Proposed
Hurunui and Waiau River Regional Plan

And Proposed Plan Change 3 to the Canterbury Natural Resources Regional Plan

Section 42A Report
September 2012

Implications for Water Quality

Prepared by

Edward (Ned) Norton

Water Resource Management Consultant

NIWA, Christchurch

Environment Canterbury Regional Council
Kaunihera Taiao ki Waitaha

1. Introduction

1.1 Author

1. My name is Edward John (Ned) Norton. I am a Water Resource Management Consultant at NIWA based in Christchurch. I have 17 years of experience in the field of water resource management including 10 years in water resources science at NIWA. I have previously worked for regional councils, consultancies, the University of Canterbury and NIWA's predecessor DSIR Marine and Freshwater Division (Taupo). In my position at NIWA I have lead many projects that have assessed the effects of water takes and discharges on the environment. I have contributed to a number of guidelines for the management of water quality and quantity, and to the development of several tools for water management. I have authored or co-authored several scientific publications in the field of water management.

2. I have a BSc in Microbiology and Ecology, and an MSc (1st Class Hons) in Biochemistry, both from the University of Canterbury. I also have a PMP (Project Management Professional) qualification from the Project Management Institute. I am a member of the Resource Management Law Association of New Zealand, the Freshwater Sciences Society and the Environment Institute of Australia and New Zealand.

3. My specialist area is the integration of multi-disciplinary science information related to freshwater quantity and quality resource management problems, and application to planning and management. Of particular relevance for this hearing is my experience in water quality 'limit setting' and consequences for freshwater ecology, specifically tackling cumulative effects. My work has been focused on this area for the last 10 years including:

   a. Involvement in developing concepts for measurable objectives and related limits in the early stages of development of the water quality chapter of ECan's Natural Resources Regional Plan (NRRP) (Norton and Snelder 2003);

   b. NRRP hearings (water quality chapter) in 2009 (e.g., Norton and Snelder 2009);

   c. Technical work for ECan to generate options for nutrient load limits for the upper Waitaki (Lake Benmore) catchment (Norton et al., 2009), the Hurunui catchment (Norton and Kelly 2010; and the Waihora/Ellesmere catchment (in progress);

   d. Contribution to the ECan reports *Nutrient Management in Hurunui: A Case Study in Identifying Options and Opportunities* (Brown et al., 2011) and *Developing a Preferred Approach for Managing the Cumulative Effects of Land Use On Water Quality* (ECan 2012);

   e. Technical report for MfE titled *Technical and Scientific Considerations When Setting Measurable Objectives and Limits for Water Management* (Norton et al., 2010), some of the principles of which appear in guidelines (MfE 2011) to the implementation of the National Policy Statement Freshwater Management 2011 (NPSFW);

f. Contribution to the Land and Water Forum (LAWF) including some of the key recommendations in the LAWF 1 final report (LAWF 2010);

g. Contribution to the LAWF 2 process, advising the LAWF Secretariat (e.g. Norton et al., 2011),the 'Limit Setting' sub-working group, and contribution to recommendations in the LAWF 2 final report (LAWF 2012). LAWF is tasked with making recommendations to government on aspects of limit setting, amongst other things, in 2012;

h. Numerous applied projects that required aspects of water quantity limit setting (i.e. flows and allocations): e.g. reports and evidence for Waitaki Allocation Plan, North Bank Tunnel Hydro Project, Hunter Downs Irrigation Scheme, Mokihinui Hydro Project; and

i. Numerous applied projects that required aspects of water quality limit setting (e.g., water quality objectives, standards and load limits): e.g. reports and evidence for Waitaki Allocation Plan, Hunter Downs Irrigation Scheme, Upper Waitaki (Laker Benmore) quality limit setting, ECan's Land Use & Water Quality Project limit-setting studies for the Hurunui catchment and Selwyn-Waihora catchment.

4. Although this is a Council Hearing, I have read the Code of Conduct for Expert Witnesses contained in the Environment Court's Consolidated Practice Note dated 1 November 2011. I have complied with that Code when preparing my written statement of evidence and I agree to comply with it when I give any oral evidence.

5. I have not omitted to consider material facts known to me that might alter or detract from the opinions expressed. The literature and other material which I have used or relied upon in support of my opinions is referenced throughout my evidence and listed at the end.

6. The scope of my evidence relates primarily to the effect of the HWRRP water quantity and quality limits on in-river water quality and associated ecological values, and implications for nutrient mitigation methods and the capacity for further land use intensification in the catchment. I confirm that the issues addressed in this statement of evidence are within my area of expertise, although I note that my evidence integrates several technical disciplines and therefore necessarily relies on the expertise of numerous others (as referenced to documents throughout my statement) and in particular upon the evidence of:

a. Dr Jeff Smith

b. Dr Ton Snelder

c. Mr Maurice Duncan

d. Dr Don Jellyman

e. Dr Murray Hicks

f. Mr Ian Brown

1.2 Content of the officer's report

7. This report is prepared under the provisions of section 42A of the Resource Management Act 1991 (RMA).

1.3 Explanation of terms and coding used in the report

DIN	Dissolved Inorganic Nitrogen
DRP	Dissolved Reactive Phosphorus
Headroom	Means the amount of room below a specified limit. Headroom is thus the available capacity for new resource use. When applied to nutrient load limits, headroom is the difference between the measured (or modelled) current load and the load limit specified in Schedule 1 of the HWRRP. If the current load is greater than the load limit there is no headroom and the load is deemed to be "over-allocated". Mitigations that reduce the current load can be used to "claw back" an over-allocated situation and create headroom.
HWRRP	Proposed Hurunui and Waiau River Regional Plan
HWZ	Hurunui Waiau Zone or Waiau Hurunui Zone (the area defined in the CWMS as the Hurunui Waiau Zone or Waiau Hurunui Zone. These terms have historically been used interchangeable; the Waiau Hurunui Zone is identical to the Hurunui Waiau Zone)
Load	The load of a contaminant is estimated at a given point in a river as: Load (in kg or tonnes/year) = concentration of the contaminant x flow. The load of a contaminant lost below the root zone from a given area of land can also be estimated using models such as Overseer.
Load over-allocation	Over-allocation (of a nutrient load) occurs where the current load (whether measured or estimated using models such as Overseer) is greater than the load limit.
TP	Total Phosphorus
TN	Total Nitrogen
ZC	Hurunui Waiau Zone Committee (established under the Canterbury Water Management Strategy)
ZIP	Zone Implementation Programme

2. Scope of Evidence

8. I have been asked by ECan to prepare evidence primarily in relation to the implications of the HWRRP water quantity limits (i.e. minimum flows and allocation blocks) and quality limits (i.e., load limits) on in-river water quality and associated ecological values in the Hurunui River, and implications for further land use intensification in the catchment, including consideration of whether nutrient mitigation methods could create further capacity for use.

9. I have also been asked to comment on:

   a. The merits of managing one or both nutrients;

   b. The relationship of the load limit setting approach used in the HWRRP compared to ECan's regional approach; and

   c. Some miscellaneous matters such as updating the water quality data record to include the last year of monitoring and the latest estimate of current annual nitrogen and phosphorus loads in the Hurunui River.

3. Implications for water quality and land use

3.1 Background

10. The HWRRP sets fairly clear water quality objectives for maintaining in-river outcomes for the mainstem rivers, associated with mauri, biota and habitats, periphyton, chronic nitrate toxicity for aquatic species and human consumption (Objective 5.1); and for the tributaries, outcomes associated with chronic nitrate toxicity for aquatic species and human consumption (Objective 5.2). Policies 5.1 – 5.4 set out how these objectives are to be achieved by taking a community-based best nutrient management approach, by maintaining dissolved inorganic nitrogen (DIN)[1] and dissolved reactive phosphorus (DRP) loads in the Hurunui River at 2005-2010 levels (actual numbers provided in Schedule 1 to the HWRRP) in the long term, while in the future progressively also setting nutrient limits in the tributaries and the Waiau River catchment (numbers not yet set in Schedule 1).

11. The HWRRP also sets Objective 3, to allocate water so as to enable further economic development, while ensuring that a defined list of environmental aspects including water quality and associated in-river values are achieved.

[1] DIN and DRP are dissolved inorganic forms of the nutrients nitrogen (N) and phosphorus (P) respectively. Nitrogen (N) and phosphorus (P) are the two key macronutrients required for plant (including algae) growth and occur in all living cells (being key elements in proteins and DNA amongst other things). DIN includes nitrate, nitrite and ammonia. DRP includes phosphate. Numerous other forms of nitrogen and phosphorus exist and are commonly referred to in the field of water quality (e.g. organic and particulate forms) but it is the dissolved forms DIN and DRP that are most readily available for uptake by plants and are thus most relevant for assessing effects on nuisance growths in rivers. The terms total nitrogen (TN) and total phosphorus (TP) refer to the sum total of all the forms in any given sample and these tend to be the most relevant measure for assessments in lakes and coastal waters. Nitrate and ammonia, at high enough concentrations, also have toxic effects on aquatic biota (and humans in the case of nitrate) and this effect is independent of their significance as plant nutrients.

Policies 3.1 – 3.6 then provide a three-tiered A, B, C water quantity allocation block framework that potentially makes water available according to an Environmental Flow and Allocation Regime (Table 1 of the HWRRP), provided that defined environmental conditions, including maintaining water quality, can be met.

