Environment Canterbury
Regional Council
Kaunihera Taiao ki Waitaha

TECHNICAL REPORT Investigations and Monitoring Group

South Canterbury Coastal Streams (SCCS) limit setting process

Predicting consequences of futur scenarios: Overview Report

Report No. R15/29
ISBN 978-0-478-15141-1 (print)
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Executive summary

Between 2012 and 2015, Environment Canterbury ran a collaborative and community-centred process to set water quality and quantity limits in the South Canterbury Coastal Streams (SCCS) catchments. The collaborative process built upon an earlier process known as the 'preferred approach' developed in the Hurunui catchment and evolved in the Selwyn Te Waihora and Hinds Plains catchments.

The Lower Waitaki Zone Committee (ZC), supported by community groups, was the recipient of a large body of technical information, and was responsible for recommending water quality and quantity limits to the Environment Canterbury Commissioners.

To inform decisions on these limits, a set of seven exploratory scenarios was developed to examine the social, cultural, economic and environmental consequences of different futures for the catchment. This information was used by the ZC, community and stakeholder participants to debate the merits of the scenarios.

Based on the seven exploratory scenarios and feedback from the community and ZC, a draft 'Solutions Package' of regulatory and non-regulatory actions, plus catchment water quality and quantity limits and associated allocation systems, was developed with the ZC and presented to the wider community for discussion in November 2013. The draft Solutions Package was revised as discussions evolved during 2014. The ZC reached agreement on the key aspects of their final Solutions Package (the ZCSP) and made recommendations to the Environment Canterbury Commissioners by way of their Zone Implementation Programme (ZIP) Addendum in July 2014. The ZIP Addendum was formally received by the Environment Canterbury Commissioners and Waimate and Waitaki District councils by September 2014. Further discussions were held on refinements to some of the minimum flow and allocation regimes in the period to March 2015.

The ZIP Addendum recommendations and all of the technical information and community feedback that underlies them have been used to prepare the Proposed Variation 3 to the Proposed Canterbury Land and Water Regional Plan (LWRP) – Section 15 – Waitaki and South Coastal Canterbury.

This report summarises the technical work used to support the policy development process. The Summary Matrix on the next page summarises how each scenario and the ZCSP is predicted to perform against the aspirations of the ZC (i.e. the ZC outcomes) for the catchment, and against current state. The Summary Matrix is a high level, quick reference guide for comparing the relative merits of scenarios across a range of social, economic, cultural and environmental indicators, and also indicates the level of uncertainty with predictions; the matrix is based on the assessments summarised in this report and described in detail in Appendices 4 to 22.

It is not possible to achieve all the desired ZC outcomes to the maximum level simultaneously, at least not in the near future based on current technology. Difficult decisions have been necessary to build a ZCSP that achieves most of the outcomes to a high level of attainment through time, and progressively improves those outcomes that are not met initially. Overall, it is predicted that the ZCSP will achieve a net environmental improvement through time, as illustrated by the colour-coded Summary Matrix comparison between 'current state' (far left coloured column) and the progressively improving future situation under the ZCSP (far right three columns).

There is uncertainty arising from many sources in the assessments on which decisions have been based, which is normal for land and water resource management. Uncertainties have been identified and reduced where possible, and the remaining unavoidable uncertainties communicated so that they could be incorporated into the decision-making process. It is likely there are sources of uncertainty that are unknown and unidentified.

It is possible that future advances in technology will allow ZC outcomes to be achieved to a higher level than the technical assessments predict. It is also possible that some outcomes will not be achieved to the extent predicted and thus review of the ZCSP and regional plan is important so that

any necessary adjustments can be made in future. This is a normal situation and a reason for the regular review cycle of regional planning and resource management in general.

From a technical perspective the process was successful to the extent that it produced a transparent, objective, technical assessment of the effects of various future scenarios across multiple values (environmental, social, cultural and economic), and communicated those effects, along with the uncertainty associated with predictions, to willing community participants (Part 1 of this report). There was then community debate on the merits of different options, and a transparent process whereby the ZC selected a preferred pathway forward – that pathway is the ZCSP as documented in the ZIP Addendum. Part 2 of this report provides a technical assessment of the extent to which the proposed ZCSP is likely to achieve outcomes over time.

The Summary Matrix uses a five-class colour-coded presentation system (see Section 2.10.3 for detail) to estimate the likelihood that the Zone Committee outcomes would be achieved under each of the seven exploratory scenarios, and with the Zone Committee Solution Package (ZCSP), as shown below.

The colour classes indicate either …						
	The **likelihood** that each outcome will be achieved (where there is an absolute indicator to assess – see [A]); or	Almost certainly	Probably	Possibly	Unlikely	Highly unlikely
	The **relative merit** of each scenario (where the indicator only allows assessment relative to current – see [R]).	Very high (maximum)	High	Medium	Low	Very Low (minimum)

ZONE COMMITTEE OUTCOMES	TECHNICAL INDICATORS (These are used to assess the extent to which the Zone Committee (narrative) outcomes would be achieved. Some indicators allow an absolute [A] assessment against numeric criteria such as a numeric LWRP outcome, while other indicators allow only a relative [R] assessment. See Appendix 1 for explanation of the rationale for scoring Current State)	Absolute [A] or Relative [R] assessment	CURRENT STATE #	EXPLORATORY SCENARIOS: Status Quo – pre HDI 1a: pLWRP minimum flows & allocations	1b: Alternative min. flows & allocation – Manawhenua & environment	1c: Alternative min. flows – Enhanced water use	HDI as consented 2a: HDI as consented – no flow augmentation	2b: HDI + flow augmentation	Advanced mitigations 3a: HDI (no augmentation) + maximum feasible mitigation (MFM)	3b: HDI (no augmentation) + mid-point mitigation	ZONE COMMITTEE SOLUTIONS PACKAGE: Achieved progressively through time as indicated by… 2017	2022	2030
Vibrant economy and sustainable growth	Utilisation of irrigable area to achieve production potential – Canterbury Water Management Strategy (CWMS) Target 7	R			SCCSarea / Local								
- A growing local economy	On farm economic impacts (revenue, farm working expenses, variable expenses and EBIT)	R			SCCSarea / Local				↑		*	**	**
- Highly reliable and secure irrigation	Number of farmers and farm workers engaged in dairy, dairy support, horticulture and arable	R			↓								
- Protection of Wahi Tapu & Wahi Taonga	Regional economic impacts including GDP, earned household income, rates and taxes	R											
- Diversity of farming systems	On farm and regional employment	R											
	School rolls	R											
- Good rural & urban land management practice is common practice	Individual household income	R			SCCSarea / Local						*	**	**
	Engagement in GMP	R											
- Safe water for contact recreation throughout the zone	Population in SCCS project area	R											
	Services - health, infrastructure and education. Social connectedness	R											
- Safe drinking water supplies exist in the Zone	Drinking water – nitrate in deep groundwater – test MAV	A											
	Drinking water – nitrate in shallow groundwater – test MAV	A							↑	↓			
	Drinking water – microorganisms in surface & shallow groundwater – test MAV	A			↑	↓	↓	↓	↑	↓			
- Safe water for cultural use	Fishing activity in streams and Wainono	R					↑QN↓QL	↑Wain	↑QN↓QL	↑QN↓QL			
	Recreational use	R					↓	↑Wain		↓			
- Catchment drainage & flood risk managed	Game bird hunting in Wainono	R											
Coastal streams have high water quality	Flows in Streams - high minimum flows compared to natural 7d MALF	R											
	Flows in streams – high variability and frequency of freshes	R						↑Hook					
- that supports aquatic life and biodiversity	Flows in streams – low intermittence (dry length, frequency, duration)	R						↑Hook					
	Large amount of habitat for key fish species (compared to % of habitat at natural MALF)	R											
- flows support aquatic life and biodiversity suitable for each waterway	High diversity and abundance of aquatic invertebrates – test LWRP outcomes (QMCI)	A					↑QN↓QL	↑QN↓QL		↑QN↓QL			
	High diversity and abundance of native fish	R					↑QN↓QL	↑QN↓QL	↑	↑QN↓QL			
	Provision of suitable mudfish habitat	R					↑QN↓QL	↑QN↓QL	↑	↑QN↓QL			
- connected groundwater has healthy flows and high water quality	Healthy periphyton and macrophyte communities – test LWRP outcomes (% cover)	A					↓	↑Hook		↓			
	Ensure hydrological requirements for wetlands are met	R											
	Baseflow at springs increases	R											
	Groundwater levels to support wetlands improved	R			↑	↓							
	Nitrate-N toxicity for aquatic species - test at least 80% level protection	A			↑		↓	↓	↑	↓			
	Water clarity and suspended sediment	R					↓	↓	↑	↓			
	Sedimentation of stream beds	R			↑	↓	↓	↓	↑	↓			
	Periphyton risk for recreation & benthic biodiversity – test LWRP outcomes (% cover)	A					↓	↑Hook↓Rest	↑	↓			
	Benthic cyanobacteria risk for recreation – test LWRP outcomes (% cover)	A					↓	↑Hook↓Rest	↑	↓			
	Macrophyte risk for recreation & benthic biodiversity – test LWRP outcomes (% cover)	A			↑	↓	↓	↓	↑	↓			
	Suitability for contact recreation – microbial quality – test LWRP outcomes (SFRG)	A			↑	↓	↓	↓	↑	↓			
	Riparian condition (stock exclusion and vegetation)	R											
Wainono Lagoon is a healthy ecosystem	Opening regime - supports fish passage/recruitment	R											
- abundant mahinga kai	Opening regime - manages drainage/flooding	R						↓					
	Lake Level - supports wetland ecosystem	R					↑		↑	↑			
- fish passage is provided throughout the catchment where appropriate	Seasonal runs and migrations of taonga species observed	R											
	Supports customary fish populations (tuna, patiki, inanga)	R							↑	↓			
	Mataitai Reserve – fisheries & other mahinga kai	R							↑	↓			
- enhanced wetlands and protection of springs	Water quality – sediment load reduced	R					↓	↑	↑	↓			
	Water quality - clarity and colour improved	R			↑	↓	↓			↓			
- no further reduction in water quality of the Lagoon *(acknowledging and allowing for its transitional state)*	Water quality – nutrient state - test Trophic Level Index (TLI) 6.0 achieved	A			↑		↓			↓			
	Water quality – test LWRP outcomes (dissolved oxygen, pH, temperature)	A			↑	↓	↓			↓			
	Macrophyte beds present – test Variation 3 LWRP outcome (20% cover)	A			↑	↓	↓			↓			
- Catchment flows and water quality support a healthy Lagoon	Risk of cyanobacteria and/or other toxic algae reduced	R					↓	↑		↓			
	Fringing wetlands & related biodiversity enhanced	R			↑	↓		↑					
- Maintenance & enhancement of the Mataitai Reserve	Aquatic biodiversity (flow-related) enhanced	R					↑	↑	↑	↑			
	Suitability for contact recreation - test LWRP outcomes (SFRG = Fair)	A						↑	↑	↓			
	Watercress is safe to eat	R					↓	↑	↑	↓			
- Enhanced riparian management	Base flow at springs increases in vicinity of Wainono	R											

Notes:
See Appendix 1 for an explanation of the link between ZC outcomes and technical indicators, and the rationale for scoring 'current state".
Acronyms shown in this table are defined in the Glossary (EBIT, GDP, GMP, MALF, TLI, SFRG, MAV, QMCI).
Cells showing half colours indicate significant negative and positive impacts for different users as follows:
*Those over the cap for nitrogen allocation will be required to undertake potentially significant mitigation or land use change.
**Those over the cap for nitrogen allocation, and those shifting to alternate water sources with changes to the surface water allocation and environmental flow regimes, may face significant costs.
Arrows (↑↓) indicate relative change (more/less likely to deliver an outcome) compared to Scenario 1a but not sufficient change to justify shifting to a new colour class.
↑QN indicates an improvement in terms of water quantity (ecological flows); ↓QL indicates a decline in terms of water quality; ↑Wain indicates improvement in Wainono Lagoon but not in all rivers; ↑Hook = improvement in Hook River.
Half yellow/red cells indicate significant negative impacts at the local scale in some catchments (red), but small impact at the scale of the whole SCCS area

Acronyms used in this report

Some of these terms are also defined in the Glossary at the end of this report.

CWMS	Canterbury Water Management Strategy
EBIT	Earnings before Interest and Tax (see Glossary)
FDE	Farm Dairy Effluent (ponds)
FTE	Full Time Equivalents (of employed people) (see Glossary)
GDP	Gross Domestic Product (see Glossary)
GIS	Geographic Information System
GMP	Good Management Practice (see Glossary)
HDI	Hunter Downs Irrigation (Scheme)
LSR	Land Surface Recharge (see Glossary
LUT	Look-up Table (of nitrate losses for different land uses, soil types and climates)
pLWRP	Land and Water Regional Plan (proposed)
MALF	Mean annual 7 day low flow (see Glossary)
MAV	Maximum Acceptable Value (of the NZ drinking-water standards) (see Glossary)
MGIS	Morven Glenavy Irrigation Scheme
MGM	Matrix of Good Management (Project) (see Glossary)
MFM	Maximum Feasible Mitigation (see Glossary)
NARG	Nitrogen Allocation Reference Group
NOF	National Objectives Framework
NPSFM	National Policy Statement for Freshwater Management (2011 & 2014)
NRRP	Natural Resources Regional Plan
QMCI	Quantitative Macroinvertebrate Community Index (see Glossary)
SCCS	South Canterbury Coastal Streams
SFRG	Suitability for Recreation Grade (see Glossary)
TLI	Trophic Level Index (see Glossary)
TN	Total nitrogen
TP	Total phosphorus
TWWG	Tangata Whenua Working Group
WD	Waihao Downs (Irrigation Scheme)
WDC	Waimate District Council
WRP	Wainono Restoration Project
ZC	Zone Committee (specifically the Lower Waitaki Zone Committee)
ZCSP	Zone Committee Solution Package
ZIP	Zone Implementation Programme

Table of contents

List of Figures

List of Tables

1 Introduction

1.1 Report purpose

This report documents the technical work undertaken to inform and support the community-centred policy process for developing water quality and quantity limits in the South Canterbury Coastal Streams (SCCS) area (see Figure 2-1). The report summarises the predictions of social, cultural, economic and environmental consequences of a range of possible future water management and land use scenarios.

1.2 Versions of this report

This is the third and final version of the Overview Report for the SCCS limit setting process. The first two draft version Overview Reports were presented at public workshops (and posted on a website) in June 2013 and August 2013 respectively, as part of informing the community process. Those earlier draft reports provided summary information on the current state of the land and water environment and resource use in the SCCS area, and predicted consequences of seven exploratory future management scenarios. Those workshops in 2013 and many subsequent meetings through to February 2015 have produced discussion, debate, requests for further information, and proposed management solutions, that are now reflected in this final Overview Report.

1.3 Regional policy drivers

1.3.1 Canterbury Water Management Strategy (CWMS)

Environment Canterbury is functioning under the Environment Canterbury (Temporary Commissioners and Improved Water Management) Act 2010 (Environment Canterbury Act) and the Canterbury Water Management Strategy (CWMS). The CWMS was developed by a region-wide partnership between Environment Canterbury, Ngāi Tahu, and Canterbury's district and city councils, and was released in November 2009 following a region wide community and stakeholder engagement process (Canterbury Mayoral Forum 2009). The CWMS established a shared vision, principles, ten target areas and a framework for collaborative, integrated water management. The ten target areas represent both in-stream and out-of-stream values and the intention is co-delivery of all ten target areas. Each set of targets has associated goals and timeframes for achievement out to 2040. The Environment Canterbury Act requires particular regard to be had for the vision and principles of the CWMS.

The CWMS outlines a governance structure to deliver on its targets, and splits Canterbury into 10 water management zones, establishing a Zone Committee for each zone, plus an overarching regional water management committee. The Zone Committees are tasked to "work collaboratively to develop effective water management solutions that deliver economic, social, cultural and environmental outcomes in consultation with the local community"[1]. They articulate these solutions in non-statutory documents called Zone Implementation Programmes (ZIPs) which then serve as a basis for Environment Canterbury to prepare statutory regional plans as described in the next section.

1.3.2 Proposed Land and Water Regional Plan (pLWRP)

The Proposed Land & Water Regional Plan (pLWRP)[2] was notified on 11 August 2012 and is effective from 18 January 2014. The pLWRP sets objectives, policies and rules that cover the whole Canterbury Region. However the pLWRP also divides the region into 10 sub-regions (one of which includes SCCS) and provides for each of these sub-regions to be managed in future by their own sub-regional plan sections that can have locally specific flow, allocation and water quality limits, and policies and rules to manage within those limits. The views of the local Zone Committee and wider community can help to shape each of these sub-regional plan sections.

When sub-regional plan sections are produced, the policies and rules in the sub-regional sections will apply instead of (i.e. supersede), or in addition to, those set in the region-wide pLWRP. The first such

[1] http://ecan.govt.nz/get-involved/canterburywater/committees/Pages/Default.aspx
[2] http://ecan.govt.nz/our-responsibilities/regional-plans/regional-plans-under-development/lwrp/pages/default.aspx

sub-regional section (known as Variation 1 to the pLWRP) for the Selwyn and Te Waihora area has been through hearings in 2014 and a decision is pending. The second sub-regional section (Variation 2) for the Hinds Plains area was notified on 27 September 2014 and hearings are planned for 2015. The third sub-regional section (Variation 3) is to be notified on 25 April 2015 for the SCCS area and has been informed by this Overview Report and the ZIP prepared by the Lower Waitaki Zone Committee (hereafter ZC).

1.4 National policy drivers

1.4.1 National Policy Statement for Freshwater Management 2011

The National Policy Statement for Freshwater Management 2011 (NPSFM, 2011) contains a preamble, some interpretation (definitions of important phrases), and five main sections on water quality, water quantity, integrated management, tāngata whenua roles and interests, and progressive implementation programmes. The NPSFM (2011) introduced the mandatory requirement for councils to set freshwater objectives (intended environmental outcomes) and limits (the maximum amount of resource use available), both for water quantity and quality, that allow the freshwater objectives to be met.

The NPSFM (2011) required that overall water quality within a region must be maintained or improved, and over-allocation (where community goals set out in a regional plan are not met and/or water quantity limits have been exceeded) must be remedied. Councils must also protect the significant values of wetlands and improve the quality of water-bodies that have been degraded to the point of being over-allocated. Where water bodies do not meet freshwater objectives, councils must specify targets and implement methods to meet those targets within a defined timeframe. Councils are also required to address efficient allocation and use of water, and consider the potential for transferrable water consents. Councils are also required to phase out any over-allocation of water, again within a defined timeframe.

1.4.2 National Policy Statement for Freshwater Management 2014

The NPSFM was amended and a new version came into effect on 1 August 2014. The changes were intended to provide greater direction and support to help regional councils apply the requirements of the NPSFM in a consistent way across the country[3]. Key features of the NPSFM (2014) are:

- Retains the mandatory requirement for councils to set freshwater objectives and limits for water quantity and quality, as first established in the NPSFM (2011);
- Establishes two compulsory national values for “Human health for recreation” and “Ecosystem health”;
- Adds a water quality framework known as the National Objectives Framework (the NOF) which contains compulsory water quality related elements (called “attributes”) and minimum acceptable “national bottom line” standards for these attributes;
- Requires councils to establish a system to account for all resource use that affects fresh water (specifically water takes and sources of contaminants);
- Requires councils to monitor progress towards achieving their freshwater objectives; and
- Allows councils until 2025 to complete implementation of the NPSFM (2014) policies, including the NOF.

The appendices to the NPSFM (2014) provide more detail on national values of water, attributes that affect or contribute to these values, and numbers for those attributes at four states (A, B, C and D) with the minimum acceptable state (the “national bottom line”) represented by the threshold between attribute state C and D. Where a council determines that a value should be provided for in a given water body, it must assign a state for each relevant attribute that is at or above the “national bottom line” for that attribute. The compulsory value of “Human health for recreation” has two mandatory attributes (*E.coli* bacteria and cyanobacteria), whereas the compulsory value “Ecosystem health” has

[3] http://www.mfe.govt.nz/fresh-water/national-policy-statement/developing-2014-nps

several mandatory attributes (phytoplankton (or trophic state), as well as total nitrogen and total phosphorus, in lakes; and periphyton, dissolved oxygen, nitrate toxicity and ammonia toxicity in rivers).

1.4.3 Handling new terminology introduced by the NPSFM (2014)

The new terminology introduced by the NPSFM (2014), in particular the “compulsory national values”, “attributes” and “national bottom lines”, came late in the SCCS process described in this Overview Report. To reduce confusion in the community, the terminology used in this final Overview Report is consistent with that used in earlier versions and throughout the process, rather than using the new NPSFM terms mentioned above. However the linkages, from a technical perspective, between terms used in this Overview Report and the NPSFM (2014) are described below:

- The two “compulsory national values” (“Ecosystem health” and “Human health for recreation”) are both addressed in existing pLWRP Table 1a (Outcomes for Canterbury Rivers) and Table 1b (Outcomes for Canterbury Lakes) where the terms “Ecological health indicators” and “Microbiological indicator – Suitability for contract recreation” are used (see Appendix 1 for copies of pLWRP Tables 1a and 1b);

- All of the mandatory “attributes” of the NPSFM (*E.coli* bacteria, cyanobacteria, phytoplankton (or trophic state), total nitrogen, total phosphorus, periphyton, dissolved oxygen, nitrate toxicity and ammonia toxicity) are addressed either directly or indirectly[4] in the numeric “indicators” contained in pLWRP Table 1a (Outcomes for Canterbury Rivers) and Table 1b (Outcomes for Canterbury Lakes), and/or by other “indicators” in the list of “Technical Indicators” used to make assessments in this Overview Report and its multiple appended technical reports (e.g. the list of Technical Indicators summarised in the Summary Matrix in the Executive Summary and in Appendix 1). The exception to this is the NPSFM (2014) attribute for ammonia toxicity which has not featured in pLWRP outcomes tables or in the Technical Indicators used in this report and will be discussed further below;

- The pLWRP Table 1a (Outcomes for Canterbury Rivers) and Table 1b (Outcomes for Canterbury Lakes) indicators used to compare scenarios in this Overview Report (and its multiple appended technical reports) are all consistent with maintaining an environmental state that is above the “national bottom lines” for attributes defined in the NPSFM (2014);

- The list of “Technical Indicators” used to make assessments in this Overview Report (and its multiple appended technical reports) includes several more measurable “indicators” that are not included as NPSFM (2014) “attributes”. Examples of these are the Quantitative Macroinvertebrate Community Index (QMCI), macrophyte percent cover and fine sediment percent cover indicators.

In summary, all of the NPSFM (2014) mandatory “attributes” associated with both of the “compulsory national values” are addressed in this report by reference to assessments against pLWRP outcomes for rivers and lakes and/or other “indicators” in the list of “Technical Indicators”.

The exception to this is the NPSFM (2014) attribute for ammonia toxicity which has not been described or assessed in this Overview Report, simply because it is not considered to be a contaminant of significant issue for management in the SCCS area. Ammonia is primarily a point-source contaminant and is manageable as such by discharge consents. Environment Canterbury routinely monitors ammonia concentration in rivers and this data has been used to include proposed in-river concentration limits for ammonia in proposed LWRP Variation 3 (for the SCCS area) in order to align with requirements of the NPSFM (2014). This inclusion late in the process is not considered to materially affect any of the scenario assessments described in this Overview Report.

[4] Examples where NPSFM (2014) “attributes” are indirectly addressed are: i) the “attributes” total nitrogen, total phosphorus and phytoplankton (chlorophyll-a) are addressed by the single Trophic Level Index (TLI) eutrophication indicator (which is calculated using total nitrogen, total phosphorus and chlorophyll-a); and ii) the “attribute” *E. coli* is addressed by use of the Suitability for contact recreation grade (SFRG) which is a grade that includes consideration of *E. coli* concentrations as described in the Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas (MfE 2003).

1.5 Preferred approach

In 2009, Environment Canterbury initiated the 'Land use and Water Quality' project in the Hurunui catchment to address deteriorating water quality and on-going pressure from land intensification in the Canterbury region. One of the objectives of this project was to agree a collaborative approach for setting water quality limits that could be used across the remainder of the region. One of the results of this case study was the development of the 'preferred approach', (Environment Canterbury, 2012) which was agreed and endorsed by the Environment Canterbury Commissioners. The preferred approach has been further tested and developed during subsequent limit setting processes in the Selwyn and Te Waihora and the Hinds Plains zones. The limit setting process in the SCCS area has followed the overarching principles of the preferred approach while adopting lessons from Selwyn Te Waihora and Hinds Plains along the way.

A schematic of the collaborative preferred approach is shown in Figure 1-1. The national and regional policy drivers described above (i.e., the NPSFM 2011 & 2014, CWMS, pLWRP) are represented at top left. The outputs from the process, in terms of producing a proposed sub-regional section to the statutory regional plan (i.e. Variation 3 to the pLWRP) containing mandatory freshwater objectives (outcomes) and limits, are represented at bottom left. The iterative collaborative community process shown in green boxes is the subject of this report and will be described in detail in the methods in Section 2.

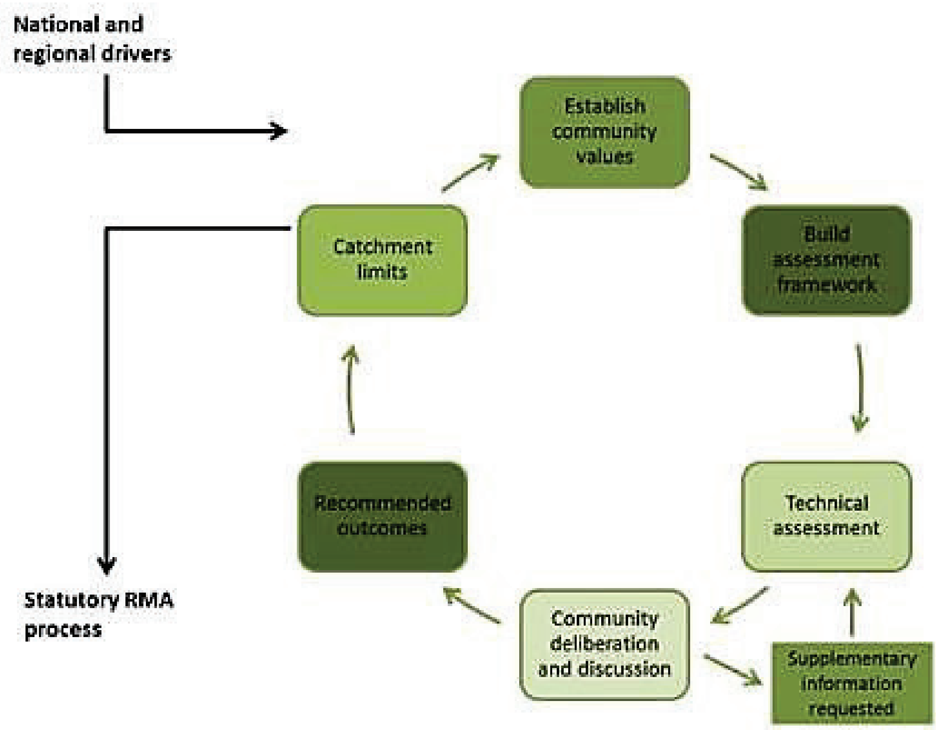


Figure 1-1: Schematic of the approach for setting water quality and quantity limits

1.6 Report layout

A large amount of technical work has been done to support and inform this planning process. To make the reporting easier, the work is reported as:

- A high-level Overview Report summarising the technical work (this report)
- 19 technical reports covering the modelling and assessment work (Appendices 4-22)
- A supplementary technical information compendium

Figure 1-2 shows the relationship between the various reports.

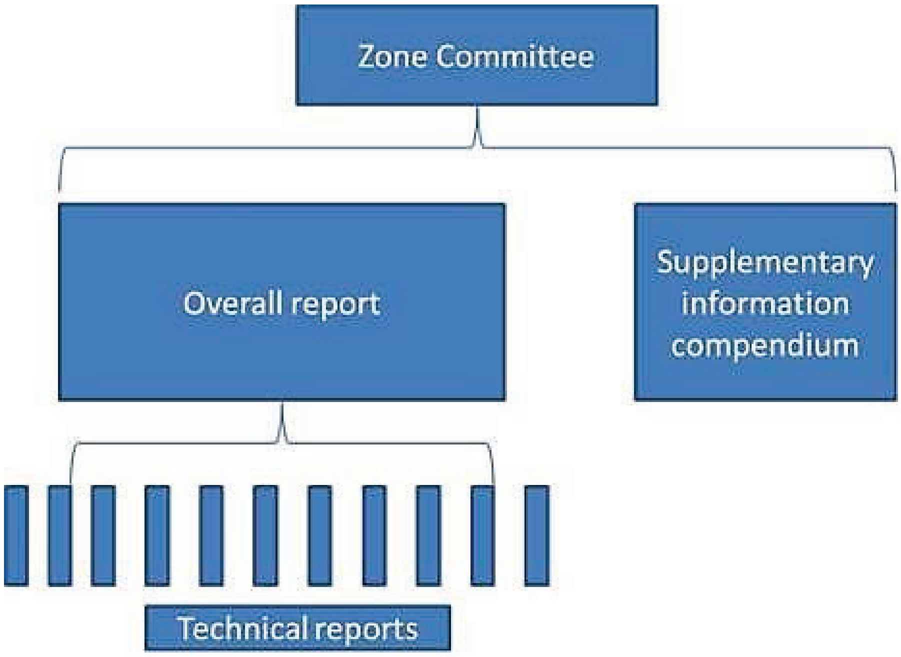


Figure 1-2: Report structure for technical information

A list of acronyms used is provided immediately after the Executive Summary

There is a glossary at the back of this report containing definitions for many technical terms used throughout the report.

2 Method

In brief, the following method was used to develop the technical work:

1. The Zone Committee described their aspirations for the catchment in the form of outcomes, published in their Zone Implementation Programme (ZIP) (LWZC 2012 and updated in LWZC, 2014)
2. The technical team developed indicators based (see section 2) on these outcomes, against which attainment of outcomes could be assessed technically
3. The Zone Committee agreed a suite of future scenarios, to test 'what if' questions and to understand the consequences of alternative management options
4. The technical team developed models, tested each of the scenarios, and used the indicators to predict the likely consequences of each scenario on the community outcomes. This information was integrated, simplified and communicated back to the Zone Committee and wider community to help inform their discussions
5. After the exploratory scenarios had been considered, the Zone Committee, wider community and technical team each brainstormed all potential aspects of a draft solutions package. The draft solutions package was modelled in the same way as the earlier scenarios and the outcomes delivered to the Zone Committee and wider community at a public open day
6. The Zone Committee then had a period of iterative discussions where additional information and analyses were requested and delivered, and the draft solutions package was refined
7. A final package of solutions, the 'Zone Committee Solutions Package' was agreed upon. This was recommended to the Environment Canterbury Commissioners by way of a published ZIP Addendum, and then modelled by the technical team to generate the catchment limits that relate to the agreed outcomes

The Environment Canterbury planning team and Zone facilitator worked constantly with the Zone Committee and were responsible, with support from the technical team, for turning the final package of solutions into an amended ZIP Addendum and a proposed Resource Management Act (RMA) regional plan - specifically the Proposed Variation 3 to the Proposed Canterbury Land and Water Regional Plan (LWRP) – Section 15 – Waitaki and South Coastal Canterbury.

The following sections describe the role of the technical team and the method steps in more detail.

2.1 The role of the technical team

Setting outcomes and limits to the use of land and water resources (i.e. deciding on the available capacity of resources for use) is not simply a technical exercise. Decisions on outcomes and limits are value judgements that involve weighing up, trading off, and balancing between conflicting values and outcomes. The key role[5] for the technical team is to inform those decisions, by making the consequences of options transparent for others to discuss, rather than imposing value judgements themselves. To perform this role the technical team needs to supply relevant and credible information to a community in a way that allows them to understand the options and make recommendations in the knowledge of likely consequences; i.e. to make informed value judgements.

New Zealand's Prime Minister's Chief Science Advisor Gluckman (2013) defines five key features of evidence informed policy making (Box 2-1) and notes that policy "must take into account both robust evidence derived from research, as well as an understanding of social values." He states that "Crucially, science advisors are obliged to advise in the context of the policy process. This means elucidating the evidence-informed options, rather than simply advocating a course of action" and "Policy-makers and elected officials rightly guard their responsibility to define policy – and this means choosing between options with different trade-offs. This is not the domain of a science advisor" (Gluckman 2014).

[5] Described by New Zealand's Prime Minister's Chief Science Advisor Peter Gluckman as the preferred "honest broker" role to be played by science advisors to policy development processes (Gluckman 2014), and is described in more detail by Pielke (2007).

Box 2-1: Key features of evidence-informed policy making (Source: Gluckman 2013)

1. Quality and accessible data
2. Robust and accessible data collection and analytical instruments
3. Critical awareness of analytical assumptions and choices, and of theoretical perspectives that underpin the research methodology
4. Understanding the limitations of even the most robust evidence
5. Adjusting expectations of certainty and being able to manage uncertainty.

The technical team has strived to perform the role described above, and also in accordance with the attributes that have long been required of an expert witness operating in a resource management hearing context under the New Zealand Environment Court's Code of Conduct for Expert Witnesses[6].

2.2 Establish community values

As required by the Canterbury Water Management Strategy (CWMS) the Lower Waitaki Zone Committee (ZC) developed a Zone Implementation Programme (ZIP) (LWZC, 2012). The CWMS outlines high level regional outcomes across ten target areas: economic, social, cultural and environmental. The ZC developed a set of priority outcomes in the initial ZIP published in 2012 and added to these, as a result of the limit setting process, in the ZIP Addendum (LWZC 2014) quoted as follows:

"*The Zone Committee developed the following* ***outcomes*** *under the CWMS for the area:*

Wainono Lagoon is a healthy ecosystem

- *Abundant mahinga kai*
- *Fish passage is provided throughout the catchment where appropriate*
- *Enhanced wetlands and protection of springs*
- *No further reduction in water quality of the lagoon (acknowledging and allowing for its transitional state)*
- *Catchment flows and water quality support a healthy lagoon*
- *Maintenance and Enhancement of the Mataitai Reserve*
- *Enhanced riparian management*

Vibrant economy and sustainable growth

- *A growing local economy*
- *Highly reliable and secure irrigation*
- *Protection of Wahi Tapu and Wahi Taonga*
- *Diversity of farming systems*
- *Good rural and urban land management practice is common practice*
- *Safe water for contact recreation throughout the Zone*
- *Safe drinking and stock water supplies exist in the Zone*
- *Safe water for cultural use*
- *Catchment drainage and flood risk is managed*

[6] http://www.justice.govt.nz/courts/environment-court/legislation-and-resources/practice-notes

Coastal Streams have high water quality

- *That supports aquatic life and biodiversity*
- *Flows supports aquatic life and biodiversity suitable for waterway*
- *Connected groundwater has healthy flows and high water quality*

2.3 Build assessment framework

The technical assessment framework was built around the following key elements:

1. Identify fit-for-purpose scope
2. Define spatial boundaries
3. Identify the types of limits to be set in the regional plan
4. Define future scenarios for testing
5. Select models and other technical methods for assessing effects of scenarios on;
    - biophysical;
    - social;
    - economic; and
    - cultural outcomes.
6. Manage uncertainty
7. Integrate and communicate results into the community process
8. On-going adjustment based on community feedback

The following sections will describe each of these elements in more detail.

2.4 Identify a fit-for-purpose technical scope

The scope of the technical work was influenced by community values and outcomes expressed in the original ZIP (LWZC 2012) and at subsequent public meetings that led to refinements in the ZIP Addendum (LWZC 2014) (see Section 2.2); these covered environmental, economic, social and cultural aspects. The technical scope was also influenced by:

- National and regional level policy requirements to set water quantity and quality limits for managing the types of land and water resource uses relevant for the project area;
- Consideration of the level of detail needed for making the key limit-setting and management decisions;
- The availability of assessment techniques and robust indicators needed in order to test the effects of future scenarios;
- Time and resource constraints, meaning that existing models were used or adapted where possible, and where no model existed, simple models were built;
- Feedback received during the process, meaning that adjustments and new assessments were added through the process.

2.5 Define spatial boundaries

The project area spans from the Otaio catchment in the north to the Morven catchment in the south and includes the entire Waihao-Wainono catchment of the ecologically and culturally significant Wainono Lagoon (Figure 2-1).

The project area has been subdivided into three distinct areas (Northern Streams, Waihao Wainono, and Morven Sinclairs) primarily because the sensitivity of the environment to land and water resource use differs between these three areas but is similar within each area (Figure 2-1). Generally though, the detailed technical assessments in Appendices 4 to 22 have been made at the level of each individual catchment (in some cases sub-catchments), and this is the level at which most of the water quantity and quality limits have been proposed in the regional plan. The main catchments are:

- Otaio
- Kohika
- Horseshoe Bend
- Makikihi
- Waihao-Wainono (includes Hook, Waimate, Waituna, Sir Charles and Buchanans)
- Sinclairs
- Morven

The whole Waihao-Wainono catchment is considered to be (i.e., is defined as) the catchment of Wainono Lagoon for diffuse contaminant limit setting purposes, even though the Waihao River flows directly to the sea via the Waihao Box (i.e. bypassing Wainono Lagoon) for about half of the time and only flows up the Waihao Arm into Wainono lagoon about half of the time, on average (see Appendix 19 for detail).

Further spatial subdivision of the project area has been useful for some of the technical assessments, such as defining tributary sub-catchments for flow regime assessment (e.g., Appendices 7, 9-13 and 16-17) groundwater allocation zones (e.g., Appendix 8), different soil and land use classes (e.g. Appendices 4 and 6) and a ‘steep hill country’ class defined and mapped in order that nitrogen limits can be set appropriately for that area (see Appendices 4 and 22).

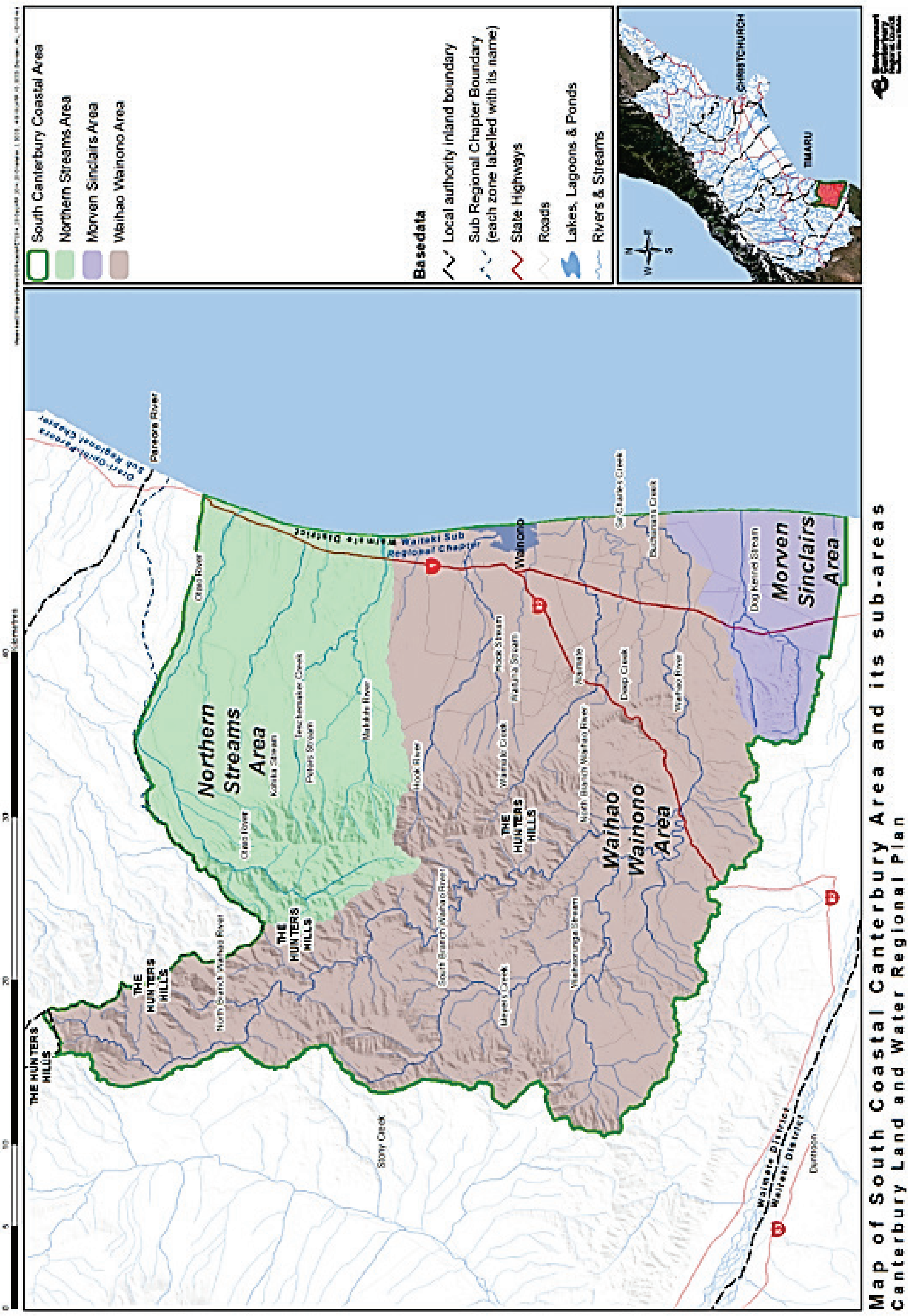


Figure 2-1: Map showing the SCCS project boundary, the main catchments and three distinct areas separated out for some of the assessments

2.6 Identify types of limits needed for regional planning

The national and regional level policy setting[7] requires that limits be set in regional plans for both water quantity and water quality.

In the SCCS area the relevant water quantity limits include both allocation block limits and environmental flow regimes for streams and rivers (i.e. surface water), and volumetric allocation limits for groundwater.

The key water quality contaminants relevant for the SCCS area are primarily diffuse (i.e., non-point) source pollutants typical of agricultural land use-dominated catchments (i.e., nitrogen, phosphorus, sediment and faecal microorganisms). The main pathway for nitrate-nitrogen loss is via leaching. As drainage[8] water leaves the root-zone, it can carry soluble nitrate with it. Phosphorus, sediment and faecal bacteria are generally lost via overland flow or shallow interflow via artificial drainage although phosphorus leaching is also possible (Webb *et al.,* 2010). The models available at the time of this work were not able to characterise phosphorus, sediment or faecal bacteria loss pathways to water in a manner adequate for setting quantitative catchment load limits such as those that have been proposed for nitrogen. However these contaminants are undoubtedly important and their effects have been assessed as best possible at this time in a risk-based, semi-quantitative manner (see Appendix 7). Avoidance, management and mitigation actions (e.g., Farm Environment Plans and catchment restoration initiatives) for these contaminants have also been included as an important part of the solution package described later.

A small number of point source discharges also exist in the SCCS area and these have been included in the assessments and limit setting process.

The assessment framework has by design integrated the consideration of both water quantity and quality matters, and interactions between the two, primarily by incorporating various options for both types of limits into the design of the exploratory scenarios, as described in the next section. The implications of water quantity limits for water quality and vice versa have been explicitly considered at the level of each individual technical report (Appendices 4-22). This has been particularly important in the SCCS area because two new irrigation schemes have been proposed in this water-short area and these schemes would potentially relieve some pressure on in-catchment rivers, streams and groundwater, but would allow land use change and intensification that poses further risks for water quality. The SCCS area was thus clearly a case requiring integrated catchment management and coordinated setting of limits for quantity and quality.

2.7 Define exploratory future scenarios

The purpose of scenarios is to explore various alternative futures for land and water resource use and for management. Exploring scenarios increases understanding of the area and facilitates discussions among all parties with an interest in the future management of land and water resources.

Two types of scenarios were developed; initial exploratory scenarios and subsequently a 'solutions package' scenario. The exploratory scenarios will be described in this section and the solutions package, which was developed later based on learnings from the exploratory scenarios, is described in Part 2 of this report.

The exploratory scenarios were developed by Environment Canterbury staff and the ZC based on the following considerations:

i) A technical understanding of the current state of land and water resource use in the area;

ii) The local community's known aspirations for the area, as expressed in public meetings and recorded from previous public processes such as the preparation of the ZIP (LWZC 2012) and earlier regional plans (e.g., LWRP and the earlier Natural Resources Regional Plan (NRRP))

[7] i.e., the National Policy Statement for Freshwater Management (NPSFM), the Canterbury Water Management Strategy (CWMS) and the Canterbury Regional Policy Statement.

[8] See Glossary for definition of 'drainage'.

and earlier large-scale consent processes for the proposed Hunter Downs (HDI) and Waihao Downs (WD) irrigation schemes;

iii) Deliberate design to allow exploration around key decision areas for limits – specifically water allocation block sizes, environmental flows, and catchment and on-farm limits for water quality contaminants (primarily nitrogen).

The exploratory scenarios and the key assumptions that define them were agreed with the ZC and the Tangata Whenua Working Group (TWWG) before undertaking analysis. The exploratory scenarios are summarised in Table 2-2 and a detailed description of scenario assumptions is provided in Appendix 2.

By way of brief overview explanation of the scenario design, Scenarios 1a, 1b and 1c allowed exploration of the consequences of different surface water allocation block sizes and environmental flow regimes for rivers within the project area, thus informing the difficult decisions concerning the appropriate amount of water to be allocated for use versus the amount that should be left in local rivers to support ecological, cultural, recreational and amenity values.

Scenarios 2a and 2b explored the consequences of bringing new, out-of-catchment (Waitaki) water via the proposed (consented but not yet built) HDI and WD schemes; Scenario 2a assumed HDI and WD schemes would be built as consented while Scenario 2b explored the merits of flow augmentation for Wainono Lagoon, which is a major potential measure to mitigate effects of the increased land use intensity, made possible by the irrigation schemes, on water quality.

Scenarios 3a and 3b allowed exploration of alternative (or additional) water quality mitigation measures by testing the merits of requiring more demanding nitrogen limits than merely Good Management Practice (GMP) as required for the schemes as currently consented (i.e., compared to Scenario 2a). Scenario 3a assumed Maximum Feasible Mitigations (MFM) on farms while Scenario 3b assumed somewhat less demanding limits than this at the midpoint between GMP and MFM.[9]

[9] The terms GMP, MFM and the ‘midpoint’ between GMP and MFM are defined in the Glossary.

Table 2-1: Summary description of the exploratory scenarios (For a detailed description of each scenario and its assumptions see Appendix 2)

Scenario 1 **(pre HDI & WD)**	This scenario considers what the future will look like before Hunter Downs Irrigation (HDI) and Waihao Downs (WD) irrigation schemes are built, consented schemes that will bring new (Waitaki) water into the SCCS area. Assumptions include: • Negligible new irrigated area due to in-catchment water constraint and regional water quality rules in the pLWRP; • All land users required by the pLWRP to operate at Good Management Practice (GMP – see definition in Glossary) Three sub-scenarios with different flow and allocation limits are considered as below. Scenario 1 is indicative of how the catchment may develop over the next 10 years in the absence of HDI and WD.
Scenario 1a **(approx. current minimum flows & allocations)**	Assumes the pLWRP minimum flow and allocation limits for streams, rivers and groundwater within the SCCS area[10]. For most rivers these allocation limits are approximately the current total allocation; the exceptions are the Otaio, Kohika, Horseshoe Bend Creek and the Makikihi, for which the default pLWRP minimum flows (50% MALF7d[11]) and allocation limits (20% of MALF7d) are applied.
Scenario 1b **(manawhenua & environment - higher flows)**	Assumes alternative minimum flows that are generally higher and with smaller total allocations to better meet the preferences of Manawhenua[12] and to benefit environmental values.
Scenario 1c **(lower minimum flows)**	Assumes alternative minimum flows that are generally 25% lower than Scenario 1a. For most rivers the same allocation limits as Scenario 1a (i.e. current allocation) apply; the exceptions again are the Otaio, Kohika, Horseshoe Bend Creek and the Makikihi, for which the current allocation applies and this is significantly higher than the 20% of MALF7d assumed in Scenario 1a.
Scenario 2a **HDI & WD as consented** **(no flow augmentation)**	This scenario considers what the future looks like if HDI and WD schemes are developed as consented, bringing approximately 20 m^3/s new (Waitaki) water into the SCCS area. Scenario 2a looks at what may happen with these schemes out to 20 years (allowing time for them to be built) and beyond. Key assumptions include: irrigation of all potentially irrigable area; GMP employed across the entire SCCS area, an HDI-levied environment enhancement fund, increased nutrient concentrations and loads in fresh waters and Wainono Lagoon, some increase in groundwater levels and therefore stream flows, but with no direct flow augmentation to streams or Wainono Lagoon because this was not part of the HDI consent requirements.
Scenario 2b **HDI & WD with flow augmentation**	As for Scenario 2a, but with additional Waitaki water (~1m^3/s average) to augment flow and dilute nutrients in the lower Hook River and through Wainono Lagoon.
Scenario 3a **HDI & WD + maximum (MFM) mitigations**	As for Scenario 2a, but explores what the costs and benefits would be of employing Maximum Feasible Mitigations (MFM) on-farm, which equate to an average 30% reduction in N losses compared to GMP (varies between 0 and 40% reduction depending on land use type).
Scenario 3b **HDI & WD + midpoint mitigation**	As for Scenario 2a, but includes on-farm mitigations at the "mid-point" between GMP and MFM (i.e. an average 15% reduction in N losses compared to GMP (varies between 0 and 20% depending on land use type).

[10] See Section 15 of the pLWRP and Regional rule 5.96 (version Aug 2012) - Proposed Canterbury Land & Water Regional Plan
[11] MALF = Mean Annual Low Flow: See Glossary for definition.
[12] The flow and allocation preferences of Manawhenua are expressed in Appendix 16 (Tipa 2012). These are partly (but not entirely) based on recommendations in the proposed NES (i.e. minimum flow 90%MALF; allocation 30% MALF) (MfE 2008a,b).

2.8 Select models and/or other technical methods

The assessment methods were used to make predictions of the consequences of the scenarios on aspects of the catchment that are of interest to the community for making decisions on limits, including environmental, social, cultural and economic outcomes.

2.8.1 The need for integration

The assessment methods should ideally take account of land and water resource uses, surface and groundwater, water quantity and quality, physical, chemical, biological and social, cultural and economic elements, and interactions between all these. This is a very challenging requirement from both a technical modelling and project management perspective.

Because there is no fully integrated model of the "catchment system" that represents all the components and processes that this assessment is concerned with, the approach has been to "enchain" available models, in the process making assumptions and accepting limitations about how accurately the resulting assessment represents the ways different components of the "catchment system" interact and produce outcomes.

The approach has been to employ a multidisciplinary team of experts to work closely together, each making predictions for their own particular area, based on a common set of assumptions across the team, to ultimately produce an integrated set of predictions of the consequences of future scenarios. This has required a well-defined system of managing the team of experts and integrating their outputs. The role of integration has been explicitly identified and taken by the Technical Lead (author of this report) on the project throughout the process. Integration has been achieved by formally blending technical models and/or tools from different disciplines where possible but has largely been an exercise in diligent human communication within the technical team and beyond to the wider Environment Canterbury project team, the ZC, stakeholders and the interested public.

The detailed methods used by each technical expert for their assessment are described in each of the technical reports in Appendices 4-22. An overview is provided below.

2.8.2 Conceptual understanding of the catchment and key assumptions

A conceptual understanding of how water and nutrients moved through the catchment was developed between the technical team, the Zone Committee and input from the wider community at public meetings. Detailed descriptions of the current state of the environment are provided for each technical discipline in the reports in Appendices 4-22, and all of the assessments of future scenarios are considered against that understanding of current state as summarised later in Sections 3 and 4 of this report. An overview of relevant concepts follows:

Hill-fed rivers and lowland stream flows

The SCCS area has two types of rivers. The small, naturally intermittent, hill-fed rivers (including the Waihao, Waimate, Hook, Kohika, Makikihi and Otaio) are generally fed from overland flow and shallow subsurface flow. When these rivers leave the hills they generally lose their flow to groundwater and so cease to flow naturally in the mid segments in summer. However the extent and duration of periods with no surface flow are generally exacerbated by water takes from rivers and shallow connected groundwater. These rivers periodically have significant floods from heavy rainfall in the catchment.

The groundwater-fed lowland streams include Sir Charles and Buchanans creeks, Waituna and Merrys streams, and Hook Beach Drain. These streams have more stable flows and few flood events.

The hydrology (e.g. surface flow) of the rivers and streams is relatively well understood (i.e. compared to groundwater) although flow recorders are not available on all rivers and thus synthetic (i.e. estimated) flow records have been necessary in some cases. The general nature of how surface flow drains into the gravel aquifers in the upper and middle river segments and discharges to rivers and streams in segments near the coast is understood (see Figure 2-2). However the quantification and spatial pattern of flow-losing and flow-gaining reaches (i.e., the length of zero flow and flowing reaches), and how this varies seasonally and in response to abstraction is only coarsely understood. This is because spatial pattern and quantification of flow losses and gains vary depending on the local sub-surface geological structure (e.g. different sedimentary layers with different properties affecting water movement) which is only coarsely defined.

