

**Nutrient Management in
Hurunui: A Case Study in
Identifying Options and
Opportunities**

Report No. R11/114

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Executive summary

This report records the main conclusions of the pilot study of how the cumulative effects of land use on water quality should be managed in the Hurunui catchment. The project was conducted in 2010 and 2011 through three work streams considering policy, science and community issues respectively.

The Hurunui catchment was chosen because of the mixture of existing land uses, the reasonable level of resource information for the catchment and the established relationships with landowners.

The appropriateness of Hurunui for the pilot study was confirmed by the review of the state of water (conducted as part of the study) that concluded that occasional breaches of the desired outcomes in the lower Hurunui in the past, and persistent breaches in the tributaries, have justified consideration of a limit-setting approach for managing the cumulative effects of land use in the catchment on surface and groundwater quality.

Land use in the catchment is dominated by sheep and beef (almost 50% of the land area) with dairy the third largest identified land use with 7952 ha (4% of the land area), all of which is irrigated. There is significant potential for dairy expansion but this is dependent on irrigation.

Modelling shows that dairying (on the dairy platform) yields the highest N and P losses per hectare of any use in the catchment. A broader analysis, however, shows dairy has the lowest N loss per dollar of profit. This reflects the high returns from dairying relative to other uses. This relatively high return from dairy translates into a significant contribution to economic and social conditions in the catchment and more broadly (as assessed by GDP, employment and population growth indicators).

In that context, the pilot designed a process for setting load limits that took account of the social, economic, cultural and environmental costs. It did this by the use of scenarios of different future development options (different levels of land use intensification, irrigation and mitigation).

Modelling was carried out to show the various economic, social, cultural and environmental costs of each development scenario together with an assessment of the probability of the desired outcomes (including the water quality objectives of the NRRP) being achieved under each scenario⁶.

The results of that modelling exercise were debated through a community deliberation process. There was a general acceptance that the option that would 'probably' achieve all environmental outcomes was the appropriate risk management approach. This value judgement reflects an acceptance of only modest risk of breaching environmental outcomes - i.e. outcomes are likely to be

⁶ This evaluation was carried out in the knowledge that the limitation of nutrient loss through controlling land use and land management practices was only part of the toolbox of potential broad scale solutions. The management of flow regimes and water temperature/riparian management were also recognised as critical in achieving water quality objectives and community acceptance of land use change.

achieved most, but not all, of the time and occasional breaches were, upon weighing all values, tolerable for the Group.

Importantly, this position was reached only after there had been a failure of the process to agree on development scenario given very different perceptions of risk of achieving environmental objectives amongst stakeholders. That disagreement led to the development of a new scenario (that would “probably” achieve the objective) that was based on a staging of development that would provide for monitoring and adaptive management in future

The scenario that would “probably” achieve the Canterbury Natural Resources Regional Plan objectives in the Hurunui main stem is a “current use”/maintain water quality at 2005-2009 levels. For the tributaries it meant a land use scenario that would lead to improvement on the current state (i.e. Scenario B returning to 1990-1995 water quality). All parties agreed with that although it was also recognised that further analysis with the inclusion of river flow regime information, and deliberations were needed to confirm or otherwise the acceptance of these limits.

That issue aside, the Hurunui pilot study did generate useful analytical and synthesising work, identified innovative approaches and underpinning principles that represent broad agreement over the general approach to be used going forward (as well as identifying the main tensions between stakeholders).

Importantly, the community deliberation process indicated that given the uncertainty around the science and the large scale of development/irrigation schemes development may need to be staged as a risk management/adaptive management strategy. There are, however, costs associated with such an approach and further work would need to be done on the feasibility of staging when any firm development proposal is put forward.

In addition to advocating the setting of a catchment development strategy and associated catchment nutrient loads, the project considered the mechanisms to implement the approach. This report touches on these implementation mechanisms. These implementation mechanisms are further discussed in the accompanying report *“Developing a Preferred Approach for Managing the Cumulative Effects of Land Use on Water Quality” (2011)*.

To take the preferred approach forward in the Hurunui it is recommended:

1. That further steps are taken to confirm an agreed development scenario and nutrient load limits for the tributaries. These steps should include a more finely-grained analysis of costs and benefits and should include a further community deliberation stage.
2. That where there is sufficient certainty with load calculations nutrient load limits be considered for inclusion in the Hurunui Waiau catchment plan. Where there is significant uncertainty (as will likely be the case for the tributaries) load limits should remain interim and sit outside the regional plan.
3. That the Hurunui-Waiiau Zone Implementation Programme be the primary vehicle for coordinating water quantity and quality management with the management of land use effects.

1 Introduction

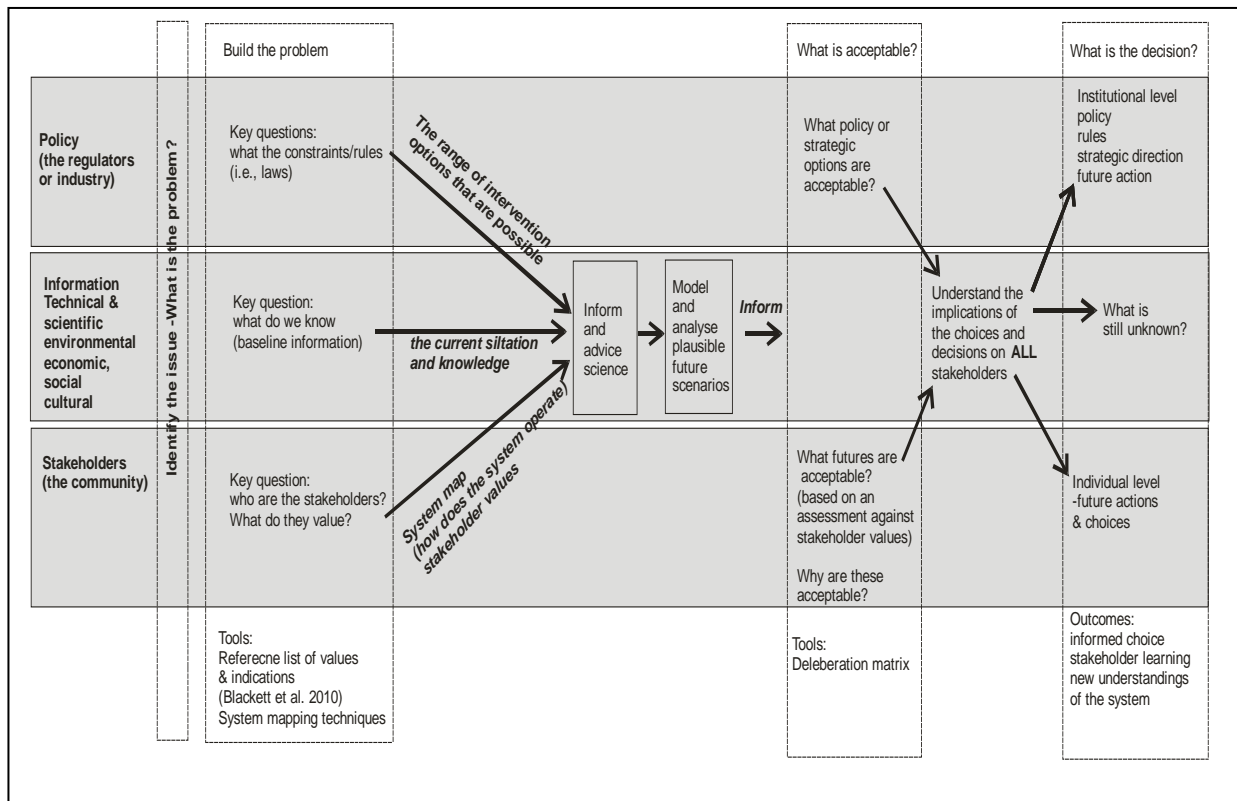
Developing effective policies for managing the cumulative effects of diffuse discharges is currently one of the most challenging resource management issues, at both a national and regional level. In Canterbury the Land Use and Water Quality (LU&WQ) project is attempting to address this issue in a collaborative manner, using a broad-thinking and pragmatic approach. It has initiated work by piloting an approach to managing land use effects in the Hurunui catchment. This report documents the Hurunui case study – how it was undertaken and what it concluded in terms of future land use in the Hurunui.

The lessons learned from this have been developed into a model for use elsewhere in Canterbury. That model is described in the companion report “*Developing a Preferred Approach for Managing the Cumulative Effects of Land Use on Water Quality*”.

2 The pilot methodology

The work programme to develop the preferred approach involved three distinct work streams; policy, science and community. These three work streams and the linkages between them are presented in Figure 1.

Figure 1 - The process used to develop the preferred approach



2.1 Policy work stream

The policy work stream provided the overall framework for the project and the key questions to be answered. The key questions included:

1. What are the nutrient loss targets required to sustain water quality expectations?
2. In applying these targets what are the trade-offs at farm, catchment and regional level from an economic, social and cultural perspective?
3. What is the feasibility from an economic and practicality perspective of achieving the levels of change required at farm level?
4. What does “good nutrient management practice” look like?
5. How much flexibility should be allowed in applying available tools (must do activities / should do activities)?
6. How best can nutrients be allocated in a fair and equitable manner?
7. What are the drivers or catalysts for change?
8. How do we avoid making irreversible decisions?
9. How fast do we have to move?
10. How do we make this work at a catchment level and capitalise on the opportunities for offsets e.g. wetlands etc?
11. How do we monitor performance against the management objectives at farm and catchment scale?
12. What do we need to do to future proof the system (research – tomorrow’s solutions)?

Significant analysis around many of these questions was undertaken by the policy work stream members.

2.2 Science work stream

The science work stream informed the other two work streams generally by describing:

- i) current water quality and associated values;
- ii) the effects of land-use intensification on water quality and related values;
- iii) options for limits that could be used to manage cumulative effects;
- iv) options for mitigation measures to reduce adverse effects.

The intention was to build on existing knowledge and resource management processes wherever possible. The research and applied science fields have been accumulating knowledge necessary to tackle cumulative water quality effects over the last several decades. However a key challenge for this project was to harness current science knowledge and apply it for policy development within a community-engaged process. In doing so the science work stream built on earlier approaches to

addressing cumulative effects in the NRRP (e.g. Snelder and Guest 2000; Ford and Taylor 2006; Norton and Snelder 2003, 2009; Hayward et al. 2009) and aimed for consistency with the Canterbury Water Management Strategy (CWMS) and recent recommendations arising out of Government's Fresh Start For Freshwater (2010) and the Land and Water Forum report (2010). The science work stream was also influenced by initiatives in other parts of New Zealand, in particular Horizons' development of nutrient limits in their proposed One Plan (e.g. Roygard and McArthur 2008) and the setting of nutrient load limits to manage cumulative water quality effects in Lake Taupo and the Rotorua lakes by Environment Waikato and Environment Bay of Plenty respectively. The approach is consistent with that recently recommended in a review for the Ministry of the Environment of science considerations for limit setting in water management (Norton et al. 2010).

2.3 Community work stream

The issues surrounding the cumulative impacts of land use of water quality are characterised by complexity and uncertainty, and a lack of consensus on their definition and the most appropriate solutions. In recognition of this a systems approach coupled with a deliberative process was used as the basis for the community work stream. A systems approach provides a way of understanding change, uncertainty and complexity. Systems approaches also provide a way of identifying leverage points, potential obstacles or barriers and potentially, any unintended consequences of actions and decisions. Systems methodologies were used at both organisational and community levels.

At the organisation level it was recognised that a 'preferred approach' could not be developed in isolation from the organisations that would influence its development and implementation. In order for us to gain an understanding of the role that these organisations may have on creating and influencing the "common problem" and identifying potential means of addressing it, a series of contextual workshops were held with key stakeholders and organisations to elicit the information.

At community level, five catchment workshops involving 11 different stakeholder groups were held between October 2010 and February 2011. The purpose of the catchment workshops was to inform and guide the development of the preferred approach by considering the links between land, water and people, and by using a multi-party deliberative approach to assess the consequences of a range of possible future scenarios on stakeholder values.

The Resource Management Act (1991) places sustainable management in the context of a balance between environmental, economic, social and cultural values. Different communities and groups within communities hold these values in differing relationships. The deliberation process used allowed each stakeholder group to clearly articulate their values and to assign a relative weighting within and between the environmental, economic, social and cultural "well-beings". Stakeholders were asked to judge the acceptability or unacceptability of a range of future land use scenarios against these values.

Quotes from the catchment workshops

"that being exposed to the differing viewpoints changed their own outlook. By consolidating opinions and views it has made things clearer"

"It was good to hear the views of stakeholders and it did highlight the differences in opinion".

The deliberation process used is recognised as a means of enhancing collective learning between various stakeholder groups and also as a means of evaluating stakeholder trade-offs between value sets. However, while considerable information and insight into the value sets of the various parties was gained, the full benefits in terms of a trade-off analysis were not realised because of time constraints. Some changes to the way in which the process is used elsewhere in Canterbury are recommended, to ensure that a full trade-off analysis takes place.

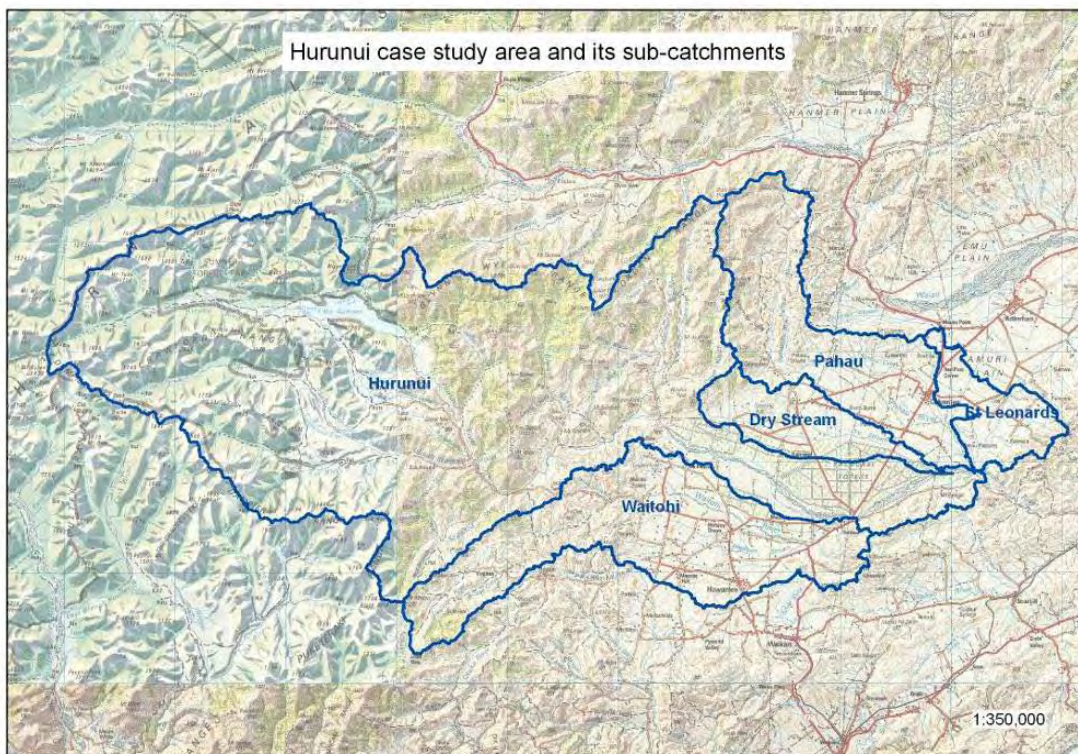
3 Biophysical, economic, social and cultural baseline information

3.1 Description of the Hurunui case study area

The Hurunui catchment was chosen as a case study because of its existing mixture of land uses and their cumulative impacts on water quality, a situation that mirrors other catchments in the region. A good working relationship between landowners and Environment Canterbury has also been established in the Hurunui catchment, while a reasonable amount of resource information (water quality and flow data) is available with which to test various nutrient management options.

The Hurunui case study area comprises 210,000 ha within the Hurunui catchment, stretching from near Harpers pass in the Southern Alps to the Lowry Peaks gorge below State Highway 7 (see Figure 2). The case study area does not include the lower areas of the Hurunui catchment below the Lowry peaks gorge or the Waikari catchment, a tributary of the Hurunui. However, the case study does consider how the various nutrient management options would influence nutrient state and values in the lower Hurunui at State Highway 1.

