4.1.1 Introduction

In 2009 two reports were released examining causal factors of and trends in excessive periphyton in rivers and streams in New Zealand [19]. Periphyton is algae that grow on the beds of streams and lakes. Periphyton play a core function within the functioning of the ecosystems of a stream, by absorbing dissolved nutrients and converting them into biomass that is then in turn utilised as a food source for invertebrates, and subsequently fish and birds. Therefore it is important that for a healthy stream, some nutrients are present, to support a periphyton population. Nutrient supply is a controlling factor in the growth rates and extent of periphyton. Excessive concentrations of nutrients can lead to proliferation of periphyton beyond desirable or acceptable levels. The bioavailability of nutrients can be considered in terms of both the relative abundance of the two key nutrients nitrogen and phosphorus, and by the absolute concentrations of each.

The abundance of periphyton is not a function solely of the concentration of either of nitrogen or phosphorus. Not only must both nutrients be present above minimum levels, and in the correct ratio, but there must also be sufficient warmth, sunlight, streambed stability, suitable benthic conditions, a balance between periphyton and invertebrate grazers, and extended low flow velocity conditions that allow establishment and avoid scouring once established.

Excessive periphyton (either as long filamentous strands, or as thick extensive mats) has an aesthetic impact (the stream becomes un-inviting) and/or an ecological impact (biodiversity is adversely affected through the loss of sensitive invertebrate species). In addition, cyanobacteria ('blue-green algae') can cause off-flavours in water and in fish flesh, odours when they dry on stream margins, and potentially toxins that may affect various species.

There are two sets of guidelines applied within New Zealand to guard against the potential for ecological and aesthetic effects.

The guidelines for threshold periphyton cover levels to protect against aesthetic and recreational nuisances are: less than 30% of the visible bed covered by filamentous algae, and less than 60% covered by mats (i.e. more than 2 mm thick). In the review discussed below, the authors also used a combined guideline, of less than 40% total periphyton.

The National Objectives Framework for protection of benthic biodiversity states that at less than 50 mg chlorophyll-*a* per square metre (a measure of the amount of the pigment present in algae, and hence a parameter indicating the total density of algae present), periphyton 'blooms' will be rare, and water quality can be deemed to be in the

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[19] *Trends in nuisance periphyton cover at New Zealand National River Water Quality Network sites 1990-2006* NIWA June 2009, prepared for the Ministry for the Environment; and '*Nitrogen and phosphorus in New Zealand streams and rivers: control and impact of eutrophication and the influence of land management*' (McDowell, Larned and Houlbrooke, NZ Journal of Marine and Freshwater Research 2009)

'A' category. 'B' and 'C' categories are applied to chl-a concentrations of 50-120 and 120-200 mg chlorophyll-*a* per square metre, respectively, while water quality is deemed to be below the national bottom line ('D' category) if chl-a is present at greater than 200 mg chlorophyll-*a* per square metre. These criteria include a tolerance of 1-2 exceedances per year in results obtained from monthly sampling. In the two studies under consideration, the authors used only a 50 mg chlorophyll-*a* per square metre reference value.

In the review, 'Nitrogen and phosphorus in New Zealand streams and rivers: control and impact of eutrophication and the influence of land management', scientists from AgResearch and NIWA assessed water quality data for nitrite/nitrate ('dissolved inorganic nitrogen'), dissolved reactive phosphorus, total nitrogen, and total phosphorus, for the period 1996-2007 across 769 freshwater sites use by regional councils around New Zealand. Data from Taranaki's 10 SEM sites was incorporated in this review. This data was then used to consider the frequency of exceedance of the respective ANZECC nutrient guidelines for protecting against undesirable growth, the ratios of dissolved phosphorus to nitrite/nitrate at each site to determine whether periphyton proliferation was in fact constrained by one or other or both of the nutrients being limiting (if one of the necessary nutrients is in short supply, then an over-supply of the other essentially makes no difference- the periphyton cannot utilise it), and, in conjunction with flow variation data, to model the likelihood of an exceedance of the periphyton guideline for protection of biodiversity.

In the other review, NIWA scientists conducted a study into trends in levels of nuisance periphyton cover found at the 77 New Zealand National River Water Quality Network (NRWQN) sites for the period 1990-2006, on behalf of the Ministry for the Environment. Significantly, this covers the period when concentrations of phosphorus, and more particularly and recently nitrogen, were increasing nationally. Concerns are being expressed about the implications of this increase. The study was based on exceedances of the recreational and aesthetic-based guidelines for the acceptable extent of periphyton growths. The NRWQN includes 3 sites in Taranaki.

4.1.2 Nutrient concentrations, the limiting nutrient, and hydrological factors

In the first study, the mean concentration of the nutrient species was calculated for each region. Canterbury was shown to have a significantly higher mean concentration of nitrite/nitrate than any other region. Taranaki lay towards the middle of all 16 regions for this nutrient species, with Auckland, Waikato, Wellington, and Southland all having higher mean nitrite/nitrate. For total nitrogen, Taranaki was even lower down the list-Auckland, Bay of Plenty, Hawkes Bay, Wellington, Canterbury, and Southland have higher levels. That is, by national comparisons Taranaki did not have high levels of nitrogen in its streams. (Note that the study was using data to 2009. Nitrogen levels in Taranaki's streams have fallen since then).

Likewise for dissolved phosphorus: Northland and Waikato had the highest levels, with Bay of Plenty and Manawatu-Wanganui next. For total phosphorus, Manawatu-Wanganui, Northland and Waikato were highest, followed by Auckland and Hawkes Bay. That is, by national comparisons Taranaki did not have high phosphorus.

In terms of guideline criteria in use at the time, the ANZECC guidelines, Taranaki had mean levels well above ANZECC guideline values for both nitrogen and phosphorus species. Taranaki exceeded the ANZECC phosphorus guidelines by a relatively greater degree than it did the nitrogen guidelines.

40% of Taranaki's SEM sites had mean nitrite/nitrate levels exceeding the ANZECC guidelines. This was exactly the same percentage as for all sites nationwide taken collectively. This again reinforced the point that by national comparisons, Taranaki's levels of nitrogen were no worse (and no better) than the overall national picture, but a number of other regions had higher concentrations. For dissolved phosphorus nationwide, 63% of all sites exceeded the ANZECC DRP guideline (74% in the North Island), while 90% of Taranaki's sites exceeded the guideline.

In terms of which nutrient species is the limiting nutrient, the study showed that across New Zealand, 5 times as many sites were P-limited as were co-limited or N-limited. That is, it is the concentration of P, not the concentration of N, that was determining whether there was a potential for excessive periphyton.

On a site by site basis, those sites in Taranaki closest to the Egmont National Park were found to be N-limited. That is, because of the naturally high phosphorus levels, and the low cumulative inputs of nitrogen from pastoral activity in the upper catchments, in the region's upper streams nitrogen is the nutrient in short supply. From the perspective of biodiversity management, however, it should be noted that :(i) excessive periphyton is not an issue in upper catchments; and (ii) with low N inputs, anyway, it would be hard to apply some mechanism that significantly reduces N.

