**BEFORE THE ENVIRONMENT COURT**

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| *In the matter of* : | the Resource Management Act 1991 ("the Act") |
| *And in the matter of:* | the Proposed One Plan for the Manawatu-Wanganui Region |
| *Between:* | **MINISTER OF CONSERVATION**<br>**ENV-2010-WGL-000150**<br>**FEDERATED FARMERS OF NEW ZEALAND**<br>**ENV-2010-WLG-000148**<br>**ANDREW DAY**<br>**ENV-2010-WLG-000158**<br>**HORTICULTURE NEW ZEALAND**<br>**ENV-2010-WLG-000155**<br>**WELLINGTON FISH &GAME COUNCIL**<br>**ENV-2010-WLG-000157**<br>Appellants |
| *And:* | **MANAWATU-WANGANUI REGIONAL COUNCIL**<br>Respondent |

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# STATEMENT OF EVIDENCE OF OLIVIER MICHEL NICOLAS AUSSEIL ON BEHALF OF THE MINISTER OF CONSERVATION AND WELLINGTON FISH AND GAME COUNCIL

## WATER QUALITY

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## 1. INTRODUCTION

1.1 My full name is Dr Olivier Michel Nicolas Ausseil. I am Principal Scientist - Water Quality for Aquanet Consulting Limited.

1.2 I hold a PhD of Environmental Biosciences, Chemistry and Health from the University of Provence, France. I also hold a Master of Science Degree of Agronomical Engineering from the National Higher Agronomical School of Montpellier, France, and a DEA (equivalent Masters Degree) in Freshwater Environmental Sciences from the University of Montpellier II, France.

1.3 I am a certified Commissioner under the Ministry for the Environment “Making good decisions” programme. I was a Hearing Commissioner appointed by Horizons Regional Council to hear New Zealand Defence Force’s consent applications to discharge treated wastewater from the Waiouru wastewater treatment plant to the Waitangi Stream, in June 2011 and February 2012.

1.4 I have over 9 years experience in New Zealand as a scientist working in local government and as a private consultant working for Regional Councils and Local Authorities, central government and government agencies, and the private sector.

1.5 Prior to forming Aquanet Consulting Ltd, I was employed by the Regional Planning Group of Horizons Regional Council (Horizons) from July 2002 to June 2007, where I held the positions of Project Scientist, Environmental Scientist-Water Quality and Senior Scientist - Water Quality.

1.6 My responsibilities at Horizons included leading the water quality and aquatic biodiversity monitoring and research programme and providing technical support to policy development. I was the primary author of three technical reports underpinning the waterbody values framework and water quality standards in the notified version of the Proposed One Plan (Ausseil and Clark, 2007a, 2007b and 2007c). I was also heavily involved in the development of the Water Management Zones and Sub-Zones framework as included in the notified version of the Proposed One Plan.

**1.7** Since July 2007, I have been Principal Scientist at Aquanet Consulting Limited. In this position, I have been engaged by 10 different Regional, District or City Councils, the Ministry for the Environment, the Department of Conservation, Fish and Game New Zealand and Silver Fern Farms Limited to provide a variety of technical and scientific services in relation to water quality and aquatic ecology.

**1.8** I have worked as a technical advisor on behalf of the consenting authority, the applicant and/or submitters on well over 100 resource consent applications, compliance assessments and/or prosecution cases for discharges to land and/or water. In July 2010, I ran a training workshop for Horizons staff on the technical assessment of resource consent applications for discharges to water.

**1.9** I am in the final stages of completing a series of technical reports for Greater Wellington Regional Council recommending water quality and ecological limits for the protection of a range of river values throughout the Wellington Region in relation to a range of ecological (Aquatic Ecosystems), recreational (contact recreation, trout fishery and trout spawning) and water usage (livestock drinking water) management purposes. The series of reports include a report specifically detailing recommended in-stream nutrient limits in relation to the above stream and river management purposes. I was part of an expert panel providing recommendations to Greater Wellington Regional Council in relation to toxicant limits within aquatic ecosystems (Pawson and Milne, 2011). I was also a peer-reviewer of Environment Canterbury’s technical report providing recommendations on water quality objectives and standards for the Council’s Natural Resources Regional Plan (Hayward *et al.*, 2009).

**1.10** I have produced a number of catchment or region-wide water quality reports focussing largely on in-stream nutrient concentrations, in-stream nutrient loads and catchment nutrient yields, and their effects on periphyton growth for Hawke’s Bay Regional Council (Ausseil, 2008, 2009a and 2009b), Environment Canterbury (Ausseil, 2010) and Greater Wellington Regional Council (Ausseil 2011).

**1.11** I was engaged by Environment Southland as mentor and peer-reviewer for their 2010 State of the Environment report (Environment Southland and Te Ao Marama Inc., 2011); and wrote the section of this report relating to nutrient limitation. I also peer-reviewed a number of regional State of the Environment reports for Environment Canterbury (2010), Environment Southland (2010), West Coast Regional Council (2008), and Hawke's Bay Regional Council (Haidekker 2009 a and b, Stansfield 2009 a and b), as well as the 2009 report on Clean Streams Accord water quality monitoring on behalf of the Ministry for the Environment (MfE, 2009).

**1.12** I was the national "champion" on behalf of a group of Regional Councils to coordinate the FRST-funded development of the recent national protocols and guidelines for assessing the effects of deposited fine sediment on in-stream values (Clapcott et al., 2011).

**1.13** I am currently the Science Leader on behalf of Hawke's Bay Regional Council for the Ruataniwha Water Storage Project, a large water storage and land irrigation project. My responsibilities within this project involve coordinating the water quality and aquatic ecology studies undertaken as part of the feasibility study. These studies involve, in particular, extensive land use, water quality and aquatic ecology modelling aiming at assessing the potential effects of land use intensification associated with the Scheme.

**1.14** I am authorised to present evidence on behalf of the Wellington Fish and Game Council and the Minister of Conservation in relation to the components of their appeals relating to water quality and aquatic biodiversity.

**1.15** I have read and am familiar with the Code of Conduct for Expert Witnesses in the Environment Court Consolidated Practice Note, 2011. I agree to comply with that Code. Other than where I state that I am relying on the evidence of another person, my evidence is within my area of expertise. I have not omitted to consider material facts known to me that might alter or detract from the opinions that I express.

**1.16** I am familiar with the information contained in the technical evidence bundle pertaining to the issue of water quality and non-point source discharges and with the joint technical expert statement, and supplementary statement, of Dr Roygard, Ms McArthur and Ms Clark (hereafter referred to as Dr Roygard *et al*, 2012 and Dr Roygard & Ms Clark, 2012).

## 2. SCOPE OF EVIDENCE

**2.1** I have been asked to present evidence on behalf of the Wellington Fish and Game Council and the Minister of Conservation. Both appellants sought the re-inclusion of a number of water management zones back into the Proposed One Plan (POP) Table 13-1. In my evidence, I particularly discuss the Coastal Rangitikei water management zone (Rang_4). Both appellants sought the reinstatement of nitrogen leaching limits from existing dairying, cropping and intensive sheep and beef activities. I was asked to examine the predicted water quality outcomes arising from a number of options for the management of non-point source discharges of nutrients.

**2.2** In my evidence I will discuss:

(a) The development of waterbody values and water quality standards in the POP;

(b) The effects of nutrients on in-stream ecological and recreational values;

(c) Methodologies used for the estimation of in-stream nutrient loads, and a comparison with the results of the method used by Dr Roygard *et al* (2012) in parts of the Manawatu and Rangitikei catchments;

(d) The state of water quality in the Manawatu-Wanganui Region;

(e) The state of water quality in the Rangitikei catchment, with a particular focus on the Coastal Rangitikei Water Management Zone (WMZ);

(f) The predicted water quality outcomes arising from a number of options for the management of non-point source discharges of nutrients in some of the Manawatu catchment WMZs and in the Coastal Rangitikei WMZ (Rang_4).

**2.3** The main reason for presenting a detailed analysis of water quality state for the Rangitikei catchment is to provide an update based on the latest monitoring data. State of the environment monitoring at the Rangitikei at McKelvies monitoring site located at the downstream end of the Coastal Rangitikei WMZ, started in July 2006. The analysis presented at the Council hearing (e.g. Ms McArthur's S42A report) therefore relied on only 3 years of data or less. The analysis presented in this evidence relies on five full years of water quality data.

**2.4** There were two main reasons for undertaking the water quality modelling in relation to paragraph 2.2(f) above:

(a) The first reason was to run similar scenarios to some of those presented by Dr Roygard and Ms Clark (2012), but using an independently developed modelling approach to independently assess the validity of Dr Roygard and Ms Clark (2012);

(b) The second reason was to explore the water quality outcomes of additional land use scenarios. These additional scenarios were developed on the basis of Dr Alison Dewes's evidence, and involve a combination of different projected dairy expansion rates, the intensification of non-dairy land to support dairy expansion, and different management regimes. These scenarios are set out in detail in Section 8 of my evidence. The definition of plausible future land use scenarios and the assumptions underpinning them is outside my area of expertise and was based on the evidence and advice of Dr Dewes. My evidence relates to the interpretation of the water quality outcomes of the scenario modelling.

## 3. The development of river values and water quality standards in the POP

**3.1** As indicated in Section 1 of this report, I was the primary author of three reports that underpin the definition of the river values and water quality standards incorporated in the notified version of the Proposed One Plan. I thus consider myself well positioned to comment on methodologies and principles used in their determination.

**3.2** I have reviewed the S42A report of Ms McArthur and consider that it provides a good summary of the values framework and how the water quality standards were derived.

**3.3** I will however, emphasise a number of essential points relating to how the values were derived, how water quality standards were derived to achieve each of those values and then how the water quality standards were derived for each individual water management zone.

*Overall framework: from values to standards*

**3.4** The One Plan catchment management framework is composed of 19[1] river values in four groups (Ecosystem, Recreational/Cultural, Consumptive Use and Social/economical), superimposed over a spatial framework consisting of 44 water management zones (WMZ) and 117 water management sub-zones (WMsZ).

**3.5** The framework of zones and sub-zones basically corresponds to surface catchments and sub-catchments. Their boundaries were determined following a pragmatic evaluation of available information to delineate sensible management units. For example, boundaries were designed to make use of monitoring sites, natural boundaries (e.g. above/below gorge in the Manawatu catchment) and to recognise where major activities such as water abstractions and point source discharges took place. The WMZ and WMsZ were developed to serve as the spatial framework for both water quality and water quantity management (thus also including land management). In effect, they are the spatial basis for integrated catchment management. McArthur *et al.* (2007) is the key technical report on the development of the WMZ and WMsZ framework.

**3.6** Waterbody values (the Schedule AB values) were determined through a two-step process:

(a) First, a comprehensive set of values was drawn up using the Third Schedule of the Resource Management Act 1991 as a starting point; and

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[1] 19 in the 2010 decision, and 23 originally. Some were removed following staff recommendations (e.g. drainage), some were removed by panel decision (e.g. amenity).

(b) Second, the values were assigned to each WMZ, WMsZ, or specific river reaches on the basis of policy direction, consultation with key stakeholders and technical information. Some values were assigned to all waterways (e.g. life-supporting capacity, contact recreation, stock drinking water), and some only to some WMZ/WMsZ or specified reaches of streams.

**3.7** Once values had been assigned to water management zones, water quality standards were determined for those values that had the potential to be affected by water quality or where maintenance of that particular value required water quality standards to be set.

**3.8** It was considered that most values within the “Ecosystem”, “Recreational/Cultural” and “Consumptive use” value groups could be affected by poor water quality, and thus required water quality standards. However, some of the values were considered to be able to be covered by water quality standards developed for other values (refer to Table 1).

**3.9** It is important to note that ‘value’ does not equate with activity. For example, applying the Irrigation value to a waterbody recognises that some of the water may be used for irrigation, and thus should be of a certain quality to be able to be used for that purpose. It does not relate to the activity of taking that water (i.e. recognising the irrigation value does not presume that any of the water should, must or will be made available for this use).

**3.10** Furthermore, it is important to realise that the values were not ranked or prioritised. Rather, the intent of the values framework was to provide a comprehensive set of values within a common framework.

**3.11** Finally, a set of water quality standards (mostly numerical, but some narrative) was determined for each water management zone taking into account all the different values in each management zone. The general guiding principle used was that the water quality standard would represent the point beyond which some of the values would be compromised. The idea was to pitch the water quality standards at a “good” state of the water quality in relation to the waterbody values, not at a “pristine” or a “passable” level.

**Table 1: Summary of waterbody values as defined in Ausseil and Ms Clark (2007b), and definition of water quality standards in relation to the different values as in Ausseil and Ms Clark (2007c)**

| Values | | | Potentially affected by water quality? | Specific water quality standards defined? |
|---|---|---|---|---|
| Group | Short name | Full name | | |
| Ecosystem values | NS | Natural state | Yes | Yes (narrative) |
| | LSC | Life-Supporting capacity | Yes | Yes, based on 8 LSC classes |
| | SoS-A | Sites of Significance - Aquatic | Yes | No (covered by LSC) |
| | SoS-R | Sites of Significance - Riparian | Yes | No (covered by LSC) |
| | NFS | Native fish spawning | Yes | No (covered by LSC) |
| Recreational /cultural | CR | Contact Recreation | Yes | Yes |
| | Am | Amenity | Yes | No (covered by CR) |
| | NF | Native Fishery | Yes | No (covered by LSC) |
| | M | Mauri | Yes | Considered covered by LSC and CR standards |
| | SoS-C | Sites of Significance - Cultural | Yes | Considered covered by LSC and CR standards |
| | SG | Shellfish Gathering | Yes | Yes |
| | TF | Trout fishery | Yes | Yes (based on 3 classes of trout fisheries) |
| | TS | Trout spawning | Yes | Yes |
| | Ae | Aesthetics | Yes | No (covered by CR) |
| Consumptive use | WS | Water Supply | Yes | Covered by NES |
| | IA | Industrial abstraction | Yes | Covered by LSC and CR standards. Can also be covered on a case-by-case basis |
| | I | Irrigation | Yes | Covered by LSC and CR standards. Can also be covered on a case-by-case basis |
| | SW | Stockwater | Yes | Yes |
| Social economic values | CAP | Capacity to assimilate Pollution | Yes [a] | No – CAP directly defined by final set of standards in each zone |
| | FC | Flood control | No | No |
| | D | Drainage | No | No |
| | EI | Existing Infrastructure | No | No |
| | GE | Gravel Extraction | No | No |

[a] poor water quality means less or no CAP available

**3.12** Where two different standards were recommended in relation to two different values (e.g. water clarity of 1.6m in relation to the contact recreation value, and 2.5 m in relation to the trout fishery value), the most stringent (in this case 2.5m) was retained to ensure protection of all values applying to the said zone.

