*Palmerston North City Council*

# Review of Water Quality Standards in the Proposed One Plan

**Prepared for Palmerston North City Council to inform submission on the Proposed One Plan.**

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# Contents

## Executive Summary

Opus International Consultants was commissioned to provide ecological advice to Palmerston North City Council (PNCC) relating to the PNCC's submission on the proposed One Plan – the combined Regional Policy Statement and Regional Plan for the Manawatu-Wanganui Region. There are some aspects of the proposed water quality standards in the proposed One Plan that need further justification. These include:

The proposed water quality standard in the proposed One Plan has been reviewed with respect to their suitability to the Lower Manawatu Mana_11a subzone. Some of the proposed water quality standards are conservative and adjusting the framework of policies and water management zones may allow the proposed water quality standards to be more precise. In particular a less precautionary approach to water quality standards would be possible if there was a policy to prevent further deterioration of water bodies, there was more differentiation of habitats within a sub-zone, and if some values (e.g. contact recreation) were applied more precisely.

Recommendations are made to change some of the proposed water quality standards for the Mana_11a sub-zone as follows:

- Most of the water quality standards would be more appropriate to expressed as percentile values (e.g. 90$^{th}$ percentile) instead of maximum values implied by the expression "shall not exceed".

- The proposed water quality standard for pH would be more appropriate to express as 10$^{th}$ and 90$^{th}$ percentile values. Furthermore, ensuring that diurnal fluctuations of pH are in the reference dataset may allow a less conservative standard.

- The proposed water quality standard for temperature and dissolved oxygen was considered reasonable.

- The proposed water quality standard for $BOD_5$ would be more appropriate to express as a mean of $cBOD_5$.

- Setting a water quality standard for QMCI is not recommended given the structure of the proposed One Plan. Some issues could be addressed by differentiating sites using the REC, using alternative indices such as O/E values and expressing scores as a median values or in terms of a percentage change.

- The proposed water quality standard for POM is not appropriate in its current form. If there is a POM standard it should be applied as a change value specific to discharges, and based on mean or median values.

- The proposed water quality standard for total ammonia is overly conservative. In my view the standard should be applied to average values, be set as the table of pH values in Table 8.3.7 of ANZECC (2000) rather than on a single pH value, and only be set to protect the freshwater clam *Sphaerium novaeselandiae* in areas where this species is considered an important component of the aquatic ecosystem. Data from

Horizons SOE reports suggests that *Sphaerium* spp. is rare in the major rivers of the region.

- The proposed WQ standard for turbidity of 15 NTU when the river is below three times the median flow is a little conservative, and should at least be applied as a $90^{th}$ percentile value.

- The proposed water quality standard for periphyton is considered reasonable but should be specifically applied to filamentous algae.

- The proposed water quality standard for phosphorus was considered reasonable but there may be potential to relax the standards during winter without causing excessive periphyton growth. To justify seasonal standards further information is needed on the extent of periphyton cover and biomass during winter, and whether periphyton in the Manawatu River can practice luxury uptake of nutrients. Flow related standards might also be justified if luxury uptake does not occur for Manawatu periphyton, however flows suitable for relaxed nutrient standards could be quite high.

- The proposed water quality standard for nitrogen should be increased to at least be consistent with ANZECC guidelines.

- The proposed water quality standard for *E. coli* bacteria of 260/100mL would be better justified if it was not applied to less than median flows, but instead applied to actual locations where swimming is more common. The water quality standard for *E. coli* bacteria of 550/100mL is reasonable to apply more widely to water bodies and periods where the value of contact recreation is being protected.

# 1 Introduction

Opus International Consultants was commissioned to provide specialist ecological advice to Palmerston North City Council (PNCC) relating to the PNCC's submission on the proposed One Plan – the combined Regional Policy Statement and Regional Plan for the Manawatu-Wanganui Region. This report provides comments on the proposed water quality standards in the proposed One Plan, with a focus on the implications of proposed standards on the Palmerston North City Council waste water treatment plant (WWTP) discharge.

The aim of this report is to provide PNCC with initial guidance as to appropriateness of the water quality standards in the proposed One Plan from an ecological view point. There are some information gaps limiting the extent of some comments, where applicable these gaps have been highlighted. The primary documents considered in the review were:

Ausseil O and Clark M, 2007a. *Recommended water quality standards for the Manawatu-Wanganui Region: Technical report to support policy development*. Prepared for Horizons Regional Council, June 2007.

Horizons Regional Council 2007. *Proposed One Plan*. Prepared for Horizons Regional Council, May 2007. Chapter 6 and schedule D

# 2 Policy Context

## 2.1 Policies of the proposed One Plan

The proposed One Plan sets up a framework for managing water quality in the Manawatu-Wanganui Region by dividing the region into 'water management zones' and identifying values in each water management zone for which the rivers and lakes shall be managed (Policy 6.1).

Water quality standards relating to the values have been developed for each water management zone (in schedule D of the proposed One Plan). Policy 6.2 states that the water quality standards shall be used for the management of surface water quality.

These water quality standards define an environmental bottom line beyond which values are considered to be lost or compromised. Policy 6.3 requires ongoing compliance where water quality standards are met, and Policy 6.4 requires enhancement where water quality standards are not met.