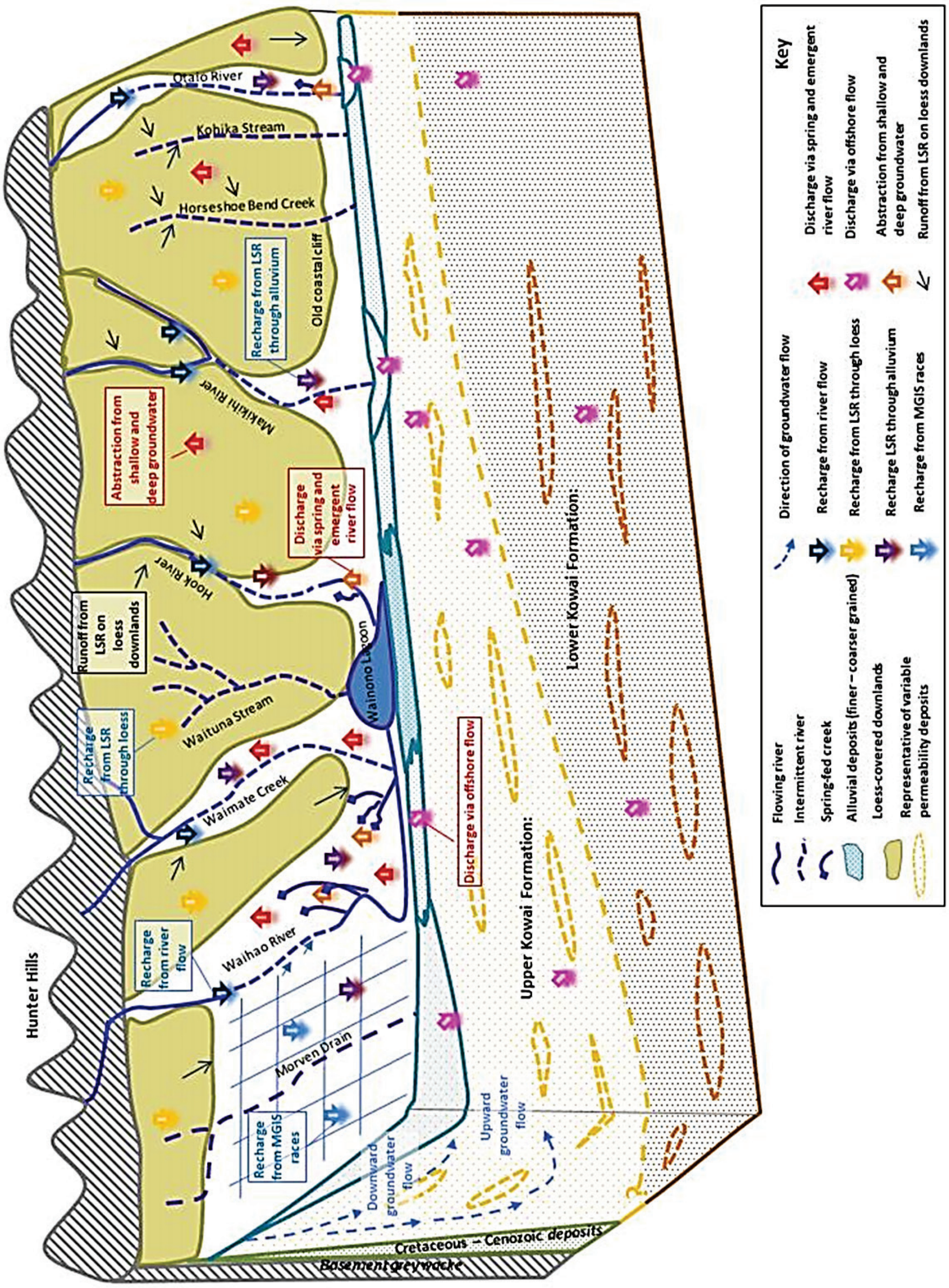


Figure 2-2: Schematic block diagram incorporating geological structure, groundwater flow directions and recharge/discharge sources for the SCCS area (Source: Aitchison-Earl 2015, Appendix 8)

Groundwater quantity

The shallow groundwater resource occurs in Quaternary age alluvial deposits within river valleys incised into loess-covered downlands[13] (see Figure 2-2). River flows, rainfall and application of irrigation water recharge the shallow groundwater system which subsequently discharges to support river flow in the coastal river sections. Shallow groundwater of the river valleys is primarily controlled by changes in river flow. It has little storage and groundwater levels drop relatively quickly during prolonged periods of low river flow. Thus the majority of groundwater level variation in shallow aquifers is related to river recharge. The surrounding downlands are covered by a relatively impervious loess mantle which impedes infiltration and increases runoff.

Deeper and older groundwaters are found in the Pliocene-Pleistocene age Kowai Formation (locally known as the 'Cannington Gravels'). A thick sequence of fine materials separates this system from the overlying shallow groundwaters, although the deep groundwater must receive recharge from the overlying shallow groundwater. Localised utilisable groundwater is also present in smaller quantities within older Paleogene to Neogene age deposits such as the Southburn Sands and Taratu Formation. The deeper groundwaters are old, with limited age determination indicating ages over 1,000 years.

The deeper groundwater is heavily used but there is uncertainty in how it is recharged, where it discharges to, and therefore the long-term sustainability of groundwater use. We do not know the recharge rate, or if recharge is sufficient to support the current level of allocation or any further allocation.

We also do not fully understand discharge from the deep groundwater. It may partly discharge directly to sea offshore and partly to coastal shallow groundwater and hence support river flows in their lower reaches. The effects of abstraction from deep groundwater on discharge to shallow aquifers at the coast (and hence the support of river and spring flows) or to maintaining the fresh/salt water interface is therefore uncertain.

Environment Canterbury has research projects in progress to understand more about the deep groundwater resource in future but results will not be available in the timeframe for the current planning process.

Groundwater quality

There is a relatively good set of groundwater quality monitoring data for the SCCS area. The data show that wells with elevated nitrate-N concentrations are generally shallow (less than 30 m deep) and therefore it is assumed that nutrients lost from land largely remain within groundwater in the shallow alluvial deposits. These deposits are generally found near rivers and streams and hence shallow groundwater is assumed to be a key part of the pathway for nutrients to enter surface waterways. Generally, the data show that deeper groundwater has not been affected by land use change, although this could potentially change in the future.

Other contaminants of concern include pathogens from human or animal waste as indicated by the presence of the water quality indicator *E.coli*. Shallow groundwater wells in the SCCS area are most at risk of contamination from pathogens. Land surface recharge water carries pathogens down into shallow groundwater especially after heavy rainfall events or with excessive irrigation. Data show that some such contamination of shallow wells does occur, although this may be at least partly explained by poor wellhead security on some wells rather than representing shallow groundwater quality generally.

Land use and loss of contaminants to water

Assumed conceptual model for nitrate transport

Water draining through soil is assumed to carry nitrate nitrogen into shallow groundwater at a rate that varies depending on the soil type, land use type and amount of rainfall, as estimated for a range of soils, land uses and rainfall zones across the SCCS area using a modified version of the Canterbury 'Lookup Table' (LUT) as described in Appendix 4. The shallow groundwater containing nitrate is

[13] See definition of 'downlands' in Glossary.

assumed to resurface in the lower part of catchments either directly to gaining reaches of hill-fed rivers or through a network of springs that provide the baseflow for lowland streams as described in the sections above. This assumed 'conceptual model' for how water and nitrate travel through SCCS catchments is shown in Figure 2-3.

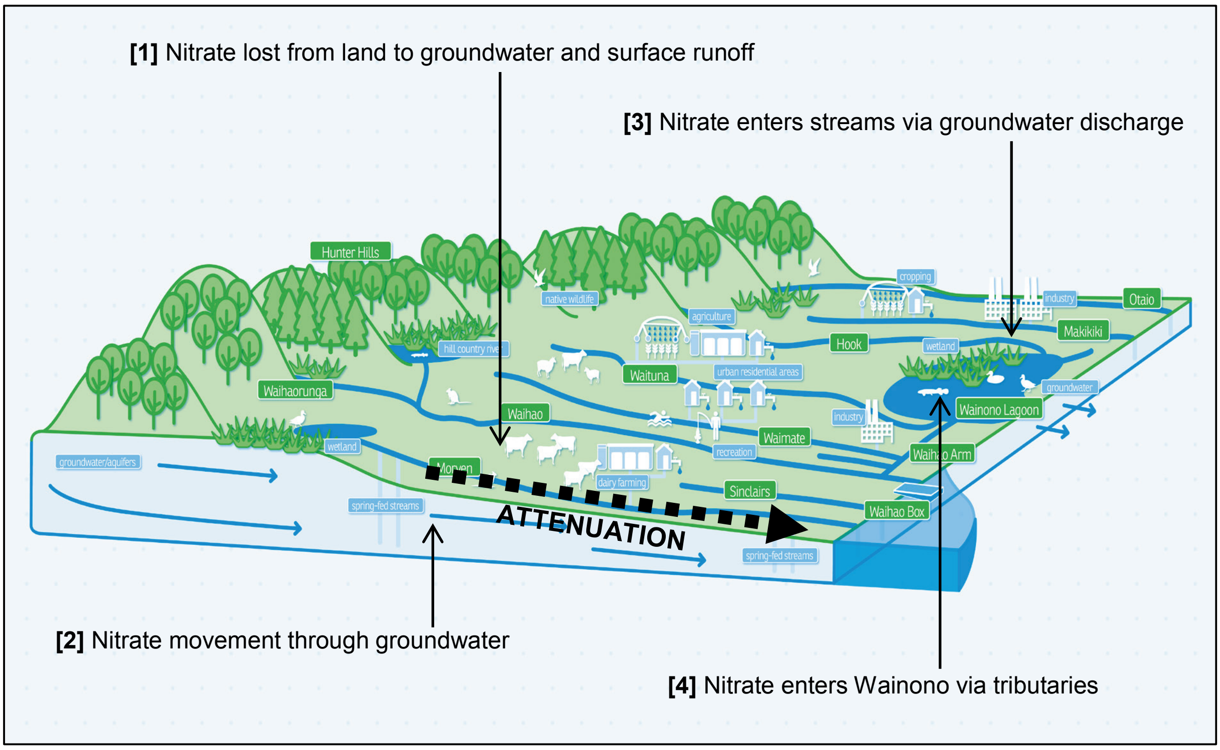


Figure 2-3: Schematic diagram showing some of the key processes by which water and nitrate move through SCCS catchments. Nitrate is lost from land to groundwater [1], travels with groundwater [2] and is discharged to spring-fed streams and the lower reaches of hill-fed rivers [3] which are tributaries of Wainono Lagoon [4]. Nitrate is attenuated along the way due to a variety of processes including denitrification in anoxic groundwater and soil, uptake by riparian vegetation, and uptake by periphyton and macrophytes in streams and rivers

Assumed attenuation of nitrate

It is assumed that some proportion of contaminants lost at source in a catchment (e.g. nitrate loads lost from land as predicted by the LUT or OVERSEER® model) will be attenuated as they travel down a catchment (e.g. by denitrification in any reducing (i.e. anoxic) areas, uptake by algae and other plants into the food chain in streams, rivers and lakes) such that the contaminant load at a measurement point at the bottom of a catchment will be some fraction of the load generated at source (Figure 2-3). That fraction is often referred to as the 'catchment attenuation factor'[14] or a 'catchment co-efficient'[15] and may be estimated by subtracting the estimated receiving environment load at the measurement point at the bottom of the catchment from the estimated source loads. According to this definition, a catchment attenuation factor of 0.5 (for example) implies that 50% of the N generated at the source (such as leached from the root zone) is attenuated before reaching the bottom of the catchment.

[14] In mathematical terms this definition of a catchment attenuation factor (CAF) is CAF = (Qd –Qr)/Qd; where Qd is the source N load (e.g. leaching from the root zone as estimated by OVERSEER® plus any point discharges) and Qr is the receiving environment N load (e.g. measured at some point at the bottom of the catchment.

[15] A coefficient of attenuation could also be calculated in a similar way using OVERSEER® estimated concentrations for groundwater and measured concentrations in groundwater-fed receiving streams.

For the SCCS project we have relied on this empirical approach to estimating catchment attenuation factors and, importantly, have relied on an assumption that the catchment factor does not change for all future scenarios. This has been a particularly important assumption when using predictions of groundwater nitrate concentration increases under future land use change scenarios (Appendix 6). The assumption means that the estimated increases in nitrate loss under future land use result in the equivalent relative increase in surface water nitrate concentrations in rivers (Appendix 7) and therefore loads to Wainono Lagoon (Appendix 19) as described further in the method in Section 2.8.3 below. The implications of this assumption for using OVERSEER® to set and implement nitrogen limits are described in Section 6.

Assumed travel times (i.e. “lag times”) for nitrate transport
In Canterbury generally there can be considerable travel time (i.e. “lag time”) until drainage water carrying nitrate lost from soil on the plains resurfaces in lower plains rivers and lowland streams (e.g. years to decades for parts of mid Canterbury; Bidwell, 2009). Therefore it is necessary to assume that there is an amount of nitrate that is already in transit, or a nitrate ‘load to come’ that will inevitably arrive in the lower reaches of hill-fed rivers, lowland streams, and Wainono Lagoon regardless of subsequent changes in land use or practices.

In the SCCS case we estimate that the relevant lag time to consider in our assessment will vary spatially but in general will be considerably less than the mid-Canterbury Plains, partly because the SCCS catchments are considerably shorter and partly because of the close interaction (and hence relatively fast travel times) between the shallow groundwater and surface flow along the length of most of the SCCS rivers. A comparison of surface water data following a period of years when land use change has occurred in some lower catchment areas in SCCS (approximately 2000-2005) suggests that contaminants have travelled to surface waters relatively quickly (i.e. in less than three years). As a general estimate, based on expert knowledge of the local hydrogeology (e.g. Scott and Etheridge, 2015, Aitchison-Earl, 2015; see Appendices 6 and 8 respectively) and previous estimates by URS (2007), it has been assumed that travel time from shallow groundwater at the base of foothills to the bottom of river catchments is in the order of approximately 10 years, while travel time from the more intensively farmed (irrigated) areas, which are mostly in the lower third of SCCS catchments, is less than three years. Travel times for areas where shallow groundwater interacts with rivers (i.e. in the river valleys – see Figure 2-2) would be significantly faster (i.e. less than a year). Given that there has been limited new irrigation and thus land use change likely to increase nitrate losses in the last three years, due to water limitations (e.g. Figure 4.3 in Aitchison-Earl, 2015; Appendix 8), it has been assumed that there is only a small nitrate ‘load to come’ in SCCS catchments. Furthermore it has been assumed that this small ‘load to come’ will in round terms be offset in time by improving current land use practices up to the standard of GMP; i.e. it has been assumed that the water quality data observed today represent likely future water quality if current land use types remain unchanged and GMP is achieved by all land users. We can’t accurately quantify either the ‘load to come’ or the load reduction resulting from improvement to GMP; the assumption that the two will approximately offset each-other was pragmatic.

This assumption has simplified the analysis and communication of scenarios in SCCS compared to some other catchments with more significant lag times and ‘load to come’ (e.g. the Selwyn Waihora catchment). When combined with the nitrate attenuation assumption described above, it meant that estimated proportional increases (or decreases) in nitrate loss under future land use change scenarios resulted in the equivalent relative increase (or decrease) in surface water nitrate concentrations measured in rivers currently.

Other contaminants
Finally, for contaminants other than nitrate (e.g. phosphorus, sediment and faecal microorganisms) it is runoff from land, shallow subsurface drainage and/or direct discharges to waterways, rather than soil drainage (i.e. leaching), which is assumed to be the source of the majority of the phosphorus, sediment and faecal contamination.

Wainono Lagoon

Wainono Lagoon is a medium-sized (approximately 325 ha), turbid (murky – low clarity) coastal lake which is usually about 1m deep and is separated from the sea by a gravel beach barrier up to 8 m height. The lagoon receives inflow from Waituna Stream, the Hook River, the northern Hook Beach

Drain, as well as reverse flow at times from the Waihao River via the Waihao Arm (Note: the Waihao Arm is also incorrectly referred to at times historically as the Dead Arm, which is in fact a short blind arm coming off part way along the Waihao Arm). The water can range from brackish to fresh depending on flow, level and sea wave conditions.

The gravel beach barrier is slowly migrating landwards and this is gradually, over decades, changing the position, shape and size of the lagoon. Despite this natural coastal process the lagoon and associated gravel barrier are expected to be permanent features of the landscape for the foreseeable future.

The lagoon regularly opens to the sea via the 100 year old 'Waihao Box', a wood and concrete structure that allows the lagoon water to flow to the sea. The Box maintains lake level typically at an average of about 1 m above mean sea level, although level varies within hours as the Box alternately opens and constricts with wave-driven gravel. The Box provides drainage and alleviates flooding of low lying land, as well as providing passage for fish species that migrate to and from the sea at certain times of the year to complete their life cycles. There was general agreement expressed during the SCCS community process amongst local landowners, farmers, manawhenua, fishers and recreationists that the Waihao Box has served this purpose well and there is a strong desire to retain the current system. The Box has recently been repaired (largely reconstructed) and it has been assumed for all scenarios that operation will continue with similar to historic effectiveness for the foreseeable future.

Water in the lagoon is highly nutrient enriched and the lagoon has a long history of sediment build up on its bed resulting from erosion of soil in the catchment. The lagoon has significant ecological, recreational and amenity value, and is a very important taonga to manawhenua. It has designated Mataitai Reserve status which prohibits commercial fishing and is currently subject to significant restoration effort under the Wainono Restoration Project.

Water quality contaminants (nitrogen, phosphorus, sediment and faecal microorganisms) arrive via surface flow from all the lagoon's tributaries, albeit that some nitrate contamination discharges from shallow groundwater into the lower reaches of rivers just upstream of their confluence with Wainono Lagoon. Water balance analyses suggest there is negligible direct contribution of groundwater to the lagoon itself. The implication of this is that the entire Waihao-Wainono catchment is assumed to contribute contaminants to Wainono Lagoon, even though the Waihao River flows directly to the sea via the Waihao Box (i.e. bypassing Wainono Lagoon) for about half of the time and only flows up the Waihao Arm into Wainono lagoon about half of the time.

The Waitaki River

The Waitaki River is outside the SCCS project area (Figure 2-1) but is relevant because it supplies water to the existing Morven Glenavy Irrigation Scheme (MGIS) and is the consented source of water for the proposed HDI and WD schemes. The Waitaki River is a very large river (mean flow approximately 360 m^3/s) compared to the rivers in the SCCS area, the largest being the Waihao with a mean flow of approximately 3.9 m^3/s. The Waitaki also differs from rivers in the SCCS area in that it is alpine lake-fed with headwaters on the main divide of the Southern Alps and flow is regulated for hydro-electric generation, both of which ensure it is a very reliable source of irrigation water compared to the small rivers with seasonally variable flows in the SCCS area. It is also relevant, when considering the use of water for flow augmentation of Wainono Lagoon (e.g. Scenario 2b), that water quality in the lower Waitaki River at the point of abstraction for MGIS and future proposed schemes (i.e. Stonewall) is very good, significantly better (with regard to nitrate, phosphorus and *E.coli* concentrations) than water quality in the SCCS area rivers.

2.8.3 Biophysical modelling

The main purpose of the biophysical modelling is to predict the biophysical effects of the scenarios, including effects of both land and water use, on surface and groundwater, and on water quantity and quality. Thus there is a requirement for the integration of multiple traditional biophysical disciplines.

There is currently no fully integrated biophysical model that can answer all of the questions required of the biophysical part of a catchment limit-setting process. There are models that may in time come close to providing much of what is required. As part of its long-term science strategy Environment

Canterbury is developing capability in the use of such an integrated model that is likely to further inform land and water planning processes in future. Work in progress on one such integrated catchment model (called MIKESHE) in the SCCS area has helped inform aspects of the technical assessments in this project, in particular for understanding groundwater movement (e.g. see Appendix 8).

As already described in Section 2.8.1 the approach has been to "enchain" available models by employing a team of technical experts in different biophysical disciplines to work together under a managed set of assumptions to assess each linked step in the chain. The technical reports in Appendices 4-22 approximately reflect steps in this chain, although the assessment process required interactive communication between authors and was iterative rather than linear in nature. The biophysical steps may be summarised as:

- Climate, land use and soil
- Groundwater quality
- Surface water quality – river ecology
- Groundwater quantity
- Surface water quantity – ecological flows in rivers
- Wainono Lagoon water quantity, quality and ecology

Climate, land use and soil

A series of GIS[16] layers was created that characterise soil type, rainfall, land use, irrigation, predicted drainage and predicted nitrate losses across the entire SCCS area under current and future land use scenarios. The detailed method, data sources and analytical assumptions are described in Lilburne (2015) (Appendix 4) and scenario-specific assumptions are listed in Appendix 2.

Groundwater quality

The GIS outputs characterising predicted drainage and predicted nitrate losses (Lilburne, 2015) were used to predict nitrate concentrations in shallow groundwater across the various groundwater zones under current and future scenarios. The 'modelled current' concentrations were then compared with current groundwater monitoring data for validation, and the modelled future scenario nitrate concentrations were compared to the Maximum Acceptable Value (MAV) of 11.3 mg/L to assess the suitability of groundwater for drinking. Detail of the method, data sources and assumptions are described in Scott and Etheridge (2015) (Appendix 6).

The difference in nitrate concentrations in drainage between the current state and each of the modelled scenarios was then calculated to indicate the relative magnitude of change in groundwater quality. The predicted relative change in groundwater nitrate concentrations (i.e. 'increase coefficients') for each scenario were then used in assessing effects on surface water quality, as described below.

Surface water quality – river ecology

The increase coefficients from above (Scott and Etheridge, 2015) were applied to known current nitrate concentrations at surface water monitoring sites throughout the SCCS area, thus generating predictions of future nitrate concentration under each future scenario. This approach recognised the importance of catchment attenuation (described previously in Section 2.8.2) of nitrate as it travels from its source through shallow groundwater into and along streams and rivers. In general, nitrate concentrations in streams and rivers of the SCCS area are consistently lower than nearby groundwater concentrations indicating that attenuation processes occur. Applying the increase coefficients rather than the actual model predicted groundwater concentrations from Scott and Etheridge (2015) to current measured surface water nitrate concentrations ensured that the catchment attenuation factor for each monitoring site was maintained through all scenarios.

A similar approach was taken for phosphorus except that the increase coefficients for phosphorus were taken from worst case predictions made by Fraser and Flemming (2006) for the HDI scheme

[16] Geographical Information System (GIS) is a way to capture, manage and present all types of spatial data, like maps.

consent applications and were applied only to Scenario 2a. Predictions for other scenarios were made semi-quantitatively relative to the predictions for Scenario 2a. Predictions for other contaminants such as *E.coli* and sediment were made using a qualitative risk based assessment. Predicted contaminant concentrations were combined with knowledge of flow predictions from other technical assessments (i.e. Clarke 2015, Appendix 9) and relevant national guidelines to conduct a relative assessment of effects on river ecology indicators such as peripyton, cyanobacteria, macrophytes, nitrate toxicity and benthic invertebrate biodiversity, and suitability for contact recreation. Further detail of the method, data sources and assumptions are described in Kelly (2015) (Appendix 7).

The predicted changes to nitrate and phosphorus concentrations at river sites on Wainono tributaries were then used in assessing effects on Wainono Lagoon water quality and ecology. Predicted effects on river ecology and recreation values were also used to inform assessments of social and cultural effects (e.g. Appendix 15).

Groundwater quantity

The conceptual hydrogeological model developed for the SCCS area was informed by geological cross-sections, groundwater level analysis, aquifer testing, water chemistry and age determination. The model was used as a basis for subsequent analysis of the groundwater resource where shallow and deeper groundwaters were assessed as being independent in the shorter-term (days-months), although in reality they are likely to be connected in the longer term (years-decades).

To evaluate the effects of different land use and river flow scenarios a series of monthly time-step water balance models was developed for each shallow groundwater area within each river valley. The models accounted for recharge sources (river losses and land-surface recharge (LSR), which represents rainfall and irrigation water), and discharges (emergent groundwater into springs and rivers, groundwater abstractions and discharge to the sea). Recharge inputs to the water balance models were varied to assess the effect of changing minimum flow regimes (Scenarios 1a, 1b and 1c), and increasing irrigated area under the proposed HDI and WD schemes (Scenario 2) on coastal discharge from the shallow groundwater system. In addition a MODFLOW model was developed to simulate steady-state groundwater levels under average recharge over the period 1970-2012, to assess the impact of increased irrigated area on groundwater levels.

The models are based on simplifications that do not represent many system components and so provide predictions that are useful but uncertain. The predictions of change to groundwater levels and flow in the lower river reaches were then used to inform assessments of ecological flow regimes (see below) and river water quality and ecology (see above). Further detail of the method, data sources and assumptions are described in Aitchison-Earl (2015) (Appendix 8).

Surface water quantity – ecological flows in rivers

Multiple aspects of ecological flows were considered in the assessment of effects of scenarios on ecological health in rivers (Clarke 2015, Appendix 9), including:

i) Analysis of hydrological statistics provided by Martin and Leftley (2012, Appendix 11) and Martin (2015, Appendix 12) to assess minimum flows relative to the flow statistic MALF[17];

ii) Use of habitat modelling (Ballard 2013, Appendix 10) to estimate the amount of habitat available for key species at different flows;

iii) Consideration of flow variability and frequency of freshes;

iv) The frequency, extent and duration of dry reaches, which were informed by the groundwater assessment described above (Aitchison-Earl 2015, Appendix 8);

v) The diversity and abundance of aquatic invertebrates and native fish, including mudfish;

vi) Implications for periphyton and macrophytes, which were informed by the surface water quality and ecology assessment described above (Kelly 2015, Appendix 7); and

[17] MALF = Mean Annual Low Flow: See Glossary for definition

vii) Implications for wetlands, which were informed by groundwater level and lower reach flow predictions made by Aitchison-Earl (2015, Appendix 8).

Wainono Lagoon water quantity, quality and ecology

Multiple aspects were considered in the assessment of effects of scenarios on Wainono Lagoon water quality and ecology including:

i) Analysis of historic water quality data and mass balance calculations to predict consequences of increased nutrient concentrations in tributaries (from Kelly 2015, Appendix 7) on lake nutrient load, trophic state (as indicated by the Trophic Level Index (TLI)[18]), risk of cyanobacteria blooms and other ecological indicators, with and without the addition of flow augmentation (Sutherland and Norton, 2011, Appendix 18);

ii) Building on above, the use of numerical models (one-dimensional and three-dimensional) to simulate a range of physical, chemical and biological lake processes in response to changing nutrient loads and several options for managing flow augmentation. This modelling predicted responses to TLI, risk of cyanobacteria blooms and several other indicators (Abell *et al.,* 2015, Appendix 19);

iii) Consideration of historic water quality and ecological data and palaeo-limnological analysis using bed sediment cores to assess the recent (160 years) environmental history of Wainono Lagoon, including ecological trajectories and degradation from various human pressures (e.g. flow changes, vegetation clearance and sediment and nutrient load increases) through time (Schallenberg and Saulnier-Talbot, 2014, Appendix 21);

iv) Consideration of nutrient loading thresholds for shallow coastal lakes in the international literature relevant for Wainono Lagoon (Schallenberg, 2013, Appendix 20);

v) Implications of groundwater level changes and flow regime changes in tributary rivers and springs on wetland vegetation and minimum lagoon level, based on predictions made by Aitchison-Earl (2015, Appendix 8) and Clarke (2015, Appendix 9);

vi) Implications of maintaining the Waihao Box opening regime for lagoon level, farmland drainage management and maintaining fish passage and seasonal recruitment of taonga species from the sea;

vii) Consideration of the merits of re-establishing native macrophyte beds in the lagoon (Appendices 18-21);

viii) Consideration of other proposed restoration initiatives (e.g., tributary and lagoon riparian planting and weed control, catchment erosion and sediment control measures, and potential constructed treatment wetlands) as part of the Wainono Restoration Project;

ix) Consideration of the diversity and abundance of wetland habitat, vegetation, aquatic invertebrates, native fish and birds;

x) Consideration of conditions for game bird hunting and other recreation on and around the lagoon.

2.8.4 Social impact assessment

The social impact assessment identified potential positive and negative social effects associated with predicted changes under each scenario (Taylor *et al.,* 2015; Appendix 15). The two main components of the assessment were:

i) Definition of the current socio-economic context – i.e., the ‘social profile’ of the SCCS area;

ii) An impact assessment for each scenario based on selected social indicators.

[18] TLI is a classification system to indicate the health of New Zealand lakes. TLI ranges from less than 1 (almost pure water) to more than 7 (highly degraded)

The social profile was assembled using a range of data sources including:

- published information from a number of literature sources
- official statistics, including the 2013 census
- other documentary sources including local histories and manuscripts
- comparison case data from throughout Canterbury
- visitor brochures, websites and other visitor information
- interviews and discussions conducted in the assessment area
- discussions at three community workshops

The social impact assessment used comparative cases to assess the likely social change with different levels of irrigation and farm intensification that are the basis for the scenarios. The assessment drew on New Zealand research and case studies of social change that is driven by land-use and associated changes in farm systems, farm ownership and community demographics typical of new irrigation. The scenario assessments used baseline information in conjunction with comparative case data from the Amuri/Hurunui, Central Plains/Selwyn, Hinds/Ashburton, Waitaki Valley and Opuha irrigation areas. These comparison cases were only used as indicators of social change; local conditions were taken into account in predicting the impacts of each scenario. Discussions of the scenarios at public workshops provided important information for refining the social assessment.

The social impact assessment also used information and predictions of scenario effects from the rest of the technical team including biophysical, economic and cultural assessments.

2.8.5 Economic impact assessment

The economic impact assessment used a combination of farm scale and regional scale economic models to predict the consequences of different land use scenarios (for detail see Harris 2015, Appendix 14).

A set of revenue, expense and cash farm surplus estimates was derived from MAF farm monitoring reports (last 3 years). For dairy and sheep and beef properties, the revenue and variable expense estimates were adjusted linearly to reflect differences in stocking rate, and for sheep and beef the fixed expenses were adjusted in a non-linear fashion to reflect the change in fixed expenses/stocking rate ratio across a number of different farm types. This results in the prediction that profitability increases with increasing stocking rate[19]. For arable, horticulture and forestry properties a fixed budget was used. The data sources were:

- Hunter Downs Irrigation Scheme (HDI) – material produced by the Agribusiness Group for Meridian Energy Ltd for the HDI project. Generally the production data were used and matched with more recent Ministry of Primary Industry (MPI) estimates of revenue and expenses. Where the HDI financial data were used, the price series was updated to average of the last five years.
- Environment Canterbury data – custom models produced by Environment Canterbury (Appendix 5, and Leo Fietje, pers. comm.)
- MacFarlane Rural Business data (draft only) produced for use in the Hinds area.
- MPI Farm Monitoring Data – the period from 2010 – 2012 was used with the farm types most closely applicable to the SCCS situation.

[19] For dairy this can be problematic since there are situations where operators with low stocking rates have similar or better profitability than those with high stocking rates, and management skill is probably a better predictor of profitability than stocking rate. Harris, 2015 (Appendix 14) discusses how this was dealt with in further detail.

Estimates of regional outcomes from changes in agricultural land use were derived from a regional input/output model developed for the region but updated for this project. This input/output model was developed by Butcher Partners Ltd and the sectors included in the model were customised to more closely match those required in this study[20]. In this approach the input/output tables are developed to describe the interdependencies of different aspects of a regional (or national) economy and are based on production functions and profitability relationships. Regional input/output modelling tends to overestimate the total impact of land use change because it does not include feedback effects[21], but is the only model type suitable for use at this scale. The outputs generated include regional GDP and employment, revenue and profit, capital expenditure, taxes and population.

Estimates of the cost of improved on-farm practice (in Scenarios 3a and 3b) were derived using data from several literature and industry sources as described in Harris, 2015 (Appendix 14). Estimates of the cost of providing flow augmentation to Wainono Lagoon via the proposed HDI scheme were based on data provided by HDI. Costs of other mitigation measures such as riparian planting were based on literature sources referenced in Harris (2015) (Appendix 14).

2.8.6 Cultural assessment

Cultural values, and the effects of the various future scenarios on them, were assessed using the following three separate but complementary approaches:

i) Preparation of the document *Cultural Associations and their Flow and Water Management Implications for the Waihao / Wainono Catchment* (Tipa 2012, Appendix 16) and the subsequent companion report *Cultural Values and Water Management Issues for a Selection of South Canterbury Catchments* (Tipa 2013, Appendix 17) both of which utilised COMAR[22] methodology. It was significant that the first of these reports was completed early in the process because this allowed Mātauranga Māori (knowledge) and in particular the flow regime preferences of manawhenua (i.e. numbers) to be built into the design of the exploratory scenarios, thus forming part of the foundation of the whole assessment process;

ii) Formation of a Tangata Whenua Working Group (TWWG) made up of local members of the Waihao and Arowhenua Rūnanga and representation from staff at Te Rūnanga o Ngāi Tahu, with whom the Environment Canterbury technical, planning and CWMS facilitator staff met on a regular basis specifically to collaborate on all aspects of the scenario assessment and solution package development process, throughout the project. This included discussions at the initial stages identifying values and outcomes, designing the scenarios for testing, assessing the scenarios, and contributing ideas for development of the draft and subsequent final ZC solutions package. Using this approach enabled the TWWG to directly (i.e. face-to-face) contribute to the process design as well as assess effects of scenarios on manawhenua values as the project progressed, while using the written reports from Tipa (2012 and 2013) as base documentation. Meetings between Environment Canterbury staff and the TWWG were separate and in addition to the public community meetings, although the TWWG members also attended the public meetings and were able to express their views at times, having been introduced to the material beforehand at TWWG meetings;

iii) Contributions and feedback to the Environment Canterbury team at meetings via the Waihao and Arowhenua Rūnanga representatives sitting on the ZC. The Waihao and Arowhenua Rūnanga representatives also attended the TWWG meetings described above and so were able to contribute TWWG messages through to the ZC discussions, as well as lead the process as part of the ZC, and thus also participate in the debate and wider decision-making function of the ZC.

2.8.7 On-farm assessment

On-farm information was derived from a variety of sources and was presented to the Zone Committee and at some of the public meetings. The key types of information used were on farm nitrate losses (see Lilburne, 2015, Appendix 4), the cost and efficacy of nutrient loss reduction measures across a

[20] Butcher, 2013 pers. comm.

[21] An example of a feedback effect is where a change increases demand for labour in an area, which results in higher wages, which in turn impacts on demand for labour across a range of sectors.

[22] COMAR: Cultural Opportunity Mapping, Assessment and Responses – see Tipa 2012 (Appendix 16) for detail.

range of farm types and soils and the Maximum Feasible Mitigation (MFM) possible across farm types, and associated financial implications (see both Lilburne 2015, Appendix 4; and Harris 2015, Appendix 14). This information was used in the modelling as well as directly by the ZC and community groups in their deliberations, in particular the Nitrogen Allocation Reference Group (NARG) process described in detail in Norton *et al.,* 2015 (Appendix 22).

Farm losses of nitrate were based on the lookup tables (LUT) as described previously and in detail in Lilburne (2015) (Appendix 4). Where scenarios required better than good management performance (GMP) (i.e. Scenarios 3a and 3b), a reduction was applied to nitrate losses from farm up to an assumed maximum feasible mitigation[23] for a range of land uses in the catchment (Table 2-2). Maximum Feasible Mitigation (MFM) is the largest reduction in nutrient losses that a farm system can achieve without changing land use given current technology[24]. This does not imply that a farm will necessarily be financially viable at this level of mitigation. There are usually costs associated with reductions in nutrient losses to GMP and better, and the greater the reduction, the greater the cost. The costs of mitigation will be different across industries as described in the assessment of Harris 2015 (Appendix 14).

Table 2-2: Percent reductions applied in Scenarios 3a and 3b, based on estimated maximum feasible mitigation (MFM) for nitrate over good management practice (GMP) for different agricultural land uses (Source: Robson 2014, In Lilburne 2015, Appendix 4)

Land use	*Scenario 3a: Maximum reduction (%)*	*Scenario 3b: Half maximum reduction (%)*
Dairy	40	20
Irrigated dairy support	40	20
Dryland dairy support	20	10
Irrigated livestock	20	10
Dryland livestock	10	5
Arable/Horticulture	10	5
Forestry	0	0
Lifestyle	0	0

2.9 Handling uncertainty

An important part of the technical role identified in Section 2.1 is to understand the limitations of knowledge and to communicate uncertainty so that it can be managed in decision-making (see Box 2-1). It is widely recognised that uncertainty inevitably arises from many sources in resource management policy development processes and must be managed (e.g. Fenemor, 2014; MfE, 2008b; FRST 2007; PCE 2003; Rouse and Norton 2010). In particular for the technical team, there is uncertainty with the input sources of information and with the numeric models and assessment techniques used to make predictions. In general, it has been necessary to:

i) Identify and acknowledge sources of uncertainty;

ii) reduce uncertainty where possible; and

iii) communicate remaining unavoidable uncertainty so that it may be managed in decision-making

Examples of methods used to *identify and acknowledge* uncertainty are:

- Build a team of experts in relevant areas and encourage experts to consult widely across their fields;

[23] For the purpose of this project, the lookup table values are assumed to be at good management practice (GMP). The GMP assumptions are included in the Glossary and in Appendix 2.

[24] See Glossary definition of MFM for typical practices that would be considered MFM for several farming types.

- Maintain an open and positive attitude toward good quality data and assumptions from sources outside of the technical team;
- Agree a conceptual understanding of catchment hydrology, hydrogeology and water and contaminant flow paths with the technical team and through discussion and review by the community and stakeholders; then document key assumptions leading to uncertainty (as done in Section 2.8.2);
- Examine the outputs from each model component for sense and plausibility before passing information around the technical team (including review of relevant literature where applicable);
- Quantify model uncertainty where possible (e.g. by using measures of data distributions as well as central tendency and calculating estimates of errors where possible);
- Test the scenario results by review, first across the multidisciplinary technical team, then with the community and stakeholders, and ultimately via independent technical peer review;
- An independent peer review process was carried out for all technical reports (see Section 7).

Examples of methods used to *reduce* errors and to *reduce* uncertainty where possible are:

- The best information and data available at the time of the assessment was used. This was not always the best information theoretically possible but was the best available within time and resource constraints;
- Individual model components were calibrated using local information where possible;
- Sensitivity analyses were used in some cases to understand the impact of uncertainty with some assumptions;
- Use multiple assessments and models in parallel and look for converging lines of evidence where possible.

Despite these efforts there remains significant unavoidable uncertainty with the assessments. The technical team has attempted to summarise and communicate this remaining uncertainty so that it can be built into the decision-making process. It is necessary to share the burden of this unavoidable uncertainty, both with the community as they deliberate their preferred path for the future, and with decision-makers as they make the ultimate value judgements that must incorporate this uncertainty.

Examples of methods used to *communicate* unavoidable uncertainty are:

- Explain modelling and assessment components and assumptions to the community and stakeholders
- Make all the relevant information publically available on the website including all underlying technical material
- Communicate uncertainty in terms of likelihood of outcomes being achieved using the Summary Matrix (described further in Section 2.10.3 below).
- Make scenario assessment information available at three differing levels of complexity and detail for different audiences, i.e. the Summary Matrix, the Overview Report, and the appended multiple detailed individual technical reports (described further in Section 2.10.5 below).

In communicating unavoidable uncertainty it has been anticipated that this will be taken into account (and managed) in making the difficult value judgement decisions necessary to select a preferred path for the future, including setting limits. When uncertainty is communicated the burden of it is shared amongst technical advisors, the community and decision-makers. Decisions can then be more transparent, and can include risk management strategies such as adaptive management and appropriate precaution.

2.10 Integrate and communicate results

2.10.1 Integration

As already discussed in Section 2.8.1, responsibility for integrating the contributions from multiple technical disciplines has been explicitly identified and designated primarily to the Technical Lead (author of this report). Integration has been handled by:

- Creating a team environment where all technical experts understand the purpose of the project and their role within the iterative "assessment chain";
- Creating lines of communication to ensure that technical experts constantly share their assumptions, learnings and results across the team, and in particular with other experts needing to use inter-dependent predictions;
- Defining common analytical assumptions;
- Defining common scenario assumptions for testing (i.e. Appendix 2);
- Defining indicators specific to each technical discipline, but which relate to the common set of ZC outcomes, and which may be presented in a common format (see Section 2.10.2 below for further explanation);
- Designing a common system for summarising and presenting multidisciplinary results – the Summary Matrix (see Section 2.10.3 below for further explanation);
- Managing project timelines and time dependencies for deliverables needing to pass between experts on the iterative assessment chain (i.e. the critical project path) in order to deliver results to pre-programmed ZC and community meetings;
- Ensuring that ultimate responsibility for reviewing and checking common assumptions and robust analytical linkages across the team rests with an individual (in this case the Technical Lead).

2.10.2 Indicator development

While each of the scenarios had to be tested against the ZC's identified outcomes, the narrative way those outcomes were expressed (as quoted in Section 2.2) was not in a form that could be consistently assessed or modelled directly using available technical tools. Thus the technical team worked with the ZC to develop a list of indicators they could use to test each outcome. The resulting list of indicators is shown together with the related ZC outcomes in Appendix 1. That list of outcomes and related indicators forms the basis for the common assessment framework and the "Summary Matrix" (described further below) that is used throughout the rest of this report to summarise the effects of scenarios.

2.10.3 The Summary Matrix

The Summary Matrix has been designed to provide a high level, quick reference guide for comparing the relative merits of scenarios across a wide range of social, economic, cultural and environmental technical indicators.

The entire Summary Matrix assessment is shown in the Executive Summary of this Overview Report, while relevant parts of the Summary Matrix are presented for each technical discipline assessment in Section 3 (the exploratory scenarios) and Section 4 (the ZC Solutions Package).

The Summary Matrix uses a five-class colour-coded presentation system to estimate the ***extent to which*** the technical team expects the Zone Committee outcomes (as tested using the indicators listed in Appendix 1) would be achieved under each scenario, as shown below.

Where there is a clearly defined desired outcome or an absolute (e.g. numeric) indicator to test, an assessment is made of the **likelihood** that the outcome will be achieved… (five-class scale)…	Almost certainly	Probably	Possibly	Unlikely	Highly unlikely
Indicative numeric probability out of 10	9,10	7,8	4,5,6	2,3	0,1

Where there is not a clearly defined desired outcome, or the indicator allows only a relative assessment, the assessment reflects only the ***relative merit*** of each scenario compared to current… (five-class scale)…	Very high (maximum)	High	Medium	Low	Very low (minimum)

This presentation system is intended to assist discussions and decision-making by simplifying complex multidisciplinary information in a common assessment format. When predicting the consequences of future scenarios for complex resource management problems, uncertainty is inevitable and must be communicated. This presentation system is intended to help make uncertainty transparent and thus to inform decision making. However the tool should be used with care because simplifying complex information obviously neglects the detail. The technical assessment reports in Appendices 4 to 22 should be consulted for detail.

2.10.4 Communication with ZC and community

The key formal lines of communication with the ZC and community over the course of the project since it began in September 2012 were:

- Monthly ZC meetings from September 2012 to March 2015 (more than 25 meetings);
- Three public workshops to discuss technical information on the current state of the environment and predictions for future scenarios in May, July and August 2013;
- A public open day in November 2013 to discuss scenario results, community feedback and a draft solutions package;
- Face to face interviews with the ZC, technical staff and each of the twelve stakeholder groups and/or individuals who accepted an invitation to present written and verbal feedback on the scenarios and draft solutions package;
- A phone survey in November 2013 seeking feedback on the scenarios and draft solutions package;
- Ten public meetings of the Nitrogen Allocation Reference Group (NARG) to deliberate options for allocating nitrogen;
- A public workshop in April 2014 to discuss the proposed Land and Water Regional Plan and implications of the draft ZIP Addendum for the SCCS area
- A public meeting in May 2014 to discuss national, regional and local issues relating to setting and allocating nitrogen limits – organised by the local NARG group and the national level Land and Water Partnership group (see Appendix 22);
- A public meeting in June 2014 to discuss nitrogen allocation in the neighbouring Otago region – in conjunction with NARG;
- Numerous meetings with the Otaio Water Users Group and other interested Otaio stakeholders, the upper Waihao water users and the Waihao Wainono users;
- Multiple meetings with the Tangata Whenua Working Group (TWWG) as already described in Section 2.8.6;
- A 'questions and answers' page was provided on the project website containing technical team answers to key questions raised at public meetings.

In addition there were many informal phone conversations, emails and face to face meetings with ZC members, TWWG members, primary industry stakeholders, other stakeholders (e.g. Fish and Game and Department of Conservation) and interested public, many of which have been referenced in some way in the detailed technical reports, and many that have not been formally referenced.

2.10.5 Documenting technical work

The technical information was offered at several levels of detail for each public meeting (following assessment of each new scenario), in an attempt to serve the various needs of different parts of the community, as follows:

- At the most summarised level the assessment results for all scenarios were simplified and provided in the Summary Matrix on one A3 page (such as the one in the Executive Summary of this Overview Report);
- An oral presentation (with visual slides) was presented summarising scenario results in more detail than the Summary Matrix but limited to approximately an hour (50 slides);
- An Executive Summary (2-5 pages) of the Overview Report, containing just the key take-home messages from the technical scenario assessment;
- The Overview Report (170 pages) containing an integrated but discipline-by discipline summary of the technical scenario assessment, organised around the ZC outcomes and indicators. This document contained key results (including important graphs, tables and figures) from each individual technical report but presented in relatively simple language, using a common presentation format, without detailed technical referencing.
- The individual reports for each technical discipline (typically 50-150 pages) contained detailed description of data, assessment methods, assumptions, results and conclusions suitable for those readers interested in the underlying technical detail. At the public meeting for Scenario 1 there were eight such reports and by the end of the process there were 19 technical reports as found in Appendices 4-22.
- For the public open day in November 2013 the summary results were converted into several posters that were placed on display panels along with other project information.

All draft reports and presentations were made available in draft form on the SCCS project website[25] either before the relevant public meeting or immediately after. As more scenarios were assessed the reports were revised and new draft versions posted on the website.

2.11 Adjust based on community feedback

Because the technical assessment and communication process described above (Section 2.10.3) was an evolving ‘live’ process carried out over more than two years, there were, by design, numerous opportunities to invite and receive feedback from the community. All of the lines of communication listed in Section 2.10.3 above were used as opportunities to gather feedback and this has shaped the final version of this Overview Report and each of the technical reports in Appendices 4-22.

2.12 Consider climate change

The national and regional policy setting (i.e. the NPSFM and the Regional Policy Statement) requires that consideration be given to the reasonably foreseeable effects of climate change. However it was decided not to do this by adding climate change scenarios into the suite of exploratory scenarios for the SCCS project. It was decided that climate change considerations could be more efficiently assessed using existing literature and previous climate change analyses conducted in the SCCS area or nearby mid-Canterbury. That assessment is provided later as part of assessing the Zone Committee Solutions Package in Section 4.7.

[25] SCCS website address: http://ecan.govt.nz/our-responsibilities/regional-plans/regional-plans-under-development/south-canterbury-coastal-streams/Pages/Default.aspx

3 Part 1: The exploratory scenarios

This section contains an assessment of the effects of all seven exploratory scenarios (1a, 1b, 1c, 2a, 2b, 3a, 3b) on environmental, social, cultural and economic outcomes.

The content of this section is as it was presented to community workshops and numerous ZC meetings throughout 2013 and 2014. The material in this section helped inform the community and ZC as they debated the pros and cons of different scenarios and management options, and thus contributed to the development of the Zone Committee Solution Package (ZCSP). The ZCSP is described and assessed in Section 4.

3.1 Organisation of this assessment

Social, economic, cultural and environmental matters are all interconnected and important - there is no 'right' way to split or organise these for assessment. For convenience, this assessment is organised into three sections to cover the three main 'outcome' areas identified by the ZC (as detailed in section 2.2):

1. Social and economic (section 3.3)
2. Streams, rivers and groundwater (section 3.4)
3. Wainono Lagoon (section 3.5)

Cultural matters are relevant for, and appear under, all three of these headings, rather than being separated out. There is no ranking of importance implied by the presentation order in this report.

In each sub-section below, numerous technical indicators are used to assess the extent to which each scenario achieves the ZC outcomes. While each scenario was considered separately in the detailed technical reports (see appendices), this Overview Report provides an integrated commentary on the relative merits of all seven scenarios for each technical indicator and outcome.

3.2 Scenario definition and assumptions

The seven exploratory scenarios were described in Table 2-1 of Section 2.7 and the technical assumptions are provided in Appendix 2.

3.3 Social and economic assessment

This section is based on technical reports on economics (Harris, 2015), social considerations (Taylor *et al.,* 2015) and manawhenua values (Tipa, 2012); see Appendices 14, 15 and 16 respectively.

3.3.1 Current land use and irrigation

In 2010, agriculture, forestry and fishing collectively contributed approximately 19% of the South Canterbury area (Timaru to Waitaki) Gross Domestic Product (GDP), with manufacturing contributing 18% and wholesale and retail trade 11%. Dairy farming was the largest employer in the South Canterbury area accounting for approximately 6% of total employment. For the Waimate District, which is a smaller area and has no major service centres within it, agriculture is even more significant, contributing over 50% of employment and GDP.

Current land use in the SCCS study area is shown in Figure 3-1 and Figure 3-4. Sheep and beef is the dominant land use, then dairy followed by arable. Forestry is the only other major land use in the catchment currently. Looking just at the irrigated land, dairy makes up the largest percentage (40%) with sheep and beef (30%) and arable (23%) also being significant (Figure 3-2).

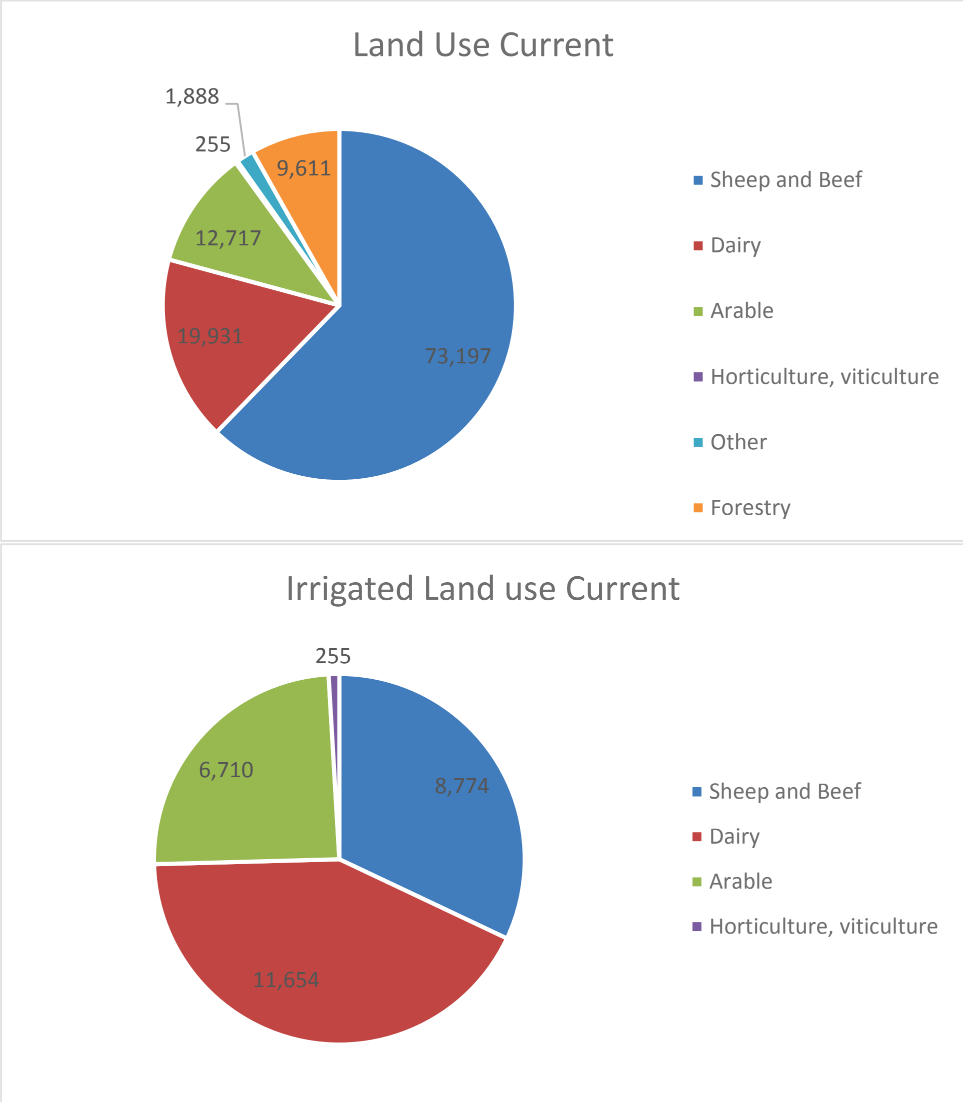


Figure 3-1: Current land use breakdown for the SCCS area (ha)

3.3.2 Irrigation using water from local coastal streams

Currently about 27,700 ha of land is irrigated in the SCCS area (Figures 3-1 and 3-3). While the Morven Glenavy Irrigation Scheme (MGIS) is served by Waitaki River water with high reliability to the Morven and Sinclairs catchments in the south and a relatively small area of the lower Waihao (Figure 3-3), the remaining currently irrigated land is irrigated using relatively low reliability surface water from the numerous local coastal streams and/or groundwater.