**3.13** The resulting set of standards for each water management zone is now referred to as Schedule D. The basis for each zone-specific set of standards was to ensure the maintenance of all values determined for each zone.

*How the in-stream nutrient water quality standards (DRP, SIN) were defined*

**3.14** Four main sources of information were used in the process of determining the nutrient water quality standards (soluble inorganic nitrogen or SIN and dissolved reactive phosphorus or DRP):

(a) New Zealand Periphyton Guidelines (NZPG) model (Biggs, 2000). The model was applied to all sites in the region where sufficient data were available. Dr Barry Biggs provided key recommendations for the appropriate use of the (NZPG) model;

(b) Expert opinion: Dr Barry Biggs provided recommendations in relation to each periphyton biomass objective for different classes of rivers. His recommendations were:

- 0.005 to 0.006 mg/L (DRP) and 0.055 to 0.070 mg/L (SIN) in upland rivers and streams where the recommended periphyton biomass standard was 50 mg/m$^2$;
- 0.010 mg/L (DRP) and 0.110 mg/L (SIN) where the periphyton biomass standard was 120 mg/m$^2$ (most hard-bottomed hill country and large rivers and trout fisheries); and
- 0.015 mg/L (DRP) and 0.165 mg/L (SIN) where the recommended periphyton biomass standard was 200mg/m$^2$ (lowland and soft-bottomed rivers).

(c) ANZECC (2000) Guidelines: 0.009 mg/L (DRP) and 0.167 mg/L (SIN) for upland streams, and 0.010 mg/L (DRP) and 0.444 mg/L (SIN) for upland/lowland areas;

(d) Monitoring data: Where available, monitoring data were primarily used to compare the recommended standards with the current state.

**3.15** The NZPG model was found to provide stringent nutrient concentration outputs, sometimes unrealistically low (i.e. lower than natural levels). On the basis of advice from Dr Biggs, it was also clear that the model is not adapted to some river types in the region, such as the central Plateau streams. Therefore, in the end, the NZPG model did not have a major bearing on the actual numbers recommended, but instead greater reliance was placed on the expert opinion obtained from Dr Biggs as summarised in point 3.14(b) above.

**3.16** Where monitoring data indicated that water quality was significantly worse than the standard and there was a clear indication of one nutrient being limiting (e.g. DRP), then the standard relating to the other nutrient (e.g. SIN) was significantly relaxed.

**3.17** This departure from Dr Biggs' recommended standards resulted in less stringent SIN (but not DRP) standards in a significant number of WMZ. In particular, 37 of the 49 Water Management Sub-Zones (75%) in the Manawatu catchment were allocated a far more pragmatic water quality standard in relation to SIN than his recommendations would have required.

*Water quality standards*

**3.18** With specific reference to water quality standards, I note that the final report making recommendations relating to water quality standards was published in July 2007, several months after the Proposed One Plan notification, and there are some discrepancies between the water quality standards in the notified version of the Proposed One Plan and the final recommendations in Ausseil and Clark (2007c). For example, the Proposed One Plan notified version included water quality standards relating to water turbidity, whilst Ausseil and Clark (2007c) recommended the use of visual clarity rather than turbidity.

**3.19** Several technical experts have presented evidence on behalf of Horizons Regional Council in relation to water quality standards recommended for rivers and streams (Drs Quinn, Davies Colley, and Wilcock), including some recommended changes (compared with the POP notified version) to the wording and sometimes numerical values of a number of water quality standards. I have reviewed the Section 42A Reports of Drs Quinn, Davies-Colley and Wilcock and fully support their recommendations relating to changes to the water quality standards contained in the POP notified version.

**3.20** Excessive deposited fine sediment can have a major effect on a number of river values, including life-supporting capacity, trout fishery and contact recreation/amenity. This was recognised during the development of the recommended water quality standards for the POP notified version. However it was also recognised at that stage that monitoring methodologies and environmental guidelines were not developed enough to recommend robust deposited sediment standards. A FRST-funded project prompted a major nation-wide monitoring and research effort over the last three years, which resulted in the production of national protocols and guidelines for assessing the effects of fine deposited sediments (Clapcott *et al.*, 2011).

**3.21** It is my opinion that numerical standards/targets for deposited sediment based on the above national guidelines are now able to be developed for the protection of the Schedule AB values. It is also my opinion that, given the scale of sediment and erosion-associated issues in the Manawatu-Wanganui Region (as summarised, for example in Ms McArthur's S42A report and Dr Death's statement of evidence), deposited sediment standards/targets should be included in Schedule D.

**3.22** In his statement of evidence, my colleague Dr Death provides information in relation to the effects of deposited sediments and recommends numerical standards/targets for inclusion in Schedule AB. I have discussed Dr Death's evidence with him, and fully support his recommendations.

**3.23** **Summary of Section 3:**

(a) The values identified in Schedule AB were established through consultation and by using existing monitoring information;

(b) Water quality standards were set for those values potentially affected by water quality;

(c) Where two different values applied to a water management zone, the water standard attributed to that zone was the most conservative one required in order to safeguard both values;

(d) Water quality standards were designed to achieve a 'good' standard of water quality, not a pristine state; and

(e) Schedule D requires the inclusion of a deposited sediment standard and I concur with the standard proposed in Dr Death's evidence

## 4. Effects of nutrients on ecological and recreational values

4.1 The effects of nutrients on stream and river ecological and recreational values have been extensively described in existing literature (e.g. Biggs, 2000; Biggs and Kilroy, 2004) and in Dr Bigg's Section 42A report (paragraph 21) and Dr Death's evidence. I agree with description of the nature and possible scale of effects described by Dr Biggs and Dr Death, and will not repeat it in my evidence. I will however provide some additional comments on:

(a) Nutrient limitation and implications for nutrient management of rivers; and

(b) Nitrate toxicity.

*<u>Nutrient limitation</u>*

4.2 Periphyton growth is generally controlled by a number of physical (e.g. substrate, river flow, sunlight, temperature) chemical (e.g. bioavailable nutrients) and biological (e.g. grazing by invertebrates) phenomena (Biggs, 2000).

4.3 The forms of nitrogen that plants can assimilate directly (i.e. bioavailable) include oxides of nitrogen (nitrate- and nitrite- nitrogen) and total ammonia nitrogen, the sum of which is called Soluble Inorganic Nitrogen (SIN). Dissolved Reactive Phosphorus (DRP) is generally considered as the measurement of bioavailable phosphorus.

4.4 Both nitrogen and phosphorus are needed for periphyton growth in an average weight ratio of 7.5:1, as defined in the Redfield equations (Stumm and Morgan, 1996 in Wilcock *et al.*, 2007). A ratio of approximately 7.5 is the theoretical limit between N-limited (ratio<7.5) and P-limited (ratio >7.5) conditions.

4.5 The SIN:DRP ratio can be a useful indicator of which, of SIN or DRP, is the likely limiting nutrient for periphyton growth. Generally, elevated SIN:DRP ratios are indicative of P-limited conditions, and low ratios indicative of N-limited conditions. Ratios close to the Redfield ratio are generally inconclusive or may indicate that the nutrient limitation may "switch" between the two nutrients at different times of the year or at different flows. It is important to note that nutrient limitation may only occur when other factors controlling periphyton growth, such as sunlight, hydrological regime and biological activity are favourable <u>and</u> nutrient concentrations (at least one of SIN or DRP) are sufficiently low to limit periphyton growth. When both nutrients are in sufficient supply, nutrient concentration is unlikely to limit algal growth.

**4.6** As indicated in Section 1 of this evidence, I have written, reviewed, or contributed to, catchment- or region-wide water quality reports in 6 regions in New Zealand. One general conclusion that I have drawn from this work is that the nutrient limitation status of a given river should not be seen as fixed in time and space. On the contrary, most river systems display considerable temporal and spatial variation in their nutrient limitation status. For example some rivers are dominated by N-limitation in their upper reaches, and switch to predominantly P-limited conditions further downstream. At a given point or monitoring site, the nutrient limitation status, as indicated by SIN:DRP ratios, also often display significant temporal variations associated with season or river flow conditions.

**4.7** Based on this experience, I consider that the use of an aggregated single SIN:DRP ratio per site or per river (for example the use of annual average SIN:DRP ratios) is generally insufficient as it does not account for seasonal or river flow-related variations in nutrient limiting conditions. The use of one annual average SIN:DRP ratio to draw conclusions on the nutrient limitation status of a river is, in my opinion fraught with risk, in particular that of drawing erroneous conclusions with significant resource management implications.

**4.8** The Manawatu catchment is a prime example of this. A simple examination of annual average SIN:DRP ratios would indicate that most of the Manawatu catchment would likely be P-limited. The phosphorus-limited status of the Manawatu River (and of many rivers in New Zealand) appeared to be the generally accepted view in the 1990s when the Manawatu Catchment Water Quality Regional Plan water quality standards (which include a standard relating to DRP, but none relating to SIN) were developed. Recent work by Horizons (McArthur *et al.* 2010) has highlighted that nutrient limitation in the upper Manawatu catchment varied with time, flow, season and location and that large parts of the Upper Manawatu catchment appear to be dominated by co-limited or N-limited conditions, at least during periods of low river flows. I have carefully reviewed this work and am satisfied that the approach and conclusions are sound. The approach taken by McArthur *et al.* (2010) is actually very similar to one I independently developed and applied to catchments in the Hawke's Bay (Ausseil, 2008, 2009 a and 2009b), Canterbury (Ausseil 2010) and Wellington regions (Ausseil 2011). The "shift" from P-limited conditions to co-limited or N-limited conditions during periods of low river flows, as described in the Manawatu catchment by McArthur *et al.* (2010) appears to be a relatively common pattern, described for example in the neighbouring Ruamahanga catchment (Ausseil, 2011).

**4.9** The recommendation of an independent panel of leading experts to Horizons and Hawke's Bay Regional Council was that management of both N and P should generally be contemplated to limit periphyton growth in rivers. Even where there is a key indication of a single, limiting nutrient (e.g. P), the expert panel suggested that it would not be sensible to focus on managing that nutrient and neglect controls on the other macronutrient (e.g. N) (Wilcock *et al.*, 2007). In my opinion, the "key indication" of limitation should be determined following detailed analysis of the nutrient limitation status of a river or catchment under different season and river flow conditions; the use of a single annual average SIN:DRP ratio being, in my opinion, inadequate.

### *Nitrate toxicity*

**4.10** Similarly to ammoniacal–nitrogen, nitrate-nitrogen can be toxic to aquatic species above certain concentrations. Whilst the potential toxic effects of ammoniacal-nitrogen have been discussed in detail in the council hearing evidence of several technical witnesses (e.g. Dr Wilcock's S42A report), the toxicity of nitrate-nitrogen has not, to my knowledge, been discussed or addressed specifically. This may be due to the timing of the release of a recent report (Hickey & Martin, 2009) in relation to the POP hearings.

**4.11** Hickey & Martin (2009) undertook a review of nitrate toxicity to freshwater aquatic species to support the development of numerical water quality objectives in the Canterbury Region. To my knowledge, none of the data, information or methodologies used in the report to derive "trigger values" were specific to the Canterbury Region. The findings and conclusions of the report are therefore, in my opinion, transferable to the Manawatu-Wanganui Region.

**4.12** Hickey and Martin (2009) used the toxicity dataset compiled through their review of available scientific literature to derive “trigger” nitrate-N concentration values, for different levels of protection of aquatic communities: protection of 80%, 90%, 95% and 99% of species. The trigger values were derived using the same methodology as the ANZECC (2000) guidelines. They are expressed both as acute (i.e. short-term exposure – typically less than 4 days) and chronic (long-term exposure, typically weeks) toxicity trigger values. The recommended acute trigger value is 20 mg $NO_3$-N/L. The chronic trigger values, which indicate that prolonged exposure may affect the behaviour, growth, reproduction or survival of species, are 1.0 mg/L, 1.7 mg/L, 2.4 mg/L and 3.6 mg/L for the 99%, 95%, 90% and 80% ecosystem protection levels, respectively.

**4.13** Both the notified and the 2010 decision versions of the Proposed One Plan set protection levels in relation to the concentration of toxicants in the water for the different management sub-zones, at either 95% or 99% species protection level. In my evidence I will provide an analysis of existing water quality in the Coastal Rangitikei WMZ in relation to the above trigger values.

## 5. In-stream nutrient load calculation methods

**5.1** The estimation of in-stream nutrient loads is central to the issue of managing non-point source discharges, and I believe it is useful to reiterate some of its basic principles.

**5.2** One of the key principles is that only continuous river flow and continuous contaminant concentration measurements would enable an actual measurement of contaminant loads (Richards, 1998). Whilst continuous river flow records are routinely maintained, in-stream nutrient concentration data are usually based on grab or composite water quality samples. One is thus reduced to estimating (not measuring) actual nutrient loads. A number of methods have been developed, including the “averaging method”, the “regression approach” and the “Beale Ratio estimator”, as described in (Richards, 1998).

**5.3** The averaging and the Beale Ratio estimator methods are reasonably simple and robust methods, and have been used in the Horizons (Ledein *et al.*, 2007), Hawke’s Bay (e.g. Ausseil, 2008; Haidekker, 2009a; Stansfield, 2009a) and Canterbury

Regions (Norton and Kelly, 2010; Ausseil, 2010). The Beale ratio estimator method presents the advantage of enabling the calculation of the Root Square Mean Error (RMSE), which provides an approximation of the standard error of the annual load estimate.

**5.4** Horizons have developed a different method to estimate nutrient loads, based on modelling of average loads within 10 river flow “bins”. Details of the method are described in Roygard *et al,* (in press). This method is useful in that it allows the estimation of loads at flows below the 20th exceedance percentile flow (i.e. when the nutrient concentration standards/targets apply) as well as annual nutrient loads at all river flows (which is similar to what other methods provide).