## 2.2 Water Management Zone

The PNCC Waste water treatment plant is located in the Lower Manawatu Management Zone – sub zone Lower Manawatu (Mana_11a). The downstream zone is Coastal Manawatu (Mana_13a). This report has focused on the proposed standards for Mana_11a, with some consideration for the values in Mana_13a.

The Life Supporting Capacity (LSC) Class for Mana_11a is Hill Mixed and the LSC Class for Mana_13a is Lowland Mixed.

### 2.3 Values in the

The values given to the Lower Manawatu Management Zone – sub zone Lower Manawatu (Mana_11a) in Table D.2 of Schedule D are:

| | |
|---|---|
| CR | Contact recreation |
| Am | Amenity |
| Mau | Mauri |
| TF | Trout Fishery III (other) |
| SW | Stockwater |
| SoS R | Sites of significance for riparian diversity |
| CAP | Capacity to assimilate pollution |
| WS | Water supply |
| IA | Industrial Abstraction |
| I | Irrigation. |

The downstream zone of Mana_13a has the additional values of SoS A (Sites of significance for aquatic diversity), NFS (Native Fish Spawning), and NF (Native Fishery); but is not assigned the value IA (Industrial Abstraction).

### 2.4 General comments on the policies, values and Water Management Zones

I have assumed that the water management zones and values set for the Manawatu River are generally appropriate. However the classification of water bodies and the assigning of values is interrelated to the setting appropriate water quality standards, and some issues with the definition of values and management zones have become apparent. These are:

**Possible to pollute water bodies up to water quality standard**: While Objective 6.2 of the proposed One Plan requires maintenance of exiting water quality, there is no policy or water quality standard to prevent any further deterioration in the current state of the Region's water bodies due to human activity. This potentially creates a situation where water bodies can be polluted up to the limits set by the proposed water quality standards. This places a lot of trust in the proposed water quality standards and may lead to an argument for overly conservative water quality standards on the basis of using the 'precautionary approach' in the face of uncertain knowledge. Not having such a policy may also be inconsistent with Section 63(3) of the RMA, unless very conservative standards are set.

**Contact Recreation Value applies to all natural streams and rivers:** The value of contact recreation appears to have been assigned to every water body in the Region. This does not account for the extent of actual use and hence actual risk to the community. Achieving compliance in all natural streams and river waters with the Additional Water Quality Standards set for *Escherichia coli* will be a challenge. In addition these proposed standards apply the trigger values that are stricter than those set in the microbiological water quality guidelines (MfE 2002). This will be discussed in more detail later in the report.

**Water management zones do not differentiate habitat for sensitive species**. The water management zones and sub-zones provide a reasonably high level differentiation of different river and stream types. However the zoning approach has lost a lot of detail present in the Regional Environment Classification (REC), on which it is based. As a result there is likely to be considerable variability in species composition of different types of streams within a single zone. For example a small incised lowland creek running through farm land will have very different species composition compared to the main stem of the Manawatu River at Palmerston North which is still influenced by the hill country streams.

Water quality standards for total ammonia have been set to protect 99% of species on the basis of the freshwater clam (*Sphaerium novaeselandiae*) being common in lowland rivers (Ausseil and Clark 2007), but this stricter target is being applied to rivers where *S. novaeselandiae* does not appear to be present – resulting in overly strict water quality standards. A simple alternative to allow better targeting of water quality conditions would be specifically identify *S. novaeselandiae* as a specific value in rivers where it is present (perhaps as 'biodiversity value') and apply more strict standards only to these streams. Alternatively, a 'do not deteriorate policy' may be adequate to protect the biodiversity value of *S. novaeselandiae.*

**Water bodies to which values and water quality standards apply**: Some values apply to whole management sub-zones and others are site-specific values (Ausseil and Clark 2007a). The water quality standards have been based on the zone wide values, and apply to all water bodies in a sub-zone regardless their specific values. Water quality standard specific to a value can reasonably be expected to be applied for some distance upstream of the value, but if a strict water quality standard is set for a value applied to an upstream site (e.g. trout spawning, aesthetics or amenity) it may place unnecessarily tights standards on downstream sites. It would be useful for the proposed One Plan to clarify in a policy if the water quality standards apply to all water bodies in a zone, or just to the water body with the particular value[1].

[1] This is not a specific issue of the subzone Mana_11a but it may be if a different approach was taken to setting water quality standards for sensitive species or recreational bathing water.

### 2.5 Current water quality in the Manawatu River

To allow comparison with the proposed water quality guidelines the current water quality of the Manawatu River upstream and downstream of the PNCC WWTP is presented in Table 1 below. These summary results are based on monthly sampling from January 2004 to June 2007 for Consent No. 101929.

**Table 1: Current water quality in the Manawatu River upstream and downstream of the PNCC WWTP. Cells are shaded where standards in the proposed One Plan are exceeded.**

| Parameter | Statistic in proposed One Plan | | Statistic as recommended in this report | |
|---|---|---|---|---|
| | **Upstream** | **Downstream** | **Upstream** | **Downstream** |
| pH | | | | |
| Temperature (°C) (max) | 20.3 | 20.3 | 20.3 | 20.3 |
| Dissolved oxygen ($g/m^3$) | 7.0 (min) | 7.6 (min) | 7.0 (min) | 7.6 (min) |
| $BOD_5$ ($g/m^3$) | 4 (max) | 3 (max) | 1.2 (mean) | 1.1 (mean) |
| POM ($g/m^3$) | 66 (max) | 65 (max) | 4.8 (mean) | 4.9 (mean) |
| Total ammonia ($mg/m^3$) | 29 (max) | 670 (max) | 30 (mean) | 233 (mean) |
| Clarity (m) | 0.5 (min) | 0.5 (min) | 0.6 ($10^{th}$%) | 0.59 ($10^{th}$%) |
| DRP ($mg/m^3$) mean | 11 | 81 | 11 | 81 |
| SIN ($mg/m^3$) mean | 488 | 697 | 488 | 697 |
| *E. coli* (CFU/100mL) | 11200 (max) | 15500 (max) | 5655 ($95^{th}$%) | 2630 ($95^{th}$%) |