Lower in Taranaki's catchments, the streams are P-limited. That is, despite the naturally high P levels, inputs of nitrogen in mid and lower catchments increase to the point where N becomes non-limiting, and hence reductions in N inputs in the mid and lower catchments would have comparatively little benefit when seeking to manage periphyton to protect in-stream biodiversity through nutrient control.

It should be noted that the analysis of nutrient concentrations and potential for excessive periphyton growth in this study did not take into account seasonality of nutrient concentrations. Also (and this is noted in the study), no attempt was made to consider other variable factors such as light and temperature.

However, a key factor in the analysis was to incorporate the frequency of flood flows in streams on a regional basis. Flood flows tend to reduce temperatures (and hence constrain periphyton growth rates), but more importantly tend to scour and flush periphyton growths from streams and also tend to disturb the stream beds, and so are an important factor in modifying periphyton behaviour. The study used the concept of 'days of accrual', being the average number of days between flood events that exceed 3 times the median flow, to model the potential for excessive periphyton growth on a region by region assessment. The longer the time interval between flood events, the greater the amount of periphyton biomass that can establish.

The study shows that Taranaki has the lowest average 'days of accrual' of all regions. In other words, the region's streams are flushed by relatively high flow events more often than in any other region in NZ. (Note that this is not related to how often it rains, but how often there are comparatively very high flows relative to the median flows).

In other words, once hydrological conditions are recognised alongside nutrient availability, the picture of the potential for excessive periphyton growth alters substantially. For example, for Taranaki, instead of 90% of sites being considered susceptible to excessive periphyton based solely on phosphorus concentrations, there are 0% of sites susceptible once flow patterns in the region are taken into account.

Once hydrology is recognised alongside the application of ANZECC nutrient concentration guidelines, the picture of susceptibility to excessive periphyton biomass changes significantly. The study demonstrated that this applies most of all to the Taranaki region.

The second study assessed trends in periphyton cover in New Zealand. It utilised data gathered by NIWA scientists from the 77 sites in the National River Water Quality Network (NRWQN), rather than the regional council state of the environment sites used in the other study. Sites are monitored monthly, year round. Observations of periphyton made from January 1990 to December 2006 were utilised in this study.

At only 2 of the 73 sites nationwide (neither of these were in Taranaki) did the **average** extent of periphyton cover exceed any of the 3 guidelines. At most of the sites (78%), the **maximum** extent ever observed throughout the 16 years covered by the study did exceed one of the guidelines at least once. On an annualised basis, the study found that periphyton cover can be expected to be sufficiently high to impact on recreational and aesthetic values at some time during the year, at about one-quarter of the NRWQN sites nationwide. In other words, in the course of a typical year, three-quarters of the NRWQN sites nationwide would remain below periphyton guidelines throughout the entire year.

Of the three NRWQN sites within Taranaki, two (Manganui and Waingongoro) had mean annual maximum values that did not exceed any of the periphyton guidelines for aesthetic and recreational values, while the third (Waitara) had a mean annual maximum filamentous cover of 32%, just over the relevant MfE guideline of 30%, and a mean annual total periphyton cover of 49%, just over the relevant guideline of 40%. In other words, in the course of a typical year, two of the three sites in Taranaki would remain below periphyton guidelines for the entire year, while the third could be expected to reach just over the guidelines only when at its worst.

The mean extent of periphyton cover at each of the three sites was below 20%, the 'best' category to which sites were assigned in the study. The average cover combining the data from the three Taranaki sites together (i.e. a crude representation of 'periphyton cover in rivers in Taranaki') was lower than the national mean, for all three guidelines (filamentous, mats, and total periphyton).

On a national basis, comparing 'baseline' with 'impact' sites showed that mean and maximum cover was generally higher at the latter, and a greater proportion of impact sites had an annual maximum coverage exceeding an MfE guideline than for baseline sites. By way of comment, this is only to be expected, for a number of reasons- impact sites are lower in catchments, and therefore have less cover and more exposure, higher temperatures, more light, slower flows, more stable beds, and higher nutrients and organic contaminants- all factors for periphyton growth.

Trend analysis was carried out on the data. Nationally, many more sites showed reductions (improvement in water quality value) in cover than increases (decline in value. The report noted that this finding was unexpected, given an increase in nitrogen inputs in intensive agriculture and general trends of increasing nutrient levels over the total period. The discussion in the report noted that decrease in organic point source discharges (such as in industry and dairy shed effluent) may be related to the improvement. While poor clarity can inhibit periphyton, there has been an overall improvement in clarity across NRWQN sites over the period, so this cannot be the cause of the trend of less nuisance periphyton in New Zealand rivers. Other possible factors such as flow variability, temperature fluctuations, and the abundance of invertebrate grazers, were identified but not explored, although there is no suggestion as to whether and why these should be changing during the period coved by the study.

For the three NRWQN sites in Taranaki, two showed no significant change, while the third (Waingongoro) showed a statistically significant reduction in both mean annual filamentous extent, and in annual maximum filamentous extent.. In other words, both the peak coverage and the average coverage by filamentous periphyton at this site are reducing.

The other two Taranaki sites were shown to be stable (ie no evidence of a trend). (Note that an analysis of more recent data in trends in periphyton cover is included in this review in section 3.1.2).

4.2 RFWP implications

In some particular situations around New Zealand a very high level of interventionary control of nutrient inputs into surface waters can be justified.

But the analysis provided by the two studies discussed above provide a national context and a perspective that is helpful when weighing up the justification, costs, and potential benefits of nutrient control measures, and also again highlight that nutrient management cannot be viewed as the be-all and end-all of natural resource maintenance and enhancement. Other measures such as riparian exclusion and plantings, which provide additional mechanisms for stream ecology and biodiversity enhancement alongside that of nutrient abatement, receive additional endorsement through the findings of studies such as this.

The study notes: '*it would be sensible to select BMP* [best management practice] *to maximise cost-effectiveness ($ ha^{-1} of nutrient conserved) depending on the farm system, the limiting nutrient, and where most of the limiting nutrient was lost...consequently, if water is P-limited, targeting BMP to areas of surface runoff and P loss may maximise BMP cost-effectiveness and have greater benefits for stream and river quality than catchment-wide BMPs targeting N.*'

The study concludes *'when used in isolation,* [N and P] *guidelines gave an incomplete picture of the potential for periphyton growth...Although strategies to decrease N losses should always be practised, mitigating P losses will be increasingly important to prevent algal growth'*.