12. There is a large amount of land (up to 100,000ha, of which about 30,000ha is currently irrigated according to the HWRRP Introduction) in the Hurunui and Waiau Zone that could be irrigated if reliable water could be sourced and distributed to that land. Unfortunately, intensified land use increases water quality contaminants in waterways (e.g. nutrients nitrogen and phosphorus, sediment and micro-organisms) and water abstraction from rivers can exacerbate water quality effects, primarily by reducing in-river dilution and by reducing the frequency and duration of freshes and floods that cleanse the riverbed.

13. The HWRRP, through Objectives 3, 5 and their related policies, is making water potentially available so as not to foreclose on future economic opportunities associated with irrigation, but has defined conditions, including water quality limits, around which that water can be taken and used. It is implicit that HWRRP water quality limits could constrain water takes and thus irrigation and economic opportunities, but the degree of constraint is not clear. It is unlikely that all of the A, B and C block water will be able to be taken and used within water quality limits at this time, but it is also possible that future innovation may reduce the constraints that currently exist.

3.2. Key question?

14. The Hurunui Waiau Zone Committee (ZC), in its Zone Implementation Plan (ZIP) set the goal of "*delivering economic growth and healthy rural* communities *through an additional 60,000ha of irrigation while ensuring environmental, Runanga, local community, and recreational values are maintained and where possible enhanced*". The key question of course is:

- How much economic growth associated with irrigation can be delivered while ensuring water quality and associated values are maintained within defined limits?

15. This is one of the key questions that the ZC has grappled with, and around which they have acknowledged there is considerable uncertainty and risk that all elements of the goal may not be achievable to the maximum extent at this time. ECan has asked me to address this question.

3.3. Assessment approach

16. The key factors that influence the answer to the above question are:

    a. The defined HWRRP water quality-related outcomes (Objective 5.1 and 5.2) and the in-river DIN and DRP load limits deemed necessary to attain concentrations that achieve those outcomes;

    b. The current measured DIN and DRP loads to the Hurunui River mainstem and the four main tributaries, and the difference between these current loads and the load limits;

c. The effect that taking more water has on the river flow regime (including dilution and flushing flows) and therefore the change to the DIN and DRP load limits that would be necessary to attain concentrations that achieve the same (HWRRP Objective 5.1 and 5.2) defined in-river outcomes[2];

d. The amount of "headroom"[3] that can be created for new development by using different types of mitigation measures currently available to reduce existing nutrient loads from current land use; and

e. The amount of extra nitrogen and phosphorus load that would be generated by using a specified amount of new water for a specified area and type of new intensified land use, with specified new mitigation.

17. The first factor in the above list (i.e. desired in-river outcomes) is fixed in the proposed HWRRP as described at paragraph 10, even though the load limits necessary to achieve those outcomes must vary if flow regime varies (see footnote). The second factor is also fixed in that measured estimates of current loads are available. The remaining three factors can each be estimated for any given scenario, either in absolute terms or, more coarsely, as a relative percentage increase or decrease compared to the current situation. By summing the increases and decreases (relative to the load limit) across the latter three factors, it is possible to estimate whether the load limit and associated in-river water quality outcomes will be achieved under any given scenario.

18. One way of doing this would be to take a specific development proposal, identify what that proposal means quantitatively for each of the latter three factors above, and then use that information to assess whether that proposal would achieve the defined water quality-related outcomes. However this requires detailed knowledge of individual project proposals that is not available to me and is beyond the scope of my evidence for this hearing. As an alternative I have identified various sources of general (non-project specific) information that can be used to quantify the above factors for a set of defined hypothetical (but realistic) future scenarios. I have used this approach to broadly assess the extent to which various water allocation scenarios contemplated in the HWRRP could actually be undertaken while still achieving the Plan's in-river water quality outcomes. This is a high level

[2] A fundamental concept is that a catchment load limit is not an end in itself – rather it is a number that is calculated to achieve an in-river contaminant concentration that will support a desired in-river outcome, the latter being of ultimate importance. Because 'load' = 'flow' x 'concentration' it is obvious that the load needed to achieve a given concentration will vary as flow regime changes. By definition then, a load limit is only valid for the flow regime assumed for its calculation (as described for the Hurunui case in Norton and Kelly 2010). My entire analysis for this evidence is premised on the assumption that the load limit must be recalculated if there are substantial changes to the flow regime. I provide further comments on this and the use of load limits in planning generally in Section 5 of my evidence.

[3] The term "headroom" used in my evidence means the difference between the load limit and the current load. If the current load is lower than the load limit then the difference is the amount of headroom that is available. If the current load (whether modelled or measured) is greater than the load limit there is no headroom and the load is deemed to be "over-allocated". Mitigations that reduce the existing load can be used to claw back over-allocated load and even create headroom. Headroom can also be thought of as the available "capacity for use"; i.e. the catchment can accommodate new activities that generate additional contaminant load equal to the amount of headroom available.

assessment that I consider is appropriate for a plan hearing. The assumptions and uncertainties associated with this approach are described in Section 3.4 below. In future, perhaps during consent hearings, project–specific assessments could refine these assumptions and further reduce the uncertainty around predictions.

3.4. Information sources and analysis

HWRRP outcomes, load limits and measured current load estimates

19. For my analysis I have used load limits for the Hurunui mainstem sites (Mandamus and State Highway 1) from HWRRP Schedule 1. For the tributaries I have used the recommended load targets and current load estimates in Tables 6 and 7 of the report *Nutrient Management in Hurunui: A Case Study in Identifying Options and Opportunities* (Brown et al., 2011). The methods for calculating load limits and estimating current loads from in-river measurements is described in Norton and Kelly 2010. All the numbers I have used are shown in Attachment 1.

Water allocation scenarios

20. I have used the five water allocation scenarios discussed in the evidence of Andrew Parish to reflect the range of water abstraction that may be allowable for the Hurunui River under the HWRRP (see Table 1).These are exactly the same flow allocation scenarios used by other witnesses for ECan and are described in detail in the evidence of Dr Smith. A synthetic flow record was produced for each scenario by Dr Smith. Hydrological statistics and graphics were produced for each scenario by Dr Snelder and hydrological differences between the scenarios are described in the evidence of Dr Snelder. I obtained mean flow statistics for each scenario from Dr Snelder and used the relative difference between mean flows for each scenario and the Status Quo to estimate the relative change in annual flow volume and therefore dilution of annual nutrient (DIN and DRP) load for each scenario. The effects of each scenario on dilution (as a percentage compared to the Status Quo) are shown in Attachment 1. I have relied on the evidence of Dr Snelder for his assessment of the effect of each scenario on mid-range flows including flushing flows and thus the frequency of nuisance periphyton blooms.

21. I note that my approach here is based on simple dilution of annual load by annual volume and is insensitive to seasonal variations in load and flow; such seasonal considerations may be possible for future assessments that consider specific development proposals but are beyond the scope of my evidence.

Table 1. **Flow scenarios assessed for the Hurunui River. Scenarios assume that the full water allocation block indicated (A, B or C) is taken for fully consumptive use, and while abiding by the minimum flow rules listed beneath the table. For a full description of these scenarios see the evidence of Dr Smith.**

Scenario number	Scenario name	A-block (m^3s^{-1})	B-block (m^3s^{-1})	C-Block (m^3s^{-1})
1	Status Quo	-		
2	ABlockOnly	7		
3	AandBblocks	7	10	
4	ABCSeasonal	7	10	16.5 (Autumn and Spring) 33 (Winter)
5	ABCAllYear	7	10	33 (All year)

A-block minimum flows are 15 m^3s^{-1} September to April and 12 m^3s^{-1} for May to August.
B and C-block minimum flows are 27 m^3s^{-1} and 37 m^3s^{-1} respectively from September to April and 19 m^3s^{-1} and 29 m^3s^{-1} for the rest of the year.

Mitigation scenarios

22. I have relied on the mitigation options and estimates of likely success that were used for the LUWQ (Hurunui) Project and reported in the *Hurunui catchment-scale land use and water quality modeling report* (Lilburne et al., 2011). Specifically, I have used the predicted percentage reduction in total nitrogen (TN) and total phosphorus (TP) loads for the mitigated current scenario reported in Table 9 (i.e., from CLUES modelling) and predicted reduction in nitrate loads for the mitigated current scenario reported in Table 11 (i.e. from AquiferSim modelling).

23. The mitigation methods and effectiveness assumed for modelling were summarized in Table 4 of Lilburne et al. (2011). These came from: i) Lilburne et al. (2010) - for nitrate reduction efficiency of converting border-dyke irrigation to spray irrigation; and ii) Monaghan et al. (2010) – for a range of other measures including (for dairy farms) reduced winter grazing, lower N fertilizer application rates, strategic placement of wetlands, use of low-N feed, and best practice for effluent management, and (for sheep and beef farms) riparian protection and strategic placement of wetlands. Lilburne et al. (2011) applied these mitigations to their modelling work taking into consideration the soil characteristics of the Hurunui catchment and the actual existing situation with regard to current land use and the amount of border dyke irrigation in each tributary sub-catchment.

24. The mitigation measures are also described in Appendix 6 of Brown et al. (2011). There are obvious implications of these mitigation measures at the farm scale including: i) considerable variability in effectiveness between farms (e.g. Robson and Dunham 2012; Monaghan et al. 2010); ii) significant cost to implement; and iii) significant time to fully implement. Mr Brown describes some of these farm scale and implementation issues in his evidence. In my analysis I assume that the effectiveness numbers reflect the long term average potential reductions possible at a catchment scale, taking into account spatial variability and implementation time. In this respect my analysis, like that of Lilburne et al. (2011), is optimistic. I do not consider implementation costs.