The purpose of Scenarios 1a, 1b and 1c was to explore the implications of using more water from the coastal streams for irrigation (Scenario 1c) versus reducing abstraction from the coastal streams (Scenario 1b) compared to the current level of abstraction (Scenario 1a). The analysis showed there are trade-offs between the amount of water left in rivers for in-stream values, the reliability of supply for users, and the area of land that can be irrigated. Compared with approximately the current minimum flows and allocations, the analysis showed that:

- Higher minimum flows and smaller allocations (Scenario 1b) significantly improve ecological, amenity and recreation values over current but would reduce irrigated area and reliability, resulting in significant adverse impacts on economic and related social outcomes.

- Lower minimum flows with current allocations (Scenario 1c) adversely impact ecological values, provide limited economic gains, and are the least likely scenario to meet the RMA test of sustainable management.

In short, the local coastal streams are at or over the limit of what they can provide for irrigation, and this situation has led to proposals for further irrigation schemes using Waitaki River water.

3.3.3 Proposed irrigation schemes (HDI and WD)

Under Scenario 2 (a and b) and 3 (a and b) the consented HDI and WD irrigation schemes will double the irrigated area from about 27,700 ha to 54,700 ha (Figure 3-3). This represents full irrigation development of the potentially irrigable land in the SCCS area. Figures 3-2 and 3-4 show that land use is expected to change under full irrigation, to more intensive uses such as dairying.

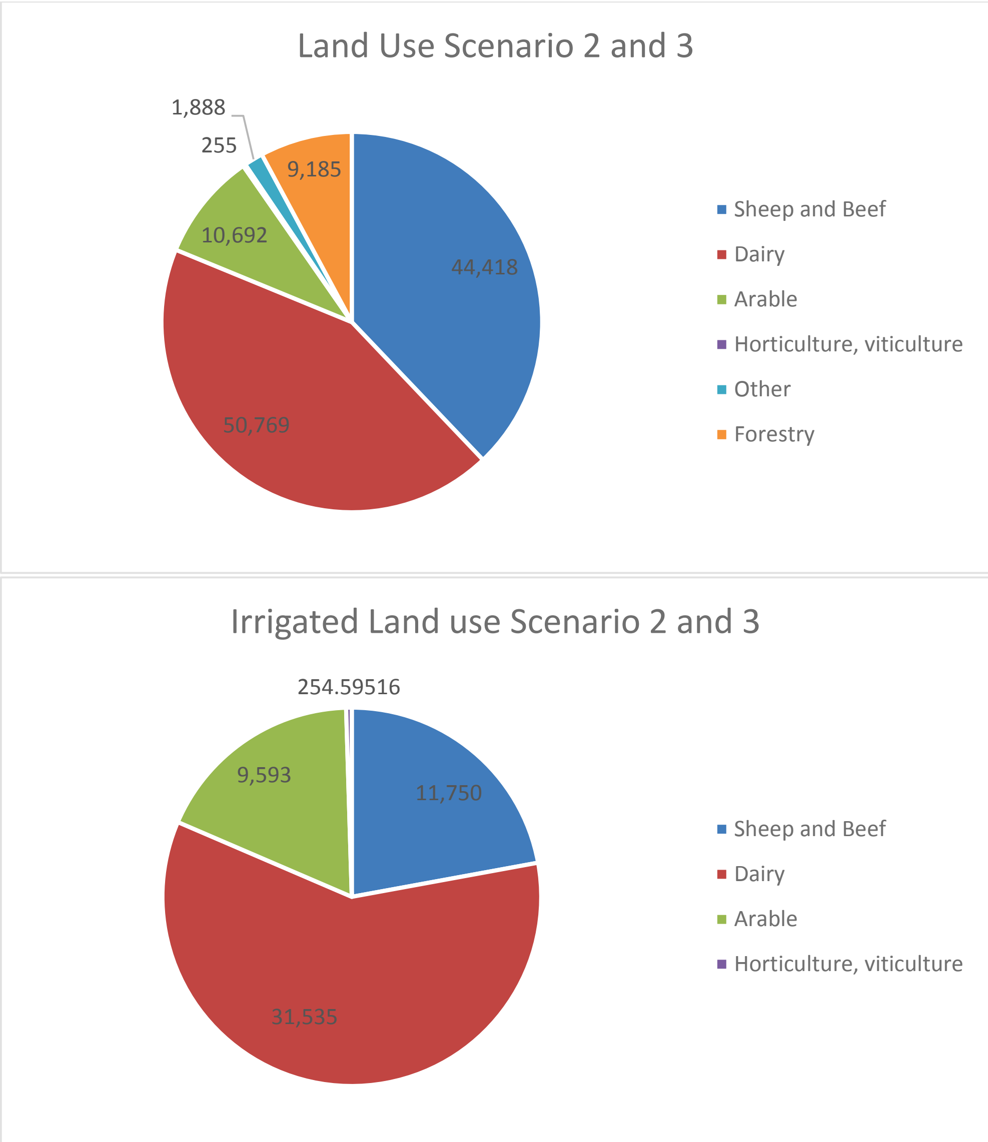


Figure 3-2: Estimated future land use breakdown with full irrigation development in Scenarios 2 (a and b) and 3 (a and b)

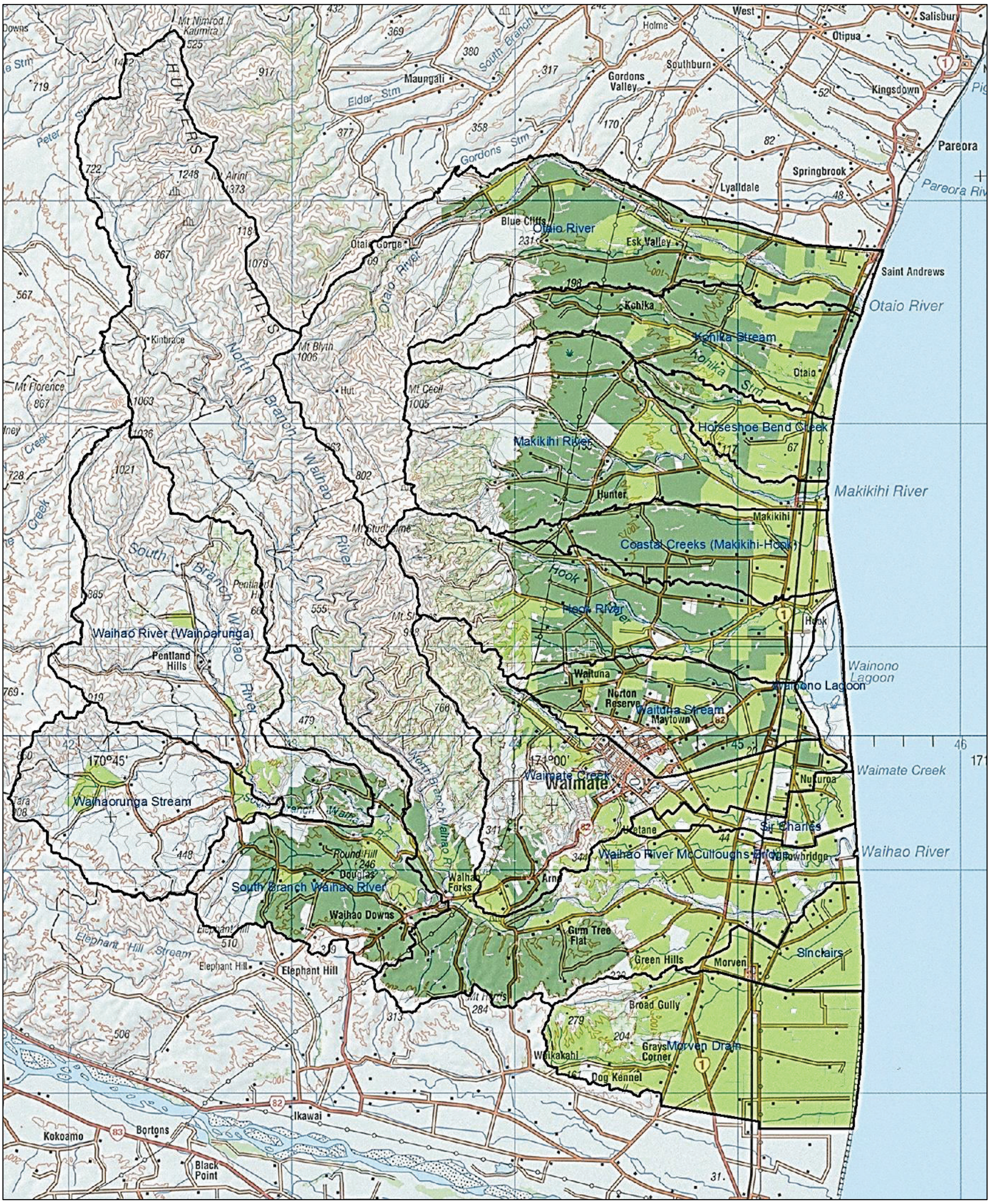


Figure 3-3: Estimated area currently irrigated (light green 27,700 ha) and the additional area that is irrigated under Scenarios 2 and 3 by the HDI and WD schemes (dark green ~27,000 ha) within the SCCS project area (outer black boundary)

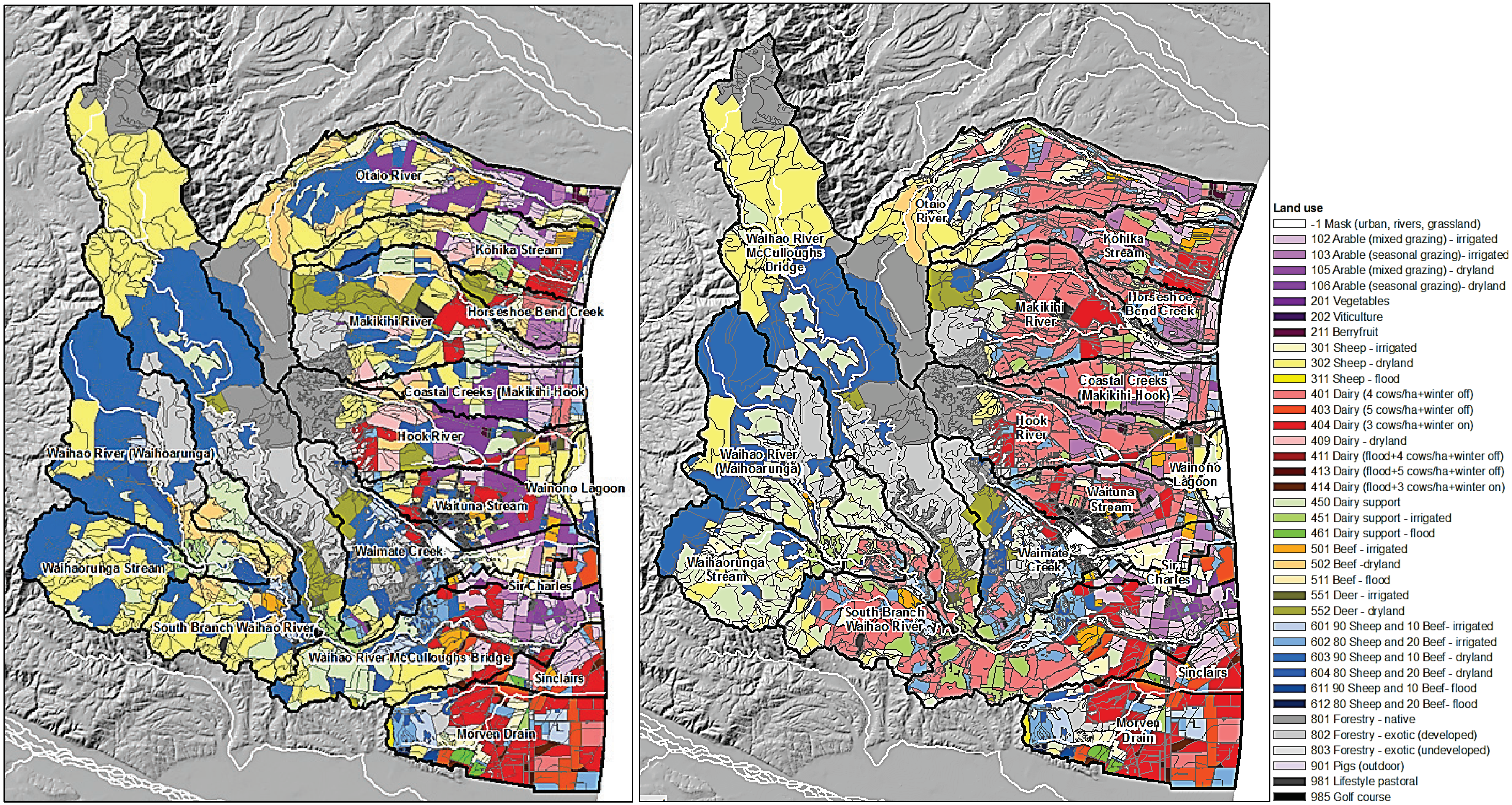


Figure 3-4: Estimated land use mix under Scenario 1 (left map) and Scenarios 2 and 3 (right map) (Source: Lilburne 2015, Appendix 4)

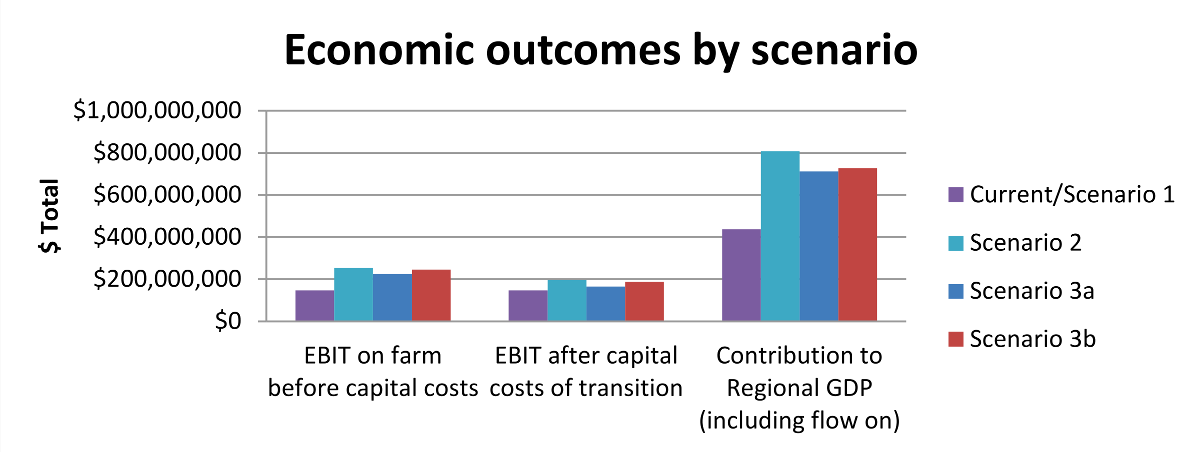
3.3.4 Regional economics and the importance of irrigation

Estimates of the economic effects of land use in the study area are provided in Figure 3-5 and outlined in greater detail in Appendix 14. They show the total contribution of the primary sector to the economy. Across the study area the current cash farm surplus is $150 million per annum and the current contribution to GDP $440 million per annum. On farm employment is currently 770 employees locally, and 3,800 regionally including processing of the primary products produced in the study area. Household income regionally that is driven by the primary sector in the SCCS area is estimated at $210 million, and the total regional contribution to local and central government revenue associated with the primary-sector driven parts of the economy is estimated at $120 million per annum. The detailed data in Appendix 14 show that dairying, despite being only 16% of the land use, produces approximately 40% of agriculture's contribution to the regional economy. Sheep and beef produces about 40% of the contribution and arable produces about 10%. All other primary sector land uses contribute about 10%.

Both Scenarios 2a and 2b significantly increase economic activity, both on farm and in the region (Figure 3-5). Compared to the current situation, the on farm Earnings before Interest and Tax (EBIT) increases from $150 million to $250 million, and is reduced to $200 million when including costs of moving to irrigation. The primary sector contribution to regional GDP almost doubles from $440 million to $810 million (Figure 3-5). Similar magnitudes of increase are seen in household income regionally that is driven by the primary sector ($210 to $380 million) and rates and taxes ($120 to $220 million). Employment associated with the study catchment increases from 3900 Full Time Equivalents (FTE) to 6600 FTEs across the region (Figure 3-6). On farm the current employment of 800 FTEs increases to 1400 FTEs (Figure 3-6). The difference between Scenario 2a and 2b (i.e. the provision of flow augmentation to Wainono Lagoon under 2b) was originally estimated (during the exploratory scenarios process) to be a cost of between $5 and $8 million to provide augmentation via the HDI scheme (i.e., the equivalent annual cost including depreciation over 50 years was between $0.4 and $0.7 million annually). However note that later work on the ZCSP has led to a revised estimate of a total cost of $39 million for augmentation (see Section 4.4.6).

The detailed data in Appendix 14 show that dairying is even more dominant as a contributor to economic activity under Scenario 2 (a and b) than currently. Dairying provides 60% of the profit before capital, and about 70% of regional GDP, household income and employment. Sheep and beef reduces to 15% of the EBIT, 20% to 30% of the GDP and household income, and 14% - 25% of the employment. Other land uses contribute <10% to economic indicators.

In Scenarios 3a and 3b the regional economic indicators are reduced from Scenario 2 by the inclusion of mitigation. EBIT reduces by $30 million before and after the capital costs of transition when full mitigation is applied (Scenario 3a), and by about $10 million when only half mitigation is applied (Scenario 3b) compared with Scenario 2 (Figure 3-5). Note that the differences between Scenario 2 and Scenario 3b are obscured in the graphs and tables by rounding errors. However the differences in wider regional economic indicators are greater, with regional GDP reduced by about $100 million in both Scenarios 3a and 3b relative to Scenario 2. Regional household income reduces by about $40 million, and rates and taxes by about $30 million, all for Scenarios 3a and 3b relative to Scenario 2. There is a similar reduction of 600 – 700 FTEs with mitigation.



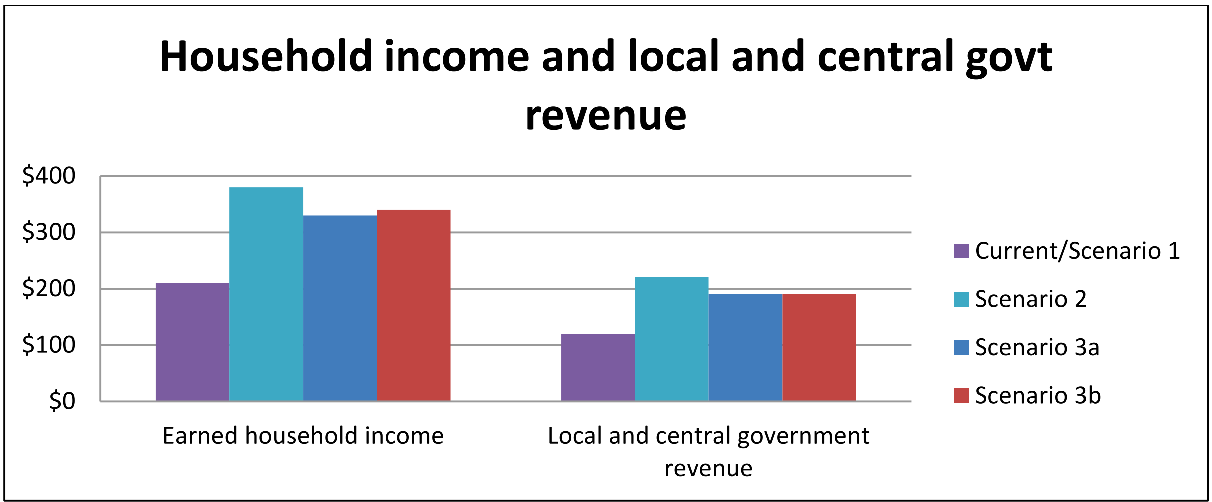


Figure 3-5: Estimates of economic outcomes by scenario for SCCS area

3.3.5 Summary comparison of scenarios - economic indicators

The key differences between scenarios for economic indicators can be summarised as shown in the summary assessment matrix (Table 3-1) and as listed below:

- <u>Scenario 1(a, b and c) versus Scenario 2</u>: Scenario 2 has a significantly higher impact in terms of regional economic activity. Scenario 2 brings an increase in EBIT of about $50 million after capital costs of transition, and an almost doubling of indicators of contribution to wider economic activity in the region.

- <u>Scenario 2a versus 2b</u>: The difference between the scenarios (i.e. providing augmentation of Wainono Lagoon) was originally estimated to be $5 to $8 million, but this has subsequently increased to $39 million (see Section 4.4.6).

- <u>Scenario 2 versus 3</u>: Scenario 3 shows a reduction in profit of $10 - $30 million, and in regional indicators of about 10%. The profit effect is greater in Scenario 3a than 3b, but the regional economic indicators are essentially the same for both 3a and 3b.

- <u>Scenario 1(a, b and c) versus Scenario 3:</u> The profit and wider economic impact is significantly increased in Scenario 3 relative to Scenario 1, with profit after capital costs of transition increasing by 10% – 30%.

Table 3-1: Assessment of the scenarios for economic indicators: This assessment uses a five-class colour-coded scoring system as described in Section 2.10.3. (Note: Economic indicators allow only an assessment of the ***relative merit*** of each scenario to be made because there is no absolute (e.g. numeric) threshold defining attainment of the ZC's economic outcomes. See Appendix 1 for explanation of the link between ZC outcomes and technical indicators, and that current state has been nominally assessed as "Medium" (yellow) for economic outcomes on the basis that only half the irrigable area is currently utilised. Other scenarios are assessed relative to this current state).

TECHNICAL INDICATORS	SCENARIOS						
	1a	1b	1c	2a	2b	3a	3b
Utilisation of irrigable area to achieve production potential - CWMS Target 7		SCCS area local					
On farm economic impacts (revenue, farm working expenses, variable expenses and EBIT)		SCCS area local				↑	
Regional economic impacts including GDP, earned household income, rates and taxes							

Notes:
Arrows (↑↓) indicate relative change (more/less likely to deliver an outcome) compared to Scenario 1a but not sufficient change to justify shifting to a new colour class.
Cells showing half yellow and half red indicate significant negative impacts at the local scale in some catchments (red), but small impact at the scale of the whole SCCS area.

3.3.6 On-farm and regional employment

The 2006 Census showed 2600 full time employed, 890 part time employed, and 100 unemployed people resident in the Waimate District. The very limited increase in irrigated area and further intensification in Scenario 1 (including all sub-scenarios) is likely to be associated with weaker employment growth compared to Scenarios 2 and 3, where a major increase in irrigated area will drive further intensification of farming and substantial growth in the dairy sector in particular, with dairy becoming an increasingly important contributor to the area economy and employment (Figure 3-6). The impact of mitigation in Scenario 3 reduces employment levels on farm and in the region, but they remain significantly elevated above the current situation (Figure 3-6).

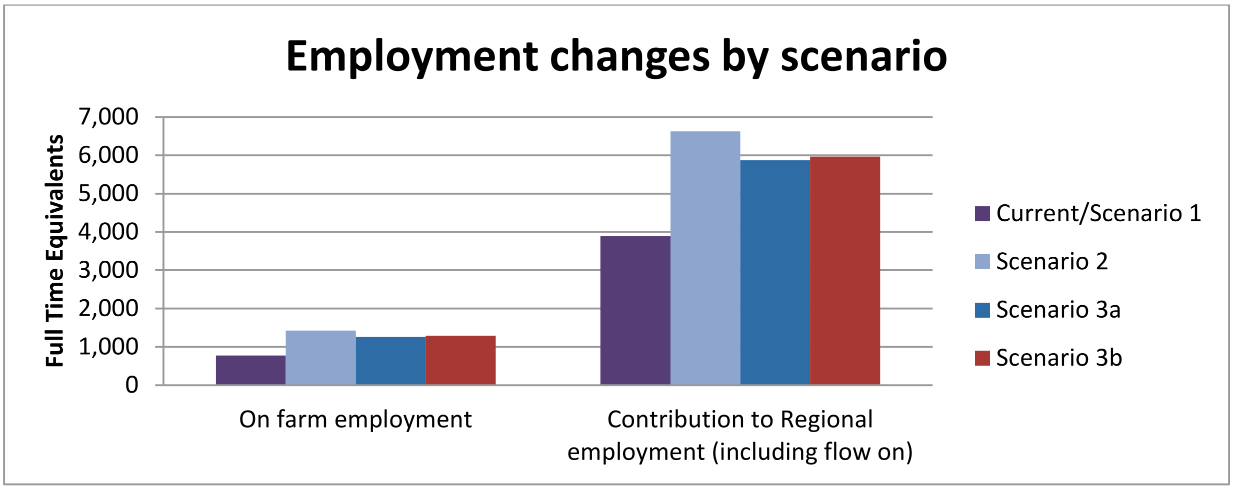


Figure 3-6: Estimates of agricultural contribution to employment by scenario, SCCS study area

Under all scenarios employment in food processing will continue to be located both inside and outside the SCCS area, with two current plants in the area and a new one proposed for Glenavy. Meat processing will remain outside the SCCS area with two major plants currently operating within commuting distance, subject to any future rationalisation in this sector. Unemployment is likely to remain low.

3.3.7 Number of farmers and farm workers

In Scenario 1 (a, b and c) the number of farmers and farm workers employed in dairy, dairy support and arable farming is likely to increase to a minor extent for the next 5 to 10 years. Beyond this period, constraints on water uses and improvements in management efficiency and mechanisation could lead to a gradual decline in the numbers of people employed on farms. However, the level of employment should be relatively sustainable, with employment likely to be maintained even if declines in commodity prices are experienced by the dairy, meat and wool sectors over the short term.

The economic analysis indicates the number of farmers and farm workers employed in dairy, dairy support and arable farming is likely to increase by 500 to 600 FTEs under Scenario 2 (a and b). However, under Scenario 3a (Maximum Feasible Mitigation) the analysis shows the increase in employment will be a little less – in the order of 100 FTEs fewer regionally (on and off farm), with little difference between Scenarios 3a and 3b.

A protracted period of economic stress for the dairy sector, however, could result in a reduction in cow numbers and a shift back to arable or pastoral farming that would reduce the level of employment and change the mixture of occupational skills away from dairy and dairy support.

3.3.8 Population in the SCCS area

Under Scenario 1 (a, b and c) the population of the SCCS area is likely to remain at about the 2012 level of 6,080 over both the short and long terms. Any small changes in the population base will occur slowly, driven by limited employment opportunities and will ultimately be influenced by the balance of inward or outward migration i.e., people shifting to the town (Waimate) for retirement, work (in the dairy sector especially) or lifestyle reasons, versus those leaving because opportunities are limited (particularly for youth and younger workers).

Under Scenarios 2 and 3 the two irrigation schemes (HDI and WD) would increase the population growth of the Waimate District by 1,000 to 1,200 people. Increase in the population of the Waimate township is likely to occur in the construction stage and then with changes in land use (particularly dairying) and associated services. With the regional labour market being bolstered by the range of new jobs on-farm, a long-term effect will be to support the viability of services available in Waimate town. The estimated range in population increase allows for possible small variations between sub scenarios, depending on their employment outcome.

3.3.9 Social services and community cohesion

Under Scenario 1 (a, b and c), as population remains stable or in slow decline there is unlikely to be any significant gains in the form of improvements to health services, schools and community facilities from increased funding on a per capita basis. At best in the current tight fiscal climate, access to those services and facilities within the district is likely to be maintained at current levels. This means it remains a challenge to meet the needs of the aging population of the area (22% of the district's population were aged 65 years and over in 2006).

Under Scenarios 2 and 3, with the increase in the number of dairy farmers and farm workers, the proportion of total farm workers aged under 30 years will increase and there is likely to be an increase in the number of younger families. These changes would rejuvenate the farming community and the growth in population will most likely drive significant gains for health services, schools and community facilities from increased funding on a per capita basis. These improvements will also help to meet the needs of the aging population as well as the total population generally.

There will be new social needs to meet under all three scenarios. In Scenario 1, with increasing differences between productive and non-productive sectors, and also from competition between irrigators for the water available in the area, there will be differing views of stakeholders and tensions about how this water should be used. In scenarios 2 and 3 there will be different sorts of tensions, especially from the need to integrate newcomers into the communities, including workers from overseas. The increase in dairy farming will increase the number of corporate farms and increase the number of paid employees, who will have different needs and attitudes to community participation.

Some environment-focussed stakeholders will remain concerned about high nutrient and sediment levels in Wainono Lagoon despite efforts to manage this effect, with least concern under Scenario 3a which includes the most on-farm mitigation (i.e. MFM).

3.3.10 School rolls

At best school rolls will remain steady in Scenario 1 (a, b and c), with a slow decline in numbers most likely as the population ages overall. There may be pressure on schools to merge or close over time. Dairy production will continue to bring younger families engaged in the dairy sector. The increased irrigation in Scenarios 2 and 3 should strengthen school rolls.

3.3.11 Individual and household income

Under Scenario 1 (a, b and c), individual and household income in the area will remain relatively steady in real terms. There is some potential growth in incomes associated with a small increase in dairying. However, increases in productivity are likely to be offset by a higher proportion of the population (mainly elderly) receiving limited incomes, with an expanding difference between incomes evident. Under Scenarios 2 and 3, increase in dairying will benefit on and off-farm employment and incomes in the area. Growth in employment and incomes (Figures 3-5 and 3-6) will help to offset a high proportion of the population receiving limited incomes due to the high proportion of elderly, but there will be increases in income differential, particularly between town and rural areas.

3.3.12 Drinking water quality

Current Waimate District Council (WDC) drinking water supplies sourced from deep groundwater bores (Waimate town) will likely remain unaffected and continue to meet drinking water standards under all scenarios.

WDC rural scheme supplies sourced from rivers (i.e. Cannington Motukaika, Hook Waituna, Otaio Makikihi, Waihaorunga and Waikakahi schemes) may, depending on the location of intakes, be affected by an increase in contaminants (nitrate and microorganisms) under Scenarios 2a, 2b, 3a and 3b. However most of these supplies are sourced from upper-river reaches where pathogen contamination rather than nitrate is the main issue. Appropriate treatment can remove or deactivate pathogens and it is unlikely that treatment requirements for the upper-river sourced supplies would change significantly under any of the scenarios.

The WDC Lower Waihao domestic supply scheme (which includes supply to the Waihao Marae) is sourced from a shallow groundwater bore located near Ferry Rd, Glenavy, which is outside of the modelled SCCS project area. For this supply we are not expecting an increase in pathogens because the conversion from border dyke to spray irrigation anticipated in this area in future would be likely to reduce pathogens.

For private domestic supply bores sourcing shallow groundwater, in general it is predicted there would be an increase in the risk of pathogenic microorganisms (e.g. Campylobacter) in shallow groundwater associated with increased animal numbers under all scenarios. This will make disinfection treatment of supply (which occurs currently) even more important.

In terms of nitrate presence in drinking water the main impacts will be experienced in domestic bores in shallow groundwater. The following comments can be made (see groundwater quality section 3.4.2 later for detail):

- There are only minor differences likely to occur between Current and Scenario 1 with additional intensification.
- Scenario 2 results in an increase in likelihood that wells will exceed MAV from 4% under the current scenario (6 wells) to 9% of all wells (6 additional wells).
- Scenario 3a results in an increase in the proportion of wells likely to experience an exceedance of MAV, from 4% to 5% of wells (1 additional well).
- Scenario 3b results in an increase in the proportion of wells from 4% to 7% (4 additional wells).

There are potentially costs associated with these changes in nitrate concentrations in drinking water. The costs were assessed by assuming that some wells would have to be drilled deeper[26] into uncontaminated water sources, or would require treatment by installation of under bench (reverse osmosis) treatment systems. These costs are summarised in Table 3-2 below. They show that the costs associated with the need for increased treatment of drinking water under Scenarios 2 (a and b), 3a and 3b are generally small compared to the magnitude of the total economic benefits of those scenarios in the SCCS study area (i.e. <$0.05 million total), although would be significant for those individuals involved.

Table 3-2: Estimated cost of drinking water changes by scenario

Scenario	Proportion exceeding MAV	Number of wells affected above Current	Cost of drilling deeper	Cost of underbench treatment
Current	6%	0	0	0
Scenario 2	9%	6	$72,000	$12,000
Scenario 3a	5%	<1	0	0
Scenario 3b	7%	4	$48,000	$8,000

3.3.13 Recreational fishery

The streams of the SCCS area provide numerous fishing opportunities and brown trout provide a regionally important recreational fishery. In the NIWA Angler Days survey for 2012, the Waihao River and Waimate Creek were identified as receiving 1300 and 290 'angler days' respectively. For both waterways, this represented an increase from previous surveys in 1994/5 and 2001/2. Using an angler day valuation (travel cost) @ $46/day (Kerr, 2004) gives a valuation for the recreational trout fishery in the study area in the order of $0.1 million/annum.

The analysis of effects of Scenarios 2 and 3 on ecological flows and water quality (described later in Sections 3.4.3 and 3.4.4) suggest some small changes to the trout fishery. Compared to current and Scenario 1a, these would amount to:

- Small positive effect for Scenarios 2a, 3a and 3b as a result of increased baseflows in some streams, particularly the Hook and Otaio.
- Greater positive effect for Scenario 2b as a result of augmentation flows to the lower Hook River.
- Negative effect for Scenario 2a and 3b in terms of a further decline in water quality, but Scenario 3a similar to current water quality.

Given the current scale of the monetised estimate of the recreational fishery values in the catchment, the economic impact of these changes will be very small in relation to the other monetised values. Note however this assessment is of the monetised value only and does not express the full true value of the fishery. Effects on angling and other recreation in rivers are assessed later in Section 3.4.4.

3.3.14 Other recreational activity

Popular swimming areas include the Otaio River at the Reserve and the Waihao River at sites such as "Black Hole" and "Bradshaws" (or "the Rocks"). The Otaio Reserve is upstream of significant agricultural influence and is expected to remain suitable for recreation under all scenarios. For the monitored recreation sites on the Waihao River at Black Hole and at Bradshaws Bridge, recreational quality is already compromised or at risk from toxic cyanobacteria blooms. The Black Hole site currently has a 'Very Poor' contact recreation grade based on microbiological indicators. Under Scenario 2a and 2b the risk of toxic cyanobacteria blooms increases and so too does the risk of

[26] Assumed 10m depth to water, and an additional 30m required to reach uncontaminated water. Drilling costs are assumed to be $250/m with $2000 establishment costs (Ian McIndoe, Aqualinc, pers.comm.). Underbench treatment $1500/unit (http://www.wellingtonwaterfilters.co.nz/RO/Merlin.html) plus $500 installation cost.

faecal contaminants from more extensive and intensified agricultural land use. Under Scenario 3a the risk is probably similar to the current risk, while Scenario 3b sits somewhere between Scenario 2 (a and b) and 3a in terms of risk of cyanobacteria blooms.

3.3.15 Communities and the natural environment

A high quality environment, including good river flows, healthy wetlands and lakes, with good water quality, also brings multiple benefits for the well-being of communities that cannot be quantified in economic terms. These benefits exist across all cultures and are expressed in different ways by different people. From the perspective of manawhenua; "*Water is a taonga that provides for and sustains all life. It is integral to cultural and personal identity and wairua for whanau, hapu and iwi*." (Kaitiakitanga section - Canterbury Water Management Strategy). Water quantity and quality in rivers, groundwater, wetlands and Wainono Lagoon is described in the next sections 3.4 and 3.5.

3.3.16 Manawhenua values

The streams in South Canterbury, including those in the Waihao – Wainono system, have high traditional and current cultural significance. These waters are associated with the first recorded arrival of the waka Uruao, and the exploratory journey of Rakaihautu through Te Waka O Aoraki (the South Island) around 850 AD. The Waihao River was named by the wife of Rakaihautu in recognition of the sweetness of the hao eel, a significant species in the river. Today, the cultural and spiritual importance of these waterways and resources continues through the passing from generation to generation of Mātauranga (knowledge), and through manawhenua continuing to carry out cultural practices (e.g. kai gathering).

The Canterbury Water Management Strategy recognises numerous regional manawhenua values and sets targets for Kaitiakitanga including: formal recognition and involvement; addressing environmental flows, point and diffuse pollution, and unnatural mixing of waters; providing marae and associated papakainga with high quality drinking water; preventing further loss or degradation and restoring wahi taonga and mahinga kai; and recognising and providing for the principle of kaitiakitanga in water management.

Information on manawhenua values and management preferences for the Waihao-Wainono catchment are described in detail in the two reports by Tipa (2012, Appendix 16; and 2013, Appendix 17). Flow preferences from the Tipa (2012) report were the assumed basis for Scenario 1b and so Scenario 1b explicitly reflects manawhenua preferences to support values.

The relative merits of the exploratory scenarios for manawhenua values have been considered by manawhenua via the multiple hui of the Tangata Whenua Working Group (TWWG) process and via the hui involvement of Waihao and Arowhenua Rūnanga representatives on the Zone Committee, as described in Section 2.8.6. Using this approach enabled the TWWG to directly (i.e. verbally face-to-face) contribute to the scenario process design, as well as to assess effects of scenarios on manawhenua values as the project progressed, while using the written reports from Tipa (2012 and 2013) as base documentation. The technical team has not attempted to summarise the merits of scenarios for manawhenua values in this Overview Report, although many of the technical indicators reported here have been relevant for manawhenua in forming their views on the scenarios. Rather, the input from the TWWG, Waihao and Arowhenua Rūnanga ZC representatives and Te Rūnanga o Ngāi Tahu, is reflected in the agreed elements of the Zone Committee Solutions Package assessed in Part 2 (Section 4) of this Overview Report.

3.3.17 Summary comparison of scenarios – social indicators

Table 3-3: Assessment of the scenarios for social indicators: This assessment uses a five-class colour-coded scoring system as described in Section 2.10.3. (Note: Most social indicators allow only an assessment of the ***relative merit*** of each scenario to be made (i.e. those marked with an [R] below) because there is no absolute (e.g. numeric) threshold defining attainment of most of the ZC's social outcomes. The exception is for drinking water indicators which allow an absolute assessment to be made of the ***likelihood*** of achieving (absolute) MAV numbers (i.e. those marked with an [A] below). See Appendix 1 for explanation of the link between ZC outcomes and technical indicators, and the basis for scoring the 'current state'. Other scenarios are assessed relative to the current state. Scenario 1a scores identical to current state)

TECHNICAL INDICATORS	SCENARIOS						
	1a	1b	1c	2a	2b	3a	3b
Number of farmers and farm workers engaged in dairy, dairy support, horticulture and arable [R]		↓					
On farm and regional employment [R]							
School rolls [R]							
Individual household income [R]		SCCS area / Local					
Engagement in GMP [R]							
Population in SCCS project area [R]							
Services - health, infrastructure and education. Social connectedness [R]							
Drinking water – nitrate in deep groundwater – test MAV [A]							
Drinking water – nitrate in shallow groundwater – test MAV [A]						↑	↓
Drinking water – microorganisms in surface & shallow groundwater – test MAV [A]		↑	↓	↓	↓	↑	↓
Fishing activity in streams and Wainono [R]				↑QN↓QL	↑Wain	↑QN↓QL	↑QN↓QL
Recreational use [R]				↓	↑Wain		↓
Game bird hunting in Wainono [R]							

Notes:
Arrows (↑↓) indicate relative change (more/less likely to deliver an outcome) compared to Scenario 1a but not sufficient change to justify shifting to a new colour class.
↑QN indicates an improvement in terms of water quantity (ecological flows)
↓QL indicates a decline in terms of water quality
↑Wain indicates an improvement in Wainono Lagoon but not in all rivers
Cells showing half yellow and half red indicate significant negative impacts at the local scale in some catchments (red), but small impact at the scale of the whole SCCS area.

3.4 Streams, rivers and groundwater

This section is based on technical reports on groundwater quantity (Aitchison-Earl, 2015), groundwater quality (Scott and Etheridge, 2015), ecological flows in rivers (Clarke, 2015) and surface water quality and associated values in rivers and streams (Kelly, 2015); see Appendices 8, 6, 9 and 7 respectively.

3.4.1 Groundwater quantity

Effects of Scenarios 1a, 1b and 1c

There are only small differences between Scenarios 1a, 1b and 1c for groundwater quantity, levels and related effects on stream flows. This is because differences in minimum flows and allocations are small relative to the total water budget in each catchment. Scenario 1a was assessed to be no different to the current situation for groundwater. Scenario 1b (higher minimum flows and smaller allocations) resulted in a slight increase in groundwater recharge, and therefore a small increase in stream flows (5 - 20 L/s) in the lower reaches (i.e. in the vicinity of SH 1 and below). Scenario 1c (lower minimum flows plus current allocations) resulted in a minor decrease in groundwater recharge and therefore a minor decrease in stream flows near the coast.

An additional effect which applies equally to Scenarios 1a, 1b and 1c compared to current, is that conversion of border dyke to spray irrigation in some catchments in the MGIS area (i.e. the current 50/50 ratio to 85/15 in Scenario 1) will significantly reduce drainage losses to groundwater (i.e. land surface recharge (LSR)), which could reduce groundwater discharge contribution to stream flows near the coast in Morven Drain and Sinclairs Creek. This is described further as part of assessing the effects of Scenario 2 below.

Effects of Scenario 2 (a, b) on groundwater quantity
The use of Waitaki water (HDI and WD) to double the irrigated area under Scenario 2 is predicted in most catchments to increase LSR, and to increase runoff from the loess-covered downlands to the river valleys. Two methods have been used to estimate the resulting additional surface flow in streams near the coast (Table 3-4). The increased flows in Table 3-4 are predicted maximums for the lower ‘gaining’ stream reaches near the coast (i.e. from around State Highway 1 downstream); the amount of additional flow would decrease upstream from State Highway 1. The benefit of this extra flow for habitat and ecological values is described in Section 3.4.3. Note that the negative values (i.e. reduced flows) in Table 3-4 (Morven and Sinclairs) result from the decreased contribution from border dyke irrigation to groundwater and thus lower stream discharge.

Table 3-4: Estimated maximum increase in stream flows in the gaining reach below State Highway 1, from increased land surface recharge (LSR) and runoff to river valleys from increased irrigation under Scenario 2, compared to current state

SCCS catchments	Estimated increase in surface flow compared to current state (L/s)
Coastal Creeks (Makikihi-Hook)	60
Hook River	56
Horseshoe Bend Creek	14
Kohika Stream	67
Makikihi River	76
Morven Drain	-353
Otaio River	110
Sinclairs Drain	-36
Sir Charles Creek	0
Buchanans Creek	0
South Branch Waihao River	76
Waihao River (Waihoarunga)	12
Waihao River McCulloughs Bridge	136
Waihaorunga Stream	0
Waimate Creek	26
Wainono Lagoon	0
Waituna Stream	42

Effects of Scenario 2b (augmentation) on groundwater quantity
The augmentation flow (approximately 1 m^3/s) through Wainono Lagoon via the lower Hook River is predicted to have a minor effect on groundwater levels, primarily because it is assumed to be

discharged to the lower 'flow gaining' reach of the Hook River where losses to groundwater would be minimal and most augmentation flow would pass through Wainono Lagoon.

Effects of Sub-scenarios 3a and 3b
Scenarios 3a and 3b explore advanced on-farm mitigation measures to reduce nutrient and other contaminant losses. These make negligible difference to groundwater quantity and are therefore the same as Scenario 2a in that respect.

Summary matrix comparison – groundwater quantity

Table 3-5: Assessment of the scenarios for groundwater quantity-related indicators: This assessment uses a five-class colour-coded scoring system as described in Section 2.10.3. (Note: Groundwater quantity indicators allow only an assessment of the relative merit of each scenario to be made because there is no absolute (e.g. numeric) threshold defining attainment of the ZC's groundwater quantity outcomes. See Appendix 1 for explanation of the link between ZC outcomes and technical indicators, and the basis for scoring the 'current state'. Other scenarios are assessed relative to the current state. Scenario 1a scores identical to current state)

TECHNICAL INDICATORS	SCENARIOS						
	1a	1b	1c	2a	2b	3a	3b
Baseflow at springs increases							
Groundwater levels to support wetlands improved		↑	↓				

Note: Arrows (↑↓) indicate relative change (more/less likely to deliver an outcome) compared to Scenario 1a but not sufficient change to justify shifting to a new colour class.

3.4.2 Groundwater quality

Contaminants of concern for groundwater
One of the key groundwater quality issues for irrigation and land use change is increasing nitrate-nitrogen concentrations (hereafter 'nitrate'). Increasing nitrate concentrations are relevant because:

- Nitrate can be toxic in drinking water supplies. The Ministry of Health's New Zealand drinking-water standards set a Maximum Acceptable Value (MAV) for nitrate nitrogen at 11.3 mg/L (equivalent to 50 mg/L of nitrate), based on a risk to bottle-fed babies. Community & Public Health also recommends applying this MAV to drinking water for pregnant women. More frequent monitoring is required when nitrate concentrations exceed ½ MAV (5.6 mg/L).
- Nitrate can also be toxic for aquatic life in groundwater and groundwater-fed streams/rivers, having chronic (not acute) effects on aquatic life at concentrations in the order of 1-10 mg/L depending on the species and life-stages (i.e. risk can be higher for juveniles of some species).
- Nitrogen is a plant nutrient and, in combination with phosphorus (P) contributes to nuisance periphyton and macrophyte growth in streams/rivers, increased algae (phytoplankton) growth in Wainono Lagoon, and associated deterioration of water quality (e.g. dissolved oxygen and pH) that can stress ecological values.

Land use change and intensification also tends to increase the risk of pathogens entering groundwater, such as bacteria, viruses and protozoa. The effects of scenarios on groundwater contamination by nitrate and pathogens are considered in this section.

Effects of Scenarios 1a, 1b and 1c
There is little difference between Scenarios 1a, 1b and 1c for groundwater quality because the differences in minimum flows and allocations are not large enough to influence groundwater contaminant concentrations.

However there are differences predicted between current and all three Scenarios 1a, 1b and 1c. Nitrate concentrations are predicted to increase in all catchments (on average by about 9%), mainly due to assumed intensification of current land use and despite the lack of any further increase in irrigated area or substantial land use change. In some catchments (Morven Drain in particular) the increase in predicted nitrate concentrations is largely due to the assumed conversion of border to spray irrigation, which reduces drainage and thus dilution of nitrate concentrations.

It is predicted that nitrate concentration increases would cause a small increase in the number of shallow groundwater wells exceeding the drinking water MAV at times (to about 8%), noting that about 6% of shallow wells currently exceed the MAV at times. About 14% of the SCCS project area is estimated to be currently at risk of exceeding the MAV and this would increase to 17% under Scenario 1. An increase in the risk of pathogens in shallow groundwater is also predicted as a result of increased animal numbers, even though GMPs and conversions from border to spray irrigation in some catchments would partially mitigate this increase in risk from pathogens.

Effects of Scenarios 2 (a, b) and 3 (a, b) on groundwater quality
The major difference between Scenario 1 and Scenarios 2 and 3 is the approximate doubling of irrigated area and associated increase in nitrate losses with the latter two scenarios.

For Scenario 2 (a, b) the modelling predicts that nitrate concentrations may increase by 33% in the shallow groundwater (<30 m deep), assuming on-farm GMPs across the SCCS area (Table 3-6). Note that Scenario 2b (flow augmentation of Wainono Lagoon via the Hook River) is identical to Scenario 2a for shallow groundwater nitrate contamination because flow augmentation is assumed to only dilute surface flow nitrate concentrations, not groundwater concentrations (see section 3.5.4 for details).

The difference between Scenarios 2 (a, b), 3a and 3b is in the level of on-farm mitigations employed to reduce nutrient losses; this has a significant effect on predicted nitrate concentrations in groundwater. Using Maximum Feasible Mitigations (MFM) throughout the SCCS area (Scenario 3a) there is only a 1% increase in nitrate concentrations in shallow groundwater compared to the modelled current situation (Table 3-6). In other words the model predicts that MFM could approximately offset the increase in nitrate that results from increased irrigated area. With mid-point mitigations (Scenario 3b) there is a predicted 20% increase in nitrate concentrations compared to the modelled current situation (Table 3-6).

On average across all land use types, MFM mitigations (Scenario 3a) are predicted to reduce the amount of nitrate-N lost from land (compared to GMP in Scenario 2) by about 30%, while the mid-point mitigations (Scenario 3b) reduce nitrate-N loss by about 15%. The effectiveness of on-farm mitigations (i.e. the percentage reductions possible) is highly variable across land use types, with approximately 40% reductions (compared to GMP) assumed to be achievable for high leaching land uses such as dairy platform while 0% reductions may be achievable for land uses that are already low leaching such as forestry (see Section 2.8.7 for detail).

Effects on drinking water wells
There is a risk that shallow groundwater (<30 m deep) in some areas may become unsuitable for drinking as a result of intensification and land use change under irrigation. We expect deep groundwater (>30 m) will be unaffected but nitrate levels in shallow wells could increase.

The township of Waimate is served by two deep wells (i.e. at 82 m and 110 m depth). Because these wells are screened in the deep groundwater of the Cannington gravels we do not expect them to be impacted by land-use activities under any of the scenarios. Environment Canterbury's annual monitoring programme includes well J40/0022 and the results confirm low nitrate concentrations.

There are also a number of private domestic water supply bores including 124 shallow (<30 m) domestic supply wells and 29 deep (>30 m) domestic supply wells in the SCCS area (based on Environment Canterbury records). We do not expect the deep wells to have nitrate issues or to be impacted by land-use activities under any of the scenarios. We do not know how many of the 124 shallow wells are likely to have nitrate concentrations exceeding the MAV. Our best estimate is based on the percentage of all wells less than 30 m deep that Environment Canterbury has sampled that currently exceed the MAV. This is currently about 4% (6 out of 137 wells) suggesting about 4% of the 124 domestic wells may currently also exceed the MAV at times.

The modelling suggests that the area where shallow groundwater concentrations will exceed MAV is about 14% of the SCCS project area currently, and would increase to 31% in Scenario 2 (both Scenario 2a and Scenario 2b), 24% under Sub-scenario 3b and to 16% under Scenario 3a. If these same relative changes are applied to the estimated 4% of domestic wells that currently exceed the MAV then it is predicted that 9% will exceed MAV in Scenario 2, 7% in Scenario 3b and approximately 5% under Scenario 3a.

Effects on bacteria contamination in groundwater

Pathogens from human or animal waste can cause contamination of groundwater and make it unsuitable for drinking. Groundwater in the SCCS is vulnerable to contamination as gravel aquifers allow pathogens to travel quite rapidly. The presence of pathogens is normally indicated by the presence of *E. coli*. The drinking water MAV for *E. coli* is less than one organism in 100 ml sample. From Environment Canterbury sampling, 53% of groundwater wells in the SCCS area have had a detection of *E. coli* in one or more samples. This may not necessarily indicate the extent of bacterial contamination in groundwater generally, because poor wellhead security has been shown to allow localised entry of *E. coli* from the surface.

Shallow wells are most at risk of contamination from pathogens. Land surface recharge water carries pathogens down into shallow groundwater especially after heavy rainfall events or with excessive irrigation. Under all scenarios, it is predicted there would be a general increase in the risk of pathogenic microorganisms in shallow groundwater caused by increased animal numbers, even though GMPs and conversions from border to spray irrigation in some catchments would partially mitigate the increase in risk. On-farm mitigations under Scenario 3a (MFM) are likely to be more effective than ‘mid-point mitigations’ (Scenario 3b), which are in turn more effective than GMP (Scenarios 2a and 2b) for bacterial contamination. Any decline in drinking water quality could result in a range of responses by health agencies, councils and individuals.

Table 3-6: Modelled shallow groundwater nitrate-N concentrations in each catchment for all scenarios. Coloured shading indicates values that are greater than MAV (11.3 mg/L) (red), between MAV and ½ MAV (5.6 mg/L) (orange), or below ½ MAV (green). Change (mg/L and %) refers to the difference from modelled current state. (Note: the equivalent predictions for drainage (m^3/year) and nitrate-N load (tonnes/year) can be seen in Scott and Etheridge 2015 (Appendix 6)

	Current	Scenario 1 (pre-HDI & WD)			Scenario 2 (HDI/WD + GMP)			Scenario 3a (HDI/WD + MFM)			Scenario 3b (HDI/WD + midpoint)		
	Nitrate-N mg/L	Nitrate-N mg/L	Change mg/L	% change	Nitrate-N mg/L	Change mg/L	% change	Nitrate-N mg/L	Change mg/L	% change	Nitrate-N mg/L	Change mg/L	% change
Coastal Creeks (Makikihi-Hook)	4.7	5.1	0.5	10.1%	5.6	0.9	18.9%	4.1	-0.5	-11.5%	5.0	0.4	7.9%
Hook River	5.2	5.7	0.6	10.7%	6.8	1.6	30.7%	4.7	-0.4	-8.6%	5.8	0.6	11.8%
Horseshoe Bend Creek	7.9	8.8	0.9	11.1%	9.5	1.6	19.7%	7.2	-0.7	-9.4%	8.7	0.7	9.4%
Kohika Stream	5.9	6.7	0.8	13.7%	7.6	1.7	28.6%	5.3	-0.6	-9.7%	6.6	0.7	12.3%
Makikihi River	5.2	5.8	0.6	12.1%	8.0	2.9	55.3%	5.7	0.6	10.8%	6.9	1.8	34.3%
Morven Drain	10.7	12.9	2.2	20.6%	12.9	2.2	20.6%	9.2	-1.5	-14.1%	11.7	1.0	9.2%
Otaio River	3.9	4.4	0.5	12.1%	6.2	2.3	59.3%	4.7	0.8	21.0%	5.6	1.7	42.7%
Sinclairs	8.0	8.6	0.6	7.7%	8.6	0.6	7.7%	6.4	-1.6	-19.6%	7.9	-0.1	-0.7%
Sir Charles	3.9	4.3	0.4	9.7%	4.4	0.5	13.1%	3.2	-0.7	-18.1%	3.7	-0.1	-3.8%
South Branch Waihao River	8.2	9.3	1.2	14.5%	13.1	5.0	60.8%	9.7	1.5	19.0%	11.7	3.6	44.0%
Waihao River (Waihoarunga)	5.7	6.6	0.8	14.6%	8.7	2.9	51.0%	7.1	1.3	23.3%	8.0	2.2	38.8%
Waihao River (McCulloughs)	4.4	4.9	0.5	12.3%	6.3	1.9	43.6%	5.1	0.7	15.9%	5.9	1.5	34.4%
Waihaorunga Stream	7.2	8.3	1.1	15.0%	12.7	5.5	76.8%	10.9	3.7	51.0%	12.2	5.0	69.2%
Waimate Creek	4.8	5.4	0.6	12.1%	6.6	1.8	37.7%	5.3	0.5	9.4%	6.0	1.2	24.8%
Wainono Lagoon	2.7	3.1	0.4	13.1%	4.4	1.7	61.9%	3.4	0.7	23.9%	3.7	1.0	36.4%
Waituna Stream	4.6	4.9	0.3	6.8%	5.3	0.7	15.4%	3.8	-0.8	-16.8%	4.6	0.0	-0.9%
Total project area	5.9	6.4	0.5	8.6%	7.8	1.9	32.7%	5.9	0.1	1.0%	7.1	1.2	20.1%
Total Wainono Lagoon^	5.1	5.7	0.6	12.6%	7.4	2.3	45.1%	5.8	0.7	13.7%	6.7	1.6	31.4%

^ Total Wainono Lagoon catchment is the average of all catchments which may contribute nutrients to the lagoon and include: Coastal Creeks (Makikihi-Hook), Hook River, Sir Charles, South Branch Waihao River, Waihao River (Waihaorunga), Waihao River McCulloughs Bridge, Waihaorunga Stream, Waimate Creek, Wainono Lagoon and Waituna Stream. It is different from the Wainono Lagoon row in the upper part of the table which only includes a small area around the Lagoon itself.