## 3 Proposed Water Quality Standards

### 3.1 General

The water quality standards relating to rivers in the One Plan are set out in Schedule D Table D.16, Table D.17 and the Additional Water quality standards following these tables. An explanation for the standards is provided in Ausseil and Clark (2007a).

This section provides comments on the way the standards are spelt out in Table D.16, followed by specific comments on each relevant parameter and the Additional Water Quality Standard.

## 3.2 Expressing standards as 'shall not exceed' limits

The Proposed One Plan Schedule D (Table D.16 and the additional water quality standards) expresses almost all the water quality standards (with the exception of DRP, SIN and changes of pH, temperature and clarity) in terms of maximum values (or "shall not exceed"). A more appropriate expression of the water quality standards would be in terms of $10^{th}$ percentiles, median, average or $90^{th}$ percentiles. The general reasons for this are as follows:

- A maximum values requires 100% compliance but may reflect an instantaneous spike or a measurement error that has little or no impact on aquatic biota.
- Some of the water quality standards recommended by Ausseil and Clark (2007a) appear to be derived from 10 percentile values (e.g. lower limits of pH) and 90 percentile values (upper limit for pH). The same statistic should be applied to the standard to ensure it is not overly conservative or lenient.
- The microbial water quality guidelines for marine and freshwater recreational areas (MfE 2003) expresses limits for the Microbial Assessment Category as 95-percentile values.
- The ANZECC guidelines do not specify what statistic to use in comparing guideline values for ammonia toxicity but equivalent ammonia guidelines in other countries are typically set as a percentile value (e.g. $90^{th}$ percentile value in the UK, $95^{th}$ percentile value in the European Freshwater Fish Directive).
- An average or median value has more biological relevance than a maximum value for many parameters (e.g. Biological Oxygen Demand (BOD), turbidity, QMCI, periphyton, and nutrients). This is because the organisms and biological processes respond more strongly to average concentrations than to an instantaneous peak. The NZ Periphyton Guidelines (Biggs 2000) specifically state that the nutrient concentration guidelines are designed to be mean monthly values for the given average days of accrual.
- There are circumstances, outside the control of the operators that will, at some stage lead to one or more of the analytes limits being exceeded. Over sizing the treatment plant does not necessarily help in this regard as under loading can be as much of a problem as overloading in a biological plant. Consequently expressing standards as maximum values, 'shall not exceed', or 100 percentile compliance limits is no longer common practice for consent conditions relating to discharges from biological process waste water treatment plants.

I will discuss a preferred expression of the standards when discussing each parameter below. It should also be noted that percentile values (e.g. $90^{th}$ percentile) can only be accurately calculated on a reasonably sized data set (e.g. at least 12 data points). A practical alternative to a $90^{th}$ percentile value could be to express standards as "no more than one in ten samples shall exceed…". This is not exactly the same as a $90^{th}$ percentile value but is a pragmatic expression that would achieve the same purpose.

### 3.3 pH

For the management zone Lower Manawatu (Mana_11a) Table D.16 states:

*"The pH of the water shall be in the range 7 to 8.5*

*The pH of the water shall not be changed by more than 0.5"*

Water quality (WQ) standards for pH in the Life Supporting Capacity (LSC) in the Lower Manawatu (Mana_11a) (category of Hill Mixed (HM)) has been based on available spot sampling data from reference and slightly disturbed sites of streams in categories Hill Mixed (HM), Hill Soft Sedimentary (HSS), and Upland Volcanic Mixed (UVM). The WQ standard appears to be based on the $10^{th}$ percentile and $90^{th}$ percentile values since the $5^{th}$ percentile value of the HM category is as low as pH 6.6. It is unlikely that the reference data used adequately captured diurnal fluctuations; if it did not the standard may be overly restrictive, particularly considering that the tolerances of biota is much wider than the proposed pH range (i.e. 5.9 to 9.7).

I recommend that the proposed WQ standards are reviewed to address natural diurnal variations and that they are expressed as $10^{th}$ percentile and $90^{th}$ percentile values.

### 3.4 Temperature

For the management zone Lower Manawatu (Mana_11a) Table D.16 states:

*"The temperature of the water shall not exceed 22 degrees Celsius.*

*The temperature of the water shall not be changed by more than 3 degrees Celsius"*

Based on the results of Cox and Rutherford (2000) the proposed standard seems a little conservative because it uses results from 96hr $LT_{50}$ experiments under constant temperatures subtracts an empirical safety margin of $3^oC$ to protect against sub-lethal effects of high temperature, and applies it as maximum temperatures when rivers naturally have a fluctuating temperature regime.