4.3 Summary of findings re key factors for periphyton and in-stream health

With regard to **drivers of in-stream health and water quality**, this review notes that first of all it is important for the regional community to be aware that (i) nitrogen is not the key determinant of in-stream ecology (periphyton and macrophytes) in Taranaki streams in any case. Rather, phosphorus is recognised as the limiting nutrient - that is, the extent of periphyton growth, including any excessive growth, will determined by the availability of phosphorus. Thus, measures that focus on reducing nitrogen inputs would be mis-placed, and conversely, measures that reduce phosphate loadings would have much more direct benefit; (ii) secondly, excessive nutrients (if indeed they were to be present) do not of themselves actually lead to adverse environmental consequences. A number of other environmental factors must also simultaneously be present before excessive periphyton would be promoted. In particular, the duration of low, warm, and slow flows is a controlling factor. The independent national study found that the Taranaki region is essentially the least susceptible region in New Zealand for excessive periphyton to occur, because of the frequency of rainfall events even during summer (this is not about total rainfall, but the return interval between rainfall events that result in flushing effects in rivers). This prognosis is borne out by the actual observations of periphyton made during monitoring at critical times by both NIWA scientists and the Council's staff (see above).

4.4 Proposed Council interventions and their purpose

4.4.1 The science

There is a copious and comprehensive body of scientific literature that demonstrates not only that riparian shading has significant benefits for in-stream ecological health and controlling eutrophication even in the presence of other factors that favour periphyton, but that riparian management is cost-effective as an intervention. A brief selection of references is discussed below.

The reader is also referred to 'Transforming Taranaki' (TRC 2011) for further references and reviews (http://www.trc.govt.nz/Land-management-2/).

NIWA states that a key method for farmers to avoid nutrients entering waterways is to prevent cattle entering waterways by using bridges and culverts over regular crossings, fencing waterways, and riparian planting[20].

NIWA further stated[21] '*Fencing of stream banks in pastoral landscapes, ideally with a set-back to create a riparian buffer, is increasingly recognised as the most important BMP* [beneficial management practice] *to arrest this pollutant pathway* [livestock direct access]*, with bridged stream crossings also important on dairy farms where cows move usually twice –daily to milking sheds, often crossing streams*'. In respect of diffuse overland flow, the same paper noted '*Beneficial Management Practices that are most appropriate to overland flow are those that act as 'filters' to intercept diffuse pollutants in the surface runoff. These include contour tilling and planting, grassy strips, wetlands and stream-bank vegetation.*. As a means of attenuation of diffuse pollution, the paper noted '*attenuation of runoff through riparian vegetation on stream edges has been the subject of long study in New Zealand, …showed the value of riparian vegetation on pasture streams as nutrient traps for overland flow of phosphate to stream channels during rain storms. The study provided strong support for the use of buffer strips of vegetation along stream channels as a means of protecting streams from phosphate losses*'.

20 *Waste not want not* Water and Atmosphere, NIWA November 2014

21 *Diffuse Pollution and Freshwater Degradation: New Zealand Perspectives,* C Howard-Williams et al, 14th International Conference 2010, IWA Diffuse Pollution Specialist Group, publ. in Water November 2011

Jyväsjärvi et al determined that fine sediment was the driver of ecological condition in streams[22], and proposed that degraded sites would benefit from riparian works.

Goss et al found that temperature, sediment, and nutrients changed rapidly, and macroinvertebrate composition improved rapidly (even within a few metres), as agricultural streams entered zones that were riparian planted. They noted that forest fragments play an important[23] part in maintaining stream ecological integrity. The conclusion was '*the rapid changes in a variety of attributes (*ecological health, nitrate, temperature, suspended solids/sediment*) that occurred at both streams suggest that even small fragments of forest may be able to recover stream characteristics typical of more undisturbed catchments'. … 'Furthermore, these results support the idea that discontinuous conservation and restoration of forest fragments may be an important strategy for managing stream integrity in agricultural landscapes'.*

They particularly noted the beneficial effects upon macroinvertebrate assemblages. The authors also referenced research showing that stream temperatures could drop by up to 5°C within 200 metres of entering a shaded zone, with lower (by 1.6-2.4°C) maximum temperatures. They noted other benefits of riparian trees - leaf litter as food source, wood debris enhancing in-stream nutrient processing; filtration of overland flow prior to entering a stream; and enhanced habitat quality, suggesting that forest fragments may be important areas for nitrogen processing (reduction in nitrate concentrations) under some circumstances.

Lyons et al found that both grassy and woody riparian margins offered water quality and in-stream ecological benefits, with the need for a case by case consideration as to what riparian plantings provided the greatest benefit[24].

Gascuel et al[25] provided a description of the benefits of riparian planting as follows: *'Vegetative buffers are areas in the transition zone between the border of cultivated fields (eg croplands, grazing lands) and the hydrographic network (eg ditches, brooks, rivers and lakes). They are intended for removing sediments, nutrients and some other pollutants contained in flowing water. Buffer strips are located at the edge of the fields where the surface water flow leaves the field. The intention is to 'filter' pollutants contained in surface flow originated from the field; effects on subsurface flows are limited….*

A general idea is that a strip of 3 to 10 metres width on slopes < 6% reduce ca. 70 to 90% sediment and particulate P and 30-50% of dissolved nutrients. Norwegian experiments showed a retention efficiency varying from 42-96%, 27-81%, 55-97% and 83-90% for P, N, particles and organic matter, respectively. The report concluded '*Properly placed and managed vegetative buffer effectiveness can be expected to be more than 70% for sediments and 50% for dissolved compounds (PO4, NP3, pesticides). Even a small filter (eg 2 m) along ditches has positive effects in reducing P transfer due to the protection of the banks.'*

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[22] *Does the taxonomic completeness of headwater stream assemblages reflect the conservation status of the riparian forest?* Forest Ecology and Management Volume 334, 15 December 2014

23 *Shifts in attributes along agriculture-forest transitions of two streams in central Ohio, USA* Agriculture, Ecosystems & Environment Volume 197, 1 December 2014

24 *Grass versus trees: Managing riparian areas to benefit streams of central North America* Wiley on-line Library June 2007

25 Create and manage vegetated buffers at field boundaries 2011

Gascuel et al further noted *In addition to a better water quality, the vegetated zone has some positive side effects. It increases the slope stability by armouring the soil with plant roots which reduce the erosion and P loss…benefits include not only water quality improvement but also aesthetic values and ecological benefits…vegetated buffers contribute to an increase in biodiversity…'*

Moore and Palmer found very rich in-stream ecology in both urban and agricultural catchments when streams had riparian cover, by comparison with streams with open banks[26]. Macroinvertebrate diversity was much greater in the headwater streams of agricultural catchments than in the urban catchments, which they associated with the degree of riparian management of the streams in the agricultural catchments. They found that the maintenance of riparian forests even in highly urbanised watersheds may help alleviate ecological disturbances that might otherwise limit macroinvertebrate survival. They considered that both forested and herbaceous riparian management had clear benefits for maintenance or restoration of in-stream ecological condition.

Borin et al found a 6 metre-wise buffer strip (comprised of grass, shrubs, and trees) reduced total run-off by 78%, reduced nitrogen losses from the overland flow by 75%, total phosphorus losses by 80%, and solids losses by over 90%[27]. The conclusion was that the study had confirmed the capacity of even narrow riparian margins (buffer strips) to retain water and contaminants from potential agricultural run-off.