**5.5** I provide below my results of load estimations made using the “averaging” and Beale ratio estimator methods for a number of water management zones and sub-zones for which Dr Roygard and Ms Clark (2012) have provided nutrient load estimates calculated using the Roygard *et al.* (in press) method.

**5.6** The primary aim of this exercise is to enable a comparison and “peer-review” of the Dr Roygard and Ms Clark (2012) results against more widely used methods.

**5.7** Three key monitoring sites were selected in the Upper Manawatu catchment: the Manawatu at Hopelands, the Mangatainoka at Pahiatua and the Manawatu at Upper Gorge. The Manawatu at Palmerston North monitoring site was also selected to provide a comparison point downstream of the Upper Manawatu catchment. Annual SIN and DRP loads were also calculated at four key water quality monitoring sites on the Rangitikei River (from upstream to downstream) Pukeokahu, Mangaweka, Onepuhi and McKelvies.

**5.8** Results show general very good agreement between the three estimation methods, which provide results within 1% to 27% of each other, which can be considered to be within the error margins[2] (Table 2 and Table 3).

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[2] The average RMSE (Root Square Mean Error) for SIN load calculations (as % of the average estimated load) is 29% at Hopelands, 18% for the Mangatainoka at SH2, 21% at Upper Gorge.

5.9 Given these results, I am satisfied that the Roygard *et al.* (in press) method provides results that are consistent with two established methods of in-stream nutrient load estimation. For consistency and direct comparability of results I will make use of the in-stream nutrient load values reported in Dr Roygard and Ms Clark's (2012) supplementary statement in all subsequent analysis and modelling presented in this evidence.

**Table 2: Estimated annual SIN loads (Tonnes N/year) at selected water quality monitoring sites. N.= number of complete hydrological years during which annual loads were calculated. Horizons estimates from Dr Roygard and Ms Clark (2012).**

| Site | Estimated annual SIN load (T/yr) | | | Variation | Horizons estimates |
|---|---|---|---|---|---|
| | Method | Average | N. | | |
| Manawatu at Hopelands | Averaging method | 960 | 8 | 18% | 786.5 |
| | Beale Estimator | 957 | 8 | 18% | |
| Mangatainoka at SH2 | Averaging method | 740 | 9 | 27% | 542.3 |
| | Beale Estimator | 602 | 5 | 10% | |
| Manawatu at Upper Gorge | Averaging method | 2,148 | 5 | 6% | 2,281 |
| | Beale Estimator | 2,059 | 5 | 11% | |
| Manawatu at Palmerston North | Averaging method | 2,221 | 4 | N.A. | N.A. |
| | Beale Estimator | 2,056 | 4 | N.A. | |
| Rangitikei at Pukeokahu | Averaging method | 37 | 4 | N.A. | N.A. |
| | Beale Estimator | 37 | 4 | N.A. | |
| Rangitikei at Mangaweka | Averaging method | 263 | 5 | 4% | 251.7 |
| | Beale Estimator | 272 | 5 | 7% | |
| Rangitikei at Onepuhi | Averaging method | 401 | 4 | 14% | 343 |
| | Beale Estimator | 428 | 4 | 20% | |
| Rangitikei at McKelvies | Averaging method | 568 | 4 | 1% | 573.1 |
| | Beale Estimator | 581 | 4 | 1% | |

**Table 3: Estimated annual DRP loads (Tonnes N/year) at selected water quality monitoring sites. N.= number of complete hydrological years during which annual loads were calculated. Horizons estimates from Dr Roygard and Ms Clark (2012).**

| Site | Estimated annual DRP load (T/yr) | | | Variation | Horizons estimates |
|---|---|---|---|---|---|
| | Method | Average | N. | | |
| Manawatu at Hopelands | Averaging method | 28 | 8 | 17% | 23.1 |
| | Beale Estimator | 29 | 8 | 20% | |
| Mangatainoka at SH2 | Averaging method | 8.0 | 9 | 22% | 6.2 |
| | Beale Estimator | 6.4 | 5 | 3% | |
| Manawatu at Upper Gorge | Averaging method | 47 | 5 | 17% | 54.9 |
| | Beale Estimator | 53 | 5 | 3.5% | |
| Manawatu at Palmerston North | Averaging method | 54 | 4 | N.A. | N.A. |
| | Beale Estimator | 62 | 4 | N.A. | |
| Rangitikei at Pukeokahu | Averaging method | 5.1 | 4 | N.A. | N.A. |
| | Beale Estimator | 5.2 | 4 | N.A. | |
| Rangitikei at Mangaweka | Averaging method | 24 | 5 | 8% | 22.0 |
| | Beale Estimator | 26 | 5 | 15% | |
| Rangitikei at Onepuhi | Averaging method | 29 | 4 | 7% | 27.1 |
| | Beale Estimator | 35 | 4 | 23% | |
| Rangitikei at McKelvies | Averaging method | 41 | 4 | 2% | 41.7 |
| | Beale Estimator | 47 | 4 | 5% | |

## 6. State of water quality in target catchments

**6.1** I have reviewed the information presented by Ms McArthur in her council hearing S42A Report and by Dr Roygard, Ms McArthur and Ms Clark in their joint statement of evidence (Dr Roygard *et al.*, 2012) in relation to the state of water quality in target catchments for farm strategy management in the Manawatu-Wanganui Region. Unless specifically stated, I generally agree with their analysis and the conclusions they have reached and will not duplicate them in my evidence.

**6.2** In particular, I agree with the conclusions reached by Dr Roygard *et al.* (2012) with regards to the degraded state of water quality and aquatic communities in the upper Manawatu River at Hopelands and Weber Road, and the lower Mangatainoka River at SH2 (paragraphs 67 to 69 and 80 to 82 in Dr Roygard *et al.*, 2012). I have also reviewed, and am comfortable with their analysis of the state of water quality within the Waikawa catchment (paragraphs 102 to 104 in Dr Roygard *et al.*, 2012).

**6.3** With regards to the coastal Rangitikei WMZ, water quality monitoring at the Rangitikei at McKelvies started in July 2006, thus the analysis of water quality at this site presented in Ms McArthur's S42A report relied on less than three years of data. Dr Roygard *et al*. (2012) do not provide a detailed analysis of the state of water quality for the Rangitikei catchment (although they do provide a summary of recent periphyton and macroinvertebrate data, and have undertaken nutrient load analysis and scenario modelling in the Rangitikei catchment, as referred to in other parts of my evidence). I was asked to provide a detailed analysis of the state of water quality within the Coastal Rangitikei WMZ, which is provided in Section 7 below.

## 7. Coastal Rangitikei Water Management Zone

*Brief description of the Coastal Rangitikei WMZ*

**7.1** The Coastal Rangitikei Water Management Zone encompasses the Rangitikei River catchment from the Onepuhi Road monitoring site to the river mouth at Tangimoana. It comprises four Water Management sub-Zones (WMsZ). One Water Management sub-Zone comprises the reach of the Rangitikei River from Onepuhi downstream to the McKelvies monitoring site, which is located above the reach of the Rangitikei River that is influenced by tides. Two Water Management sub-Zones are made of the catchments of two tributaries flowing into the Rangitikei River between Onepuhi and McKelvies, the Porewa and the Tutaenui streams.

**7.2** The analysis presented in this evidence is generally only relevant to the non-tidal reaches of rivers and streams; for this reason the Rang_4b water management subzone (Tidal Rangitikei, i.e. reach of the Rangitikei located downstream of McKelvies) was removed from all analysis presented in this evidence. The analysis presented in this evidence thus refers to the parts of the Rangitikei catchment situated upstream of the Rangitikei at McKelvies monitoring site.

**7.3** The Rangitikei River within this Water Management Zone (WMZ) receives a number of relatively small tributaries, including (from upstream to downstream) the Porewa, Rangitawa, and Tutaenui Streams.

**7.4** These tributaries, and any other flow inputs within the zone make only a small contribution to the overall Rangitikei River flow: the mean flow in the Rangitikei River increases only by 7% between Onepuhi (66.3 $m^3/s$) and McKelvies (70.9 $m^3/s$).

**Table 4: Summary of flow statistics used in this evidence (Based on July 1993 to July 2010 data, provided by Horizons regional Council). All flows in $m^3/s$.**

| Site | Mean flow | Median flow (50th exceedance %ile) | Half median flow | 20th exceedance %ile flow |
|---|---|---|---|---|
| Pukeokahu | 24.164 | 16.133 | 8.067 | 33.130 |
| Mangaweka | 63.384 | 22.522 | 11.261 | 68.687 |
| Onepuhi | 66.292 | 45.553 | 22.777 | 92.522 |
| McKelvies | 70.924 | 48.064 | 24.032 | 100.158 |

**7.5** Land use in the Coastal Rangitikei Water Management Zone is heavily dominated by sheep and beef (69%), followed by dairying (19%) (Table 5).

**7.6** Most towns in the Coastal Rangitikei Water Management Zone discharge their treated municipal wastewater to water. Bulls treated wastewater is discharged directly to the Rangitikei River. Other towns discharge to tributaries of the Rangitikei River: Marton to the Tutaenui Stream, Hunterville to the Porewa Stream, Sanson to the Piakatutu Stream and Halcombe to the Rangitawa Stream.

**7.7** Other point-source discharges within the WMZ include the discharge of treated wastewater from the Riverlands meat processing plant at Bulls, and the discharge of treated sewage from the Ohakea Air Force base.

**Table 5: Land use capability by land use type in the Coastal Rangitikei WMZ (Rang_4) (not including Tidal Rangitikei). Data from Horizons Regional Council.**

| Land use | LUC | | | | | | | *Total* |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 6 | 7 | Blank | |
| Builtup/Parks/Others | 5.5 | 204.6 | 19.9 | 1.9 | 3.4 | 0.2 | 360.4 | *595.8* |
| Cropping | 193.6 | 913.6 | 114.9 | 33.8 | 58.3 | | 37.8 | *1,351.9* |
| Dairy | 532.7 | 7,691.5 | 1,781.1 | 721.9 | 762.1 | 69.0 | 46.1 | *11,604.5* |
| Exotic Cover | 69.5 | 528.8 | 269.6 | 159.8 | 1,061.7 | 1,016.8 | 401.5 | *3,507.6* |
| Horticulture-Other | 3.4 | 5.2 | | | | 0.3 | | *8.9* |
| Horticulture-Veg | | 2.1 | | | | | | *2.1* |
| Native Cover | 58.9 | 399.6 | 100.8 | 70.4 | 349.8 | 252.6 | 7.5 | *1,239.5* |
| Other | 0.9 | 99.4 | 32.2 | 13.6 | 79.6 | 6.1 | 14.1 | *245.8* |
| Sheep and/or Beef | 2,659.7 | 18,805.5 | 4,078.5 | 3,517.7 | 11,361.2 | 1,196.7 | 685.2 | *42,304.5* |
| Water Body | 0.0 | 43.3 | | 23.3 | 103.3 | 0.8 | 280.6 | *451.3* |
| *Total* | *3,524.0* | *28,693.6* | *6,397.0* | *4,542.3* | *13,779.4* | *2,542.4* | *1,833.2* | *61,311.9* |

### *Water quality state of the Rangitikei River mainstem (SoE data)*

**7.8** This section of my evidence presents an analysis of the state of water quality in the mainstem of the Rangitikei River, based on Horizons State of the Environment (SoE) water quality data for the July 2001 to June 2011 period at four sites (from upstream to downstream): Pukeokahu, Mangaweka, Onepuhi and McKelvies.

**7.9** The results of this analysis are summarised in Table 6 and Table 7. The state of water quality in tributaries of the Rangitikei River and the effects of point-source discharges on water quality are described later in this evidence. The overall compliance with Schedule D water quality targets (as in the POP Decision Version) is assessed following the methodology described in Ausseil and Clark (2007b).

**7.10** The Joint Statement from Horizons experts (Dr Roygard *et al.*, 2012) provides a summary of the state of periphyton and macroinvertebrate communities in the Rangitikei catchment based on the most recent state of the environment data. Dr Russell Death's statement of evidence also provides a description of the state of periphyton and macroinvertebrate communities in the Rangitikei catchment. I will refer to both statements of evidence.

**7.11** Compliance with the water <u>temperature</u> targets is good at Pukeokahu, but decreases further down in the catchment: 87% at Mangaweka, 82 % at Onepuhi and 75% at McKelvies, although the target at McKelvies (22°C) is less stringent than at Onepuhi (19°C). As can be expected, most of the exceedances are observed during summer under low flow conditions.

**7.12** <u>Dissolved oxygen saturation</u>: The One Plan (DV) targets are always complied with at all four SoE sites.

**7.13** <u>Total Ammonia-N toxicity</u>: The One Plan (DV) contains two targets relating to total ammonia-N: one relating to chronic toxicity (i.e. resulting from long-term exposure), the other to acute toxicity (i.e. resulting from short-term exposure). Both concentration targets are always complied with at all four SoE sites.

**7.14** <u>Nitrate toxicity</u>: The Hickey and Martin (2009) revised trigger values are always met at all four SoE sites.

**7.15** <u>Water clarity:</u> The One Plan (DV) targets are generally not met at all four monitoring sites. There is a gradual degradation in water clarity between Pukeokahu and McKelvies (Figure 1).

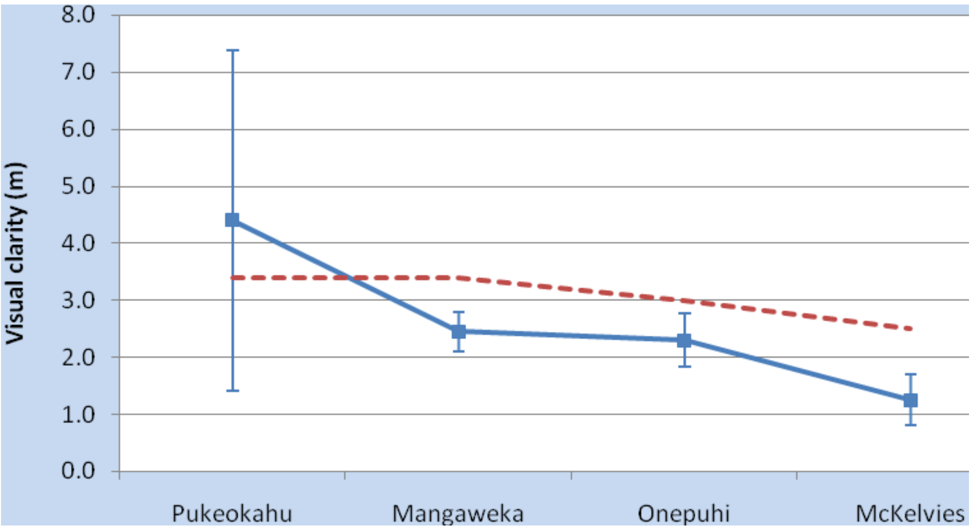

**Figure 1: Median visual clarity (m) at four rangitikei River monitoring sites (± 95% confidence interval).**

**7.16** SIN concentrations: The One Plan (DV) SIN concentration targets are met by a margin of more than 30% at Pukeokahu, Mangaweka and Onepuhi. The target concentration is only just met at McKelvies (annual average concentration at river flows below the 20th exceedance percentile of 0.106 g/m$^3$, against a target of 0.110 g/m$^3$).