Summary matrix comparison – groundwater quality

Table 3-7: Assessment of the scenarios for groundwater quality-related indicators: This assessment uses a five-class colour-coded scoring system as described in Section 2.10.3. (Note: The groundwater quality-related indicators allow an assessment of the *likelihood* of achieving NZ Drinking Water Standard MAV numbers. See Appendix 1 for explanation of the link between ZC outcomes and technical indicators, and the basis for scoring the 'current state'. Other scenarios are assessed relative to the current state. Scenario 1a scores identical to current state)

TECHNICAL INDICATORS	SCENARIOS						
	1a	1b	1c	2a	2b	3a	3b
Drinking water – nitrate in deep groundwater - test MAV							
Drinking water – nitrate in shallow groundwater - test MAV						↑	↓
Drinking water – microorganisms in surface & shallow groundwater - test MAV		↑	↓	↓	↓	↑	↓

Note: Arrows (↑↓) indicate relative change (more/less likely to deliver an outcome) compared to Scenario 1a but not sufficient change to justify shifting to a new colour class.

3.4.3 Rivers and streams – ecological flows

Current state

The SCCS area has two distinctly different types of rivers: these are classified in the pLWRP as "Hill-fed" rivers and "Spring-fed plains" streams. The first type is small, naturally intermittent hill-fed rivers (including the Waihao, Waimate, Hook, Kohika, Makikihi and Otaio). The second type is spring-fed lowland streams (including Sir Charles and Buchanans Creeks, Waituna and Merrys streams and the Hook Beach Drain).

When the small, intermittent hill-fed rivers leave the hills they generally lose some of their flow to groundwater and so cease to flow naturally in the mid segments in summer, with flow discharging from shallow groundwater back to the surface in the lower segments (i.e., in the vicinity of State Highway 1). There are obvious negative consequences for aquatic communities when rivers are completely dewatered, including; loss of habitat, loss of migration opportunities for fish, and loss of downstream drift and colonisation opportunities for invertebrates. Work completed in the Selwyn River in recent years indicated that the longer a river reach remains with zero flow (i.e. dry), the less diverse the invertebrate and fish species when flow returns (Clarke 2015; Appendix 9).

In SCCS hill-fed rivers in particular, the extent and duration of low flows and drying reaches, and thus ecological stress on fish and invertebrates, is exacerbated by:

i) the relatively large current allocation for takes from rivers and shallow connected groundwater;

ii) the relatively low minimum flows currently set for some of these rivers.

For example the minimum flows currently set for the upper Waihao, Waimate and Kohika rivers are below those recommended in ecological assessments to maintain healthy instream communities (i.e., at the level of habitat at 90% of 7D MALF), and the Otaio and Makikihi rivers currently have no minimum flow set at all (Table 3-8). Surface water allocation is currently high in most rivers and is particularly high (greater than 7D MALF) in the Waihao, lower Hook, Makikihi and Otaio catchments (see Table 3-9), thus exacerbating ecological stress from low flows and zero flow (dry) reaches in these rivers. The notable exception is the lower Waihao River (below where Bradshaws Bridge once stood) where flow is generally good for maintaining healthy instream communities despite abstractions (e.g., minimum flow at 172% of the natural 7D MALF) as a result of flow augmentation from the MGIS discharge (Table 3-8).

Table 3-8: Comparison of current minimum flows with naturalised MALF

Site	Naturalised MALF (L/sec)	Current minimum flow (L/s)	Current minimum flow as percentage of naturalised MALF
Otaio River @ Otaio Gorge recorder site	107	none	n/a
Kohika @ Puttick Intake	n/a	2*	n/a
Makikihi @ Teschemaker Valley Rd	21	none	n/a
Upper Hook River (above WDC intake)	35	32	91%
Lower Hook River @ Hook Beach Rd	71	64	90%
Waimate Creek @ d/s intake	68	15	22%
Sir Charles Creek @ Rooney's Bridge	n/a**	100	n/a
Buchanans Creek @ Fletchers Bridge recorder	183	150	82%
Waihao @ McCulloughs	354	300	85%
Waihao @ Bradshaws (without MGIS*** discharge)	58	100	172%

*As a residual flow below intake.
**An estimate based on only a few gaugings is 234 L/s but this is not a reliable estimate.
***Morven Glenavy Irrigation Scheme.

Table 3-9: Comparison of current surface water allocation with naturalised MALF

Surface Water Allocation Zone	Naturalised MALF (L/sec)	Current allocation (including community drinking supply takes* (L/s)	Current allocation as percentage of naturalised MALF
Sinclairs (only deep groundwater)	n/a	0	0%
Morven (only deep groundwater)	n/a	0	0%
Upper Waihao	354	389	110%
Lower Waihao	58	186	321%
Buchanans (spring)	183	95	52%
Sir Charles (spring)	n/a**	157	n/a
Waihao Arm	n/a	90	n/a
Waimate	68	41	60%
Waituna (only deep groundwater)	n/a	0	0%
Upper Hook	35	30	86%
Lower Hook	71	84	118%
Hook Beach Drain (only deep groundwater)	n/a	0	0%
Makikihi	21	88	419%
Horseshoe Bend (only deep groundwater)	n/a	0	0%
Kohika	n/a	2.8	n/a
Otaio	107	421	393%

*Current surface water allocation data from Environment Canterbury Consents Database as at December 2014.
**An estimate based on only a few gaugings is 234 L/s but this is not a reliable estimate.

Another feature of current environmental flow regime management that exacerbates ecological stress is the lack of partial restrictions above the minimum flow, even for those rivers that do currently have a minimum flow. This increases the period of time that rivers spend at or near the minimum flow (i.e., the duration of flow 'flat-lining') and reduces flow variability above the minimum, both of which increase stress on ecology.

Effects of Scenarios 1a, 1b and 1c on flows for ecology
A comparison of Scenarios 1a, 1b and 1c shows the effects of different flow and allocation scenarios within SCCS catchments, and highlights that there are trade-offs between the amount of water left in rivers for ecological and cultural purposes, the reliability of supply for users, and the area of land that can be irrigated. The economic effects were described in Section 3.3.2. For ecological values the analysis shows that:

i) Scenario 1a approximately reflects the current minimum flows and allocations. The ecology of rivers and streams is regularly low-flow stressed in summer, and this is exacerbated by the current relatively large allocations from the small streams, rivers and shallow connected groundwater.

ii) Sub-scenario 1b (higher minimum flows / smaller allocations) would relieve some low flow stress and be significantly better for ecological values and manawhenua preferences.

iii) Sub-scenario 1c (lower minimum flows / current allocations) is the lowest level of protection for ecological values and provision for manawhenua values, and is the least likely scenario to meet the RMA test of sustainable management.

Effects of Scenario 2 (a, b) on ecological flows
The use of Waitaki water (HDI and WD) to double the irrigated area under Scenario 2 is predicted in most catchments to increase both drainage losses to groundwater and runoff from the loess-covered downlands to the river valleys. This is predicted to increase base flow, but just in the lower 'gaining' reaches of most rivers and streams near the coast (i.e. from around State Highway 1 downstream) with a generally positive flow-on effect for public perceptions and recreational use of the streams.

For the Otaio and Hook Rivers the maximum predicted additional base flow is of a similar magnitude to the current MALF (Table 3-10). This would benefit aquatic habitat by reducing the frequency, duration and extent of intermittent segments during times of low flow stress. However it would not necessarily provide a significant increase in connectivity along the whole length of the river (Table 3-10). For Waituna Stream the predicted maximum additional 42 L/s base flow is significant in the context of this small stream and would benefit aquatic habitat. For the Horseshoe Bend Creek and Kohika Stream, which are currently often ponded or even stagnant for long periods in the lower reaches, the additional base flow may provide a small benefit to habitat quality. For the Makikihi River the predicted additional flow will likely remain sub-surface and offer little benefit for aquatic habitat except perhaps at times in a very short emergent reach very near the coast. For Waimate Creek the predicted flow increase is relatively small and will likely remain sub-surface with little benefit for aquatic habitat.

Table 3-10: Estimated maximum increase in stream flows in the gaining reach below State Highway 1, from increased land surface recharge (LSR) and runoff to river valleys from increased irrigation under Scenario 2 (a, b), compared to current state. The naturalised mean annual low flow (MALF) is also shown (where available) and the estimated maximum increase in flow as a percentage of MALF

SCCS catchments	Estimated maximum increase in surface flow compared to current (L/s)	Naturalised mean annual low flow (MALF)	Maximum increase in flow (as a percentage of MALF)	Notes
Coastal Creeks (Makikihi-Hook)	60	No data	No data	
Hook River @ Hook Beach Rd	56	71	79%	
Horseshoe Bend Creek – SH1	14	No data	No data	
Kohika Stream - SH1	67	0	NA	Increased flow may remain sub-surface
Makikihi River – SH1	76	0	NA	Increased flow will likely remain sub-surface
Morven Drain	-353	No data	No data	
Otaio River - SH1	110	50	220%	
Sinclairs	-36	No data	No data	
Sir Charles - Haymans Rd	0	234*	0%	
Buchanans – Fletchers Bridge	0	183	0%	
South Branch Waihao River	76	119	64%	
Waihao River (Waihoarunga)	12	112	11%	
Waihao River McCulloughs Bridge	136	354	38%	
Waihaorunga Stream	0	21	0%	
Waimate Creek - SH1	26	0	NA	Increased flow will likely remain sub-surface
Waituna Stream - SH1	42	0	NA	Large increase in flow likely

*Coarse estimate of MALF based on limited data.

For the South Branch Waihao River, the Waihao River at Waihaorunga and the Waihao River at McCulloughs Bridge, the predicted additional base flow is small (less than MALF) but nonetheless may still benefit aquatic habitat in the lower reaches during times of low flow stress. For the Waihaorunga Stream, Buchanans and Sir Charles creeks, there is no expected difference to the current or Scenario 1 flows.

For Sinclairs and Morvens Drain there is predicted to be a significant reduction in base flow compared to the current situation, from the decreased contribution to groundwater from border dyke irrigation that is assumed to be mostly converted to spray irrigation in future in those catchments. These two drains have modest ecological values and thus, on balance, the effects of increased base flow in the lower reaches of most rivers and streams across the SCCS area under Scenario 2 (a, b) is significantly positive.

Maintenance of wetland habitat and habitat suitable for the nationally critically threatened Canterbury Mudfish is closely related to high groundwater levels in relevant areas. The increased base flow described above (and higher groundwater levels generally) will be positive for maintaining and increasing potential Mudfish habitat under Scenario 2 (a, b), although the risk that increased water levels could increase connection between Mudfish habitat and waterways containing predatory trout and eels would need to be monitored and managed.

The increased base flow will make no difference to the frequency of flushing flows between the three scenarios and therefore the frequency of removing nuisance periphyton and accumulated fine sediment from the riverbed.

Effects of Scenario 2b (augmentation) on ecological flows
The augmentation flow (approximately 1 m^3/s) through Wainono Lagoon via the lower Hook River is predicted to have a significant beneficial effect on aquatic habitat in the augmented reach of the Hook River (assumed to be below State Highway 1). The Waitaki water augmentation is expected to eliminate the periods of zero flow (drying) in that reach and improve water quality, thus benefiting trout and native fish populations as well as the invertebrate communities they feed on.

A potential negative effect of augmentation is that the invasive alga Didymo *(Didymosphenia geminata)* is not currently known to be present in the Hook catchment, and the introduction of Didymo from the Waitaki River (where it is present) to the Hook River could have negative effects on this short reach. However the relatively close proximity of the Hook River to the Waitaki River and to the MGIS irrigation network (which carries Waitaki water and therefore Didymo) means that the Hook River is already highly likely to be exposed to the introduction of Didymo by movement of people, vehicles and birds. It is unknown whether Didymo would establish at nuisance levels if introduced to the Hook River.

For the reach upstream of State Highway 1, and for the rest of the SCCS area, there is no difference between Scenarios 2a and 2b.

Effects of Scenario 3 (a, b) on ecological flows
Scenarios 3a and 3b explore the benefit of advanced on-farm mitigation measures to reduce nutrient and other contaminant losses. These make no difference to ecological flows. Therefore Scenarios 3a and 3b are identical to Scenario 2a described above for ecological flow-related indicators, although clearly there are differences between these scenarios for water quality effects on ecology as is described in the next section.

Summary matrix comparison – ecological flows

Table 3-11: Assessment of the scenarios for ecological flow-related indicators: This assessment uses a five-class colour-coded scoring system as described in Section 2.10.3. (Note: Some ecological indicators allow only an assessment of the *relative merit* of each scenario to be made (i.e. those marked with an [R] below), while some ecological indicators allow an absolute assessment to be made of the *likelihood* of achieving numeric outcomes defined in the LWRP (i.e. those marked with an [A] below). See Appendix 1 for explanation of the link between ZC outcomes and technical indicators, and the basis for scoring the 'current state'. Other scenarios are assessed relative to the current state. Scenario 1a scores identical to current state)

TECHNICAL INDICATORS	SCENARIOS						
	1a	1b	1c	2a	2b	3a	3b
Flows in Streams - high minimum flows compared to natural 7d MALF [R]							
Flows in streams – high variability and frequency of freshes [R]					↑Hook		
Flows in streams – low intermittence (dry length, frequency, duration) [R]					↑Hook		
Large amount of habitat for key fish species (compared to % of habitat at natural MALF) [R]							
High diversity and abundance of aquatic invertebrates - test LWRP outcomes (QMCI)[A]				↑QN↓QL	↑QN↓QL	↑	↑QN↓QL
High diversity and abundance of native fish [R]				↑QN↓QL	↑QN↓QL	↑	↑QN↓QL
Provision of suitable mudfish habitat [R]				↑QN↓QL	↑QN↓QL	↑	↑QN↓QL
Healthy periphyton and macrophyte communities - test LWRP outcomes (% cover) [A]				↓	↑Hook		
Ensure hydrological requirements for wetlands are met [R]							

Note: Arrows (↑↓) indicate relative change (more/less likely to deliver an outcome) compared to Scenario 1a but not sufficient change to justify shifting to a new colour class.
↑QN indicates an improvement in terms of water quantity (ecological flows)
↓QL indicates a decline in terms of water quality
↑Hook indicates an improvement in Hook River only

3.4.4 Rivers and streams - water quality

The different land-use change scenarios have different implications for dissolved nutrients (N and P), nitrate toxicity, plant and algae indicators, sediment, microorganisms, and related environmental values in the hill-fed and lowland spring-fed streams in the SCCS area.

The current risk to various in-stream ecological and environmental values has been estimated by looking at data for nutrients, periphyton and macrophytes, and assessing these data against national guidelines for nitrate toxicity and suitability for contact recreation. To assess the effects of future scenarios, modelled nutrients and modelled plant and periphyton responses were compared with current measured nutrients and current ecological indicators. The results are shown in Table 3-13 (Hill-fed rivers) and Table 3-14 (Spring-fed streams) and the key messages to take from these results are described below.

Effects of Scenarios 1 (a, b, c) on surface water quality
Currently, most reaches of hill-fed streams located directly downstream of the Hunter Hills and bush-covered country meet pLWRP outcomes for periphyton, aquatic biodiversity/fish values, aesthetics and contact recreation. This is not expected to change across any of the scenarios.

The mid and lower reaches of most hill-fed rivers and streams are currently at risk either of not meeting, or already do not meet, pLWRP outcomes for periphyton, aquatic biodiversity/fish values, and aesthetics and recreation. Compared to current state, Scenario 1a will increase the risk to values for reaches located between the downlands and the coast, and not change the risk for the remainder of hill-fed reaches. While Scenario 1b should reduce the risk of nuisance periphyton and improve aesthetic/ recreational and aquatic biodiversity values, these values will remain at risk. Scenario 1c will increase the risk to all environmental values in hill-fed rivers located between the downlands and the coast.

Most spring-fed lowland streams currently do not meet, or are at risk of not meeting, pLWRP outcomes for periphyton, macrophytes, aquatic biodiversity/fish values, aesthetics and contact recreation. Under Scenario 1a the risk will increase further. Scenario 1b will decrease the risk of nuisance periphyton but the lowland streams are likely to remain at risk of nuisance macrophyte growth, and of not supporting benthic biodiversity and fish values. Scenario 1c is likely to further increase the risk of not meeting outcomes for the range of environmental values.

Effects of Scenario 2 (a, b) on surface water quality

The use of Waitaki water (HDI and WD schemes) to double the irrigated area under Scenario 2 (a, b) is predicted in most catchments to significantly increase N and P concentrations in shallow groundwater and in runoff from the loess-covered downlands to the river valleys. This is predicted to increase N and P concentrations in most rivers and streams in the SCCS area. Consequently under Scenario 2a, as compared to current, all environmental values assessed (i.e. periphyton, macrophytes, aquatic biodiversity/fish values, aesthetics and contact recreation) in Hill-fed rivers within the HDI and WD scheme areas are likely to be at further risk, or not change from a state that currently does not support these values at the level of the pLWRP outcomes (Table 3-13).

Similarly, under Scenario 2a all spring-fed lowland streams are likely to be at further risk or not change from a state that currently does not meet all pLWRP outcomes (Table 3-14).

Effects of Scenario 2b (augmentation) on surface water quality

Flow augmentation in the Lower Hook River will have a beneficial effect on environmental values in the augmented reach of the Hook River (assumed to be below State Highway 1). A reduction in the risk of nuisance periphyton, and improved benthic biodiversity and fish communities are expected in this short reach (Table 3-13), but the assumed cessation of flow augmentation in winter results in a risk of chronic nitrate toxicity similar to that under Scenario 2a (Table 3-13). For the reach upstream of State Highway 1, and for the rest of the SCCS area, there is no difference between Scenarios 2a and 2b.

Effects of Scenario 3a on surface water quality

Under Scenario 3a (MFM mitigations), and as compared to current, the environmental values assessed in most Hill-fed rivers are likely to be at reduced risk because of the assumed reduction in nutrients (Table 3-13). However, benthic biodiversity could remain at risk in most sites because of degraded physical habitat (fine sediment/ low flows). The upper to middle Waihao is likely to remain prone to nuisance periphyton and to pose a risk to benthic biodiversity, trout habitat and angling and contact recreation (Table 3-13).

Based on modelled nutrient reductions, most spring-fed streams are likely to be at reduced risk of nuisance plant and periphyton growths under Scenario 3a compared to current (Table 3-14). However nuisance plant growth remains a risk because of existing high levels of fine bed sediment and a lack of riparian shading. Because of this, benthic invertebrate biodiversity remains at risk and the streams may not provide trout habitat sufficient to support good angling.

Effects of Scenario 3b on surface water quality

Under Scenario 3b (mid-point mitigations), most environmental values in hill-fed rivers will be at greater risk than current or in Scenario 3a, but at lower risk compared to Scenario 2a (Table 3-13).

In Spring-fed rivers most environmental values will be at greater risk than under Scenario 3a, but at lower risk as compared to Scenario 2a (Table 3-14). In comparison to current state, all environmental values are expected to be at similar or increased risk under Scenario 3b.

Summary matrix comparison – surface water quality

Table 3-12: Assessment of the scenarios for surface water quality-related indicators: This assessment uses a five-class colour-coded scoring system as described in Section 2.10.3. (Note: Some ecological indicators allow only an assessment of the *relative merit* of each scenario to be made (i.e. those marked with an [R] below), while some ecological indicators allow an absolute assessment to be made of the *likelihood* of achieving numeric outcomes defined in the LWRP (i.e. those marked with an [A] below). See Appendix 1 for explanation of the link between ZC outcomes and technical indicators, and the basis for scoring the 'current state'. Other scenarios are assessed relative to the current state. Scenario 1a scores almost identical to current state except that both water clarity and riparian condition indicators are expected to improve (light green) compared to current (yellow)).

TECHNICAL INDICATORS	SCENARIOS						
	1a	1b	1c	2a	2b	3a	3b
High diversity and abundance of aquatic invertebrates – test LWRP outcomes (QMCI) [A]				↑QN↓QL	↑QN↓QL		↑QN↓QL
High diversity and abundance of native fish [R]				↑QN↓QL	↑QN↓QL	↑	↑QN↓QL
Healthy periphyton and macrophyte communities – test LWRP outcomes (% cover) [A]				↓	↑Hook		↓
Nitrate-N toxicity for aquatic species (test at least 80% level protection) [A]		↑		↓	↓	↑	↓
Water clarity and suspended sediment [R]				↓	↓	↑	↓
Sedimentation of stream beds [R]		↑	↓	↓	↓	↑	↓
Periphyton risk for recreation & benthic biodiversity – test LWRP outcomes (% cover) [A]				↓	↑Hook↓Rest		↓
Benthic cyanobacteria risk for recreation – test LWRP outcomes (% cover) [A]				↓	↑Hook↓Rest		↓
Macrophyte risk for recreation & benthic biodiversity – test LWRP outcomes (% cover) [A]		↑	↓	↓	↓	↑	↓
Suitability for contact recreation – microbial quality – test LWRP outcomes (SFRG) [A]		↑	↓	↓	↓	↑	↓
Riparian condition (stock exclusion and vegetation) [R]							

Note: Arrows (↑↓) indicate relative change (more/less likely to deliver an outcome) compared to Scenario 1a but not sufficient change to justify shifting to a new colour class.
↑QN indicates an improvement in terms of water quantity (ecological flows);↓QL indicates a decline in terms of water quality; ↑Hook indicates an improvement in Hook River only

Table 3-13: Hill-fed rivers: Assessment of whether ecological outcomes are currently being (current WQ state) or likely to be achieved (Scenario 2a, 3a, 3b). For detail see Kelly 2015 (Appendix 7)

<table>
<tr><th>ACHIEVES…</th><th colspan="6">Current water quality state</th><th colspan="6">Sub-scenario 2a – HDI (GMP mitigations) (relative to current)</th><th colspan="6">Sub-scenario 3a – HDI Maximum Feasible Mitigations</th><th colspan="6">Sub-scenario 3b – Midpoint Mitigations</th></tr>
<tr><td>Nuisance periphyton growth (weighted composite cover <30%)</td><td colspan="2">YES
Bush tribs., Lower Hook and Waihao Rivers</td><td colspan="2">At RISK
Kohika; Esk Valley St.</td><td colspan="2">NO
Hook St., Upp. Waihao McCulloughs</td><td colspan="2">YES
Bush tribs.</td><td colspan="2">Further ↑ RISK
Kohika; Esk Valley St, Horseshoe bend Ck, Upper & Lower Hook, Lower Waihao & Otaio</td><td colspan="2">NO
Hook Stream, Waihao McCulloughs</td><td colspan="2">YES
Bush tribs.</td><td colspan="2">Reduced Risk
Kohika; Horseshoe bend Ck, Hook St., Hook R., Lower Waihao & Otaio
At RISK
Esk Valley St.</td><td colspan="2">NO
Waihao McCulloughs</td><td colspan="2">YES
Bush tribs.</td><td colspan="2">AT or ↑ RISK
Kohika; Esk Valley St, Horseshoe bend Ck, Upper & Lower Hook, Lower Waihao & Otaio Rivers</td><td colspan="2">NO
Hook Stream, Waihao McCulloughs</td></tr>
<tr><td>Visual aesthetics/ Recreation (due to algae/ cyanobacteria blooms)</td><td colspan="2">YES
Bush tribs.; Lower Hook R. and Waihao Bradshaws</td><td colspan="2">At RISK
Kohika; Esk Valley St. Horseshoe bend Ck.</td><td colspan="2">NO
Hook St., Waihao Forks to lower river</td><td colspan="2">YES
Bush tribs.</td><td colspan="2">Further ↑ RISK
Kohika; Esk Valley St, Horseshoe bend Ck, Upper & Lower Hook, Lower Waihao & Otaio</td><td colspan="2">NO
Hook Stream, Waihao Forks to lower river</td><td colspan="2">YES
Bush tribs.</td><td colspan="2">Reduced Risk
Kohika; Horseshoe bend Ck, Hook St., Hook R., Lower Waihao & Otaio
At RISK
Esk Valley St.</td><td colspan="2">NO
Waihao Forks to lower river</td><td colspan="2">YES
Bush tribs.</td><td colspan="2">AT or ↑ RISK
Kohika; Esk Valley St, Horseshoe bend Ck, Upper & Lower Hook, Lower Waihao & Otaio Rivers</td><td colspan="2">NO
Hook Stream, Waihao McCulloughs</td></tr>
<tr><td>Suitability for contact recreation (due to microbial contamination/ cyanobacteria)</td><td colspan="2">YES
Otaio gorge</td><td colspan="2">At Risk
Lower Waihao Bradshaws</td><td colspan="2">NO
Waihao at Black Hole</td><td colspan="2">YES
Otaio gorge</td><td colspan="2">Further ↑ RISK
Lower Waihao Bradshaws</td><td colspan="2">NO
Waihao at Black Hole</td><td colspan="2">YES
Otaio gorge</td><td colspan="2">At Risk
Lower Waihao</td><td colspan="2">NO
Waihao at Black Hole</td><td colspan="2">YES
Otaio gorge</td><td colspan="2">↑ RISK
Lower Waihao Bradshaws</td><td colspan="2">NO
Waihao at Black Hole</td></tr>
<tr><td>Benthic biodiversity (obs. QMCI, response to algae/ plants/N toxicity)</td><td colspan="2">YES
Bush tribs., Upp. Hook River,</td><td colspan="2">At RISK
Upper Kohika; Esk Valley St.</td><td colspan="2">NO
Hook Stream; mid-Waihao; Lower Hook, Kohika & Otaio Rivers</td><td colspan="2">YES
Bush tribs.</td><td colspan="2">At RISK
(Upper Hook)
Further ↑ RISK
Upper Kohika; Esk Valley St, Horseshoe Bend Ck, Lower Waihao</td><td colspan="2">NO
Hook Stream; mid-Waihao; Lower Hook, Kohika & Otaio Rivers</td><td colspan="2">YES
Bush tribs.</td><td colspan="2">Reduced Risk
Upper Hook R.
At RISK
Esk Valley St., Hook Stream, Kohika, Lower Hook & Otaio</td><td colspan="2">NO
Waihao McCulloughs</td><td colspan="2">YES
Bush tribs.</td><td colspan="2">↑ RISK
Upper Hook, Esk Valley St., Upper Kohika</td><td colspan="2">NO
Hook Stream, Lower Hook, mid-Waihao, Lower Kohika & Otaio</td></tr>
<tr><td>Trout habitat & angling (response to algae/invert food/ N toxicity)</td><td colspan="3">YES
Bush tribs., Upp. Hook River, Waihao Bradshaws</td><td colspan="3">At RISK
Hook Stream, Kohika, Esk Valley St; Waihao McCulloughs, Lower Hook, Kohika and Otaio</td><td colspan="3">YES
Bush tribs.</td><td colspan="3">Further ↑ RISK
Hook Stream, Esk Valley St; Waihao, Hook, Kohika and Otaio</td><td colspan="3">YES
Bush tribs.</td><td colspan="3">Reduced Risk
Upper Hook R.
At RISK
Esk Valley St, Hook St. Kohika, Waihao McCulloughs, Lower Hook & Otaio</td><td colspan="3">YES
Bush tribs.</td><td colspan="3">↑ RISK
Hook Stream, Esk Valley St; Waihao McCulloughs, Hook, Kohika & Otaio</td></tr>
<tr><td>Nitrate toxicity: 99 % aquatic biodiversity protection (~1.5 mg/L)</td><td colspan="3">YES
Bush tribs., Upp. Hook River, Otaio River; Upp.Waihao McCulloughs</td><td colspan="3">NO
Hook Stream; Lower Hook & Kohika rivers; Waihao Bradshaws</td><td colspan="3">YES
Bush tribs., Upp. Hook River, Upp.Waihao McCulloughs</td><td colspan="3">NO
Hook Stream; Lower Hook & Kohika rivers; Waihao Bradshaws, Otaio River</td><td colspan="3">YES
Bush tribs., Upp. Hook River, Upp.Waihao McCulloughs</td><td colspan="3">NO
Hook St.; Lower Hook, Kohika Waihao & Otaio</td><td colspan="3">YES
Bush tribs., Upp. Hook River, Waihao McCulloughs</td><td colspan="3">NO
Hook St.; Lower Hook, Kohika Waihao & Otaio</td></tr>
<tr><td>Nitrate toxicity: 95 % aquatic biodiversity protection (~3.5 mg/L)</td><td colspan="3">YES
Bush tribs., Upp. Hook River, Otaio River ; Waihao McCulloughs & Bradshaws</td><td colspan="3">NO
Hook Stream; Lower Hook & Kohika rivers;</td><td colspan="3">YES
Bush tribs., Upp. Hook River, Otaio River; Upp.Waihao McCulloughs & Bradshaws</td><td colspan="3">NO
Hook Stream; Lower Hook & Kohika rivers;</td><td colspan="3">YES
Bush tribs., Upp. & Lower Hook, Otaio River, mid and lower Waihao, Lower Kohika</td><td colspan="3">NO
Hook St.</td><td colspan="3">YES
Bush tribs., Upp. Hook River; Waihao McCulloughs & Bradshaws</td><td colspan="3">NO
Hook St., Lower Hook, Otaio & Kohika</td></tr>
<tr><td>Nitrate toxicity: 90 % aquatic biodiversity protection (~5.6 mg/L)</td><td colspan="6">YES
all</td><td colspan="6">YES
all</td><td colspan="6">YES
all</td><td colspan="6">YES
all</td></tr>
<tr><td>Nitrate toxicity: 80 % aquatic biodiversity protection (~9.8 mg/L)</td><td colspan="6">YES
all</td><td colspan="6">YES
all</td><td colspan="6">YES
all</td><td colspan="6">YES
all</td></tr>
<tr><td>Nitrate toxicity: drinking water (~11.3 mg/L)</td><td colspan="6">YES
all</td><td colspan="6">YES
all</td><td colspan="6">YES
all</td><td colspan="6">YES
all</td></tr>
</table>

Table 3-14: Spring-fed plains streams: Assessment of whether ecological outcomes are currently being (current WQ state) or likely to be achieved (Sub-scenario 2a, 3a, 3b). For detail see Kelly 2015 (Appendix 7)

ACHIEVES…	Current water quality State		Sub-scenario 2a – HDI (GMP mitigations) (relative to current)		Sub-scenario 3a – HDI Maximum Feasible Mitigations		Sub-scenario 3b – Midpoint Mitigations	
NRRP plant outcome (50%)	**YES** Merry's Stream	**NO** Buchanans, Sir Charles, Hook Drain, Waituna Stream,	**↑ RISK** Merry's Stream	**NO** Buchanans, Sir Charles, Hook Drain, Waituna Stream	**Reduced Risk** Merry's, Sir Charles, Hook Drain, Waituna Stream	**NO** Buchanans	**AT RISK** Merry's	**NO** Buchanans, Sir Charles, Hook Drain, Waituna
Nuisance periphyton growth (weighted composite cover <30%)	**YES** Buchanans Ck; Merry's Stream	**NO** Sir Charles Ck.	**↑ RISK** Merry's Stream, Buchanans, Hook Drain, Waituna Stream	**NO** Sir Charles	**Reduced Risk** All		**AT or ↑ RISK** All	
Visual aesthetics/ Recreation (due to plants/ algae/ cyanobacteria blooms)	**YES** Merry's Stream	**NO** Buchanans, Sir Charles, Hook Drain, Waituna Stream	**↑ RISK** Merry's Stream	**NO** Buchanans, Sir Charles, Hook Drain, Waituna Stream	**Reduced Risk** Merry's, Sir Charles, Hook Drain, Waituna Stream **AT RISK** Buchanans		**AT RISK** Merry's	**NO** Buchanans, Sir Charles, Hook Drain, Waituna
Benthic biodiversity (obs. QMCI, response to algae/ plants/N toxicity)	**NO** Buchanans, Sir Charles, Hook Drain, Waituna Stream		**NO** Buchanans, Sir Charles, Hook Drain, Waituna Stream		**NO** Buchanans, Sir Charles, Hook Drain, Waituna Stream		**NO** Buchanans, Sir Charles, Hook Drain, Waituna Stream	
Trout habitat & angling (response to algae/ plants/ N toxicity)	**At RISK** Buchanans, Sir Charles	**NO** Hook Drain, Waituna Stream	**Further ↑ RISK** Buchanans, Sir Charles	**NO** Hook Drain, Waituna Stream	**At RISK** Buchanans, Sir Charles	**NO** Hook Drain, Waituna Stream	**↑ RISK** Buchanans, Sir Charles	**NO** Hook Drain, Waituna Stream
Nitrate toxicity: 99 % aquatic biodiversity protection (~1.5 mg/L)	**NO** all		**NO** all		**NO** all		**NO** all	
Nitrate toxicity: 95 % aquatic biodiversity protection (~3.5 mg/L)	**YES** Buchanans Ck., Merry's Stream	**NO** Sir Charles, Hook Drain	**YES** Buchanans Ck., Merry's Stream	**NO** Sir Charles, Hook Drain	**YES** Buchanans Ck., Sir Charles, Merry's Stream	**NO** Hook Drain	**YES** Buchanans Ck., Sir Charles, Merry's Stream	**NO** Hook Drain
Nitrate toxicity: 90 % aquatic biodiversity protection (~5.6 mg/L)	**YES** all		**YES** all		**YES** all		**YES** all	
Nitrate toxicity: 80 % aquatic biodiversity protection (~9.8 mg/L)	**YES** all		**YES** all		**YES** all		**YES** all	
Nitrate toxicity: drinking water (~11.3 mg/L)	**YES** all		**YES** all		**YES** all		**YES** all	

3.5 Wainono Lagoon

This section is based on numerous technical references that are available on the SCCS project website[27], and in particular several reports that are directly relevant for scenario biophysical assessment; Sutherland and Norton (2011), Abell *et al.,* (2015), Schallenberg (2013), Schallenberg and Saulnier-Talbot (2014), which are all provided as Appendices 18, 19, 20 and 21 respectively.

In addition, Tipa (2012; Appendix 12) summarises water-dependent cultural values of the Waihao-Wainono catchment, identifies key issues and threats, and documents manawhenua preferences for Wainono tributary and lagoon flow management.

3.5.1 Current state

Physical

Wainono Lagoon is a medium-sized (approximately 325 ha), turbid (murky – low clarity) coastal lake which is usually about 1 m deep and is separated from the sea by a gravel beach barrier up to 8 m height. The lagoon receives inflow from Waituna Stream, the Hook River, the northern Hook Beach Drain, as well as reverse flow at times from the Waihao River via the Waihao Arm. The water can change from brackish to fresh depending on flow, level and sea wave conditions.

The gravel beach barrier is slowly migrating landwards and this is gradually, over decades, changing the position, shape and size of the lagoon. Despite this natural coastal erosion process the lagoon and associated gravel barrier are expected to be permanent features of the landscape for the foreseeable future.

The lagoon has a regular opening to the sea via the 100 year old 'Waihao Box', a wood and concrete structure that allows the lagoon water to flow to the sea (Figure 3-7). The Box maintains lake level typically at an average of about 1 m above mean sea level, although level can vary within hours as the Box alternately opens and constricts with wave-driven gravel. The Box provides drainage and alleviates flooding of low lying land, as well as providing passage for fish species that migrate to and from the sea at certain times of the year to complete their life cycles.

There seems to be general agreement amongst local landowners, farmers, manawhenua, fishers and recreationists that the Waihao Box has served its purpose well and there appears to be a strong desire to retain the current system. The Box has recently undergone much needed reconstruction and it has been assumed for all scenarios that the repaired Box will function effectively and that outflow management will continue with similar efficacy to the past.

Water quality and ecology

The lagoon water is highly nutrient enriched; the current Trophic Level Index (TLI) score (annual mean) of around 6.5 regularly exceeds the maximum TLI of 6.0 set in the pLWRP outcomes for coastal lakes (Figure 3-8). The lagoon and its tributary catchments support numerous plant and animal species including 26 fish species and over 100 bird species, at times shallow water native aquatic weedbeds (macrophytes), flax, rush and sedge swamp, saline mudflats, shingle beach ridge habitat, as well as willows and introduced grasses. The lagoon and its associated wetlands meet the criteria of internationally significant wetlands under the Ramsar Wetland Convention although this status has not been formalised. The lagoon and wetlands have national status of Wildlife Refuge and Conservation Area.

[27] www.ecan.govt.nz/south-canterbury-coastal-streams

Figure 3-7: The Waihao Box facilitates flow from the Waihao-Wainono catchment draining to the sea. The lower Waihao River (top right) joins the Waihao Arm (centre right) at the Waihao Box.

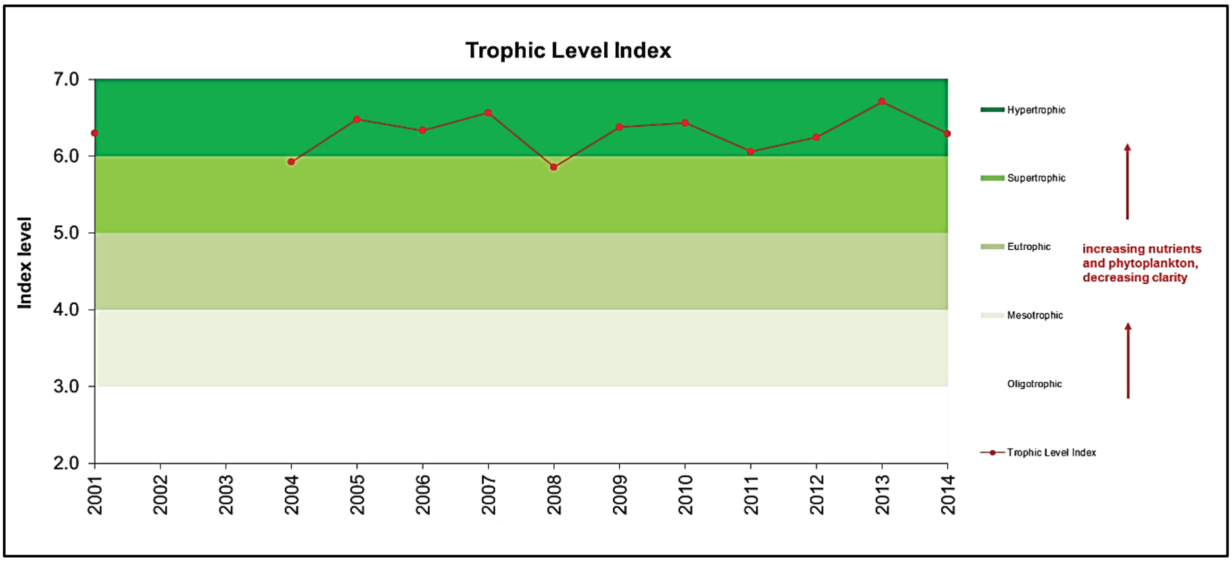


Figure 3-8: Annual Trophic Level Index (TLI) results based on Environment Canterbury Wainono Lagoon measurements since 2001. Note this is based on a TLI calculation using TP, TN and chlorophyll *a* but not Secchi depth. TLI has been calculated on data from a water year (July to June).

Cultural values
To manawhenua, Wainono is a taonga (treasure) equivalent to Te Waihora (Lake Ellesmere) and Wairewa (Lake Forsyth). It provides important habitat for waterfowl, migrating birds, coastal birds and native fish, many of which are taonga species, in particular tuna (eels). To manawhenua, the value of the Waihao-Wainono system as home to taonga species, and as a source of mahinga kai cannot be overstated; the health of mahinga kai will be the ultimate indicator of the health of the system. The treasured status is reflected in the designation of the lagoon and the lower reaches of its tributaries (Hook, Waituna and Waihao) as the "Waihao Mataitai Reserve" (Figure 3-9) which prohibits commercial fishing and promotes customary sustainable management. The lagoon and surrounding area also has sites of considerable historical significance to both Māori and Europeans, with numerous sites identified as wāhi taonga (treasured places) and wāhi tapu (sacred places).

Fishing, hunting and other recreational use
The lagoon and surrounds are important to both local and regional communities for amenity and recreation including bird watching, walking, picnicking, whitebaiting, eeling, floundering, game bird hunting (Canada geese, black swans, mallard, grey and paradise ducks) and trout fishing. Fishing activity is likely to remain concentrated in the area of the Waihao box where there is good access to the Waihao River. Contact water activities such as swimming and water skiing also mainly take place around the Waihao Box.

Wainono Restoration Project
The Wainono Restoration Project[28] was established in 2012 when the Ministry for the Environment (MfE) awarded the project $800,000 from the Fresh Start for Freshwater Clean-up Fund over a two year period (2012 - 2014). The work is now well advanced and is expected to continue benefiting the lagoon over the next few decades under all scenarios. For example, sediment trapping techniques (e.g. on-farm bunds) and stock exclusion are expected to reduce sediment (and therefore also phosphorus) load to the lagoon which is a significant water quality issue currently (Figure 3-10). An increase in riparian planting and wetland enhancement activities around the lagoon will also improve biodiversity and increase recreational value, as well as assist with efforts to improve water quality.

Environment Canterbury, with the support of its partners in the Wainono Restoration Project, the Lower Waitaki Zone Committee and Te Rūnanga o Waihao, is currently seeking funding for implementation of a proposed extended restoration plan for the Wainono Lagoon that would deliver aspects of the ZCSP and this is described further later in Section 4.6.4.

[28] See website http://ecan.govt.nz/advice/biodiversity/area/lower-waitaki/Pages/wainono.aspx

Figure 3-9: Location of the Waihao Mataitai Reserve (red area and lines) that came into effect on 13 September 2012. Mataitai reserves can be established over traditional fishing grounds of special importance to local Māori. Establishing a mataitai reserve does not prevent recreational fishing, access to reserves, beaches or rivers, and does not change existing arrangements for access to private land. Only commercial fishing is prohibited in a mataitai reserve (Tipa 2012, Appendix 16)

Figure 3-10: Photos illustrating the high sediment load plume from the Hook River entering Wainono Lagoon (left) and sediment-laden water flowing from Wainono Lagoon down the Waihao Arm and through the Box to the sea (right) during flood conditions in August 2012

3.5.2 Effects of Scenarios 1a, 1b and 1c

Scenario 1 (a, b, c) causes only a small increase in nutrient concentrations and the agricultural N load to Wainono Lagoon (i.e. 11% load increase; Table 3-15) as a result of intensification of current land use but no further irrigated area. Thus, with respect to water quality, only minor change is predicted. The TLI score is expected to remain around 6.5 (Figure 4-2), with similar risk of algal blooms and associated negative effects (e.g. dissolved oxygen fluctuations).

With respect to water quantity Scenario 1a reflects the current situation. Scenario 1b, with its higher minimum flows in tributaries (e.g. Waihao and Hook) and smaller allocations, would better support fish passage (e.g. tuna, inanga) between the lagoon and its tributaries. Scenario 1b would also benefit lagoon levels at times of low flow, and would be favourable for maintaining fringing wetlands around the lagoon margins and the lower Hook River delta. Consequently Scenario 1b would, from a water quantity perspective, be more likely (than current) to meet outcomes for fisheries and other mahinga kai associated with the Mataitai Reserve, and for all recreational fishing (e.g. whitebaiting, floundering, eeling). Scenario 1c, with its lower minimum tributary flows would be less likely to meet outcomes for all Wainono values mentioned above.

Provided effective opening management is maintained at the Waihao Box, no significant difference is expected between Scenarios 1a, b and c for drainage and flood management.

3.5.3 Effects of Scenario 2a

Increased irrigated area and intensification under Scenario 2 (both Scenarios 2a and 2b) will increase the load of N and P to the lagoon by around 60% (total nitrogen - TN) and 13% (total phosphorus - TP) respectively. Wainono Lagoon is already highly nutrient enriched (current TLI 6.5) and these load increases will further degrade water quality under Scenario 2a to an estimated TLI score of around 7.0 (Figure 3-12). This means an increased risk of algal blooms and associated risk of negative effects on lake visual aesthetics (e.g., see Figure 3-11 for current green colour), and also a small increase in the risk of toxic blooms that may affect recreation opportunities. If cyanobacteria and/or other potentially toxic phytoplankton blooms did occur, such as those that occur in Lakes Ellesmere/Te Waihora and Lake Forsyth/Wairewa, these would negatively affect food gathering and recreation in the lagoon.

Increased nutrient enrichment will also increase the (already present) risk of adverse effects on aquatic life including invertebrates and fish (e.g. eels, whitebait, flounder and mullet) in the lagoon and in the lower Waihao River and Waihao Box area. It is likely (but not certain) that these species will still persist with the further degraded water quality (i.e. TLI 7.0). However they may be exposed to more frequent periods of stress due to low dissolved oxygen, which could limit population size by an un-quantified amount.

Increased nutrient load could also lead to loss of native macrophyte beds which have been sparse or absent in recent years, although factors other than nutrients also influence macrophyte beds (e.g. water clarity, sediment, wind disturbance and grazing). If the loss of native macrophytes was permanent this would reduce biological species diversity and also reduce the diversity of habitat for invertebrates, fish and birds, and make the lagoon more vulnerable to algal blooms and other threats to water quality. Some bird species (e.g. waterfowl – ducks, geese, swans) feed on macrophytes and so this could also affect numbers of these birds feeding in the lagoon.

The further enrichment and general degradation of the lagoon environment may have a significant impact on manawhenua. Any adverse effect on the use of these waters for mahinga kai has a significant flow-on effect. It may make it difficult to continue traditional practices, including the passing on of mātauranga Māori from generation to generation, and the ability to provide visitors (manuhiri) with locally gathered kai. Manawhenua have expressed these concerns during the process and this has informed development of the ZCSP assessed in the next Section 4 of this report.

Adverse impacts on game birds are indirect and difficult to predict. The main adverse effect is probably the risk to their food items (i.e. the effects described above on macrophytes, invertebrates and fish), which could lead to some of them feeding elsewhere. Poorer water quality and the increased risk of nuisance algae blooms could impact the game-bird hunting experience for hunters.

Figure 3-11: The Waihao Arm at Poingdestres Road, approximately 1 km downstream from the Wainono outlet, showing the green colour of Wainono outflow water during calm conditions on the lagoon

3.5.4 Effects of Scenario 2b

Under Scenario 2b the use of Waitaki water to augment flow through Wainono Lagoon via the Hook River could significantly mitigate the effects of the increased nutrient load and the related water quality deterioration described in Section 3.5.3 above, by diluting nutrient concentrations with very low nutrient water from the Waitaki River. Flow augmentation could potentially improve water quality and related aesthetic and ecological values to better than the current situation, potentially sufficient to achieve the proposed LWRP outcome of a TLI less than 6.0 (Figure 3-12) and also reduce dissolved oxygen and temperature fluctuations, and improve the risk of adverse cyanobacteria blooms. Achieving a TLI of less than 6.0 (Scenario 2b) is still a very nutrient-enriched state for a lake; however it is a significant improvement on the current situation. See Sutherland and Norton 2011 (Appendix 18) and Abell *et al.,* 2015 (Appendix 19) for detailed assessments of the merits of augmentation.

Flow augmentation may also offer opportunities to help reduce sediment accumulated on the lagoon bed and could increase the chances of maintaining and enhancing macrophyte beds, both of which would be positive for aesthetic and ecological values. The lower the TLI that can be achieved (i.e. further below 6.0) the better the water quality and the lower the risk for related aesthetic and ecological values.

There are risks associated with flow augmentation that would need to be managed, such as avoiding sediment-laden source water when the Waitaki River is in flood. It is also imperative that functional opening is maintained at the Waihao Box in order to pass the additional flow, avoid any increase in the incidence or severity of flood events, and maintain fish passage to and from the sea at appropriate times (spring and autumn in particular). Flow augmentation would enhance the risk of spreading didymo and invasive macrophytes (e.g. *Lagarosiphon major*) from the Waitaki catchment into the Hook River and Wainono Lagoon, while at the same time reducing the salinity of the lagoon, making the habitat more suitable for *Lagarosiphon*. The risk of spreading invasive species is already present via the existing Waitaki water flow augmentation to the lower Waihao River. Nonetheless all of these concerns would need to be addressed as part of a detailed feasibility assessment if augmentation is included as part of a future solution.

3.5.5 Effects of Scenarios 3a and 3b

Scenarios 3a and 3b explore the merits of advanced on-farm mitigation measures to reduce nutrients and other contaminants; these sub-scenarios do not include the flow augmentation described for Scenario 2b. Scenario 3a (maximum feasible mitigations – MFM) would be a significant improvement on Scenario 2a (GMP) and would probably maintain around the current nitrogen load to the lagoon and the current average TLI score of 6.5 (Figure 3-12). Thus Scenario 3a would approximately maintain the current level of (degraded) water quality and related aesthetic and ecological values. Scenario 3b sits halfway between Scenario 2a and 3a in terms of nitrogen load to the lagoon and a TLI score in the order of 6.75. The relative merits of all scenarios for lagoon TLI score, which may be considered a proxy for the level of water quality and risk of algal blooms and related adverse effects, is shown in Figure 3-10.

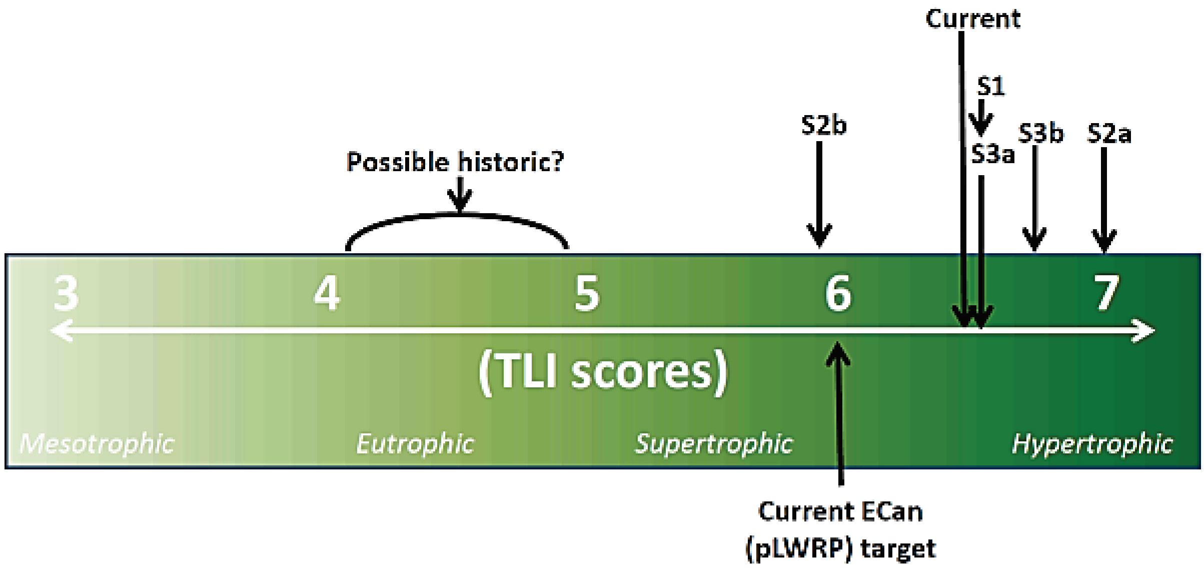


Figure 3-12: Illustration of Trophic Level Index (TLI) scale showing relative position of current state (today) and future scenarios 1 (a, b, c), 2 (a, b), 3 (a, b), estimated historic (pre-European) state and pLWRP outcome target

3.5.6 Estimated nutrient loads in the Wainono Lagoon catchment

Current and predicted future nutrient loading and TLI scores for Wainono Lagoon are summarised for all scenarios in Table 3-15 below. The modelled nitrate-N loads, average drainage concentrations and drainage volume were derived as described in the groundwater quality section 3.4.2 above. Note that the estimated load in Table 3-15 is the modelled diffuse 'agricultural load' lost from the root zone across the catchment (i.e. based on the Canterbury Look-up Table (OVERSEER® v6 Patch) method of Lilburne, 2015; Appendix 4). This does not include the load from point discharges in the catchment. An estimate of point source loads of nitrogen and phosphorus is provided in Table 3-16.