25. For my analysis I followed Lilburne et al. (2011) in grouping the mitigations into three simple categories. These are: i) 'No mitigation'; ii) 'Border-dyke to spray' which assumes conversion of all current border dyke to spray irrigation; and iii) 'Full Tier 1 and 2 mitigation' which assumes the maximum possible implementation of all mitigation measures considered. The percentage load reductions I have used for each of these three categories are shown in Attachment 1. A list of Tier 1 and Tier 2 type mitigation practices is shown in Attachment 2. I also reiterate the discussion emphasised in Lilburne et al. (2011) that there is considerable uncertainty around how effective each mitigation measure might be. I am comfortable though, that the numbers used are provided by leading experts in this field (e.g. Dr Monaghan) and are the best estimates currently available for this kind of analysis.

26. While my analysis considers full mitigation to be Tier 1 and Tier 2 type measures (e.g. Attachment 2), I note that there may also be options for mitigation at the catchment scale, such as large scale constructed wetlands, that may provide even further load reductions (i.e. these are sometimes referred to as Tier 3 measures). ECan commissioned NIWA (Dr Chris Tanner) to investigate the potential for large scale wetlands in the St Leonards and Lowry Peaks streams catchments. As described in his evidence to this hearing, Dr Tanner has predicted that around 200 ha of wetlands in total could reduce DIN loads in each of those streams by half or more (Tanner 2012). This prediction is similar to the load reductions assumed for full mitigation in St Leonards Stream (see Attachment 1). It is uncertain just how much further load reduction could be achieved by employing such large scale (i.e. Tier 3) wetlands in ***addition*** to other (Tier 1 and 2) reduction measures upstream; it is certainly not valid to simply add together the reduction percentages for different measures but there would likely be some additive benefit. I have not attempted to include an assessment of the additive benefit of Tier 3 measures and this remains a topic for consideration at the project-specific level. The cost of catchment scale (Tier 3) wetlands is substantial, in the order of $9-15 million for the fully constructed 200ha examples in the St Leonards and Lowry Peaks catchments (Tanner 2012). I also note the possibility that future innovation will throw up new methods and/or increase the efficiency of current methods.

Intensification scenarios

27. I have used the intensification scenarios (Scenarios 2a and 3) assessed for the LUWQ (Hurunui) Project and reported in Brown et al. (2011) and Lilburne et al., 2011). I am not aware of any other work where predictions have been made for increased nutrient loads under any future scenario with specified area and type of new land use. I presume that the developers of specific scheme proposals in the catchment would be undertaking such predictions, but for my purpose here the LUWQ project Scenarios 2a and 3 provide good hypothetical (but realistic) future development scenarios. The scenarios assessed in Brown et al. (2011) and Lilburne et al. (2011) are:

- Scenario 2a: Business as usual 2030. There is some intensification in line with historical trends. All border-dyke irrigation is converted to spray irrigation.

- Scenario 3: Extensive (~25,000 ha new) irrigation. There is full irrigation of suitable land. All border-dyke irrigation is converted to spray irrigation.

28. In order to estimate the net effect of these intensification scenarios on nutrient loads, I used Lilburne et al. (2011) Table 9 (i.e., predictions from CLUES modelling) to calculate the percentage increase in TN and TP between the current situation with assumed full mitigation applied (i.e. their 'Scenario 1 + full mitigation') and their 'Scenario 2a + mitigation' and 'Scenario 3 + mitigation' respectively. I applied these proportional increases to DIN and DRP loads respectively, making the assumption that the proportional effect on total nutrients would be similar to dissolved nutrients, an assumption that has been used throughout the Hurunui LUWQ project. The numbers I used are shown in Attachment 1.

Integrating water quantity and quality considerations

29. Finally I note that the LUWQ (Hurunui) project technical work (e.g. Brown et al. (2011), Lilburn et al. (2011), Norton and Kelly (2010) and others) did not, for a number of reasons at the time, factor into the analyses possible changes to the Hurunui River flow regime that might arise as a result of taking further water to support Scenario 3 intensification. Then, as now, several possible water sources and delivery mechanism options were being considered. My analysis for this evidence addresses this short-coming by integrating the predictions for Scenario 2a and 3 load increases, estimates of mitigation options effectiveness, current measured nutrient load status relative to the HWRRP limits ***and*** altered flow regime scenarios.

3.5 Results

30. I summed the relative DIN and DRP load increases and decreases (due to reduced dilution and mitigation respectively), and factored in the current measured load, to estimate for each scenario whether there was still "headroom available"[4] or whether "load over-allocation" occurred (Tables 2 and 3). In Tables 2 (DIN) and 3 (DRP) the orange cells show scenarios where there is load over-allocation. Green cells show scenarios where sufficient headroom is created for development to the extent of LUWQ Project Scenario 3 (i.e. ~25,000 ha new intensification). Yellow cells show marginal headroom available for lesser development. The blue columns show the percentage load increases predicted for Scenarios 2a and 3, which can be compared with the amount of headroom available (i.e. where negative values appear in the coloured cells to the left).

[4] See explanations for the terms "headroom" and "over-allocation" in footnote 2 in Section 3.3.

Table 2. **Available capacity (i.e. 'headroom') available for DIN load, compared to predicted load increases under development scenarios.** (Potential capacity estimates are based on data sources shown in Table A1.1. Predicted load increases for intensification scenarios are calculated from CLUES modelling outputs in Lilburne et al. (2011).)

		Potential headroom for DIN load (% of current) created by mitigation, assuming various water take scenarios that affect dilution (-ve numbers indicate headroom created; +ve numbers indicate load over-allocation)					Predicted load increase (% of current + mitigation) under two intensification scenarios modelled in ECan LUWQ Project	
Dissolved Inorganic Nitrogen (DIN)	Mitigation options	Status Quo	A Block Only	A and B blocks	ABC Seasonal	ABC All Year	Scenario 2a (efficiency gains)	Scenario 3 (25,000 ha new)
Hurunui SH1	No mitigation	0	2	17	34	43	10	29
	B-dyke to spray	-19	-17	-2	15	24		
	Tier 1 & 2 mitigation	-30	-28	-13	4	13		
Hurunui @ Mandamus	No mitigation	0	2	17	34	43	1	1
	B-dyke to spray	n/a	n/a	n/a	n/a	n/a		
	Tier 1 & 2 mitigation	n/a	n/a	n/a	n/a	n/a		
Waitohi 1.6km u/s Hurunui	No mitigation	-28	-28	-28	-28	-28	32	51
	B-dyke to spray	-28	-28	-28	-28	-28		
	Tier 1 & 2 mitigation	-46	-46	-46	-46	-46		
Pahau @Dalzells	No mitigation	7	7	7	7	7	16	24
	B-dyke to spray	-35	-35	-35	-35	-35		
	Tier 1 & 2 mitigation	-53	-53	-53	-53	-53		
Dry Stream	No mitigation	-279	-279	-279	-279	-279	22	69
	B-dyke to spray	-327	-327	-327	-327	-327		
	Tier 1 & 2 mitigation	-339	-339	-339	-339	-339		
St. Leonards Stream	No mitigation	49	49	49	49	49	24	24
	B-dyke to spray	21	21	21	21	21		
	Tier 1 & 2 mitigation	-9	-9	-9	-9	-9		

Table 3. **Available capacity (i.e. 'headroom') available for DRP load, compared to predicted load increases under development scenarios.** (Data sources are as described for Table 2 above.)

		Potential headroom for DRP load (% of current) created by mitigation, assuming various water take scenarios that affect dilution (-ve numbers indicate headroom created; +ve numbers indicate load over-allocation)					Predicted load increase (% of current + mitigation) under two intensification scenarios modelled in ECan LUWQ Project	
Dissolved Reactive Phosphorus (DRP)	Mitigation options	Status Quo	A Block Only	A and B blocks	ABC Seasonal	ABC All Year	Scenario 2a (efficiency gains)	Scenario 3 (25,000 ha new)
Hurunui SH1	No mitigation	0	2	17	34	43	1	1
	B-dyke to spray	-2	0	16	32	42		
	Tier 1 & 2 mitigation	-9	-7	8	25	35		
Hurunui @ Mandamus	No mitigation	0	2	17	34	43	0	0
	B-dyke to spray	0	2	17	34	43		
	Tier 1 & 2 mitigation	-2	-1	15	31	41		
Waitohi 1.6km u/s Hurunui	No mitigation	20	20	20	20	20	4	12
	B-dyke to spray	20	20	20	20	20		
	Tier 1 & 2 mitigation	-2	-2	-2	-2	-2		
Pahau @Dalzells	No mitigation	34	34	34	34	34	2	4
	B-dyke to spray	29	29	29	29	29		
	Tier 1 & 2 mitigation	15	15	15	15	15		
Dry Stream	No mitigation	20	20	20	20	20	6	-6
	B-dyke to spray	10	10	10	10	10		
	Tier 1 & 2 mitigation	-4	-4	-4	-4	-4		
St. Leonards Stream	No mitigation	20	20	20	20	20	0	0
	B-dyke to spray	1	1	1	1	1		
	Tier 1 & 2 mitigation	-18	-18	-18	-18	-18		

31. The following observations can be made from Tables 2 and 3:

Effects of flow allocation on water quality

32. As total allocation increases through the scenarios (left to right in Tables 2 and 3), dilution decreases in the Hurunui mainstem and therefore the in-stream concentration of nutrients increases. Thus, the nutrient load that the environment can accommodate while still achieving the defined in-river outcomes (i.e. Objective 5.1) decreases with increasing allocation. In effect this means the load limits given in HWRRP Schedule 1 would need to be recalculated if significant additional water is taken. Based on the estimates of reduced dilution in Attachment 1, if only the full A block is taken the load limit would only need to be reduced by 2%, which is likely within the margins of error and could perhaps be ignored. However if the full B block is taken (in addition to A block), the load limit would need to be reduced by 17%. If C block water is taken only on a seasonal basis ('ABC Seasonal' scenario) the load limit would need to be reduced by 34%, while under the 'ABC All Year' scenario load limits would need to be reduced by 43%.