Cox and Rutherford (2000) found that under a fluctuating temperature regime (temperature range $10^oC$) 50% mortality occurred when the daily mean temperature was about 10% lower (i.e. $21.9^oC$) than the $LT_{50}$ derived for constant temperature experiments, and 50% mortality occurred when the daily maximum temperature was about 10% higher (i.e. $26.9^oC$) than the $LT_{50}$ derived for the constant temperature experiment. They concluded that limits derived from constant temperature experiments should be applied to a limit midway between the daily average and daily maximum temperature of the diurnal profile.

However, considering that other experiments have found lower thermal tolerances for *Deleatidium* species (i.e. $LT_{50}$ (constant T) of $22.6^oC$ in Quinn *et al* (1994)), I consider that the results applied as a maximum are not unreasonable. I have not assessed whether these proposed standards are realistic compared to natural temperature variations at reference/slightly modified sites (no continuous diurnal monitoring data was presented for reference sites), or under possible future conditions resulting from global warming.

### 3.5 Dissolved Oxygen (DO) and Biological Oxygen Demand ($BOD_5$)

For the management zone Lower Manawatu (Mana_11a) Table D.16 states:

*"The concentration of dissolved oxygen shall exceed 70% saturation.*

*The five-day biological oxygen demand shall not exceed 2 grams per cubic metre."*

I consider the proposed WQ standard for dissolved oxygen is appropriately set as a minimum level. This is consistent with the USEPA guidelines.

The proposed standard for $BOD_5$ was set to maintain the existing standard in the Manawatu Catchment Water Quality Regional Plan (MCWQ Plan). However, because the proposed $BOD_5$ standard is a maximum value, it is stricter than in the MCWQ Plan – which requires the daily average of $BOD_5$ to be less than 2 $g/m^3$.

It is desirable to minimise the load of $BOD_5$ to rivers because of its impact on dissolved oxygen levels and the promotion of heterotrophic growths. Herterotrophic growths (e.g. sewage fungus) respond to prolonged periods of discharge, the concentration of which is better reflected by the mean or median value rather then a maximum or 90-percentile value. MfE (1992) recommend that the daily average $cBOD_5$ concentration is maintained below 2 mg/l to avoid heterotrophic growths. Expressing the results as carbonaceous $BOD_5$ ($cBOD_5$) ensures that the effect of nitrifying bacteria do not influence the results.

I recommend that the standard is expressed as mean carbonaceous $BOD_5$ ($cBOD_5$).

### 3.6 Quantitative Macroinvertebrate Index (QMCI) and Particulate Organic Matter (POM)

For the management zone Lower Manawatu (Mana_11a) Table D.16 states:

*"The quantitative macroinvertebrate index shall exceed 5, unless natural physical conditions are beyond the scope of application of the QMCI.*

*The concentration of particulate organic matter shall not exceed 5 grams per cubic metre."*

**QMCI**

The composition of macroinvertebrate communities are often considered to reflect the integrated water quality of a river and to be a good measure of 'river health'. The indices MCI, QMCI and SQMCI are commonly used in New Zealand to indicate how the macroinvertebrate community has responded to the amount of pollution in a river. The proposed standard for QMCI appears to be based on the original descriptions provided in

Stark (1985). The MCI was developed for stony streams in Taranaki and I would have expected an attempt to develop region specific QMCI standards based on data from reference sites, this was not done and no data is provided on QMCI scores at reference sites. Cameron (2004) found SQMCI scores upstream of the PNCC WWTP discharge of ca. 3.5 in 2003 and ca. 5.2 in 2004. This suggests that a QMCI standard of 5 is achievable in the Manawatu River.

Macroinvertebrate indices do have potential to be used in water quality standards, but I would not recommend their inclusion as a standard in the One Plan for the following reasons:

- The zoning approach taken in the One Plan provides relatively poor habitat differentiation. Much better habitat differentiation is provided by the Regional Environment Classification (REC). In any one sub-zone there are likely to be rivers with different potential QMCI values, yet they are all expected to meet the same QMCI standard. For example, the potential QMCI values for a creek running through Palmerston North is likely to be considerably less than the potential QMCI value for the main stem of the Manawatu River.

- The QMCI was designed for hard bottomed stony rivers and it is not necessarily the correct index for soft-bottomed rivers. Other indexes are being developed that may meet this purpose.

- There can be considerable spatial variability in QMCI scores from different habitats in a river and often the results need to be interpreted in the context of the particular habitat that was sampled.

- There are many factors that influence the macroinvertebrate community and subsequent QMCI scores (e.g. river flows, substrate, water quality, periphyton growth, predation, temperature, riparian vegetation and its debris). This makes QMCI scores a useful measure to integrate many factors but it also makes it more difficult to interpret what might be causing any failure to meet a QMCI standard. Without the ability to interpret results and causes this could lead to a situation where limits were placed on a discharge when the core issue was sedimentation or a lack of riparian shading.

It would be more appropriate to use the QMCI scores in a guideline rather then as a standard, as this would allow more interpretation of the results and better consideration of the factors discussed above. Whether QMCI is used as a standard or a guideline I would recommend that it is expressed as a median or in terms of a percentage change e.g. a point source discharge shall cause no more than 20% decline in the QMCI score. Some other measures of macroinvertebrate community such as O/E scores may address some of the concerns about spatial variability (see Joy and Death 2003).