In combination the diffuse agricultural load *and* point source load make up the 'manageable' (i.e. human influenced) portion of the source N load to Wainono Lagoon. The catchment load limit defined by Sub-Regional Section 15 of the pLWRP applies to this 'manageable' source load. The N load that *actually* enters Wainono Lagoon (i.e. the receiving environment load) is what remains of the combined source loads after attenuation (e.g. microbial denitrification processes and uptake by stream periphyton, macrophytes and other plants), and will also include N load from lagoon birds[29]. For modelling and limit setting purposes, the natural background N load and proportional rate of assimilation/uptake in the catchment have been assumed to remain approximately constant through all scenarios as described in the methods in Section 2.8.2. Some implications of using the OVERSEER® model for setting and implementing N load limits are discussed later in Section 6.

[29] The N load from lagoon birds has been estimated to be approximately 3 tonnes per year (TN), which is a minor proportion (less than 1%) of the total estimated diffuse agricultural N load lost from the root zone.

Table 3-15: Estimated Trophic Level Index (TLI) and modelled agricultural nitrate-N load and concentration in drainage water for the Wainono Lagoon catchment under modelled 'current state' and Scenarios 1 (includes a, b and c), 2a, 2b, 3a and 3b. Source of nitrate load and drainage estimates is Scott and Etheridge (2015; Appendix 6) who used outputs from Lilburne (2015; Appendix 4) based on the Canterbury Look-up Table (LUT) OVERSEER® v6. Source of TLI estimates is the method of Sutherland and Norton (2011; Appendix 18)

	Modelled 'current state'	Scenario 1	Scenario 2a	Scenario 2b	Scenario 3a	Scenario 3b
TLI_3 score (annual average)	6.5	6.5	7.0	<6.0	6.5	6.75
Nitrate-N load (tonnes/year)	690	767 (11%)	1101 (60%)	1101 (60%)	864 (25%)	1006 (46%)
Average Nitrate-N concentration in drainage (mg/L)	5.1	5.7 (13%)	7.4 (45%)	7.4 (45%)	5.8 (14%)	6.7 (31%)
Drainage (M^3/year)	136 million	134 million (-1%)	149 million (10%)	149 million (10%)	149 million (10%)	149 million (10%)

Table 3-16: Estimated annual total nitrogen and phosphorus loads from consented and permitted activities for each Nutrient Management Allocation Zone (NMAZ - as defined in the pLWRP) in the SCCS area. (Data sourced from Loe 2012)

NMAZ	Source	Number of	N	P tonnes/yr
Otaio	On-site sewage - post 2006	47	0.1	0.1
	On-site sewage - pre 2006	230	2	0.5
	Farm Dairy Effluent (FDE) ponds	5	0.5	0.1
		Sub-total	**2.6**	**0.7**
Makikihi	On-site sewage - post 2006	17	0.05	0.03
	On-site sewage - pre 2006	230	2	0.5
	FDE ponds	10	1	0.2
	Potato processing wastewater		8	no data
		Sub-total	**11.05**	**0.73**
Wainono	On-site sewage - post 2006	100	0.3	0.2
	On-site sewage - pre 2006	200	1.8	0.4
	FDE ponds	15	1.5	0.3
	Milk processing wastewater	1	40	10
		Sub-total	**43.6**	**10.9**
Waihao	On-site sewage - post 2006	11	0.03	0.02
	On-site sewage - pre 2006	200	1.8	0.4
	FDE ponds	2	0.2	0.04
		Sub-total	**2.03**	**0.46**
Morven Glenavy	On-site sewage - post 2006	20	0.06	0.04
	On-site sewage - pre 2006	250	2.3	0.5
	FDE ponds	23	2.3	0.5
		Sub-total	**4.66**	**1.04**
TOTAL SCCS AREA			**64**	**14**

3.5.7 Summary matrix comparison - Wainono Lagoon

Table 3-17: Assessment of the scenarios for Wainono Lagoon indicators: This assessment uses a five-class colour-coded scoring system as described in Section 2.10.3. (Note: Some Wainono indicators allow only an assessment of the *relative merit* of each scenario to be made (i.e. those marked with an [R] below), while some indicators allow an absolute assessment to be made of the *likelihood* of achieving numeric outcomes defined in the LWRP (i.e. those marked with an [A] below). See Appendix 1 for explanation of the link between ZC outcomes and technical indicators, and the basis for scoring the 'current state'. Other scenarios are assessed relative to the current state. Scenario 1a scores identical to current state)

TECHNICAL INDICATORS	SCENARIOS						
	1a	1b	1c	2a	2b	3a	3b
Opening regime - supports fish passage/recruitment [R]							
Opening regime - manages drainage/flooding [R]					↓		
Lake Level - supports wetland ecosystem [R]				↑		↑	↑
Seasonal runs and migrations of taonga species observed [R]							
Supports customary fish populations (tuna, patiki, inanga) [R]						↑	↓
Mataitai Reserve – fisheries & other mahinga kai [R]						↑	↓
Water quality – sediment load reduced [R]				↓	↑	↑	↓
Water quality - clarity and colour improved [R]		↑	↓	↓			↓
Water quality – nutrient state – test Trophic Level Index (TLI) 6.0 achieved [A]		↑		↓			↓
Water quality – test LWRP outcomes (dissolved oxygen, pH, temperature) for healthy ecosystem [A]		↑	↓	↓			↓
Macrophyte beds present – test Variation 3 LWRP outcome (20% cover) [A]		↑	↓	↓			↓
Risk of cyanobacteria and/or other toxic algae reduced [R]				↓	↑		↓
Fringing wetlands & related biodiversity enhanced [R]		↑	↓		↑		
Aquatic biodiversity (flow-related) enhanced [R]				↑	↑	↑	↑
Suitability for contact recreation – test LWRP outcomes (Fair SFRG) [A]					↑	↑	↓
Watercress is safe to eat [R]				↓	↑	↑	↓
Base flow at springs increases in vicinity of Wainono [R]							

Note: Arrows (↑↓) indicate relative change (more/less likely to deliver an outcome) compared to Scenario 1a but not sufficient change to justify shifting to a new colour class.

3.6 Key messages for resource management arising from exploratory scenarios

The following key messages were compiled by the technical team as a result of the assessment of all seven exploratory scenarios. These messages were included as an Executive Summary at the front of the Draft Overview Report that was provided to the ZC and community at the last public workshop for exploring scenarios (August 2013)[30]. These key messages were 'draft' at that time and were subsequently used, along with all of the exploratory scenario material and public feedback, as a basis for deliberation and development of a draft solutions package.

Scenarios 1a, 1b and 1c – the situation without HDI & WD schemes

- Scenarios 1a, 1b and 1c consider the situation before the consented HDI and WD irrigation schemes are built. Under these scenarios, only half of the total irrigable land in the SCCS area (approximately 54,000 ha) is irrigated (approximately 27,000 ha).
- Scenario 1a represents approximately the current situation with regard to in-catchment minimum flows and allocations. In a national policy context (e.g. guided by the Proposed National Environmental Standard on Ecological Flows and Levels), in-catchment rivers would be considered highly to over-allocated. While many of the rivers in the area are naturally intermittent and their ecology is regularly stressed by low flows and zero flow (dry) reaches in summer, this stress is worsened by the current relatively large consented allocation to out-of-stream use from small streams, rivers and shallow connected groundwater.
- Scenario 1b would increase minimum flows and reduce allocation, and would thereby reduce flow stress on ecological, recreation and amenity values. Scenario 1b would better satisfy environmental outcomes and the preferences of manawhenua. However existing abstractors from these rivers and connected shallow groundwater would experience a reduced reliability of supply, imposing costs that could seriously affect livelihoods. Analysis suggests that Scenario 1b would result in significant reductions to currently irrigated area outside the MGIS scheme.
- Scenario 1c has lower minimum flows and as a consequence would increase flow stress on ecosystems and is likely to reduce recreational and amenity values. Additional gains in irrigated area in Scenario 1c will be small, and thus the economic and social gains would be limited.
- It follows from above that key decisions will need to be made concerning whether or not to increase minimum flows (e.g. Scenario 1b), the timing of such increases if they were to occur, and whether to wait, to lessen economic and social impacts, until new (Waitaki) water becomes available. These decisions will involve value judgements that weigh in-stream and out-of-stream values.

Deep groundwater

- Deep groundwater is an uncertain irrigation resource in the SCCS area, both in terms of sustainability of supply and the unknown effects of abstraction on recharge to coastal streams. Further allocation of the deep groundwater resource would therefore be a risky option at this time.
- Deep groundwater is, however, a useful drinking supply resource given the current risks associated with nitrate and pathogens in shallow groundwater in some parts of the SCCS area, and the likelihood these risks will increase under future land use change scenarios (see below). Deep groundwater, such as that used for Waimate town supply, is expected to remain of high quality (i.e. low concentrations of nitrate and pathogens) under future scenarios, although may still require treatment for natural contaminants (e.g. iron and manganese).

[30] The August (2013) version of the Draft Overview Report is still available on the SCCS website for transparency of process. There have been minor changes to some of the assessment numbers presented at that time as a result of updated technical tools (e.g., model versions) and corrections raised during the process; however the substantive content in Part 1 (Section 3) of this Final Overview Report remains the same as the August (2013) version.

Scenario 2a - HDI & WD as consented – plus GMP on all farms

- Scenario 2a assumes HDI and WD use Waitaki River water to irrigate a further 27,000 ha of land. This will lead to more intensive land uses, dairying in particular, and bring considerable economic and social benefits.
- Compared to the current situation, the on farm Earnings before Interest and Tax (EBIT) increases from $150 million to $250 million, and after costs of moving to irrigation to $200 million. The primary sector contribution to regional GDP almost doubles from $440 million to $810 million. Similar increases are seen in household income regionally that is driven by the primary sector ($210 to $380 million) and rates and taxes ($120 to $220 million). Employment contribution from the SCCS area increases from 3900 full time equivalents (FTE) to 6600 FTE across the region. On farm the current employment of 800 FTE increases to 1400 FTE. These are significant increases in economic activity associated with the SCCS study area.
- Social benefits will flow from the economic benefits of additional employment in particular. Following a period of construction activity, the additional employment, mainly in the dairy sector, will generate an extended period of population growth and positive effects for local schools, social services and social wellbeing, particularly if the process of change is managed well.
- Increased irrigation is expected to increase the volume of drainage contributing to shallow groundwater (i.e. land surface recharge), thus producing a small increase in groundwater levels and increased contribution of base flow to the lower (below State Highway 1) reaches of rivers and streams during summer low flows. This is a small improvement to the quantity of aquatic habitat and a small reduction in the frequency and extent of summer drying (zero flow) in the lower reaches.
- Land use change and intensification is expected to deteriorate water quality in shallow groundwater (<30 m deep), in particular increasing the concentration of pathogens, and of nitrate by an average of around 33% (range 8% to 77%). This is estimated to increase the number of shallow domestic wells that breach the drinking water standards (Maximum Acceptable Value - MAV) from about 4% currently to about 9% (12 out of 137 wells). This will require either deeper wells to be drilled or treatment for those supplies affected. The cost of this has been assessed in the order of $10,000-50,000.
- Water quality is also expected to deteriorate in rivers and streams, with increasing nitrate and phosphorus concentrations in particular. With the level of on-farm mitigations assumed for Scenario 2a (i.e. GMP – Good Management Practice) the average 33% increase in nitrate concentrations is still expected to meet the 90% level of protection for nitrate toxicity to aquatic life. However increases in nutrients will further increase the risk of nuisance periphyton and macrophytes, and thereby risk further degradation of aquatic biodiversity, aesthetic and contact recreation values compared to the current state which already does not meet the level of the proposed Land and Water Regional Plan (pLWRP) outcomes for those values.
- Water quality in Wainono Lagoon is also expected to worsen, with the agricultural load of nutrients to the lagoon increasing by around 60% (total nitrogen [TN]) and 13% (total phosphorus [TP]) respectively. Wainono Lagoon is already very nutrient enriched and has a current average Trophic Level Index (TLI) score of around 6.5; these nutrient load increases are expected to push the TLI score up to around 7.0 under Scenario 2a. This means an increase to the already present risk of algal blooms, some of which may potentially be toxic, and associated fluctuations in dissolved oxygen that can stress aquatic invertebrates and fish (e.g. eels, whitebait, flounder and mullet), thus also affecting mahinga kai.
- Increased nutrient load could also contribute to loss of native macrophyte beds which have in recent years been alternating between low-level presence and absence in the lagoon. If the loss of native macrophytes was permanent this would reduce biological species diversity and also reduce the diversity of habitat for invertebrates, fish and birds, and make the lagoon more vulnerable to algal blooms.
- Further nutrient enrichment of the lagoon environment may have a significant impact on manawhenua. Any adverse effect on the use of these waters for mahinga kai has a flow-on effect. It may make it difficult to continue traditional practices, including the passing on of

mātauranga Māori from generation to generation, and the ability to provide visitors (manuhiri) with locally gathered kai.

Scenario 2b - (HDI & WD + flow augmentation for Wainono Lagoon

- Flow augmentation has the potential to achieve significant benefits for water quality and related ecological, aesthetic and recreation values in the lower Hook River (below State Highway 1) and in Wainono Lagoon. There is uncertainty about exactly how augmentation would be implemented. However if managed carefully it could help to achieve a Wainono TLI score better (i.e. lower) than 6.0, which is an outcome stated in the pLWRP. Even if a TLI of 6 was achieved the lagoon would still be in a very nutrient-enriched state, but this would be a significant improvement on the current situation. This could reduce ecological stress caused by dissolved oxygen fluctuations, reduce the likelihood of nuisance blooms, assist with reducing bed sediment in the lagoon, and increase the chances of enhancing and stabilising native macrophyte beds in the lagoon, if this is desired.
- There are risks associated with augmentation that would need to be managed, such as avoiding sediment-laden source water when the Waitaki River is in flood. It is also imperative that functional opening is maintained at the Waihao Box in order to pass the additional flow, avoid any increase in the incidence or severity of flood events, and maintain fish passage to and from the sea at appropriate times (spring and autumn in particular). Flow augmentation would enhance the risk of spreading didymo and invasive macrophytes (e.g. *Lagarosiphon major*) from the Waitaki catchment into the Hook River and Wainono Lagoon, although some risk is already present via the existing Waitaki water flow augmentation to the lower Waihao River. All of these concerns would need to be addressed as part of a detailed feasibility assessment if augmentation is included as part of a future solution.
- The cost of augmentation has been estimated at less than $1 million annually, which is small in the context of the economic benefits of Scenario 2a. The social benefits include an enhanced perception of the lagoon environment and greater potential for mahinga kai and recreational uses.
- In all other respects for water quantity and quality across the SCCS area other than the lower Hook River and Wainono Lagoon, Scenario 2b is identical to Scenario 2a.

Scenario 3a - HDI & WD + maximum feasible on-farm mitigations (MFM)

- The on-farm maximum feasible mitigations (MFM) assumed across the whole SCCS area in Scenario 3a are predicted to mitigate the effects of the schemes and hold average nitrate concentrations in shallow groundwater to only 1% greater than current (range -19% to 51%), and would thus also reduce nitrate concentrations in some rivers and streams. The MFM measures would also be expected to reduce losses of sediment, phosphorus and pathogens from agricultural land compared to the on-farm GMP assumed under Scenarios 2a and 2b.
- On average across the SCCS area, the MFM measures would mitigate the adverse effects on shallow groundwater and surface water quality, ecology, aesthetics and contact recreation values in streams and rivers described for Scenario 2a above, offering an overall slight improvement on the current situation. However the upper to middle Waihao would be likely to remain prone to nuisance periphyton and to pose a risk to benthic biodiversity, trout habitat and angling, and contact recreation. Most spring-fed streams would also remain prone to nuisance plant (macrophyte) growth, and poor benthic invertebrate biodiversity, trout habitat and angling.
- For Wainono Lagoon, the MFM measures effectively offset the nitrogen and phosphorus load increases predicted under Scenario 2a, such that approximately the current TLI score of 6.5 is predicted, with the current level of risk of nuisance algae blooms and associated stress on ecology and mahinga kai.
- The cost of MFM measures is significant. Compared to Scenario 2a, on-farm EBIT reduces by $30 million before and after the capital costs of transition to irrigation. The differences in wider regional economic indicators are greater, with regional GDP reduced by ~$100 million

compared to Scenario 2a. Regional household income reduces by ~$40 million, rates and taxes by about $30 million, and regional employment reduces by 600 – 700 FTE, all compared to Scenario 2a.

- Social benefits from Scenario 3a include enhanced stream and river environments, and improvements to recreational uses, offset by the above-mentioned decrease in employment and associated social benefits.

Scenario 3b - HDI & WD + 'mid-point' on-farm mitigations

- Scenario 3b assumes that the level of on-farm mitigations is mid-way between GMP and MFM. The expected effects on shallow groundwater and surface water quality are about mid-way between those described above for Scenarios 2a and 3a, and coincidentally are approximately the same as for Scenario 1 (a, b and c). Nitrate concentrations in shallow groundwater are expected to increase on average by about 20% (range -4% to 69%) and thus nitrate concentrations in rivers and streams are expected to increase by a similar amount. For Wainono Lagoon, a 46% increase in nitrogen load is predicted and a TLI score in the order of 6.75.
- The cost of 'mid-point' mitigations is almost as significant as MFM. Compared to Scenario 2a, on farm EBIT reduces by only $10 million instead of $30 million before and after the capital costs of transition. However the differences in wider regional economic indicators are similar to MFM, with regional GDP reduced by ~$100 million, regional household income reduced by ~$40 million, rates and taxes by about $30 million, and regional employment by 600 – 700 FTE, all compared to Scenario 2a.

Other mitigations for water quality effects

- The Wainono Restoration Project (WRP) is already initiating and funding several projects that will help to improve water quality and related ecological values, and this is anticipated to continue into the future. These projects include: i) riparian planting around the lagoon and tributaries; ii) on-farm reduction of erosion and soil loss (e.g. through use of retention bunds) in all catchments but particularly the Hook; iii) weed control (e.g. willows) around Wainono Lagoon. These efforts have been assumed equal across all scenarios for the purpose of assessment in this report.

Building catchment-wide solutions

- Following consideration of all the scenarios in community workshops it was anticipated that the Zone Committee would take parts of some or all these scenarios to be combined and/or modified into a 'solutions package' containing identified outcomes and limits that could be included in the Sub-Regional Section 15 of the Land and Water Regional Plan. It was assumed that the WRP initiatives would be a key part of the solutions package, and that additional mitigation projects to be included in the package may come out of community workshops.

4 Part 2: The Zone Committee Solutions Package

4.1 Development of the ZC Solutions Package

Following consideration of results of the exploratory scenarios at public meetings in May, July and August 2013, the ZC, wider community and technical team each brainstormed potential aspects of a draft solutions package. The draft solutions package was assessed in the same way as the earlier scenarios and the results discussed with the ZC in October 2013 and presented to the wider community at a public open day on 30 November 2013.

The ZC subsequently invited and received written and verbal feedback on the draft solutions package in a series of purpose-booked interviews with stakeholders and interested members of the public in November 2013. The ZC also received feedback by way of a phone survey conducted by Environment Canterbury planning staff to understand the views of communities in the townships of Waimate, St Andrews, Willowbridge and Morven. Based on all of this feedback and comments received at monthly public ZC meetings through to December 2013, the draft solutions package was refined ready for re-consideration at a ZC meeting on 19 February 2014.

At the ZC meeting on 19 February 2014 a large group of farmers voiced their discontent with a particular part of the draft solutions package, specifically the proposed nitrogen allocation framework. The group requested the ZC to extend the timeframe to enable better engagement with the farming community and further consideration of the nitrogen allocation framework. A time extension was subsequently requested by the ZC to Environment Canterbury Commissioners who granted an extension till July 2014. In that five month extension period a locally-based Nitrogen Allocation Reference Group (NARG) was formed and undertook, with technical support, a very intensive collaborative process that eventually allowed an agreed position to be reached on a modified nitrogen allocation framework. The process and outcomes of the NARG form an important part of the solutions package and are described in detail in a technical report by Norton *et al.,* (2014) (see Appendix 22).

The ZC reached agreement on the content of the final ZC Solutions Package (the ZCSP), which included the nitrogen allocation framework recommended by the NARG, on 16 July 2014 and this was subsequently published in their ZIP Addendum document (LWZC 2014). The ZIP Addendum was accepted by Environment Canterbury Commissioners (24 July 2014) and the Waitaki and Waimate District councils (16 and 17 September 2014 respectively).

4.2 Solutions Package (ZCSP) definition and assumptions

The ZIP Addendum (LWZC 2014) identified the following opportunities and major pathways for the ZCSP to achieve outcomes (quoted):

"Opportunity Statement

There is the opportunity to improve the health and mana of Wainono Lagoon, which is considered a taonga to tangata whenua, while realising the gains from the consented Waihao Downs (WD) and Hunter Downs Irrigation schemes (HDI). The solutions package splits the South Canterbury Coastal Streams (SCCS) area into three distinct parts:

1. ***Waihao Wainono** consists of Wainono Lagoon and the rivers and streams that flow into it*
2. *The **Northern Streams** consisting of Otaio River, Makikihi River, Kohika Stream and Horseshoe Bend Creek.*
3. ***Morven Drain and Sinclairs Creek**.*

The solutions package aims to reduce the trophic level for Wainono Lagoon to a Trophic Level Index (TLI) score of 6, improve Waihao and other tributary flows and habitat over time, and provide a protection level of 90% for nitrate toxicity for the streams, while the irrigated land area increases by 27,000ha via the consented WD and HDI. For the Northern Streams, the package aims to improve flows and habitat over time while maintaining a protection level of 90% for nitrate toxicity, and providing for development at good management practice. For Morven Drain and Sinclairs Creek, the package aims to protect the current quality of groundwater.

Outcomes

…[see outcomes quoted in Section 2.2]…

Major Pathways

The major pathways to achieve the outcomes are listed below and form the basis of the recommendations. They are designed as an integrated package and include: a focus on non-statutory actions, good environmental stream flows, good management practice, augmentation of Wainono Lagoon, and a fully functional and funded Waihao Box.

1. *Support for **Catchment Groups**: for collective action and support for practices to reduce losses of sediment, phosphorus and nitrogen*
2. *Use of **Farm Environment Plans** using available templates: to facilitate and demonstrate Good Management Practices and actions*
3. *Realising the gains from the **Wainono Project** and a successor to the project: for catchment and on-farm actions to improve Wainono Lagoon; including identification of critical source areas, sediment traps, stream battering, wetland rehabilitation and biodiversity enhancement, optimal lagoon level management and the development of a de-nitrifying wetland*
4. ***Good Management Practice** (GMP) requirements for agricultural, and for urban and industrial discharges*
5. *A **Simple Framework** to support limits implementation*
6. ***Augmentation** of Wainono Lagoon: to improve lagoon health*
7. *Capping current **Water Allocation** and reducing over-allocation over time as new water sources are available and irrigation efficiency improves, enabling alternative sources of water, and signaling a future date for higher flows to be implemented*
8. *Securing the future functioning of the **Waihao Box**, through a more sustainable and equitable funding arrangement" [end quote].*

In terms of the exploratory scenarios assessed in Section 3, the ZCSP is essentially a blend of Scenario 2b (HDI + WD + flow augmentation) plus a nitrogen allocation framework that requires better than GMP on light soils (e.g. with similar effect to Scenario 3b), plus environmental flows that are similar to Scenario 1b although implemented over a period of time, plus an extended Wainono Restoration Project.

The ZCSP as assessed in this Overview Report contains the following specific elements staged out to 2025 and beyond:

a) HDI and WD schemes are fully developed – this doubles the irrigated area in SCCS.

b) All land users have Farm Environment Plans that include OVERSEER® budgets for N, an assessment of P loss risk and identification of critical source areas for management of contaminant loss (sediment, P, N, microorganisms).

c) Total N load limits are defined for all catchments (includes farming and point discharge limits).

d) All land users are subject to the nitrogen allocation framework developed by the NARG and endorsed by the ZC that includes:

- Minimum effort of GMP for all users;
- "Maximum caps" (based on soil type) that require high emitters to reduce N loss to better than GMP in some cases through time;

- A "flexibility cap" for low emitters that increases through time as flow augmentation is implemented and N gains are realised from the maximum caps.

e) Augmentation of flows into the Wainono Lagoon.

f) Improving ecological flows in SCCS streams and rivers by increasing minimum flows and reducing allocations through time – ultimately meeting Manawhenua preferences (Scenario 1b flows from Tipa (2012; Appendix 16) in many streams by 2025 and almost meeting preferences in the remainder.

g) Small further increase to flows in lower reaches of rivers due to increased irrigation.

h) Waihao Box repaired and maintained – improved opening frequency to support both effective drainage and fish passage.

i) Catchment Group actions supported and continuing (e.g., riparian restoration)

j) Wainono Restoration Project (WRP) extended and fully implemented including the following:

k) Decreased soil and bank erosion from bunding, battering and planting;

l) Restoration of Hook delta wetland (weed management and planting);

m) Identification of optimal water level for lagoon management;

n) Development of sediment retention and denitrifying wetland at lower Hook Drain;

o) Spring-head wetlands enhanced through restoration planting;

p) Riparian corridor planting and shading to reduce periphyton and macrophytes in rivers and streams where practical;

q) Targeted in-stream sediment removal using sand wand or similar;

r) Targeted stream habitat and biodiversity enhancement;

s) Identification and protection of remnant mudfish populations by protecting habitat and excluding predator (trout) access;

t) Monitor & respond to problem areas – HDI consent required monitoring and HDI Environment Enhancement Fund – backed up by Environment Canterbury state of environment and plan effectiveness monitoring.

Detailed technical assumptions for the ZCSP are provided in Appendix 3.

4.3 Organisation of this assessment

Social, economic, cultural and environmental matters are all interconnected and important - there is no 'right' way to split or organise these for assessment. For convenience this assessment is organised the same way as for the exploratory scenarios in Section 3, into three sections to cover the three main 'outcome' areas identified by the ZC, these being:

1. Social and economic (Section 4.4)
2. Streams, rivers and groundwater (Section 4.5)
3. Wainono Lagoon (Section 4.6)

Cultural matters are relevant for, and appear under, all three of these headings, rather than being separated out. There is no ranking of importance implied by the presentation order in this report.

4.4 Social and economic assessment

This section is based on technical reports on economics (Harris, 2015), social considerations (Taylor *et al.,* 2015) and manawhenua values (Tipa, 2012); see Appendices 14, 15 and 16 respectively.

4.4.1 Land use

As described previously in Section 3.3, current land use is dominated by sheep and beef, with dairy and dairy support the next most significant land use with approximately 18% of the total catchment area and arable following with 10%. In the assumptions for the ZCSP (Appendix 3) dairy and dairy support is the most significant land use, with 42% of the total area, and sheep and beef has reduced to 32%. Arable remains approximately the same with 8% of the total area (Figure 4-1). These figures reflect the dominance of dairy in the assumptions about the HDI and WD schemes, and the associated need for dairy support alongside the milking platforms. A map showing the assumed land use mix for the ZCSP (which is the same as for Scenario 2) is shown in Figure 3-4 in the earlier Section 3.3.3.

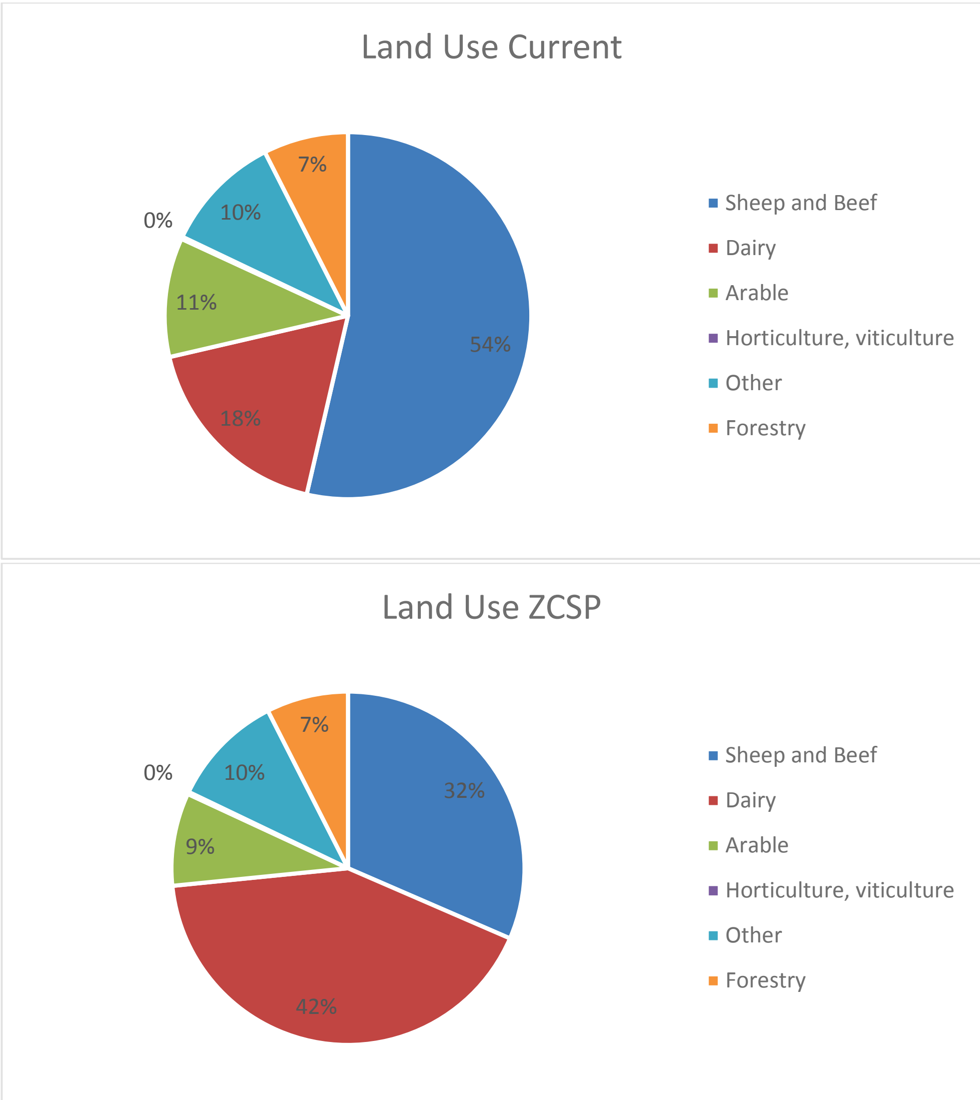


Figure 4-1: Comparison of current and ZCSP land use (as proportion of total area)

4.4.2 Irrigation using water from local streams

The ZCSP provides for current use of water from local rivers and streams for irrigation to continue in the short term (e.g. until 2025 in some cases), but imposes more restrictive environmental flows and allocation limits on the local rivers and streams in the long term (e.g. after 2025). This will better meet environmental outcomes and the preferences of manawhenua in time (as described in more detail later) but is expected to require existing irrigation water users to make greater use of the more reliable water from existing (MGIS) and new (HDI and WD) schemes as these are built. There will be costs for users to move to greater use of scheme water and these have been incorporated into the economic assessment described in the following sections.

4.4.3 Irrigation from schemes (HDI and WD)

The ZCSP is based on Scenario 2 assumptions where the consented HDI and WD irrigation schemes double the current irrigated area from about 27,700 ha to about 54,700 ha (see Figure 3-3 in earlier Section 3.3.3). This represents full irrigation development of the potentially irrigable land in the SCCS area. Dairy is expected to be the dominant irrigated land use (Figure 4-2).

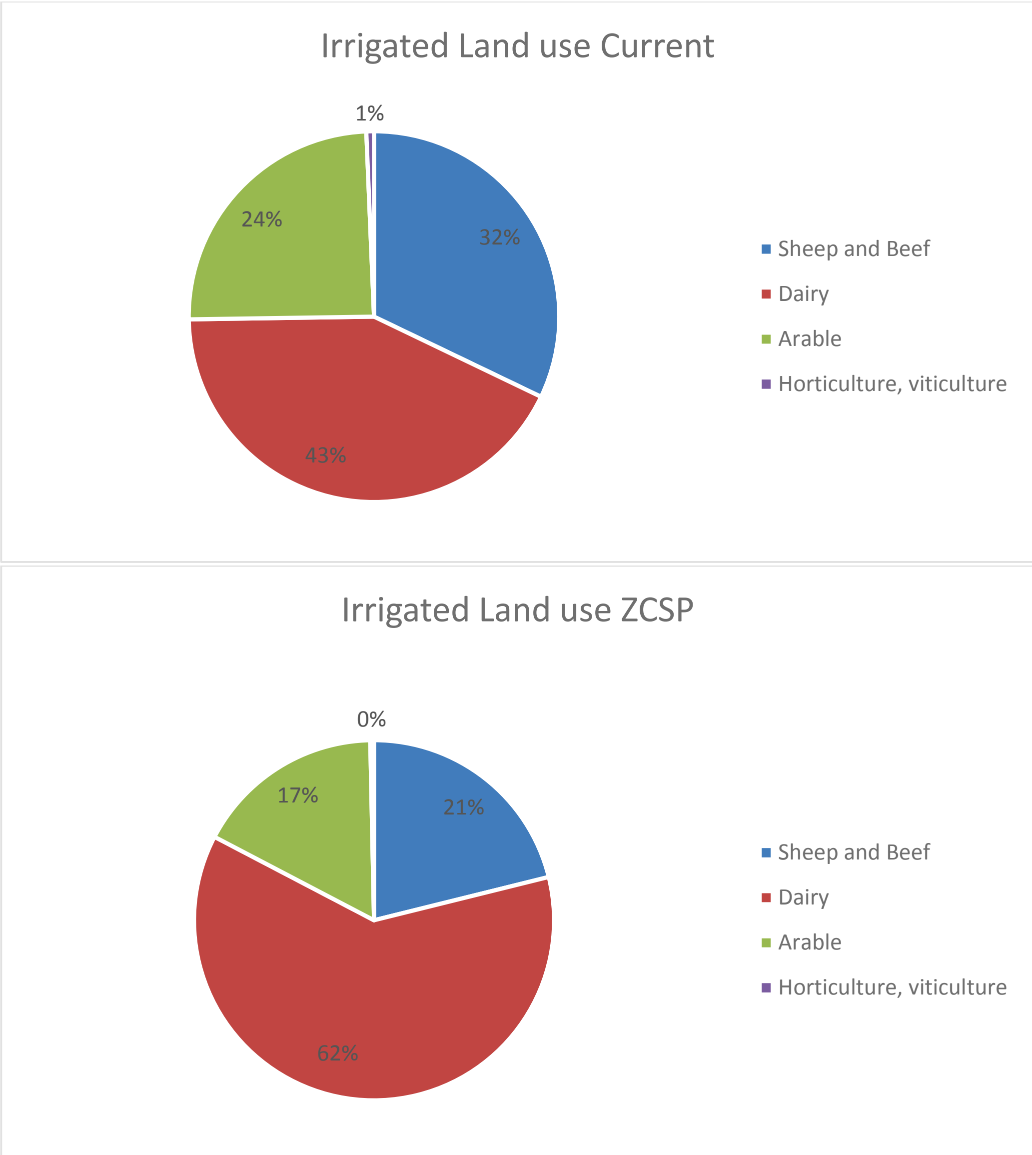


Figure 4-2: Comparison of current and ZCSP irrigated land use (as proportion of total area)

4.4.4 Farm and regional economics and employment

Estimates of ZCSP effects on farm and regional economic indicators are summarised in Figure 4-3 and outlined in greater detail in Harris, 2015 (Appendix 14). In summary the assessment shows that:

- Primary sector revenue increases from $290 million per annum currently to $480 million/annum under ZCSP (Figure 4-3). This is accompanied by an increase in operating profit before capital from $140 million/annum currently to $200 million per annum under ZCSP. However after capital costs are factored in, the gains are relatively small (e.g. less than the rounding margins) which suggests that the capital costs of conversion and intensification are approximately offsetting the increase in profit.

- Regional economic indicators of contribution to regional GDP increases significantly, from $430 million/annum currently to $730 million per annum under the ZCSP (Figure 4-3). The increase in regional economic activity is largely driven by increases in revenue, which tends to be reflected in increases in expenditure on activities in other parts of the economy, either through the farm business, or indirectly through wages, salaries and profits.

- Irrigated land use contributes the majority of this economic activity in ZCSP, with 80% – 90% of revenue, operating profit and contribution to regional GDP. Dairy and dairy support, which are the dominant irrigated land uses, contribute 75% of the revenue, 74% of the operating profit, and 76% of the contribution to regional GDP, which reflects the high intensity associated with dairying as a land use (see Harris, 2015, Appendix 14 for detail).

- Employment changes are also very significant under ZCSP. On farm employment increases from 800 Full Time Equivalents (FTEs) to 1300 FTEs, and when regional flow on impacts are included the total employment increases from 3800 to 5900 FTEs (Figure 4-3). Dairy and dairy support contributes 76% of the on farm employment and 72% of the contribution to regional employment. Much of this contribution is associated with the milking platform expansion under the HDI and WD schemes in the ZCSP, because of the higher employment intensity associated with the milking platform as opposed to dairy support (labour units per ha or per $million revenue). Irrigated land contributes the majority of employment, with dryland a very minor source of employment in the ZCSP scenario. The dryland activities have a very low employment rate per ha due to their lower intensity of operation.

- Household income and local government rates and taxes generally follow the employment changes. Household income increases from $210 million per annum currently to $350 million per annum under the ZCSP, and local and central government revenue from $120 to $200 million per annum (Figure 4-3). These are significant increases for an economy the size of the SCCS area. The local and central government revenue changes are associated with an increase in both demand for services and the ability to deliver them. As with other economic indicators, the majority (80%-90%) of this comes from irrigated land. Dairy and dairy support contributes 75% of the earned household income and 80% of the rates and taxes in the ZCSP scenario.

4.4.5 On farm mitigation costs of the ZCSP

The cost of on farm mitigation is driven by the cost of meeting the nitrogen allocation “Maximum Cap” requirements, and has been included in the overall economic impact analysis shown above. The specific cost associated with meeting the maximum caps for different land use types, and the area of those land uses in SCCS, has been estimated in some detail in Harris 2015 (Appendix 14). In summary the total cost of meeting the nitrogen maximum caps in the SCCS area is estimated at $3.9-5.2 million per annum[31], with most of this (68%) in mitigation of existing land use rather than the cost of changing the land use to achieve lower nitrogen emissions. The most significantly affected land uses will be dairy and dairy support. Together these land uses account for almost all (99%) of the land requiring mitigation or land use change, with sheep and beef only a very small proportion (intensive beef production on light soil only). The total cost of $3.9-5.2 million per annum is approximately 2-3% of total operating profit (before the capital cost of transition) in the ZCSP scenario, and 3-4% of the total dairy and dairy support operating profit. Care should be taken with these aggregate figures however because the effects will be disproportionately experienced by some operators, particularly those with more intensive operations and with lighter soils (see Harris, 2015, Appendix14 for detail).

[31] The range reflects estimates from two different methods as described in Harris 2015 (Appendix 14).

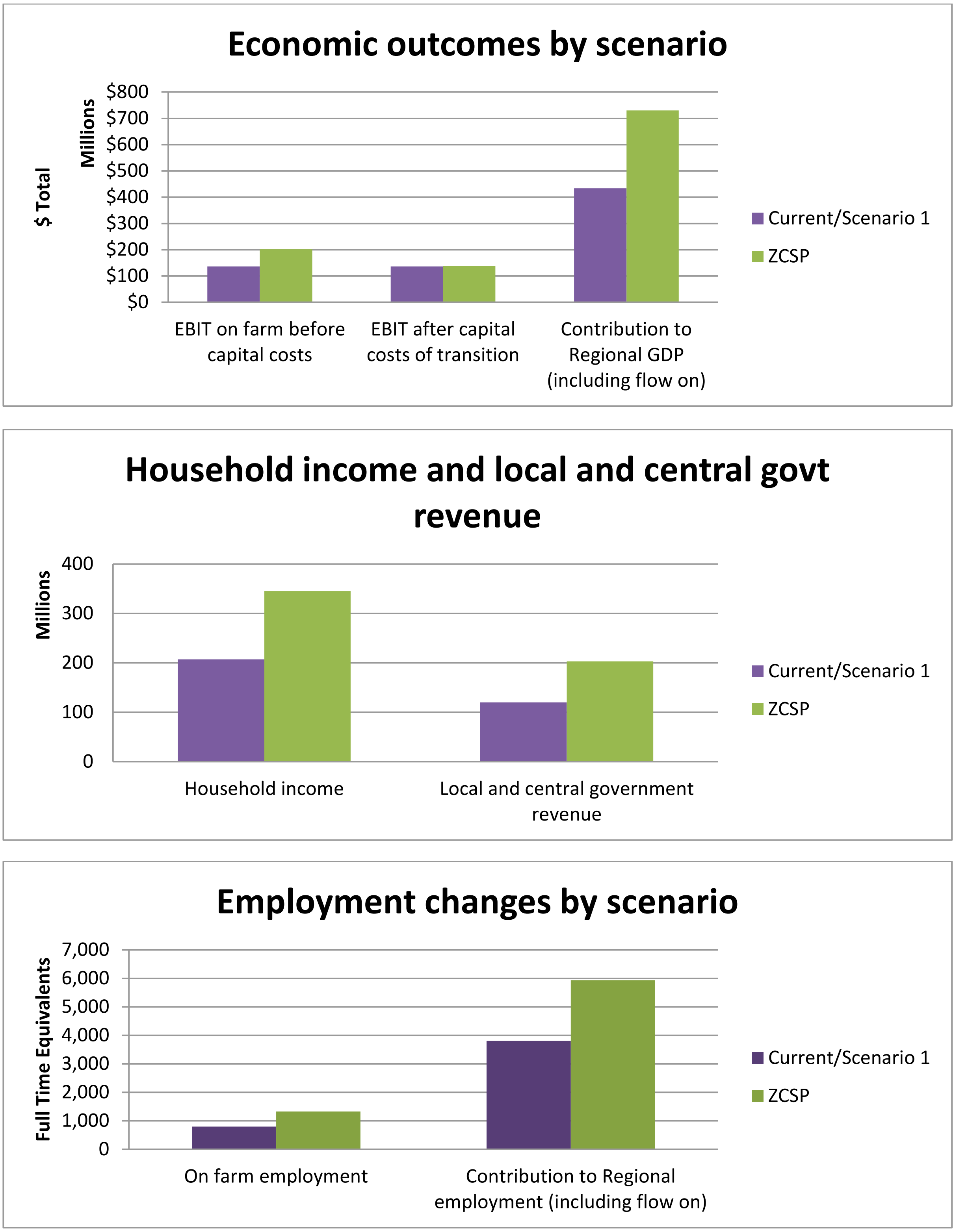


Figure 4-3: Economic and employment outcomes from the ZCSP in the SCCS area

4.4.6 Other costs of the ZCSP

The cost of other mitigations in the ZCSP including riparian planting, lagoon augmentation and management are estimated approximately in Harris, 2015 (Appendix 14). The total cost of these is estimated at $103 million total capital cost and $1.3 million per annum in ongoing maintenance and other costs. Flow augmentation is estimated to cost $39 million which is based on updated costings for supplying the necessary water from the HDI scheme[32]. Riparian planting is the second largest item at ~$30 million. The costs for riparian planting are derived from actual costs experienced in the Waihora Ellesmere Trust activities for Te Waihora. The extension of the Wainono Restoration Project is estimated to cost $11 million, including the reconstruction of the Waihao Box.

All these costs are equivalent to $11.0 million per annum if the work were to be done immediately then paid off as a loan over 20 years, or $6.5 million per year if the work were to be done over 20 years (i.e. 1/20th of the work each year).

Indicative costs of moving from surface water to groundwater take
The cost of moving from current surface water to groundwater take, as allowed for in a limited number of cases in the ZCSP to improve surface flow in local rivers and streams, will vary greatly depending on the individual case. Drilling costs are in the order of $800 - $1000/m for an established well, and pumps and associated electrical equipment can be in the order of $50 - $100,000 for a 12 inch well (I. MacIndoe, Aqualinc, pers. comm.). Local (Otaio) information suggests that costs for a 270 ha dairy farm would be in the order of $300,000 for capital items (2 x 80 l/s wells, pumps, electrical) and approximately $130,000 per annum for pumping costs (Harris, 2015, Appendix 14). However there are also significant benefits in moving to a high reliability groundwater source for irrigators on low reliability surface water. It is likely that these benefits will partially or fully offset the costs of moving onto groundwater.

Indicative costs of HDI scheme
The cost of water from the HDI scheme is unknown at time of writing. HDI project managers have suggested that costs will be in the order of $1000/ha/annum, which suggests capital costs in the order of $10,000 per annum, with the split between capital and operating dependent on whether a pumped or gravity scheme is adopted (Harris, 2015, Appendix 14). The estimated costs of full uptake of HDI water have however been factored into the economic analysis results described in the previous sections (see Harris 2015, Appendix 14 for detail).

4.4.7 Summary of ZCSP effects on economic indicators

The key effects of the ZCSP on economic indicators are shown in the matrix below (Table 4-1).

Table 4-1: Assessment of ZCSP for economic indicators: This assessment uses a five-class colour-coded scoring system as described in Section 2.10.3. (Note: Economic indicators allow only an assessment of the *relative merit* of the ZCSP compared to current because there is no absolute (e.g. numeric) threshold defining attainment of the ZC's economic outcomes. See Appendix 1 for explanation of the link between ZC outcomes and technical indicators, and that current state has been nominally assessed as "Medium" (yellow) for economic outcomes on the basis that only half the irrigable area is currently utilised

TECHNICAL INDICATORS	Current	ZC Solutions Package		
		2017	2022	2025
Utilisation of irrigable area to achieve production potential - CWMS Target 7				
On farm economic impacts (revenue, farm working expenses, variable expenses and EBIT)		*	**	**
Regional economic impacts including GDP, earned household income, rates and taxes				

Notes:
Cells showing half colours indicate significant negative and positive impacts for different users, as detailed below.

*Those over the cap for nitrogen allocation will be required to undertake potentially significant mitigation or land use change.

**Those over the cap for nitrogen allocation, and those shifting to alternate water sources with changes to the surface water allocation and environmental flow regimes, may face significant costs.

[32] Brian Ellwood, Hunter Downs Irrigation, pers. comm. Email to Simon Harris 5 February 2015.

4.4.8 Employment

The economic analysis above indicated that the number of farmers and farm workers employed in dairy, dairy support and arable farming is likely to increase by 500 FTEs, and when regional flow-on impacts are included the total employment increase predicted regionally is from 3800 to 5900 FTEs (Figure 4-3). There will be a particular boost to employment during the construction stage of the HDI and WD irrigation projects.

Employment in food processing will continue to be located both inside and outside the SCCS area, with milk processing plants in the area planning to expand and a new one proposed for Glenavy. Meat processing will remain outside the SCCS area with two major plants currently operating within commuting distance, subject to any future rationalisation in this sector. Unemployment is likely to remain low.

However a protracted period of economic stress for the dairy sector could result in a reduction in cow numbers and a shift back to arable or pastoral farming that would reduce the level of employment and change the mixture of occupational skills away from dairy and dairy support.

4.4.9 Population in the SCCS area

The additional employment described above is expected, in turn, to drive growth in employment and population by 1,000 to 1,200 people in the Waimate District. Growth in the population of the Waimate township is likely to occur in the scheme construction stage and then with changes in land use (particularly dairying) and associated services. With the regional labour market being bolstered by the range of new jobs on-farm, a long term effect will be to support the viability of services available in Waimate town.

4.4.10 Social services and community cohesion

As the growth in population described above will largely involve working-age people and some younger families, there will be benefits to community life such as an increase in participation in recreation, sport, community groups and voluntary activity, which is particularly important in the face of the currently aging population. The growth in population should also flow into benefits for population-based services such as health services, schools and community facilities from increased funding on a per capita basis. These improvements will all help to meet the needs of the aging population as well as the total population generally.

However there will be new social needs to meet. The ZCSP could reduce social cohesion as a result of the arrival of new workers (from New Zealand and overseas) with different cultural values and expectations about community participation. The increase in dairy farming will increase the number of corporate farms and increase the number of paid employees, who will also have different needs and attitudes around community participation. The community will need to make a concerted effort to involve such newcomers and encourage their participation, thereby maximising positive social effects.

These new social tensions should be offset to some extent by a reduction in tensions between farm production values and recreation and amenity values in the rivers and lagoon because of some improvements in their ecological status. However it is not certain that these values will be supported at all times and some environment-focussed stakeholders will remain concerned about high nutrient and sediment effects on ecology, amenity and recreation values in rivers and Wainono Lagoon despite efforts to reduce these effects.

A new set of community concerns is likely to arise, with evidence of declining status of drinking water in domestic wells as a result of land-use intensification. Such a trend could see an increased incidence of wells exceeding MAV for nitrogen and also *E. coli,* with families taking measures to protect their health. These measures could include buying water to mix baby formula, seeking information about water quality and having wells tested more regularly, and for some, an effort to improve wellhead protection or even sink deeper wells.

4.4.11 Individual and household income

Continued growth in dairying will benefit on and off-farm employment and incomes in the area (Figure 4-3). Growth in employment and incomes will help to offset a high proportion of the population receiving limited incomes due to the high proportion of elderly, but there will be increases in income differential, particularly between town and rural areas.

4.4.12 Drinking water quality

Current Waimate District Council (WDC) drinking water supplies sourced from deep groundwater bores (Waimate town) will likely remain unaffected and continue to meet drinking water standards under all scenarios.

WDC rural scheme supplies sourced from rivers (i.e. Cannington Motukaika, Hook Waituna, Otaio Makikihi, Waihaorunga and Waikakahi schemes) may, depending on the location of intakes, be affected by an increase in contaminants (nitrate and microorganisms). However most of these supplies are sourced from upper-river reaches where pathogen contamination rather than nitrate is the main issue. Appropriate treatment can remove or deactivate pathogens and it is unlikely that treatment requirements for the upper-river sourced supplies would change significantly under the ZCSP.

The WDC Lower Waihao domestic supply scheme (which includes supply to the Waihao Marae) is sourced from a shallow groundwater bore located near Ferry Rd, Glenavy, which is outside of the modelled SCCS project area. For this supply we don't expect an increase in pathogens because the conversion from border dyke to spray irrigation anticipated in this area in future would be likely to reduce pathogens.

For private domestic supply bores sourcing shallow groundwater, in general it is predicted there would be an increase in the risk of pathogenic microorganisms (e.g. Campylobacter) in shallow groundwater associated with increased animal numbers under the ZCSP. This will make disinfection treatment of supply (which occurs currently) even more important.

In terms of nitrate presence in drinking water the main impacts will be experienced in domestic bores in shallow groundwater. It is estimated that the ZCSP will increase the likelihood that wells will exceed MAV from about 6% currently to around 17% of all wells (around 22 wells) - see groundwater quality Section 4.5.2 later for detail.

There are potentially costs associated with these changes in nitrate concentrations in drinking water. The costs were assessed by assuming that some wells would have to be drilled deeper[26] into uncontaminated water sources, or would require treatment by installation of under bench (reverse osmosis) treatment systems. The costs associated with the need for increased treatment of drinking water for 22 wells is in the order of $44,000-$264,000, which is relatively small at the scale of the SCCS study, although significant for those individuals involved.

4.4.13 Recreational fishery

The effects of the ZCSP on ecological flows and water quality that affect the recreational fishery are described later (Sections 4.5.3 and 4.5.4). In brief the effects compared to current are:

- Positive effect as a result of increased flows in most rivers and streams in time as a result of reduced surface water allocations, improved minimum flows, and greater discharge from groundwater in the lower reaches. The improvement is particularly significant in the Waihao River.
- Positive effects as a result of augmentation flows to the lower Hook River.
- Negative effects in terms of increased loads of contaminants (e.g. nitrate) to water quality.
- Positive effects from the riparian planting, sediment management and other initiatives under the Wainono Restoration Project to mitigate the negative water quality effects above.

However given the current scale of the monetised estimate of the recreational fishery values in the catchment (see earlier Section 3.3.13), the economic impact of these changes will be very small in relation to the other monetised values described in this section.

4.4.14 Other recreational activity

Popular swimming areas include the Otaio River at the Reserve and the Waihao River at sites such as "Black Hole" and "Bradshaws" (or "the Rocks"). The Otaio Reserve is upstream of significant agricultural influence and is expected to remain suitable for recreation under the ZCSP. For the monitored recreation sites on the Waihao River at Black Hole and at Bradshaws Bridge, recreational quality is already compromised or at risk from toxic cyanobacteria blooms. The Black Hole site currently has a 'Very Poor' contact recreation grade based on microbiological indicators. Under the ZCSP the risk of toxic cyanobacteria blooms and faecal contamination at these sites is mitigated by the extensive range of mitigations but it is still uncertain whether the recreation grade will be improved.