33. There is no decreased dilution effect in the tributaries because water is assumed to be taken only from the mainstem. There would in fact likely be increased flow (and therefore possibly a small increase in dilution) to some tributary reaches as a result of increased groundwater levels and stream contribution under further irrigation. This has not been included in my analysis and would need to be assessed on a project-specific basis.

34. Tables 2 and 3 show only the dilution effects of allocation scenarios. When the effects of reduced flushing flows for periphyton are also included (Dr Snelder's evidence) there is a double impact (decreased dilution and decreased flushing flows) for periphyton and associated values in the Hurunui mainstem, particularly under the 'ABC Seasonal' and 'ABC All Year' scenarios. I will integrate both of these effects in my final conclusions at Section 3.6. There is no decreased flushing flow effect in the tributaries.

Implications for each river/stream

35. For the Hurunui mainstem at SH1, Table 2 suggests there could be DIN load capacity for significant new irrigation (i.e. Scenario 3 ~25,000 ha) if full mitigation (Tier 1 and 2) is adopted throughout the catchment and only A block water is taken. If B block water is also taken then there is perhaps only capacity for half that intensification. It seems unlikely there would be capacity for further land-use intensification if A, B and C block water is taken. For DRP the pattern is similar, although Table 3 suggests that taking B block water might put DRP limits out of reach. Certainly allocating C block water makes the DRP load limit unattainable.

36. For the Hurunui mainstem at Mandamus there is little ability to create headroom with mitigation and so any further water taken from the Hurunui above Mandamus creates a nutrient over-allocated situation. However it seems unlikely, based on current water quality at Mandamus (data not shown) that A and B block takes would create a real risk for periphyton-related environmental values at this site, assuming no further load is added from the hill country (Note that downstream is of course another matter as described in the paragraph above). This would need to be considered on a project-specific basis and the load limit in HWRRP Schedule 1 would need to

be recalculated if water is allowed to be taken from above Mandamus. The LUWQ Project Scenarios 2a and 3 did not anticipate further significant DIN or DRP load from land use above Mandamus. I note that Tier 1 and Tier 2 mitigation options were not considered for land above Mandamus and so this part of my analysis is incomplete.

37. For the Waitohi River, Table 2 suggests there would be DIN capacity for significant new intensification if Tier 1 and 2 mitigation measures are adopted but Table 3 suggests that phosphorus load limits could be difficult to achieve. This analysis is based on Tables 2 and 3 only and does not consider the effects (potentially both positive and negative) of a large storage option in the Waitohi catchment. Such considerations would require knowledge of project specific details.

38. For the Pahau River, Table 2 suggests that ample headroom could be created for DIN for new intensification but again DRP limits appear difficult to achieve, even with Tier 1 and 2 mitigation measures.

39. For Dry Stream, Table 2 shows there is currently ample headroom for DIN. Table 3 shows again that DRP is challenging, but significant new development seems feasible if Tier 1 and 2 mitigation measures are employed.

40. For St Leonards Stream, Tables 2 and 3 show that Tier 1 and 2 mitigation measures will be necessary to create any headroom at all for both DIN and DRP, and this might be enough for some new development but not to the extent of Scenario 3.

41. I note that my analysis has treated all the tributaries equally in terms of water quality requirements and this implies an assumption that they are valued equally. I have taken this approach because the HWRRP does not distinguish any difference in the way individual tributaries are valued by the community. However it is my observation that the Waitohi and Pahau Rivers are probably more highly valued than Dry Stream and St Leonards Stream, certainly in terms of ecological values (data not shown).

Comment on the links between loads and the objectives they are intended to achieve

42. For the Hurunui mainstem the load limits set in HWRRP Schedule 1 are based on achieving current (2005-2010) water quality. The most nutrient-sensitive aspect of Objective 5.1 is maintaining the current frequency of nuisance periphyton growths and therefore habitat conditions for other biota and for mauri. Nitrate toxicity concentrations are higher than those needed to maintain periphyton conditions and so it was the latter rather than the former that was the driving influence for the load limit numbers set in Schedule 1. In this respect the link between the load limits and Objective 5.1 is relatively clear.

43. For the tributaries, no load limits are set in HWRRP Schedule 1. For the tributaries Objective 5.2 refers only to nitrate toxicity and specifically does not mention controlling periphyton. The DIN load targets I have used (from Brown et al. 2011) in this analysis were derived to achieve the nitrate toxicity criteria of 1.7 mg/L (deemed to protect 95% of aquatic species as per Hickey and Martin 2009). Implicit in this is that DIN loads would be allowed to increase

above concentrations that could cause frequent nuisance periphyton blooms unless other factors limit growth. The hope is (from LUWQ Project stakeholder and HWZC discussions) that limiting DRP loads in the tributaries to 1990-95 levels (i.e. approximately a 20% reduction from current) will, by virtue of being the limiting nutrient, control periphyton growth despite elevated DIN (Brown et al. 2011). However because Objective 5.2 does not mention controlling periphyton at all, the DRP load targets I have used from Brown et al. (2011) for the tributaries may be unnecessarily low. If nuisance periphyton (and associated ecological effects) were to be an accepted consequence of intensive development in the tributaries, then tributary DRP load limits could be relaxed in the tributaries. Such a decision has not yet been made because Policy 5.4 delays the setting of nutrient limits in the tributaries for some future time. In this respect the link between load targets and Objective 5.2 is not entirely clear and remains to be clarified in future. I will address in more detail the topic of nutrient limitation and the merits of targeting only one nutrient in Section 4 of my evidence.

3.6. Conclusions

44. In responding to the key question; *how much economic growth associated with irrigation can be delivered while ensuring water quality and associated* values *are maintained within defined limits?* - I conclude that:

45. It is not possible at this time to take and use full HWRRP A, B and C block Hurunui River water for intensified agricultural land use and stay within water quality limits designed to achieve HWRRP Objectives 5.1 and 5.2.

46. Some further land use intensification in the Hurunui catchment would be possible while achieving water quality limits provided that extensive (i.e. Tier 1 and 2) mitigation measures are employed. The cost of such measures would be significant although I have not made a detailed assessment of this. If no mitigation is employed the catchment is, by definition, currently fully nutrient load allocated.

47. It is not possible to be definitive about exactly how much water could be taken and how much land irrigated because the answer will depend on project-specific options for water take, storage and distribution details that are not considered in my analysis. However my high level analysis suggests that allocating A and B blocks will push close to water quality limits, and allocating C block water will almost certainly result in water quality deterioration and failing to achieve Objectives 5.1 and 5.2, primarily due to significantly reduced dilution and flushing flows combined with increased nutrient loads.

48. It seems plausible that further intensification in the order of LUWQ Project Scenario 3 (~25,000ha) could, assuming A block water and full Tier 1 and 2 mitigation measures, achieve water quality objectives in the Hurunui mainstem at SH1, but some compromise of tributary water quality would be likely, even with full mitigation. The wording of Objective 5.2 provides a focus on nitrate toxicity for the tributaries and this may well be achievable with full Tier 1 and 2 mitigation and catchment-scale wetlands. However phosphorus load targets are more challenging under Scenario 3 and it is likely that nuisance periphyton would increase in the tributaries, causing some deterioration in ecological and other values. The relative value the community holds for the tributaries, compared to the mainstem and also between

tributaries (e.g. Waitahi and Pahau are higher value than Dry and St Leonards Streams) is a relevant consideration.

49. There is considerable uncertainty in this assessment that arises from many sources in each of the steps in the analysis. This is reflected in the multiple reports by many contributors that I have relied on. This uncertainty is unavoidable at this time and is greater for my high level analysis than would be the case for a detailed project-specific analysis. In particular there is uncertainty around how to ensure that mitigation measures are implemented on the ground, and how effective they will be. There is also uncertainty around the predicted links between nutrient load limits and the in-river outcomes (i.e. periphyton cover and biomass, and toxicity) they are designed to achieve.

50. It is possible that the HWRRP may stimulate future innovation that may improve mitigations and identify creative water delivery and river flow regime solutions that could increase the amount of irrigation possible within defined water quality limits. It seems sensible to me not to foreclose on that future possibility. However it does seem unlikely to me that the full C block allocation could be achieved at this time without significantly relaxing environmental objectives.

51. Finally, I have provided a high level summary of my predictions of the consequences of Scenario 3 (~25,000ha) development, with Tier 1 and 2 mitigation measures, and under different flow allocation scenarios, for various water quality-related indicators that relate to HWRRP outcomes, in the matrices in Attachment 3. That assessment is based on the analysis I have presented in my evidence, as well as my interpretation of the evidence of Dr Snelder, Dr Hicks, Mr Duncan and Dr Jellyman, and using references from the LUWQ (Hurunui) project.

4. Comments on managing one or both nutrients

52. It is important to consider the management of both nitrogen and phosphorus because they are the two major nutrients influencing aquatic plant (e.g. periphyton and macrophyte) growth and, in addition, elevated concentrations of nitrogen in the form of nitrate (NO_3) and ammonium (NH_4) are toxic to animals (including humans).