**Particulate Organic Matter (POM)**

The standard proposed for POM are based on the results of a study by Quinn and Hickey (1993) that found that increases in mean suspended sediments (SS) of >7 $g/m^3$ were associated with significant changes in density of >50 percent reduction in QMCI scores, and that receiving water criteria of < 4 $g/m^3$ increase in SS may be required to prevent severe impacts on sensitive EPT taxa in stream invertebrate communities. In the study POM was about 50% of SS but the variation was high.

In my view the results of the study have not been applied appropriately to the proposed standard for the following reasons:

- The numbers adopted from the study related to SS rather than POM.
- The upstream POM results in the study were considerably higher than that applied to the proposed standard (i.e. 2.8 mg/l compared to 1 mg/l).
- The water quality results in the study were based on mean values rather than maximum values.
- The study results found strong correlations between suspended solids, particulate organic matter (POM), $BOD_5$, total ammonia concentrations and dilution. So effects on the macroinvertebrate community identified for POM may have been related to other parameters.

It would be more appropriate to apply a POM or SS standard as a change value specific to discharges, rather than an as an absolute value (e.g. mean change in SS due to discharge of < 7 $g/m^3$). It is noted that there is already a change value for turbidity (which is strongly correlated with SS concentrations). Also, as an environmental bottom line it is likely to be sufficient to rely on standards set for $BOD_5$, turbidity change and QMCI.

In summary, I would recommend that no standard is applied for POM, but if there is a standard it is applied as a change value specific to discharges, and based on mean or median values.

### 3.7 Total Ammonia

For the management zone Lower Manawatu (Mana_11a) Table D.16 states:

*"The concentration of ammonia nitrogen shall not exceed 400 milligrams per cubic meter."*

I suspect that there has been an error in drafting this condition and it is intended to read: *"The concentration of total ammonia nitrogen shall not exceed 400 milligrams per cubic meter ($mg/m^3$)."* This is approximately equivalent to the ANZECC guideline for protecting 99% of species. For comparison, the ANZECC guidelines recommends, for slightly–moderately disturbed ecosystems, using values for protecting 95-percent of species, i.e. 900 $mg/m^3$ total ammonia[2].

The toxicity of ammonia is complex. Generally total ammonia becomes more toxic at higher pH values because at higher pH there is a greater proportion of unionised ammonia in

[2] Equivalent to unionised ammonia of 35 $mg/m^3$ (at 20°C and pH=8).

solution; however ionised ammonia can also be toxic. Total ammonia toxicity tables, like those in the ANZECC guidelines, take this into account and are not simply a translation of the proportion of unionised ammonia at a certain pH and temperature.

In using the ANZECC guidelines to set a water quality standard for total ammonia there are two main factors to consider. One, how to account for different toxicity at different pH values, and should a value be set to protect 95 percent of species or 99 percent of species. I suggest that the total ammonia water quality standard should be based on table 8.3.7 in the ANZECC guidelines (ANZECC 2000). This ensures that the standard set is appropriate to the different pH of different rivers and at different time of day. Setting a single number, regardless of pH, is likely to result in an overly strict standard in some situations and undermines the principle of the WQ standards being an environmental bottom line.

The total ammonia values in the ANZECC guidelines are considered sufficiently protective of most slight-moderately disturbed systems, or 95 percent of species. Stricter guidelines can be justified for total ammonia if the aquatic community contains important species that are particularly sensitive to ammonia. The freshwater clam *Sphaerium novaeselandiae* is very sensitive to ammonia and if it is considered important to protect these species at a site the ANZECC guidelines (2000) recommends using total ammonia values of half the 95-percent trigger value i.e. a value of 0.45 g $NH_4$-N/m$^3$ (when pH=8 and temperature=20$^o$C), or using the trigger value for 99-percent protection of species – 0.32 g $NH_4$-N/m$^3$ (when pH=8 and temperature=20$^o$C).

Although *Sphaerium* spp. is typically widespread in lowland rivers it does not appear to be present in the major rivers of the Manawatu Whanganui region. Macroinvertebrate surveys of the Manawatu River by Cameron (2004) did not identify *Sphaerium* spp. and Horizons MW State of Environment reports from 1999 to 2006 only identified *Sphaeriidae* at two sites in 2000; at both these sites (i.e. Whanganui at estuary and Hautepu u/s Rangatiki) only one individual was found. I do not think it is appropriate to apply the stricter guidelines for protecting *Sphaerium* spp. to rivers where it is naturally absent. Instead rivers where it is an important part of the community could be given a specific value as discussed in section 2.4 above, and a stricter standard applied.

The ANZECC guidelines do not specify a particular statistic to apply to the total ammonia guideline, but because they relate to chronic toxicity (e.g. over a 96-hour period) I believe they are best compared against average values. Using median or average values with the guideline is further supported by the follow:

1. Many of the calculations in studies used to derive the guidelines were based on median ammonia concentrations under different nominal doses (e.g. Hickey and Martin (1999) study into the toxicity of ammonia to Sphaerium sp).

2. The Criteria Continuous Concentration used by the USEPA (1998), which is broadly similar to the ANZECC guideline, is based on a 30-day average concentration.

3. It has been common practice for Regional Councils to compare this guideline against median values for the purpose of State of the Environment reporting (e.g. Environment Canterbury, Environment Southland, Otago Regional Council).

The total ammonia values in the ANZECC guidelines are based on chronic toxicity data and in my view should be applied to 90th percentile values.