Poole et al found that the proportion and abundance of sensitive aquatic macroinvertebrates was highly correlated with the extent of riparian forest present within a short distance of the waterways.[28]

The EPA of Scotland recognises riparian planting and management as a key mitigation measure for diffuse bacteriological pollution (reductions of between 66 and 81%, with a 10 metre strip for example reducing bacteriological discharges by 70%). Likewise, riparian buffers are recognised as a key mitigation measure for phosphorus, with reductions reported of up to 97% for riparian strips. Even under adverse conditions (very fine sediment, high proportion of soluble phosphorus, and very narrow riparian strips), phosphorus discharges were still reduced by 30-40%.[29]

Hilton et al[30] found that there is little evidence in short-retention-time rivers that the plant biomass (macro and micro) is actually limited by nutrient concentrations, and they made the case that the interaction of hydraulic drag (flushing) together with light limitation provides the main limiting factor against eutrophication.

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[26] *Invertebrate Biodiversity In Agricultural And Urban Headwater Streams: Implications For Conservation And Management* Ecological Applications 15(4), 2005

[27] *Effectiveness of buffer strips in removing pollutants in runoff from a cultivated field in North-East Italy.* Agriculture, Ecosystems & Environment Volume 105, Issues 1–2, January 2005

[28] *Optimizing agri-environment schemes to improve river health and conservation valu*e, Agriculture, Ecosystems & Environment Volume 181, 1 December 2013

[29] http://www.scotland.gov.uk/Publications/2009/01/08094303/17

[30] *How green is my river? A new paradigm of eutrophication in rivers* Science of the Total Environment 365 (2006)

Hutchins et al[31] examined river flow and quality data, including measures of biomass and eutrophication such as chlorophyll-a, for several agricultural and urban catchments in England. In particular they examined drivers of eutrophic state, future scenarios, and options for reducing anticipated deterioration in quality and health. They found *'reducing nutrient pollution was less effective at suppressing phytoplankton growth than the less costly option of establishing riparian shading'*. In particular, constraining agricultural activity was modelled to lead to a reduction in phytoplankton mass by only 10%, whereas riparian shading would reduce phytoplankton levels by 47%.

Further, the authors noted that in river systems the relationship of nutrient levels to phytoplankton growth is not clear, and cautioned against setting river nutrient limits because of inherent difficulties. '*Hydrological response and the complexity of river ecology, coupled with the influence of geology, water temperature and riparian shading implies that* ***significant variation in threshold nutrient levels between different rivers will occur****.* *'…'For example, high flows are likely to suppress levels by flushing phytoplankton downstream…Thus* ***in terms of nutrients, the critical threshold concentrations for transitions between ecological states cannot be fixed****. However, values for phosphorus have been proposed for legislative purposes (UKTAG, 2008); albeit linked to ecological indicators not of total river phytoplankton biomass but rather to the more-specific trophic diatom index, a measure of benthic algal community composition (Kelly, 2008). Many other biological* ***criteria of river health focus on macro-invertebrates and these… are not useful for*** *understanding short-term changes* ***and are difficult to relate to specific drivers*** *or pressures'* (emphases added).

In terms of modelling the costs and benefits of various potential management interventions (reducing point sources, reducing diffuse run-off by controlling land use, or the introduction of riparian shading), the authors found '*planting riparian tress is a considerably more promising measure and is more cost-effective* (the figures showed the costs of riparian shading over a 20–year timeframe were more than an order of magnitude lower than the other options) *than the others tested, reducing peak chlorophyll-a by more than 30-40%, and probably one capable of offsetting most of the detrimental impacts of climate change'*.

In conclusion, the authors also noted '*substantial nutrient limitation, whereby peak chlorophyll-a is cut by over 20%, is* ***only likely if nutrient loads are cut to levels seen in near-pristine environments*** *where municipal and agricultural influence is negligible'*….and ' *Water Framework Directive* ***compliance could be attained more cost-effectively by controlling light conditions through riparian shading rather than curtailing nutrient inputs.'***

In a subsequent media release[32], the lead author commented '*Since 2000, under an EU directive, there's been a big drive to reduce phosphorus going into rivers from sewage treatment works, but we found that cutting phosphorus isn't as effective as planting trees. Tree planting is a radical alternative that appears to be both cheap and effective at reducing eutrophication, although putting this kind of scheme into practice throughout a river catchment would need the support of lots of stakeholders and landowners'*.

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[31] *Which offers more scope to suppress river phytoplankton blooms: reducing nutrient pollution or riparian shading?* Science of the Total Environment, 2010

[32] *Tree cover cuts algal growth*, National Environment Research Council, 6 September 2010

The National Environment Research Council (UK) subsequently reported[33] on the environmental benefits of riparian fencing as a measure to reduce bacteriological pollution. '*There are plenty of high-tech ideas to tackle pollution, but recent research suggests that some of the biggest gains in keeping our waterways clean could come from a more traditional technology - fences. Simply fencing off streams and drainage ditches so farm animals can't deposit manure in and around them could cut levels of faecal pollution dramatically, according to scientists. This would protect the health of people exposed to river water and help Britain comply with EU rules on water quality.'*

A model was used to test the effectiveness of different methods aimed at cutting faecal pollution. Fencing off streams came out ahead by a big margin- around a 60% reduction. The next most effective, cutting the number of cows to reduce potential run-off loadings, offered only a 12% reduction, and slashing fertiliser usage to make grass less nutritious and drive a reduction in stocking rates, offered less than a 10% reduction.

The research reinforced the finding of an earlier study[34], that also identified stream-bank fencing as one of the most effective methods to tackle faecal pollution from agricultural discharges.

Dalton et al[35] determined periphyton community responses to nutrient gradients on the western plains of Canada, using both periphytometer experiments (artificial environments introduced into stream settings to monitor the subsequent development of periphyton in conjunction with stream conditions) and paired measurements of stream and habitat quality across agricultural and non-agricultural catchments. They found that at the individual site scale, introducing nutrients had no effect-that is, other factors were periphyton-limiting (and hence controlling nutrients would provide no benefit). Similarly, when data on the catchment scale was analysed, the concentration of reactive (dissolved) phosphate and the ratio of dissolved nitrogen (nitrate) to phosphate were found to have no relationship at all with the periphyton biomass. That is, once again other factors were the dominant drivers of periphyton or its limitation.

The concentration of nitrate was found to affect periphyton biomass, through driving a shift in community composition as nitrate concentrations increased. However, it should be noted that (i) there was a very high degree of 'scatter' for this data- that is, there was a very poor fit between the concentration of nitrate and the extent of periphyton at any individual site; and (ii) the research showed the rate of change in biomass was very slight compared with the relative change in nitrate concentration. For example, a doubling of nitrate (an increase of 100%) led to an overall average increase of about 20% in periphyton biomass.

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[33] *Fences reduce water pollution*, NERC 20 October 2010

[34] *Reducing fluxes of faecal indicator compliance parameters to bathing waters from diffuse agricultural sources,* Environmental Pollution Vol 147, May 2007

[35] *Determining in situ periphyton community responses to nutrient and atrazine gradients via pigment analysis* Science of the Total Environment 515-516 (2015)

That is, a large reduction in nitrate would not have changed the extent of periphyton cover to any great degree, and control of nutrients would not offer a significant advantage in control of periphyton.