Figure 2: Hurunui case study area



3.2 Biophysical environment

The case study area has been divided into four distinct areas, upper catchment, mid-catchment Hurunui main stem, mid-catchment tributaries and Culverden Basin groundwater. These areas and their key water quality characteristics are described below.

3.2.1 Surface water quality

Upper catchment

This comprises the headwaters of the upper Hurunui River to its confluence with the Mandamus River and includes rivers and lakes within DOC conservation land that are classified as 'natural state' waters, as well as upland alpine, hill-fed, spring-fed and lake-fed river types. There are also several lakes in the upper catchment, including Lake Sumner, which is Canterbury's only unregulated large high country lake, Lake Marion, which is one of only two DOC fauna reserves in the South Island, as well as numerous medium-sized lakes (e.g. Sheppard, Taylor, Mason, Katrine).

There is one long-term water quality monitoring site within the upper Hurunui area located on the main stem just above the confluence of Mandamus River. This monitoring site is run by NIWA. Data from this site show nutrients, *E. coli* and turbidity were generally at levels protective of recreational and aesthetic values. This was further supported by periphyton percent cover in the Hurunui above Mandamus, which indicated that observed nutrient levels were not causing nuisance algal growths (Kelly 2010).

Mid-lower catchment – Hurunui River main stem

This is the main stem reach of the Hurunui River from where it emerges from the basin foothills at Mandamus and flows across the Culverden Basin before entering the lower gorge and passing the Hurunui State Highway 1 Bridge. The river forms a wide multi-braided channel as it flows across the basin.

Occasional breaches of *E. coli* guideline values in the lower Hurunui indicate an ongoing risk to contact recreational activities such as swimming, kayaking, and fishing. Ausseil (2010) estimated that the Pahau, St. Leonards Stream and Dry Stream collectively contributed 34% of the total *E. coli* loads to the catchment.

Concentrations of both phosphorus and nitrogen increase downstream in the main stem of the river. In comparison with the water quality in the upper catchment, dissolved nitrogen is up to 20 times higher in the lower river (SH1 site), while dissolved phosphorus is about 2-3 times higher at SH1. There has been a steady trend of increasing nitrate concentration in the lower Hurunui River over the past 20 years, and a pattern of increasing phosphorus concentrations up to around 2001, after which phosphorus concentrations have reduced again. Correspondingly, the cover of filamentous algae + algal mats was relatively high during summers of 2001-2005 but has since decreased to levels that are similar to the water quality outcomes stipulated in Environment Canterbury's Natural Resources Regional Plan (NRRP).

The average QMCI score over the last 21 years for invertebrate samples collected in summer (likely to be annual minima) was 5.0, with QMCI values of <5 on 11 years and >6 on 6 years. However, there has been a declining trend in QMCI since 1989.

These results indicate that the NRRP filamentous periphyton cover objective is 'probably' being met, but the invertebrate QMCI objective has often not been met in the past decade.

Mid catchment tributaries

There are four main tributaries that emerge out of the mid catchment foothills, flow across the Culverden Basin and enter the main stem of the Hurunui River near the lower gorge. Two of the tributaries, St Leonards Stream and Dry Stream, are classified as 'spring-fed – lower basin' streams, and are fed by groundwater emerging across the Culverden Basin. The other two tributaries, Pahau and Waitohi rivers, are classified as 'hill-fed river' types and are fed by rainfall in the foothills, but they also have spring-fed tributaries such as Cold Stream that emerge on the plains.

Previous reports highlighted elevated nutrient levels and indicators of faecal contamination as major water quality issues in Culverden Basin streams and the lower Hurunui (Hayward 2009; Ausseil 2010). Current monitoring data for these streams indicate dissolved inorganic nitrogen (DIN) concentrations remained elevated and nitrate concentrations (the dominant component of DIN) breach the 95% level of aquatic species protection occasionally in Waitohi River and Dry Stream and frequently in the Pahau River and St Leonards Stream. The potential for nitrate toxicity on Culverden streams requires further investigation. Concentrations of dissolved reactive phosphorus (DRP) and *E. coli*, and turbidity values continue to breach guidelines at all stream sites in Culverden. However, a declining trend in DRP concentrations in the lower Pahau is encouraging and probably reflects efforts to manage wipe-off water (Kelly 2010).

3.2.2 Groundwater

The main groundwater aquifers within the study area occur in the Culverden Basin. This groundwater system is fed from river seepage as the Hurunui River and tributaries emerge from the foothills onto the plains plus land surface recharge (leakage through the soil profile) from rainfall and irrigation. It is generally accepted that the groundwater re-emerges either in the lower parts of the mid catchment tributaries or the main stem of the Hurunui River near the lower gorge. Groundwater is used for private domestic and community drinking water supplies.

Groundwater in the study area recharged via the land surface currently displays nitrate concentrations around half the New Zealand Drinking Water Standards maximum acceptable value (MAV) of 11.3 mg/L, and concentrations above the MAV are rare. *E. coli* is more commonly detected in wells less than 25 m deep highlighting vulnerability of shallow groundwater to bacterial contamination (Abraham 2010).

The available data for the Hurunui catchment suggest overall groundwater quality in the catchment probably meets Objectives WQL2 (a) and (b) in the NRRP (released October 2010). The overall maximum nitrate-nitrogen concentration for the catchment is around 2.75 mg/L based on the median of the maximum concentration measured in each of the 56 wells. This is below the 5.6 mg/L and 11.3 mg/L thresholds, specified in parts (a) and (b) of the objective. The few wells with

concentrations above the MAV represent localised decline in groundwater quality but this seems acceptable under this objective (Abraham 2010).

Part (a) of the objective also aims to keep the rate of increase in nitrate-nitrogen concentration to below 1.5 mg/L every ten years. However this condition is only applicable if the overall maximum is > 5.6 mg/l. This is not the case in the Hurunui.

The collation and communication of this base information was an initial first step in the Hurunui pilot. This information represented the collective understanding on which further steps were undertaken.

In summary, key findings were as follows:

- existing water quality achieves the desired outcomes in the main-stem Hurunui River most of the time.
- existing water quality fails to achieve desired outcomes in the lower reaches of tributaries much of the time.
- groundwater quality generally meets the desired outcomes for drinking water objectives, but has a strong influence on spring-fed streams such that they are likely to breach nitrate guidelines.
- occasional breaches of the desired outcomes in the lower Hurunui in the past and persistent breaches in the tributaries has justified consideration of a limit-setting approach for managing the cumulative effects of land use in the catchment on surface and groundwater water quality.

3.3 Land use

Current land use information (see Table 1) was sourced from Agribase™ and complemented by local information. This shows that sheep and beef is the dominant land use overall, and is also the main land use on the flatter, intensive part of the catchment. However dairy is the dominant irrigated land use. Land use in the upper part of the catchment is primarily the “other category”, mainly scrub, tussock and mountain land and hill country sheep and beef, which occupy similar shares of the upper catchment.

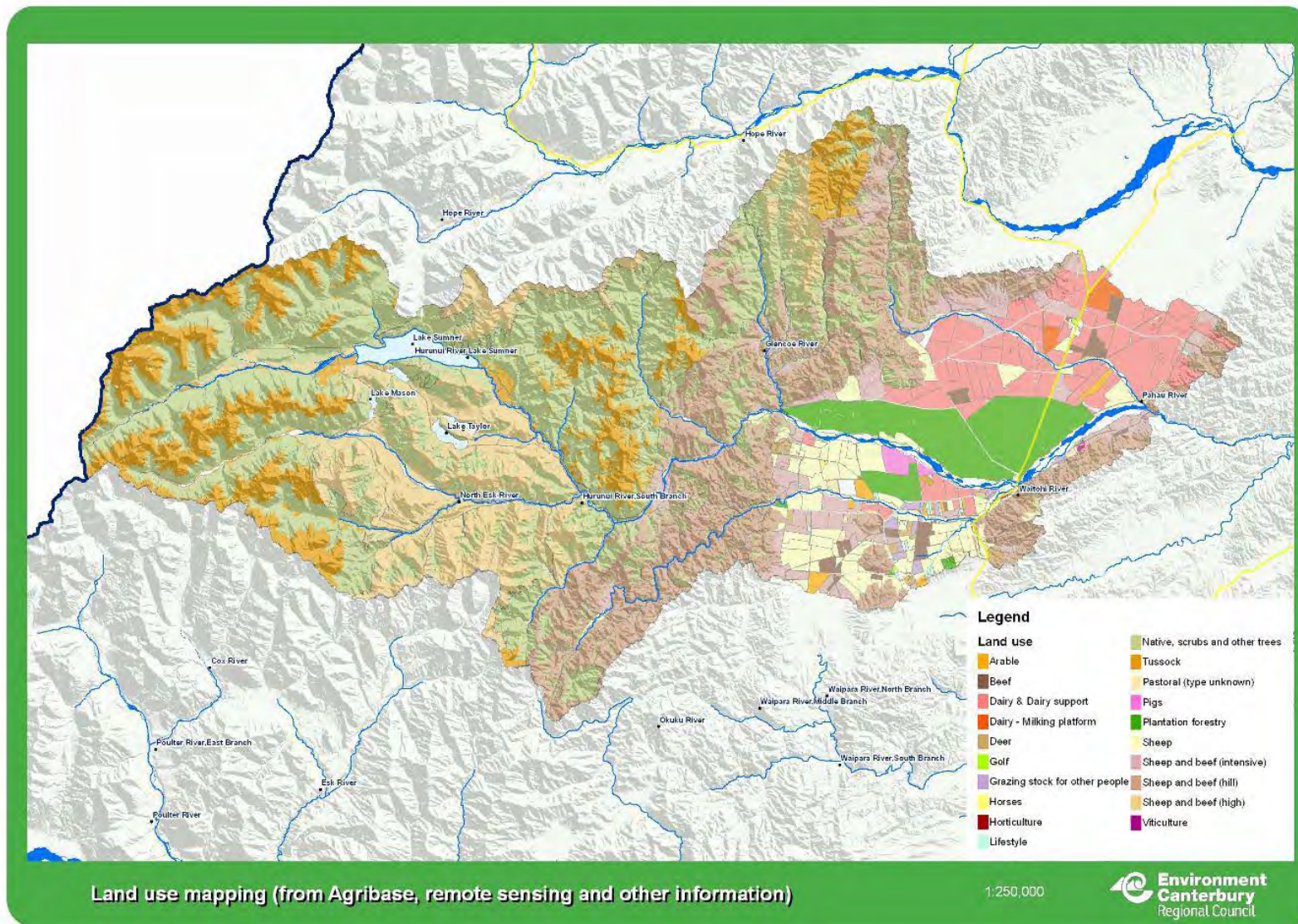
Forestry is a relatively minor part of the catchment, and the majority is in the Balmoral forest in the flat part of the catchment.

Future development of agricultural land in the Hurunui (and elsewhere in Canterbury) is dependent on provision of irrigation water. Currently, the 17,000 ha of irrigated land within the case study area is supplied by the Balmoral and Amuri Irrigation schemes. Options for further irrigation have been explored, with proposals put forward for water storage within the Hurunui catchment that could potentially irrigate up to an additional 35,000 ha of land.

Table 1: Estimates of current land use in LUWQ study area (2010)

Land Use	Irrigated	Dryland	Hill country	Total
Sheep and beef	7,885	16,233	78,026	102,144
Dairy	7,952		0	7,952
Arable	254	701	0	955
Horticulture, viticulture	100		0	100
Other	197	1,354	85,349	86,900
Forestry	0	10,023	0	10,023
Total	16,388	28,311	163,375	208,074

Figure 3 - Land use in the Hurunui case study area



3.3.1 Farming within the Hurunui

Typical farming systems within the Hurunui were described using farm-specific information from a small number of farms plus information gained through farmer interviews. These farm systems are:

1. Dairy platform (young stock grazed off and cows wintered off for 8 weeks)
2. Dairy plus support. Young stock (22% replacement rate) grazed on runoff and cows wintered on runoff.
3. Sheep and beef (irrigated) plus dairy support. The dairy support scenarios considered were: rearing young stock only (no winter crop component), wintering cows on crop only, or rearing young stock and wintering R2 on crop.
4. Sheep and beef (dryland) plus dairy support. The dairy support scenarios we considered were: rearing young stock only (no winter crop component), wintering cows on crop only, or rearing young stock and wintering rising 2 year olds (R2) on crop.
5. Extensive sheep with no dairy support.

The catchment also has a number of cropping farms with and without dairy support, a small number of pig and deer farms and a relatively large area of forestry.

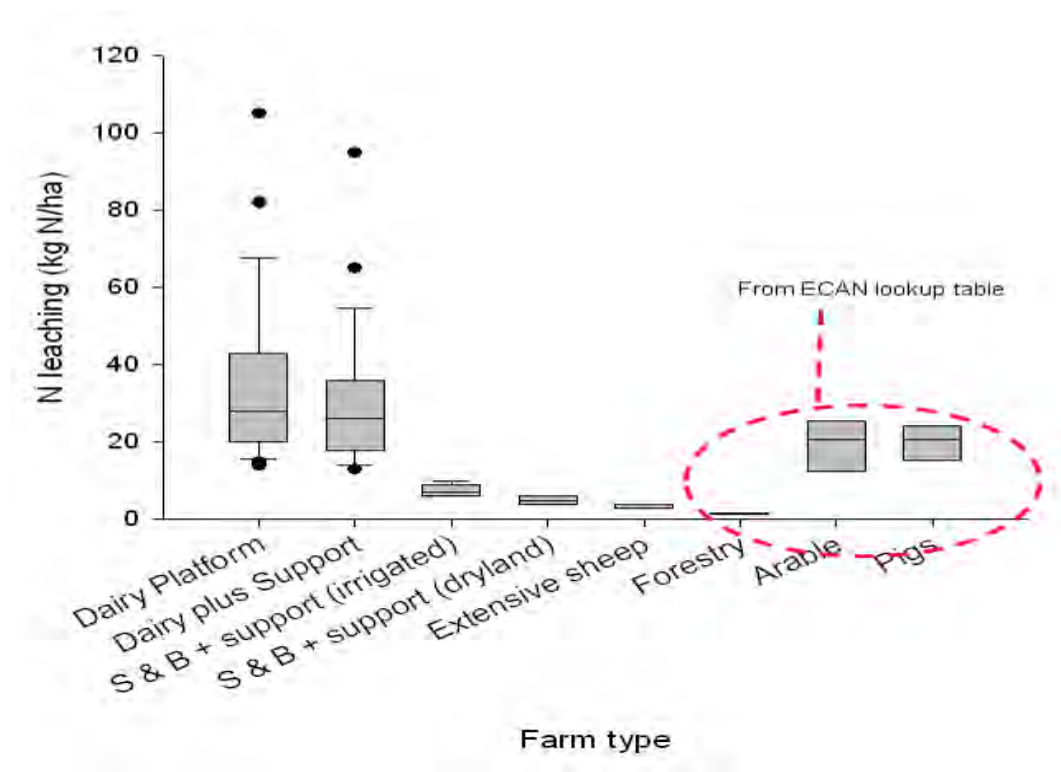
3.3.2 Nutrient losses from different land uses

In order to plan for the future we need to understand how current land use influences the loads of N and P entering the water system. As this cannot be done for every farm in the catchment, five “representative” pastoral farming enterprise types described above were initially defined and modelled to benchmark farm N and P losses.

Using the information gathered, the *Farmax* and *Overseer Nutrient Budgets* models were run to define the productivity, profitability and nutrient (N and P) losses of each of the different farm types in the Hurunui. Assessments of the potential of some mitigation measures identified to reduce farm N and P losses were also derived using this modelling approach.

Estimates of annual N losses to water from the various farm types are plotted in Figure 4. For comparison, N leaching estimates for forestry arable and pig farming enterprises are also plotted. These values were obtained from Environment Canterbury’s look-up table of N leaching rates from rural land uses.