**7.17** DRP concentrations: The One Plan (DV) DRP concentration target is just met at Pukeokahu. The DRP target at Pukeokahu (0.006 g/m$^3$) was purposely set at a stringent level in this WMZ to maintain periphyton biomass at low levels, in turn to protect high macroinvertebrate biodiversity values expected in this WMZ (Ausseil and Clark, 2007c). This concentration probably reflects near natural DRP concentration for the Upper Rangitikei River. The One Plan (DV) DRP concentration target is 0.010 g/m$^3$ for the remainder of the Rangitikei River downstream of Pukeokahu. This target is met at Mangaweka and Onepuhi (annual average concentration at river flows below the 20th exceedance percentile of 0.008 g/m$^3$ at both sites). The target is only just exceeded at McKelvies.

**7.18** The macroinvertebrate community index (MCI) target for the Coastal Rangitikei WMZ is a score of 100. When considering average MCI scores (from Table 4 in Dr Roygard *et al.*, 2012), the Coastal Rangitikei target is just met at Onepuhi (average score of 103) although the target that arguably applies at this site (120) is never met. Onepuhi is at the transition point between the WMZ immediately upstream and the Coastal Rangitikei. The average MCI score is just breached (average score of 97) at McKelvies.

**7.19** Based on Table 5 of Dr Roygard et al., 2012, periphyton biomass and cover targets were always met at Onepuhi. However, periphyton cover targets were exceeded on occasions at McKelvies.

**7.20** Dr Death’s evidence provides more detailed comments and interpretation of the macroinvertebrate and periphyton data.

**Table 6: Assessment of compliance with One Plan (DV) targets in the Rangitikei catchment. Overall assessment based on levels of compliance recommended by Ausseil and Ms Clark (2007).[(a)]: This site also serves as the downstream monitoring site for the Bulls STP discharge. Grey-shaded cells indicate where all flow data (instead of <median flow data) were used, where flow data were not available.**

| WMsZ | Site | Temperature (°C) | | | DO Saturation (%) | | | Ammonia (mg/L) | | | Nitrate toxicity (mg/L) | | | Clarity (m, <median flow) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Target | % Cpl | Overall | Target | % Cpl | Overall | Target | % Cpl | Overall | Target | % Cpl | Overall | Target | % Cpl | Overall |
| Rang_2a | Rangitikei at Pukeokahu | 19 | 95 | ✓ | 80 | 100 | ✓ | 0.32 | 100 | ✓ | 1.0 | 100 | ✓ | 3.4 | 59 | × |
| Rang_2b | Rangitikei at Mangaweka | 19 | 87 | ≈ | 80 | 100 | ✓ | 0.32 | 100 | ✓ | 1.0 | 100 | ✓ | 3.4 | 22 | × |
| Rang_3a | Rangitikei at Onepuhi | 19 | 82 | ≈ | 80 | 100 | ✓ | 0.40 | 100 | ✓ | 1.0 | 100 | ✓ | 3.0 | 32 | × |
| Rang_4a | Porewa U/S Hunterville STP | 22 | 95 | ✓ | 70 | 100 | ✓ | 0.40 | 100 | ✓ | 1.7 | 100 | ✓ | 1.6 | 43% | × |
| Rang_4a | Porewa D/S Hunterville STP | 22 | 92 | ≈ | 70 | 100 | ✓ | 0.40 | 92 | ≈ | 1.7 | 100 | ✓ | 1.6 | 26% | × |
| Rang_4a | Porewa Onepuhi Rd | 22 | 100 | ✓ | 70 | 100 | ✓ | 0.40 | 100 | ✓ | 1.7 | 97 | ✓ | 1.6 | 43% | × |
| Rang_4a | Rangitawa U/S Halcombe STP | 22 | 96 | ✓ | 70 | 62 | × | 0.40 | 100 | ✓ | 1.7 | 84 | × | 2.5 | 15% | × |
| Rang_4a | Rangitawa D/S Halcombe STP | 22 | 98 | ✓ | 70 | 75 | × | 0.40 | 70 | × | 1.7 | 84 | × | 2.5 | 15% | × |
| Rang_4a | Rangitikei U/S Bulls STP | 22 | 93 | ≈ | 70 | 100 | ✓ | 0.40 | 100 | ✓ | 1.7 | 100 | ✓ | 2.5 | 15% | × |
| Rang_4a | Rangitikei U/S Riverlands[(a)] | 22 | 94 | ≈ | 70 | 100 | ✓ | 0.40 | 100 | ✓ | 1.7 | 100 | ✓ | 2.5 | 25% | × |
| Rang_4a | Rangitikei D/S Riverlands | 22 | 88 | ≈ | 70 | 100 | ✓ | 0.40 | 68 | × | 1.7 | 90 | ≈ | 2.5 | 7% | × |
| Rang_4a | Tutaenui U/S Marton STP | 24 | 100 | ✓ | 60 | 90 | ≈ | 0.40 | 100 | ✓ | 1.7 | 60 | × | 2.5 | 18% | × |
| Rang_4a | Tutaenui D/S Marton STP | 24 | 100 | ✓ | 60 | 79 | × | 0.40 | 79 | × | 1.7 | 67 | × | 2.5 | 22% | × |
| Rang_4a | Piakatutu U/S Sanson STP | 22 | 91 | ≈ | 70 | 30 | × | 0.40 | 94 | ≈ | 1.7 | 88 | ≈ | 2.5 | 0% | × |
| Rang_4a | Piakatutu U/S Sanson STP | 22 | 91 | ≈ | 70 | 30 | × | 0.40 | 53 | × | 1.7 | 88 | ≈ | 2.5 | 0% | × |
| Rang_4a | Rangitikei at Mckelvies | 22 | 75 | × | 70 | 100 | ✓ | 0.40 | 100 | ✓ | 1.7 | 100 | ✓ | 2.5 | 21 | × |

**Table 7: Assessment of compliance with One Plan (2010) targets in the Rangitikei catchment. Overall assessment based on levels of compliance recommended by Ausseil and Ms Clark (2007). [(a)]: This site also serves as the downstream monitoring site for the Bulls STP discharge. Grey-shaded cells indicate where all flow data (instead of <3*median flow data) were used, where flow data were not available.**

| WMsZ | Site | SIN (g/m³, flows <20th exceedance %ile) | | | DRP (g/m³, flows <20th exceedance %ile) | | |
|---|---|---|---|---|---|---|---|
| | | Target | Mean | Overall | Target | Mean | Overall |
| Rang_2a | Rangitikei at Pukeokahu | 0.070 | 0.039 | ✓ | 0.006 | 0.006 | ✓ |
| Rang_2b | Rangitikei at Mangaweka | 0.110 | 0.092 | ✓ | 0.010 | 0.009 | ✓ |
| Rang_3a | Rangitikei at Onepuhi | 0.110 | 0.152 | ≈ | 0.010 | 0.010 | ✓ |
| Rang_4a | Porewa U/S Hunterville STP | 0.110 | 0.205 | ≈ | 0.010 | 0.033 | × |
| Rang_4a | Porewa D/S Hunterville STP | 0.110 | 0.351 | × | 0.010 | 0.199 | × |
| Rang_4a | Porewa Onepuhi Rd | 0.110 | 0.475 | × | 0.010 | 0.027 | × |
| Rang_4a | Rangitawa U/S Halcombe STP | 0.110 | 1.100 | × | 0.010 | 0.035 | × |
| Rang_4a | Rangitawa D/S Halcombe STP | 0.110 | 1.968 | × | 0.010 | 0.515 | × |
| Rang_4a | Rangitikei U/S Bulls STP | 0.110 | 0.094 | ✓ | 0.010 | 0.008 | ✓ |
| Rang_4a | Rangitikei U/S Riverlands[(a)] | 0.110 | 0.069 | ✓ | 0.010 | 0.013 | × |
| Rang_4a | Rangitikei D/S Riverlands | 0.110 | 0.925 | × | 0.010 | 0.326 | × |
| Rang_4a | Tutaenui U/S Marton STP | 0.110 | 1.690 | × | 0.010 | 0.044 | × |
| Rang_4a | Tutaenui D/S Marton STP | 0.110 | 3.566 | × | 0.010 | 0.491 | × |
| Rang_4a | Piakatutu U/S Sanson STP | | 0.776 | × | 0.010 | 0.118 | × |
| Rang_4a | Piakatutu U/S Sanson STP | | 2.887 | 🟧 | 0.010 | 0.938 | × |
| Rang_4a | Rangitikei at Mckelvies | 0.110 | 0.106 | ≈ | 0.010 | 0.010 | ≈ |

**7.21** <u>Nutrient limitation</u>: Using nutrient diffusing substrates at 11 sites across the Rangitikei catchment during a low flow period in February 2005, my colleague Dr Death and myself concluded that N was the limiting nutrient at all sites but two (Death and Ausseil, 2007). These two sites were located downstream of point source discharges, and the study concluded that periphyton growth was probably not nutrient-limited at these sites. This study covered 5 sites on the Rangitikei mainstem, with four of them located in the Middle Rangitikei WMZ (Pukeokahu, Mangaweka, upstream and downstream of the Hautapu River confluence). Only one site was located in the Coastal Rangitikei WMZ, but it was a site directly affected by a point-source discharge (downstream of Bulls oxidation pond).

**7.22** Flow-related analysis of SIN:DRP ratios indicates that:

(a) At the Rangitikei at Pukeokahu monitoring site, co-limited conditions are likely to dominate at flows above median flows, and co-limited and N-limited conditions are likely to dominate at flows below median flow (Figure 2). Median SIN/DRP under different conditions confirm that this site is likely co-limited at median to high flows, and N-limited under median flow (Table 8). This conclusion is in agreement with our conclusions (Death and Ausseil, 2007) when we found that this site was N-limited under low flow conditions;

(b) At the Rangitikei at Mangaweka monitoring site, SIN:DRP ratios indicative of co-limited conditions are dominant at flows above median flow, but with a significant minority of points (75%) indicative of P-limited conditions. Flow conditions below median are strongly dominated by SIN:DRP ratios indicative of co-limited and N-limited conditions (Figure 3). Again, median SIN:DRP ratios calculated under different flow conditions confirm this site is likely co-limited at median to high flows, and N-limited under median flow (Table 8). This conclusion is also in agreement with our findings (Death and Ausseil, 2007); and

(c) The Rangitikei at Onepuhi and Rangitikei at McKelvies monitoring sites also display a dominance of co-limited conditions at flows above median flow, and a dominance of ratios indicative of N-limited conditions at flows below median flow (Figure 4 and Figure 5). At flows below half median flow, the proportion of samples with a SIN:DRP ratio lower than the Redfield ratio is more than 85% at Onepuhi and more than 90% at McKelvies, which is strongly indicative of N-limited conditions.

**7.23** My overall conclusion is that all four sites on the Rangitikei River mainstem are dominated by co-limited conditions at flows above median flow, and N-limited conditions at flows below median flows. The indication of N-limitation is stronger at low flows and is stronger at McKelvies than Onepuhi (the indication of N-limitation being in turn stronger at Onepuhi than at Mangaweka).

**Table 8: SIN:DRP ratios under different flow conditions at four Rangitikei River sites.**

| Site | Median DIN/DRP | | | Death and Ausseil 2007 | Overall conclusion |
|---|---|---|---|---|---|
| | < ½ median flow | ½ median to median flow | Median flow to 20th %ile | | |
| Pukeokahu | 3.7 | 4.9 | 6.4 | N-limited | Co-limited above median flow; N-limited under median flow |
| Mangaweka | 4.2 | 6.7 | 10.5 | N-limited | Co-limited above median flow; N-limited under median flow |
| Onepuhi | 2.9 | 4.3 | 11.4 | N.A. | Co-limited above median flow; N-limited under median flow |
| McKelvies | 2.7 | 3.6 | 15.4 | N.A. | Co-limited above median flow; N-limited under median flow |

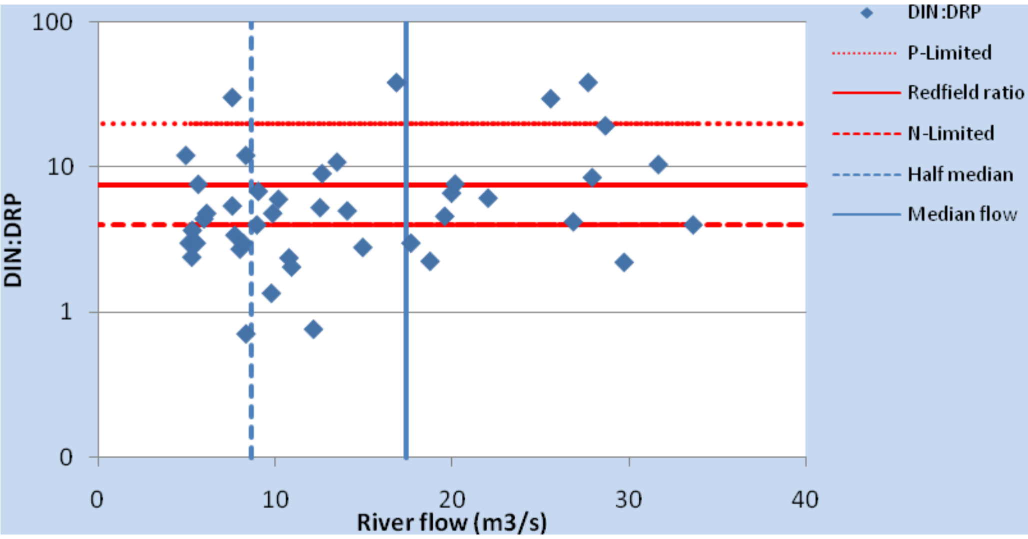

**Figure 2: SIN:DRP ratios at the Rangitikei at Pukeokahu monitoring site at river flows below the 20th exceedance percentile.**