When analysis of data was undertaken in a manner that adjusted results for other confounding influences, then the ratio of dissolved nitrogen (nitrate) to dissolved phosphate was found to influence periphyton cover through causing a shift in community composition.

Canonical correspondence analysis proved that turbidity, stream velocity, average depth, and maximum depth were the key determinants of periphyton proliferation and periphyton community composition.

4.4.2 Proposed Council policies for RFWP

The RMA requires all persons exercising a function under the Act to have particular regard to [section 7(f)] *the maintenance and enhancement of the quality of the environment'.* Every regional council has, amongst other functions for the purpose of giving effect to the RMA, [30(1)(c) *the control of the use of land for the purpose of- (ii) the maintenance and enhancement of the quality of water in water bodies…(iiia) the maintenance and enhancement of ecosystems in water bodies'*. With regard to how the regional council may exercise these functions, it is obliged to review the appropriateness, effectiveness, and efficiency of any objectives, policies, rules, or other methods of achieving desired outcomes, including evaluating their benefits and costs and the risk of acting or not acting if there is uncertain or insufficient information about their subject matter [RMA Section 32].

The *National Policy Statement for Freshwater Management 2014* has as one of its objectives for water quality, '*The overall quality of fresh water within a region is maintained or improved while…*' [Objective A2].

Thus, it is imperative upon the Council to consider the extent to which water quality in the Taranaki region can be further improved, notwithstanding its current good to high quality, as measured in both ecological and physico-chemical terms, and notwithstanding that there are widespread trends of improvement. But any new measures have to be justified having regard to their costs and their benefits, their likely effectiveness (how much difference would they make?), and their likely efficiency (how much effort would they require, weighted up against other options to achieve a similar sort of outcome?).

The Council is proposing two significant new measures for introduction in the next RFWP: the region-wide diversion of dairy shed effluent from discharge to water, to discharge to land as a general rule, and the completion of the current riparian exclusion and planting programmes across the region's ring plain. Currently about half the region's dairy farms discharge to water, although the proportion is gradually reducing; the Council considers that this can be accelerated and discharge to land made the regulatory rule. This would effectively eliminate one of the three major sources of organic, bacteriological, and nutrient loadings to Taranaki's waterways (the others being diffuse runoff and groundwater inflow).

The second measure would see elimination of overland flow (runoff) from diffuse sources of contamination, such as eroding soil, fertiliser, and animal wastes, on pastoral land, and the consequences of animals entering or damaging the banks of streams (soil erosion and the direct deposition of animal wastes). Because phosphate binds to soil, prevention of soil loss and soil transport into streams has a major added benefit of reduced phosphate transport. Overseas studies indicate that riparian control can reduce sediment, phosphate, and bacteriological loadings from diffuse pollution runoff by up to 80% or more. It is recognised that riparian plantings are less effective at reducing nitrogen transport into streams (because nitrogen is generally transported in dissolved form via groundwater rather than surface runoff), but this qualification needs to be placed within the context that in-stream nitrogen concentrations are already reducing, the diversion of dairy shed effluent will of itself significantly further reduce nitrogen loadings on waterways, and nitrogen is of less significance environmentally in Taranaki than in some other regions. The Council will continue to encourage (rather than require) the adoption of other good farming practices such as nutrient modelling and the use of balanced nutrient budgets, the avoidance of heavy stocking of saturated pastures near streams, maintaining soil nutrient levels at optimal instead of at excessive concentrations, and matching fertiliser application to times and degree of greatest demand (precision fertilisation). Given the scale of the anticipated benefits of the proposed measures, it is difficult to see how harsher or more punitive regulatory measures to reduce nutrient loadings can be justified.

4.5 Consideration of future drivers

4.5.1 Review by the Parliamentary Commissioner for the Environment

In terms of future trends within the dairying industry, much has been made of intensification of land use (conversion to dairying or to higher stocking rates on existing pasture) within the context of the conversation around national water quality. This review notes an investigation of the issue by the Parliamentary Commissioner for the Environment[36]. The PCE found that it was the conversion of land previously used for purposes such as extensive agriculture or forestry, to intensive dairying (usually involving irrigation) that was the root driver of a deterioration of water quality (as measured by nutrient concentrations). Taranaki is not vulnerable to this prospect to the same degree as other regions. The ring plain is essentially already fully developed for dairying purposes and essentially no intensification can happen across this area; on the northern and southern coastal plain margins there may be a degree of swapping between dairy pasture and fodder cropping, but topography limits the extent to which dairying could be introduced to new catchments or land use extensively change within catchments.

The concerns of the PCE focused on nitrogen and not on phosphorus (it was indeed noted that riparian control is effective at abating phosphorus), because nitrogen was seen as a trigger of excessive periphyton. Monitoring by the Council and modelling by NIWA shows that actual or predicted periphyton levels in Taranaki are not excessive as assessed by national guidelines.

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[36] *Water Quality in NZ Land use and nutrient pollution* A report by Parliamentary Commissioner for the Environment November 2013, available at http://www.pce.parliament.nz/assets/Uploads/PCE-Water-quality-land-use-web-amended.pdf

The study noted that eliminating effluent discharges to water would reduce nitrogen losses to water by about 20%. The elimination of essentially all remaining effluent discharges to water is a new measure being proposed by the Council for the community's consideration in the RFWP review process.

The PCE's study suggested that phosphate discharges to water had reduced in Taranaki by 2% between 1996 and 2008, with a further small reduction anticipated by 2020. The Council's monitoring shows a greater degree of reduction has already occurred.

The PCE assessment for Taranaki was that the area of land dedicated to intensive dairying since 1996 had in fact reduced by about 7%; while an increase by 2020 was predicted through modelling, the magnitude of this predicted increase in absolute terms above the 1996 level was less than 3%. The PCE report presented modelling that suggested nitrogen loadings to Taranaki's waterways had increased 4% 1996-2008, and can be expected to increase another 5% by 2020. However, monitoring shows that in actual fact concentrations of total nitrogen in the region's waterways have remained stable throughout 1996- 2014, when loadings had supposedly increased according to the modelling; and over the last seven years - when the area of dairying was increasing again - nitrogen concentrations are actually reducing on a regional basis.

Thus, any imperative for a proactive intervention based on an anticipation of a future major issue around increasing nutrients in the region's waterways is not supported upon close examination. The modelling undertaken for the PCE report indicates that Taranaki is unlikely to see a major expansion of intensive dairying into catchments that hitherto were not exposed to this land use; and in addition, monitoring to date shows that the modelled outcomes are conservative- that is, they present a picture that is more pessimistic than is borne out in realisation.