In summary, I recommend that the total ammonia standard in the One Plan for zone Mana_11a require average values to be less than the total ammonia guidelines set in Table 8.3.7 of the ANZECC guidelines (2000).

## 3.8 Turbidity and Clarity

For the management zone Lower Manawatu (Mana_11a) Table D.16 states:

*"The turbidity of the water when the river is at of below half median flow shall not exceed 2.5 NTU.*

*The turbidity of the water when the river is at of below three times the median flow shall not exceed 15 NTU.*

*The turbidity of the water shall not be changed by more than 30 percent. This standard shall apply only when physical conditions existing at the site prevent adequate water clarity measurements.*

*The clarity of the water measured by the horizontal sighting range of a 200mm black disc shall not be changed by more than 30%."*

In my view the proposed WQ standard for turbidity of 15 NTU when the river is below three times the median flow is a little conservative, and should at least be applied as a 90th percentile value. The value corresponds to recommendations in Boubee et al (1997) to avoid fish avoidance behaviour. This is a conservative turbidity limit – laboratory studies indicate the banded kokopu avoid waters with turbidity of 20 - 25 NTU (Rowe *et al* 2000). This limit on turbidity may not necessarily protect against siltation or sedimentation of the stream bed, but no data is presented in Ausseil and Clark (2007a) as to what limit might adequately protect against siltation.

The proposed WQ standard for turbidity of 2.5 NTU when the river is below half the median flow is based on the 20th percentile of water clarity measurements from a reference site and converted to an equivalent turbidity concentration[3]. The guidelines were considered for different flows. The approach taken is sound and consistent with ANZECC guidelines. I have not assessed the suitability of the reference sites used. It should be noted that setting a water quality standard based on deviation from a reference site does not necessarily correspond to any impacts on biota.

[3] Based on the correlation between black disc and turbidity at Manawatu River at Teaches College (Ausseil and Clark 2007a) 2.5 NTU corresponds to about 1.3 metres black disc clarity. Turbidity of 1.9 NTU corresponds to just under 1.6 m clarity.

I would recommend not stating that the black disc should be specifically 200mm diameter, since a smaller disk is more appropriate to use when the clarity is less than one metre. This is also one of the recommendations in Ausseil and Clark (2007a).

The ANZECC guidelines recommend that the water clarity of recreational waters should not exceed 1.6 metres. This is the generally accepted guideline for contact recreation waters but it is arguable as to whether all water bodies in the region should be classified as contact recreation.

In summary the standards set for turbidity are not unreasonable but should be applied to $80^{th}$ percentile values.

### 3.9 Periphyton

For the management zone Lower Manawatu (Mana_11a) Table D.16 states:

*"The algal biomass on the stream or river bed shall not exceed 120 milligrams of chlorophyll_a per square metre.*

*The maximum cover of visible stream or river bed periphyton (as filamentous algae more than 2 centimetres long) shall not exceed 30 percent."*

The proposed WQ guideline for algal biomass of 120 $mg/m^2$ and periphyton cover of 30 % is reasonable if applied to filamentous algae. When applied to filamentous algae it is consistent with the NZ periphyton guidelines (Biggs 2000) for protection of aesthetics/ recreation and trout habitat.

I would recommend that the wording change to: *The filamentous algal biomass on the stream or river bed shall not exceed 120 milligrams of chlorophyll_a per square metre.*

### 3.10 Nutrients Dissolved Reactive Phosphorus (DRP) and Soluble Inorganic Nitrogen (SIN)

For the management zone Lower Manawatu (Mana_11a) Table D.16 states:

*"The annual average concentration of dissolved reactive phosphorus when the river flow is at or below three times the median flow shall not exceed 10 $mg/m^3$.*

*The annual average concentration of soluble inorganic nitrogen when the river flow is at or below three times the median flow shall not exceed 444 $mg/m^3$."*

The nutrients nitrogen and phosphorus are naturally found in rivers but high concentrations can stimulate the growth of excess periphyton growths. The ANZECC (2000) guidelines set default trigger levels for species of nitrogen and phosphorus but for limiting nutrients it is more appropriate to use the NZ Periphyton Guidelines (Biggs 2000).

Based on the NZ Periphyton Guidelines for maintaining trout habitat and angling the in-stream concentrations (after reasonable mixing) of dissolved reactive phosphorus (DRP) should be below 26 $mg/m^3$ and/or the in-stream concentrations of soluble inorganic nitrogen (SIN) should be below 295 $mg/m^3$ - assuming a 20 day accrual period (Biggs 2000). On this basis the proposed WQ standard for DRP is tight and the proposed WQ standard for SIN is relaxed.

The following general method was used in Ausseil and Clark (2007a) to derive the nutrient guidelines. For each water management sub-zone, the Mean Days of Accrual (MDA) of periphyton was calculated and fed into the model in the NZ periphyton guidelines along with the applicable periphyton biomass standard. In the Mana_11a sub-zone the nitrogen guideline was relaxed on the basis of phosphorus being limiting and the SIN concentration being much higher than the guideline value. Nutrient controls were applied year round (including winter) on the basis that blooms can occur any time of year and that periphyton growth and vigour is influence by antecedent water quality. On this basis only flood conditions are excluded from the nutrient standards.

While the general approach taken appears sound there are some issues worth consideration, these are discussed below.