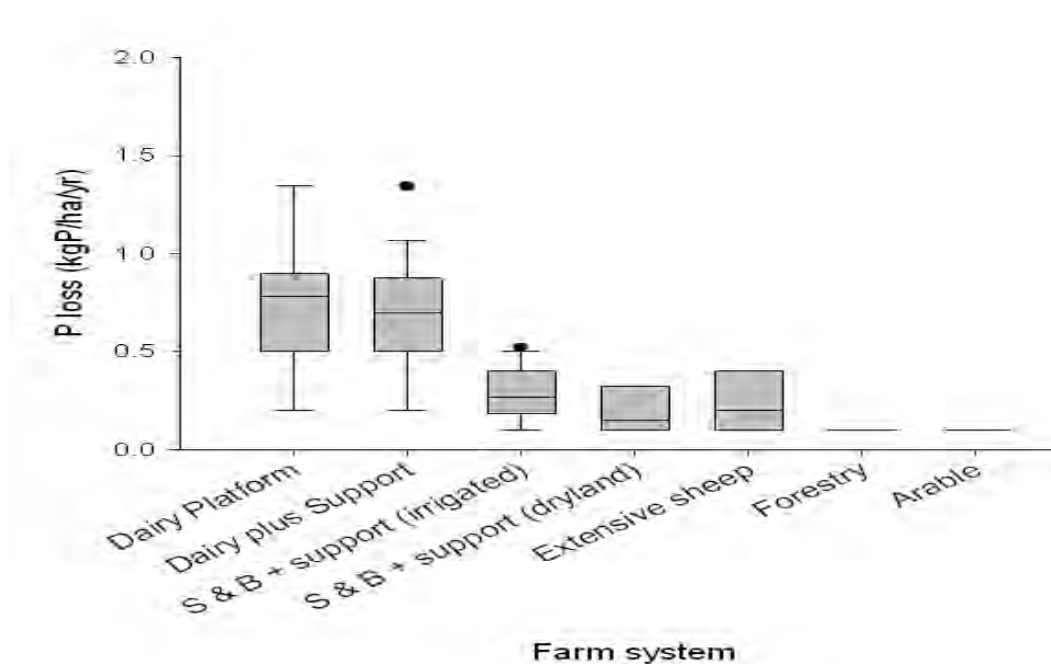
Figure 4 - Ranges in estimated annual N leaching losses (kg N/ha/yr) from the different farming enterprises in the Hurunui catchment



Considerable research into N flows within grazed pastures over the past three decades clearly shows that the amount of N excreted by animals, particularly urine N, is the most important determinant of N leaching losses. Stock type, stocking rate and feed type are thus key parameters that influence N leaching rates. Soil type, climate and farm management practices also exert a strong influence on N leaching losses. The effects of these input variables contribute to the wide ranges evident in the modelled N losses documented in Figure 4.

Figure 5 shows estimated P losses. As with the reported N losses, caution must be taken when interpreting the total farm P loss estimates. In some cases, high P loss values for individual blocks (e.g. a border dyke-irrigated block) can be diluted at a farm scale by lower estimated P losses from large areas of less intensively farmed blocks on the remainder of the farm.

Figure 5 - Ranges in estimated annual P losses (kg P/ha/yr) from the different farming enterprises in the Hurunui catchment



3.3.3 Effect of potential mitigations on nutrient loss rates

A key mitigation practice that has been estimated to significantly reduce the amount of nitrate and phosphorus lost is the conversion of border dyke irrigation to spray irrigation. The resulting reduction in nitrate losses is covered by Lilburne et al. 2010. An estimated 20% reduction in P was applied for removal of border-dyke irrigation from dairy areas, and 5% for intensive sheep and beef in the modelling exercise; this takes into account the representative proportion of border dyke versus spray irrigation found in the Hurunui and the expected effect of converting to spray on those farms that currently have border-dyke irrigation.

Percentage reductions in nutrient loss rates due to land management mitigations other than a change from border dyke irrigation to spray irrigation were supplied (pers. comm. Ross Monaghan). The mitigations include reduced winter grazing, lower N fertiliser application rates, strategic placement of wetlands, use of low N feed, and best practice for effluent management (storage, low rate application where needed etc) for dairy farms. Nutrient losses for riparian protection and strategic placement of wetlands were estimated for sheep/beef farm types. There is considerable uncertainty as to how effective each of these mitigation strategies might be, and therefore the reductions given in Table 2 are approximate only and do not vary with soil type.

Table 2 - Percentage reductions in nutrient leaching due to mitigation

	% N reduction with maximum feasible mitigation (excluding border dyke conversion)	% P reduction with maximum feasible mitigation (excluding border dyke conversion)
Arable	30	10
Dairy milking platform	50	20
Dairy milking plus support	50	20
Dairy support dryland	25	20
Forestry	0	0
Intensive irrigated sheep and beef	20	20
Intensive dryland sheep and beef	10	20
Hill country sheep and beef	0	20
High country sheep and beef	0	0
Other productive	10	20
Other unproductive	0	0

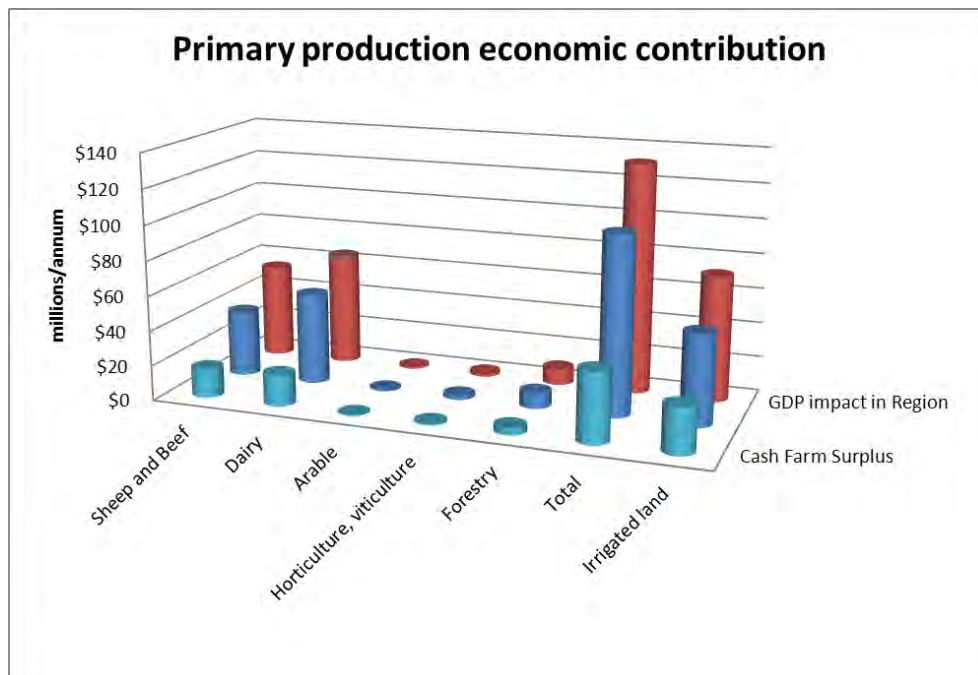
3.4 Economic contribution of primary production

Economic production in the Hurunui catchment is dominated by dairying and irrigation. Irrigated land, which is 8% of the catchment, produces 65-73% of the economic output by value and employment.

Dairy land comprises just 4% of the catchment but produces approximately half the revenue, cash farm surplus and GDP. Dairy is associated with half the direct and indirect employment.

This dominance is illustrated by Figure 6 below

Figure 6 – Economic contribution of primary production in the Hurunui catchment



3.4.1 Farm profitability

Assessments of farm profitability showed a wide range in per hectare returns from the different farming enterprises, as expected (Table 3). These ranged from around \$80/ha/year for the large extensive sheep farm, through to around \$3600/ha/year for the dairy milking platform that was modelled. One surprising result was the marked difference in per hectare profitability between the dairy milking platform and the dairy + support units, where profit for the latter was estimated at c. \$1770/ha/year. The lower returns for the dairy + support unit are presumably tolerated because of the perceived benefits farmers have in owning their dairy support land (i.e. greater control of feeding and cow condition scores and less overall risk). For comparison, the reported profitability of the MAF Canterbury dairy model farm budgeted for 2009/10 (payout of only \$4.74/kg MS) was \$2190/ha/year.

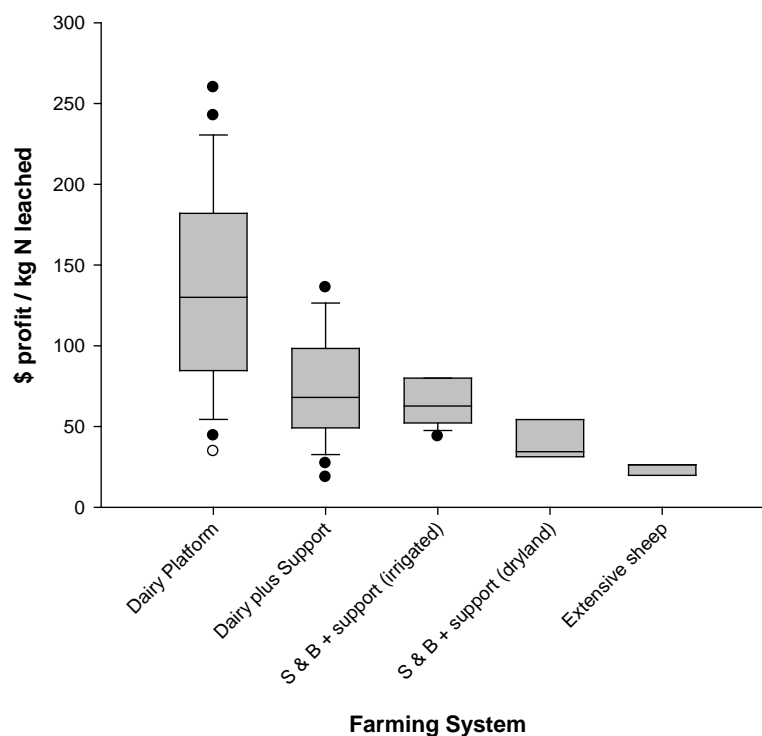
Table 3- Ranges in cash operating profits for the different model farm systems

	Profit (\$/ha/year)	Effective hectares (ha)
Dairy Platform (\$6.10/kgMS)	\$3640	170
Dairy + Support (\$6.10/kgMS)	\$1770	489
Sheep-beef + Support (irrigated)	\$230 - \$270	669
Sheep-beef + Support (dryland)	\$160 - \$220	1685
Extensive sheep	\$80	4565

Another way of looking at the production efficiencies of different farming systems is to express profit as a ratio of nutrient losses e.g. kg nutrient lost per dollar profit. This approach can help to illustrate and recognise the value of different farming systems. When the figures are looked at in this way we can see that dairy systems (on average) have a lower N leached figure per unit of profit than the dry stock operations (Figure 7).

Figure 7 - Estimated production efficiencies (kg N leached/\$ profit) of the different farm systems modelled for the Hurunui catchment

Estimated production efficiencies (\$ profit/kg N leached) for the different farm systems modelled for the Hurunui catchment



3.5 Social characteristics

Employment/unemployment, income and population distribution and change are indicators of the Hurunui catchment's social conditions.

As discussed earlier, irrigated land uses (including dairying) are the catchment's biggest employer (see Figure 8). It is also clear from Figure 9 that population increase and income levels are highest in irrigated areas of the catchment (north of the river) while unemployment levels are lower south of the river.

Figure 8 - Primary production contribution to employment

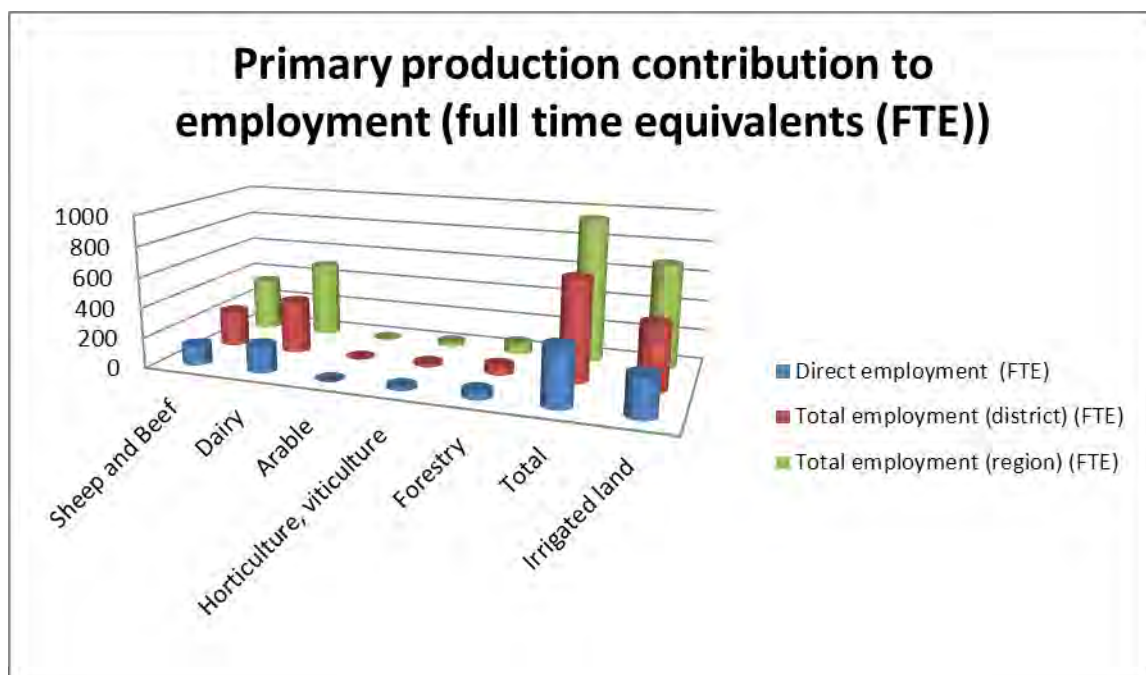
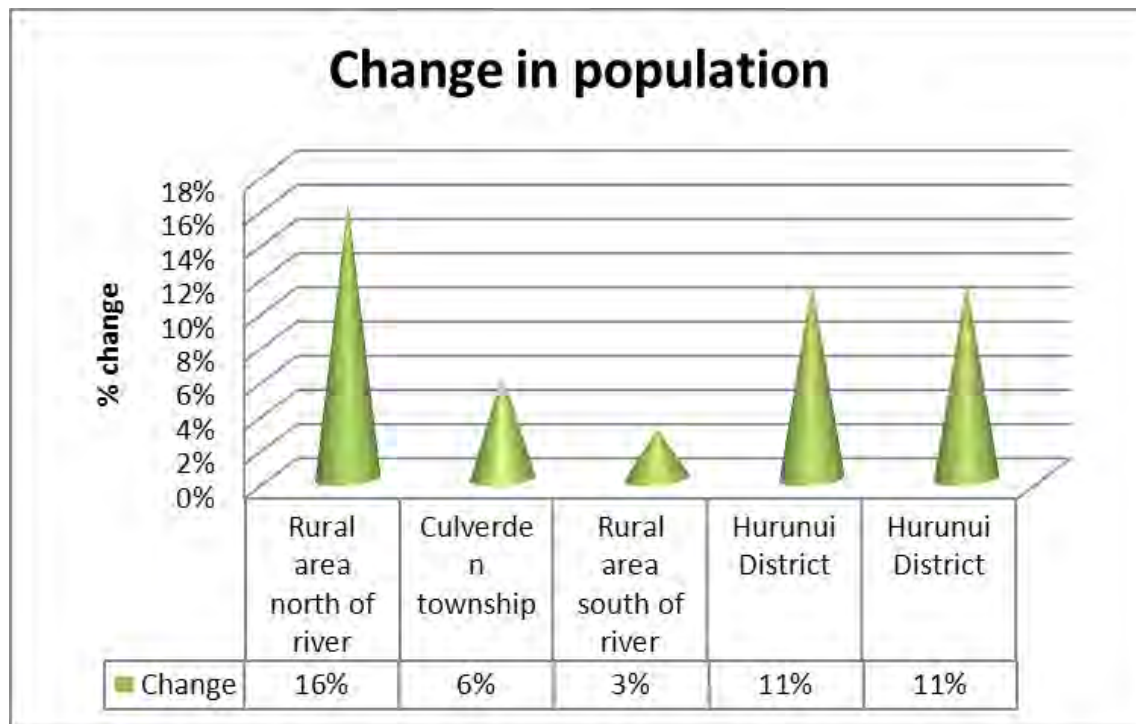


Figure 9 – Population change, unemployment and median income in Hurunui Catchment



4 Establishing limits for water quality

It was agreed that the first stage in managing nutrients is to set catchment *nutrient load limits* that reflect the environmental values people hold for freshwater⁷.