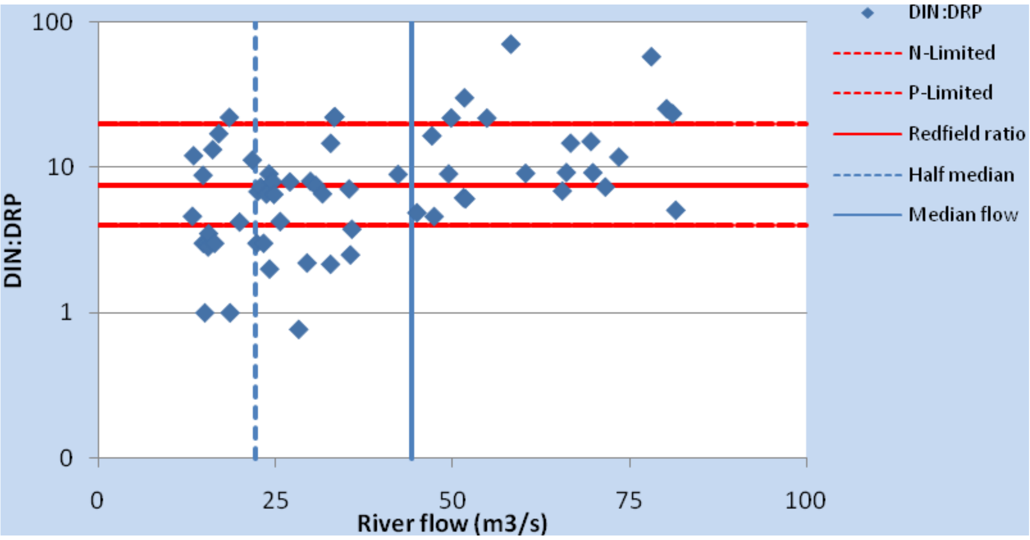

Figure 3: SIN:DRP ratios at the Rangitikei at Mangaweka monitoring site at river flows below the 20th exceedance percentile.

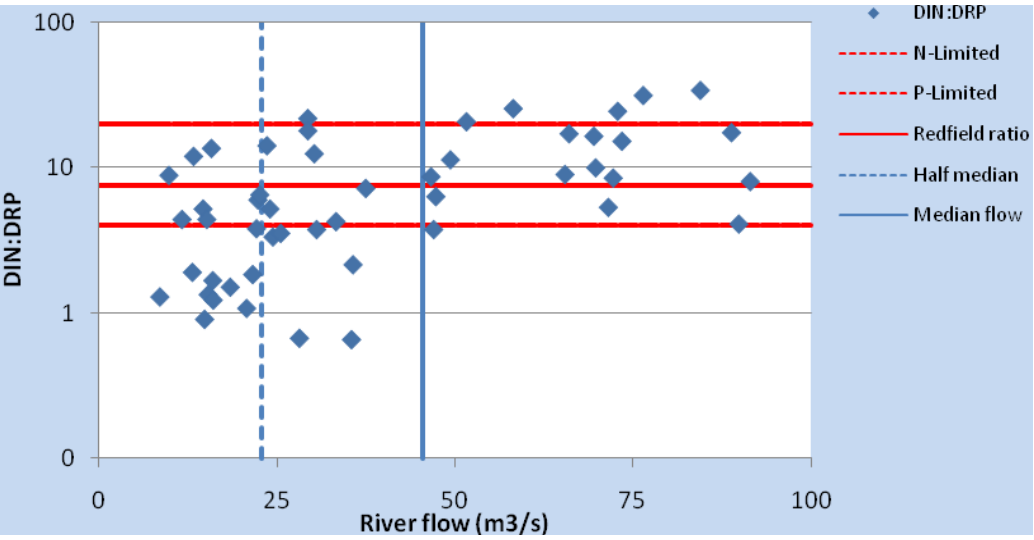

Figure 4: SIN:DRP ratios at the Rangitikei at Onepuhi monitoring site at river flows below the 20th exceedance percentile.

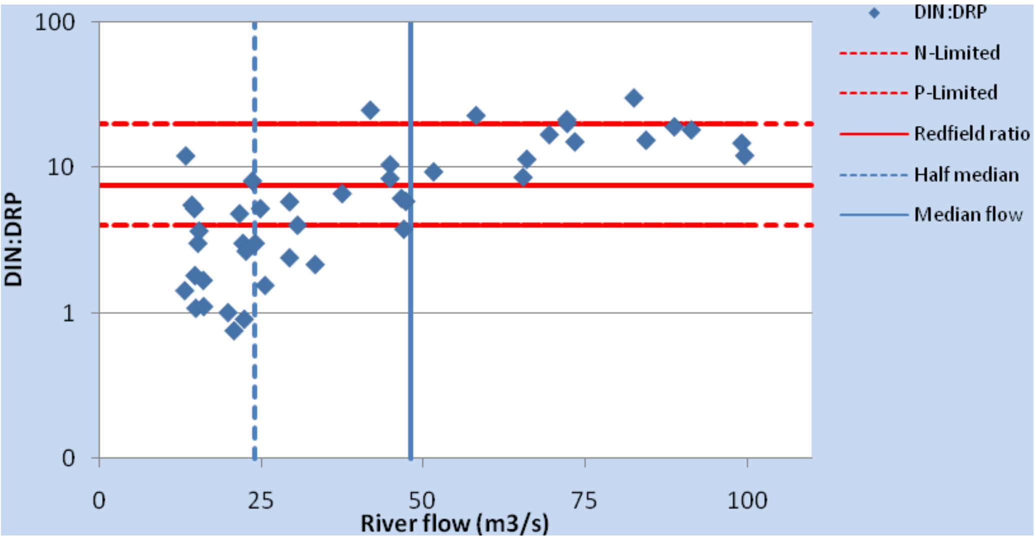

**Figure 5: SIN:DRP ratios at the Rangitikei at McKelvies monitoring site at river flows below the 20th exceedance percentile.**

<u>*Direct point-source discharges to the Rangitikei River*</u>

**7.24** Water quality data are collected immediately upstream and downstream of the two significant direct point source discharges to the Rangitikei River within the Coastal Rangitikei WMZ: the discharge of treated municipal wastewater from Bulls and the discharge of treated wastewater from the Riverlands meat processing plants. The two discharge points to the river are only a few hundred metres apart, and the "downstream of Bulls STP" monitoring site also serves as the upstream monitoring site for the Riverlands discharge.

**7.25** Essentially, the water quality data show a significant degradation in a number of water quality determinants caused by each discharge, and cumulatively by the two discharges, in particular (Table 6 and Table 7):

(a) Each discharge results in a significant increase in total ammonia-N concentrations. Whilst the total ammonia-N concentration remains generally below the One Plan targets downstream of the Bulls STP discharge, it exceeds the chronic toxicity target more than 30% of the time, and the acute toxicity target exceeded nearly 10% of the time downstream of the Riverlands discharge;

(b) An increase in annual average DRP concentration from 0.008 g/m$^3$ to 0.013 g/m$^3$ downstream of the Bulls STP discharge, then to 0.326 g/m$^3$ downstream of the Riverlands discharge; and

(c) An increase in annual average SIN concentration from 0.069 g/m$^3$ downstream of the Bulls STP to 0.925 g/m$^3$ downstream of the Riverlands discharge (no increase between upstream and downstream of the Bulls STP).

**7.26** It is my understanding that the sampling downstream of these discharges takes place at the end of the zone of reasonable mixing defined in each resource consent, but that the discharges are not fully mixed with the river water at the points of sampling. In other words, it is my understanding that sampling takes place within the partially mixed wastewater plume. The results and conclusions above should not be seen as representative of fully-mixed conditions, and therefore should only be interpreted as localised effects. In particular, in the absence of robustly assessed dilution/mixing, the upstream/downstream results should not be used to try and estimate the contaminant loads contributed by each discharge.

### *State of Water Quality in tributaries within the Coastal Rangitikei WMZ*

**7.27** Horizons have provided me with water quality data collected in four tributaries of the Rangitikei River within the Coastal Rangitikei WMZ: the Porewa, Piakatutu, Tutaenui and Rangitawa streams. Daily mean flow estimates were only available for the Tutaenui Stream.

**7.28** All four streams receive point-source discharges of treated municipal wastewater (refer to paragraph 7.6). The dataset is composed of paired samples taken upstream and downstream of the zone of reasonable mixing associated with each discharge. To my knowledge, each tributary only receives one significant point-source discharge; and the catchment of each tributary above the point source discharge is dominated by agricultural land use. The “upstream” samples are therefore representative of water quality in the catchment in the absence of each of the point-source discharges, i.e. provide useful information on the effects of agricultural non-point source discharges within these catchments, whilst the incremental change in water quality between “upstream” and “downstream” can be attributed to the point-source discharge.

**7.29** Water quality is also monitored at a third site on the Porewa Stream, upstream of its confluence with the Rangitikei River. This site is useful in providing some indication of the influence on water quality of the remainder of the Porewa catchment downstream of the Hunterville STP discharge point.

**7.30** “Upstream” water quality data show, by comparison with the relevant One Plan (DV) targets:

(a) In general compliance with the relevant water temperature and total ammonia-N targets;

(b) Generally moderate to poor microbiological water quality;

(c) The dissolved oxygen saturation targets are met all the time in the Porewa Stream, most of the time (92% of the time) in the Tutaenui Stream, 62% of the time in the Piakatutu Stream but only 30% of the time in the Rangitawa Stream;

(d) Nitrate-N concentration exceed the Hickey and Martin (2009) revised chronic toxicity thresholds for the 95% of species protection level (1.7 g/m3) in the Rangitawa Stream (19% of the time), the Tutaenui Stream (15% of the time) and the Piakatutu Stream (12% of the time), indicating a risk of toxic effects on aquatic biota from nitrate-N in these streams;

(e) Annual average DRP concentration exceed the One Plan targets in all four tributaries by at least a factor of 3;

(f) Annual average SIN concentrations exceed the One plan targets in all four tributaries. Annual average SIN concentrations are particularly high in the Rangitawa stream (1.255 g/m3, 11 times the target concentration) and the Tutaenui and Piakatutu streams (more than 5 times the target concentration; and

(g) The average MCI score in the Porewa and Tutaenui Streams are well below the score of 80, i.e. indicative of “probable severe pollution” (refer to Figure 10 in Dr Death’s statement of evidence).

**7.31** When compared with “upstream” data, “downstream” water quality data show a general incremental degradation in most water quality determinants. In particular, each discharge causes an increase in SIN, DRP and ammonia concentrations, and a decrease in the rate of compliance with the relevant POP DV Schedule D targets.

*Nutrient loads*

**7.32** SIN and DRP annual loads were estimated at the four Rangitikei mainstem SoE sites, using two different methods (the “averaging” and the “Beale ratio estimator” methods). Results are presented in Table 9 and Table 10.

**7.33** Estimated SIN annual loads increase 36% (averaging) to 42% (Beale ratio) between Onepuhi and McKelvies. The increase in mean flow between the two sites is only 7%, thus the increase in load cannot solely be explained by an increase in river flows. The nominal annual load increase between the two sites is estimated at 160 Tonnes per year.

**7.34** The total target load is exceeded at both sites, but more so at McKelvies (2.3 times) than at Onepuhi (1.8 times). Dr Roygard and Ms Clark (2012) Tables 5 and 6 show that the target load for flows below the 20th exceedance percentile is met at Onepuhi, but exceeded (1.4 times) at McKelvies.

**7.35** The total inputs of SIN from point-source discharges within the Coastal Rangitikei WMZ are estimated at approximately 27.4 tonnes per year (from Table 12 in Dr Roygard *et al.*, 2012[3]). The total load increase between Onepuhi and McKelvies attributable to non-point source discharges can be estimated as the difference between the total load and the point-source load, at 130 tonnes per year. I note however, that this method of calculation does not account for any in-river attenuation of SIN, and thus is likely to grossly overestimate the contribution that point-source inputs make to the total load measured at the bottom of the catchment.

**7.36** Similarly to DIN, DRP load increases from upstream to downstream in the catchment. Within the Coastal Rangitikei WMZ, the estimated annual DRP load increases by 34 to 41% between Onepuhi and McKelvies. The nominal load increase between these two points is estimated at 12 tonnes per year. Total point source discharges within the zone are estimated to total about 6.4 tonnes per year (Table 12 in Dr Roygard *et al.*, 2012), which represents slightly more than 50 % of the total estimated DRP load increase between Onepuhi and McKelvies, but only 15% of the total estimated DRP load at McKelvies. Although this direct method of calculation is likely to grossly overestimate the contribution that point-sources

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[3] Dr Roygard et al.’s number of 30 tonnes per year includes inputs from the Taihape STP discharge, which are outside the Coastal Rangitikei WMZ.

make to the overall load measured at the bottom of the WMZ, these results indicate that point source discharges are probably a significant contributor to the increase in estimated DRP loads between Onepuhi and McKelvies.