53. There are situations where water resource managers might want to consider the merits of targeting the control of one nutrient over the other, generally with the intention of limiting the growth of periphyton and/or macrophytes by ensuring that at least one nutrient is limiting for growth. In theory if one of the two major nutrients is limiting the other one may increase with little impact on plant growth. However this is a risky strategy for a number of reasons as documented comprehensively for the New Zealand situation by Wilcock et al (2007), Young (2007) and Larned et al. (2011), including:

a. The limiting nutrient at a given location can change at daily, seasonal or multiple year timescales;

b. Simultaneous limitation by both nutrients (i.e. co-limitation) can occur; and

c. Algae in upstream and downstream reaches of the same river, tributaries and estuaries (e.g. Hapua) may be limited by different nutrients.

54. In short, the recently documented consensus amongst several leading New Zealand experts on this topic is that managing both nutrients is generally the least risky and usually most appropriate strategy.

55. Nonetheless when the economic consequences of controlling both nutrients is high, the pressure to take risk increases and there has been much discussion in the Hurunui catchment about targeting phosphorus rather than nitrogen for controlling the effects of land-use intensification on nuisance periphyton and associated ecological, amenity and recreation values. The argument for considering this option is based on: i) the fact that nutrient data show that phosphorus has likely been most commonly the limiting nutrient in the lower Hurunui mainstem (SH1) in the past (Hayward 2011a and b; which relies on Ausseil 2010 and Wilks 2008, 2009); and ii) that the high economic cost (to land users) of limiting nitrogen justifies taking some level of risk on environmental values. My observation during the process was that the dairy industry advocated this approach.

56. The HWRRP (Schedule 1) DIN and DRP load limits are based on managing both nutrients with no relaxation of the DIN limit that would put reliance on the DRP limit. However the tributary DIN and DRP load targets stated in Brown et al. (2011) (and used in my analysis in Section 3 of my evidence) are based on a strategy that targets phosphorus control to limit periphyton in the tributaries. Of course it is not feasible to have no control or standard for DIN at all, because nitrate is toxic to aquatic life at higher concentrations than those enabling nuisance periphyton growths. The DIN load targets for the tributaries stated in Brown et al. (2011) are based on allowing nitrate concentrations of 1.7mg/L, the criteria deemed to protect 95% of aquatic species as per Hickey and Martin (2009) stated previously. As I have already mentioned (at paragraph 43) the tributary load targets in Brown et al. (2011) are not part of the HWRRP and remain an option for the future under Policy 5.4.

57. My view is that targeting phosphorus limitation for controlling periphyton growth and relaxing nitrogen control up to nitrate toxicity levels is, without any doubt at all, a risky strategy. There is an increased risk of nuisance periphyton ***and*** an increased risk of chronic nitrate toxicity effects, as I described in a presentation to the ZC (Norton 2011b). Any increase in phosphorus load, such as that which could result from an increase in phosphate fertilizer use for sheep and beef production in the hill country, could cause increased problems under this strategy[5]. However it appears that the costs associated with mitigation measures to control nitrogen (e.g. Hayward 2011a and b) may justify debate and consideration of this managed risk strategy (I have not assessed these costs). It is a value judgement as to whether the costs justify the risk taken on the environment. I note that the risk to the environment would be significantly greater if this strategy were used for setting load limits

[5] Note that the current phosphorus load (and therefore the DRP load limits in Schedule 1 of the HWRRP) is based on measurements over the last five years, during which time I understand there would have been little fertiliser use in the hill country due to the poor returns for sheep and beef production. While this is not my area of expertise I understand from conversations at ZC meetings that recent improved returns for sheep and beef production could stimulate the desire for increased fertiliser use in the hill country. A nutrient management strategy that targets and relies on phosphorus control clearly has implications for such land use in the hill country.

for the Hurunui mainstem because ecology, amenity and recreation values are significantly greater than in the tributaries. Finally I think it is important that future decisions made on this matter of single targeted nutrient control are transparent. By this I mean that the environmental risks are acknowledged – the available science knowledge does not support single nutrient management in general (i.e. Wilcock et al. 2007; Young 2007; Larned et al. 2011).

5. Comments on using load limits in management and planning

58. Nutrient load limits have the potential to be a very useful tool and part of the solution for tackling cumulative effects of non-point source pollution, an Achilles Heel in water resource management for many years. For example, the analysis I presented in Section 3 of my evidence has estimated the capacity for resource use at the catchment scale, predicted how that capacity changes with changes to river flow regime, and predicted how a given amount of land use intensification takes up that capacity. This would not have been possible using analysis based just on in-river concentrations of nutrients and periphyton biomass or river-bed cover objectives.

59. However a catchment load limit (i.e. a load limit calculated at or near the bottom of the catchment defining the sum total sustainable load for the whole catchment) only defines the “size of the pie” (i.e. the resource) for the whole catchment. In my view, management of cumulative effects will not be fully achieved until a mechanism is in place for allocation of that resource (i.e. “the pieces of pie”) such that it becomes clear what the responsibility is at the level of each property owner. The regional approach that ECan is currently developing (i.e. the draft Land and Water Regional Plan, ECan 2012b) proposes that the allocation mechanism will use nutrient discharge allowances (NDAs) at the farm or enterprise level. NDAs define the amount of nutrient load that each individual landowner can discharge in order that the whole catchment is managed to a budget and within the catchment load limit.

60. The allocation of NDAs is important for a number of reasons, not least because it makes the limit clear for each landowner and thus assists resource use investment decisions[6]. By contrast, periphyton (river-bed cover) and other environmental objectives, in-river nutrient concentrations and even total catchment load limits themselves, are not meaningful criteria to an individual land owner. While the analytical linkages between in-river objectives, nutrient concentrations, catchment load limits and NDAs are important, it is the NDA that provides meaningful criteria at the farm level. Figure 1 below illustrates these linkages.

---

[6] Landowners are able to use farm-scale models such as OVERSEER® to estimate the current nutrient discharge from their land, as well as predict losses associated with any intended development and/or mitigation practices, and compare these against their allocated NDAs.

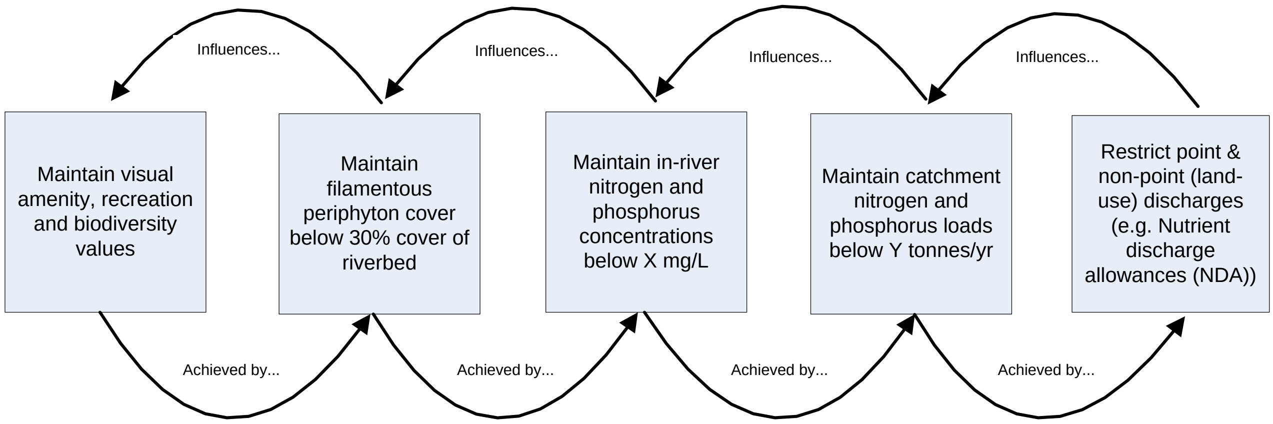

Figure 1. Illustration of the chain of linkages between in-river values, periphyton outcomes, nutrient concentrations, catchment load limits and NDAs.

61. The HWRRP was developed over a timeframe in parallel to the ECan draft Land and Water Regional Plan and has been drafted before the information necessary to define and allocate NDAs has been produced. My observation is this led to the HWRRP using its catchment load limits in a different way – as a monitoring-based "trigger" mechanism for defining permitted activity status (i.e. Rule 10.2 makes land use change a permitted activity provided (amongst other conditions) that the annual monitored DIN and DRP loads in the Hurunui River are below the Schedule 1 limits). While I understand the motivation for this given the information available when the HWRRP was drafted, I do not believe that this mechanism (i.e. Rules 10.1 to 11.2) is the best way to manage cumulative effects ***or*** provide clarity to resource users for their future investment decisions. There are a number of reasons for this and key amongst these are:

a. Setting only catchment load limits in a plan, without converting those limits through to NDAs (or other similar allocable quantity), does not make clear the responsibility of individual landowners. This may reduce the likelihood of achieving environmental outcomes and hinder resource use investment decisions.

b. Annual nutrient loads are estimated by calculation using recorded flow measurements and nutrient sample data, and are imprecise and highly variable inter-annually. It will only be possible to observe any meaningful trends in measured load estimates over many years (i.e. >5 years). From a technical perspective they are therefore a poor basis for a trigger mechanism. There is as much chance as not that the annual load estimate will exceed the Schedule 1 limit in the first year[7] and thus place all land use changes into the 'discretionary'