In other words, the first stage is to translate environmental values (such as fishing or recreation) in freshwater to in-stream outcomes (e.g. periphyton cover) to nutrient concentrations in-stream (e.g. mg/L of N), to catchment load limits (i.e. maximum cumulative nutrient inputs to freshwater – tonnes/yr).

While this can be done in a purely technical sense, the approach taken recognised a need for the setting limits of load limits to be not only technically robust, but to take full account of the social and economic consequences of limits set.

This task was carried out and reported in detail by Norton and Kelly (2010). It is also recorded in the Preferred Approach report. It is summarised in diagrammatic form in Appendix 3.

⁷ It is important to note, however, that limiting nutrients directly or via the control of land use is not the only means by which the effects on in-stream outcomes can be managed. Managing flow regimes and water temperature also have a role and need to be considered in the scenario mix.

Essentially, it involved developing *scenarios* of different development futures within the catchment (i.e. different levels of land use change and intensification/irrigation); modelling the costs and benefits of each scenario; and presenting that information to the affected community to make a *value judgement* about the level at which load limits should be set.

As reported in the preferred approach report, initially five scenarios were developed and modelled as follows. (This was subsequently altered by the addition of a further scenario where future development would be staged as discussed in section 5.2).

Table 4 - Future land use scenarios

1	Current land use	Based on current land use
2	Business as usual*	Some intensification in line with historic trends. All border dyke irrigation converted to spray irrigation.
3	Extensive irrigation*	Full irrigation of suitable land. All border dyke irrigation converted to spray irrigation.
A	Conservative	All productive land was converted to forestry, aimed at achieving the highest level of confidence of meeting NRRP objectives for periphyton.
B	1990 – 95 Hurunui Water Quality	A combination of some land use change and mitigations that aim to meet water quality as it was in the Hurunui River in the early 1990s. All border dyke irrigation converted to spray irrigation.

*Assumes current land use practice – no additional mitigation.

Development Scenarios 2 and 3 assumed current land use practice with no additional mitigation measures that might reduce nutrient losses and associated impacts on water quality. (Mitigation options and their potential effectiveness are discussed in Appendix 6).

4.1 Implications for environmental values

The effects of the five scenarios on selected environmental values were then modelled. Modelling results are summarised for each of the six study sites in Appendix 4 (Tables A4a-A4f). The environmental values and related criteria listed in the first column of each table do not represent all values affected by water quality, rather they were selected on the basis that robust technical information was available to assess consequences of the five scenarios. The tables show predictions for whether environmental values (or related criteria) are *likely* to be achieved under each scenario. These results were presented as high-level predictions designed for a general audience.

There is considerable uncertainty associated with these predictions (see Norton and Kelly (2010)). To illustrate how uncertainty varies between scenarios, predictions are expressed using a four-class system whereby scenarios are judged ‘almost certainly’, ‘probably’, ‘possibly’ or ‘unlikely’ to support environmental values. The technical methodology behind the predictions is not reported here in full detail. In summary, the predictions are based on an integrated consideration of several lines of evidence including:

- Existing measured data (Environment Canterbury and NIWA).
- Empirical periphyton model predictions (Biggs 2000, In Norton and Kelly 2010).
- Nutrient load model predictions (CLUES, AquiferSim and a Culverden Basin Nitrate Account Model) (Lilburn et al. 2011).
- Bayesian Belief Network (BBN) model predictions (Quinn, pers. comm.)

Tables A4a-A4f (Appendix 4) provide a colour-coded 'snap-shot' illustration (green = best; yellow = worst) of how environmental state would vary between the different scenarios and river sites. Uncertainty with the predictions increases generally from left (green) to right (yellow). The risk of adverse effects on environmental values also increases from left (green) to right (yellow). For example, it is clear that the Hurunui upstream of Mandamus (Table NN3) is in the best environmental condition and is least likely to be adversely affected under any future scenario. At the other end of the spectrum, St Leonards Stream and Dry Stream are in relatively poorer condition and are highly likely to be further degraded under development scenarios.

The classification system also indicates the proportion of time that environmental outcomes are likely to be achieved; i.e. 'almost certainly' means environmental outcomes are likely to be achieved almost all the time, 'probably' means most of the time, 'possibly' means some of the time, and 'unlikely' means even less of the time. For example in the Hurunui (at SH1) under scenarios A and B it is likely that periphyton blooms would occur very rarely, while under scenario 1 blooms might occur occasionally for a few weeks during particularly hot dry summers every few years. Under scenarios 2 and 3 there is increasing risk that blooms could occur more frequently and for longer duration, even during average summers.

4.2 Implications for economic and related social values

The implications of the five future scenarios for economic and related social values were described in detail by Harris (2010). In general, the economic and related social benefits increase across the five scenarios (left to right in Figures 10-12, ignoring for present purposes the Adaptive Steps). The analysis shows there is direct conflict between the environmental values (Tables NN2-NN7) and the economic and associated social values. This shows clearly that value judgements are needed to settle on the acceptable balance between multiple values and thus enable selection of a preferred option for setting nutrient load limits. It is not possible to optimise all values. Any decision will involve trade-offs.

Figure 10 - Economic outcomes by scenario⁸

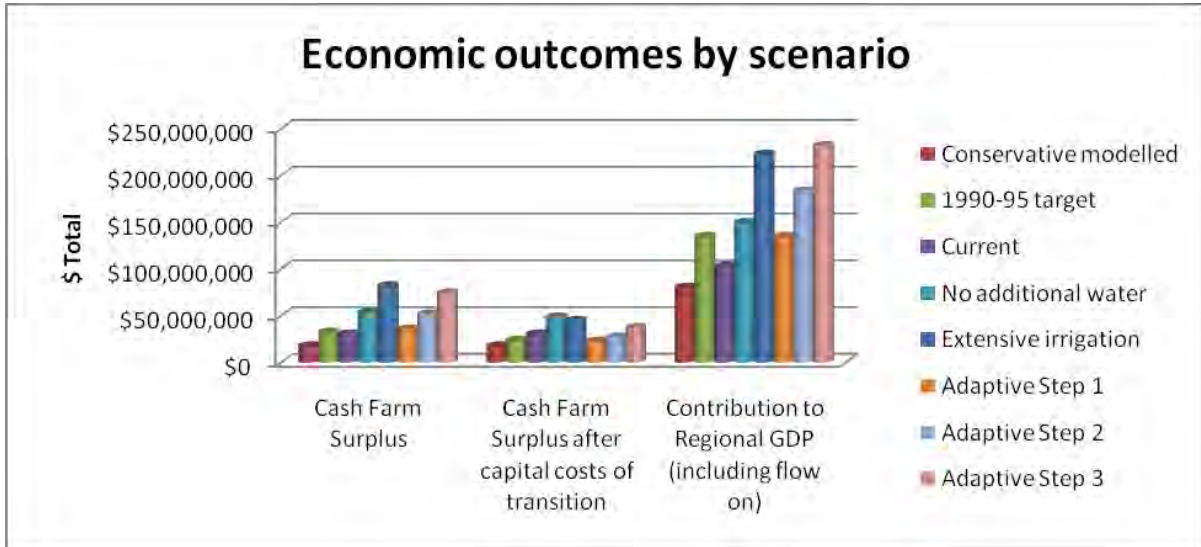
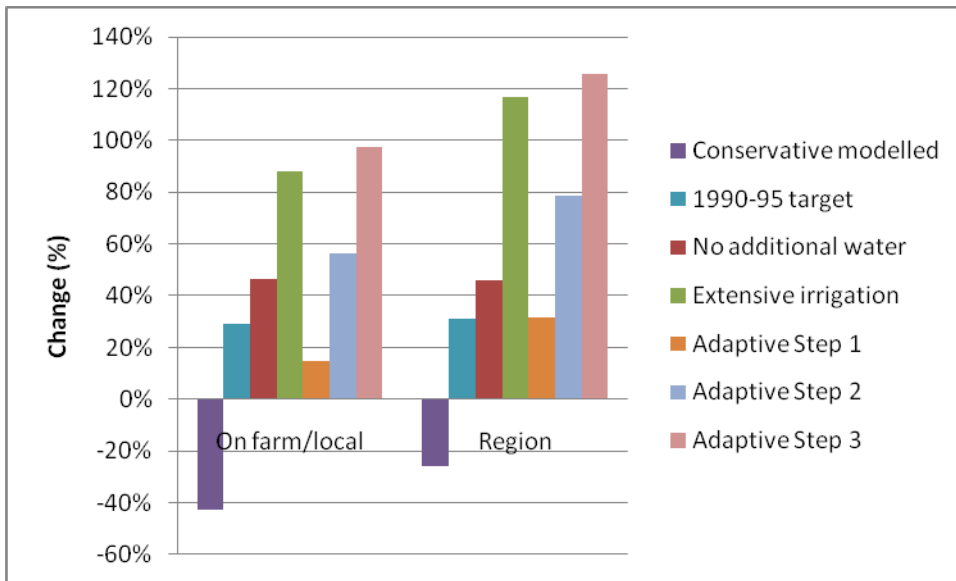
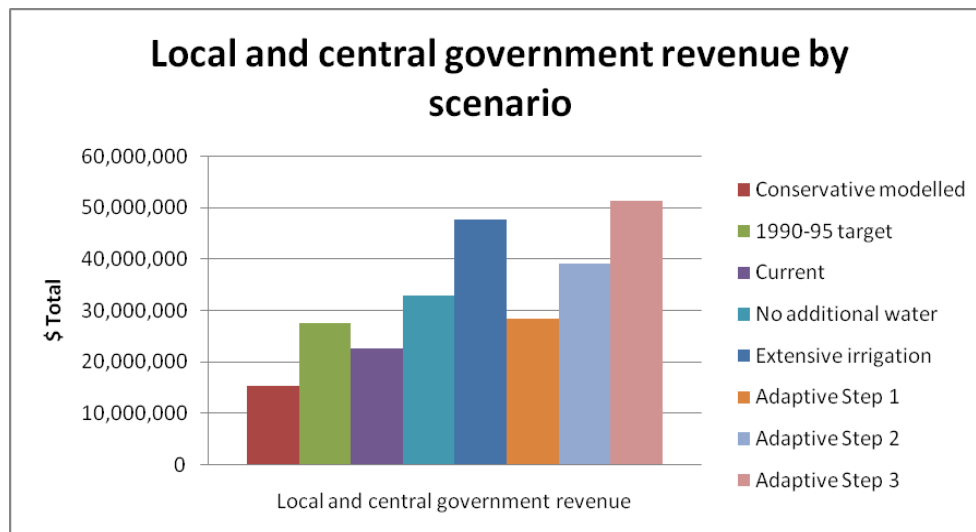


Figure 11: Expected change in contribution of case study area to local and regional population



⁸ Adaptive Steps 1 – 3 describe stages of development that could potentially take place under the preferred approach. The third step in this is effectively the same as the “Extensive irrigation” scenario, but with a high level of mitigation included. These stages are described more fully in Section 5.2.

Figure 12: Local and central government revenue by scenario



The key finding from the economic and social evaluation of options was that (predictably) there is direct conflict between environmental values and the economic and social values associated with intensified land use.

This simply confirmed that “value judgement” decisions are needed on the acceptable balance between multiple values.

4.3 Managing uncertainty

As noted above, a key dimension to factor into the evaluation is the uncertainty associated with the predictions for delivery of environmental values. This uncertainty was considerable.

Sources of uncertainty include measurement error, incomplete data and models, and natural variability (Norton and Kelly 2010). Similarly there are many sources of uncertainty with predictions of economic and related social effects. This uncertainty results in a risk that a decision on a preferred option will either over-protect environmental values while under-utilising land and water resources, or under-protect environmental values while allowing unsustainable resource development. For example, it is clear from the analysis described in sections 4.1 and 4.2 that Scenario A achieves high certainty (low risk) for environmental outcomes but has serious risk of negative economic and social consequences, and in that respect is arguably unrealistic. Conversely Scenario 3 provides the greatest economic and related social benefits but carries a high risk of adverse environmental effects that may be costly to reverse.

How this was addressed is discussed further in section 5.2.

4.4 Selecting an outcome – making value judgements

The five alternative future scenarios were presented at catchment community workshops, together with a description of consequences for environmental, social and economic values, to inform a community deliberation process (described in Appendix 5). The material was subsequently presented to a Governance Group workshop (29 November 2010) and feedback sought from the Group on the

need to make value judgements, manage uncertainty and risk, and select a preferred option for determining nutrient load limits.

Feedback from technical workshops, community deliberation workshops and the Governance Group varied across the different stakeholder groups but there was a general preference for the option that would ‘probably’ achieve all environmental outcomes in the Hurunui and its tributaries, but which would also provide for monitoring and adaptive management in future.

That value judgement reflects an acceptance of only modest risk of breaching environmental outcomes - i.e. outcomes are likely to be achieved most, but not all, of the time and occasional breaches were, upon weighing all values, tolerable for the Group.

For the Hurunui main-stem (at SH1) this means maintaining environmental values at or about current state, i.e. Scenario 1 (current land use). For the tributaries this means improvement on current state is required, in the order of achieving Scenario B (1990-1995 water quality). This direction from the deliberation process and Governance Group provided the value judgement step necessary to commence the technical step of calculating recommended nutrient load limits.

4.5 Calculated nutrient load limits for the Hurunui case study area

The nutrient load limits for dissolved inorganic nitrogen (DIN) and dissolved reactive phosphorus (DRP) that corresponds to the land development scenarios Scenario 1) generally agreed to probably deliver objectives for the Hurunui main-stem are shown in Table 5. The numbers are taken from current estimated mean annual DIN and DRP loads reported in Norton and Kelly (2010).

Table 5 - Calculated nutrient (DIN and DRP) load limits for the Hurunui River

Site	Recommended DIN load limit (tonnes/year)	Recommended DRP load limit (tonnes/year)
Hurunui @ Mandamus	40	3.6
	(35 - 45)	(3.3 - 3.8)
Hurunui @ SH1	693	10.2
	(654 - 731)	(9.7 - 10.6)

The recommendations are based on the median value from the range in estimated nutrient load reported in Norton and Kelly (2010) (in parentheses).

Calculated nutrient load limits for DIN and DRP in the tributaries are shown in Tables 6 and 7 respectively. These limits are based generally on improving current environmental state in the tributaries (Scenario B). Limits for DIN are based on achieving the nitrate toxicity threshold of 1.7 mg/L, which is deemed to protect 95% of aquatic species from the chronic effects of nitrate toxicity as per Hickey and Martin 2009).

Calculated load limits for DRP are based on achieving estimated 1990-1995 quality. Because there is no water quality data for the tributaries for 1990-1995, estimates have been calculated based on the relative difference between 1990-1995 and 2005-2009 quality in the Hurunui at SH1. Thus a 20% scaled reduction in target DRP concentration has been applied uniformly to all tributary sites.

Recommended DRP load limits were then calculated using the target DRP concentration and available flow data according to the method reported for calculating standard annual load limits in Norton and Kelly (2010).