4.4.15 Communities and the natural environment

A high quality environment, including good river flows, healthy wetlands and lakes, with good water quality, also brings multiple benefits for the well-being of communities that cannot be quantified in economic terms. These benefits exist across all cultures and are expressed in different ways by different people. From the perspective of manawhenua; "*Water is a taonga that provides for and sustains all life. It is integral to cultural and personal identity and wairua for whanau, hapu and iwi*." (Kaitiakitanga section - Canterbury Water Management Strategy). Water quantity and quality in rivers, groundwater, wetlands and Wainono Lagoon is described in the next sections 4.5 and 4.6, but the value of those aspects to communities is noted here.

4.4.16 Manawhenua values

The merits of the ZCSP for manawhenua values have been considered by manawhenua via the multiple hui of the Tangata Whenua Working Group (TWWG) process and via the hui involvement of Waihao and Arowhenua Rūnanga representatives on the Zone Committee, as described in Section 2.8.6. Using this approach enabled the TWWG to directly contribute (i.e. face-to-face) to the scenario design and assessment process, and to development of the ZCSP.

The technical team has not attempted to summarise the merits of the ZCSP specifically for manawhenua values in this Overview Report because manawhenua will be able to speak to their own values during the planning process that follows notification of the proposed plan in April 2015. However many of the technical indicators reported here have been relevant for the TWWG, Waihao and Arowhenua Rūnanga ZC representatives and Te Rūnanga o Ngāi Tahu in forming their views on the proposed content of the ZCSP.

4.4.17 Management of social change

In order to maximise the potential social benefits of the ZCSP, while minimising the potential negative social effects, it is proposed (by Taylor *et al.,* 2015, Appendix 15) that a programme of social change management should be incorporated into implementation of the non-statutory aspects of the ZCSP (i.e. it is unlikely this could be included in the regional plan). Such a programme would include:

- Community development to maximise the benefits from newcomers in the community, and to resolve any issues that emerge – this sort of collaborative approach is already underway in South Canterbury, providing a good basis to develop further.[33]
- A strategy for enhancing local business and employment opportunities from constructing and operating the HDI and WD through to training and business development.[34]
- A recreation development strategy building on the Waimate District Council's current initiatives.[35]

4.4.18 Overall effects on social wellbeing

An overall assessment of the ZCSP on social and economic wellbeing[36] and the long-term implications for people and communities is provided by Taylor *et al.,* 2015 (Appendix 15) as follows:

[33] http://www.southcanterbury.org.nz/PicsHotel/SouthCanterbury/Brochure/Settling_In_Aoraki.pdf

[34] The facility to run such a strategy is available through the Waimate Resource Centre.

[35] As has already happened with the Waimate Trackways Incorporated group formed following analysis of the Waimate District Council Sport & Recreation Plan.

Economy, business activity, income and employment – The overall effect is expected to be positive due to the longer term positive effect of the new irrigation areas allowed for. Increased work opportunities and incomes are key determinates of health.

Lifelong learning and education – The shift to good management practices and in time to advanced mitigation, will require a constant process of updating skills amongst farmers and rural services such as fertiliser firms, irrigation specialists and veterinarians.

Physical and mental health – There will be increased pressure on farmers and farm families from new policies and planning rules and possibly from downward pressure on farm profitability, especially in the low points of farm commodity cycles. There are some risks to health from declining quality of shallow water tapped for drinking. Health status will benefit from higher incomes and employment.

Outdoor areas, natural environment and open space – Improvements to the water quality in streams and Wainono Lagoon will be a positive outcome, as the lagoon is an important local and cultural resource because of its amenity values.

Lifestyles, leisure and recreation - Improvements to the ecological status of streams and lagoon will flow into the amount and quality of recreational activity locally and for visitors.

Family, social attachment and support – An ongoing trend towards larger farms and increasingly mechanised farm systems, especially with irrigated farming, will see more farm workers and fewer owners, reducing the number of farm families. New social networks will continue to form, as is already happening with migrant workers.

Participation in community and society – Collaborative approaches and community based activities, such as enhancement programmes, will have a positive outcome for community processes and cohesion. Some social tension will continue around major value conflicts over water uses, especially for increased agricultural intensification.

[36] In terms of Resource Management Act (s5) considerations, elements of social wellbeing have been developed by Taylor Baines from international and national sources including the OECD and New Zealand Royal Commission on Social Policy.

4.4.19 Summary of ZCSP effects on social indicators

Table 4-2: Assessment of ZCSP for social indicators: This assessment uses a five-class colour-coded scoring system as described in Section 2.10.3. (Note: Most social indicators allow only an assessment of the *relative merit* of the ZCSP compared to current (i.e. those indicators marked with an [R] below) because there is no absolute (e.g. numeric) threshold defining attainment of most of the ZC's social outcomes. The exception is for drinking water indicators where an assessment is made of the *likelihood* of achieving MAV (absolute) numbers (i.e. those indicators marked with an [A] below). See Appendix 1 for explanation of the link between ZC outcomes and technical indicators, and the basis for scoring the 'current state')

TECHNICAL INDICATORS	Current	ZC Solutions Package		
		2017	2022	2025
Number of farmers and farm workers engaged in dairy, dairy support, horticulture and arable [R]				
On farm and regional employment [R]				
School rolls [R]				
Individual household income [R]				
		*	**	**
Engagement in GMP [R]				
Population in SCCS project area [R]				
Services - health, infrastructure and education. Social connectedness [R]				
Drinking water – nitrate in deep groundwater – test MAV [A]				
Drinking water – nitrate in shallow groundwater – test MAV [A]				
Drinking water – microorganisms in surface & shallow groundwater – test MAV [A]				
Fishing activity in streams and Wainono [R]				
Recreational use [R]				
Game bird hunting in Wainono [R]				

Notes:
Cells showing half colours indicate significant negative and positive impacts for different users, as detailed below.

*Those over the cap for nitrogen allocation will be required to undertake potentially significant mitigation or land use change.

**Those over the cap for nitrogen allocation, and those shifting to alternate water sources with changes to the surface water allocation and environmental flow regimes, may face significant costs.

4.5 Streams, rivers and groundwater

This section is based on technical reports on groundwater quantity (Aitchison-Earl, 2015), groundwater quality (Scott and Etheridge, 2015), ecological flows in rivers (Clarke, 2015) and surface water quality and associated values in rivers and streams (Kelly, 2015); see Appendices 8, 6, 9 and 7 respectively.

4.5.1 Groundwater quantity

There are three main consequences of the ZCSP on groundwater quantity to consider, one of which is positive while the other two effects are potentially negative unless carefully managed. These are:

i) Positive effects of increased flow in most streams

ii) Negative effects of reduced flow in Morvens and Sinclairs drains

iii) Risks associated with allowing swaps from surface takes to deep groundwater

Positive effects on flow in most streams from increased groundwater recharge

As already described for Scenario 2 in Section 3.4.1 the use of Waitaki water (HDI and WD schemes) to double the irrigated area is predicted in most catchments to increase LSR, and to increase runoff from the loess-covered downlands to the river valleys. The resulting additional surface flow in streams near the coast was estimated for the exploratory scenarios and shown in Table 3-4 in the earlier Section 3.4.1. However this analysis has since been updated and so slightly different revised estimates of additional flow are provided in Table 4-3 below. The benefit of this extra flow for habitat and ecological values is described in Section 4.5.3.

Table 4-3: Maximum potential increase in flow (as a result of both increased river recharge and groundwater discharge) to coastal segments of rivers under the ZCSP compared to current. Source: Modified based on Aitchison-Earl 2015 (Appendix 8)

Catchment	Increase in potential groundwater discharge to coastal segments of rivers under the ZCSP compared to current (to nearest 10 L/s)
Otaio River	100
Kohika Stream	20
Horseshoe Bend Creek	< 10
Makikihi River	50
Coastal Creeks (Makikihi-Hook)	< 10
Hook River	70
Wainono Lagoon	0
Waituna Stream	0
Waimate Creek	20
Sir Charles Creek	0
Waihao River (sub)	170
Sinclairs Drain	No increase in irrigated area is assumed under ZCSP. Increased efficiency through conversion from border to spray irrigation is likely to reduce recharge to groundwater over time
Morven Drain	

Negative effects on flow in Morven and Sinclairs due to decreased groundwater recharge

As already described in Section 3.4.1 the conversion of border dyke to spray irrigation in the Morven and Sinclairs catchments in the MGIS area (i.e. the assumed shift from a current 50/50 ratio to 85/15) will significantly reduce drainage losses to groundwater (i.e. land surface recharge (LSR)) and thus could reduce groundwater discharge contribution to stream flows near the coast in Morven Drain and Sinclairs Creek. This is predicted to occur under all scenarios, not just the ZCSP, as border to spray conversions are already occurring as part of improving water use efficiency and reducing contaminant losses. The predicted reduction in flow for these two drains was also shown in Table 3-4 in the earlier Section 3.4.1 and the updated prediction is shown in Table 4-3. The relatively small consequence of this for habitat and ecological values is described in Section 4.5.3.

Risks associated with allowing swaps from surface takes to uncertain deep groundwater

As part of reducing surface water allocation in local rivers and thereby improving environmental flows for ecological, amenity, recreation and manawhenua values, the ZCSP includes an allowance for swapping a limited number of existing surface water takes to deep groundwater (Appendix 3). While this would provide immediate and certain benefit to river environmental flows the long-term sustainability of abstracting further from the deep groundwater resource, and the effect of deep groundwater abstraction on discharge near the coast are both uncertain, as already identified in Section 3.6. Current short-term monitoring has not shown a sustained decline in winter groundwater levels from existing groundwater abstraction; however the period of monitoring is too short to draw any conclusions on aquifer sustainability.

An assessment of this management option is described in detail in Aitchison-Earl 2015 (Appendix 8) and concludes that the SCCS community needs to weigh the potential immediate benefits to surface waters by allowing a swap to deep groundwater in a limited number of cases, against potential risks to the sustainability of the deep groundwater resource. The effects of abstraction on the deep groundwater resource would appear gradually over time as a constant background effect, which may take years to decades to manifest in effects on shallow groundwater and associated coastal streams. Once (and if) effects occur however, they would take a similarly long time to reverse by reducing deep abstraction. Risks for deep groundwater abstraction may include reduced groundwater discharge to support flows in coastal streams, and reduced offshore flow to maintain the salt/fresh water interface and prevent landwards incursion of sea water into the deep aquifer. Continued and increased monitoring of groundwater levels in the Kowai Formation will be integral to future assessment of resource sustainability.

The ZCSP includes allowance for limited swapping of existing surface takes to deep groundwater and manages the risks by:

iii) Not allowing any new consents to take deep groundwater (i.e. capping at current consented allocation);

iv) Requiring existing consented water take volumes to be reviewed through time and revised to reflect actual water use, which current data suggest is significantly less than the current consented allocation volume, thus creating room within the existing consented volume for some limited swapping from surface to deep groundwater to occur;

v) Capping the amount of swapping from surface to deep groundwater that can occur and being clear about the risks that would-be swappers take when they invest in wells knowing the future sustainability of the deep resource is uncertain;

vi) Monitoring of the deep groundwater resource and research to better understand aquifer recharge and discharge so that future plan reviews will be further informed on this aspect.

Summary matrix comparison – groundwater quantity

Table 4-4: Assessment of ZCSP for groundwater quantity-related indicators: This assessment uses a five-class colour-coded scoring system as described in Section 2.10.3. (Note: Groundwater quantity indicators allow only an assessment of the relative merit of the ZCSP against current because there is no absolute (e.g. numeric) threshold defining attainment of the ZC's groundwater quantity outcomes. See Appendix 1 for explanation of the link between ZC outcomes and technical indicators, and the basis for scoring the 'current state')

TECHNICAL INDICATORS	Current	ZC Solutions Package		
		2017	2022	2025
Baseflow at springs increases				
Groundwater levels to support wetlands improved				

4.5.2 Groundwater quality

Effects of ZCSP on shallow groundwater quality for nitrate

The effect of the ZCSP on shallow groundwater quality is described in detail in Scott and Etheridge 2015 (Appendix 6) for both the situation when the nitrogen allocation "flexibility cap" (see Appendix 3 for detail) is 15 kg/ha/yr (i.e. the ZCSP[15]) and if the flexibility cap is increased to 17 kg/ha/yr (the ZCSP[17]).

For the ZCSP[15] the modelling predicts that nitrate concentrations may increase by an average 39% in the shallow groundwater (<30 m deep) across the SCCS area, but the predicted increases range from 18% to 85% (with one outlying exception)[37] (Table 4-5).

For the ZCSP[17] the modelling predicts that nitrate concentrations may increase by an average 45% in the shallow groundwater (<30 m deep) across the SCCS area, but the predicted increases range from 20% to 107% (with one outlying exception, as above) (Table 4-5).

The average shallow groundwater concentrations in three of the catchments (Morven Drain, South Branch Waihao River and Waihaorunga Stream) are predicted to exceed the MAV (see red cells in Table 4-5). The concentration in the Sinclairs catchment is also predicted to be high, approaching the MAV. However as described previously, it is possible that Morven Drain and Sinclairs catchments will continue to receive recharge water from the water races and the Waitaki River, which are not accounted for in the modelling method and which are probably the reason that measured current concentrations are much lower than modelled current. Thus in the Morven and Sinclairs catchments it is possible that nitrate concentrations may stay below the MAV.

Effects on drinking water wells

There is a risk that shallow groundwater (<30 m deep) in some areas may become unsuitable for drinking as a result of intensification and land use change under the ZCSP. We expect deep groundwater (>30 m) will be unaffected but shallow wells could show increased levels of nitrate.

The township of Waimate is served by two deep wells J40/0022 (82 m) and J40/0250 (110 m). Because these wells are screened in the deep groundwater of the Cannington gravels we do not expect them to show impacts of land-use activities under the ZCSP.

There are also a number of private domestic water supply bores including 124 shallow (<30 m) domestic supply wells and 29 deep (>30 m) domestic supply wells in the SCCS area (based on Environment Canterbury records). We do not expect the deep wells to have nitrate issues or to show impacts of land-use activities under the ZCSP. The modelling suggests that the area where shallow groundwater concentrations will exceed MAV is about 14% of the SCCS project area currently, and would increase to 38% under the ZCSP[15] and 39% under the ZCSP[17]. Based on these relative increases we estimate the proportion of the 124 shallow domestic supply wells which exceed the MAV may increase from about 6% currently to 17% under the ZCSP[15] and from 6% to 18% under the ZCSP[17] (i.e. about 22 of the 124 shallow wells in both cases). As described in Section 4.4.12 the costs associated with the need for increased treatment of drinking water (or drilling deeper wells) for those 22 wells is estimated to be in the order of $33,000-$264,000.

Effects on bacteria contamination in groundwater

The ZCSP is predicted to have the same effects as those described previously for Scenario 2 in Section 3.4.2; i.e., a general increase in the risk of pathogenic microorganisms in shallow groundwater caused by increased animal numbers, even though GMPs in Farm Environment Plans and conversions from border to spray irrigation in some catchments would partially mitigate the increase in risk.

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[37] The exception is a small area around Wainono Lagoon which increases by 220%. This is considered an outlier because the large percentage increase results from a small area of poorly drained soils with very low current N loss that is assumed to increase to the flexibility cap of 15 kg/ha/yr. This produces a large percentage increase result even though the actual increase in N load is very small.

Table 4-5: Modelled shallow groundwater nitrate-N concentrations in each catchment for the ZCSP with flexibility cap of 15 kg/ha/yr, and ZCSP with flexibility cap of 17 kg/ha/yr. Coloured shading indicates values that are greater than MAV (11.3 mg/L) (red), between MAV and ½ MAV (5.6 mg/L) (orange), or below ½ MAV (green). (Note: the equivalent predictions for drainage (m^3/year) and nitrate-N load (tonnes/year) can be seen in Scott and Etheridge 2015 (Appendix 6)

	Current	ZCSP[15]			ZCSP[17]		
	Nitrate-N mg/L	Nitrate-N mg/L	Change mg/L	% change	Nitrate-N mg/L	Change mg/L	% change
Coastal Creeks (Makikihi-Hook)	4.7	5.8	1.2	25.0%	6.6	1.9	40.3%
Hook River	5.2	7.1	2.0	37.9%	7.7	2.5	48.0%
Horseshoe Bend Creek	7.9	9.4	1.5	18.6%	9.6	1.7	20.9%
Kohika Stream	5.9	7.8	2.0	33.3%	8.4	2.5	42.9%
Makikihi River	5.2	7.3	2.2	41.9%	7.9	2.7	53.1%
Morven Drain	10.7	17.4	6.7	62.0%	17.4	6.7	62.0%
Otaio River	3.9	6.3	2.4	61.0%	6.7	2.8	71.3%
Sinclairs	8.0	10.4	2.4	29.8%	10.4	2.4	29.8%
Sir Charles	3.9	7.2	3.3	85.6%	8.0	4.2	107.3%
South Branch Waihao River	8.2	12.2	4.0	49.2%	12.4	4.3	52.2%
Waihao River (Waihoarunga)	5.7	9.0	3.3	57.0%	9.3	3.6	62.3%
Waihao River (McCulloughs)	4.4	5.6	1.2	28.5%	5.7	1.4	31.4%
Waihaorunga Stream	7.2	11.8	4.7	64.7%	12.2	5.0	69.8%
Waimate Creek	4.8	8.0	3.2	67.3%	8.5	3.7	77.1%
Wainono Lagoon	2.7	8.8	6.0	220.4%	9.9	7.2	261.7%
Waituna Stream	4.6	7.3	2.7	58.6%	8.2	3.6	77.4%
Total project area	5.9	8.2	2.3	38.8%	8.5	2.6	44.6%
Total Wainono Lagoon^	5.1	7.4	2.3	45.2%	7.8	2.7	52.0%

^ Total Wainono Lagoon catchment is the average of all catchments which may contribute nutrients to the lagoon and include: Coastal Creeks (Makikihi-Hook), Hook River, Sir Charles, South Branch Waihao River, Waihao River (Waihaorunga), Waihao River McCulloughs Bridge, Waihaorunga Stream, Waimate Creek, Wainono Lagoon and Waituna Stream. It is different from the Wainono Lagoon row in the upper part of the table which only includes a small area around the Lagoon

Summary matrix comparison – groundwater quality

Table 4-6: Assessment of ZCSP for groundwater quality-related indicators: This assessment uses a five-class colour-coded scoring system as described in Section 2.10.3. (Note: The groundwater quality-related indicators allow an assessment of the *likelihood* of achieving NZ Drinking Water Standard MAV (absolute) numbers. See Appendix 1 for explanation of the link between ZC outcomes and technical indicators, and the basis for scoring the 'current state'

TECHNICAL INDICATORS	Current	ZC Solutions Package		
		2017	2022	2025
Drinking water – nitrate in deep groundwater - test MAV				
Drinking water – nitrate in shallow groundwater - test MAV				
Drinking water – microorganisms in surface & shallow groundwater - test MAV				

4.5.3 Rivers and streams – ecological flows

There are three main consequences of the ZCSP on ecological flows in rivers and streams, all of which are positive:

i) Improvements to environmental flow and allocation regime rules
ii) Additional positive effects on ecological flows from increased groundwater recharge
iii) Positive effects of flow augmentation

Improvements to environmental flow and allocation regimes

The minimum flows and allocation limits proposed for each catchment in the ZCSP are shown in the tables in Appendix 3. The ZCSP uses a staged approach, beginning with approximately the current minimum flows and allocations, then increasing minimum flows and decreasing allocations through time (i.e. after 2025). To implement these changes the ZCSP relies on new alternative water being made available in future by the HDI and WD schemes, some limited swapping of current surface takes to deep groundwater, and improved water use efficiency.

There are many methods to assess the merits of environmental flow regimes, and several of these methods have been used by Clarke (2015, Appendix 9) in order to use intersecting lines of evidence to assess effects. One of the methods involves simple comparison of the proposed ZCSP minimum flow rules (i.e. the flow at which abstractions must completely cease) against the minimum flow that would occur naturally each year (e.g. the naturalised 7D MALF[38]). This comparison (Table 4-7) provides a high level view of the extent to which the ZCSP minimum flow rules align with manawhenua preferences and ecological flow recommendations of a minimum of about 90% of MALF[39].

In general the ecological assessments show that:

- The ZCSP flow regimes represent a significant improvement through time from the current minimum flow rules, many of which are significantly below 90% of MALF or have no minimum flow rule at all (see earlier Section 3.4.3)
- The ZCSP minimum flows are all near to or greater than 90% MALF (Table 4-7) with the exception of Waimate Creek, the latter situation mitigated by the fact that allocation from Waimate Creek is very small (2 L/s) after 2025.

[38] See Glossary for a definition of MALF.

[39] See Clarke (2015 (Appendix 9) for further detail but the 90% of MALF recommendation derives from several sources including Tipa 2012 (Appendix 16), technical ecology reports and the proposed National Environmental Standard on Ecological Flows and Levels Discussion Document (NES).

- Allocations reduce in most catchments over time (see Appendix 3), some significantly so (e.g. Waihao, Hook and Otaio), which reduces the duration of low flow and improves flow variability, all positive effects for ecological values.
- Partial restrictions imposed in the ZCSP (Appendix 3) also reduce the duration of low flow and improve flow variability, positive for ecological values.

Table 4-7: Comparison of the ZCSP minimum flows (after 2025) with naturalised MALF

Site	Naturalised MALF (L/sec)	ZCSP minimum flow (from 2025) (L/s)	ZCSP minimum flow as percentage of naturalised MALF
Otaio River @ Otaio Gorge recorder site	107	90	84%
Kohika @ Puttick Intake	n/a	2*	n/a
Makikihi @ Teschemaker Valley Rd	21	20	95%
Upper Hook River (above WDC intake)	35	35	100%
Lower Hook River @ Hook Beach Rd	71	64	90%
Waimate Creek @ d/s intake	68	15****	22%
Sir Charles Creek @ Rooney's Bridge	n/a**	100	n/a
Buchanans Creek @ Fletchers Bridge recorder	183	150	82%
Waihao @ McCullochs	354	400	113%
Waihao @ Bradshaws (without MGIS*** discharge)	58	100	172%

*As a residual flow below intake
**Estimate based on few gaugings only is 234 L/s but this is not a reliable estimate
***Morven Glenavy Irrigation Scheme
****Note Waimate Creek has only a very small allocation of 2 L/s after 2025

Positive effects on ecological flows from increased groundwater recharge

The positive effect on river flows arising from increased recharge from groundwater was described previously in the groundwater quantity Section 4.5.1. The benefit is increased base flow in the lower 'gaining' segments of most rivers and streams from around State Highway 1 downstream to the coast, with generally positive flow-on effects for ecology and recreational use of the streams. Effects specific to each catchment are:

- For the Otaio and Hook rivers the additional base flow (Table 4-3) is significant compared to the current MALF and this would benefit aquatic habitat by reducing the frequency, duration and extent of zero flow (dry) reaches during times of low flow stress. However it would not necessarily provide a significant increase in connectivity along the whole length of the river.
- For the Horseshoe Bend Creek and Kohika Stream, which are currently often ponded or even stagnant for long periods in the lower reaches, the additional base flow (Table 4-3) may provide a small benefit to habitat quality.
- For the Makikihi River the predicted additional flow is significant (Table 4-3) but will likely remain sub-surface and offer little benefit for aquatic habitat except perhaps at times in a very short emergent reach very near the coast.
- For Waimate Creek the predicted flow increase is relatively small (Table 4-3) and will likely remain sub-surface with little benefit for aquatic habitat.
- For the Waihao River the predicted additional base flow is small (around 30% of MALF) but nonetheless may still benefit aquatic habitat in the lower reaches during times of low flow stress.

- For the Waituna Stream, Waihaorunga Stream, Buchanans and Sir Charles creeks, there is no predicted increase in base flow (Table 4-3).
- For Sinclairs and Morvens Drain there is likely to be a significant reduction in base flow due to decreased contribution to groundwater from border dyke irrigation that is assumed to be mostly converted to spray irrigation in future. This is a negative effect on ecological values in these waterways. These two waterways have modest ecological values compared to the other mentioned rivers and streams across the SCCS area.

Maintenance of wetland habitat and habitat suitable for the nationally critically threatened Canterbury Mudfish is closely related to high groundwater levels in relevant areas. The increased base flow described above (and higher groundwater levels generally) will be positive for maintaining and increasing potential Mudfish habitat under the ZCSP, although the risk that increased water levels could increase connection between Mudfish habitat and waterways containing predatory trout and eels will need to be monitored and managed.

Effects of flow augmentation
The augmentation flow (approximately 1 m^3/s) through Wainono Lagoon via the lower Hook River is predicted to have a significant beneficial effect on aquatic habitat in the augmented lower reach of the Hook River (assumed to be below State Highway 1). The flow augmentation is expected to eliminate the periods of zero flow (i.e. drying) in that reach and improve water quality, thus benefiting trout and native fish populations as well as the invertebrate communities they feed on.

As discussed previously a potential negative effect of augmentation is the introduction of the invasive alga Didymo *(Didymosphenia geminata)* to the Hook catchment, which could have negative effects on this short reach. However the relatively close proximity of the Hook River to the Waitaki River and to the MGIS irrigation network (which carries Waitaki water and therefore Didymo) means that the Hook River is already highly likely to be exposed to the introduction of Didymo by movement of people, vehicles and birds. It is unknown whether Didymo would establish at nuisance levels if introduced to the Hook River.

Summary matrix comparison – ecological flows

Table 4-8: Assessment of ZCSP for ecological flow-related indicators: This assessment uses a five-class colour-coded scoring system as described in Section 2.10.3. (Note: Some ecological indicators allow only an assessment of the *relative merit* of the ZCSP compared to current (i.e. those marked with an [R] below), while some ecological indicators allow an absolute assessment to be made of the *likelihood* of the ZCSP achieving numeric outcomes defined in the LWRP (i.e. those marked with an [A] below). See Appendix 1 for explanation of the link between ZC outcomes and technical indicators, and the basis for scoring the 'current state'. Note also that this assessment does take account of some of the water quality related effects described in the next section 4.5.4)

TECHNICAL INDICATORS	Current	ZC Solutions Package		
		2017	2022	2025
Flows in Streams - high minimum flows compared to natural 7d MALF [R]	[yellow]	[yellow]	[light green]	[dark green]
Flows in streams – high variability and frequency of freshes [R]	[orange]	[orange]	[orange] ↑Hook	[light green]
Flows in streams – low intermittence (dry length, frequency, duration) [R]	[orange]	[orange]	[yellow]	[light green]
Large amount of habitat for key fish species (compared to % of habitat at natural MALF) [R]	[yellow]	[yellow]	[light green]	[dark green]
High diversity and abundance of aquatic invertebrates - test LWRP outcomes (QMCI)[A]	[red]	[red]	[red] ↑QN↓QL	[yellow]
High diversity and abundance of native fish [R]	[yellow]	[yellow]	[yellow] ↑QN↓QL	[light green]
Provision of suitable mudfish habitat [R]	[yellow]	[yellow]	[light green]	[light green]
Healthy periphyton and macrophyte communities - test LWRP outcomes (% cover) [A]	[red]	[red]	[red] ↑QN↓QL	[yellow]
Ensure hydrological requirements for wetlands are met [R]	[yellow]	[yellow]	[light green]	[light green]

Notes:
↑QN↓QL indicates an improvement in water quantity (ecological flows) but a decline in water quality
↑Hook indicates an improvement in Hook River only

4.5.4 Rivers and streams - water quality

Land use change and intensification under the ZCSP has several different implications for dissolved nutrients (N and P), nitrate toxicity, plant and algae indicators, sediment, microorganisms, and related environmental values in the hill-fed and lowland spring-fed streams in the SCCS area.

The current risk to various in-stream ecological and environmental values has been estimated by Kelly 2015 (Appendix 7) by looking at data for nutrients, periphyton and macrophytes, and assessing these data against national guidelines for nitrate toxicity and suitability for contact recreation. To assess the effects of the ZCSP, modelled nutrient changes and modelled plant and periphyton responses were compared with current measured nutrients and current ecological indicators. The risk-based assessment results are shown in Table 4-10 (Hill-fed rivers) and Table 4-11 (Spring-fed streams). The messages to take from these results are discussed below.

There are several key aspects of the ZCSP to consider for water quality related values:

i) Negligible effects on streams in the hills and bush-covered country;

ii) Significant potential negative effects on water quality associated with land use change and intensification (particularly nitrogen, phosphorus, sediment and microorganisms), which the ZCSP attempts to mitigate in several ways as follows;

iii) Mitigation by setting nitrogen load limits and requiring GMP for nitrogen loss (or better in some cases) and other good management practices for phosphorus, sediment and microorganisms via Farm Environment Plans;

iv) Mitigation by a suite of catchment initiatives such as riparian stabilisation and planting, erosion control, targeted sediment removal, river and wetland habitat enhancement, all under an extended Wainono Restoration Project;

v) Mitigation by increasing ecological flows in rivers and streams, via flow and allocation rules and via flow from increased groundwater recharge under increased irrigation;

vi) Mitigation by supplying flow augmentation to Wainono Lagoon via the lower Hook River

Negligible effects on streams in the hills and bush-covered country
Currently, most reaches of hill-fed streams located directly downstream of the Hunter Hills and bush-covered country meet pLWRP outcomes for periphyton, aquatic biodiversity/fish values, aesthetics and contact recreation. This is not expected to change under the ZCSP.

Negative effects on water quality associated with land use change and intensification
The use of Waitaki water (HDI and WD schemes) to double the irrigated area under the ZCSP is predicted in most catchments to significantly increase N and P concentrations in shallow groundwater and in runoff from the loess-covered downlands to the river valleys. This is predicted to increase N and P concentrations in most rivers and streams in the SCCS area. Consequently, unless significant mitigations are employed, all environmental values assessed (i.e. periphyton, macrophytes, aquatic biodiversity/fish values, aesthetics and contact recreation) in Hill-fed rivers and Spring-fed streams within the HDI and WD scheme areas are likely to be at further risk, or not change from a state that currently does not support these values at the level of the pLWRP outcomes (see assessment of Scenario 2a in Tables 3-11 and 3-12 in earlier Section 3.4.4).

Mitigations: N limits, GMP, Farm Environment Plans, riparian management, habitat restoration
Under the numerous non-flow related mitigations proposed in the ZCSP, there is still predicted to be a risk to several environmental values in hill-fed river sites because of the predicted increase in nitrate concentrations (Table 4-10). Shading, provided by proposed extensive riparian management could offset the risk of increases of periphyton blooms at sites located on small narrow rivers or lead to no net change in this risk. However, a further risk of blooms is expected at sites in large and wider rivers in the schemes' command area because riparian planting is not expected to provide sufficient shading. In addition, contact recreation at popular swimming sites in the Waihao River is likely to remain an issue because of the risk of nuisance periphyton/cyanobacteria blooms and faecal contamination (Table 4-10).

There will be reduced risk to stream health and trout habitat at most sites located on small hill-fed rivers because of proposals to manage sediment and implement Farm Environmental Plans. Stream health and trout habitat and angling at sites on the larger rivers, such as the Waihao and Otaio, are also likely to be at reduced risk. In the lower Hook River, there may initially be some risk to stream health from chronic nitrate toxicity but longer term increases in flow are expected to dilute nitrate concentrations, thus reducing the risk there (Table 4-10).

In spring-fed river sites, the non-flow related mitigations of ZCSP may partly offset or balance the increased risk of land use intensification. For example, sediment management should reduce the risk of nuisance macrophyte growths and improve physical habitat quality for invertebrates and fish. However, the modelled increase in nitrate poses a further risk of chronic nitrate toxicity, nuisance periphyton blooms, and their negative effects on associated environmental values. Therefore, most environmental outcomes in spring-fed streams are likely to remain "At Risk" (Table 4-11).

Additional mitigation by increasing ecological flows
Under the full ZCSP the increase to minimum flows and surface flow volumes is significant in the long term (i.e. beyond 2015). This is expected to benefit environmental values as described previously in Section 4.5.3 and further offset some of the negative water quality effects described above. Thus on balance with the negative effects and risks described above, the risk of not achieving periphyton and macrophyte thresholds and associated environmental values in most hill-fed and spring-fed stream sites is expected to be reduced (Tables 4-10 and 4-11). However it is still unlikely they will be

achieved at all sites in the short to medium term, and not certain they will be achieved at all sites even in the long term (Table 4-10; Table 4-11; Table 4-9).

Mitigation by flow augmentation
Flow augmentation in the Lower Hook River will have a beneficial effect on environmental values in the augmented reach of the Hook River (assumed to be below State Highway 1). A reduction in the risk of nuisance periphyton, and improved benthic biodiversity and fish communities are expected in this short reach (Table 4-10).

Summary matrix comparison – surface water quality

Table 4-9: Assessment of ZCSP for surface water quality-related indicators: This assessment uses a five-class colour-coded scoring system as described in Section 2.10.3. (Note: Some ecological indicators allow only an assessment of the *relative merit* of the ZCSP compared to current (i.e. those marked with an [R] below), while some ecological indicators allow an absolute assessment to be made of the *likelihood* of the ZCSP achieving numeric outcomes defined in the LWRP (i.e. those marked with an [A] below). See Appendix 1 for explanation of the link between ZC outcomes and technical indicators, and the basis for scoring the 'current state'.

TECHNICAL INDICATORS	Current	ZC Solutions Package		
		2017	2022	2025
High diversity and abundance of aquatic invertebrates – test LWRP outcomes (QMCI) [A]			↑QN↓QL	
High diversity and abundance of native fish [R]			↑QN↓QL	
Healthy periphyton and macrophyte communities – test LWRP outcomes (% cover) [A]			↑Hook	
Nitrate-N toxicity for aquatic species (test at least 80% level protection) [A]				
Water clarity and suspended sediment [R]				
Sedimentation of stream beds [R]				
Periphyton risk for recreation & benthic biodiversity – test LWRP outcomes (% cover) [A]			↑Hook↓Rest	
Benthic cyanobacteria risk for recreation – test LWRP outcomes (% cover) [A]			↑Hook↓Rest	
Macrophyte risk for recreation & benthic biodiversity – test LWRP outcomes (% cover) [A]				
Suitability for contact recreation – microbial quality – test LWRP outcomes (SFRG) [A]				
Riparian condition (stock exclusion and vegetation) [R]				

Notes:
↑QN indicates an improvement in terms of water quantity (ecological flows);↓QL indicates a decline in terms of water quality; ↑Hook indicates an improvement in Hook River only

Table 4-10: Hill-fed rivers: Assessment of whether ecological outcomes are currently achieved (current WQ state) or likely to be achieved under the ZCSP (compared to Scenario 1a). For detail see Kelly 2015 (Appendix 7)

ACHIEVES…	Current water quality state			Scenario1a			ZCSP (relative to Scenario 1a)		
Nuisance periphyton threshold met (weighted composite cover <30%)	**YES** Bush tribs., Upp. Hook Waimate-Hunter rd. & L. Hook at Beach Rd, Lower Waihao at Bradshaws	**At RISK** Kohika Backline rd. & SH1; Esk Valley St. Backline rd.	**NO** Hook Stream Waimate-Hunter rd., Waihao McCulloughs	**YES** Bush tribs, Upp. Hook River Waimate-Hunter rd	**At RISK** Kohika; Esk Valley St. Horseshoe bend Ck. Lower Hook at Beach Rd, Waihao at Bradshaws , Otaio at SH1	**NO** Hook Stream Waimate-Hunter rd., Waihao McCulloughs & SH1	**YES** Bush tribs, Upp. Hook River Waimate-Hunter rd	**Reduced RISK** Makikihi Milnes rd., Hook Stream Waimate-Hunter rd., Kohika; Esk Valley St. Horseshoe bend Ck. Hook Beach rd., **At RISK** Waihao at Bradshaws; Otaio SH1	**NO** Waihao McCulloughs
Visual aesthetics/ amenity/ recreation (WCC indicator/ cyanobacteria blooms)	**YES** Bush tribs.; Upp. Hook Waimate-Hunter rd. & L. Hook at Beach Rd, Lower Waihao at Bradshaws.	**At RISK** Kohika Backline rd. & SH1; Esk Valley St. Backline rd.	**NO** Hook Stream Waimate-Hunter rd., Waihao McCulloughs to SH1	**YES** Bush tribs , Upp. Hook River,	**At RISK** Kohika; Esk Valley St. Horseshoe bend Ck. Hook at Beach Rd, Waihao at Bradshaws , and Otaio river at SH1	**NO** Hook Stream Waimate-Hunter rd., Waihao McCulloughs & SH1	**YES** Bush tribs, Upp. Hook River,	**Reduced RISK** Makikihi Milnes rd., Hook Stream; Kohika; Esk Valley St. Horseshoe bend Ck. Lower Hook, **At RISK** Waihao at Bradshaws; Otaio SH1	**NO** Waihao McCulloughs and SH1
Suitable for contact recreation (SFRG/ microbial contamination/ cyanobacteria)	**YES** Otaio gorge	**At RISK** Waihao Bradshaws	**NO** Waihao at Black Hole	**YES** Otaio gorge		**↓RISK** Mid-Lower Waihao (Black Hole; Bradshaws)	**YES** Otaio gorge		**Reduced RISK** Mid-Lower Waihao (Black Hole; Bradshaws)
Stream Health (obs. QMCI <5, WCC indicator/ N toxicity)	**YES** Bush tribs., Upp. Hook at Waimate-Hunter rd.	**At RISK** Kohika Backline rd. & SH1; Esk Valley St. Backline rd.	**NO** Hook Stream Waimate-Hunter rd. & Gunns rd.; Waihao McCulloughs; Hook Beach rd., Kohika & Otaio at SH1	**YES** Bush tribs , Upp. Hook River,	**At RISK** Kohika Backline rd, Esk Valley St.,. Lower Hook & Waihao Rivers	**NO** Hook Stream Waimate-Hunter rd. & Gunns rd.; Waihao McCulloughs; Hook Beach rd., Kohika & Otaio at SH1	**YES** Bush tribs , Hook R. Waimate-Hunter rd.	**Reduced Risk** Makikihi Milnes rd.; Kohika, Otaio, Esk Valley St., Horseshoe bend Ck., Hook Stream Gunns rd. & Waimate-Hunter rd., Hook R. Beach rd. & Waihao McCulloughs & Bradshaws	
Suitable trout habitat & angling (response to WCC & macrophyte indictors/ QMCI/ N toxicity)	**YES** Bush tribs., Upp. Hook Waimate-Hunter rd., Waihao Bradshaws	**At RISK** Hook Stream, Kohika, Esk Valley St; Waihao McCulloughs, Hook, Kohika and Otaio Rivers		**YES** Bush tribs , Hook Waimate-Hunter rd., Waihao Bradshaws	**At RISK** Hook Stream Gunns rd. & Waimate-Hunter rd., Kohika; Esk Valley St. Horseshoe bend Ck. Lower Hook at Beach Rd, Waihao at McCulloughs & Bradshaws, Kohika and Otaio at SH1		**YES** Bush tribs , Hook R. Waimate-Hunter rd., Waihao Bradshaws		**Reduced Risk** Hook Stream Gunns rd. & Waimate-Hunter rd., Kohika; Esk Valley St. Horseshoe bend Ck. Lower Hook at Beach Rd, Waihao at McCulloughs & Bradshaws, Kohika and Otaio at SH1
Nitrate toxicity: 99 % aquatic biodiversity protection (~1.5 mg/L)	**YES** Bush tribs., Upp. Hook River Waimate-Hunter rd., Otaio River SH1; Waihao McCulloughs	**NO** Hook Stream Gunns rd.; Hook Beach rd. & Kohika rivers; Waihao Bradshaws		**YES** Bush tribs., Hook River Waimate-Hunter rd., Otaio SH1; Waihao McCulloughs	**NO** Hook Stream Gunns rd.; Hook Beach rd., Kohika SH1; Waihao Bradshaws		**YES** Bush tribs., Hook River Waimate-Hunter rd., Otaio SH1; Waihao McCulloughs		**NO** Hook St.; Hook Beach rd. & Kohika SH1, Horseshoe bend Ck.; Otaio SH1; Waihao Bradshaws, Esk Valley St.
Nitrate toxicity: 95 % aquatic biodiversity protection (~3.5 mg/L)	**YES** Bush tribs., Hook River Waimate-Hunter rd., Otaio SH1, Kohika Backline rd. & SH1, Waihao McCulloughs & Bradshaws	**NO** Hook Stream at Gunns rd.; Lower Hook at Beach rd.		**YES** Bush tribs., Hook River Waimate-Hunter rd., Otaio SH1; Waihao McCulloughs & Bradshaws	**NO** Hook Stream at Gunns rd.; Lower Hook at Beach rd., Kohika SH1		**YES** Bush tribs., Upp. Hook River, Otaio River; Upp.Waihao McCulloughs & Bradshaws		**NO** Hook Stream; Hook Beach rd. & Kohika SH1
Nitrate toxicity: 90 % aquatic biodiversity protection (~5.6 mg/L)	**YES** All			**YES** All			**YES** All except lower Hook		**At RISK** Hook R. Beach rd.
Nitrate toxicity: 80 % aquatic biodiversity protection (~9.8 mg/L)	**YES** all			**YES** All			**YES** All		
Nitrate toxicity: drinking water (~11.3 mg/L)	**YES** All			**YES** All			**YES** All		

Table 4-11: Spring-fed plains streams: Assessment of whether ecological outcomes are currently achieved (current WQ state) or likely to be achieved under the ZCSP (compared to Scenario 1a). For detail see Kelly 2015 (Appendix 7)

ACHIEVES…	Current water quality State		Scenario1a		ZCSP (relative to Scenario 1a)	
Nuisance macrophyte threshold met (total macrophyte cover < 50%)	**YES** Merrys Stream SH1	**NO** Buchanans u/s Waihao, Sir Charles Haymans rd., Hook Drain Beach rd., Waituna Stream SH1	**YES** Merrys Stream SH1	**NO** Buchanans u/s Waihao, Sir Charles Haymans rd., Hook Drain Beach rd., Waituna Stream SH1	**YES** Merrys Stream SH1	**REDUCED RISK** Buchanans u/s Waihao, Sir Charles Haymans rd., Hook Drain Beach rd., Waituna Stream SH1
Nuisance periphyton threshold met (weighted composite cover <30%)	**YES** Buchanans Ck u/s Waihao confl.; Merrys Stream SH1	**NO** Sir Charles Ck. Haymans rd.	**At RISK** Buchanans, Merrys Stream, Hook Drain, Waituna Stream	**NO** Sir Charles Haymans rd.	**REDUCED RISK** All	
Visual aesthetics/ amenity/ recreation (WCC & macrophyte indicators/ cyanobacteria blooms)	**YES** Merrys Stream SH1	**NO** Buchanans u/s Waihao, Sir Charles Haymans rd., Hook Drain Beach rd., Waituna Stream SH1	**YES** Merrys Stream SH1	**NO** Buchanans u/s Waihao, Sir Charles Haymans rd., Hook Drain Beach rd., Waituna Stream SH1	**REDUCED RISK** All	
Stream Health (obs. QMCI <4.5, WCC & macrophyte indicators/ N toxicity)	**NO** Buchanans u/s Waihao, Sir Charles Haymans rd., Hook Drain Beach rd., Waituna Stream SH1		**NO** Buchanans u/s Waihao, Sir Charles Haymans rd., Hook Drain Beach rd., Waituna Stream SH1		**REDUCED RISK** All	
Suitable trout habitat & angling (response to WCC & macrophyte indicators/ QMCI/ N toxicity)	**At RISK** Buchanans u/s Waihao confl., Sir Charles Haymans rd.	**NO** Hook Drain Beach rd., Waituna Stream SH1	**At RISK** Buchanans u/s Waihao, Sir Charles Haymans rd.	**NO** Hook Drain Beach rd., Waituna Stream SH1	**REDUCED RISK** All	
Nitrate toxicity: 99 % aquatic biodiversity protection (~1.5 mg/L)	**NO** All		**NO** all		**NO** All	
Nitrate toxicity: 95 % aquatic biodiversity protection (~3.5 mg/L)	**YES** Buchanans Ck u/s Waihao confl.; Merrys Stream SH1	**NO** Sir Charles Haymans rd., Hook Drain Beach rd.	**YES** Buchanans Ck u/s Waihao confl.; Merrys Stream SH1	**NO** Sir Charles Haymans rd., Hook Drain Beach rd.	**YES** Buchanans Ck u/s Waihao confl.; Merrys Stream SH1	**NO** Sir Charles Haymans rd., Hook Drain Beach rd.
Nitrate toxicity: 90 % aquatic biodiversity protection (~5.6 mg/L)	**YES** all		**YES** all		**YES**	**NO** S Sir Charles Haymans rd., Hook Drain Beach rd.
Nitrate toxicity: 80 % aquatic biodiversity protection (~9.8 mg/L)	**YES** all		**YES** all		**YES** All	
Nitrate toxicity: drinking water (~11.3 mg/L)	**YES** all		**YES** all		**YES** All	

4.6 Wainono Lagoon

There are several key aspects of the ZCSP to consider for effects on Wainono Lagoon as follows:

i) Significant potential negative effects on Wainono water quality, associated with land use change and intensification under the new HDI and WD irrigation schemes (particularly for nitrogen, phosphorus, sediment and microorganisms), which the ZCSP then attempts to mitigate and enhance in several ways as follows;

ii) Setting nitrogen load limits and requiring a minimum of GMP for nitrogen loss (and better than GMP in some cases) and other good management practices for phosphorus, sediment and microorganisms via Farm Environment Plans in the catchment;

iii) Flow augmentation to Wainono Lagoon;

iv) A suite of catchment-scale initiatives such as riparian stabilisation and planting, erosion control, targeted sediment removal from tributaries, river and wetland habitat enhancement, all under an extended Wainono Restoration Project;

v) Increasing ecological flows in tributaries (e.g. the Waihao and Hook rivers in particular), via flow and allocation rules and via flow from increased groundwater recharge due to increased irrigation in the catchment;

4.6.1 Negative effects of land use change on water quality

The HDI and WD schemes doubling of the irrigated area under the ZCSP will lead to land use change and intensification that is predicted to increase particularly nitrogen and to a lesser extent phosphorus concentrations in shallow groundwater and in runoff from the loess-covered downlands to the river valleys. Thus increased nitrogen and to a lesser extent phosphorus loads are predicted in tributaries of Wainono Lagoon.

Consequently, unless significant mitigations are employed, water quality and associated values in Wainono Lagoon would be expected to deteriorate. For example predictions provided earlier for Scenario 2a suggested the load of N and P to the lagoon would increase by around 60% (total nitrogen - TN) and 13% (total phosphorus - TP) respectively. Wainono Lagoon is already highly nutrient enriched (current TLI 6.5) and these load increases, if unmitigated, would further degrade water quality to an estimated TLI score of around 7.0 (Figure 4-4). This would lead to a suite of exacerbated adverse water quality-related effects as previously described in Section 3.5.3 including:

- An increased risk of algal blooms and associated risk of negative effects on lake visual aesthetics (e.g. green colour seen in Figure 3-11);
- A small increase in the risk of toxic blooms that may affect recreation and mahinga kai food gathering opportunities;
- More frequent exposure of aquatic life to periods of stress due to low dissolved oxygen and therefore;
- Increased risk of adverse effects on aquatic life including invertebrates and fish (e.g. eels, whitebait, flounder and mullet) in the lagoon and in the lower Waihao River and Box area;
- Loss of native macrophyte beds which have been sparse or absent in recent years, although factors other than nutrients also influence macrophyte beds (e.g. water clarity, sediment, wind disturbance and grazing);
- If the loss of native macrophytes was permanent this would reduce biological species diversity and also reduce the diversity of habitat for invertebrates, fish and birds, and make the lagoon more vulnerable to algal blooms and other threats to water quality;
- Some bird species (e.g. waterfowl – ducks, geese and swans) feed on macrophytes and so this could also affect numbers of these birds feeding in the lagoon;
- Further enrichment and general degradation of the lagoon environment may have a significant impact on manawhenua. Any adverse effect on the use of these waters for mahinga kai has a significant flow-on effect. It may make it difficult to continue traditional practices, including the

passing on of mātauranga Māori from generation to generation, and the ability to provide visitors (manuhiri) with locally gathered kai;

- Poorer water quality and the increased risk of nuisance algae blooms could impact the game-bird hunting experience for hunters.

4.6.2 Mitigation: Nitrogen limits and good farm management practices

In order to constrain nitrogen load and allow for mitigation of adverse effects on water quality, the ZCSP contains nitrogen load limits for the Waihao Wainono catchment and a nitrogen allocation framework that allocates the catchment nitrogen load out at the level of individual farming properties, and to existing industrial point dischargers. This defines the responsibility of all individual users to collectively stay within the catchment nitrogen load limit.

The catchment nitrogen load limit in Proposed Variation 3 to the LWRP (Section 15) has been calculated by summing the estimated nitrate losses from all land in the Waihao-Wainono catchment under a modelled scenario that includes all of the assumptions of the ZCSP (see Lilburne 2015, Appendix 4 for detail of the method). Those load estimates are shown (Table 4-12) for two ZCSP scenarios, one reflecting the initial situation where the nitrogen flexibility cap is set at 15 kg/ha/yr - the ZCSP[15], and the second where the flexibility cap may be increased in future to 17 kg/ha/yr - the ZCSP[17], the latter only being allowed if monitoring shows that Wainono Lagoon outcomes are being met[40]. The methodology used to arrive at these flexibility cap numbers is described in Norton *et al.,* 2015; Appendix 22). Note that similar estimates have been calculated for catchment nitrogen load limits for all the other catchments in the SCCS area and these are documented in Lilburne 2015 (Appendix 4); all load estimates have been made using the Canterbury Look-up Table (LUT) OVERSEER® v6 Patch.

It is important to be clear, as already described in Section 3.5.6, that the estimated loads in Table 4-12 are the modelled diffuse 'agricultural load' lost from the root zone across the catchment and this does not include the load from point discharges. An estimate of point source loads of nitrogen and phosphorus for each catchment is provided in Table 3-16 (Section 3.5.6).

In combination the diffuse agricultural load *and* point source load make up the 'manageable' (i.e. human influenced) portion of the source N load to Wainono Lagoon. The catchment load limit defined by Sub-Regional Section 15 of the pLWRP applies to this 'manageable' source load. The N load that *actually* enters Wainono Lagoon (i.e. the receiving environment load) is what remains of the combined source loads after attenuation (e.g. microbial and chemical denitrification processes and uptake by stream periphyton, macrophytes and other plants), and will also include N load from lagoon birds[41]. For modelling and limit setting purposes, the natural background N load and proportional rate of assimilation/uptake in the catchment have been assumed to remain constant through all scenarios including the ZCSP[15] and ZCSP[17], as described in the methods in Section 2.8.2.

There are many implications of using nitrogen load limits based on modelled estimates (e.g. using OVERSEER®) of the manageable diffuse load lost from the root zone. A key benefit is that the allocation framework and implementation of that framework can (and must) also use the same model (and same version) (i.e. OVERSEER®) to estimate the losses of each individual farm in order to test whether individual allowances are being met and thus the catchment load limit achieved. Further implications of this for regional planning are discussed later in Section 6.

[40] Note this is as agreed for the NARG nitrogen allocation framework adopted by the ZC – see Appendices 3 and 22 for detail of how this was derived.

[41] The N load from lagoon birds has been estimated to be currently approximately 3 tonnes/year TN, which is a minor proportion (less than 1%) of the total estimated diffuse agricultural N load lost from the root zone.

Table 4-12: Estimated Trophic Level Index (TLI) and modelled agricultural nitrate-N load and concentration in drainage[42] water for the Wainono Lagoon catchment under the ZCSP[15] and ZCSP[17] scenarios, and the modelled 'current state' and earlier Scenario 2b for comparison. Source of nitrate load and drainage water estimates is Scott and Etheridge (2015; Appendix 6) who used outputs from Lilburne (2015; Appendix 4) based on the Canterbury Look-up Table (LUT) OVERSEER® v6. Source of approximate TLI estimates is the method of Sutherland and Norton (2011), (Appendix 18), subsequently supported by the modelling of Abell *et al.,* 2015 (Appendix 19)

	Modelled 'current state'	ZCSP[15][1]	ZCSP[17][1]	Scenario 2b
TLI_3 score (annual average)	6.5	<6.0	<6.0	<6.0
Nitrate-N load (tonnes/year) (% increase from 'modelled current' in brackets)	690	1105 (60%)	1156 (67%)	1101 (60%)
Average Nitrate-N concentration in drainage water (mg/L) (% increase from 'modelled current' in brackets)	5.1	7.4 (45%)	7.8 (52%)	7.4 (45%)
Drainage[39] water (M^3/year) (% increase from 'modelled current' in brackets)	136 million	149 million (10%)	149 million (10%)	149 million (10%)

[1] ZCSP[15] and ZCSP[17] refers to the Zone Committee Solutions Package with flexibility caps of 15 and 17 kg/ha/yr respectively

4.6.3 Mitigation: Flow augmentation

The ZCSP includes use of Waitaki water to augment flow through Wainono Lagoon via the Hook River and this could significantly mitigate the effects of the increased nutrient load and the related water quality deterioration, by diluting lagoon nutrient concentrations with very low nutrient water from the Waitaki River, as described previously in section 3.5.3. Flow augmentation could potentially improve water quality and related aesthetic and ecological values to better than the current situation, potentially sufficient to achieve the proposed LWRP outcome of a TLI less than 6.0 (Figure 4-4 and Table 4-12) and also reduce dissolved oxygen and temperature fluctuations, and lessen the risk of adverse cyanobacteria blooms. A TLI of 6.0 is still a very nutrient-enriched state for a lake; however it is a significant improvement on the current situation. See Sutherland and Norton, 2011 (Appendix 18) and Abell *et al.,* 2015 (Appendix 19) for detailed assessments of the merits of augmentation.