**Table 9:Estimated annual SIN loads (Tonnes N/year) at the main Rangitikei water quality monitoring sites. N.= number of complete hydrological years during which annual loads were calculated. Target Load at Pukeokahu estimated based on mean flow. Target loads at Mangaweka, Onepuhi and McKelvies from Dr Roygard *et al,* 2012.**

| Site | SIN Estimated actual annual load (T/yr) | | | Target Load (T SIN/Yr) |
|---|---|---|---|---|
| | **Method** | **Average** | **N.** | |
| Rangitikei at Pukeokahu | Averaging method | 37 | 4 | 53 |
| | Beale Estimator | 37 | 4 | |
| Rangitikei at Mangaweka | Averaging method | 263 | 5 | 220 |
| | Beale Estimator | 272 | 5 | |
| Rangitikei at Onepuhi | Averaging method | 401 | 4 | 230 |
| | Beale Estimator | 428 | 4 | |
| Rangitikei at McKelvies | Averaging method | 568 | 4 | 248 |
| | Beale Estimator | 581 | 4 | |

**Table 10: Estimated annual DRP loads (Tonnes N/year) at the main Rangitikei water quality monitoring sites. N= number of complete hydrological years during which annual loads were calculated.Target Load at Pukeokahu estimated based on mean flow. Target loads at Mangaweka, Onepuhi and McKelvies from Dr Roygard *et al,* 2012.**

| Site | SIN Estimated actual annual load (T/yr) | | | Target Load (T SIN/Yr) |
|---|---|---|---|---|
| | **Method** | **Average** | **N.** | |
| Rangitikei at Pukeokahu | Averaging method | 5.1 | 4 | 4.6 |
| | Beale Estimator | 5.2 | 4 | |
| Rangitikei at Mangaweka | Averaging method | 24 | 5 | 20.0 |
| | Beale Estimator | 26 | 5 | |
| Rangitikei at Onepuhi | Averaging method | 29 | 4 | 20.9 |
| | Beale Estimator | 35 | 4 | |
| Rangitikei at McKelvies | Averaging method | 41 | 4 | 21.6 |
| | Beale Estimator | 47 | 4 | |

### *Summary of conclusions and discussion – Water quality in the coastal Rangitikei WMZ*

**7.37** Apart from water clarity, most One Plan (DV) Schedule D water quality targets are met or only just exceeded in the Rangitikei River mainstem, including nutrient concentration targets.

**7.38** Macroinvertebrate communities in the Rangitikei River mainstem show some degradation between Onepuhi and McKelvies, but are generally close to meeting the Schedule D MCI target (DV) for the Coastal Rangitikei WMZ. Periphyton biomass and cover targets are always met at Onepuhi, but periphyton cover targets are exceeded on occasion at McKelvies.

**7.39** Water quality in the tributaries of the Coastal Rangitikei WMZ is generally poor as a result of non-point source discharges and is further degraded by point-source discharges.

**7.40** With specific regards to nutrients, the One Plan SIN and DRP concentration targets are met at Onepuhi. There is an increase in annual average concentrations of both SIN and DRP between Onepuhi and McKelvies. Annual average SIN and DRP concentrations at McKelvies are essentially equal to the One Plan targets. Any future significant increase in dissolved nutrient concentrations is likely to result in the One Plan targets being exceeded.

**7.41** Annual load estimations show a 35 to 42% (depending on the estimation method) increase in both SIN and DRP annual load between Onepuhi and McKelvies. Non-point source discharges are the major source of the SIN load increase, whilst point-source discharges may make a significant contribution to the DRP load.

**7.42** There is good evidence that periphyton growth in the Rangitikei River mainstem is generally co-limited at flows above median and strongly N-limited the rest of the time. Given the physical characteristics of the lower Rangitikei River (i.e. a wide, shallow, gravel bed river with relatively long periods of stable flow), increased dissolved nutrient concentrations, particularly during periods of stable river flows, are likely to result in increased periphyton growth[4].

**7.43** Having regard to the above conclusions, my recommendations in relation to the management of water quality in the Coastal Rangitikei WMZ are:

(a) If the aim for this WMZ is to achieve compliance with the One Plan targets, then nutrient inputs to the Rangitikei river mainstem should be

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[4] Higher nutrient concentrations mean that periphyton will grow faster and reach proliferation levels in shorter times (Dr Biggs, Revised Section 42A Report, 2010)

maintained at or below current levels. Maintaining nutrient concentrations at current levels is likely to maintain periphyton growth at current levels, and likely to contribute to maintaining macroinvertebrate communities at their current level as well;

(b) Water quality in tributaries within this zone is in a degraded state, due to both point-source and non-point source discharges. A reduction in contaminant inputs from both point-source and non-point source discharges would be required to bring water quality and aquatic communities closer to Schedule D targets;

(c) Nutrient management in the Coastal Rangitikei WMZ (and more widely in the Rangitikei catchment) should focus on SIN as a priority, although DRP inputs should also be managed given the often co-limited status of the river. This recommendation is consistent with that of Wilcock *et al.* (2007);

(d) Non-point source discharges are the key source of SIN in the Coastal Rangitikei WMZ. Nitrogen management within this WMZ should therefore focus on diffuse sources of nitrogen; and

(e) Conversely, management of DRP within this WMZ should first focus on point-source discharges.

## 8. Catchment land use scenario modelling – water quality outcomes of nitrogen loss limits - methodology

**8.1** In their joint statement of evidence, Dr Roygard *et al.* (2012) set out a number of land use scenarios (including current and possible future land use) in which they explore the consequences for in-river nutrient load of different land management regimes (some involving the application of nitrogen loss limits from land use). They examine the water quality outcomes of applying LUC N-leaching limits to existing and/or future dairying (assuming 11% intensification of dairy farming), single number limits and doing nothing.

**8.2** I have re-run a handful of scenarios that Horizons ran, using an independently developed model based on slightly different methodology, in order to verify that our results are similar where we have used the same assumptions and data.

**8.3** Dr Dewes raised some concerns in her evidence relating to some of the assumptions made by Dr Roygard et al. (2012). Dr Dewes is of the opinion that the increase in land area used for dairy farming may in the future increase more than assumed by Dr Roygard et al. (18% rather than 11%) and that extensive sheep and beef farming is likely to undergo some intensification associated with supporting the dairy industry. This may increase the amount of nitrogen leaching from the non-dairy land uses, which has not been considered in any of Horizons' scenarios.

**8.4** Therefore, I have worked with Dr Dewes to examine possible impacts on in-stream nitrogen loads in a number of key water management zones (including the Coastal Rangitikei as the Minister of Conservation and Wellington Fish and Game Council have sought its re inclusion into table 13.1), in order to explore the consequences for water quality if land use development follows her predictions.

### Methodology

**8.5** Modelling of the water quality outcomes of a number of land use scenarios was undertaken for two WMZ (Coastal Rangitikei and Mangatainkoa) and one group of WMZ (the five WMZs situated upstream of Hopelands). Land use and LUC classification within these areas are summarised in Table 5, Table 11 and Table 12.

**Table 11: Land use capability by land use type in WMZ Mana_1 to Mana_5 (inclusive), i.e. the Manawatu catchment upstreamof Hopelands (data provided by Horizons Regional Council).**

| Land use | LUC Class (Area ha) | | | | | | | | *Total* |
|---|---|---|---|---|---|---|---|---|---|
| | 2 | 3 | 4 | 5 | 6 | 7 | 8 | Blank | |
| Builtup/Parks/Others | 20.4 | 51.2 | 18.9 | | 0.2 | 36.7 | 0.4 | 328.8 | *456.6* |
| Cropping | 20.3 | 413.0 | 31.7 | | 2.7 | 11.3 | | | *478.9* |
| Dairy | 5,704.3 | 7,489.6 | 3,207.3 | 116.8 | 2,409.6 | 1,210.6 | | 0.6 | *20,138.8* |
| Exotic Cover | 253.2 | 532.8 | 221.0 | 14.6 | 1,899.9 | 843.1 | 27.4 | | *3,792.0* |
| Horticulture-Other | 7.2 | 8.5 | 3.0 | | 2.1 | | | 0.2 | *20.9* |
| Native Cover | 233.0 | 383.9 | 159.9 | 1.8 | 2,100.7 | 4,813.0 | 5,064.8 | | *12,757.0* |
| Other | 85.6 | 199.9 | 94.6 | | 478.5 | 63.3 | | | *921.9* |
| Sheep and/or Beef | 5,531.3 | 10,888.0 | 7,231.8 | 663.9 | 47,614.4 | 13,569.7 | 57.7 | 120.1 | *85,676.8* |
| Water Body | 16.1 | 26.9 | 17.7 | | 6.5 | 22.0 | 13.3 | | *102.5* |
| *Total* | *11,871.2* | *19,993.9* | *10,985.8* | *797.1* | *54,514.6* | *20,569.5* | *5,163.6* | *449.7* | *124,345.4* |

**Table 12: Land use capability by land use type in the Mangatainoka Water Management Zone (data provided by Horizons Regional Council).**

| Land use | LUC Class (Area ha) | | | | | | | | | Total (ha) |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | Blank | |
| Builtup/Parks/Others | | 56.8 | 16.6 | | | 4.5 | | 2.5 | 177.2 | 257.6 |
| Cropping | | 3.1 | 1.5 | | | | | | | 4.6 |
| Dairy | 407.9 | 5,540 | 2,558 | 651.7 | | 3,674 | 248.6 | 81.3 | | 13,161.9 |
| Exotic Cover | 0.1 | 85.6 | 82.5 | 11.2 | 5.8 | 278 | 196.1 | 16.5 | 0.3 | 676.4 |
| Horticulture-Other | | 0.4 | | | | | | | | 0.4 |
| Native Cover | | 171.1 | 148.1 | 52.6 | 7.3 | 1,085 | 3,771 | 3,562 | 0.8 | 8,797.8 |
| Other | 6.2 | 85.1 | 55.7 | 0.2 | | 17.4 | 11.3 | 0.0 | | 176.1 |
| Sheep and/or Beef | 174.1 | 4,716 | 2,700 | 705.7 | 247.6 | 9,968 | 1,762 | 173.9 | 77.3 | 20,524.6 |
| Water Body | 4.2 | 61.4 | 55.8 | 4.6 | | 1.3 | 1.1 | | 3.6 | 132.0 |
| Total (ha) | 592.5 | 10,720 | 5,618 | 1,426 | 260.7 | 15,029 | 5,990 | 3,83 | 259.1 | 43,731.4 |

**8.6** The land use scenario "modelling" is based on extremely simple basic principles:

(a) assume different N loss rates (current or projected, expressed as kg/ha/yr) for different land use types and Land Use Capability (LUC) class combinations, then

(b) multiply these assumed N loss rates by the area (current or projected) occupied by each land use type/LUC class combination to obtain individual N loads (expressed as Tonnes per year) lost from each land use type/LUC class combination; then

(c) add up these individual N losses to produce a total N loss estimate for the WMZ (or group of WMZs) under consideration.

**8.7** This methodology is essentially similar to that applied by Dr Roygard *et al.* (2012), with the exception of the calculation and subsequent use of the attenuation/transmission factor, which is explained below.

**8.8** The assumed N loss rates for the different land use type/LUC combinations and the projected changes in land use (e.g. increase in the land surface area used for dairying within a given WMZ) constitute the base parameters for the different land use modelling scenarios.

**8.9** The definition of these parameters (i.e. N loss rates and changes in land use types within a zone) is outside my area of expertise and was based on the evidence of Dr. Dewes. My evidence relates to the interpretation of the water quality outcomes of the scenario modelling.

**8.10** The "attenuation" factor represents the ratio between the nutrient loads measured in the river and the nutrient loads lost from the land beyond the root zone. The method applied in the scenario modelling described in this evidence was to calculate an attenuation factor specifically for each zone considered, based on the ratio between the estimated in-river nutrient load (estimated from water quality and flow data) and the estimated current nutrient load lost from land (based on current land use data and assumed current N loss rates). This calculated attenuation factor was subsequently kept constant for all scenario modelling within that zone.

**8.11** It is my opinion that this approach, which consists in calibrating the attenuation factor within each study area, is more robust than an approach that utilises the same attenuation factor in all catchments, for the following reasons:

(a) The amount of nutrients being utilised in-stream (i.e. in-stream attenuation) will depend on a number of factors, including the amount of algal biomass present, and the overall channel morphology. As such, one would expect different attenuation factors in different catchments;

(b) A given algal biomass will only be able to absorb a finite amount of nutrients. Thus, one would expect the overall proportion of nutrient being utilised (i.e. attenuated) in-river to decrease when the overall nutrient concentration increases, particularly when nutrient concentrations are sufficiently high to be in excess of plant requirements. Conversely, one would expect a greater relative attenuation where nutrient concentrations are relatively lower; and

(c) Forcing the attenuation to a fixed valued constrains the other parameters of the model to reach unlikely or impossible values, such as the negative or very low sheep and beef N loss values calculated by Dr Roygard and Ms Clark in their Table 37 for the Waikawa and Rangitikei catchments. Calibrating the attenuation factor for each catchment allows the model to keep N loss at levels estimated or assumed based on data or expert opinion.

**8.12** Notwithstanding the above points, the key role of the scenario modelling is, in my opinion, to enable the comparison of effects on water quality of different management options under different land use situations. In this context, both the approach used by Dr Roygard and Ms Clark and that presented in this evidence are likely to provide valid indications of the "direction" (i.e. an improvement or a degradation) and scale of change.

**8.13** The following Nitrogen loss rates were assumed in relation to the current land use. Loss rates for the native cover, forestry, built-up/Park/others categories were as determined by Dr Roygard and Ms Clark (2012). Current loss rates from dairy land were the average loss rates for each WMZ/catchment, from Dr Roygard *et al.* (2012). Other loss rates were recommended by Dr Dewes (Table 13).

**Table 13: Assumed average annual N loss rates from different land use types (all in kg N/ha/yr).**

| | Upper Manawatu | Mangatainoka | Coastal Rangitkei |
|---|---|---|---|
| Builtup/Parks/Others | 3 | 3 | 3 |
| Cropping | 50.5 | 50.5 | 50.5 |
| Dairy | 26.09 | 24.71 | 21.95 |
| Exotic Cover | 4 | 4 | 4 |
| Horticulture-Other | 10 | 10 | 10 |
| Horticulture-Veg | 80 | 80 | 80 |
| Native Cover | 2.4 | 2.4 | 2.4 |
| Other | 3 | 3 | 3 |
| Sheep and/or Beef | 10 | 10 | 10 |
| Water Body | 0 | 0 | 0 |

**8.14** The following LUC N loss limits have been used, and are subsequently referred to in this evidence as "DV" (for the N-loss limits set out in Table 13-2 of the Decision Version) and "NV yr 20" (from the POP notified version) N-loss limits respectively (Table 14).