Table 6 - Calculated nutrient (DIN) load limits for the Hurunui tributaries

Site	DIN concentration required to achieve nitrate toxicity threshold (mg/L)	Recommended DIN load limit (standard annual load limit) (tonnes/yr)	Current estimated mean annual DIN load (tonnes/yr)	DIN reduction required (-) or increase allowed (+)
L. Pahau @ Dalzells	1.7	182.1 ±23	196.3	-7%
L. Waitohi	1.7	85.5 ±43	66.7 (62.1-71.3)	+28%
St. Leonards Stream	1.7	68.3 ± 3.2	132.8	-49%
Dry Stream	1.7	52.9 ±15.5	13.8	+283%

Table 7 - Calculated nutrient (DRP) load limits for the Hurunui tributaries

Site	DRP nutrient concentration based on Scenario B	Recommended DRP load limit (standard annual load limit) (tonnes/yr)	Current estimated mean annual DRP load (tonnes/yr)	DRP reduction required
L. Pahau @ Dalzells	0.0136	1.46 ±0.19	2.2	-33%
L. Waitohi	0.0056	0.28 ±0.14	0.35 (0.3-0.4)	-20%
St. Leonards Stream	0.012	0.48 ±0.02	0.6	-20%
Dry Stream	0.0128	0.4 ±0.12	0.5	-20%

Numerous assumptions and data limitations for these calculations are discussed in Norton and Kelly (2010). In particular it was assumed that the current river flow regimes would remain the same in future. This assumption affects load calculations in two key ways. First, river flow reductions would reduce dilution and thus load limits would need to be reduced accordingly. Second, reduced flood frequencies would hinder the removal of periphyton accumulations and make the river more sensitive to nutrients, thus requiring reduced load limits. If river flow changes significantly, such as could result from dams and/or major abstractions in the Hurunui catchment, then the recommended nutrient load limits would need to be recalculated. This could be done using the method of Norton and Kelly (2010) but with revised estimates for annual flow volume and flood frequency based on defined proposed future flow regime scenarios.

5 Implications of the proposed limits and related issues

5.1 *Establishing management objectives*

One key issue to emerge from the community deliberation process was that establishing the management objective ought not to just reflect the load limit (output dimension) and associated development future (spatial and intensity dimension) but also a *temporal* dimension i.e. – how could development be *staged* to give the community confidence that outcomes will be delivered in the face of uncertainty.

5.1.1 Management of risk and uncertainty

A key feature of the discussions around the trade offs was the perception of risk that different scenarios carried. Stakeholders were acutely aware that despite the way in which the scenarios had been developed, different scenarios carried different levels of risk to the environment. Thus extensive development was seen as of low acceptability to a number of stakeholder groups because of the risk posed to values.

However, once the concepts of adaptive management and staging were introduced in the scenario mix to reduce the risk associated with development, the acceptability of the scenarios, and implicitly the potential trade-offs, was increased. These concepts allowed stakeholders to select an option that carries modest (not nil or extreme) risk to their values, and then employ an *adaptive management approach*⁹ that allows for future adjustment of the options if monitoring shows this is justified. Risk management and adaptive management are two well-recognised methods for dealing with uncertainty in natural resource management (e.g. Rouse and Norton 2010).

It is clear therefore that the setting of management objectives for the catchment cannot be undertaken in the absence of the temporal dimension or “*development pathway*” for that catchment. This development pathway defines both how the expected outcomes to different values will arise, but also the level of risk that is posed to those values if the expectations are not met.

It was decided that *management objectives* should be established at both the overall catchment level and at sub-catchment level. In the case of the Hurunui case study area this means that management objectives should be established for the Hurunui as a whole and for the sub-catchments. (i.e. St Leonards, Pahau, Dry Stream and Waitohi stream). From feedback received through the catchment workshops there was a very strong message that the management objectives should encompass not only environmental protection and enhancement objectives but also objectives relating to economic, social and cultural enhancement.

Establishment of a full set of management objectives for the Hurunui case study area was beyond the scope of this study. Nevertheless, it is envisaged that as a minimum such a set should include

⁹**Adaptive management** is a structured, iterative process of decision making in the face of uncertainty, with aims of reducing uncertainty over time via system monitoring and the taking corrective management responses (if necessary) in the face of improved information as it becomes available.

objectives relating to, the environmental limits, environmental enhancement, and to the potential for further development within the catchment.

This could be usefully articulated in the Zone Implementation Programme.

5.2 Staging of development

Because options for supply of water are still open, no firm staging proposals were put forward for the Hurunui. The scenario outlined here is a hypothetical trial of the approach. It has the staging of full irrigation development in the catchment divided into three parts.

- The first part would utilise efficiency gains in existing water, and potentially one of the smaller storage sites or Waiau water, to irrigate areas with the Pahau and St Leonards, some conversion of Balmoral, and some riparian areas on the south side of the Hurunui.
- The second stage would utilise a smaller storage site, transfer of water from the Waiau, and likely a swap of water with riparian areas lower in the Hurunui enabling irrigation higher in the catchment. This would irrigate all areas to the north of the Hurunui, and all accessible areas to the south of the Hurunui (referred to as Peaks in the CWMS Stage II report). There may also need to be some limited infrastructure development to provide water into the Hawarden area south of the Waitohi.
- The final stage would see full development of all irrigable areas in the catchment, as well as areas outside the catchment in the HWP schedule.

In order for such a scenario to work out, there would need to be a high level of control by the irrigation company over the ability to rearrange water supply at different stages of development. For example initially the irrigation consents lower in the Hurunui could be supplied with Waiau water passed through the existing Amuri infrastructure, freeing this water for use higher up in the case study area.

Modelling of these stages was undertaken to determine how much nutrient losses from the land may be affected. These results suggest that for all targets except Waitohi and Dry Stream:

- In stage 1, targets could be achieved with only Tier 1 and some Tier 2 (see Appendix 6) mitigations such as DCDs and off paddock wintering. Because of the need to achieve efficiency gains, all border dyke would be converted to spray irrigation over Stages 1 and 2 which has the benefit of significantly improving water quality outcomes. The risk and time may be reduced by including off-farm mitigations at this early stage, or some combination of on and off farm measures. The deliberation workshops demonstrated that there was a good understanding of the impact of best management practice: *“there will be best practice requirements put on new water and we expect that there would be more water available for better minimum flows for riparian”; “I mean that is my take on it and I think it is a reasonable one for me to look at that”; “The recognition that good management practice by all stakeholders will improve water quality was a worthwhile outcome”.*

- In Stage 2 a very high level of on farm mitigation would be required, which would be likely to include housing of animals for at least the winter period. There is a potential need for other catchment scale mitigations such as dilution or wetlands to ensure that targets are met.
- In Stage 3 there is a strong likelihood that there will be a need for all on farm mitigations and for catchment scale mitigations. There may also need to be a limit to some of the more P intensive land uses, or minimisation of their occurrence on sensitive soil types or topographies.

The achievability of targets for Waitohi and Dry Stream will depend on the nature of land uses adopted in those areas, and other measures such as flow alteration for dilution. The mitigation requirements are summarised in Table 8.

Some caution is needed in viewing this staging. Key points are:

- The figures are demonstrative rather than authoritative. There are many potential configurations and staging, which will need to be determined through detailed engineering work. The pathway presented here is potentially feasible, but has many question marks particularly around the distribution system.
- Requirements – the process outlined here requires an ability to move water provision around different parts of the catchment. This will only be possible in a situation where the irrigation water provider controls all the consents in the catchment, thus allowing them to swap water from one location to another as infrastructure is commissioned. Alternatives such as agreements between consent holders may work, but are likely to be more problematic.
- Timing and transitions– the timing outlined here is dependent on the ability of existing users to mitigate their P losses in particular. In the scenario outlined, reasonably rapid transition to spray irrigation and good effluent management are envisaged. However we know that the spray conversion in particular is capital intensive, and may require a greater transition time if no external assistance is provided. This will affect the ability of development to occur in other parts of the catchment.
- Mitigation staging – in the pathway presented the staging is envisaged as first moderate on farm mitigation, then high level on farm mitigation, and then off farm/catchment scale mitigation. However because of the transition issues noted above, this staging may prove problematic. Furthermore some mitigation proposed, such as housed animals, may be unacceptable for cost, farm system and animal welfare reasons. There is a high likelihood therefore that off farm and catchment scale mitigations may be required. Because the catchment scale mitigations are largely untested for removal of dissolved P, there will need to be some immediate testing of potential mitigations for efficacy if this route is to be followed.
- Costs – staging of infrastructure development can be beneficial in terms of construction and uptake, but can also have costs. In the Hurunui water project area getting water into the upper Peaks, Hawarden, Waipara and Scargill areas is not easily staged since it requires large-scale canal infrastructure. Staging into this area with a canal would require progressive building of

sections of the canal, which would need to be oversized for its immediate delivery requirements. As an indication the inlet of the canal has an estimated cost of \$10 million at the sizing required to deliver the full irrigated area. This cost as well as oversized canal costs would need to be borne by the community until such time as the capacity could be fully utilised.

The key message in respect of the Hurunui therefore is that while staging is recognised as likely being required, the details will need to be worked out as the zone committee finalises options for water availability, and as the irrigation companies develop proposals for irrigation development. The proposals for irrigation development and water storage need to recognise the desire for staging as a risk management approach for nutrients.

Table 8 - Requirement for mitigation at different stages of development

Development Stage	Riparian fencing, nutrient management	DCDs, on-off grazing, improved effluent management, conversion to spray	Housing, all other mitigations	Catchment scale, offsets, new mitigations
1	Required	Required		
2	Required	Required	Required	(possibly required)
3	Required	Required	Required	Required

Although there are no firm staging proposals for the Hurunui, there is an argument for the Hurunui strategic catchment plan to recognise the need for irrigation development to occur in 2-3 phases as a risk management approach. Mitigation and river outcomes will need to be proven through monitoring before the following stage of development occurs.

Finalisation of the Hurunui strategic catchment plan should await firmer proposals for water provisions in the catchment. Proposals for water provision in the catchment need to recognise the requirement for staged development to manage risks to values from nutrient loads.

5.3 Implications of calculated limits

5.3.1 Implications for water quality and environmental values

Implications of the recommended nutrient load limits on environmental values can be seen at a glance by observing the Scenario 1 column for Hurunui main-stem sites in Tables A4a and A4b, and the Scenario B column for tributary sites in Tables A4d-A4e (see Appendix 4). In short, the current environmental state will 'probably' be maintained in the Hurunui main stem; there will be improvement in the tributaries but environmental values will still be compromised to some extent at times in the tributaries.

5.3.2 Social impact of proposed limits

The recommended limits have the potential to increase social indicators associated with employment and population and, potentially, to those associated with public services. Estimates of the change in contribution to population are shown in Figure 11 and in local and central government revenue in Figure 12.

They show significant additional population and local and central government revenue in all the adaptive stages. The final end point could have greater population contribution than unmitigated scenarios, because some of the mitigations are expected to increase overall revenue. However the estimates of increases in local and central government revenue are almost certainly likely to be overestimates as the modelling in this case is driven by revenue rather than cash surplus. The addition of mitigation will reduce cash surpluses, and thereby some of the contribution from taxes (although rates and employee taxes may not change under these scenarios).

5.3.3 Economic Impact of proposed limits

The economic impact of proposed limits is obvious from the comparison of scenarios shown in Figure 10.

The staging would alter the profile of returns to the community. The estimates of changes to various indicators are shown in Figure 10 to Figure 12, with the original scenarios presented to the catchment workshops included for comparative purposes.

For the preferred approach analysis, a separate item of surplus after capital costs of transition to irrigation has been included to demonstrate the potential for net benefit. The transition capital costs are charged at 8%, and the costs were based on information developed for the CWMS. Some key features of the economic indicators are:

- The Cash Farm Surplus (CFS) for the three adaptive management options are significantly lower than scenarios with equivalent irrigated areas. This is largely due to the cost of mitigation associated with these scenarios¹⁰, which increase on-farm expenses. In some cases these also increase revenue. This mix of higher revenue and lower CFS is best demonstrated by comparing Adaptive Management Step 3 with Scenario 3. These two scenarios have the same land-use mix, but Adaptive Management Step 3 has higher revenue and considerably lower CFS than Scenario 3.
- The results for surplus after capital costs are also shown in Figure 10. Modelling shows many of the scenarios produce a lower net surplus after capital and mitigation costs than does the current situation. This indicates that the proposed mix of land uses potentially produces a negative return after capital and mitigation in some scenarios.

¹⁰ The mitigation costs of catchment scale mitigation in Adaptive Management Step 3 were modelled by assuming that 2.5% of all farms were used for wetlands.

- For Step 3, where catchment scale mitigations are almost certainly likely to be required, indicatively a further \$4 - \$8 million/annum of cost may be incurred to bring the catchment P load within limits¹¹. Approximately 30% - 50% of this would be incurred in the Waitohi if no increase in loadings were allowed in this catchment.

5.3.4 Implications for current and future land uses

As noted above, the implications of the calculated nutrient load limits for economic and related social values can be seen at a glance by observing the bar graphs for Scenario 1 (Current land use) in respect of Hurunui main-stem and Scenario B (1990-95 Water Quality) in respect of the tributaries in Figures 10-12.

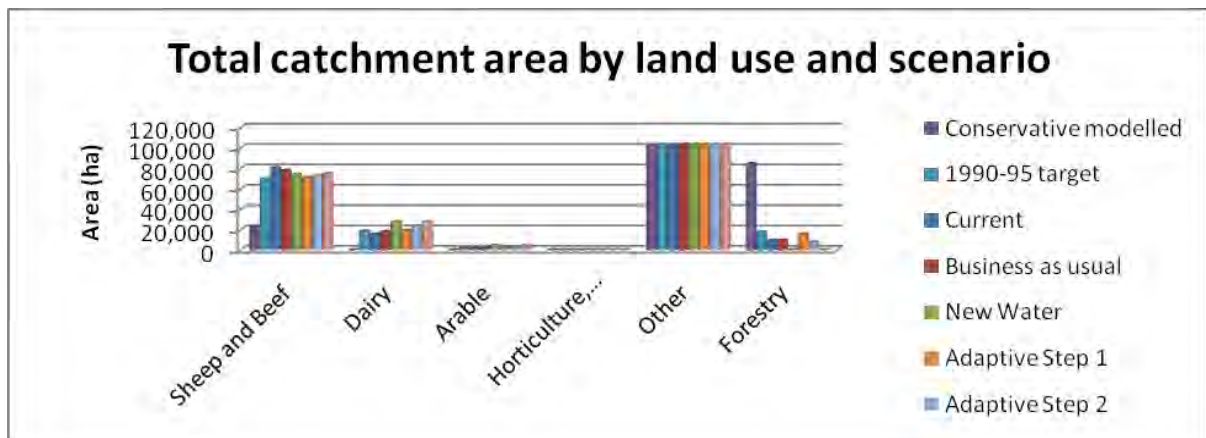
What this means for future land uses is shown in Figure 13. What is not readily apparent from that Figure is that, unless mitigation measures are employed to reduce current catchment nutrient loads, there is currently no available capacity for conversion to more intensive land uses that generate greater nutrient losses per hectare than the uses they replace.

- For the Hurunui main stem (SH1) any intensification in land use (and increase in contributed load) is dependent on a reduction in current load somewhere else in the catchment¹².
- For the tributary sub-catchments it will be necessary to reduce existing loads in the order of 20% (see Table 7) before any subsequent additional load reductions will create capacity for further intensive land uses in the sub-catchment.

¹¹ Calculated using a cost of \$1750/kg of P reduction and \$62.5 per kg of N. This is based on bottom of catchment wetlands at 5% of catchment area. These per kg estimates were sourced from graphs in the appendices of *McKergow et al. 2007. Stocktake of diffuse pollution attenuation tools for New Zealand pastoral farming systems. NIWA Client Report HAM2007-161. Report prepared for the Pastoral 21 Research Consortium*. An alternate approach used estimates by Ross Monaghan (pers. comm.) of approximately \$100/farmed ha (\$40/ha/year lost profit, fencing \$10/ha/year, planting and weed control \$50/ha/year), over 84,000 farmed ha (excluding high country) gave the upper limit of \$8 million/year.

¹² Although it is anticipated that new load could be added in anticipation of reductions occurring simultaneously as load is being added, rather than waiting for reductions to be modeled as having occurred for new load is added.

Figure 13 - Land use by scenario, Hurunui Catchment



A range of possible mitigation measures and their potential effectiveness for reducing N and P loads are discussed in Appendix 4.

5.3.5 Cost of Staging

Staging development of infrastructure may, of course come at some cost (relative to the benefits that might accrue from development occurring all at once and as market conditions dictate). That question was considered and reported separately (see Butcher, 2011).