The Parliamentary Commissioner for the Environment (PCE) released an update report on water quality in June 2015[37]. It summarises reactions to the original report and presents new information on land use that was not available in 2013. Recent changes in farm productivity and mitigation are described and trends in nutrient concentrations and water quality are presented. It focuses on nitrogen as the source of the main current nutrient stressor on waterways and that this is coming from large scale land use change – predominantly from sheep and beef farming, and to a lesser extent plantation forestry, into dairying. The PCE acknowledges in her later update report that the debate has now become more sharply focused on the key challenge: that of dealing with declines in water quality coming from changing land use.

The report presents information that shows increasing nitrate concentrations are occurring in those regions where dairy farming has expanded on a large scale, with generally decreasing or no significant change in other areas. The report also notes that dissolved reactive phosphorus (DRP) loads rose at relatively few sites and that there were considerably more sites where DRP actually fell. DRP is much easier to mitigate than nitrogen because of the relative insolubility of phosphorus.

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[37] *Update report. Water quality in New Zealand: Land use and nutrient pollution*

It should be noted that Taranaki has not experienced large scale land use change to dairying seen elsewhere in the country, and all indications from the Council's state of the environment monitoring are that nitrogen levels in the waterways across the region are in fact either improving or showing no significant change.

The PCE's report in fact notes that the impact of changing nutrient concentrations on the actual health of aquatic ecosystems is best measured by the use of bio-indicators such as the macroinvertebrate community index (MCI). The Council has long used the MCI as an indicator of the ecological health of rivers and streams in Taranaki. The PCE's report shows changes in MCI in rivers around the country between 2000 and 2010 with most sites showing no change over the decade. The report goes on to explicitly mention that there have been a number of sites in Taranaki where there have been increasing MCIs and notes that in Taranaki a programme of riparian planting has been underway for many years, linking these two points by association at least.

4.5.2 Past and future patterns of fertiliser use in Taranaki

Detailed analysis of fertiliser use in the Taranaki region has been limited by the fact that New Zealand Statistics, the Government department responsible for gathering data, abandoned its annual regional agricultural surveys in 2001. However, data on regional fertiliser use is still available on a 5 yearly basis. This data is given in figures 6 and 7 below.

The data shows that use of phosphate fertilisers has reduced since the 1970s-1980s and has remained relatively steady in the region since the late 1990s, but the use of nitrogenous fertiliser (predominantly urea) has increased markedly over the last two decades. In terms of the consequences for water quality (particularly concentrations of nutrients), two results stand out after reviewing figure 5 against figures 6 and 7:-

1. The in-stream concentrations of total nitrogen have shown no increase despite the concurrent very large increase in nitrogen loadings on to pasture over the past two decades, and more recently (since about 2006) concentrations of both total nitrogen and nitrate in the region's waterways have begun to significantly reduce on a region-wide perspective when rolling seven-year trends are calculated;
2. Likewise, since about 2004 concentrations of total and dissolved reactive phosphorus have stabilized, and have subsequently (2011) begun to show an overall region-wide pattern of reductions, when rolling seven-year trends are calculated.

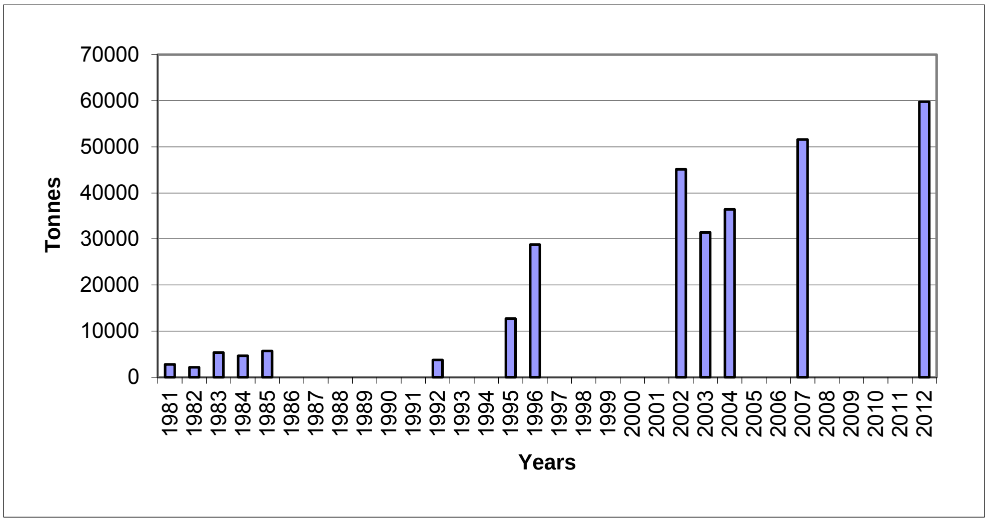

Figure 5 tonnes of nitrogenous fertiliser (excluding effluent) applied in Taranaki per year

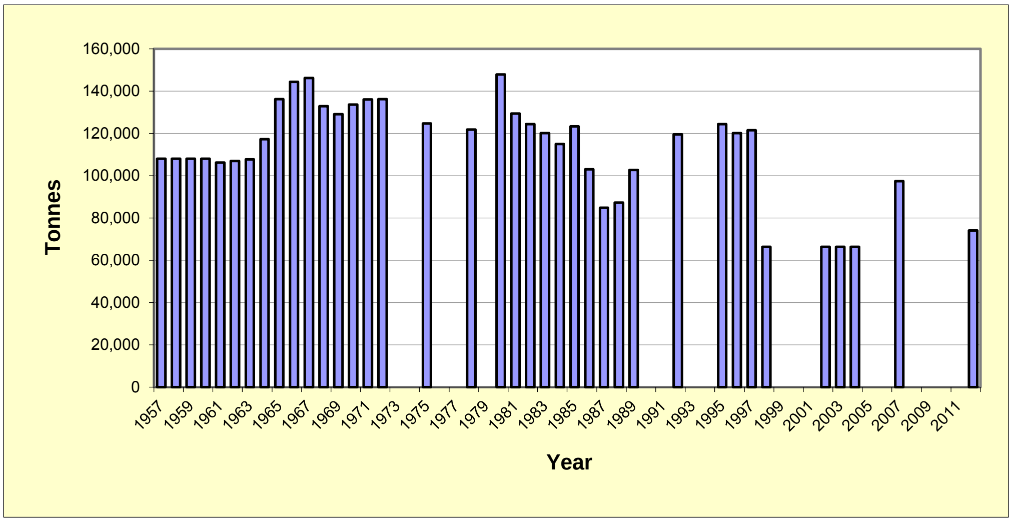

Figure 6 tonnes of phosphatic fertiliser used in Taranaki per year

4.5.3 Nitrogen concentrations in groundwater in Taranaki

In order to ascertain the successful adoption and application or otherwise of the Council's policies and methods of implementation, the Council conducts 'state of the environment' (SEM) monitoring to obtain and report up to date robust information for parameters that characterise the region's environment and resources. The results and findings of the SEM programme for the region's shallow groundwater systems can be interrogated to determine the state of and trends in the concentration of nitrate, a constituent that can be of human health and environmental concern in some circumstances. With the groundwater programme well-established, the database is extensive enough to allow robust trend analysis, conducted according to nationally recognised methodologies, for such reviews. The data has also been reviewed for indicative patterns of changes that might be occurring.