[7] I note that one way to reduce this problem, as identified and sought in submissions by the Hurunui Waiau Zone Committee, is to use the measured rolling 5 year average DIN and DRP loads (rather than the most recent annual measurement) to compare against the Schedule 1 limits. With a rolling 5 year average approach the limit trigger would tend not to be breached due to a one-off high measured load (such as might occur in a particularly wet year) and would tend to only be breached when several years of consistently high load are measured. This would have the effect of reducing "false" triggers that are

activity category, requiring the consent process to resolve the cumulative effects of multiple applications. In-river nutrient concentrations exhibit less measurement variability than loads and would be better for use in trigger mechanisms generally. However this would not solve other concerns listed here.

c. The trigger mechanism (Rule 10.2) may fail to prevent over-allocation (of nutrient assimilative capacity) because of time lag. There is an estimated time lag in the order of seven years (Lilburne et al. 2011) for nitrogen load lost from land in some parts of the catchment to travel through soil into groundwater and on to the monitoring point in the Hurunui at SH1. Therefore land use changes may be permitted (with no quantitative regulatory nutrient control) for years before the effect is picked up by the Rule 10.2 trigger mechanism. In theory the catchment could be over-allocated by seven years of development-related load increase before this is picked up in monitoring at SH1.

d. The load limits set in Schedule 1 are relevant only for the current river flow regime. As described previously the numbers need to be recalculated for scenarios where further water is taken. As described in section 3.5 the load limits should be reduced by at least 17%, 34% and 43% under allocation scenarios 'A and B block', 'ABC Seasonal' and 'ABC All Year' respectively[8].

62. In my view the catchment in-river DIN and DRP load limits for the Hurunui at SH1 (adjusted to account for future takes) should ultimately be converted through to load limits that apply at the farm (taking account of attenuation between the farm and the SH1 monitoring point, background natural load, and point discharges), and should then be allocated amongst users in the catchment using a budgeting system based on NDAs or similar mechanism. Neither the 'conversion' nor 'allocation' process is simple, and while work by ECan is progressing this (e.g. ECan 2012b; Lilburne and Webb 2012), I'm not aware that it is ready to be included at this stage for the HWRRP. A decision is needed on how to signal this in an appropriate way for this stage of the HWRRP's evolutionary development. I think key elements are:

a. Defining clear in-river outcomes. ECan proposed amendments to Policies 5.1-5.2 increase clarity for the outcomes sought, both in terms of in-river periphyton and nitrate concentrations to stay within toxicity criteria. I support these amendments.

b. The Schedule 1 DIN and DRP load limits need to be adjusted to account for future takes.

c. The trigger mechanism (Rule 10.2) could be complemented or replaced by an NDA (or equivalent) system, whether this be a future

---

due to natural flow variation, but would increase the time taken before a real increasing trend would trigger Rule 10.2(a).

[8] Note that the percentage reductions given take account of the simple reduced dilution that results from further takes and this adjustment would be expected to achieve current nutrient concentrations in the river at SH1. However this adjustment does not take account of changes to the frequency of flushing flows and associated effects on in-river periphyton objectives described in Dr Snelder's evidence – accounting for this would require a more complicated calculation and would further reduce the load limits, significantly in the case of ABC block scenarios.

amendment to the HWRRP or in a non-statutory arrangement that builds on the ‘industry benchmarks’ indicated in the Environmental Management Strategy described in the ECan proposed amendments to Schedule 2.

63. While there may be concern in the local community about NDAs, it is my view that if cumulative effects are to be managed, sooner or later the catchment load limit will need to be allocated in some meaningful way at the land owner level. NDAs would provide a mechanism for this and would overcome the time lag problem because control is applied at the load source. In addition allocation (e.g. by NDAs) creates an incentive for more efficient use of nutrients and implementation of mitigations that are needed to create the headroom desired for new development. If allocation (e.g. by NDAs) does not occur through a regional plan process (or alternative non-statutory arrangement), it will be left to the consent process to handle multiple applications for discretionary activities (under Rule 11.2) when, almost inevitably in time, the annual monitored nutrient loads will exceed the Schedule 1 limits.

64. From my observation of discussions at Zone Committee meetings and elsewhere I can see that there are advantages and disadvantages of both a regulatory and non-regulatory approach to establishing an NDA system. However, regardless of whether a regulatory or non-regulatory approach is used, it is my view that the following quantitative components will be important for an effective system for managing cumulative effects:

a. It is necessary to understand (by using Overseer or similar tool) what the current nutrient losses are from all land uses in the catchment. This will allow a relationship to be developed between the current estimated load in the river (based on measurements at SH1) and the current estimated (i.e. modelled) load from land uses. Without knowing the sum total of all current nutrient losses from land uses it will not be possible to keep an account of the amount of headroom created by mitigations, the amount of headroom taken up by new development, and/or the extent of any over-allocation. Cumulative effects cannot be quantitatively managed unless these factors are accounted.

b. It is useful to establish what is meant by “Good Practice” in terms of nutrient loss rates in kg/ha/year for all land use types because this defines the minimum expectation for each and all land users. In combination with an account of all current losses described in the bullet above, this would enable determination of how much headroom would be available for new development when all existing users are doing the minimum required.

c. A subsequent step, once the two steps above are established, could be to assess how much more mitigation effort over and above the minimum “Good Practice”, and/or what catchment scale mitigations (e.g. large wetlands), might be needed to create sufficient headroom for newcomers.

N Norton

24 September 2012

References

Ausseil, O. (2010). Hurunui River – Influence of the middle reaches on water quality of the Lower Hurunui River (2005-2008). Environment Canterbury Report No. R08/55.

Brown, I., Norton, N., Wedderburn, L., Monaghan, R., Harris, S., Ford, R. (2011). Nutrient Management In Hurunui: A Case Study In Identifying Options And Opportunities. ECan Report No. R11/114 (ISBN 978-1-927195-43-7).

ECan (2012). The preferred approach for managing the cumulative effects of land use on water quality in the Canterbury region – A working paper, January 2012.

ECan (2012b). Draft Land and Water Regional Plan – A staff working draft, April 2012.

Hayward, S. (2011a). Alternative water quality limits for the Hurunui case study area. A draft discussion paper prepared by Dairy NZ, 19 August 2011, 7p.

Hayward, S. (2011b). Options for alternative nutrient limits in Hurunui case study. Presentation to the Hurunui Waiau Zone Committee meeting, 22 August 2011.

Hickey, C.W.; Martin, M.L. (2009). A review of nitrate toxicity to freshwater aquatic species. Environment Canterbury Report No. R09/57.

Land and Water Forum (2010). Report of the Land and Water Forum: A Fresh Start for Fresh Water. Wellington, New Zealand. ISBN: 978-0-478-33296-4. www.landandwater.org.nz

Land and Water Forum (2012). Second Report of the Land and Water Forum: Setting Limits for Water Quality and Quantity Freshwater Policy- and Plan-Making Through Collaboration. Wellington, New Zealand. ISBN: 978-0-473-21471-5. www.landandwater.org.nz

Larned, S., D. Hamilton, J. Zeldis and C. Howard-Williams, (2011). Nutrient-limitation in New Zealand rivers, lakes and estuaries: a discussion paper. Prepared for Land and Water Forum, Wellington, New Zealand, September 2011, 19p.

Lilburne, L., Elliott, S., Bidwell, V., Shankar, U., Kelly, D., Hanson, C. (2011) Hurunui catchment-scale land use and water quality modelling report. Environment Canterbury Report No. R11/15 (ISBN: 978-1-927161-09-8), 51p.

Lilburne, L., Webb, T., Ford, R., Bidwell, V. (2010). Estimating nitrate-nitrogen leaching rates under rural land uses in Canterbury. Environment Canterbury report R10/127.

Lilburne, L., Webb, T. (2012). An equal-allocation method for allocation of a total nutrient load within a nutrient management zone. Environment Canterbury Report No. R12/36 ISBN 978-1-927210-28-4 (electronic).

Ministry for the Environment (2011) *National Policy Statement for Freshwater Management 2011: Implementation Guide*. Wellington: Ministry for the Environment.

Monaghan, R.M., Semadeni-Davies, A., Muirhead, R.W., Elliott, S., Shankar, U. (2010). Land use and land management risks to water quality in Southland. Report prepared for Environment Southland.

Norton, N., Rouse, H.L., Snelder, T. (2011). Limiting diffuse pollution: an approach to science informed policy development. Paper and presentation to the 15th International Conference of the IWA Diffuse Pollution Specialist Group, 18-23 September 2011, Rotorua, New Zealand.

Norton, N. (2011b). Considering environmental consequences of alternative N limits for the Hurunui River. Presentation to the Hurunui Waiau Zone Committee meeting, 22 August 2011.

Norton, E.J.; Snelder, T.H.; Rouse, H. (2010). Technical and Scientific Considerations When Setting Measurable Objectives and Limits for Water Management. NIWA Client Report CHC2010-060, 50 p, prepared for Ministry for the Environment, Wellington.

Norton, N. and Snelder, T. (2003). Options for numeric water quality objectives and standards for lakes and rivers of Canterbury. NIWA Client report: CHC2003-026, prepared for Environment Canterbury, Christchurch.

Norton, N.; Snelder, T. (2009). On measurable objectives and receiving water quality standards for Environment Canterbury's Proposed Natural Resources Regional Plan. ECan Report No. R09/19. NIWA Client Report CHC2009-040.

Norton, E. J., and Kelly, D. J. (2010), "Current Nutrient Loads and Options for Nutrient Load Limits for a Case Study Catchment: Hurunui Catchment," *ENC10515*, CHC2010-088, 60 p.