**Table 14: LUC N Loss limits used in modelling.**

| Target | N Loss by LUC class | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | I | II | III | IV | V | VI | VII | VIII |
| POP DV | 30 | 27 | 24 | 18 | 16 | 15 | 8 | 2 |
| POP NV Year 20 | 25 | 21 | 18 | 13 | 12 | 10 | 6 | 2 |

**8.15** By multiplying the above LUC N loss limits by the proportion of dairy land within each LUC class within a given study WMZ/catchment, one can easily calculate a theoretical "zone average" N loss corresponding to the above LUC N loss limits. These provide a useful comparison point to the estimated current average loss for each zone or catchment reported in Appendix 5 of the evidence by Dr Roygard *et al*. (2012)(Table 15). The differences in the "zone averages" corresponding to the same LUC N loss limits are due to the differences in the LUC classes make up of dairy land within each of the zone.

**Table 15:Theoretical average N loss rates from dairy land corresponding to different LUC N loss limits, and comparison with current average N loss rates as reported by Dr Roygard*et al.* (2012).**

| Zone | Average N loss from dairy land (kg N/ha/Yr) | | Current average N loss from dairy farms (kg N/ha/Yr, from Dr Roygard et al., 2012) |
|---|---|---|---|
| | POP DV | POP NV Yr 20 | |
| Hopelands | 22 | 16 | 26 |
| Mangatainoka | 22 | 17 | 25 |
| Coastal Rangitikei | 25 | 19 | 22 |

**8.16** It is important to bear in mind that the scenarios that involve the application of LUC N loss limits are modelled on the basis of all land to which the limits are applicable actually losing exactly the loss limits. These scenarios therefore correspond to a maximum N load theoretically lost from the land under a given regulatory regime. Therefore, where a particular scenario is deemed to allow a water quality degradation, this does not mean that water quality degradation will necessarily occur, rather that the management regime tested within the said scenario will not prevent water quality degradation.

**8.17** As explained in paragraph 5.9, my independent analysis of estimated in-river loads essentially validated the results of Dr Roygard and Ms Clark (2012). I also independently calculated target loads (i.e. based on in-stream SIN target concentration) and obtained the same results as those in Table 6 of Dr Roygard and Ms Clark (2012). For the sake of consistency and direct comparability of results, the scenario modelling presented in this evidence makes use of the in-river and target loads as reported in Dr Roygard and Ms Clark (2012).

**8.18** Dr Roygard and Ms Clark (Table 41) report the changes in N loads from the estimated current state as positive numbers to represent an improvement (i.e. a modelled decrease in load compared with the estimated current load) and negative numbers to represent degradation (i.e. a modelled increase in load). Whilst I disagree with the logics of this reporting (my preference would be to report the actual predicted change in loads, i.e. a decrease in load being represented by a negative percentage), I have elected to utilise the same reporting method as Dr Roygard and Ms Clark to avoid unnecessary confusion.

*Periphyton biomass predictions*

**8.19** The annual average SIN concentration at flows below 20th exceedance percentile was calculated by assuming that the changes in SIN loads were equally distributed across all river flow conditions. This assumption is consistent with that made by Dr. Biggs in his revised S42A report (Biggs, 2010).

**8.20** This number was then used in the New Zealand Periphyton Guidelines equations (pg. 43) to provide an estimate of maximum annual periphyton biomass. As alluded to in paragraph 3.15, the NZPG model often produces environmentally conservative estimates. This is primarily due to these equations being based on an "idealised" periphyton growth situation, which does not necessarily take into account some factors that might provide some control of periphyton growth (such as invertebrate grazing and physical abrasion by suspended particles). As a result, the periphyton biomass predictions based on the NZPG model predictions are likely to be higher than what is actually observed in-river. I consider however that the NZPG model is useful to provide an indication of the "direction" (i.e. increase or decrease) and scale of change in periphyton biomass that is likely to result from a given change in nutrient concentration.

*Land use Scenarios and options*

**8.21** All scenarios presented in this evidence were designed in collaboration with Dr Dewes, to explore the consequences on in-river nutrient load and water quality arising as a consequence of two dairy expansion predictions, i.e. to explore what will happen if dairying increases by 11% (Horizon's assumptions) or if it increases by 18% (Dr Dewes' view), then, for each of these,

(a) what would happen if the amount of land in cropping increases as anticipated by Dr Dewes; and

(b) what would happen if the average N loss rates from sheep and beef farms was to increase from the currently assumed 10 kg/ha/yr(refer to Table 13) to 12 kg/ha/yr.

**8.22** Then a number of “management options” were applied to these future land use scenarios, to explore the potential consequences on nutrient load and water quality of applying either the DV LUC or the NV yr 20 N-loss limits (Table 14) to either dairy conversions only (as proposed by the decisions version), all dairy (current and conversions) and all dairy and cropping. These scenarios are all set out in Table 16, where to avoid confusion with Dr Roygard and Ms Clark’s scenarios, I have utilised a different numbering system.

**8.23** The N losses from all other land uses are assumed to remain at their estimated/assumed current level.

**8.24** A number of scenarios assume an increase in the land area used for cropping within sheep and beef farms. This was calculated on the basis that it was anticipated that 50% of sheep and beef farmers will crop on 15% of their class I, II and III land and 10% will crop on their class IV land. The relative increase of land in cropping under these assumptions was still relatively small[5], but due to the higher assumed N-leaching rates, had the potential to influence the nutrient load and water quality outcomes.

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[5] 1.6% of the current land area used for sheep and beef farming in the Manawatu above Hopelands catchment, 2.4% in the Mangatainoka catchment and 4.6% in the Coastal Rangitikei WMZ.

**Table 16: Summary of modelled scenarios.**

| LUC N-loss limit | Land use | | Scenario number | LUC loss limits applied to |
|---|---|---|---|---|
| N/A | Current land use | | 0 | - |
| | | | | |
| DV | Current land use | | A1 | All dairy |
| | 11% increase in dairy area | - | A2 | Dairy conversion |
| | | | A3 | All dairy |
| | | Cropping increase in S&B farms | A4 | All dairy |
| | | S&B intensification (12 kg/ha/yr) | A5 | All dairy |
| | 18% increase in dairy area | - | A6 | Dairy conversion |
| | | | A7 | All dairy |
| | | Cropping increase in S&B farms | A8 | All dairy |
| | | S&B intensification (12 kg/ha/yr) | A9 | All dairy |
| | | | | |
| NV Y20 | Current land use | | B1 | All dairy |
| | 11% increase in dairy area | - | B2 | Dairy conversion |
| | | | B3 | All dairy |
| | | Cropping increase in S&B farms | B4 | All dairy + cropping |
| | | S&B intensification (12 kg/ha/yr) | B5 | All dairy |
| | 18% increase in dairy area | - | B6 | Dairy conversion |
| | | | B7 | All dairy |
| | | Cropping increase in S&B farms | B8 | All dairy + cropping |
| | | S&B intensification (12 kg/ha/yr) | B9 | All dairy |

## 9. Catchment land use scenario modelling – water quality outcomes of nitrogen loss limits – Results

*Cross validation of Dr Roygard and Ms Clark's scenarios*

**9.1** By way of cross validation, a number of the above scenarios were similar to those described in Dr Roygard and Ms Clark:

(a) Scenario 3 (Current land use, DV LUC target applied to all dairy land). This also my scenario A1 in Table 16;

(b) Scenario 4 (DV to existing and new dairy under an 11% expansion scenario). This is also my scenario A3 in Table 16; and

(c) Scenario 6 (NV yr 20 limits applied to existing and new dairy under 11% expansion). This is also my scenario B3 in

Table 16Table 16.

**9.2** Manawatu at Hopelands: The modelled outcomes of scenarios A1, A3 and B3 (Dr Roygard and Ms Clark's scenarios 3, 4 and 6) are very similar to those obtained independently by Dr Roygard and Ms Clark, which provides useful cross-validation of the methods for this site (Table 17).

**9.3** Mangatainoka at SH2: The results for scenarios A1, A3 and B3 (Dr Roygard and Ms Clark's scenarios 3, 4 and 6) are somewhat different from those obtained by Dr Roygard and Ms Clark, although the general "direction" (i.e. a reduction in in-river SIN loads in all three scenarios) and the magnitude of change are the same (Table 17). The differences can be attributed to the different assumptions and methodologies used by Dr Roygard and Ms Clark (2012). In the modelling presented in this evidence, the nutrient loss rates from the different land uses are defined as assumptions of the model, and an attenuation factor is calculated for each study catchment/zone. In the case of the Mangatainoka, the calculated attenuation factor was 0.98, meaning that 98% of the load estimated lost from the land is measured at SH2. This is different from the attenuation factor calculated for the Manawatu at Hopelands. This can have several causes:

(a) The assumed losses from one or several land uses (e.g. dairy or sheep and Beef) are lower than the actual losses (a point also discussed by Dr Roygard and Ms Clark in their paragraph 141);

(b) The groundwater and in-stream attenuation of SIN represent a relatively small proportion of the total load in the Mangatainoka. Given the high average SIN concentration observed in the Mangatainoka, one would expect low in-stream attenuation (relative to the total load) in the Mangatainoka (refer to paragraph 8.11).

**9.4** Coastal Rangitikei: The results for scenarios 4/A3 and 6/B3 are again reasonably consistent with those of Dr Roygard and Ms Clark. However, Dr Roygard and Ms Clark predict that scenario 3 (my A1) would result in no change in water quality, whilst I am predicting that his scenario would allow a 5% water quality degradation. It is my understanding that the modelling undertaken by Dr Roygard and Ms Clark comprises the whole catchment above McKelvies (i.e. nearly all of the Rangitikei catchment), whilst the modelling presented in this evidence was undertaken only considering the Coastal Rangitikei WMZ, which may explain the differences in outcome reached.

**Table 17: Summary of predicted in-river SIN Loads (in tonnes per year) at the three study sites. Predicted improvement is the percentage of change from the current load to the modelled load, with a positive number indicating an improvement (i.e. a decrease in load) and a negative number indicating a degradation (i.e. an increase in load).**

| Study area | Scenario | | Current load (T SIN /yr) | Modelled load (T SIN /yr) | Predicted improvement | |
|---|---|---|---|---|---|---|
| | This Evidence | Horizons | | | This Evidence | Horizons |
| Upper Manawatu | A1 | 3 | 762 | 717 | +5.9% | +6% |
| | A3 | 4 | | 731 | +4.1% | +4% |
| | B3 | 6 | | 667 | +12.5% | +12% |
| Mangatainoka | A1 | 3 | 538 | 506 | +5.9% | +3% |
| | A3 | 4 | | 523 | +2.8% | +5% |
| | B3 | 6 | | 444 | +17% | +12% |
| Coastal Rangitikei | A1 | 3 | 203 | 213 | -5.0% | 0% |
| | A3 | 4 | | 218 | -7.5% | -3% |
| | B3 | 6 | | 199 | +2.3% | +4% |

*Manawatu at Hopelands*

**9.5** The results of the scenario modelling for the catchment above the Manawatu at Hopelands (WMZs Mana_1 to 5) are summarised in Table 18.

**9.6** Applying the DV LUC limits to dairy conversions only, as per the POP Decision Version, is predicted to allow small increases in in-river SIN load under both the 11% (scenario A2: 1.8% degradation) and the 18% (scenario A6: 2.9% degradation) dairy expansion scenarios.

**9.7** Applying the DV LUC limits to existing dairying (A1) is predicted to result in an improvement in SIN load under the current land use (scenario A1: 5.9% improvement), and both dairy expansion scenarios (scenario A3: 4.1% improvement and scenario A7: 3% improvement).

**9.8** However, if the assumption of a likely increase in cropping area is correct, then applying the DV LUC limits to all dairy land would result in just maintaining SIN loads at current levels in an 11% dairy expansion situation (scenario A4: 0%

change) or in allowing a minor degradation in an 18% dairy expansion scenario (scenario A8: 0.9% degradation).

**9.9** Comparing the outputs from A3 (Dr Roygard and Ms Clark's scenario 4) and A4 (which is similar but includes an increase in cropping) provides an insight on the potential effects of an increase in cropping. Where Dr Roygard and Ms Clark's Scenario 4 predicted a 4.1% decrease in SIN loads, this is negated (i.e. a predicted load improvement of 0%) when cropping increases are factored in (scenario A4) which suggests that the increase in cropping in nearby land negates some of the SIN load reduction brought by the imposition of the DV LUC loss limits.

**9.10** If the average rate of loss of sheep and beef land is assumed to increase by 20% (from an assumed current rate of 10 kg/ha/yr to 12kg/ha/yr), concurrently to dairy expansion (either 11% or 18%) then applying the DV LUC limits to all dairy land is predicted to allow an increase in in-river SIN loads (scenario A5: 7.3% degradation and scenario A9: 8.3% degradation).

**9.11** Applying the NV yr 20 limits to dairy conversions only is predicted to allow small increases in in-river SIN load under both the 11% (scenario B2: 1.0% degradation) and the 18% (scenario B6: 1.6 % degradation) dairy expansion scenarios.

**9.12** Applying the NV year 20 LUC-loss limits to all dairy land or to all dairy and cropping land irrespective of the likely intensification or land use scenario, leads to the water quality (nutrient load and predicted periphyton biomass) being either maintained or improved. The largest predicted improvement results from the application of NV year 20 LUC-loss limits to all current dairy without any new conversions occurring (scenario B1: 13% improvement), although similar magnitudes of improvement to the nutrient load are predicted if the NV year 20 LUC-loss limits are applied to all dairy land under both dairy expansion scenarios (scenarios B4 and B8: 13% and 12% improvement respectively). A minor improvement in SIN loads is predicted even if the average loss from sheep and beef farms increases by 20% concurrently with dairy expansion (scenarios B5 and B9: 1.1% and 0.6% improvement respectively).