The report *State of the Environment Monitoring Nitrates in Shallow Groundwater 2002 to 2012* (Taranaki Regional Council, September 2014) provides details of the Council's 'state of the environment monitoring' programme in respect of five-yearly surveys of the concentrations of nitrate in groundwater across the region. It includes the results of monitoring of groundwater nitrate at 74 sites, sampled on four occasions at three monthly intervals in the 2012-2013 year. The report also presents an analysis of trends at those sites (56) that have been sampled in each survey since 2002. The environmental significance of the data is also discussed.

The results of the trend analyses indicate:

- Measured nitrate concentrations at 41 of the 56 sites (or 73%) have remained stable during the 2002 to 2012 period;
- Applying statistical analysis, 7 sites (or 13%) displayed an increasing trend (deterioration) nitrate concentrations.
- 8 sites (or 14%) displayed declining trend (improvement) in nitrate concentrations.
- The number of sites where there was an exceedance of the MAV has reduced across the three surveys;
- The number of individual samples exceeding the MAV has reduced across the three surveys;
- The number of samples exceeding the MAV, as a percentage of the number of all samples collected in each survey, is showing an overall reduction across the three surveys; and
- The majority of sites had their highest NNN concentration measured in the first survey, and there is a clear pattern emerging of fewer sites having their peak NNN concentrations recorded during more recent surveys.

That is, there is no evidence of any increase in concentrations of nitrate-nitrogen in the region's groundwater, despite the increased application rates for artificial nitrogenous fertiliser by broadcasting. If anything there is an overall tendency towards a reduction in these groundwater concentrations.

This is consistent with evidence elsewhere that the predominant cause of elevated groundwater nitrogen is nitrogen loss from urine patches on pasture, rather than artificial fertiliser use. Loadings from this source (grammes of nitrogen per square metre) can be twenty times or more the loading rate used when broadcasting fertiliser; further, urine is released from cattle under all weather and soil conditions, in particular when the soil is saturated during and after rainfall and percolation rates are consequently at their highest. By contrast, nitrogen fertiliser is typically spread during dry weather or preceding predicted light rainfall only, with best farming practice being to intentionally avoid loss by percolation and infiltration.

Further, over the last decade in Taranaki the stocking intensity (cows per hectare) has essentially remained static (implying little or no change in the volume of urine voided per hectare), but there has been a very large lift in productivity per cow, in the order of 20%, bolstered through increased grass growth and supplementary feed imports. Thus, a greater proportion of applied nitrogen is being converted to milk protein rather than being lost as voided urine (ie improved nitrogen conversion efficiency).

4.6 Drivers of stream health and quality: key points

A primary concern over excessive nutrient concentrations in water ways is their link under some circumstances with a proliferation of periphyton, which can lead in turn to a deterioration of ecological health through a changed habitat and depletion of dissolved oxygen. Such a proliferation also adversely affects the suitability of a water body for various other purposes and uses as well.

The work by NIWA establishes that the levels of nitrogen and phosphorus in streams in Taranaki (even in 2009) were not high by national comparison. Concerns, interventions, and actions elsewhere do not transfer directly to Taranaki.

The mid and lower catchment reaches of rivers in Taranaki are shown to be phosphate-limited: that is, actions to reduce the levels of periphyton in Taranaki's rivers (if action is needed) by reducing levels of nutrient would be more effective if they focus on phosphorus over nitrogen. However, given the frequency and nature of flushing events within Taranaki's hydrological systems, Taranaki is simply not vulnerable to extended periods of excessive periphyton. Once flow patterns (return periods for flushing events) are taken into account, the picture of susceptibility to excessive periphyton biomass. The imperative to reduce nutrient concentration has less application in Taranaki than elsewhere.

NIWA's nationwide data validates this analysis. Sites in Taranaki meet national criteria and are amongst the better sites nationally.

Fertiliser loadings (figure 6) and soil concentrations (data not shown) of phosphorus have largely remained stable over the last two decades but in-stream concentrations are showing some indications of stabilization and reductions since 2004.

Nitrogen loadings onto pasture have increased markedly, but in-stream nitrogen concentrations have remained stable and more recently (since 2006) have begun reducing.

Riparian management is shown to have multiple benefits for the aquatic environment -

- reduced loadings not only of nutrients, but of sediment (found by USEPA to be more critical as a pressure on water quality than nutrients are), organic content, and bacteria;
- enriched in-stream and stream-bank habitat, thus supporting more diverse and abundant communities;
- shading that reduces light and lowers in-stream temperature;
- greater food supply via leaf litter and woody debris;
- reduced run-off flow velocities

Riparian management has been shown to be amongst the most cost-effective and effective in absolute terms as a means of promoting stream health.

The diversion of treated dairy shed effluent from water under all but the most exceptional of circumstances will further reduce current nutrient loadings within the region. As with riparian management, this action has benefits not only for reduction of nutrient loadings, but also for reduced turbidity, suspended solids, organic loadings, and bacteriological impacts.

Given that:-

- lag times on the ring plain of Taranaki are quite short (less than 5 years) due to free-draining soil and shallow aquifers and the intensive stream network; and that
- the median concentrations of nitrate-nitrogen in shallow groundwater across the region are very low, and if anything are gradually reducing, despite the increase in applications of broadcast nitrogenous fertiliser; and that
- on a site by site basis improvements in stream ecological condition have been found to be independent of trends in nutrient concentrations at the same site (data not shown); and that
- macroinvertebrate conditions at a substantial number of sites were showing a marked improvement even when the overall pattern of nutrient concentrations in waterways was unchanging or still deteriorating at a substantial proportion of sites; and that
- the year by year increase in the number of sites showing a marked improvement in their macroinvertebrate condition is displaying a similar trajectory to the year by year increase in the extent of riparian fencing and planting; and that
- an accelerating number of stream sites are showing improvements in ecological condition that are both meaningful changes and are statistically significant, at the same time that riparian fencing and planting are accelerating on a regional basis:-

it is postulated that the current primary driver for the significant improvements in ecological condition of the Taranaki region's waterways is the implementation of the regional riparian programme. A continuation and acceleration of this programme, in association with measures to reduce effluent discharges from farm pond system, will have demonstrable and widespread benefits.

As a corollary, it emerges that macroinvertebrate community health is clearly driven by factors other than nutrient concentrations. However, the value of the riparian programme in having a marked influence upon reducing concentrations of nutrients within the region is also acknowledged.

5. Conclusions

This review of the current state of and trends in the surface water quality of Taranaki has used measures of ecological (macroinvertebrates, periphyton) and physico-chemical quality. It has examined trends in those measures, and it has compared the current state of Taranaki's waterways with statutory standards and with guidelines for a range of values and uses considered to be important for the regional community.

In doing so, it has found that by accepted criteria the water quality of Taranaki is already very good on a regional basis.

The one water quality measure that might be of concern, dissolved reactive phosphorus, is best understood as an indicator of a potential issue with the proliferation of periphyton. This is put into perspective when the findings of periphyton surveys are considered alongside physicochemical results. The results of these regional surveys of periphyton demonstrate an extremely high level of compliance with national guidelines.