Flow augmentation may also offer opportunities to help reduce sediment accumulated on the lagoon bed and could increase the chances of maintaining and enhancing macrophyte beds, both of which would be positive for aesthetic and ecological values. The lower the TLI that can be achieved (i.e. further below 6.0) the better the water quality and the lower the risk to related aesthetic and ecological values.

There are risks associated with flow augmentation that would need to be managed, such as avoiding sediment-laden source water when the Waitaki River is in flood. It is also imperative that functional opening is maintained at the Waihao Box in order to pass the additional flow, avoid any increase in the incidence or severity of flood events, and maintain fish passage to and from the sea at appropriate times (spring and autumn in particular). Flow augmentation would enhance the risk of spreading didymo and invasive macrophytes (e.g. *Lagarosiphon major*) from the Waitaki catchment into the Hook River and Wainono Lagoon, while at the same time reducing the salinity of the lagoon, making the habitat more suitable for *Lagarosiphon*. The risk of spreading invasive species is already present

[42] The term "drainage" is used here and throughout the report as defined in the Glossary to mean "The downwards movement of water though the soil profile, determined by the soil properties and gravity". Drainage volume estimates are derived from OVERSEER®.

via the existing Waitaki water flow augmentation to the lower Waihao River. Nonetheless all of these concerns will need to be addressed as part of a detailed assessment into actually delivering augmentation now that it is formally included as part of the ZCSP.

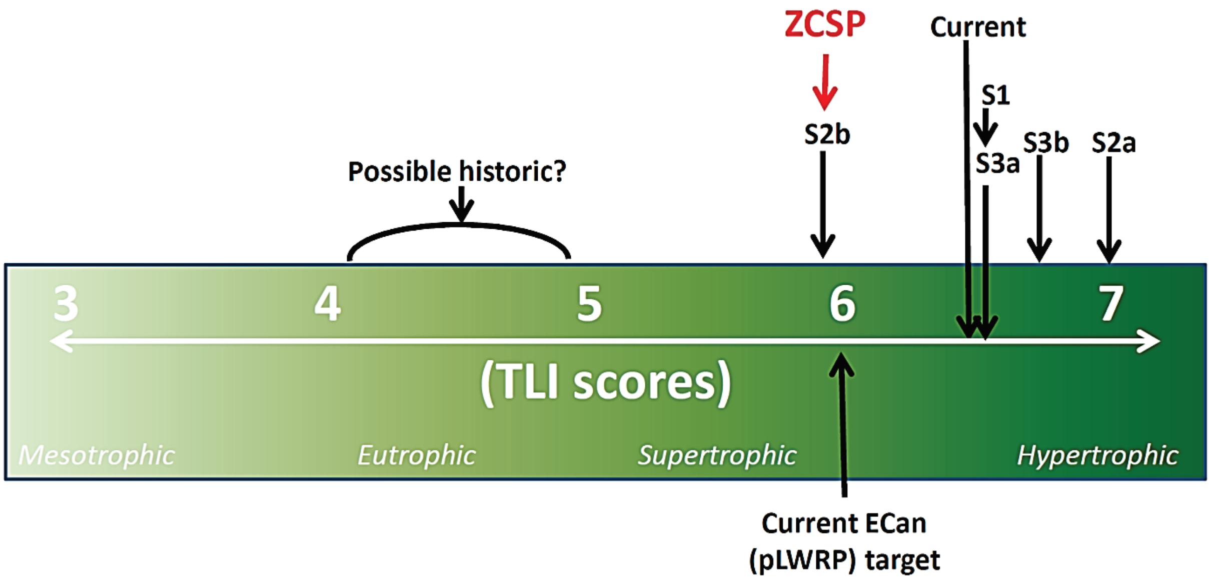

Figure 4-4: Illustration of Trophic Level Index (TLI) scale showing relative position of current state (today), future scenarios 1 (a, b, c), 2 (a, b), 3 (a, b), estimated historic (pre-European) state, the pLWRP outcome target, and the Zone Committee Solution Package (ZCSP)

4.6.4 Extension of the Wainono Restoration Project

The ZCSP also includes a number of catchment initiatives that could be delivered by an extended Wainono Restoration Project (WRP)[43]. As described previously the WRP was established in 2012 when the Ministry for the Environment (MfE) awarded the project $800,000 from the Fresh Start for Freshwater Clean-up Fund over a two year period (2012-2014). The work is now well advanced and is expected to continue benefiting the lagoon over the next few decades under all scenarios. For example, sediment trapping techniques (e.g. on-farm bunds) and stock exclusion are expected to reduce sediment (and therefore also phosphorus) load to the lagoon which is a significant water quality issue currently (Figure 3-10). An increase in riparian planting and wetland enhancement activities around the lagoon will also improve biodiversity and increase recreational value, as well as assist with efforts to improve water quality.

As a result of community discussions that have arisen during the SCCS project, Environment Canterbury, with the support of its partners in the WRP, the Lower Waitaki Zone Committee and Te Rūnanga o Waihao, is seeking funding for implementation of a proposed extended restoration plan for the Wainono Lagoon. A funding request was made to Government in 2014 for the five years from 2014-2018 and is currently being considered. This proposal is supplementary to the existing restoration project and would include:

- Extension of the current sediment and nutrient reduction and riparian management initiatives to all lagoon tributaries;
- Securing retirement of lake margin land around the perimeter of the lagoon;
- Lake margin remediation, buffer establishment and access;

[43] See website http://ecan.govt.nz/advice/biodiversity/area/lower-waitaki/Pages/wainono.aspx

- A denitrification facility (e.g. wetland);
- Catchment land, water and ecological advice and support

This extension to the WRP would further offset the negative water quality effects described in Section 4.6.1 above and would significantly improve on the current ecological, amenity, recreation and cultural values of Wainono Lagoon.

4.6.5 Increased ecological flows

The ZCSP includes significant increases to minimum flows and river flow volumes in the long term (i.e. beyond 2015), particularly in two tributaries of Wainono Lagoon (i.e. the Waihao and Hook rivers). This is expected to benefit river environmental values as described previously in Section 4.5.3 but would also better support fish passage (e.g. tuna, inanga) between Wainono Lagoon and its tributaries. Increased tributary minimum flows would also benefit lagoon levels at times of low flow, and would be favourable for maintaining fringing wetlands around the lagoon margins and the lower Hook River delta. Consequently the ZCSP would, from a water quantity perspective, be better than current for fisheries and other mahinga kai associated with the Mataitai Reserve, and for all recreational fishing (e.g. whitebaiting, floundering, eeling).

4.6.6 Managing tension between environment, drain function and flood management

There is tension between the desire for increased flow in Wainono tributaries (e.g. via increased tributary flows from reduced abstraction, from flow augmentation, and via increased groundwater recharge from up-catchment irrigation) and the need to manage both the effective operation of drains[44] and flood risks on farmland neighbouring Wainono Lagoon. These tensions have been widely and clearly expressed by the Waihao-Wainono community at public meetings.

It will be important to maintain effective opening management at the Waihao Box and effective maintenance of drains to and along the Waihao Arm, to ensure that increased tributary base flows do not adversely affect flood management for neighbouring landowners. These measures are included in the ZCSP.

The HDI scheme’s existing consents require the scheme to monitor drains and flooding characteristics before and after the scheme is implemented so that appropriate mitigation can be provided for adverse effects of the scheme on drains and flooding in the vicinity of Wainono Lagoon.

It may also be possible to further relieve some tensions by securing retirement of lake-margin land around the perimeter of the lagoon as proposed as part of the extended WRP described in above. This would open up possibilities for considering alternative minimum lagoon level management to the existing nominal 1.1 m above mean sea level, but this is not currently part of the ZCSP.

4.6.7 Cultural values and the Waihao Mataitai Reserve

Finally, and to re-emphasise, for manawhenua Wainono is a taonga (treasure) equivalent to Te Waihora (Lake Ellesmere) and Wairewa (Lake Forsyth). It provides important habitat for waterfowl, migrating birds, coastal birds and native fish, many of which are taonga species, in particular tuna (eels). To manawhenua, the value of the Waihao-Wainono system as home to taonga species, and as a source of mahinga kai cannot be overstated; the health of mahinga kai will be the ultimate indicator of the health of the system.

The technical team has not attempted to summarise the merits of the ZCSP specifically for manawhenua values in this Overview Report because manawhenua will be able to speak to their own values during the planning process that follows notification of the proposed plan (Variation 3) in April 2015. However the technical assessment provided above suggests that many aspects of the ZCSP will enhance the Mataitai Reserve and associated cultural values compared to the current degraded situation. This is by direct design as the TWWG, Waihao and Arowhenua Rūnanga ZC

[44] The term drain here refers to surface waterways carrying water from farmland to streams and rivers. This is distinctly different from use of the word “drainage” to mean the downwards movement of water through the soil profile, as used throughout this report as defined in the Glossary.

representatives, and Te Rūnanga o Ngāi Tahu staff have been directly involved in development of the ZCSP.

4.6.8 Summary matrix comparison - Wainono Lagoon

Table 4-13: Assessment of ZCSP for Wainono Lagoon indicators: This assessment uses a five-class colour-coded scoring system as described in Section 2.10.3. (Note: Some Wainono indicators allow only an assessment of the *relative merit* of the ZCSP compared to current (i.e. those marked with an [R] below), while some indicators allow an absolute assessment to be made of the *likelihood* of the ZCSP achieving numeric outcomes defined in the LWRP (i.e. those marked with an [A] below). See Appendix 1 for explanation of the link between ZC outcomes and technical indicators, and the basis for scoring the 'current state')

TECHNICAL INDICATORS	Current	ZC Solutions Package		
		2017	2022	2025
Opening regime - supports fish passage/recruitment [R]				
Opening regime - manages drainage/flooding [R]				
Lake Level - supports wetland ecosystem [R]				
Seasonal runs and migrations of taonga species observed [R]				
Supports customary fish populations (tuna, patiki, inanga) [R]				
Mataitai Reserve – fisheries & other mahinga kai [R]				
Water quality – sediment load reduced [R]				
Water quality - clarity and colour improved [R]				
Water quality – nutrient state – test Trophic Level Index (TLI) 6.0 achieved [A]				
Water quality – test LWRP outcomes (dissolved oxygen, pH, temperature) for healthy ecosystem [A]				
Macrophyte beds present – test Variation 3 LWRP outcome (20% cover) [A]				
Risk of cyanobacteria and/or other toxic algae reduced [R]				
Fringing wetlands & related biodiversity enhanced [R]				
Aquatic biodiversity (flow-related) enhanced [R]				
Suitability for contact recreation – test LWRP outcomes (Fair SFRG) [A]				
Watercress is safe to eat [R]				
Base flow at springs increases in vicinity of Wainono [R]				

4.7 Consideration of climate change

The national and regional policy setting (i.e. the NPSFM and the Regional Policy Statement) requires that consideration be given to the reasonably foreseeable effects of climate change. However it was decided not to do this by adding climate change scenarios into the suite of exploratory scenarios for the SCCS project. There were several reasons why it was decided to handle climate change considerations in a different way, as follows.

First, previous experience considering the addition of climate change scenarios for the Selwyn Waihora limit setting process had shown that there would be significant uncertainties and complexity in attempting to define a short-list of climate change scenario impacts on changes to land use, hydrology and hydrogeology (Leftley, 2012). This was partly because there is significant variability in predictions amongst the set of Global Climate Models commonly used, such that the range of predicted effects for some rivers in Canterbury spans from predicted flow increase to flow decrease, thus requiring either 'average' scenarios or multiple scenario runs to be tested. Leftley (2012) also considered that significant and time-consuming modelling effort would be required to adequately characterise a selection of climate change scenarios for running alongside the already complex and challenging modelling needed for informing water quantity and quality limit setting. In this respect a very relevant consideration for the SCCS team was that the scenarios designed to explore key decision areas around water allocation, environmental flows, land use change, nitrogen load limits and allocation of on-farm nitrogen allowances (Section 2.7) were already complex (seven scenarios) and the technical team was very aware of the risk of overloading the community with complex information and creating confusion.

Second, an assessment of the broad implications of climate change early in the project, based on relevant climate change analysis already undertaken for the SCCS area (e.g. Henderson, 2007) or other similar environments in mid Canterbury (e.g. Bright *et al.,* 2011; Renwick *et al.,* 2010; and Trolle *et al.,* 2011), suggest that superimposing (long-term global) climate change on top of the existing SCCS exploratory scenarios would be unlikely to substantially change the nature of the assessments or alter the direction of the predicted changes under existing scenarios. This is because predictions of the likely (average) consequences of climate change in or near the SCCS area (see bullet list below) all serve to accentuate, rather than conflict with, the key resource use pressures and environmental stresses currently facing the SCCS area; i.e. poor irrigation reliability and over-allocated, flow-stressed rivers with declining water quality in shallow groundwater, rivers and Wainono Lagoon:

- Increased air temperatures (0-5°C over the next 50 years), reduced or similar precipitation, with the net result being increased demand for irrigation (Henderson, 2007);
- Increased potential evaporation (up to 60 mm/yr to 2040); reduced groundwater recharge from the land surface of about 10% to 2040; increased average annual irrigation water use (~6%), decreased average annual drainage from unirrigated land (~10%) and irrigated land (~3%); generally reduced reliability from surface and groundwater sources (Bright *et al.,* 2011);
- Increased air temperatures resulting in increased evaporation loss of water (6 - 129% increase) from Te Waihora/Lake Ellesmere (which is geographically similar, but larger and deeper than Wainono Lagoon), leading to slightly lowered lake levels and a reduced frequency and duration of lake openings (Renwick *et al.,* 2010);
- Increased air and water temperatures in Te Waihora/Lake Ellesmere, in general exacerbating the adverse effects of further nutrient load increases to the lake. Predictions of temperature increases to the year 2100 could have an equivalent effect on lake trophic state as an additional 50% external nitrogen and phosphorus load to the lake (with large uncertainty around magnitude of change) (Trolle *et al.,* 2011);
- Increased flows in the Waitaki River as a result of increased precipitation in the main divide headwaters, with a large uncertainty range from 0% to 20%+ increases (Henderson 2007).

Finally, and flowing logically from above, now that the exploratory scenarios have been assessed and decisions made by the ZC regarding the preferred components of a solutions package (Section 4) to address current resource use pressures and environmental stresses, it is possible to consider overlaying the likely climate change effects listed above and conclude that :

i) Climate change adds further justification for the need to make timely, strategic decisions on setting limits for water quantity and quality;

ii) The potential impact of climate change adds only incrementally to the urgency of the need to make these decisions – i.e. even without climate change the need is urgent in the SCCS area;

iii) Consideration of climate change doesn't alter the direction of pressures and predicted changes to rivers and Wainono Lagoon under scenarios that lack significant mitigation;

iv) Consideration of climate change supports the need for pursuing a suite of interventions, not just relying on a single solution.

v) The ZCSP helps build resilience to the future effects of climate change, both in terms of environmental effects and effects on land and water resource use.

5 Conclusions: scenarios and solutions

It is not possible to achieve all the ZC's desired outcomes to the maximum level simultaneously, at least not in the near future based on current technology. Difficult decisions have been necessary to build a ZCSP that achieves most of the outcomes to a high level of attainment through time, and progressively improves those outcomes that are not met initially. Overall, it is predicted that the ZCSP will achieve a net environmental improvement through time, as illustrated by the colour-coded Summary Matrix comparison (see Executive Summary) between 'current state' (far left coloured column) to the progressively improving ZCSP (far right three columns).

There is uncertainty arising from many sources in the assessments on which decisions have been based, which is normal for land and water resource management. Some of the uncertainties have been identified and reduced where possible. The remaining known unavoidable uncertainties were communicated so that they could be incorporated into the decision-making process. Doubtless there remain sources of uncertainty that have not been identified and we do not know about.

It is possible that future technological advances will allow outcomes to be achieved to a higher level than the technical assessments predict. It is also possible that some outcomes will not be achieved to the extent predicted and thus review of the ZCSP and regional plan is important so that any necessary adjustments can be made in future. This is a normal situation and part of the regular review cycle of regional planning and resource management in general.

From a technical perspective the process was successful to the extent that it produced a transparent, objective, technical assessment of the effects of various future scenarios across multiple values (environmental, social, cultural and economic) and communicated those effects, along with an indication of the uncertainty associated with predictions, to willing community participants (Part 1 of this report). There was then community debate on the merits of different options, and a transparent process whereby the ZC selected a preferred pathway forward – that pathway is the ZCSP as documented in the ZIP Addendum. Part 2 of this report provides a technical assessment of the extent to which the proposed ZCSP is likely to achieve outcomes over time.

6 Implications of using the OVERSEER® model for setting and implementing limits

This section will:

i) Briefly review why Environment Canterbury is setting and implementing N limits for farming based on modelled (OVERSEER®) N losses from land use in a catchment, rather than relying on setting N limits in the receiving environment and measuring attainment of limits by environmental monitoring alone;

ii) Summarise key aspects of the way that OVERSEER® has been used in assessing the SCCS exploratory scenarios presented in this report, and in quantifying total catchment N loads and other types of limits (such as property level discharge allowances in kg/ha/yr) in the ZCSP;

iii) Identify some challenges that will arise when new versions of OVERSEER® are released and when the Matrix of Good Management (MGM)[45] project replaces the existing Canterbury 'Lookup Table' (LUT), which was based on OVERSEER® version 6;

iv) Highlight the need for the MGM numbers and new OVERSEER® versions due in 2015 to be considered (when available) for implications for the SCCS assessment and ZCSP described in this report; and

v) Highlight the need for development of a system to accommodate new versions of OVERSEER® (and MGM numbers) both for the 2015 releases and subsequent ongoing updates.

6.1 Why set limits based on modelled N losses rather than measurements in the receiving environment?

The use of a model such as OVERSEER® to estimate diffuse N losses from the root zone or farm boundary of all land uses in a catchment enables an explicit link to be made between catchment land use activities and water quality in the receiving environment. The N load lost from the root zone (i.e. the source load) is usually larger than the N load received and measured in the downstream environment, such as at a downstream point in a river or lake, because a proportion of the source load is usually attenuated (i.e. reduced) as it travels down a catchment, due to biophysical processes that will be described in more detail shortly in Section 6.3. An individual farmer cannot control the amount of attenuation that occurs beyond the boundary of their property; they can only control the (source) load that leaves the property. Therefore, if we are to identify the size of the allocable N load (i.e. the limit[46]), then it is the source load, not the load in the receiving environment that we must identify.

A question that is often asked is: why can't we just measure diffuse N discharges rather than use models? An answer is that there are significant practical difficulties in measuring N losses from the root zone that vary with the many different types of land use, soil and rainfall combinations that occur across multiple properties in a catchment.

A second question that is often asked is: why can't we just measure N concentrations and loads in the receiving environment of rivers and lakes? An answer is that catchments are hydrological systems with multiple surface and subsurface flow paths that may have long lag times between the loss of N from a farm and the appearance of that N in a downstream river or lake (see Section 2.8.2 for detail). This means that monitoring data from a point in a downstream receiving environment may not indicate a problem was occurring until years after the discharges from land occurred upstream. In addition, it is not possible to disaggregate a receiving environment concentration or load into portions attributable to the individual sources of the problem.

[45] See Glossary for a description of the Matrix of Good Management (MGM) project, which is a collaborative project between Environment Canterbury, Crown Research Institutes (AgResearch, Plant & Food Research and Landcare Research), and key primary sector organisations (DairyNZ, Deer Industry New Zealand, NZPork, Beef + Lamb New Zealand, Horticulture NZ and the Foundation for Arable Research).

[46] The NPSFM (2014) defines "limit" as "the maximum amount of resource use available, which allows a freshwater objective to be met"

It is still very useful to monitor N concentrations in receiving rivers and lakes, in order to track the state of the environment and trends, and to check whether management is achieving the outcomes sought. However if we are to identify the amount of resource available for use, as required by the NPSFM (2014) definition of a "limit", then for a diffuse contaminant such as N that exhibits attenuation and time lags, the source load must arguably be identified, and this inevitably (at this point in time) requires the use of models such as OVERSEER®.

Models such as OVERSEER® can be used to predict the N losses from farms both currently and under future land use and management scenarios, and are thus useful for exploring possible futures in a catchment that cannot be measured, thus informing decisions on limits. Once limits are set, OVERSEER® can be used to estimate N losses from individual farms and, by summing, source loads for whole catchments, and may thus be useful in accounting for the multiple individual contributors to a source load limit. OVERSEER® can also be used to predict the change in N loss from an individual farm if different management actions and mitigations were applied on the farm, thus helping to inform farmers in managing their operations within limits.

6.2 The conceptual catchment model for SCCS and use of OVERSEER®

As described in Section 2.8.2 the conceptual model for how water and nutrients move through SCCS catchments involves several steps including; i) nitrate loss from land to groundwater and surface runoff, ii) nitrate movement through groundwater, iii) nitrate entering streams via groundwater discharge, and iv) nitrate entering Wainono Lagoon via surface flow in tributaries (see Figure 2-3).

OVERSEER® (version 6) has been used to estimate N losses from a comprehensive set of land use, soil and climate combinations (i.e. the LUT – see Lilburne 2015, Appendix 4 for detail) and thus, by summation using a GIS tool, the total loss of N was estimated from the root zone of all land in the catchment under current and various future land use scenarios. Those OVERSEER®-based N loss estimates were used, applying considerations of dilution and attenuation (see below), to estimate N concentrations, loads and associated effects in groundwater, rivers and Wainono Lagoon for all exploratory scenarios and the ZCSP.

6.3 Accounting for catchment attenuation

In order to understand the implications of the way OVERSEER® has been used in the SCCS assessment, it is first necessary to describe the concept of attenuation and how it has been handled in the assessment. Attenuation of the source load of N as it travels down a catchment can occur due to a number of processes such as denitrification in any reducing (i.e. anoxic) areas in groundwater and soil, uptake by riparian vegetation, and uptake by algae and other plants in streams, rivers and lakes. Such attenuation means that the receiving environment load at the bottom of a catchment is usually some fraction of the estimated source load (i.e. the sum of all farm loads estimated using OVERSEER® plus any point source loads (see Figure 2-3).

The amount of N attenuated during travel down a catchment may be estimated by subtracting the estimated receiving environment load at the measurement point at the bottom of the catchment from the estimated source loads. This difference, expressed as a fraction of the source load, is referred to as the 'catchment attenuation factor'[47] or a 'catchment co-efficient'[48]. According to this definition a catchment attenuation factor of 0.5 for example implies that 50% of the N lost at the source (such as leached from the root zone) is attenuated before reaching the bottom of the catchment.

Calculating the catchment attenuation factor in this way estimates the total amount of attenuation but does not attempt to quantify the relative contribution of the different attenuation processes such as the amount of denitrification versus uptake by riparian vegetation or periphyton. The catchment attenuation factor is thus a lumped catchment estimate of all attenuation processes. If either the

[47] In mathematical terms this definition of a catchment attenuation factor (CAF) is CAF = $(Q_d - Q_r)/Q_d$; where Qd is the source N load (e.g. leaching from the root zone as estimated by OVERSEER® plus any point discharges) and Qr is the receiving environment N load (e.g. measured at some point at the bottom of the catchment.

[48] A coefficient of attenuation could also be calculated in a similar way using OVERSEER® estimated concentrations for groundwater and measured concentrations in groundwater-fed receiving streams.

OVERSEER® estimates or the measurement of the receiving environment load estimates change, then the estimate of the catchment attenuation factor will also change[49].

Catchment attenuation is expected to vary spatially and with time because the biophysical processes that contribute to attenuation vary spatially and in time. A range of estimates for catchment attenuation factors have been reported in New Zealand; these range between zero and 1.0 but a factor in the order of 50% is common[50] and in some cases much larger rates of attenuation (>50%) have been reported[51].

6.4 Use of OVERSEER® in a relative way to explore future scenarios

The assessment method used OVERSEER® (i.e. LUT) to estimate N source loads under current land use and under conditions defined by the scenarios. The assessment incorporated N attenuation by using the *relative* change in current source loads to future source loads (both estimated using OVERSEER®) to evaluate the receiving environment loads and concentrations (e.g. in groundwater, streams, rivers and Wainono Lagoon) under the scenarios. The ratio of the current source load to future source load was used as a multiplication factor (for each sub-catchment) to estimate the receiving environment N concentration (i.e. the future receiving environment concentration (or load) = current receiving environment concentration (or load) x multiplication factor). The *absolute* OVERSEER® predicted load numbers have not been used to directly assess effects in rivers and Wainono Lagoon, partly because updates to OVERSEER® numbers were always anticipated, but also because a key assumption has been that the N attenuation factors (for each sub-catchment) remain the same as current in SCCS catchments across all future scenarios considered. Thus it has been assumed that a relative change in the catchment source loads under a scenario produces the same relative change in the receiving environment load. For example if there is a 10 % increase in the source N load resulting from land use change in the catchment, there will be a 10% increase in N load in the receiving environment (putting aside for the moment considerations of time lags and potential new catchment mitigations such as flow augmentation that were also incorporated into the assessment).

In this way the technical team has to some extent managed the anticipated OVERSEER® version changes by using OVERSEER®-based (version 6) estimates of N loss in a *relative* way when assessing the effects of exploratory scenarios. This reduces the implications of updates to OVERSEER® but does not eliminate them entirely, as discussed in more detail later in this section.

6.5 Use of OVERSEER® absolute numbers to define load limits

Notwithstanding the relative use of OVERSEER® to explore the effects of future scenarios described above, once Zone Committee and community participants had deliberated those scenarios and made the value judgements necessary to decide on the key elements of the ZCSP, the absolute numbers in the LUT (OVERSEER® version 6) were used to calculate the N source load limits (i.e. the load lost at the root zone) associated with that ZCSP (see Lilburne 2015, Appendix 4). Those numbers have been carried through to the N load limits tables; Tables 15(l), 15(m) and 15(o) in proposed LWRP plan variation 3.

6.6 Benefits and challenges with updates to OVERSEER® and MGM

The OVERSEER® model is periodically updated with new versions as information improves and the model is refined. On-going improvement to OVERSEER® is beneficial because it will lead to

[49] Note that OVERSEER® estimates change (improve) each time a new updated version is released, and measurement-based estimates improve with more frequent sampling and/or a longer period of monitoring record. Thus estimates of catchment attenuation are also expected to continuously improve with time.

[50] For example; Singh *et al.,* (2014) reported N attenuation factor estimates in Manawatu catchments ranging from 0.2 to 0.7; and an attenuation factor of 0.5 is assumed in both the Taupo catchment (Waikato Regional Council's Variation 5) and in the Manawatu-Wanganui (Horizons' One Plan (Rutherford 2013).

[51] For example more than ten-fold reductions in nitrate concentrations have been measured along a section of the Tukituki River in Hawkes Bay where conditions are conducive to large growths (and therefore large nutrient uptake) of periphyton (Wilcock, 2013).

improvements in the estimates of N losses for each type of land use and also the estimates of catchment N attenuation. The next OVERSEER® version update is scheduled for April 2015 about the time that the SCCS plan variation 3 will be notified.

The release later in 2015 of MGM project estimates of (OVERSEER®-generated) N loss rates (kg/ha/yr) considered to represent 'good management practice' (GMP) for different land uses on different soil types will also be beneficial as these numbers will make the expectations concerning GMP clearer (noting that meeting GMP is a mandatory requirement of the ZCSP). These numbers will replace the LUT (OVERSEER® version 6) that has been used in SCCS to date; this has been discussed and is anticipated by the ZC and many of the other community participants.

Both these improvements (MGM and new OVERSEER® version(s)) will create challenges for setting and implementing N load limits and N discharge rate allowances (in kg/ha/yr) that have to date been based on numbers from the LUT (OVERSEER® version 6). There is the need for a system to manage the release of MGM project numbers and the on-going release of updated versions of OVERSEER®. Both the MGM numbers and new OVERSEER® versions will need to be accommodated somehow in the planning framework so that it remains workable and clear in the future. Earlier versions of OVERSEER® are no longer available once updated versions are released. Therefore, the farming community will have to use new OVERSEER® versions to test their farming activities against the provisions in the LWRP and the SCCS sub-regional variation 3. It is understood the intention is that the MGM numbers will also update as each new version of OVERSEER® is released.

6.7 Technical issues arising with updated versions of OVERSEER®

From a technical perspective there are several issues that may arise with the release of MGM and new OVERSEER® versions and these can be grouped into two categories as follows:

i) Version changes in N loss estimates which have no implications for assessment of environmental effects

ii) Version changes in N loss estimates which *potentially could* have implications for assessment of environmental effects.

These are described separately below as it is anticipated that they may be managed in different ways.

It is also worth noting at the outset that the extent of these issues will not be clear until new OVERSEER® versions are released (in particular the next release in April 2015) and there is an opportunity to work through the implications. It might reasonably be expected that the degree of change in N loss estimates between OVERSEER® versions will reduce with time as estimates tend closer to the (theoretical) 'true' answer with time. It is reasonable to expect that large changes in N loss estimates may have bigger implications than small changes and that non-uniform change in N loss estimates (i.e. some land use types changing more than others) may have more significant implications than uniform changes (i.e. where all land use types increase or decrease by a similar amount) as will become clearer below.

6.7.1 OVERSEER® version changes with no consequence for assessment of environmental effects

Where a property has not changed its land use or management and a new version of OVERSEER® results in a change to the N loss estimate for that property, there is likely to be no consequence for the assessment of environmental effects. This is because the ratio of the source load to receiving environment N load (approach described in section 4 above) would remain the same for the current and future scenarios when source loads are estimated using the old and new version of OVERSEER®. In this case the fact that the new OVERSEER® version may have estimated a larger or smaller property N load in absolute terms merely serves to change (and presumably improve) our assumed estimate of the catchment attenuation factor. There is no change to our estimate of effect on the receiving environment.

Furthermore, where a property has changed its land use and, for example, increased its N losses by an allowable amount under a plan provision, provided that the new version of OVERSEER® estimates the same relative (i.e., percentage) increase for that property as the LUT (OVERSEER® version 6), then there is likely to be no consequence for the assessment of environmental effects. This is despite the fact that the absolute N loss estimate for the property might be lower or higher under the new OVERSEER® version than the old – again this difference merely alters (and presumably improves) our assumed estimate of the catchment attenuation factor.

OVERSEER® versions that produce uniform changes to N loss estimates (i.e. where all land use types increase or decrease by a similar amount compared to the previous version) are most likely to fall into this category of having no consequence for environmental effects.

6.7.2 OVERSEER® version changes with potential consequences for assessment of environmental effects

OVERSEER® versions that produce non-uniform (i.e. differing degree of change across farms and scenarios within the catchment) and large changes to N loss estimates (i.e. some land use types change significantly more than others) could potentially have consequences for the assessment of environmental effects presented in this report (i.e., assessments that informed the SCCS community limit setting process). This is because the relative (i.e., proportional) difference in N loss between current and future land use scenarios would change with the new OVERSEER® version compared to the old version. This could alter the assessment of environmental effects for some scenarios for the reasons explained in section 4 above, and could thus potentially alter the basis on which limit-setting decisions have been made.

A second type of OVERSEER® version change that may fall into this section is where the version significantly changes land users ability to meet N discharge allowance thresholds such as the flexibility caps or maximum caps (set in kg/ha/yr) described in section 4.2.

6.8 Finding solutions

The planning solutions to the issues identified above are not yet clear but are being progressed by Environment Canterbury and discussed amongst stakeholders at the time of writing. From a technical perspective there is a need to find solutions to these issues that will:

i) Address OVERSEER® version changes that have no environmental consequences as efficiently as possible so that users are not penalised by any unintended effects of the updated version.

ii) Provide opportunity to review MGM numbers and OVERSEER® version changes (when available) to identify any potential consequences for the assessment of environmental effects that informed the community limit setting decisions and, depending on the outcome of that review, make adjustments to the limit numbers and or the planning framework to preserve the recorded intent of the ZCSP.

7 Peer review process

This Overview Report and the appended technical reports were subject to peer review at the draft stage. Amendments resulting from peer review have been incorporated into this final version of the Overview Report and appended technical reports. Peer reviews were as listed below:

Norton, N., Robson, M. (2015). South Canterbury Coastal Streams (SCCS) limit setting process. Predicting consequences of future scenarios: Overview Report.

Peer Reviewer: Ton Snelder, LWP Ltd.

Lilburne, L. (2015). South Canterbury Coastal Streams (SCCS) limit setting process: Estimating nitrogen loss under rural land use and informing nitrogen allocation options (Appendix 4)

Peer Reviewer: Melissa Robson, Agresearch.

Fietje, L. (2015). Estimating nitrogen loss from land uses in the hill country of the South Canterbury Coastal Streams (SCCS) area (Appendix 5)

Peer Reviewer: Ian Brown, Environment Canterbury (plus involved farmers and fertiliser representatives)

Scott, M., Etheridge, Z. (2015). South Canterbury Coastal Streams (SCCS) limit setting process. Predicting consequences of future scenarios: Groundwater quality (Appendix 6)

Peer Reviewer: Brydon Hughes, Liquid Earth Ltd

Kelly, D.W. (2015). South Canterbury Coastal Streams (SCCS) limit setting process. Predicting consequences of future scenarios: Surface water quality and associated values (Appendix 7)

Peer Reviewer: Cathy Kilroy, NIWA

Aitchison-Earl, P. (2015). South Canterbury Coastal Streams (SCCS) limit setting process. Predicting consequences of future scenarios: Groundwater quantity (Appendix 8)

Peer Reviewer: Ian Lloyd, Golder Associates

Clarke, G. (2015). South Canterbury Coastal Streams (SCCS) limit setting process. Predicting consequences of future scenarios: Ecological flows (Appendix 9)

Peer Reviewer: Greg Burrell, Instream Consulting Ltd

Ballard, C. (2013). Consequences of options for surface water allocation limits – South Canterbury Coastal Streams (Appendix 10)

Peer Reviewer: Ton Snelder, John Bright, Aqualinc

Martin, A., Leftley, D. (2012). Waihao-Wainono hydrological information (Appendix 11)

Peer Reviewer: Tom Heller, Consultant

Martin, A. (2015). South Canterbury Coastal Streams (SCCS) limit setting process. Hydrology (Appendix 12)

Peer Reviewer: Helen Shaw, Tim Davie, Environment Canterbury

Brown, P. (2015). South Canterbury Coastal Streams (SCCS) limit setting process. Predicting consequences of future scenarios: Irrigation reliability (Appendix 13)

Peer Reviewer: Ian McIndoe, Aqualinc; Richard DeJoux, ECS Ltd

Harris, S. (2015). South Canterbury Coastal Streams (SCCS) limit setting process. Predicting consequences of future scenarios: Economic assessment (Appendix 14)

Peer Reviewer: Duncan Smeaton, Smeaton Agricultural Consultancy Ltd

Taylor, N, McClintock, W., Mackay, M. (2015). South Canterbury Coastal Streams (SCCS) limit setting process. Social profile and assessment (Appendix 15)

Peer Reviewer: Mark Fenton, EBC Ltd

Tipa, G. (2012). Cultural associations and their flow and water management implications for the Waihao/Wainono catchment (Appendix 16)

Peer Reviewer: Te Runanga o Waihao representatives

Tipa, G. (2013). Cultural values and water management issues for a selection of South Canterbury catchment (Appendix 17)

Peer Reviewer: Te Runanga o Waihao representatives

Sutherland, D., Norton, N. (2011). Assessment of augmentation of water flows in Wainono Lagoon (Appendix 18)

Peer Reviewer: Helen Rouse, NIWA

Abell, J., Jones, H., Hamilton, D. (2015). Hydrodynamic-ecological modelling to support assessment of water quality management options for Wainono Lagoon (Appendix 19)

Peer Reviewer: Ned Norton, NNC Ltd

Schallenberg, M. (2013). Nutrient loading thresholds relevant to Wainono Lagoon (Canterbury) (Appendix 20)

Peer Reviewer: Ned Norton, NNC Ltd

Schallenberg, M., Saulnier-Talbot, E. (2014). Recent environmental history of Wainono Lagoon (South Canterbury, New Zealand) (Appendix 21)

Peer Reviewer: Anonymous peer reviewers under the Editor at the New Zealand Journal of Marine and Freshwater Research

Norton, N., Harris, S., Scott, M., Lilburn, L., Robson, M., Stapleton, J., MacDonald, M., Newman, N., Whitehouse, I. (2015).Process and outcomes of the Nitrogen Allocation Reference Group (NARG) for the South Canterbury Coastal Streams area (Appendix 22)

Peer Reviewer: Farmers Colin Hurst, Roger Small, William Hurst, and Tim Davie, Environment Canterbury

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9 Glossary

Advanced on farm mitigation - These are a range of on-farm management practices or technologies that go beyond the GMPs (Good Management Practice). These practices reduce the loss of nutrients and other contaminants from land beyond that achieved by GMP and typically may include technologies such as feed pads, nitrification inhibitor use, herd homes etc. (see also Maximum Feasible Mitigations (MFM) below).

Base flows – Groundwater contribution into surface water flow in streams

Benthic – Of the stream bed

Cyanobacteria – Cyanobacteria are also known as blue-green algae and are a group of bacteria that obtain their energy through photosynthesis. Cyanobacteria can be found in almost every terrestrial and aquatic habitat including fresh water, oceans, damp soil, bare temporarily moistened rocks and even hot springs. They play an important role in the global carbon and nitrogen budgets, being able to fix nitrogen gas from the atmosphere into ammonia and nitrates that are then available as nutrients to plants. However they can also form nuisance and toxic mats on the beds of rivers and scums on the surface of lakes, degrading habitat for other aquatic life and reducing amenity and recreation values for people. In recent years toxic cyanobacteria mats have periodically appeared in several Canterbury hill-fed rivers (including the SCCS) and have, when eaten, caused the deaths of dogs.

CWMS – Canterbury Water Management Strategy

Deep groundwater. We refer to the groundwater in the Cannington gravels as “deep” groundwater which is more than 30 m deep.

Denitrification. This is the transformation of the water soluble nitrate form into a gaseous form of nitrogen and is a permanent removal of nitrate from the catchment.

Dissolved oxygen (DO) – the amount of oxygen that is dissolved in water (DO) is an important measure of water quality because oxygen is needed by aquatic invertebrates and fish to respire and thus survive. DO is typically measured in the units mg/L or as the percentage saturation. DO can be depleted to levels that are harmful to aquatic life by excessive decomposition of organic matter and/or nutrient pollution leading to algae or macrophyte blooms.

Dissolved reactive phosphorus – Dissolved inorganic form of phosphorus that is readily available for plant or algae uptake

Downlands - Subdued landscapes of undulating smooth hills with broad ridges dissected by steep gullies draining to broad valleys, characterised by lack of trees and used mainly for cropping and pasture. Downlands in the SCCS area may be underlain by terrace gravels or bedrock and often have a mantle of loess, from which soil is formed.

Drainage - The downwards movement of water though the soil profile, determined by the soil properties and gravity.

EBIT - Earnings before Interest and Tax
E. coli (Escherichia coli) - A type of bacteria that indicates the presence of faecal contamination and the risk of exposure to pathogens.

Full Time Equivalents (FTE) – This is a term used to indicate the workload of an employed person in a way that makes workloads comparable across various contexts. An FTE of 1.0 means that the person is equivalent to a full time worker, while an FTE of 0.5 signals that a worker is only half time.

GDP - The gross domestic product is one the primary indicators used to gauge the health of a country's economy. It primarily measures the value that is added to goods and services within the country.

Good Management Practice (GMP) - This refers to good nutrient and irrigation management assumed in the 'Canterbury look up tables". Specifically this covers: use of nutrient budgets, application of fertiliser according to code of practice, stock exclusion, efficient irrigation application (80 % application efficiency), and use of compliant effluent systems.

Hill-fed stream/river - Rivers whose flow is dominated by the contribution from hilly areas. These may comprise a single thread and braided sections. Flow in upper catchments sustained by rainfall, snow melt or lake outflow, and in the lower reaches by groundwater in some rivers. Strong seasonal pattern of river flows. High flows occur in winter when precipitation is highest and for some catchments may continue into spring with snow melt. Spring peak flows decline quickly compared to alpine rivers. Tributaries or sections of the main stem may cease to flow at the bed surface for part of the year.

Intermittency – An intermittent river (or intermittent reach of a river) only has surface water flow for some of the time. Intermittent rivers are typically found in regions with limited or highly variable rainfall, or can occur (as is the case in SCCS) where a highly permeable river bed loses flow to groundwater. Typically some flow in intermittent rivers occurs beneath the surface of the river bed (even when there is no surface flow).

Land surface recharge (LSR) - refers to rainwater or irrigation water that moves down through the soil and reaches groundwater. This is the main process that leaches contaminants from the soil into groundwater.

Lowland stream/spring – Rivers whose flow is dominated by the contribution from lowland areas. These generally comprise a low gradient single thread channel. The flow generally covers the bed. Source of flow ranges from rainfall to solely springfed from groundwater. The proportion of groundwater flow generally increases in lower reaches. Rainfall dominated streams show a very strong seasonal pattern of flows, with the highest flows in winter when precipitation is highest. Tributaries or sections of the main stem may have zero surface flow (i.e. be dry) for part of the year. Spring-fed streams may show little seasonality with regular year round flows. The flow regime can be modified by irrigation.

Matrix of Good Management (MGM) Project - The Matrix of Good Management (MGM) project is a collaborative project between Environment Canterbury, Crown Research Institutes (AgResearch, Plant & Food Research and Landcare Research), primary sector organisations (DairyNZ, Deer Industry New Zealand, NZPork, Beef + Lamb New Zealand, Horticulture NZ and the Foundation for Arable Research). The outputs of the project are a suite of industry-agreed good management practices (GMP) and estimates of likely nitrate nitrogen and phosphorus losses from a range of different farm systems operating at GMP across Canterbury's soils and climates. The project outputs will provide farmers with a benchmark range of nutrient losses under GMP, and Canterbury Water Management Zone Committees with a comprehensive data set for catchment scale modelling of nutrient losses from agriculture.

Maximum Acceptable Value (MAV) - The New Zealand drinking-water standards set a Maximum Acceptable Value (MAV) for nitrate nitrogen at 11.3 mg/L (equivalent to 50 mg/L of nitrate), based on a risk to bottle-fed babies. Community & Public Health also recommend applying this MAV to pregnant women. More frequent monitoring is required when nitrate concentrations exceed ½ MAV (5.6 mg/L). There is also a drinking water MAV set for *E. coli* of less than one organism in a 100 ml sample.

Maximum Feasible Mitigations (MFM) - is the point along the advanced mitigation spectrum where all feasible mitigations have been employed for a given farm type, and is the point beyond which it would be necessary to change land use in order to achieve further reductions in nutrient (and other contaminant) losses. For the SCCS land use mix (Scenario 2 – full irrigation development) MFM is sufficient to achieve approximately an average 30% reduction in N losses compared to GMP, but varying between 0 and 40% depending on land use type. At this point in time MFM would typically include the following practices:
For 'Dairy': Improved nutrient and effluent management; deficit irrigation/ VRI; wintering off barns/pads plus autumn on off grazing; on off grazing; improved cow genetics; reduced cow numbers; reduced autumn N; use of DCD (nitrification inhibitors).

For 'Dairy Support': Improved nutrient and effluent management; deficit irrigation/ VRI; improved winter forage and stock management; improved cow genetics; low N feed; use of DCD (nitrification inhibitors).
For 'Dryland Drystock': Improved nutrient and effluent management; improved winter forage and stock management; use of DCD (nitrification inhibitors).
For 'Arable': Multiple combined interventions (e.g. tillage, fallow, soil testing, improved nutrient and irrigation management, reduced inputs by 15 %, DCD for any stocked part of rotation).

Macrophyte – A rooted aquatic plant that may be emergent (i.e. protruding above the water surface), submerged or have floating leaf parts

Manawhenua - Those who exercise customary authority or rangatiratanga.

Mahinga kai - Food and places for obtaining natural foods and resources. The work (mahi), methods and cultural activities involved in obtaining food and resources.

MALF7d (Mean annual 7 day low flow) – A commonly used statistic that indicates the lowest flow that typically occurs for a 7 day period in a year. Calculated as the mean of the lowest seven day moving average flow (ALF) for each year of record.

Mātauranga Māori – The body of knowledge originating from Māori ancestors, including the Māori world view and perspectives, Māori creativity and cultural practices.

Mid-point mitigations - This is by definition the level of on-farm mitigation effort at the mid-point between GMP and MFM. For the SCCS land use mix (Scenario 2 – full irrigation development) this is sufficient to achieve approximately an average 15% reduction in N losses compared to GMP, but varying between 0 and 20% depending on land use type.

Minimum flow - The flows at which abstractions must cease, except for domestic needs, drinking water for animals and fire fighting. Minimum flows are set to prevent abstractions reducing rivers to very low flows.

NES (Proposed National Environmental Standard on Ecological Flows and Levels Discussion Document). This document recommends interim limits of: minimum flow 90%MALF; allocation 30% MALF – see Proposed National Environmental Standard on Ecological Flows and Water Levels: Discussion Document | Ministry for the Environment.

Nitrate-N – Water soluble and oxidised inorganic form of nitrogen that is readily available for plant uptake and constitutes a large proportion of the nitrogen that is lost from land.

Phytoplankton blooms –blooms of microscopic algae that live floating or suspended in the water

Periphyton – Algae that live attached to surfaces such as a stream bed

QMCI (Quantitative Macroinvertebrate Community Index) – The QMCI is a measure of general stream ecological health. Although the index was initially developed to measure the response of the benthic macroinvertebrate community to water quality impairment caused by organic pollution, it has also been used widely to provide an indication of general stream ecological health (e.g. Stark and Maxted, 2007). As an indicator of stream health, the LWRP set numerical QMCI targets for hill-fed rivers and spring-fed streams of 5.0-6.0 and 4.5-5.0, respectively.

SFRG (Suitability for Recreation Grade) – The SFRG is a grading system published in national guidelines for assessing the suitability of a waterway for contact recreation. The grade (SFRG) is derived from both *E. coli* data and a sanitary inspection assessment, with grades ranging from "very good" to "very poor" (MfE/MoH, 2003). SFRG grades for hill-fed rivers and spring-fed streams have been set in pLWRP outcomes and range from "good" to "no value set", respectively - see Kelly 2015; Appendix 7)

Shallow groundwater. For the SCCS project area we refer to the groundwater in the Quaternary deposits as “shallow” groundwater and have set the cut off at 30 m deep. We refer to the groundwater in the Cannington gravels as “deep” groundwater which is more than 30 m deep.

Taonga – A treasure.

Tikanga **-** Lore and custom.

TN – Total nitrogen – Includes all forms of nitrogen including inorganic (nitrate, nitrite and ammonia) and organic forms of nitrogen.

TP – Total Phosphorus – Includes all forms of phosphorus including dissolved reactive phosphorus (DRP) and particulate phosphorus.

Trophic Level Index (TLI)- A classification system to indicate the nutrient status and productivity of New Zealand lakes. It ranges from <1 (almost pure water) to >7 (highly nutrient enriched)

Wāhi taonga – a treasured place

Wāhi tapu – a sacred place

10 References

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Appendix 1: Zone Committee outcomes and technical indicators

The table below shows the list of technical indicators that were developed by the technical team and the ZC to help assess the extent to which the ZC outcomes would be achieved. The table shows an assessment of the current situation (2013) against these indicators using the 5 class (colour) scoring system described in Section 2.10.3, and provides some explanation on how the indicators were assessed. Note that some indicators allow only a nominal assessment of the extent to which ZC outcomes are met because there is no absolute (e.g. numeric) threshold defining attainment of the ZC outcome. These indicators are marked with an [R] below because they are subsequently used as the basis for assessment of the ***relative merit*** of future scenarios compared to the nominally defined current state. On the other hand some indicators allow an ***absolute*** assessment to be made of the ***likelihood*** that current state achieves numeric outcomes defined in the pLWRP (i.e. those indicators marked with an [A] below). The pLWRP numeric outcomes used for assessment are shown in pLWRP Tables 1a and 1b (Decision version) copied into the following two pages. Further detail of individual assessments is provided in the appended technical reports (Appendices 4 to 22).