That analysis considered stepped development of three significant infrastructure projects being:

- Storage at Lake Sumner (involving a weir and associated distribution network) allowing irrigation of 11,000ha.
- South Branch Dam allowing irrigation of 31,000ha.
- Water from Waiau River (a variation of the South Branch dam proposal involving abstraction from the River and canals with on-farm storage).

The results of the analysis are not repeated here expect to say that there are significant effects on net present value (NPV) of development, with the extent dependent on the discount rate used, the uptake rate and mix of land use. Estimates range from \$70 million to as high as \$310 million.

Effects on affordability of schemes from the farmer perspective were also assessed. Again the effect of staging depends on the interest rates that apply to loans and the nature of the payment regime that applies.

Development of the Zone Implementation Plan provides the opportunity to assess opportunities for staging. However what the above research shows is that there is a need to carefully consider the costs and economic feasibility.

5.4 *Costs and benefits of infrastructure development*

The Hurunui experience also highlighted the need to consider costs and benefits across the full range of values when considering futures involving infrastructure development (staged or otherwise).

For example, if water storage is considered there are a number of potential benefits over and above the economic benefits if that storage is designed and operated appropriately. These include:

- Allowing for controlled flooding events could enhance survivability of some native species and flushing could reduce the effect of phosphorus.
- Greater certainty of flow knowledge potentially supports recreational activities such as kayaking.
- Provide for a dilution effect of nutrients in the surface water and potentially increase biodiversity (reflecting environmental and cultural values) through greater access to water through the summer.
- Reduce phosphorus flows from the headwaters.
- Provide greater certainty for water off take and therefore productive activity.
- Provide an option for additional drinking water.

It is, therefore, not necessarily an either /or scenario (of economic benefit versus environmental cost) but appropriate implementation can potentially result in the simultaneous enhancement of multiple values.

5.5 *Agreement on calculated load limits*

Despite the significant volume of information collected and evaluation of that information, the Hurunui process has yet to produce clear and universal agreement on the load limits that should apply in the catchment.

There was a general acceptance that the option that would ‘probably’ achieve all environmental outcomes was the appropriate risk management approach. The scenario that would “probably” achieve NRRP objectives in the Hurunui main stem is a “current use”/maintain water quality at 2005/2009 levels. For the tributaries it meant a land use scenario that would lead to improvement on current state (i.e. Scenario B returning to 1990-1995 water quality). All parties agreed with that although it was also recognised that further analysis with the inclusion of river flow regime information, and deliberations were needed to confirm or otherwise the acceptance of these limits.

6 Implementation of a land use water quality programme in the Hurunui

While there are well-established measures to minimise the loss of nutrients from land, these have not been widely applied, partly because the link between land use and the effects on water quality and habitat are not known or are poorly understood. Even if these links are well understood, this may not sway a person's behaviour, because other factors, such as production rates and economic returns are more influential. New measures may not be readily adopted, because of scepticism over their effectiveness, practical difficulties with their application, or the extra costs or work that they impose.

In short, it is clear that agreeing a nutrient load limit and associated management objectives and broad-scale catchment plan would not of itself be sufficient to bring about change in on-farm practice. However, it is an essential start point or framework – within which other means of intervention can come into play.

On the other hand, the assumption at the beginning of the project was that the results of past scientific work would provide significant information to support optimising the balance of the four values (economic, social, cultural and environmental). The scientific information provided guidance in terms of modelling the flow of nutrients (e.g. use of OVERSEER and CLUES) and assessing possible mitigation options. The ability to make links between the scientific results and the outcomes, however, proved much more difficult. In short, the science has highlighted the uncertainty in which management must operate.

This means that implementation through additional intervention needs to proceed with care lest, in the face of uncertainty, irreversible social, cultural, economic or environmental effects result.

For that reason, the basic approach proposed for Hurunui is to take an *adaptive management* approach whereby management steps are taken, monitoring occurs, effectiveness is reviewed and change is made to the nature/level of management as may be required.

This approach has significant implications for implementation in the Hurunui. Considerable policy work was carried out and options discussed before the Governance Group agreed a preferred approach. Issues for resolution include:

- How is the agreed development future assured? What specific tools should be used to drive change on-farm?
- Who should be responsible for what?
- How should any “nutrient loss potential” be allocated to new and existing users?
- What is the role of the regional plan?
- How should nutrient management be coordinated with other relevant resource management decision-making in the region (including in particular water allocation)?

7 Conclusions

The Hurunui pilot study has shown that “doing nothing” in the Hurunui catchment is not an option. Continuing to make gradual changes to land management (as may occur without further intervention) has the potential to maintain the Hurunui River at current nutrient levels and potentially reduce levels in the Pahau and St Leonard’s tributaries (as land owners improve efficiencies in, for example, water and nitrogen use and modify production practices).

However, this will also mean no further (or very slow and untargeted) development in the catchment resulting in limited or no further land use conversions and/or intensification of agricultural activities and continued uncertainties related to water supply.

The result will be to reduce business viability and resilience. Land-based businesses, like all businesses, must continue to improve productivity to remain viable. A reduction in economic viability within the catchment will impact not only on the catchment but also across the Canterbury region. Reducing the nutrient targets (whilst not a conclusion from the study) would only exacerbate the decline in both economic and social values. In order to maintain economic viability (and associated social values) further agriculture development is necessary.

The key question to be answered, then, is how can we provide for further development of the Hurunui catchment whilst providing the community confidence that adverse environmental effects can be appropriately managed?

The Hurunui study has strongly suggested the approach needs to be based on:

- Setting load limits in full knowledge of all costs and benefits.
- Fully considering all options to meeting water quality objectives (not just managing land use development and nutrient loss). Inevitably other strategies (such as managing flow regimes and influencing water temperature through shading) will be important to meet periphyton objectives.

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Appendix 1 – The nutrient problem

Why manage nutrients?

The nutrients nitrogen and phosphorus are critical for the growth of aquatic algae (e.g. periphyton and phytoplankton) and larger vascular plants (e.g. macrophytes) and they thus play a key role in sustaining primary production in the aquatic food chain. Without nutrients, freshwater aquatic ecosystems including invertebrate grazers, fish and bird species, would not exist as we know them. However, while healthy levels of nutrients are critical for sustaining aquatic ecosystems, elevated nutrients and other associated contaminants can cause water quality problems in several ways:

- Nitrate has toxic effects for humans and aquatic fauna at relatively high concentrations. The New Zealand Ministry of Health’s human drinking Maximum Acceptable Value (MAV) is 11.3 mg/L nitrate-N. The recommended trigger value for protecting 95% of aquatic species from nitrate toxicity is 1.7 mg/L nitrate-N and the trigger for protecting 80 to 90% of species is 2.4 to 3.6 mg/L nitrate-N (Hickey and Martin 2009).
- At much lower concentrations (i.e., in the order of less than 1 mg/L) nitrate and other forms of dissolved inorganic nitrogen (DIN) can, in combination with dissolved reactive phosphorus (DRP) and other environmental factors, cause proliferations of algae and macrophytes in rivers and lakes. Nuisance algae and macrophyte growths degrade visual amenity and recreation values and can also lead to eutrophication effects such as reduced dissolved oxygen concentrations and diurnal pH fluctuations which have adverse effects on aquatic invertebrates and fish. Any effects on invertebrates and fish may affect food-webs and thus also aquatic birds.

Terms

Nutrient concentration is the amount of nitrogen or phosphorus per unit volume of water. It is usually expressed in mg/L.

Nutrient load is the total amount of nitrogen or phosphorus entering a catchment during a period of time. It is usually expressed as either kg/year or tonnes/year at a defined point in the catchment e.g., a flow gauging site.

Catchment nutrient load limit (sometimes called a “nutrient cap”) is a limit set for management purposes. It represents the maximum nutrient load that can be carried by a river while maintaining a specified value (or set of values) e.g., salmonid spawning habitat. It is usually expressed as kilograms or tonnes per year at a defined point in the catchment.

Property nutrient leaching loss is the total mass of nutrients lost or discharged from a property over a specified area and time period. This includes nutrients discharged from both point and non-point sources. It may be expressed in kg/ha/year or as the total load (kg/year) for the whole property. Property leaching losses can be estimated by farm-scale nutrient loss models, or by measurement.

Property nutrient load limit is the maximum nutrient load that may be discharged from a property. The limit may be a nominal or informal target to guide land owners or a regulatory requirement. It may be expressed as either a load limit for the whole property (kg or tonnes per year) or as an average discharge in kg/ha/year.

- In addition, increased nutrient loads can sometimes be associated with increased sediment entering surface waterways. Increased sediment decreases water clarity and if sediment settles on the riverbed, may smother and degrade habitat for aquatic flora and fauna.
- Micro-organism levels (e.g. bacteria and viruses) are often elevated when nutrient loads are elevated because they come from the same source in agricultural catchments (i.e. animals and grazed pasture). Micro-organisms of human or animal origin increase the risk of illness associated with drinking the water or contact recreation such as swimming.

In general, the four contaminants mentioned above (i.e. nitrogen, phosphorus, sediment and micro-organisms) are the key contaminants of concern with respect to managing the cumulative effects of non-point source pollution of waterways. While it is important to manage all four of these contaminants, because they all arise from similar sources and are mitigated by similar practices, managing nutrients (using load limits for example) is expected to have co-benefits in terms of also managing sediment and micro-organisms. This project has focussed on nutrients because there are currently more advanced technical tools available for setting load limits for nutrients than for sediment or micro-organisms.

Appendix 2 – Modelled and measured nutrient loads

Figure A2a - Comparison of modelled and measured nitrogen loads (TN – total nitrogen, DIN – dissolved inorganic nitrogen)

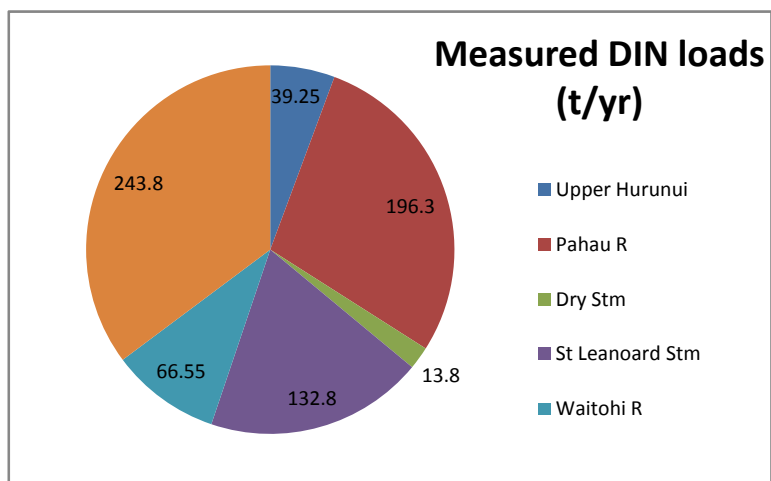
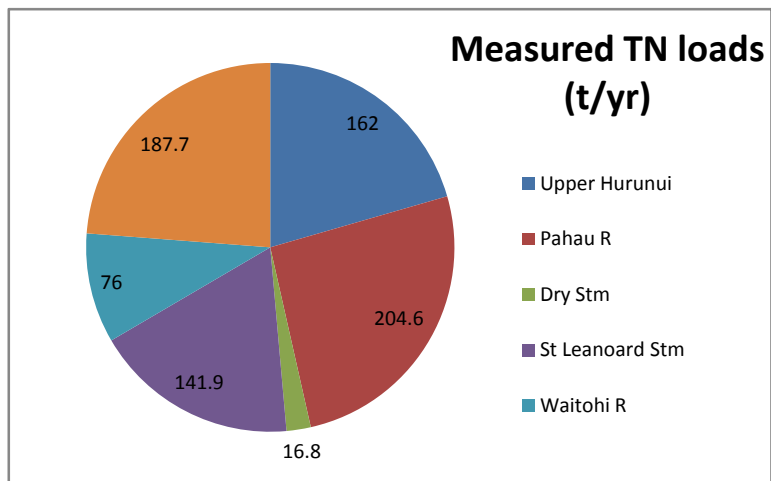
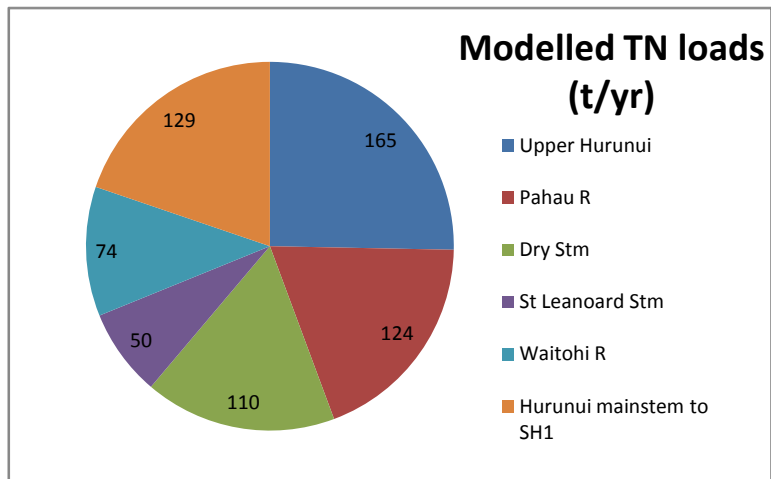
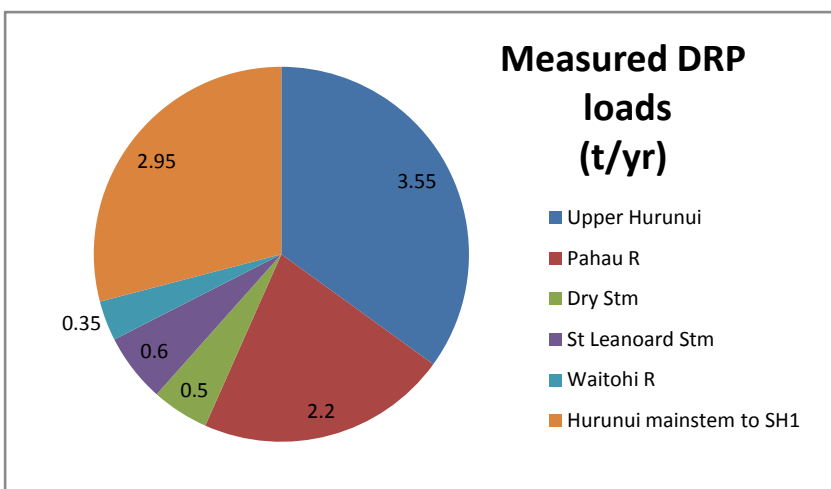
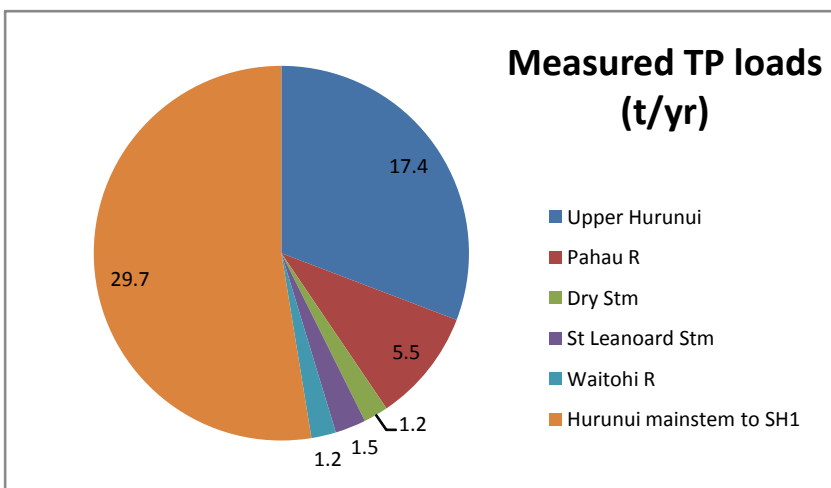
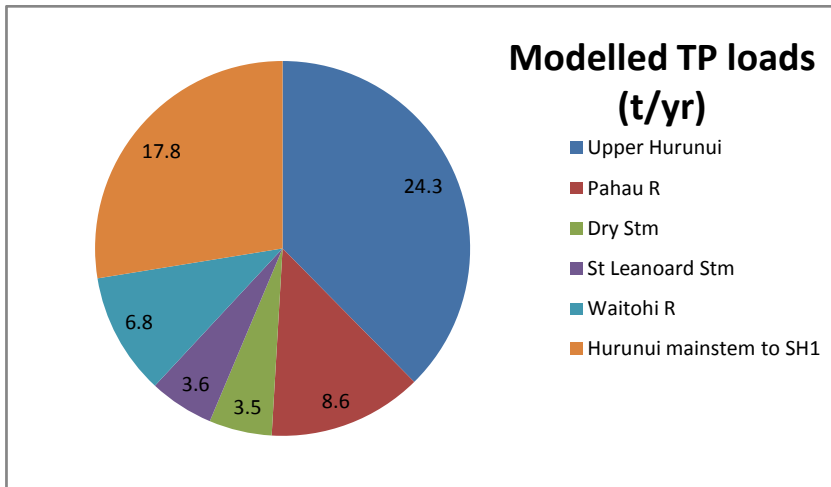