Trend analysis of physico-chemical measures shows that there is generally improvement occurring, especially in reductions in concentrations of nutrients, and that the indications of improvement are becoming more widespread and more significant.

Macroinvertebrate surveys show that there is widespread and significant improvement occurring, and that across most of the region there are fewer and fewer sites that have MCI values below what would be expected.

For the two measures of periphyton, there are statistically significant indications of reduction in up to one-third of sites, with no statistically significant deterioration in either measure at any site.

The starting point for a consideration of new policy measures and interventions is therefore that of seeking to maintain and further enhance already good state of water quality. Measures that would impose a high cost upon the community or a sector within the community cannot be justified from the perspective of prospective gains in river health and well-being.

The Council is examining three options: (i) essentially status quo; (ii) increased emphasis upon riparian planting and exclusion, with regulation in due course, together with exclusion of dairy effluent treatment pond systems from waterways (i.e. discharge to land only); or (iii) regulation of nutrient loadings to land, in order to reduce nitrogen infiltration to groundwater and thus eventually to surface water.

From the perspective of the health of the region's streams, riparian exclusion and planting has been demonstrated to offer substantial gains. Riparian management not only provides substantial reductions in nutrient runoff and some limited reductions in groundwater transport of nutrients, it has also been demonstrated to reduce sediment and bacteriological losses to water (both via overland flow and bank erosion). There are additional benefits- increases in terrestrial and particularly in aquatic biodiversity through enhanced habitat and energy supply (leaf litter fall), reduced temperature

extremes, shade, and moderated flows. The direct discharges of wastes from animals standing in or crossing streams, and trampling of stream banks, is prevented.
The diversion of pond discharges to land means that farmers can recover its nutrient value in pasture growth, and can displace imported fertiliser costs, alongside a significant reduction in nutrient loadings to waterways.

A separate study provides a review of nutrient models, including an evaluation of their inherent strengths and their limitations and also what the consequences are if their use is to be applied in a regulatory setting. From a water quality perspective, it is noted that applications of models as a catchment management tool must of necessity because of limitations on model complexity take all nutrient losses from all farms in the catchment as having an equal in-stream effect, regardless of the location of each farm within the catchment and their proximity to the watercourse. This ignores the reality of off-farm attenuation, direction of travel, and transport processes, and does not capture, for example, short-term but high impact losses from critical source areas. There is no quantifiable connection between individual on-farm losses below the root zone, and in-stream water quality (let alone consequent effects upon stream ecology). The sheer number of catchments in Taranaki, let alone the diversity of on-farm and inter-farm and length-of-catchment variables such as climate, distribution of precipitation from individual rainfall events, hydrology, geohydrology, soil characteristics, on-farm practices, and nutrient cycling within each stretch of watercourse, mean high individual variability in the degree of any contribution to water quality on a farm by farm basis. These factors preclude any efficient means of collectively relating each individual farm's activity to a desired water quality outcome via modelling. Taranaki's short and steep-run rivers do not present the same scale and homogeneity of other catchments elsewhere throughout New Zealand, where cumulative impacts are pronounced and catchment scale on-farm interventions are therefore efficient and potentially effective.

It is recognised that both riparian management and the installation of systems for discharge of effluent to land carry a direct cost to farmers. However, in the context of a drive for an appropriate level of enhancement of the waterways of Taranaki, it is suggested that these two measures are the most cost-effective and beneficial for the region to take into the next Regional Fresh Water Plan.

Glossary of common terms and abbreviations

The following abbreviations and terms may be used within this report:

Biomonitoring	Assessing the health of the environment using aquatic organisms.
BOD	Biochemical oxygen demand. A measure of the presence of degradable organic matter, taking into account the biological conversion of ammonia to nitrate.
BODF	Biochemical oxygen demand of a filtered sample.
CBOD	Carbonaceous biochemical oxygen demand. A measure of the presence of degradable organic matter, excluding the biological conversion of ammonia to nitrate.
cfu	Colony forming units. A measure of the concentration of bacteria usually expressed as per 100 millilitre sample.
COD	Chemical oxygen demand. A measure of the oxygen required to oxidise all matter in a sample by chemical reaction.
Condy	Conductivity, an indication of the level of dissolved salts in a sample, usually measured at 20°C and expressed in mS/m.
Cumec	A volumetric measure of flow- 1 cubic metre per second (1 m^3s^{-1}).
DO	Dissolved oxygen.
DRP	Dissolved reactive phosphorus.
E.coli	Escherichia coli, an indicator of the possible presence of faecal material and pathological micro-organisms. Usually expressed as colony forming units per 100 millilitre sample.
Ent	Enterococci, an indicator of the possible presence of faecal material and pathological micro-organisms. Usually expressed as colony forming units per 100 millilitre of sample.
FC	Faecal coliforms, an indicator of the possible presence of faecal material and pathological micro-organisms. Usually expressed as colony forming units per 100 millilitre sample.
Fresh	Elevated flow in a stream, such as after heavy rainfall.
g/m^3	Grams per cubic metre, and equivalent to milligrams per litre (mg/L). In water, this is also equivalent to parts per million (ppm).
l/s	Litres per second.
MCI	Macroinvertebrate community index; a numerical indication of the state of biological life in a stream that takes into account the sensitivity of the taxa present to organic pollution in stony habitats.
mS/m	Millisiemens per metre, a measure of conductivity.
Mixing zone	The zone below a discharge point where the discharge is not fully mixed with the receiving environment. For a stream, the 'mixing zone' is conventionally taken as a length equivalent to 7 times the width of the stream at the discharge point.
NH_4	Ammonium, normally expressed in terms of the mass of nitrogen (N).
NH_3	Unionised ammonia, normally expressed in terms of the mass of nitrogen (N).
NO_3	Nitrate, normally expressed in terms of the mass of nitrogen (N.)

NTU	Nephelometric Turbidity Unit, a measure of the turbidity of water.
pH	A numerical system for measuring acidity in solutions, with 7 as neutral. Numbers lower than 7 are increasingly acidic and higher than 7 are increasingly alkaline. The scale is logarithmic i.e. a change of 1 represents a ten-fold change in strength. For example, a pH of 4 is ten times more acidic than a pH of 5.
Physicochemical	Measurement of both physical properties (e.g. temperature, clarity, density) and chemical determinants (e.g. metals and nutrients) to characterise the state of an environment.
Resource consent	Refer Section 87 of the RMA. Resource consents include land use consents (refer Sections 9 and 13 of the RMA), coastal permits (Sections 12, 14 and 15), water permits (Section 14) and discharge permits (Section 15).
RMA	*Resource Management Act* 1991 and including all subsequent amendments.
SS	Suspended solids.
SQMCI	Semi quantitative macroinvertebrate community index.
Temp	Temperature, measured in °C (degrees Celsius).
Turb	Turbidity, expressed in NTU.

For further information on analytical methods, contact the Council's laboratory.