ZC OUTCOMES	TECHNICAL INDICATORS	Current State	Explanation of Current State assessment
Vibrant economy and sustainable growth - A growing local economy - Highly reliable and secure irrigation - Protection of Wahi Tapu & Wahi Taonga - Diversity of farming systems - Good rural & urban land management practice is common practice - Safe water for contact recreation throughout the zone - Safe drinking water supplies exist in the Zone - Safe water for cultural use - Catchment drainage & flood risk managed	Utilise irrigable area to achieve production potential - CWMS Target 7	[R]	Yellow on basis currently only irrigating half the irrigable area in SCCS area
	On farm economic impacts (revenue, farm working expenses, variable expenses and EBIT)	[R]	Yellow on basis currently only irrigating half the irrigable area
	Number of farmers and farm workers engaged in dairy, dairy support, horticulture and arable	[R]	Yellow on basis currently only irrigating half the irrigable area
	Regional economic impacts including GDP, earned household income, rates and taxes	[R]	Yellow on basis currently only irrigating half the irrigable area
	On farm and regional employment	[R]	Yellow on basis currently only irrigating half the irrigable area
	School rolls	[R]	School roles at best steady, with slow decline likely
	Individual household income	[R]	Yellow on basis only utilising part of potential – see above
	Engagement in GMP	[R]	Current engagement improving
	Population in SCCS project area	[R]	Neutral – current population stable
	Services - health, infrastructure and education. Social connectedness	[R]	Currently services challenged by aging population
	Drinking water – nitrate in deep groundwater – test MAV	[A]	Based on meeting MAV standard
	Drinking water – nitrate in shallow groundwater – test MAV	[A]	Based on 5-6% of wells exceeding MAV standard
	Drinking water – microorganisms in surface & shallow groundwater – test MAV	[A]	Based on known current need for treatment because source water exceeds MAV
	Fishing activity in streams and Wainono	[R]	Based on important but modest current fishing activity
	Recreational use	[R]	Based on modest use and current occasional cyanobacteria
	Game bird hunting in Wainono	[R]	Based on current regular high value use
Coastal streams have high water quality - that supports aquatic life and biodiversity - flows support aquatic life and biodiversity suitable for each waterway - connected groundwater has healthy flows and high water quality	Flows in Streams - high minimum flows compared to natural 7d MALF	[R]	Variable between streams – some currently have no minimum flow while some have minimum flows near MALF
	Flows in streams – high variability and frequency of freshes	[R]	Natural flow variability currently exacerbated by takes
	Flows in streams – low intermittence (dry length, frequency, duration)	[R]	Natural flow intermittence currently exacerbated by takes
	Large amount of habitat for key fish species (compared to % of habitat at natural MALF)	[R]	Variable between streams – some currently have no minimum flow while some have minimum flows near MALF
	High diversity and abundance of aquatic invertebrates – test LWRP outcomes (QMCI)	[A]	Current data show QMCI scores don't meet LWRP outcomes
	High diversity and abundance of native fish	[R]	Current native fish populations subject to several human induced stresses – flow, quality, habitat, passage
	Provision of suitable mudfish habitat	[R]	Current mudfish habitat is at risk
	Healthy periphyton & macrophyte communities – test LWRP outcomes (% cover)	[A]	Current data show LWRP outcomes regularly not met
	Ensure hydrological requirements for wetlands are met	[R]	Some current wetlands have reduced flow due to takes
	Baseflow at springs increases	[R]	Some springs affected by abstraction and groundwater level
	Groundwater levels to support wetlands improved	[R]	Neutral – current water levels influenced by takes & drainage
	Nitrate-N toxicity for aquatic species (at least 80% level protection)	[A]	80% level of protection currently met
	Water clarity and suspended sediment	[R]	Sometimes poor clarity and sediment issues from erosion
	Sedimentation of stream beds	[R]	Numerous lower reaches of streams heavily sediment-laden
	Periphyton - recreation & benthic biod. - test LWRP outcomes (% cover)	[A]	Current data show LWRP outcomes regularly not met
	Benthic cyanobacteria risk recreation - test LWRP outcomes (% cover)	[A]	Current data show LWRP outcomes regularly not met
	Macrophyte risk for recreation & benthic biodiversity - test LWRP outcomes (% cover)	[A]	Current data show LWRP outcomes regularly not met
	Suitability for recreation – microbial quality - test LWRP outcomes SFRG)	[A]	Current data show LWRP outcomes occasionally not met
	Riparian condition (stock exclusion and vegetation)	[R]	Currently improving but many sites still poor
Wainono Lagoon is a healthy ecosystem - abundant mahinga kai - fish passage is provided throughout the catchment where appropriate - enhanced wetlands and protection of springs - no further reduction in water quality of the Lagoon *(acknowledging and allowing for its transitional state)* - Catchment flows and water quality support a healthy Lagoon - Maintenance & enhancement of the Mataitai Reserve - Enhanced riparian management - Enhanced indigenous biodiversity	Opening regime - supports fish passage/recruitment	[R]	Box was failing but recently repaired – seems effective
	Opening regime - manages drainage/flooding	[R]	Box was failing but recently repaired – seems effective
	Lake Level - supports wetland ecosystem	[R]	Current level supports current ecosystem – higher minimum level would improve wetland ecosystem
	Seasonal runs and migrations of taonga species observed	[R]	Current runs challenged by naturally low flows but these exacerbated by takes – Waihao Box repair is positive
	Supports customary fish populations (tuna, patiki, inanga)	[R]	Current fish populations challenged by flows, water quality, habitat quality, passage and historical pressures
	Mataitai Reserve – fisheries & other mahinga kai	[R]	Consider score of all Wainono indicators above and below
	Water quality – sediment load reduced	[R]	Historical sediment load has degraded habitat quality
	Water quality - clarity and colour improved	[R]	Currently poor – due to enriched and high sediment state
	Water quality – nutrient state - test Trophic Level Index (TLI) 6.0 achieved	[A]	Current data show TLI greater than 6 – LWRP outcome not met
	Water quality – test LWRP outcomes (dissolved oxygen, pH, temperature) for healthy eocsystem	[A]	Current data show these indicators poor at times - LWRP outcome not met at times
	Macrophyte beds present – test Variation 3 LWRP outcome (20% cover)	[A]	Macrophytes absent but fragments appear at times – LWRP (Variation 3) outcome not met
	Risk of cyanobacteria and/or other toxic algae reduced	[R]	Currently few blooms recorded but risk moderate
	Fringing wetlands & related biodiversity enhanced	[R]	Improving due to Wainono Restoration Project -
	Aquatic biodiversity (flow-related) enhanced	[R]	Current biodiversity (e.g. passage) challenged by low flows
	Suitability for contact recreation (Fair) – test LWRP outcomes (SFRG)	[A]	Sometimes fails microbiological and cyanobacteria risk - LWRP outcome not met at times
	Watercress is safe to eat	[R]	See above – washing mitigates risk for eating
	Base flow at springs increases in vicinity of Wainono	[R]	Neutral – current springs influenced by takes

Table 1a <u>Freshwater</u>[268] Outcomes for Canterbury Rivers

Management unit	Sub-unit	Ecological health indicators			Macrophyte indicators		Periphyton indicators			Siltation indicator	Microbiological indicator
		QMCI* [min score]	Dissolved oxygen [min saturation] (%)	Temperature [max] (°C)	Emergent macrophytes [max cover of bed] (%)	Total macrophytes [max cover of bed] (%)	Chlorophyll a [max biomass] (mg/m^2)	Filamentous algae >20 mm [max cover of bed] (%)	<u>Cyanobacteria mat cover (%)</u>[269]	Fine sediment <2 mm diameter [max cover of bed] (%)	Suitability for contact recreation[SFRG*]
Natural state		Rivers are maintained in a natural state									
Alpine - upland		~~5~~ 6	90	20	No value set	No value set	50	10	<u>20</u>	10	Good
Alpine - lower							120	20	<u>30</u>		Good to Fair
Hill-fed - upland							50	10	<u>20</u>	15	Good
Hill-fed - lower							200	30	<u>50</u>		Good to Fair
	urban	3.5								20	No value set
Lake-fed		6					200	30	<u>50</u>	10	Good
Banks Peninsula		~~4~~ 5					120	20	<u>30</u>	20	No value set
Spring-fed -upland		6			20	30	50	10	<u>20</u>	10	Good
Spring-fed - lower basins		5			30	30	200	30	<u>50</u>		Fair
Spring-fed -plains		~~4.5~~ 5[270]	70		30	50	200	30	<u>50</u>	20	No value set
	urban	3.5			30	60	200	30	<u>50</u>	30	No value set
~~All river management units~~			~~Toxin producing cyanobacteria shall not render the river unsuitable for recreation or animal drinking water.~~								
			~~Fish shall not be rendered unsuitable for human consumption by contaminants in a river.~~								
			~~The natural colour of the water in a river shall not be altered.~~								
			~~Natural frequency of hāpua, coastal lake, lagoon and river openings is not altered.~~								
			~~Passage for migratory fish species is maintained unless restrictions are required to protect populations of native fish.~~								
			~~Natural continuity of river flow is maintained from source to sea, without reaches being induced to run dry.~~								
			~~Variability of flow, including floods and freshes, avoids "flat lining", enables fish passage and mobilises bed material.~~								

[268] CI16 – Minor amendment – better aligns with Freshwater NPS
[269] Fish & Game
[270] Fish & Game

Table 1b Freshwater[271] Outcomes for Canterbury Lakes

Management unit	Ecological health indicators				Eutrophication indicator	Visual quality indicator	Microbiological indicator
	Dissolved Oxygen [min] (%)		Temp [max] (ºC)	Lake SPI* [min grade]	Trophic Level Index (TLI)* [max score]	Colour	Suitability for contact recreation [SFRG]*
	Hypo-limnion	Epilimnion					
Natural state	Lakes are maintained in a natural state						
Large high country lakes	70	90	19	Excellent	2	The natural colour of the lake is not ~~altered~~ degraded by more than five Munsell Units	Good
Small to medium sized high country lakes				High	Māori Lakes and Lakes Emily, Emma and Georgina 4		Good
					All other small to medium sized high country lakes 3		
Coastal lakes				Moderate	Coopers Lagoon/Muriwai 4		No value set
					All other coastal lakes 6		
Artificial lakes - on-river				High	3		Good
Artificial lakes – others	20	Suitable for the purpose of the lake			4		Suitable for the purpose of the lake
~~All lake management units~~	~~Toxin producing cyanobacteria shall not render the lake unsuitable for recreation or animal drinking water~~						
	~~Fish shall not be rendered unsuitable for human consumption by contaminants in a lake~~						

*Key:

Lake SPI = Lake Submerged Plant Indicators from Clayton J, Edwards T, (2002) LakeSPI: a method for monitoring ecological condition in New Zealand lakes (Technical report version 1 Report by NIWA)

TLI = Trophic Level Index from: Protocol for Monitoring Trophic Levels of New Zealand Lakes and Reservoirs (Report by Lakes Consulting, March 2000)

SFRG = Suitability for Recreation Grade from: Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas, Ministry for the Environment, June 2003

[271] CI16 – Minor amendment – better aligns with Freshwater NPS

Appendix 2: Assumptions for exploratory scenarios

A2.1 Current state

The "current state" is not a scenario but refers to the current state of the environment as observed today, and as described by recently gathered data. The technical team members refer to aspects of the current state, and indeed in some cases the historic state, as they describe what each of the future scenarios might look like in the reports in Appendices 4-22.

However, for the land use and water quality analyses it has also been necessary to *model* the current state so that model comparisons with future scenarios can be robustly made. For example, the loss of nitrate from current land use has been modelled and compared with modelled losses under Scenarios 1, 2 and 3, in order to estimate the effect of those scenarios. The modelling method has been based on the latest available data for (see Lilburne 2015, Appendix 4 for detail):

- land-use;
- on-farm management practices;
- soil types;
- irrigation;
- rainfall; and
- nitrate leaching estimates from an updated version of the Canterbury Look-Up Table (Lilburne 2015, Appendix 4).

This information has all been used to predict the average nitrate-N concentrations (mg/L) in drainage below the root zone, the drainage volume (m^3/year), and the nitrate-N load (tonnes/year) in each catchment in the SCCS project area for the modelled 'current state' and for future scenarios.

Assumptions used for modelled 'current state':

Land use

Current land use is based on current (August 2012) Agribase™ data with the following modifications: To achieve a ratio of 0.75 ha dairy support to 1 ha of dairy (according to advice from DairyNZ – V. Serra pers. comm., 1 April 2013), 4,155 ha of sheep and beef and 1,385ha of arable were changed into dairy support. This extra dairy support was spread evenly on a geographic basis as the assumption is that most of the unidentified dairy support will be occurring within sheep and beef and arable operations rather than as standalone operations (see Lilburne 2015, Appendix 4).

On-farm practice

On-farm practice is assumed to be at the level of "Good Management Practice" (GMP) for all land users in the project area. GMP specifically covers: use of nutrient budgets, application of fertiliser according to code of practice, stock exclusion, efficient irrigation application (80 % application efficiency), and compliant effluent systems. GMP is nominally defined at this point in time by the estimates of drainage and nutrient load losses (kg/ha/yr) below the root zone for different farm systems and soil types provided in the current Canterbury Look-Up Table (LUT) OVERSEER® 6 Patch. These numbers will be revised as the LUT (OVERSEER® 6) Patch is reviewed and updated in future, specifically for the Matrix of Good Management (MGM) project.

Soils

The distribution of soil types across the SCCS area has been based on S-map[52], the national soils database, for areas where this was available. For areas where S-map was not available (e.g. the SCCS area hill country) a set of customised soil map classes was developed (see Lilburne 2015, Appendix 4). Combining these two sources, the resulting soil classes are shown in Figure A2.1.

[52] http://smap.landcareresearch.co.nz/home

Irrigation

Current irrigated areas have been estimated by analysing current active irrigation consents on the Environment Canterbury database and, for the MGIS area, using information provided by MGIS. A ratio of 50/50 spray/border dyke irrigation is assumed in the MGIS area based on information provided by MGIS (Robin Murphy advice to Ned Norton, pers. comm., November 2012). The estimated total currently irrigated area in SCCS is about 27,700 ha, of which about 24,000 ha is MGIS (see Lilburne 2015, Appendix 4 for detail).

Rainfall

Rainfall pattern across the SCCS area has been based on four annual rainfall categories (<650mm, 650-750mm, 750-850mm, >850mm) generated using the NIWA virtual climate station network (VCN) data.

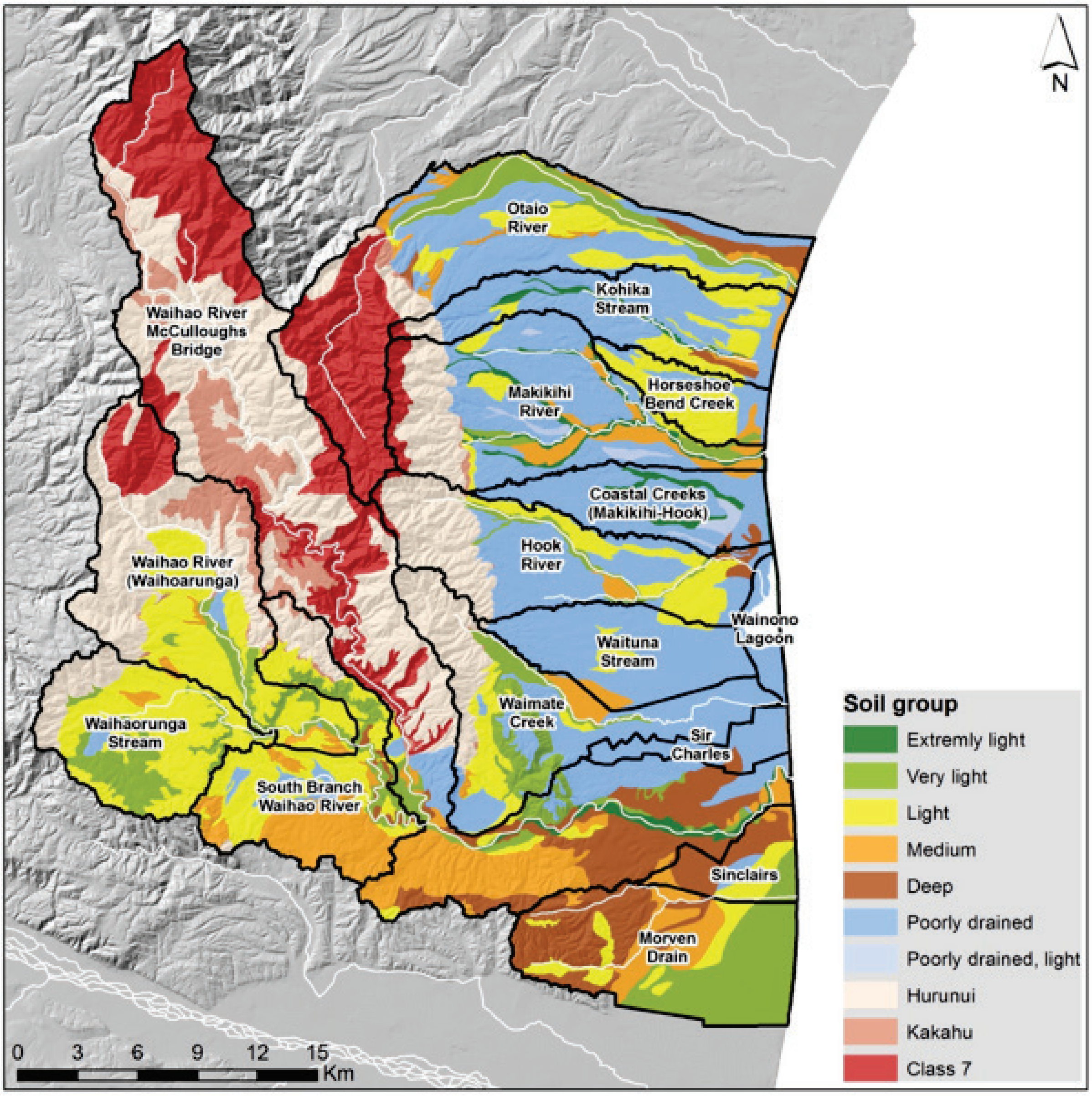

Figure A2.1 Soil map for the SCCS area (source Lilburne 2015, Appendix 4)

A2.2 Scenario 1 (a, b and c): Status Quo – pre HDI & WD

Scenario 1 considers what the future will look like ***before*** Hunter Downs Irrigation (HDI) and Waihao Downs (WD) irrigation schemes are built, these being consented schemes that will bring new (Waitaki) water into the SCCS area. Scenario 1 is looking at what may happen without these irrigation schemes out to 10 years and beyond.

Three sub-scenarios with different flow and allocation limits have been considered as below.

Sub-scenario 1a pLWRP flow and allocation limits	Assumes the pLWRP minimum flow and allocation limits for streams, rivers and groundwater within the SCCS area[53]. For most rivers these allocation limits are approximately the current total allocation; the exceptions are the Otaio, Kohika, Horseshoe Bend Creek and the Makikihi, for which the default pLWRP minimum flows (50% MALF7d) and allocation limits (20% of MALF7d) apply.

Sub-scenario 1b Manawhenua & environment flows	Assumes alternative minimum flows that are generally higher and with smaller total allocations to better meet the preferences of Manawhenua[54] and to benefit environmental values.

Sub-scenario 1c Enhanced water use	Assumes alternative minimum flows that are generally 25% lower than Scenario 1a. For most rivers the same allocation limits as Scenario 1a (i.e. current allocation) apply; the exceptions again are the Otaio, Kohika, Horseshoe Bend Creek and the Makikihi, for which the current allocation applies and this is significantly higher than the 20% of MALF7d assumed in Scenario 1a.

All minimum flow and allocation limits assumed for sub-scenarios 1a, 1b and 1c are shown in Table A2.1 at the end of this Appendix 2.

Assumptions for Scenario 1 (including Sub-scenarios 1a, 1b and 1c):

Land use

The land use mix is the same as for the modelled 'current state' above, including a dairy support/dairy ratio of 0.75 according to advice from DairyNZ (V. Serra pers. comm., 1 April 2013), but with some border dyke irrigated land converted to spray in order to achieve an increase to the spray/border dyke irrigation ratio from 50/50 to 85/15 (see Lilburne 2015, Appendix 4 for detail). A map of the estimated Scenario 1 land use is shown in Figure 7 in Section 3.3.3.

On-farm practice

On-farm practice is assumed to be at the level of "Good Management Practice" (GMP) for all land users in the project area, and with the same assumptions as for the modelled 'current state' above.

Soils

The distribution of soil types is the same as for modelled 'current state' above.

Irrigation

For Scenario 1a it is assumed there is no increase in irrigated area (compared to the modelled 'current state') because negligible new irrigation is assumed to be possible from more efficient use of existing allocated water. It is acknowledged that MGIS can expand from its current irrigated area of approximately 24,000 ha to its consented maximum of 26,400 ha but, according to advice from MGIS, the new area (2,400 ha) is likely to be largely outside the SCCS area (i.e. near Elephant Hill). Thus the total irrigated area in SCCS under Scenario 1a remains at approximately 27,700 ha.

[53] See Section 15 of the pLWRP and Regional rule 5.96 (v Aug 2012) - Proposed Canterbury Land & Water Regional Plan

[54] The flow and allocation preferences of Manawhenua are expressed in the report by Tipa (2012)(Appendix 16). These are partly (but not entirely) based on recommendations in the proposed NES (i.e. minimum flow 90%MALF; allocation 30% MALF) (MfE 2008).

A ratio of 85/15 spray/border dyke irrigation is assumed in the MGIS area, reflecting the current conversion trend and looking 10-20 years into the future.

For Scenario 1b it is likely that the higher minimum flows and smaller allocations would result in a decrease in irrigated area (see economics assessment by Harris 2015; Appendix 14); however this decrease has not been modelled for water quality – rather the same irrigated area as Scenario 1a is assumed. Similarly for Scenario 1c, the economics assessment predicts a small increase in irrigated area (~150 ha) but this has not been modelled for water quality - the same irrigated area as Scenario 1a is assumed.

Rainfall
Rainfall pattern has been based on NIWA virtual climate station network (VCN) data, as for the modelled 'current state' above.

Intensification
Intensification of current land use is assumed to the extent that there is a variable 5-16% (depending on land use) increase in N losses from different land uses. This is considered a pragmatic and realistic estimate for the future, and is also related to the 10% intensification permitted without the need for resource consent under the then rules of the proposed LWRP[55].

Travel times for groundwater contaminants ('lag times')
The travel time for groundwater (and associated contaminants such as nitrate-N) from the foothills to the bottom of the river catchments is estimated at approximately 10 years, but with an approximate travel time from currently irrigated areas (which are mostly in the lower third of the catchment) of about 3 years. This assumption is an estimate based on expert knowledge of the local hydrogeology (e.g., Scott and Etheridge 2015, Aitchison-Earl 2015; Appendices 6 and 8 respectively) and previous estimates by URS (2007).Therefore some increase in nitrate concentrations compared to those currently measured in streams is expected due to the lag in effects from recent intensification (i.e., the 'load to come'). Analysis of current surface water quality trends suggests this increase could be in the order of 5-30% varying spatially. However offsetting this increase is an expected improvement as a result of bringing all users in the catchment up to GMP (see above), and from Wainono Restoration Project initiatives (see below) – these could reduce current loss rates by a similar quantum to the load to come. In addition there is the 5-16% (average 10%) increase expected due to intensification assumed in the paragraph above. It has not been possible to accurately quantify the net effect of all these potential 'pluses' and 'minuses' at different sites across the SCCS area. Instead a coarse assumption has been made that, on balance, a net 10% increase over current surface water nitrate-N concentrations is expected for the purpose of assessing effects of Scenario 1 (a, b and c) on water quality in streams and rivers (see also discussion in the methods in Section 2.8.2).

Wainono Restoration Project
Wainono Restoration Project (WRP) initiatives (e.g. riparian planting, sediment trapping techniques and stock exclusion) are assumed to be implemented and giving benefits 10-20 years in the future. The same level of WRP effort has been assumed across scenarios 1 (a, b, c), 2 (a, b) and 3 (a, b) so that differences between scenario outcomes are not due to WRP.

Waihao Box management
It is assumed that management of the outflow from the Waihao-Wainono catchment to the sea (i.e. at the Waihao Box) continues to achieve a similar frequency and duration of openings to the sea, and a similar level of drainage and flood management for the low-lying land in the vicinity of the lower Waihao River, the Waihao Arm and Wainono Lagoon.

A2.3 Scenario 2: HDI & WD as consented

Scenario 2 considers what the future will look like ***after*** Hunter Downs Irrigation (HDI) and Waihao Downs (WD) irrigation schemes are built, these being consented schemes that will bring new (Waitaki) water into the

[55] Note that this scenario was designed in early 2013 when the 10% intensification permitted activity rule was still in place but it has subsequently been removed. Nonetheless the 10% intensification assumption remains for Scenario 1.

SCCS area. Scenario 2 is looking at what may happen with these consented irrigation schemes out to 20 years and beyond.

Two sub-scenarios are considered:

- Scenario 2a – HDI & WD as consented ***without*** flow augmentation
- Scenario 2b – HDI & WD as consented ***with*** flow augmentation

Flow augmentation assumed for Scenario 2b

In general, the concept of 'flow augmentation' involves using irrigation scheme infrastructure to deliver Waitaki River water for environmental benefits such as increased flow in rivers and flow through Wainono Lagoon.

For Scenario 2b it is assumed that 31.5 million m^3/year (average flow 1 m^3/s) of water is taken from the Waitaki River at Stonewall and is delivered, through HDI infrastructure, to the lower Hook River, a tributary of the Wainono Lagoon. There has been no detailed work undertaken to determine the feasibility of suitable locations for discharge to the Hook River, or how the augmentation water might best be distributed variably through the year (i.e. an 'augmentation flow regime'). However for the purpose of assessing the hypothetical Scenario 2b it is assumed that the discharge is to the lower Hook River (nominally in the vicinity of SH1) and the 'augmentation flow regime' would vary during the year, with a short period of approximately 4 m^3/s for 5 days in spring (early October) which is equivalent to one complete replacement of the average lagoon water volume in spring when lagoon nutrient concentrations are usually highest, followed by a lesser flow (~ 1 m^3/s) for the summer and autumn months when low flow stress on the ecosystem is greatest, and then no augmentation over the winter months. This possible augmentation regime was described as a starter for discussion in Sutherland and Norton (2011, Appendix 18). The plausibility of augmentation delivering improved lake water quality was then confirmed with a more detailed modelling investigation described in Abell et al., 2015, Appendix 19). It is assumed that management of the augmentation flow regime would be flexible enough to respond to environmental monitoring so that, for example, augmentation flow could be shut off when the Waitaki River is in flood with sediment-laden water, and conversely could be increased to replace the lagoon volume in a few days in the event of a toxic algal bloom.

It is noted that there is potential to use Waitaki augmentation water to enhance flow in other Wainono tributaries (e.g. Merrys Stream, Waituna Creek) and/or other rivers to the north or south of Wainono; however this has not been assumed for the purpose of exploring Scenario 2b.

Other assumptions for Scenario 2:

Irrigation

The new irrigated land area under Scenario 2 (including both sub-scenarios 2a and 2b) is 27,066 ha which, when combined with the 27,700 ha irrigated under Scenario 1, brings the total irrigated SCCS area to approximately 54,700 ha (i.e. approximately double the irrigated area of Scenario 1).

A ratio of 85/15 spray/border dyke irrigation is assumed in the MGIS area, the same as for Scenario 1, reflecting the current conversion rate trend and looking 10-20 years into the future. All other irrigated areas are assumed to be spray irrigation.

Land use and intensification

The land use mix assumed for all new irrigated (HDI & WD) land is shown in the following table.

Land use	**Proportion of irrigated area**	**New Area (ha)** (total 27,066)	**Type (for use in LUT)**
Dairy	70%	18,946	4 cows/ha winter off
Arable	10%	2,706	Seasonal
Sheep Beef and Deer	10%	2,706	20% sheep & beef
Dairy Support	10%	2,706	Generic

The area of dairy has increased significantly from previous estimates used in the HDI consenting process (2007) based on advice from S. Ford (advice to Simon Harris, pers. comm., 2013). This is a result of the likely price for HDI water being considerably higher than previous estimates, meaning only high value land uses will be able to afford it. Note also that the land use mix in the table above applies only to the new irrigated land under HDI and WD (27,134 ha). Further breakdown of the area of new irrigated land by catchment is provided in Lilburne 2015, Appendix 4).

The currently irrigated land under Scenario 1 (~27,700 ha) remains with the same land use mix as for Scenario 1, on the basis that i) no further land use *change* can occur in that area without consent under the pLWRP, and ii) no further *intensification* can occur in that area under the pLWRP beyond that already assumed to occur in Scenario 1 (i.e. 5-16% depending on land use).

A dairy support/dairy ratio of 0.75 has again been assumed according to the advice from DairyNZ (V. Serra pers. comm., 1 April 2013) by increasing the area of dryland dairy support.

A map of the estimated Scenario 1 land use is shown in Figure 7 in Section 3.3.3.

On-farm practice
On-farm practice is assumed to be at the level of "Good Management Practice" (GMP) for all land users in the project area, and with the same assumptions regarding the Canterbury Look-Up Table (LUT) OVERSEER® 6 Patch, as for the modelled 'current state' and Scenario 1 above.

Soils
The distribution of soil types is based on S-map, the same as for modelled 'current state' and Scenario 1 above.

Rainfall
Rainfall pattern has been based on NIWA virtual climate station network (VCN) data, as for the modelled 'current state' and Scenario 1 above.

Wainono Restoration Project
Wainono Restoration Project initiatives (e.g. riparian planting, sediment trapping techniques and stock exclusion) are assumed to be implemented and giving benefits 10-20 years in the future, the same as for Scenario 1 above.

Waihao Box management
It is assumed that management of the outflow from the Waihao-Wainono catchment to the sea (i.e. at the Waihao Box) continues to achieve a similar level of drainage and flood management for the low-lying land in the vicinity of the lower Waihao River, the Waihao Arm and Wainono Lagoon. For Scenario 2b (with flow augmentation) this is assumed to be achieved by more frequent Box openings to the sea and/or greater flow rate through the Box when open, to accommodate the additional 1 m^3/s (average) of Waitaki augmentation water.

A2.4. Scenario 3: HDI & WD plus advanced on-farm mitigations

Scenario 3 considers the case ***after*** Hunter Downs Irrigation (HDI) and Waihao Downs (WD) irrigation schemes are built, and explores what the costs and benefits would be of employing advanced on-farm mitigations (i.e. better than the GMP assumed for Scenario 2a and 2b).

Two sub-scenarios are considered:

- Scenario 3a – Full development (HDI & WD) plus maximum feasible mitigations (MFM) which equate to approximately an average 30% reduction in N losses compared to GMP (but varies between 0 and 40% reduction depending on land use type).
- Scenario 3b – Full development (HDI & WD) plus mitigations at the "mid-point" between GMP and MFM (i.e. approximately an average 15% reduction in N losses compared to GMP, but varying between 0 and 20% depending on land use type).

For further detail on the N loss reductions assumed for different land uses see Section 2.8.7 and for a description of typical farm practices associated with GMP, MFM and “midpoint mitigations” see the definition of these terms in the Glossary.

All other assumptions are identical to those for Scenario 2a above – the only difference for Scenarios 3a and 3b is the level of on-farm mitigations.

Table A2.1 Summary of minimum flow and allocation limits assumed for Sub-scenarios 1a, 1b and 1c

		SCENARIO 1a			SCENARIO 1b		SCENARIO 1c	
		"pLWRP-s15 flow limits" Proposed sub-regional section 15 provisions (2012) (For Otaio, Kohika, Horseshoe Bend and Makikihi, PLWRP default limits)[56]			"Manawhenua & environmental flow limits" COMAR report (Tipa 2012)[57]		"Enhanced reliability / water use" (Minimum flows are 75% of pLWRP & for most rivers the allocations are the same as pLWRP)[58]; the exceptions are the Otaio, Kohika, Horseshoe Bend Creek and Makikihi, for which the current consented allocation is assumed	
Min flow Location	Natural MALF7d (L/s)[59]	Minimum flow for A[60] & B permits (L/s) Summer, winter	Allocation limit for A & B permits (L/s) Summer, winter	Permitted allocation	Minimum flow (L/s)	Allocation limit (L/s)	Minimum flow for A[61] & B permits (L/s) Summer, winter	Allocation limit for A & B permits (L/s) Summer, winter
Otaio River @ Otaio Gorge (recorder site)	**107**	Min flow 50% of 7dMALF 58.5	Allocation 20% of 7dMALF 23.4		90% MALF (NES)	30% MALF (NES)	No min flow	451
Kohika River	**None measured (synthetic SH1 = 40[62])**	Min flow 50% of 7dMALF (20 - if based on synthetic at SH1)	Allocation 20% of 7dMALF (8 - if based on synthetic at SH1)		90% MALF (NES)	30% MALF (NES)	Assume 2 L/s (There is 1 take with residual flow of 2.04 l/s)	2.8
Horseshoe Bend Creek	**None measured (synthetic SH1 = 16[13])**	Min flow 50% of 7dMALF (8 - if based on synthetic at SH1)	Allocation 20% of 7dMALF (3.2 - if based on synthetic at SH1)		90% MALF (NES)	30% MALF (NES)	No min flow	0
Makikihi River (@Teschemaker Valley Rd)	**21**	Min flow 50% of 7dMALF 10.5	Allocation 20% of 7dMALF 4.2		90% MALF (NES)	30% MALF (NES)	Assume 20 L/s (There is a residual flow consent condition for 20 L/s but unsure how many consents linked)	72.8
South Branch Hook (@Gunns Bush)	**20**	A- 20 B- none	A- 7, 0 B- none		A- 13 L/s	30% MALF (NES)	13 (1 consent in this area and it currently has this condition)	A- 7, 0 B- none
Upper Hook River (above intake)	**35**	A- 32 B winter only- 200	A- 47[63], 0 B-0, 44	A-20	A 50 L/s B-200 L/s	30% MALF (NES)	No min flow (no current consents have min flow) B-150	A- 67[64], 20 B-0, 44 (A block incl permitted comm supply)
Hook @ Hook Beach Rd	**71**	A- 64 B- none	A- 15[65], 0 B- none Total allocation (Hook + Merrys) incl community A sum 102, 75 B sum-50, 44		Assume 90%MALF (Provide min depth of 300mm for passage of large longfin tuna).	30% MALF (NES)	A- 48	A- 15[66], 0 B- none Total allocation (Hook + Merrys) incl community A sum 102, 75 B sum-50, 44

[56] Min flow 50% of 7dMALF and Allocation 20% of 7dMALF (Rule 5.96(2)(a)). Note that this pLWRP default approach produces allocation limits that are significantly lower (~20x lower) than current allocation (i.e. current consents) for the Otaio and Makikihi Rivers (see far right column in Scenario 1c). It is intended to have discussions with the relevant catchment groups in these rivers to establish how much of the current allocation "on paper" is actually taken and used, and to discuss options for setting allocation limits.
[57] Permitted activities considered to be part of the 30% of MALF
[58] Unless consents have no minimum flow conditions, then these will have no minimum flow in scenario 1c.
[59] Based on flow recorders or Environment Canterbury staff estimates based on regression relationships between recorder and non-recorder sites, unless otherwise stated
[60] The A permit permits is dependent on how & when groundwater stream depletion figures are calculated
[61] The A permit permits is dependent on how & when groundwater stream depletion figures are calculated
[62] Synthetic estimate based on models of Booker and Woods (2012)
[63] Does not include allocated water from 980386
[64] Does not include allocated water from CRC040547.1
[65] CRC040547.1 consent (15L/s) when reviewed, it is recommended to be tied to this minimum flow site
[66] CRC040547.1 consent (15L/s) when reviewed, it is recommended to be tied to this minimum flow site

		SCENARIO 1a			SCENARIO 1b		SCENARIO 1c	
		"pLWRP-s15 flow limits" Proposed sub-regional section 15 provisions (2012) (For Otaio, Kohika, Horseshoe Bend and Makikihi, PLWRP default limits)[56]			**"Manawhenua & environmental flow limits" COMAR report (Tipa 2012)[57]**		**"Enhanced reliability / water use" (Minimum flows are 75% of pLWRP & for most rivers the allocations are the same as pLWRP)[58]; the exceptions are the Otaio, Kohika, Horseshoe Bend Creek and Makikihi, for which the current consented allocation is assumed**	
Min flow Location	**Natural MALF7d (L/s)[59]**	**Minimum flow for A[60] & B permits (L/s) Summer, winter**	**Allocation limit for A & B permits (L/s) Summer, winter**	**Permitted allocation**	**Minimum flow (L/s)**	**Allocation limit (L/s)**	**Minimum flow for A[61] & B permits (L/s) Summer, winter**	**Allocation limit for A & B permits (L/s) Summer, winter**
Merrys Stream @SH1	**4**	A- 5, 45 B- 45 Some in the community have expressed they want a minimum flow not a minimum level as is the case currently	A- 13, 55 B- 50, 0		A- 25 (GW managed for supply plus Lower Hook for other considerations)	30% MALF (NES)	A- 4, 34 B- 33 [67]	A 13, 55 B 50, 0
Hook Beach Drain	**-**	Not assessed in flow scenarios – no minimum flow or any allocation currently – none proposed in pLWRP						
Waituna Stream	**-**	Not assessed in flow scenarios – no minimum flow or any allocation currently – none proposed in pLWRP						
Waimate Creek @ ds intake	**68**	A- 15, 100 B- 400	A- 42, 100[68] B- 100		90% MALF (NES)	30% MALF (NES)	A- 11, 75 B- 300	A 42, 100 B 100
Sir Charles Creek @ Rooney's Bridge	**234[69]**	A- 100, 120 B- 380	A- 149, 139 B- 26		A-100 (GW managed for supply)	30% MALF (NES)	A- 75,90 B- 285	A- 149, 139 B- 26
Buchanans Creek @ Fletcher's Bridge recorder	**183**	A- 150, 178 B- none	A- 123, 123 B - none		A-200 (GW managed for supply)	30% MALF (NES)	A-112.5, 133.5	A- 123,123 B - none

[67] Currently a level limit of 250mm (A block summer) & 300mm (B Block and A Block winter) is used on consents.
[68] Room has been made in the allocation block for application CRC111332
[69] This is a coarse estimate only based on a few gaugings

		SCENARIO 1a			SCENARIO 1b		SCENARIO 1c	
		"pLWRP-s15 flow limits" Proposed sub-regional section 15 provisions (2012) (For Otaio, Kohika, Horseshoe Bend and Makikihi, PLWRP default limits)[56]			"Manawhenua & environmental flow limits" COMAR report (Tipa 2012)[57]		"Enhanced reliability / water use" (Minimum flows are 75% of pLWRP & for most rivers the allocations are the same as pLWRP)[58]; the exceptions are the Otaio, Kohika, Horseshoe Bend Creek and Makikihi, for which the current consented allocation is assumed	
Min flow Location	Natural MALF7d (L/s)[59]	Minimum flow for A[60] & B permits (L/s) Summer, winter	Allocation limit for A & B permits (L/s) Summer, winter	Permitted allocation	Minimum flow (L/s)	Allocation limit (L/s)	Minimum flow for A[61] & B permits (L/s) Summer, winter	Allocation limit for A & B permits (L/s) Summer, winter
Upper Waihao River @ McCulloughs recorder	**354 McCulloughs** **21 Waihaorunga** **112 Waihao @ Wai** **119 Waihao Sth Br**	McCulloughs A- 300 B- 1325 Waihaorunga[70] A- 16 B-150 Waihao @Waihaorunga[71] A- 90 B- 200 Waihao South Branch[72] A- 100 B-250	McCulloughs A- 242.3, 184.2 B- 200, 100 Waihaorunga A- 34, 34 B- none (no flow conditions with McCul) Waihao @Waihaorunga A- 49, 49 B- 85, 0 (flow conditions with McCul) Waihao South Branch A- 51, 0 B- none (flow conditions with McCul) Sum of all abstraction above McCulloughs A[73]- 386.4, 277.4 B- 285, 100	McCulloughs 1.6 Waihaorunga 8.4	McCulloughs A- 1400 For other 3 sites (Waihaorunga; Waihao @Waihaorunga; Waihao South Branch) assume NES 90% MALF	30% MALF (NES) Assume for all four sites	McCulloughs A- 225 B- 994 Waihaorunga A- 12 B -112.5 Waihao @Waihaorunga A- 67.5 B-150 Waihao South Branch A- 75 B-187.5	McCulloughs A- 243.9, 185.8 B- 200, 100 (A block incl permitted comm supply) Waihaorunga A- 42.4, 42.4 B- none (**no** flow conditions with McCul & A block incl permitted comm supply) Waihao @Waihaorunga A- 49, 49 B- 85, 0 (flow conditions with McCul) Waihao South Branch A- 51 B- none (flow conditions with McCul) Sum of all abstraction above McCulloughs A[74]- 386.4, 277.4 B- 285, 100
		Partial restrictions – at 600 L/s all permits reduce their rate of take by 50%			50% restriction is triggered at 1500 L/s Extraction can fully return after one week at > 1500 L/s		Partial restrictions only controlled by McCulloughs– at 450 L/s all permits reduce their rate of take by 50%	
Lower Waihao @ Bradshaws Bridge	**58 (without MGIS discharge)**	A- Modified[75] min 100 B- Modified min 600 Acknowledges MGIS discharge	A- 152, 0 B- 30, 0		A- 425, 600	30% MALF (NES)	A- Modified[76] 75 B- Modified min 450 Acknowledges MGIS discharge	A 152, 0 B 30, 0

[70] Variation 9 minimum flow
[71] Variation 9 minimum flow
[72] Variation 9 minimum flow
[73] Proposal is to manage all upper Waihao sites via McCulloughs as good correlations with other existing sites
[74] Proposal is to manage all upper Waihao sites via McCulloughs as good correlations with other existing sites
[75] Modified flow is the calculated flow after the environmental discharge is removed from the Bradshaws recorded flow
[76] Modified flow is the calculated flow after the environmental discharge is removed from the Bradshaws recorded flow

		SCENARIO 1a			SCENARIO 1b		SCENARIO 1c	
		"pLWRP-s15 flow limits" Proposed sub-regional section 15 provisions (2012) (For Otaio, Kohika, Horseshoe Bend and Makikihi, PLWRP default limits)[56]			"Manawhenua & environmental flow limits" COMAR report (Tipa 2012)[57]		"Enhanced reliability / water use" (Minimum flows are 75% of pLWRP & for most rivers the allocations are the same as pLWRP)[58]; the exceptions are the Otaio, Kohika, Horseshoe Bend Creek and Makikihi, for which the current consented allocation is assumed	
Min flow Location	**Natural MALF7d (L/s)[59]**	**Minimum flow for A[60] & B permits (L/s) Summer, winter**	**Allocation limit for A & B permits (L/s) Summer, winter**	**Permitted allocation**	**Minimum flow (L/s)**	**Allocation limit (L/s)**	**Minimum flow for A[61] & B permits (L/s) Summer, winter**	**Allocation limit for A & B permits (L/s) Summer, winter**
		Uses regional default, but specifies, Pro-rata partial restrictions as most appropriate					Uses regional default, but specifies, Pro-rata partial restrictions as most appropriate	
Waihao Dead Arm @ Poingdestres Rd	-	Height not to fall below 1.3 m above mean sea level	A- 80 B- none		Height not to fall below 1.5 m above mean sea level	None suggested	Water level 1.3m No min flow	None
Wainono Lagoon	-	Not assessed in flow scenarios – no minimum flow or any allocation currently – none proposed in pLWRP						
Sinclairs	-	Not assessed in flow scenarios – no minimum flow or any allocation currently – none proposed in pLWRP						
Morven Drain	-	Not assessed in flow scenarios – no minimum flow or any allocation currently – none proposed in pLWRP						

Appendix 3: Assumptions for Zone Committee Solutions Package (ZCSP)

For modelling purposes the ZCSP can be considered as a blend of:

1. Scenario 2b (HDI + WD + flow augmentation);
2. A nitrogen allocation framework developed by NARG (Appendix 22);
3. A set of environmental flows and allocation volume limits that come close to achieving Scenario 1b flows in time; by allowing some swaps from surface water to deep groundwater and reducing surface allocation through time as new (HDI and WD)scheme water becomes available.
4. An extended Wainono Restoration Project.

A3.1 Scenario 2b: HDI + WD + flow augmentation

All of the same assumptions laid out in Appendix 2 for Scenario 2b apply to the ZCSP with regard to the following elements (see Lilburne 2015, Appendix 4 for detail):

- Land use mix
- Irrigation
- Intensification
- Soils
- Rainfall
- Flow augmentation of Wainono Lagoon
- Wainono Restoration Project
- Waihao Box reconstruction

A3.2 The nitrogen allocation framework developed by NARG

The nitrogen allocation framework developed by NARG is described in detail in Norton et al., 2015 (Appendix 22) and the key elements of it (Tables B, C and D) are quoted from the ZIP Addendum (LWZC 2014) on the following two pages. See Lilburne 2015 (Appendix 4) for detail on how the framework was modelled.

A3.3 Environmental flows

A map of the catchments, minimum flow sites and existing consents is shown in Figure A3.1. The environmental flows and allocation limits assumed for technical assessments are shown in tables at the end of this Appendix.

A3.4 Extended Wainono Restoration Project

Environment Canterbury, with the support of its partners in the Wainono Restoration Project, the Lower Waitaki Zone Committee and Te Rūnanga o Waihao, is seeking funding for an extension that would include:

- Extension of the current sediment and nutrient reduction and riparian management initiatives to all lagoon tributaries;
- Securing retirement of lake margin land around the perimeter of the lagoon;
- Lake margin remediation, buffer establishment and access;
- A denitrification tool (e.g., wetland);
- Catchment land, water and ecological advice and support

Nitrogen allocation framework (Tables B, C and D) quoted from ZIP Addendum

Table B - Nitrogen allocation framework for farming.

<table>
<tr><th colspan="3">Framework = Good Management Practice with a Flexibility Cap and a Maximum Cap
Waihao Wainono and Northern Streams</th></tr>
<tr><td>2015

Step 1</td><td>Working to Good Management Practice for all users as per the MGM Project

Flexibility cap of 10kgs/ha/yr for low emitters in Waihao Wainono and 15kgs in Northern Streams.

The flexibility cap for “steep hill” areas (defined as Hurunui and Class 7 soils) remains at 5 kg/ha/yr in all catchments from 2015 onwards.

Maximum Cap levels are clearly signalled and the timeframe for existing users to get there. New users meet the max cap from Step 1.
(As per table below)</td><td>Plan Operative</td></tr>
<tr><td>By 2020

Step 2</td><td>Good Management Practice for all users as per the MGM Project

Flexibility Cap in Waihao Wainono increases to 15kgs

A plan must be produced by existing high emitters to show progress and methods to get down to Maximum Cap by 2025.
(New scheme users and new conversions must meet the Maximum Cap immediately)</td><td>If Augmentation has occurred</td></tr>
<tr><td>2025

Step 3</td><td>Good Management Practice for all users as per the MGM Project

High emitters have reduced to the Maximum Cap

If water quality outcomes are being met, then the gains made from the Maximum Cap reductions are available to:
provide additional flexibility for low emitters to a target of 17kgs/ha/yr
provide for any existing high emitters on XL soils that are unable to meet the 35kgs maximum cap – by application for resource consent with a strong justification required</td><td>Plan review</td></tr>
</table>

Table C – Maximum Caps for farming

<table>
<tr><th>Maximum Cap for Waihao Wainono and Northern Streams (kg/ha/yr)</th><th>Soils</th><th>New Users (HDI + WD + any other new converters)</th><th colspan="2">Existing Users</th></tr>
<tr><td>35</td><td>XL, VL, L</td><td rowspan="3">Achieve immediately on conversion</td><td rowspan="3">Must prepare a plan by 2020 showing how to achieve</td><td rowspan="3">Achieve by 2025</td></tr>
<tr><td>25</td><td>M, H, D</td></tr>
<tr><td>20</td><td>Pd, Pdl</td></tr>
</table>

Table D - Draft N-load limits for urban and industrial discharges.

Catchment	Timing	Load limit (t/yr)	What does this mean for users?
Waihao-Wainono	From April 2015	40 (milk processing wastewater) 2 (Waimate community sewerage)	• Fonterra factory milk processing wastewater may continue within current total loading rate • Waimate community wastewater treatment plant may continue within current total loading rate
Northern Streams	From April 2015	8 (potato processing wastewater)	• Makikihi factory potato processing wastewater may continue within current total loading rate
Morven - Sinclairs	From April 2015	0	• There are no existing urban or industrial discharges and no load is provided for new discharges

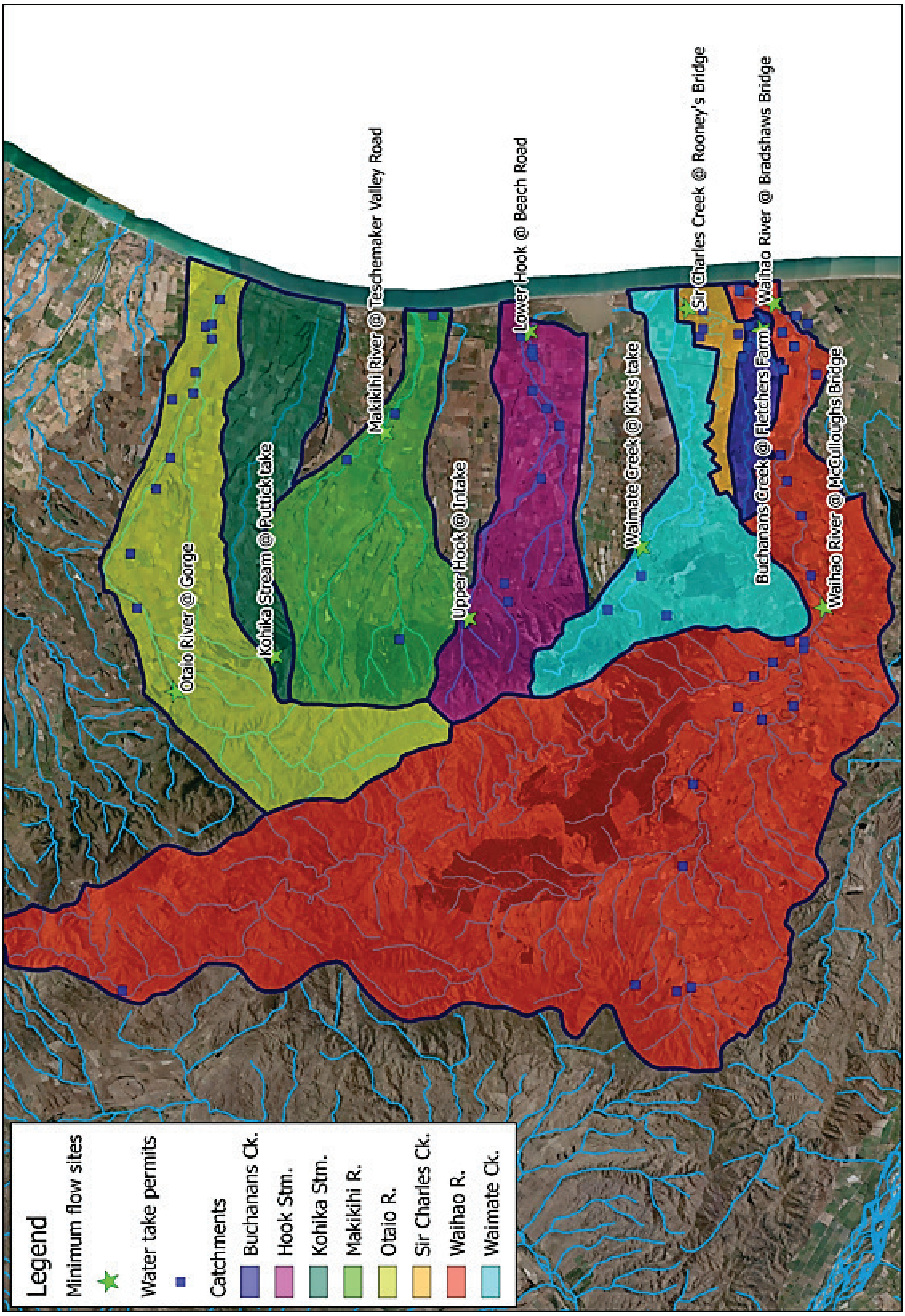

Figure A3.1: A map of the SCCS surface water catchments, minimum flow sites and existing water take consent locations. Source: Brown 2015 (Appendix 13).

Environmental flow and allocation limits assumed for the ZCSP

Notes for tables:

1. Several proposed stepped levels of "partial restriction" apply at designated flows, with the ultimate minimum flow indicated in the "100% restriction" (far right) column
2. Table A3.1 (for the period 1 April 2015 to 30 May 2025) approximately reflects the current consented allocation situation with several exceptions, most notably the Otaio and Makikihi catchments where users currently have no minimum flow requirement, whereas a minimum flow is proposed in the tables.
3. The source of the tables as laid out is Brown 2015 (Appendix 13) who, along with others in the technical assessment team, was provided the proposed allocation and minimum flow framework by Environment Canterbury planning staff for assessment based on ZC and community discussions up to November 2014. Those discussions have continued into 2015 and some further changes may be made to the proposed regime before notification of the proposed plan in April 2015. The technical assessments in this Overview Report and its appendices have been based on the proposed regime below. Any changes will be addressed by subsequent technical memos or reports during the planning process.

Table A3.1. Allocations and minimum flows for the period 1 April 2015 to 30 May 2025.

Catchment	Recorder site	Allocation (l/s)	Flow at recorder site				
			No restriction	25% restriction	50% restriction	75% restriction	100% restriction
Upper Waihao	McCullough recorder	379	>600 l/s	NA	300-600	NA	≤300 l/s
Lower Waihao[(1)]	Bradshaws recorder	186	>100 l/s	NA	NA	NA	≤100 l/s
Buchanans	Fletchers Bridge recorder	95	>150 l/s	NA	NA	NA	≤150 l/s
Sir Charles Creek	Rooneys bridge	157	>100 l/s	NA	NA	NA	≤100 l/s
Waimate Creek	Kirks Intake	41	>15 l/s	NA	NA	NA	≤15 l/s
Upper Hook	Above [WDC] Intake	10 (+20)[2]	>50 l/s	NA	35-50	NA	≤35 l/s
Lower Hook	Beach Road	84	>64 l/s	NA	NA	NA	≤64 l/s
Makikihi	Teschemaker Valley Road	88	>108 l/s	79-108	50-79	20-50	≤20 l/s
Kohika	Puttick Intake	2.8	Reliability not modelled since only one small take affected				
Otaio	Gorge	456	>546 l/s	394-546	242-394	90-242	≤90 l/s

(1) The modified minimum flow is calculated by the measured flow at Bradshaws recorder less 700 l/s, which is the MGI Waihao augmentation flow.
(2) 20 l/s Waimate District Council take, upstream of the flow recorder site, has priority

Table A3.2. Allocations and minimum flows for the period after 1 June 2025.

Catchment	Recorder site	Allocation (l/s)	Flow at recorder site				
			No restriction	25% restriction	50% restriction	75% restriction	100% restriction
Upper Waihao	McCullough recorder	153	>600 l/s		400-600		≤400 l/s
Lower Waihao[(1)]	Bradshaws recorder	152	>100 l/s				≤100 l/s
Buchanans	Fletchers Bridge recorder	95	>150 l/s				≤150 l/s
Sir Charles Creek	Rooneys bridge	157	>100 l/s				≤100 l/s
Waimate Creek	Kirks Intake	2	>15 l/s				≤15 l/s
Upper Hook	Above [WDC] Intake	10 (+20)[2]	>50 l/s		35-50		≤35 l/s
Lower Hook	Beach Road	37	>64 l/s				≤64 l/s
Makikihi	Teschemaker Valley Road	28	44 l/s		20-44		<20 l/s
Kohika	Puttick Intake	2.8	Reliability not modelled since only one small take affected				
Otaio	Gorge	175	>309	236-309	163-236	90-163	≤90 l/s

(1) The modified minimum flow is calculated by the measured flow at Bradshaws recorder less 700 l/s, which is the MGI Waihao augmentation flow.
(2) 20 l/s Waimate District Council take, upstream of the flow recorder site, has priority

Appendix 4: (Lilburne, 2015) South Canterbury Coastal Streams (SCCS) limit setting process: Estimating nitrogen loss under rural land use and informing nitrogen allocation options

Appendix 5: (Fietje, 2015) Estimating nitrogen loss from land uses in the hill country of the South Canterbury Coastal Streams (SCCS) area

Appendix 6: (Scott and Etheridge, 2015) South Canterbury Coastal Streams (SCCS) limit setting process. Predicting consequences of future scenarios: Groundwater quality

Appendix 7: (Kelly, 2015) South Canterbury Coastal Streams (SCCS) limit setting process. Predicting consequences of future scenarios: Surface water quality and associated values

Appendix 8: (Aitchison-Earl, 2015) South Canterbury Coastal Streams (SCCS) limit setting process. Predicting consequences of future scenarios: Groundwater quantity

Appendix 9: (Clarke, 2015) South Canterbury Coastal Streams (SCCS) limit setting process. Predicting consequences of future scenarios: Ecological flows

Appendix 10: (Ballard, 2013) Consequences of options for surface water allocation limits – South Canterbury Coastal Streams

Appendix 11: (Martin & Leftley, 2012) Waihao-Wainono hydrological information

Appendix 12: (Martin, 2015) South Canterbury Coastal Streams (SCCS) limit setting process. Hydrology

Appendix 13: (Brown, 2015) South Canterbury Coastal Streams (SCCS) limit setting process. Predicting consequences of future scenarios: Irrigation reliability

Appendix 14: (Harris, 2015) South Canterbury Coastal Streams (SCCS) limit setting process. Predicting consequences of future scenarios: Economic assessment

Appendix 15: (Taylor *et al.,* 2015) South Canterbury Coastal Streams (SCCS) limit setting process. Social profile and assessment

Appendix 16: (Tipa, 2012) Cultural associations and their flow and water management implications for the Waihao/Wainono catchment

Appendix 17: (Tipa, 2013) Cultural values and water management issues for a selection of South Canterbury catchment

Appendix 18: (Sutherland & Norton, 2011) Assessment of augmentation of water flows in Wainono Lagoon

Appendix 19: (Abell, Jones, Hamilton, 2015) Hydrodynamic-ecological modelling to support assessment of water quality management options for Wainono Lagoon

Appendix 20: (Schallenberg, 2013) Nutrient loading thresholds relevant to Wainono Lagoon (Canterbury)

Appendix 21: (Schallenberg & Saulnier-Talbot, 2014) Recent environmental history of Wainono Lagoon (South Canterbury, New Zealand)

Appendix 22: (Norton *et al.,* 2014) Process and outcomes of the Nitrogen Allocation Reference Group (NARG) for the South Canterbury Coastal Streams area

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