**Table 18: Summary of predicted in-river SIN Loads (in tonnes per year) at the Manawatu at Hopelands. Predicted improvement is the percentage of change from the current load or biomass to the modelled load or biomass, with a positive number indicating an improvement (i.e. a decrease in load or biomass) and a negative number indicating degradation (i.e. an increase in load or biomass). Scenarios that allow a more than 2% increase (degradation) in in-stream loads are shown in orange. Scenarios that result in a more than 2% reduction (improvement) in load are shown in blue.**

| LUC N-loss limit | Land use | | Scenario number | LUC loss limits applied to | Average N loss from dairy land (kg/ha/yr) | Modeled in-stream Non point source SIN load (T/yr) | Predicted load Improvement | Predicted periphyton biomass improvement |
|---|---|---|---|---|---|---|---|---|
| N/A | Current land use | | 0 | - | 26.1 | 762 | - | - |
| | | | | | | | | |
| DV | Current land use | | A1 | All dairy | 21.8 | 717 | +5.9% | +3% |
| | 11% increase in dairy area | - | A2 | Dairy conversion | 25.7 | 776 | -1.8%% | -0.9% |
| | | | A3 | All dairy | 21.8 | 731 | +4.1% | +2.1% |
| | | Cropping increase in S&B farms | A4 | All dairy | 21.8 | 762 | 0% | 0% |
| | | S&B intensification (12 kg/ha/yr) | A5 | All dairy | 21.8 | 818 | -7.3% | -3.6% |
| | 18% increase in dairy area | - | A6 | Dairy conversion | 25.4 | 785 | -2.9% | -1.5% |
| | | | A7 | All dairy | 21.8 | 740 | +3.0% | +1.5% |
| | | Cropping increase in S&B farms | A8 | All dairy | 21.8 | 769 | -0.9% | -0.4% |
| | | S&B intensification (12 kg/ha/yr) | A9 | All dairy | 21.8 | 826 | -8.3% | -4.1% |
| | | | | | | | | |
| NV Y20 | Current land use | | B1 | All dairy | 16.3 | 660 | +13% | +14% |
| | 11% increase in dairy area | - | B2 | Dairy conversion | 25.1 | 770 | -1.0% | -0.5% |
| | | | B3 | All dairy | 16.3 | 667 | +13% | +6.5% |
| | | Cropping increase in S&B farms | B4 | All dairy + cropping | 16.3 | 664 | +13% | +6.7% |
| | | S&B intensification (12 kg/ha/yr) | B5 | All dairy | 16.3 | 754 | +1.1% | +0.5% |
| | 18% increase in dairy area | - | B6 | Dairy conversion | 24.6 | 774 | -1.6% | -0.8% |
| | | | B7 | All dairy | 16.3 | 672 | +12% | +6.2% |
| | | Cropping increase in S&B farms | B8 | All dairy + cropping | 16.3 | 669 | +12% | +6.4% |
| | | S&B intensification (12 kg/ha/yr) | B9 | All dairy | 16.3 | 758 | +0.6% | +0.3% |

**Table 19: Summary of predicted in-river SIN Loads (in tonnes per year) at the Mangatainoka at SH2. Predicted improvement is the percentage of change from the current load or biomass to the modelled load or biomass, with a positive number indicating an improvement (i.e. a decrease in load or biomass) and a negative number indicating degradation (i.e. an increase in load or biomass). Scenarios that allow a more than 2% increase (degradation) in in-stream loads are shown in orange. Scenarios that result in a more than 2% reduction (improvement) in load are shown in blue.**

| LUC N-loss limit | Land use | | Scenario number | LUC loss limits applied to | Average N loss from dairy land (kg/ha/yr) | Modeled in-stream Non point source SIN load (T/yr) | Predicted load Improvement | Predicted periphyton biomass improvement |
|---|---|---|---|---|---|---|---|---|
| N/A | Current land use | | 0 | - | 24.7 | 538 | - | - |
| | | | | | | | | |
| DV | Current land use | | A1 | All dairy | 22.2 | 506 | +5.9% | +3.0% |
| | 11% increase in dairy area | - | A2 | Dairy conversion | 24.5 | 555 | -2.8% | -1.4% |
| | | | A3 | All dairy | 22.2 | 523 | +2.8% | +1.4% |
| | | Cropping increase in S&B farms | A4 | All dairy | 22.2 | 544 | -1.1% | -0.6% |
| | | S&B intensification (12 kg/ha/yr) | A5 | All dairy | 22.2 | 560 | -4.1% | -2.0% |
| | 18% increase in dairy area | - | A6 | Dairy conversion | 24.3 | 566 | -5.2% | -2.6% |
| | | | A7 | All dairy | 22.2 | 534 | +0.7% | +0.4% |
| | | Cropping increase in S&B farms | A8 | All dairy | 22.2 | 553 | -2.8% | -1.4% |
| | | S&B intensification (12 kg/ha/yr) | A9 | All dairy | 22.2 | 569 | -5.8% | -2.9% |
| | | | | | | | | |
| NV Y20 | Current land use | | B1 | All dairy | 16.7 | 413 | +23% | +30% |
| | 11% increase in dairy area | - | B2 | Dairy conversion | 23.9 | 548 | -1.7% | -0.9% |
| | | | B3 | All dairy | 16.7 | 445 | +17% | +9.1% |
| | | Cropping increase in S&B farms | B4 | All dairy + cropping | 16.7 | 450 | +16% | +8.6% |
| | | S&B intensification (12 kg/ha/yr) | B5 | All dairy | 16.7 | 482 | +10% | +5.4% |
| | 18% increase in dairy area | - | B6 | Dairy conversion | 23.5 | 554 | -2.8% | -1.4% |
| | | | B7 | All dairy | 16.7 | 541 | +16% | +8.5% |
| | | Cropping increase in S&B farms | B8 | All dairy + cropping | 16.7 | 455 | +15% | +8.1% |
| | | S&B intensification (12 kg/ha/yr) | B9 | All dairy | 16.7 | 486 | +9.7% | +5.0% |

*Mangatainoka at SH2*

**9.13** The results of the scenario modelling for the catchment above the Mangatainoka at SH2 is summarised in Table 19.

**9.14** Similarly to what was predicted for the Manawatu at Hopelands, applying the DV LUC limits to dairy conversions only, as per the POP Decision Version, is predicted to allow increases in in-river SIN load under both the 11% (scenario A2: 2.8% degradation) and the 18% (scenario A6: 5.2% degradation) dairy expansion scenarios.

**9.15** Applying the DV LUC limits to existing dairying (A1) is predicted to result in an improvement in SIN load under the current land use (scenario A1: 5.9% improvement), and both dairy expansion scenarios (scenario A3: 4.1% improvement), although the predicted improvement under the 18% dairy expansion scenario is minor (scenario A7: 0.7% improvement).

**9.16** Similarly to what was predicted for the Manawatu at Hopelands, an increase in cropping in sheep and beef farms associated with the dairy expansion scenarios is predicted to negate the improvements brought by the imposition of DV LUC loss limits on all dairy land (scenarios A4 and A8: 1.1% and 2.8% degradation respectively).

**9.17** An increase in the average rate of loss of sheep and beef land from 10 to 12kg/ha/yr concurrently to dairy expansion (either 11% or 18%) would also lead to increase in in-river SIN loads and periphyton biomass if the DV LUC limits were applied to all dairy land (scenario A5: 4.1% degradation and scenario A9: 5.8% degradation).

**9.18** Applying the NV yr 20 limits to dairy conversions only is predicted to allow small increases in in-river SIN load under both the 11% (scenario B2: 1.7% degradation) and the 18% (scenario B6: 2.8% degradation) dairy expansion scenarios.

**9.19** Applying the NV year 20 LUC-loss limits to all dairy land or to all dairy and cropping land leads to in-river SIN loads to be reduced by 10 to 23%, and periphyton biomass to be reduced by 5 to 30% under all modelled scenarios. The largest predicted improvement in SIN load results from the application of NV year 20 LUC-loss limits to all current dairy without any new conversions occurring (scenario B1: 23% improvement), although significant improvements to the nutrient load are predicted if the NV year 20 LUC-loss limits are applied to all dairy land under both dairy expansion scenarios (scenarios B4 and B8: 16% and 15% improvement respectively).

*Coastal Rangitikei*

**9.20** All the scenario modelling presented in this evidence in relation to the coastal Rangitikei relates to that WMZ only. As a consequence, the “measured” in-river SIN load is taken as the difference between the “measured” non-point source SIN load at McKelvies (543 Tonnes per year) minus the “measured” non-point source SIN load at Onepuhi (340 Tonnes per year). This load of 203 Tonnes represents the non-point source SIN load “generated” within the zone. The modelling was conducted based on the land use statistics for the coastal Rangitikei WMZ (excluding tidal Rangitikei) presented in Table 5. Modelling results are presented in Table 20.

**9.21** All scenarios involving the application of the DV LUC limits to dairy conversions only, or all dairy land are predicted to result in an increase in in-river SIN loads of 2.5 to 20%, with associated increases in predicted maximum periphyton biomass of 1 to 10%. This is a logical outcome given that the current average N loss from dairy farms in the Rangitikei catchment (21.95 kg/ha/yr as per Dr Roygard et al.’s evidence), which is lower than the “zone average” calculated by applying the DV LUC N loss limits to the existing land area used for dairying in this zone (25 kg/ha/yr) (refer to Table 15).

**9.22** Applying the NV yr 20 limits to dairy conversions only is predicted to allow small increases in in-river SIN load under both the 11% (scenario B2: 1.6% degradation) and the 18% (scenario B6: 2.6% degradation) dairy expansion scenarios.

**9.23** Applying the NV yr 20 limits to existing dairying (B2) is predicted to result in an improvement in SIN load under the current land use (scenario B1: 3.9% improvement), both dairy expansion scenarios (scenario B3: 2.3% improvement and scenario B7: 1.3% improvement), and both dairy + cropping expansion scenarios (scenarios B4 and B8: 4.9% and 4.0% improvement respectively).

**9.24** However, if the average rate of loss of sheep and beef land was to increase by 20% (from an assumed current rate of 10 kg/ha/yr to 12kg/ha/yr), concurrently to dairy expansion (either 11% or 18%) then applying the NV yr 20 limits to all dairy land is predicted to allow an increase in in-river SIN loads (scenario A5: 8.5% degradation and scenario A9: 9.2% degradation).

*Conclusions*

**9.25** All scenarios that involve the application of LUC N loss limits (either the DV or NV yr 20 LUC-loss limits) to dairy conversions only are predicted to allow an increase in in-river SIN loads in all three catchments modelled.

**9.26** Applying the DV LUC loss limits to all dairy land in the Upper Manawatu catchment is predicted to ensure that in-river SIN loads are maintained at or close to its current levels in scenarios that include 11 or 18% increase in the area under dairying and associated support cropping.

**9.27** If the DV LUC loss limits were applied to all dairy land in the Mangatainoka catchment, then SIN loads would be maintained at or below their current levels, but only in the 11% dairy increase scenario. An 18% increase in dairying and associated cropping is predicted to result in a 3% increase in in-stream SIN loads.

**9.28** In both the upper Manawatu and Mangatainoka catchments, the DV LUC loss limits are not predicted to be sufficient to maintain SIN loads at or below their current levels if an 18% increase in dairying is associated with a 20% increase in N losses from sheep and beef farms (scenario A9). The only modelled scenarios that are predicted to result in maintaining or improving the in-river SIN loads under this situation are those applying the NV yr 20 LUC-loss limits either to all dairy land or to all dairy and cropping land (scenarios B8 and B9).

**9.29** In the Coastal Rangitikei, all scenarios applying the DV LUC loss limits are predicted to allow a degradation in in-river SIN loads and periphyton biomass. This is due to the DV LUC loss limits being higher (when applied to the Coastal Rangitikei WMZ) than the current average N-loss for dairy farms in the Rangitikei catchment.

**9.30** Only the scenarios applying the NV yr 20 LUC-loss limits to all dairy and cropping land are predicted to result in reductions in SIN loads, although not if an 18% increase in dairying is associated with a 20% increase in N losses from sheep and beef farms.

Dr Olivier Michel Nicolas Ausseil

**14 March 2012**

**Table 20: Summary of predicted in-river SIN Loads (in tonnes per year) for the Coastal Rangitikei Water management Zone upstream of McKelvies. Predicted improvement is the percentage of change from the current load or biomass to the modelled load or biomass, with a positive number indicating an improvement (i.e. a decrease in load or biomass) and a negative number indicating degradation (i.e. an increase in load or biomass). Scenarios that allow a more than 2% increase (degradation) in in-stream loads are shown in orange. Scenarios that result in a more than 2% reduction (improvement) in load are shown in blue.**

| LUC N-loss limit | Land use | | Scenario number | LUC loss limits applied to | Average N loss from dairy land (kg/ha/yr) | Modeled in-stream Non point source SIN load (T/yr) | Predicted load Improvement | Predicted periphyton biomass improvement |
|---|---|---|---|---|---|---|---|---|
| N/A | Current land use | | 0 | - | 21.95 | 203 | - | - |
| DV | Current land use | | A1 | All dairy | 25.2 | 213 | -5.0% | -2.5% |
| | 11% increase in dairy area | - | A2 | Dairy conversion | 22.3 | 208 | -2.5% | -1.3% |
| | | | A3 | All dairy | 25.2 | 218 | -7.5% | -3.7% |
| | | Cropping increase in S&B farms | A4 | All dairy | 25.2 | 240 | -18% | -8.8% |
| | | S&B intensification (12 kg/ha/yr) | A5 | All dairy | 25.2 | 240 | -18% | -8.8% |
| | 18% increase in dairy area | - | A6 | Dairy conversion | 22.4 | 212 | -4.2% | -2.1% |
| | | | A7 | All dairy | 25.2 | 222 | -9.1% | -4.5% |
| | | Cropping increase in S&B farms | A8 | All dairy | 25.2 | 243 | -19% | -9.4% |
| | | S&B intensification (12 kg/ha/yr) | A9 | All dairy | 25.2 | 243 | -20% | -9.5% |
| NV Y20 | Current land use | | B1 | All dairy | 19.4 | 195 | +3.9% | +2.0% |
| | 11% increase in dairy area | - | B2 | Dairy conversion | 21.7 | 206 | -1.6% | -0.8% |
| | | | B3 | All dairy | 19.4 | 199 | +2.3% | +1.2% |
| | | Cropping increase in S&B farms | B4 | All dairy + cropping | 19.4 | 193 | +4.9% | +2.5% |
| | | S&B intensification (12 kg/ha/yr) | B5 | All dairy | 19.4 | 220 | -8.5% | -4.2% |
| | 18% increase in dairy area | - | B6 | Dairy conversion | 21.6 | 208 | -2.6% | -1.3% |
| | | | B7 | All dairy | 19.4 | 201 | +1.3% | +0.7% |
| | | Cropping increase in S&B farms | B8 | All dairy + cropping | 19.4 | 195 | +4.0% | +2.0% |
| | | S&B intensification (12 kg/ha/yr) | B9 | All dairy | 19.4 | 222 | -9.2% | -4.6% |

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