Norton, E.J.; Spigel, R.H.; Sutherland, D.L.; Plew, D.R.; Trolle, D. (2010). Lake Benmore water quality : a modelling method to assist with setting limits for sustainable irrigation development. Presentation and article published in Proceedings of the Water New Zealand Conference, Christchurch, N.Z., [11]p

Robson, M.; Dunham, G. (2012). Land use and water quality project – On farm management practices, mitigations and costs. Draft report for Environment Canterbury.

Tanner, C.C. (2012). Potential of wetlands to reduce nutrient loads from Lowry Peaks and St Leonard's Drains to the Waiau and Hurunui Rivers. NIWA Client Report no. HAM2012-015. Prepared for Environment Canterbury.

Wilcock, B, Biggs, B., Death, R., Hickey, C., Larned, S., Quinn, J. (2007). Limiting nutrients for controlling undesirable periphyton growth. NIWA Client Report HAM2007-006. Prepared for Horizons Regional Council, February 2007, 43p.

Wilks, T. (2008): Nutrient limitation assays and periphyton production. Environment Canterbury internal report, June 2008.

Wilks, T. (2009): Hurunui River Nutrient Tray Results 2009. Environment Canterbury internal report.

Young R. (2007). Review of report on “Limiting nutrients for controlling undesirable periphyton growth (Wilcock et al. 2007)”. A review letter prepared for Horizons Regional Council, June 2007, 3p.

Attachment 1. Data used and source references for load limits, measured loads, dilution and mitigation estimates.

Table A1.1 Data and sources used for dissolved inorganic nitrogen (DIN)

Dissolved Inorganic Nitrogen (DIN)	Load Limit (DIN) (target in the case of tributaries) (tonnes/year)[1,2]	Current Measured Load (tonnes/year)[2]	Current load over-allocation (%) (-ve means spare capacity)	Over-allocation in DIN load caused by reduced dilution under six water allocation scenarios (as % of current load)[3]: Natural	Status Quo	A Block Only	A and B blocks	ABC Seasonal	ABC All Year	Load reduction achieved with mitigation (%)[4]: No mitigation	B-dyke to spray	Tier 1 & 2 mitigation
Hurunui SH1	693	693	0	-13	0	2	17	34	43	0	-19	-30
Hurunui @ Mandamus	40	40	0	-13	0	2	17	34	43	0	0	0
Waitohi 1.6km u/s Hurunui	86	67	-28	0	0	0	0	0	0	0	0	-18
Pahau @Dalzells	182	196	7	0	0	0	0	0	0	0	-42	-60
Dry Stream	53	14	-279	0	0	0	0	0	0	0	-48	-60
St. Leonards Stream	68	133	49	0	0	0	0	0	0	0	-28	-58

Footnotes:
1. Load limits from HWRRP Schedule 1.
2. Tributary load targets and current measured loads from Brown et al. (2011).
3. Percentage reduced dilution calculated using the percentage change in estimated annual mean flow for each scenario provided by Dr Smith and Dr Snelder.
4. From Lilburn et al. (2011), who used Monaghan et al. (2010) and Lilburn et al. (2010).

Table A1.2 Data and sources used for dissolved reactive phosphorus (DRP)

Dissolved Reactive Phosphorus (DRP)	Load Limit (DRP) (target in the case of tributaries) (tonnes/year)[1,2]	Current Measured Load (tonnes/year)[2]	Current load over-allocation (%) (-ve means spare capacity)	Over-allocation in DRP load caused by reduced dilution under six water allocation scenarios (as % of current load)[3]: Natural	Status Quo	A Block Only	A and B blocks	ABC Seasonal	ABC All Year	Load reduction achieved with mitigation (%)[4]: No mitigation	B-dyke to spray	Tier 1 & 2 mitigation
Hurunui SH1	10.2	10.2	0	-13	0	2	17	34	43	0	-2	-9
Hurunui @ Mandamus	3.6	3.6	0	-13	0	2	17	34	43	0	0	-2
Waitohi 1.6km u/s Hurunui	0.28	0.35	20	0	0	0	0	0	0	0	0	-22
Pahau @Dalzells	1.46	2.2	34	0	0	0	0	0	0	0	-5	-19
Dry Stream	0.4	0.5	20	0	0	0	0	0	0	0	-10	-24
St. Leonards Stream	0.48	0.6	20	0	0	0	0	0	0	0	-19	-38

Footnotes:
1. Load limits from HWRRP Schedule 1.
2. Tributary load targets and current measured loads from Brown et al. (2011).
3. Percentage reduced dilution calculated using the percentage change in estimated annual mean flow for each scenario provided by Dr Smith and Dr Snelder.
4. From Lilburn et al. (2011), who used Monaghan et al. (2010) and Lilburn et al. (2010).

Attachment 2. Some mitigation practices of relevance to cattle-grazed farming enterprises in the Hurunui catchment (reproduced with permission from Brown et al. 2011)

Mitigation practice	Effectiveness[1], %	Cost-effectiveness	Comment
<u>Tier 1 practices</u>			
Improved management of FDE (storage; low rate and low depth application)	20 (P)	High	Of most relevance to heavy or poorly-drained soils; will also help reduce faecal pollution
Increased irrigation efficiency (improved uniformity of application, scheduling according to need, capture of irrigation by-wash etc)	Modest reductions in N leaching; ~10%?	High	Border dyke by-wash capture will also help to reduce P losses
Stock exclusion from streams and wetlands	High for P	High	Many ancillary benefits such as habitat protection, fewer stock losses etc
Nutrient management plans	High (P and N)	High	
<u>Tier 2 practices</u>			
Use of nitrification inhibitors	10-15 (N)	High	
Wintering cows in Herd Shelters	32 (N)	Medium	High capital cost
Wintering in Herd Shelter+ Restricted grazing of pastures in autumn	49 (N)	Medium	High capital cost
Limiting N fertiliser use	40 (N)	Low	Large reductions in profit
Changing from border dyke to spray irrigation	20 (P)	High	High capital cost, but does bring production benefits
Tracks and lanes sited away from streams & lane runoff diverted to land	Medium	High	Important for minimising localised impacts on streams
Substituting N-fertilised pasture with low N feeds	Modest	Medium	Cost-effectiveness very dependent on milk payout price and cost of low N feed supplement
Grass buffer strips	Modest to low	Low	
Facilitating the development of natural wetlands	Medium for N, high for sediment	Medium	Efficiency at removing faecal bacteria
Constructed wetlands	High for N, sediment and faecal bacteria	Low	

[1]Percentage values documented are those derived from the farm-scale modelling undertaken for the Hurunui LUWQ project and reported in Brown et al. (2011).

Attachment 3. Scenario evaluation tables

Introduction to scenario evaluation tables

This introduction to 'scenario evaluation tables' sets out the purpose of the tables and is therefore relevant for all ECan expert witnesses assessing aquatic environment aspects of the HWRRP.[9]

In order to provide a summary of the environmental effects expected under each of the water allocation scenarios, we have developed 'scenario evaluation tables' that use a common presentation style to show the extent to which we expect the HWRRP objectives and policies will be achieved under each scenario. It is intended that these evaluation tables will provide a succinct, colour-coded, visual summary of the key conclusions from each technical assessment that can be easily integrated across the different technical disciplines to generate an overall picture of the consequences of each scenario.

The scenario evaluation tables use a common format, with each column representing a flow allocation scenario and each row representing a type of environmental outcome taken from an identified HWRRP objective or policy. Because there is uncertainty associated with predicting most of the aquatic environment effects, we use a four-class system whereby scenarios are judged 'almost certainly', 'probably', 'possibly' or 'unlikely' to achieve the desired HWRRP outcomes (Figure A3.1).

Almost Certainly	Probably	Possibly	Unlikely

Figure A3.1. Four-class system used to assess the probability of achieving HWRRP outcomes

It is intended that this presentation system will make uncertainty transparent and will inform risk-based decision making. In general, scenarios that score green ('almost certainly' and 'probably') are associated with the least risk for environmental values while scenarios that score yellow ('possibly') or red ('unlikely') are associated with more, and most, risk for environmental values respectively. Obviously consideration of other values, such as the economic and social benefits associated with taking more water for development, may justify taking some level of risk. Such decisions could be informed by comparing our evaluation tables with social and economic assessments.

The method used to assign whether each scenario is 'almost certainly', 'probably', 'possibly' or 'unlikely' to achieve each HWRRP outcome varies between the witnesses for each technical discipline and each witness has described their own method. However the common principles are:

i. Where the HWRRP sets numerical objectives these have been used for the table rows;

[9] Ned Norton, Ken Hughey, Ton Snelder, Murray Hicks, Maurice Duncan, Don Jellyman

ii. Where the HWRRP sets narrative objectives, some measurable expression of those objectives has been assumed for the purpose of assessing the probability of achieving outcomes; assumptions have been stated for transparency;

iii. Assignment of the four probability classes uses a repeatable method based on defining numerical thresholds to assign scenarios to one of the four categories, or some other logically robust, rule-based and repeatable method.