**Flow related nutrient standards**

Three times the median flow is a commonly used rule of thumb to indicate flood events, however the actual flow sufficient to turn over stones and 'reset' the periphyton levels will vary in different rivers. Some hydrological modelling would be needed to determine precisely what flows are needed to turnover gravels /sloth periphyton in the Manawatu River.

It might be reasonable to advocate for more relaxed nutrient standards down to flows sufficient to exert a sheer force to sloth periphyton. Three times median flow is approximately the flow needed to turn over river gravels – effectively 'clearing' the stream bed of periphyton. However at flows less than three times median flow the water velocity can still be sufficient to exert sufficient shear stress[4] to sloth off the periphyton and keep biomass levels below guideline values (i.e. <2 cm long and < 120 $mg/m^2$). Filamentous green algae communities typical of the Manawatu River (e.g. *Cladophora* sp and *Stigeoclonium* sp) the highest biomass is typically found at low velocities and any increase in velocity tends to result in a major reduction in biomass (Biggs 2000). Hydrological modelling could be done to indicate what flows would exert sufficient sheer force to control periphyton biomass and the extent of the riverbed with these forces (i.e. the amount of slack water where periphyton could still proliferate).

While flows less than three times median flow will control local periphyton biomass, consideration also needs to be given to the effect of relaxed nutrient standards further downstream and the more rapid growth of periphyton due to potential luxury uptake of

[4] Shear stress is the force that flowing water exerts on the river bed. The shear stress can be calculated by the following formula. Shear stress = p g d S. Where p=density of water (1000 $kg/m^3$), g=gravity (9.8 $m/s^2$),

nutrients during periods of higher flow. In summary, it may be worth refining the definition of a ‘flood flow’ but I would not strongly advocate for flow based nutrient standards[5].

**Seasonal nutrient standards**

In my opinion it would be reasonable to advocate for more relaxed nutrient standards during winter if:

1) There is evidence of periphyton being controlled during winter conditions and

2) Luxury uptake of nutrients by periphyton is not occurring, or only stimulates growth for a short period of time (days) after uptake.

3) Nutrient recycling from river sediments in not a major component of the total nutrient load in areas where nutrient control algae growth.

There is evidence that luxury consumption of nutrients by periphyton can occur in cyanobacteria and filamentous green algae (stored as polyphosphate). The period of time over which any stored nutrients are able to be used is likely to be in the order of days to weeks, so it is reasonable to not allow high nutrient inputs during moderate flows, but it may be reasonable to allow higher nutrient inputs during winter when growth can be slower and flushing flows occur more frequently.

In some rivers high levels of periphyton biomass can occur in winter, however I’m not aware of any report of this occurring in the Manawatu River. Unfortunately Horizons MW has no monthly monitoring results of periphyton cover or biomass in the Manawatu River to confirm whether periphyton biomass can be problematic during winter. In the absence of periphyton monitoring records, further analysis would be needed of the hydrological records to confirm whether a season nutrient standard could be justified.

Henderson and Diettrich (2007) analysed the river flow in the Horizons Region. Flow statistics like FRE3 were calculated for the annual period and for the summer period, unfortunately it is not possible to compare the two periods because they were based on medians for their respective periods (i.e. the statistic of three times the median flow was much smaller in the summer period). By comparing the annual value of three time the median flow (i.e. 220 $m^3/s$ in Manawatu River at PN) with the flow variability percentiles in Table 4.2.13 it is clear that there is likely to be considerable difference in the FRE3 between summer and winter.

I would recommend reviewing whether the 24-hour FRE3 is appropriate to use for the flow needed to adequately sloth periphyton. I’d also recommend recalculating the nutrient standards for summer and winter independently based on mean days of accrual for each season.

d=water depth (m), S=river bed slope. See Biggs and Thomsen (1995) for further information on effects of shear force on periphyton communities.

[5] I understand the Horizons Regional Council is currently doing some additional work to try and refine the definition of flood flows to some flow less then three times the median flow.

**Nitrogen**

The Manawatu River upstream of the WWTP appears to be phosphorus limited, however estuaries and coastal areas are more commonly nitrogen limited and in general it is reasonable to put limits on nitrogen to help avoid potential eutrophication in these areas. There is evidence that too much nitrogen limitation can favour nitrogen fixing cyanobacteria but this is unlikely to be an issue for the Manawatu catchment.

No periphyton nutrient bioassays have been done on the Manawatu river but monthly TN:TP ratio provide some indication of whether nutrients are limiting periphyton growth for the Manawatu River. SIN:DRP ratios for the Manawatu River at Hopeland's Reserve (224 samples by Horizons MW between 1989 and 2008) suggests nitrogen limitation in about 97% of samples (217 / 224). Closer to Palmerston North, data from 10 monthly grab samples (Sept 2006 to June 2007) indicates that DRP is a potentially limiting nutrient upstream of the PNCC WWTP, while the phosphorus load from the WWTP often diminished any phosphorus limitation in the river downstream of the WWTP.

The WQ standard for SIN in the proposed One Plan is based on the lowland river trigger value for nitrate in the ANZECC guidelines[6] (i.e. 444 g/m$^3$), so it is lower than the actual ANZECC trigger value for SIN (nitrate + total ammonia) of 465 g/m$^3$. I would recommend reviewing the SIN trigger value to 465 g/m$^3$. I would also recommend some analysis of how achievable the proposed standard is in pastoral catchments.