Figure A2b - Comparison of modeled and measured nitrogen loads (TN – total phosphorus, DRP – dissolved reactive phosphorus)



Appendix 3 – Process used for setting nutrient load limits

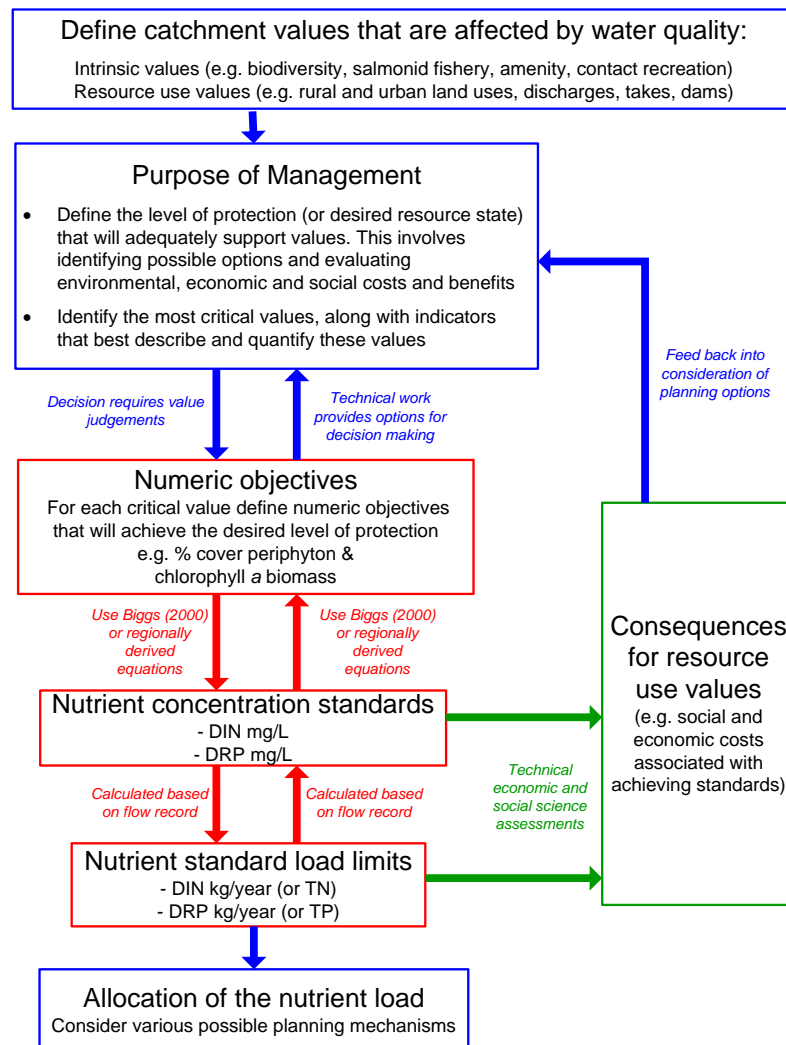


Figure NN2. Overview of the process used for defining nutrient load limits. Red arrows and text boxes show the technical steps carried out by Norton and Kelly (2010); for a series of options for numeric environmental objectives, the related nutrient concentration standards and nutrient load limits were derived. Green arrows and text box show the assessment of economic and related social consequences of options carried out by Harris and Wederburn. Blue arrows and text boxes show elements of the planning process; defining values; evaluating the balance between environmental, economic, social and cultural values; selecting a preferred option; and allocating the nutrient load amongst users.

Appendix 4 – Scenario evaluation tables

Table A4a. Predicted environmental effects of scenarios for Hurunui at SH1.

VALUES AND ASSESSMENT CRITERIA ACHIEVED FOR EACH SCENARIO...	SCENARIOS				
	A (Conservative modelled)	B (1990-1995 data)	1 (Current - 2005-2009 data)	2 (Business as usual)	3 (Extensive irrigation)
NRRP periphyton objective (120 mg/m ²)	Almost certainly	Almost certainly	Probably	Possibly?	Possibly?
Visual aesthetic values (<20% algae cover)	Almost certainly	Almost certainly	Probably	Possibly?	Possibly?
Visual water clarity	Almost certainly	Almost certainly	Almost certainly	Probably	Probably
Recreation values (safety, microbiological health)	Almost certainly	Almost certainly	Probably	Possibly?	Possibly?
Benthic biodiversity (invertebrates QMCI, EPT response to algae)	Almost certainly	Almost certainly	Probably	Possibly?	Possibly?
Trout habitat & angling (based on NZ periphyton guidelines)	Almost certainly	Almost certainly	Probably	Possibly?	Possibly?
Nitrate toxicity criteria to protect 95% aquatic species biodiversity (~1.7 mg/L)	Almost certainly	Almost certainly	Almost certainly	Almost certainly	Almost certainly
Nitrate toxicity criteria to protect human drinking quality (~11.3 mg/L)	Almost certainly	Almost certainly	Almost certainly	Almost certainly	Almost certainly
Riverbed birds (with respect to maintaining aquatic food supplies only)	Almost certainly	Almost certainly	Probably	Possibly?	Possibly?
¹ Ngai Tahu eco-cultural values	?	?	?	?	?

Note: 1 = An assessment of Ngai Tahu eco-cultural values is in progress. An agreed process for integrating an assessment of scenario implications for Ngai Tahu values has not been finalised, however it is likely to include Cultural Monitoring in the Hurunui case study area in early 2011 and associated predictions for cultural health across the five scenarios.

Table A4b. Predicted environmental effects of scenarios for Hurunui at Mandamus.

VALUES AND ASSESSMENT CRITERIA ACHIEVED FOR EACH SCENARIO...	SCENARIOS				
	A (Conservative modelled)	B (1990-1995 data)	1 (Current - 2005-2009 data)	2 (Business as usual)	3 (Extensive irrigation)
NRRP periphyton objective (50 mg/m ²)	Almost certainly	Almost certainly	Probably	Probably	Probably
Visual aesthetic values (<10% algae cover)	Almost certainly	Almost certainly	Probably	Probably	Probably
Visual water clarity	Almost certainly	Almost certainly	Almost certainly	Probably	Probably
Recreation values (safety, microbiological health)	Almost certainly	Almost certainly	Probably	Probably	Probably
Benthic biodiversity (invertebrates QMCI, EPT response to algae)	Almost certainly	Almost certainly	Probably	Possibly?	Possibly?
Trout habitat & angling (based on NZ periphyton guidelines)	Almost certainly	Almost certainly	Probably	Probably	Probably
Nitrate toxicity criteria to protect 95% aquatic species biodiversity (~1.7 mg/L)	Almost certainly	Almost certainly	Almost certainly	Almost certainly	Almost certainly
Nitrate toxicity criteria to protect human drinking quality (~11.3 mg/L)	Almost certainly	Almost certainly	Almost certainly	Almost certainly	Almost certainly
Riverbed birds (with respect to maintaining aquatic food supplies only)	Almost certainly	Almost certainly	Probably	Probably	Probably
¹ Ngai Tahu eco-cultural values	?	?	?	?	?

Table A4c. Predicted environmental effects of scenarios for Lower Pahau River at Dalzells.

VALUES AND ASSESSMENT CRITERIA ACHIEVED FOR EACH SCENARIO...	Scenarios...				
	A (Conservative modelled)	B (1990-1995 data)	1 (Current - 2005-2009 data)	2 (Business as usual)	3 (Extensive irrigation)
NRRP periphyton objective (200 mg/m ²)	Almost certainly	Probably	Possibly?	Possibly?	Possibly?
Visual aesthetic values (<30% algae cover)	Almost certainly	Possibly?	Possibly?	Possibly?	Possibly?
Visual water clarity	Almost certainly	Probably	Possibly?	Possibly?	Possibly?
Recreation values (safety, microbiological health)	Almost certainly	Possibly?	Possibly?	Possibly?	Possibly?
Benthic biodiversity (invertebrates QMCI, EPT response to algae)	Almost certainly	Possibly?	Possibly?	Possibly?	Unlikely
Trout habitat & angling (based on NZ periphyton guidelines)	Almost certainly	Possibly?	Possibly?	Possibly?	Possibly?
Nitrate toxicity criteria to protect 95% aquatic species biodiversity (~1.7 mg/L)	Almost certainly	Probably	Unlikely	Unlikely	Unlikely
Nitrate toxicity criteria to protect human drinking quality (~11.3 mg/L)	Almost certainly	Almost certainly	Almost certainly	Almost certainly	Almost certainly
¹ Ngai Tahu eco-cultural values	?	?	?	?	?

Table A4d. Predicted environmental effects of scenarios for Lower Waitohi River above Hurunui confluence.

VALUES AND ASSESSMENT CRITERIA ACHIEVED FOR EACH SCENARIO...	Scenarios...				
	A (Conservative modelled)	B (1990-1995 data)	1 (Current - 2005-2009 data)	2 (Business as usual)	3 (Extensive irrigation)
NRRP periphyton objective (200 mg/m ²)	Almost certainly	Probably	Possibly?	Possibly?	Possibly?
Visual aesthetic values (<30% algae cover)	Almost certainly	Possibly?	Possibly?	Possibly?	Unlikely
Visual water clarity	Almost certainly	Probably	Possibly?	Possibly?	Possibly?
Recreation values (safety, microbiological health)	Almost certainly	Possibly?	Possibly?	Possibly?	Unlikely
Benthic biodiversity (invertebrates QMCI, EPT response to algae)	Almost certainly	Possibly?	Possibly?	Possibly?	Unlikely
Trout habitat & angling (based on NZ periphyton guidelines)	Almost certainly	Probably	Possibly?	Possibly?	Unlikely
Nitrate toxicity criteria to protect 95% aquatic species biodiversity (~1.7 mg/L)	Almost certainly	Probably	Almost certainly	Almost certainly	Almost certainly
Nitrate toxicity criteria to protect human drinking quality (~11.3 mg/L)	Almost certainly	Almost certainly	Almost certainly	Almost certainly	Almost certainly
¹ Ngai Tahu eco-cultural values	?	?	?	?	?

Table A4e. Predicted environmental effects of scenarios for St Leonards Stream.

VALUES AND ASSESSMENT CRITERIA ACHIEVED FOR EACH SCENARIO...	Scenarios...				
	A (Conservative modelled)	B (1990-1995 data)	1 (Current - 2005-2009 data)	2 (Business as usual)	3 (Extensive irrigation)
NRRP periphyton objective (200 mg/m ²)	Almost certainly	Possibly?	Possibly?	Unlikely	Unlikely
Visual aesthetic values (<30% algae cover)	Almost certainly	Possibly?	Possibly?	Unlikely	Unlikely
Visual water clarity	Almost certainly	Probably	Possibly?	Possibly?	Possibly?
Recreation values (safety, microbiological health)	Almost certainly	Possibly?	Possibly?	Unlikely	Unlikely
Benthic biodiversity (invertebrates QMCI, EPT response to algae)	Almost certainly	Possibly?	Possibly?	Unlikely	Unlikely
Trout habitat & angling (based on NZ periphyton guidelines)	Almost certainly	Possibly?	Possibly?	Unlikely	Unlikely
Nitrate toxicity criteria to protect 95% aquatic species biodiversity (~1.7 mg/L)	Almost certainly	Probably	Unlikely	Unlikely	Unlikely
Nitrate toxicity criteria to protect human drinking quality (~11.3 mg/L)	Almost certainly	Almost certainly	Almost certainly	Almost certainly	Almost certainly
¹ Ngai Tahu eco-cultural values	?	?	?	?	?

Table A4f. Predicted environmental effects of scenarios for Dry Stream.

VALUES AND ASSESSMENT CRITERIA ACHIEVED FOR EACH SCENARIO...	Scenarios...				
	A (Conservative modelled)	B (1990-1995 data)	1 (Current - 2005-2009 data)	2 (Business as usual)	3 (Extensive irrigation)
NRRP periphyton objective (200 mg/m ²)	Almost certainly	Possibly?	Possibly?	Unlikely	Unlikely
Visual aesthetic values (<30% algae cover)	Almost certainly	Possibly?	Possibly?	Unlikely	Unlikely
Visual water clarity	Almost certainly	Probably	Possibly?	Possibly?	Possibly?
Recreation values (safety, microbiological health)	Almost certainly	Possibly?	Possibly?	Unlikely	Unlikely
Benthic biodiversity (invertebrates QMCI, EPT response to algae)	Almost certainly	Possibly?	Possibly?	Unlikely	Unlikely
Trout habitat & angling (based on NZ periphyton guidelines)	Almost certainly	Possibly?	Possibly?	Unlikely	Unlikely
Nitrate toxicity criteria to protect 95% aquatic species biodiversity (~1.7 mg/L)	Almost certainly	Probably	Almost certainly	Almost certainly	Almost certainly
Nitrate toxicity criteria to protect human drinking quality (~11.3 mg/L)	Almost certainly	Almost certainly	Almost certainly	Almost certainly	Almost certainly
¹ Ngai Tahu eco-cultural values	?	?	?	?	?

Appendix 5 – Community deliberation process

Deliberation process catchment workshops

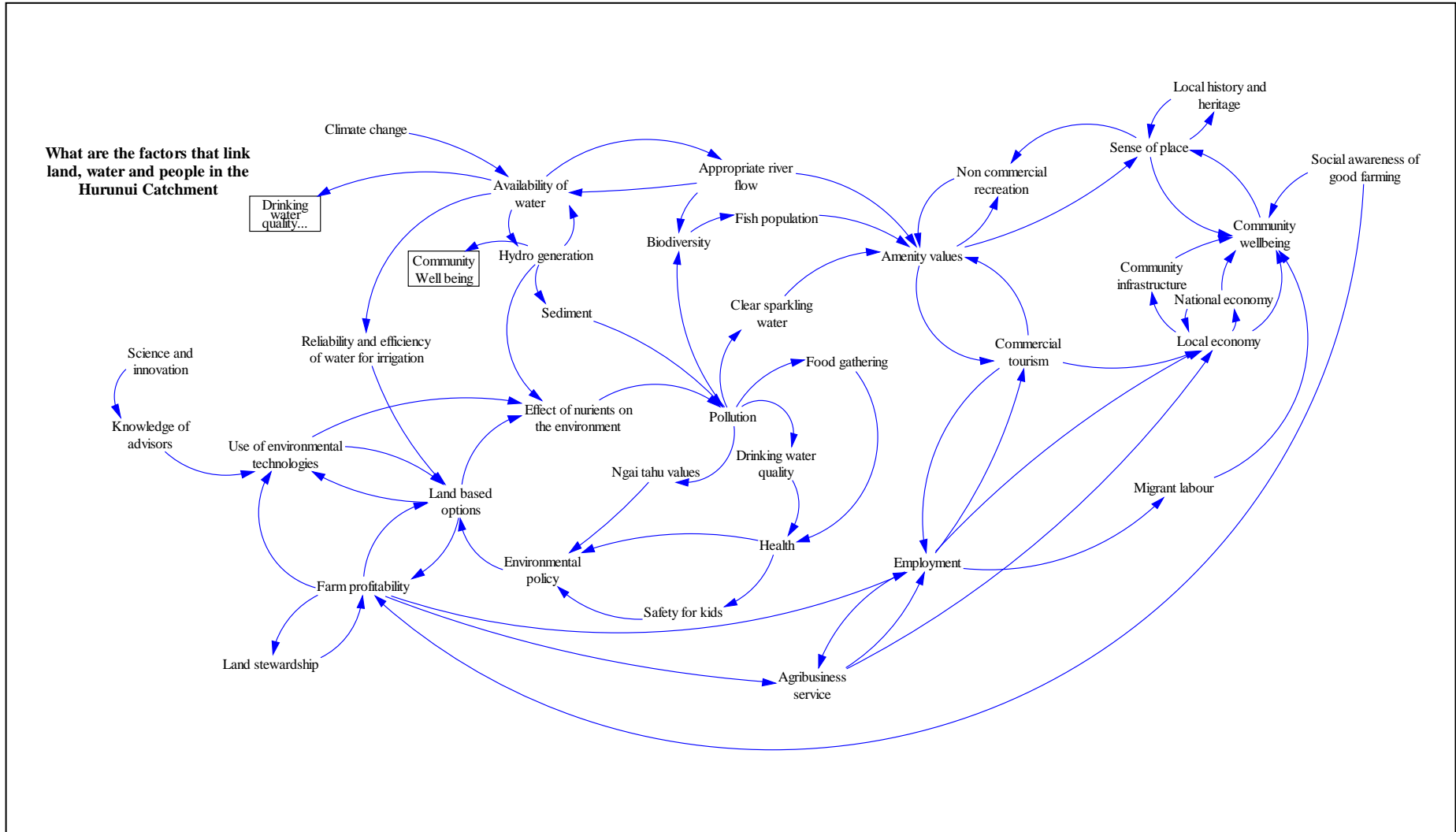
The deliberation process was worked through a series of five catchment workshops involving eleven different stakeholder groups, held in the Rotherham and Waipara community halls. The purpose of the catchment workshops was to inform and support the development of a preferred approach by: taking into consideration the links between land, water and people, and using a multi-stakeholder deliberative approach that enhanced collective learning of all the participants.