Method for water quality scenario evaluation tables

The methods used to assign the four probability classes to water quality-related HWRRP outcomes in my scenario evaluation tables are as follows:

Periphyton (Biomass <120 mg/m^2 and filaments <20% cover in 4 out of 5 years)

This outcome comes from HWRRP Objective 5.1c and the ECan submission proposed new Policy 5.1. This outcome is, based on current monitoring data, currently achieved in the Hurunui at SH1 approximately four years out of five, so maintaining current nutrient concentrations and flow regime would achieve this outcome. The analysis in Tables 2 and 3 show that the scenarios ‘Status Quo’ and ‘A Block Only’ could achieve sufficient headroom for the LUWQ Scenario 3 (~25,000ha new development) provided that Tier 1 and 2 mitigations are employed, so these scenarios are given a ‘probably’. Table 2 shows scenario ‘A and B Block’ could achieve about half the required headroom for DIN but no headroom for DRP (Table 3), so this scenario is given a ‘possibly’. Both scenarios for ABC blocks are unable to achieve any headroom at all for DIN (Table 2) or DRP (Table 3) despite Tier 1 and 2 mitigations. This situation, combined with significantly reduced frequency of flushing flows and increased flat-lining described in Dr Snelder’s evidence, means both these scenarios are given ‘unlikely’.

Visual water clarity

It is assumed that maintaining current visual water clarity is important for maintaining mauri, recreation, cultural and amenity values under HWRRP Objective 5.1a and c. Because all flow allocation scenarios are assumed in my analysis to include full conversion of existing border-dyke to spray irrigation *and* Tier 1 and 2 mitigations, I have assessed (using simple qualitative judgement[10]) that current visual water clarity would ‘almost certainly’ be achieved. Note that this assessment places heavy reliance on border-dyke conversions and other mitigations being successfully implemented.

Microbiological health and safety

Similar to the assessment for visual water clarity, it is assumed that maintaining at least the current level of attainment of microbiological recreation guidelines (*E. coli* concentrations) is important for maintaining mauri, recreation, cultural and amenity values under HWRRP Objective 5.1a and c. Again placing reliance on conversion of existing border dyke to spray irrigation *and* Tier 1 and 2 mitigations, it is assessed (using simple qualitative judgement[6]) that microbiological health and safety would ‘probably’ be achieved for ‘Status Quo’, ‘A Block Only’ and ‘A and B Block’ scenarios. Scenarios for ‘ABC Seasonal’ and ‘ABC All Year’ are given ‘possibly’ due to the

[10] No quantitative analysis has been undertaken for this outcome indicator.

significantly greater difficulty in achieving low *E. coli* concentrations with the greater loss of dilution (34% and 43% respectively) under these scenarios.

Benthic biodiversity

It is assumed that invertebrate indices such as QMCI and EPT are relevant indicators for meeting HWRRP Objective 5.1b (biota). It is also assumed that these indices would respond to the amount of periphyton biomass in the river and that the periphyton assessment therefore provides a reasonable proxy for benthic biodiversity. On this basis the same assessment categories are given as for the periphyton outcome above.

Trout habitat and angling

It is assumed that this outcome (related to HWRRP Objective 5.1b and c) is directly related to the periphyton outcome; i.e. achieving a biomass of <120mg/m^2 is deemed to support trout habitat and angling values in the New Zealand Periphyton Guidelines (MfE 2000). On this basis the same assessment categories are given as for the periphyton outcome above.

Nitrate toxicity for aquatic biodiversity (~1.7 mg/L)

This outcome relates to HWRRP Objective 5.1d. This outcome is currently easily met in the Hurunui at SH1. Based on simple consideration of reduced dilution under the 'A Block Only' (2%), 'A and B Block' (17%), 'ABC Seasonal' (34%) and 'ABC All Year' (43%), and the level of headroom created by Tier 1 and 2 mitigations (Table 2), it is assessed that this outcome would 'almost certainly' be achieved under all scenarios.

Nitrate toxicity for human drinking (~11.3 mg/L)

This outcome relates to HWRRP Objective 5.1e. This outcome is almost an order of magnitude easier to achieve than the nitrate toxicity for aquatic biodiversity outcome above. It follows therefore that this outcome would also 'almost certainly' be achieved under all scenarios.

Results

Scenario evaluation tables for water quality-related outcomes at the Hurunui mainstem (SH1 and Mandamus sites) and the four main tributaries are shown on the following pages.

Results for Hurunui mainstem at SH1 bridge

Table A2.1. Hurunui @ SH1: Likelihood of achieving HWRRP water quality-related outcomes (see notes) under six flow allocation scenarios, assuming LUWQ Scenario 3 (~25,000 ha new land development) with full Tier 1 and 2 mitigation measures.

ACHIEVES…	Scenarios…					
	Natural	Status Quo	A Block Only	A and B Blocks	ABC Seasonal	ABC All year
Periphyton[1] Biomass <120 mg/m[2] Filaments <20% cover 4 out of 5 years	Almost Certainly	Probably	Probably	Possibly	Unlikely	Unlikely
Visual water clarity[2]	Almost Certainly	Almost Certainly	Almost Certainly	Almost Certainly	Almost Certainly	Almost Certainly
Microbiological health and safety[2]	Almost Certainly	Probably	Probably	Probably	Possibly	Possibly
Benthic biodiversity[3] (invertebrates QMCI, EPT response to algae)	Almost Certainly	Probably	Probably	Possibly	Unlikely	Unlikely
Trout habitat & angling[4]	Almost Certainly	Probably	Probably	Possibly	Unlikely	Unlikely
Nitrate toxicity for aquatic biodiversity[5] (~1.7 mg/L)	Almost Certainly	Almost Certainly	Almost Certainly	Almost Certainly	Almost Certainly	Almost Certainly
Nitrate toxicity for human drinking[6] (~11.3 mg/L)	Almost Certainly	Almost Certainly	Almost Certainly	Almost Certainly	Almost Certainly	Almost Certainly

Notes:
1. HWRRP Objective 5.1c and ECan submission proposed new Policy 5.1.
2. HWRRP Objective 5.1a and c (mauri, recreation, cultural and amenity values).
3. HWRRP Objective 5.1b (biota).
4. HWRRP Objective 5.1b and c.
5. HWRRP Objective 5.1d.
6. HWRRP Objective 5.1e.

Results for Hurunui mainstem at Mandamus

Table A2.2. Hurunui River @ Mandamus: Likelihood of achieving HWRRP water quality-related outcomes (see notes) under six flow allocation scenarios, assuming LUWQ Scenario 3 (~25,000 ha new land development) with full Tier 1 and 2 mitigation measures.

ACHIEVES...	Scenarios...					
	Natural	Status Quo	A Block Only	A and B Blocks	ABC Seasonal	ABC All year
Periphyton[1] Biomass <120 mg/m^2 Filaments <20% cover 4 out of 5 years	Almost Certainly	Almost Certainly	Probably	Probably	Possibly	Possibly
Visual water clarity[2]	Almost Certainly	Almost Certainly	Almost Certainly	Almost Certainly	Almost Certainly	Almost Certainly
Microbiological health and safety[2]	Almost Certainly	Almost Certainly	Probably	Probably	Possibly	Possibly
Benthic biodiversity[3] (invertebrates QMCI, EPT response to algae)	Almost Certainly	Almost Certainly	Probably	Probably	Possibly	Possibly
Trout habitat & angling[4]	Almost Certainly	Almost Certainly	Probably	Probably	Possibly	Possibly
Nitrate toxicity for aquatic biodiversity[5] (~1.7 mg/L)	Almost Certainly	Almost Certainly	Almost Certainly	Almost Certainly	Almost Certainly	Almost Certainly
Nitrate toxicity for human drinking[6] (~11.3 mg/L)	Almost Certainly	Almost Certainly	Almost Certainly	Almost Certainly	Almost Certainly	Almost Certainly

Notes:
1. HWRRP Objective 5.1c and ECan submission proposed new Policy 5.1.
2. HWRRP Objective 5.1a and c (mauri, recreation, cultural and amenity values).
3. HWRRP Objective 5.1b (biota).
4. HWRRP Objective 5.1b and c.
5. HWRRP Objective 5.1d.
6. HWRRP Objective 5.1e.

Results for Hurunui tributaries

Table A2.3. Four Hurunui tributaries: Likelihood of achieving HWRRP water quality-related outcomes (see notes) in the four tributaries, assuming LUWQ Scenario 3 (~25,000 ha new land development) with full Tier 1 and 2 mitigation measures. Note that the Hurunui mainstem flow allocation scenarios make no difference to these predictions.

ACHIEVES…	Waitohi 1.6km u/s Hurunui	Pahau @ Dalzells	Dry Stream	St Leonards Stream
Periphyton[1] Biomass <200 mg/m^2 Filaments <30% cover 4 out of 5 years	Possibly	Unlikely	Possibly	Possibly
Visual water clarity[2]	Probably	Probably	Probably	Probably
Microbiological health and safety[2]	Possibly	Possibly	Possibly	Possibly
Benthic biodiversity[3] (invertebrates QMCI, EPT response to algae)	Possibly	Unlikely	Possibly	Possibly
Trout habitat & angling[4]	Possibly	Unlikely	Possibly	Possibly
Nitrate toxicity for aquatic biodiversity[5] Ann. avg. <1.7 mg/L Ann. max. <2.4 mg/L	Possibly	Probably	Probably	Possibly
Nitrate toxicity for human drinking[6] (~11.3 mg/L)	Almost Certainly	Almost Certainly	Almost Certainly	Almost Certainly

Notes:
1. ECan submission proposed new Policy 5.2a (excluding St leonards).
2. No direct link to HWRRP objectives or policies for this indicator.
3. No direct link to HWRRP objectives or policies for this indicator.
4. No direct link to HWRRP objectives or policies for this indicator.
5. HWRRP Objective 5.2a and ECan submission proposed new Policy 5.2b (excluding St Leonards).
6. HWRRP Objective 5.2b.