## 3.11 Additional Water Quality Standards for *E. coli*

For the management zone Lower Manawatu (Mana_11a) Table D.16 states:

*"The concentration of Escherichia coli when the river or stream is at or below median flow shall not exceed 260 per 100 millilitres. This standard applies during the period 1st November to 30th April inclusive, and*

*2. The concentration of Escherichia coli when the river or stream is at or below three times the median flow shall not exceed 550 per 100 millilitres. This standard applies year round.*

*3. The concentration of toxins due to cyanobacteria (blue-green algae) shall not exceed 20 milligrams per cubic metre. This standard applies year round."*

The wording of the proposed guidelines is more strict than that NZ microbiological water quality guidelines (MfE 2002). To be consistent with MfE (2002) all these guidelines should be applied as upper 95th percentile values.

I think it is reasonable to apply the different trigger levels in the guidelines over different months, with a stricter guideline in the summer months because of the greater likelihood of

[6] This trigger value is based on data from four lowland river baseline sites monitored by NIWA.

swimming in the summer. The amount of river use is likely to be much less affected by river flow. With the exception of floods, there is a poor correlation between the volume of river discharge and *Escherichia coli* (*E. coli)* concentrations. Instead, *E. coli* concentrations tend to be higher on the rising flood, regardless of the absolute discharge volume. A similar pattern is observed for turbidity.

In my view there should be more geographic differentiation in how the guidelines are applied. It is a big challenge to achieve recreational bathing water guideline values in every river, stream and creek in the region. If this approach is taken I would recommend that the 550 *E. coli*/100 mL trigger value is applied regionally and the more strict 260 *E. coli*/100 mL trigger value applying only to specific bathing water sites. The microbial bathing water guidelines (MfE 2002) are based on an explicit choice of acceptable risk. The upper 95$^{th}$ percentile value of 260 *E. coli*/100 mL relates to an average probability of one case of *Campylobacter* infection in every 100 exposures, and the upper 95$^{th}$ percentile value of 550 *E. coli*/100 mL relates to an average probability of five cases of *Campylobacter* infection in every 100 exposures (see Table H2 of MfE 2002). In contrast the previous guidelines required a median *E. coli* concentration of 126 per 100 mL, which corresponded to a swimming-associated illness risk of 8 per 100 bathers.

# 4 Conclusions

There are some aspects of the proposed water quality standards in the proposed One Plan that need further justification. These include:

The proposed water quality standards in the proposed One Plan has been reviewed with respect to their suitability to the Lower Manawatu Mana_11a subzone. Some of the proposed water quality standards are conservative and adjusting the framework of policies and water management zones may allow the proposed water quality standards to be more precise. In particular a less precautionary approach to water quality standards would be possible if there was a policy to prevent further deterioration of water bodies, there was more differentiation of habitats within a sub-zone, and if some values (e.g. contact recreation) were applied more precisely.

Recommendations are made to change some of the proposed water quality standards for the Mana_11a sub-zone as follows:

- Most of the water quality standards would be more appropriate to expressed as percentile values (e.g. 90$^{th}$ percentile) instead of maximum values implied by the expression “shall not exceed”.

- The proposed water quality standard for pH would be more appropriate to express as 10$^{th}$ and 90$^{th}$ percentile values. Furthermore, ensuring that diurnal fluctuations of pH are in the reference dataset may allow a less conservative standard.

- The proposed water quality standard for temperature and dissolved oxygen was considered reasonable.
- The proposed water quality standard for $BOD_5$ would be more appropriate to express a mean of $cBOD_5$.
- Setting a water quality standard for QMCI is not recommended given the structure of the proposed One Plan. Some issues could be addressed by differentiating sites using the REC, using alternative indices such as O/E values and expressing scores as a median values or in terms of a percentage change.
- The proposed water quality standard for POM is not appropriate in its current form. If there is a POM standard it should be applied as a change value specific to discharges, and based on mean or median values.
- The proposed water quality standard for total ammonia is overly conservative. In my view the standard should be applied to average values, be set as the table of pH values in Table 8.3.7 of ANZECC (2000) rather than on a single pH value, and only be set to protect the freshwater clam *Sphaerium novaeselandiae* in areas where this species is considered an important component of the aquatic ecosystem. Data from Horizons SOE reports suggests that *Sphaerium* spp. is rare in major rivers of the region.
- The proposed WQ standard for turbidity of 15 NTU when the river is below three times the median flow is a little conservative, and should at least be applied as a $90^{th}$ percentile value.
- The proposed water quality standard for periphyton is considered reasonable but should be specifically applied to filamentous algae.
- The proposed water quality standard for phosphorus was considered reasonable but there may be potential to relax the standards during winter without causing excessive periphyton growth. To justify seasonal standards further information is needed on the extent of periphyton cover and biomass during winter, and whether periphyton in the Manawatu River can practice luxury uptake of nutrients. Flow related standards might also be justified if luxury uptake does not occur for Manawatu periphyton, however flows suitable for relaxed nutrient standards could be quite high.
- The proposed water quality standard for nitrogen should be increased to at least be consistent with ANZECC guidelines.
- The proposed water quality standard for *E. coli* bacteria of 260/100mL would be better justified if it was not applied to less than median flows, but instead applied to actual locations where swimming is more common. The water quality standard for *E. coli* bacteria of 550/100mL is reasonable to apply more widely to water bodies and periods where the value of contact recreation is being protected.

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