Building an understanding of the system from presentations and from construction of systems map

To assist in building a common understanding of the working of the Hurunui catchment the stakeholders were brought up to date on the current state of water, land, economy, and social indicators in the Hurunui catchment through presentations by the research team. The stakeholders' knowledge system was captured in their development of a causal loop map (Figure A5a) representing the land, water, people system based on the following question: What are the factors that link land, water and people in the Hurunui catchment?

This map was used as a base to demonstrate the relationships between factors and to identify the flow on consequences of actions that could be placed in the system to address the water quality issue. In this way unintended consequences were identified and participants could see how their value sets impacted on others. This led to wider thinking on what further actions may be required and informed the identification of mechanisms for use in the preferred approach.

Figure A5a – The Hurunui causal loop map



The map demonstrates the following 3 key points of leverage: **availability of water** as it drives what can occur on land and water ecosystems; **land use** influences a number of relationships: water quality, ecosystem and amenity values; farm profitability, local employment and community well being; **pollution** influences biodiversity, amenity values and community well being as well as having a feedback to land use. **Community well-being** is influenced by both economic performance generated by land use and water quality. A reinforcing cycle is a positive feedback system that can either be vicious or virtuous in nature dependent on the situation.

The map identified a number of reinforcing cycles: An example of a vicious cycle is: as nutrient leaching increases from land use then pollution increases and drinking water condition may decrease, decreasing safety and increasing environmental regulations on land use. However if nutrients leaching from land use are decreased there is a decrease in pollution, increase in drinking water safety and less requirement for environmental regulation; this is an example of a virtuous cycle. The map was used to identify where actions could be targeted to turn potentially vicious cycles into virtuous ones. Examples of the type of actions that were identified were: scientific based technologies to mitigate nutrient leaching; consents to take water should be linked to a requirement to have mitigations in place by a certain time; farm profitability needs to be taken into consideration in the costs of implementing mitigations; enhanced amenity values will increase the sense of place and enhance tourism opportunities; enhancing nature's infrastructure e.g. wetlands and riparian margins will improve biodiversity and amenity values and the flow on impacts into tourism and community well being.

Choice of values and indicators

Stakeholder groups had to choose and weight a list of up to 5 values for each of four well-beings, environment, economic, social and cultural, and for each value identify up to 3 indicators that they would use to assess the acceptability of scenarios. These values and indicators were obtained from a range of sources: Long-term community council plans, CWMS, international literature and stakeholders. To aid the stakeholders in their choice an inventory of values and associated indicators was made available by the research team compiled from the sources noted above (Appendix X).

Three judgements could be chosen: green acceptable; red unacceptable; and blue we don't know the impact. The reasons for each judgement were recorded. There was commonality between stakeholders in the values that they chose however the choice of indicators to describe the values indicated differences in their thinking.

Key Messages

- The weighting of the value sets demonstrated the tension between environmental and economic outcomes between stakeholders. However there was a realisation that the two are interlinked and you cannot have one at the expense of another.
- The choice of values informed a third management objective of the preferred approach i.e. recreational and ecosystem outcomes maintained and enhanced.
- Translation between biological units to inform values of relevance to stakeholders is required.
- Not enough knowledge is available to populate social, cultural and environmental externality values.

The values and indicators guided the science team in their analysis as they attempted to parameterise the value sets. It highlighted the requirement for a translation to occur between biological units such as ppm to values such as water clarity and species diversity. Significant gaps were identified in the ability of the science team to populate social, cultural and environmental externality values and indicators. There was a distinction between stakeholder groups who chose values related to in stream water quality and associated ecosystems only and those who included agro-environmental values.

Assessment of scenarios

In catchment workshop 2, stakeholders were presented with three scenarios: 1. Current situation; 2 Business as usual and 3 Extensive irrigation. These futures were driven by land use. The stakeholders then requested that future scenarios driven by maintenance and enhancement of water quality be constructed for assessment. This resulted in scenario A Conservative modelled scenario and B 1990 – 95 Hurunui Water Quality. All stakeholder groups with the exception of Iwi had the highest number of acceptable values under scenario B. The stakeholder groups were split with farmers, growers, agribusiness, rural woman and local authority and health having a greater number of acceptable values under scenarios B and 3 and environmental, tourism, energy and recreation are having a greater number of acceptable values under scenarios A and B. This information guided the science team in their choice of management objective i.e. maintain current state of water quality in the main stem and improve some tributaries.

Stakeholder groups based their judgements on the presentations given by the science team and their own perceptions. Where the scenarios did not appear plausible, stakeholders attached their own assumptions. Certain assumptions were used by stakeholders to allocate an acceptable judgement and these were related in the main to: farmers adopting existing Good Management Practices (GMPs) and future technologies developed by science; rules would be linked to allocation of new water; voluntary initiatives would be backed by regulation; implementation of GMPs would be linked to the ability of farms to remain profitable; greater certainty would be given regards efficacy of GMPs and targets to meet. These assumptions demonstrate that stakeholders understand that business as usual will not be enough as land use change intensifies.

The impact of the scenarios on some values was unknown. This knowledge gap should be taken account of in the development of material for education packages to inform the community and build their understanding.

Key Messages

- Clear plausible options for addressing an issue must be the starting point for assessment by stakeholders.
- Analysis of the options must take into account local knowledge so that stakeholders can see what the impact is on their lives.
- The reason for the choice of judgement must be well documented and articulated to the other stakeholders.
- The judgements guided the development of nutrient limits.

Informing preferred approach

The deliberation process has informed all parts of the preferred approach:

Management Objectives: Assessment of the impact of the scenarios on value sets guided the development of the nutrient limits, the requirement for future agricultural development and the recognition of an objective related to the maintenance and enhancement of recreational and ecosystem outcomes.

Monitoring: Clear targets need to be set and monitoring achieved in accurate real time with protocols being realistic from a farmer's point of view. Principles of self auditing are accepted with third party auditors and Environment Canterbury involvement. Sub-catchment monitoring points are supported while suspicion around modelling will have to be addressed. Monitoring the impact of change is important and should include economic, social and cultural outcomes as well as water quality and results should be communicated back to farmers and the community to demonstrate progress.

Adaptive Management: Aspects of adaptive management that the stakeholders liked included the staged development approach with the addition of a fast time line for implementation. The time lines would be relooked at as science delivers new solutions. It is important when evaluating the system impact of introduced mechanisms that those people impacted are involved. The deliberations have the potential to make transparent the trade offs that different stakeholder groups are willing to make across their value sets when deciding on the most acceptable policy, mechanisms, or future scenario. In this case study stakeholders were able to make transparent how each of the scenarios would impact on their value sets and although this process guided the preferred approach it is only when the actual policies and actions are identified and their impacts at the farm and catchment scale are analysed will there be the opportunity to really identify the trade offs.

Mechanisms

The deliberations identified a number of different mechanisms that enabled a value set to be acceptable and by understanding where scenarios impacted in an unacceptable manner on values the stakeholders

Key Messages

- Deliberation process is an excellent means of stakeholders learning from each other and making transparent reasons for the choice of options, building trust and informing the process of catchment management.
- There is agreement that agricultural development could take place with a process in place to meet the agreed water quality targets and taking account of the impact on social, cultural and economic values.
- The management objectives and the components of the preferred approach are accepted in principle and more work will be required to fully understand the trade offs that will be accepted when the detail of the implementation is developed and deliberated.
- Partnerships between community, industry, and farmers are key to a successful implementation.

were able to identify mechanisms that could change the value to acceptable. The mechanisms include those that will enable behaviour change, those aimed at informing good management practice and those mechanisms aimed at reinforcing positive cycles.

Enabling Behaviour Change

The following are examples of mechanisms that will enable behaviour change: linking consent to take water with a requirement to put in place mitigations and mechanisms such as water metering to increase efficiency of use. A bigger pool of rural professionals to guide the process, especially in the environmental management area, is required to guide the use of mitigations. Building trust between stakeholders is critical to success and therefore there needs to be in place a robust process for addressing poor performance and linking rights to responsibilities including intergenerational responsibilities. In turn the community should recognise farmers for actions that are making progress.

Informing GMPs

The following are examples of mechanisms that will inform GMPs: the provision of principles that farmers can use to design their own solutions that allow flexibility to choose mitigations that will match their farm system. The cost of mitigation needs to be known so it can be balanced with the benefit to the environment. Development of farm plans should be set within the context of a catchment plan. Community sharing in catchment schemes such as riparian planting is welcomed.

Reinforcing positive cycles

By identifying the leverage points in the causal loop diagram of the Hurunui system and linking these to the stakeholder values sets the following mechanisms were identified: the requirement to have available reliable water; taking into consideration when putting in place any mechanism that the unintended consequences across the four well beings are fully understood i.e. the trade offs by all stakeholders. Investment in research and development is critical to the delivery of a long-term solution as the technological fixes will reverberate throughout the system, however robust monitoring systems must be in place to pick up the unexpected and unintended consequences.

Appendix 6 – Mitigation options in the Hurunui

A toolbox of on-farm and off-farm mitigation options

There are a number of mitigations available that can reduce the transfers of pollutants from farms to water. For convenience, these can be categorised into Tier 1 and Tier 2 mitigation practices, with Tier 1 representing those practices that have been well proven and are relatively cost-effective – these can perhaps be described as the “low-hanging fruit”. Examples include stream fencing to prevent stock access, protecting existing wetlands, nutrient management planning and the implementation of the suite of improved effluent management practices that are now available. Tier 2 practices can be considered as ones where some uncertainty remains as to their effectiveness (e.g. the use of nitrification inhibitors) or where their cost-effectiveness is relatively low (e.g. the use of Herd Shelters, constructed wetlands, etc). Below we discuss some of these Tier 1 and 2 mitigation practices that are potentially of relevance to farms in the Hurunui catchment.

There may also be mitigation option at the catchment scale (such as weirs, a large scale constructed wetlands), which for convenience may be termed Tier 3 practices (even though they may be appropriate to use before Tier 1 or 2 measures).

Irrigated cattle grazed systems

Some potential mitigation practices of relevance to cattle-grazed pastures are listed in Table 1. The cost-effectiveness of some of these options has been modelled using the generic dairy farms described in Appendices I and II; summary results are included in the Table below for context.

Table A6a - Some mitigation practices of relevance to cattle-grazed farming enterprises in the Hurunui catchment

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	

¹Percentage values documented in Table A6a are those derived from the farm-scale modelling undertaken for the project and reported in Appendix I of this report.

Table A6a shows that there are a number of practices that can potentially make significant reductions in farm scale losses of N and P. Unfortunately many of these also incur a net cost, albeit sometimes quite minor, and/or sometimes require a significant investment of capital. For nutrient-sensitive catchments, implementation of the Tier 1 practices would however appear to be a sensible recommendation given that all of these practices can be considered highly cost-effective. The implementation of Tier 2 practices is a rather more complex matter. Some pertinent points here are:

- Farm-specific assessments are important. The modelling assessments undertaken here were done to provide an indication of some of the options available to farms in the catchment and their possible costs and benefits. Actual values will vary between farms and farm-specific actions should be based on farm-specific assessments.
- Some mitigations “fit” some farms better than others. As an example, some dairy farmers express the desire to contract-out cow wintering activities so they can take a much-needed break over the winter period; for this group of farmers, the prospect of being confined to the farm to feed cows wintered in a herd shelter may be quite unattractive. Conversely, some farmers have the specific goal of retaining control over their stock during the important winter period; for this group, herd shelters may be an attractive option. Another example is the restoration and protection of wetlands: often the most practical sites for doing this are on specific parts of the landscape where natural seepage flows can be adequately intercepted and treated; for many farms on stony, very free-draining soils, few such opportunities may exist.
- Some of the measures incur large capital costs. This increases business risk that may make the purchase of large capital items such as herd shelters unpalatable.
- Some of the measures significantly reduce farm profitability. This needs to be recognised and weighed up against the seriousness of the water quality issue that is being considered.
- Some uncertainty remains around the effectiveness of many of the Tier 2 measures. Whilst the science community will never have a perfect state of knowledge, it does need to be recognised that many measures are still being actively researched to better define their effectiveness in a wider range of environments and to understand if they have any un-intended consequences. Relevant examples here include nitrification inhibitors, Herd Shelters and wetland attenuation technologies.

Dry stock farms

Some potential mitigation practices of relevance to dry stock farms in the catchment are listed in Table A6b. Given the fewer number of options available and the lower profitability of these farming systems, the distinction between Tier 1 and Tier 2 practices is probably of less importance. We have, however, attempted to rank the measures from most cost-effective to least cost-effective as a guide to where the “biggest bang for buck” might be achieved.

Exclusion of stock from streams is a key measure that has multiple benefits, particularly if accompanied by planting of riparian margins to enhance shade and provide habitat. This measure is particularly important on deer farms, although it is recognised that the capital costs of implementing

this can be considerable. Good nutrient management planning to ensure fertiliser nutrients are applied according to need, and at rates and times and in forms that maximise opportunity for plant uptake, is also an important management step that will minimise nutrient losses from farms. On-going research by NIWA (McKergow et al. 2008; Hudson 2010) continues to show that wetlands can be very effective at removing N, sediment and faecal bacteria from seepage and land drainage; the protection and enhancement of existing wetlands in the catchment should therefore be considered a measure of high priority. Changing from border dyke to spray irrigation is another measure that will help to reduce P and N losses from farms, although it is again recognised that there is a large capital investment required (approx. \$3000-4000 per hectare).

The remaining measures documented in Table A6b are also viable mitigation options for consideration, although they are assessed as having a lower cost-effectiveness and perhaps greater uncertainty regarding their performance.

Table A6b - Some potential mitigation practices of relevance to dry stock farms in the Hurunui catchment

Mitigation practice	Effectiveness	Cost-effectiveness	Comment
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	
Facilitating the development of natural wetlands	High for N, sediment and faecal bacteria	Medium	Also has many ancillary benefits
Changing from border dyke to spray irrigation	High	High	High capital cost, but does bring production benefits
Use of nitrification inhibitors	High for N?	Medium	Some uncertainty still concerning cost-effectiveness
Constructed wetlands	High for N, sediment and faecal bacteria	Low	
Grass buffer strips	Modest to low	Low	

