Environment Canterbury Regional Council
Kaunihera Taiao ki Waitaha

TECHNICAL REPORT Science Group

Waimakariri Land and Water Solutions Programme

Technical Assessment Overview

Report No. R19/73

ISBN 978-1-98-859343-2 (print)

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May 2019

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Executive Summary

Background
The Waimakariri Water Zone encompasses the Ashley River/Rakahuri and Waimakariri River northern tributaries catchments which fall within the takiwā of Ngāi Tūāhuriri, one of five primary hapū of Ngāi Tahu. The zone's rivers, streams, lagoons and wetlands have always been important places and a food basket for Ngāi Tūāhuriri. The Waimakariri Water Zone Committee (WWZC) identified a set of nine Community Outcomes which seek to maintain and improve mahinga kai, water quality and aquatic ecology; provide for safe and reliable drinking water; maintain and improve indigenous biodiversity; support social and economic sustainability, thriving communities and promote climate change resilience and adaptation.

The problem
Our analysis of current state water quality, stream flow, water allocation, stream health, and economic data identified several issues. These include: significantly degraded mahinga kai diversity, abundance and quality; low water quality and habitat in spring-fed streams causing poor stream health and aquatic biodiversity; recreational opportunities compromised by water quality issues such as cyanobacteria blooms in the Ashley River/Rakahuri; water quality issues and poor habitat in Te Aka Aka (the Ashley River/Rakahuri estuary) with associated ecological, cultural and recreational impacts; low indigenous biodiversity with ongoing threats due to continuing habitat loss and modification and pest invasion; nitrate concentrations exceeding drinking water limits in an estimated ~5% of private supply wells, with further increases likely due to lag effects. We also identified connectivity between the Waimakariri and Christchurch aquifer systems not previously understood which increases the risk of long-term nitrate concentration increases in the Christchurch aquifers due to intensive land use in the Waimakariri zone.

What we did
Environment Canterbury staff worked with the WWZC, stakeholders and the local community for over three years to evaluate a range of land and water management options to achieve the Community Outcomes. Finding the balance between environmental, social and economic outcomes which best aligns with community and stakeholder values was a major component of the WWZC's work. The WWZC used information from the Current State analysis, Current Pathway and Alternative Pathways scenarios, an options assessment process, and community and stakeholder consultation to develop a set of recommendations for statutory (e.g., regional plan provisions) and non-statutory actions (e.g. education, advocacy and enhancement projects). These are outlined in their Zone Implementation Programme Addendum (ZIPA). The extent to which the Community Outcomes are expected to be achieved through implementation of the ZIPA recommendations (solutions package) was assessed.

What we found
Nitrates in surface water and groundwater was the major focus of the solutions package. Our assessment results show that implementation of statutory ZIPA recommendations is expected to help maintain current values and support moderate improvements over time; but would not achieve all Community Outcomes. The non-statutory recommendations could help to protect current ecological and cultural values; and potentially shorten timeframes for achieving some of the Community Outcomes. The WWZC recognised that a major part of the significant degradation of mahinga kai and the associated major social impact on Ngāi Tūāhuriri was driven by historical changes in land use, drainage and management practices, and that these issues are not easily remedied by regional plan rules.

What it means
Implementation of the ZIPA recommendations will help to maintain current environmental values, deliver a moderate improvement within the next decade, provide greater clarity and a pathway to reducing water quantity overallocation and in some instances achieve a significant improvement in the longer term. However, some recommendations will have adverse economic impacts on parts of the local farming economy; the WWZC recognised this in arriving at their recommendations and particularly when allowing time for change.

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Glossary

Report term	Definition
7dMALF^{natural}	Seven day mean naturalised annual low flow; a flow statistic often considered in setting minimum flows. The lowest flow in each year of record sustained over seven consecutive days which is then averaged across the length of record. Based on the naturalised flow, which removes the effect of abstraction so that the number reflects low flows in the stream's natural condition.
7dMALF	Seven day mean annual low flow; a flow statistic often considered in setting minimum flows. The lowest flow in each year of record sustained over seven consecutive days which is then averaged across the length of record. Based on the recorded flow which considers the effects of abstractions (cf. 7dMALF^{natural}).
Alternative pathways scenarios	Possible land use configurations modelled to consider how to reach community outcomes. The three beyond Baseline GMP nitrate loss reduction options we considered were: 1. **10% beyond Baseline GMP** – all consented land use reduce nitrate losses 10% beyond Baseline GMP 2. **20 kg/ha + 10% beyond Baseline GMP** – all consented land use reduce nitrate losses 10% beyond Baseline GMP if their nitrate loss at any stage is more than 20 kg/ha. 3. **20 kg/ha + 10 & 20% beyond Baseline GMP** – Dairy reduce nitrate losses 20% and all other consented 10% beyond Baseline GMP if their nitrate loss at any stage is more than 20 kg/ha.
Baseline GMP	The average nitrogen loss rate below the root zone, as estimated by the Farm Portal, for the farming activity carried out during the nitrogen baseline period, if operated at good management practice.
COMAR	Cultural Opportunity, Mapping Assessment and Response. Shorthand for the Cultural Health Assessment report prepared by Dr Gail Tipa and Ngāi Tūāhuriri in 2016. Cultural Health Assessment report minimum flow, cultural allocation and nitrate limit recommendations are considered in this paper.
Current state	Condition of water resources, mahinga kai, stream health, social/recreational state and the local economy that we currently see and measure.
Current Pathway scenario	Condition of water resources, mahinga kai, stream health, social/recreational state and the local economy at some point in the future under the assumption that the current natural resource management regime and economic and social conditions continue along their current trajectory. Assume the hydrological and ecological system equilibrates with current land use, including any intensification that can occur under current Regional Plan and consent rules.
FMU	Freshwater Management Unit: defined in the NPS-FM as "the water body, multiple water bodies or any part of a water body determined by the regional council as the appropriate spatial scale for setting freshwater objectives and limits and for freshwater accounting and management purposes."
GAZ	Groundwater allocation zone: a planning tool for determining an allocation limit and managing groundwater abstraction. GAZs are primarily based on areas of similar hydrogeology and recharge sources. Each GAZ has an allocation limit expressed as annual volume in cubic metres per year. Their boundaries are set out in Planning Maps in the LWRP.
GMP	Good Management Practice. Defined in PC5 as "the practices described in the document entitled "Industry-agreed Good Management Practices relating to water quality" - dated 18 September 2015."

Report term	Definition
interzone source area	Area from which the groundwater model predicts water will infiltrate and flow under the Waimakariri River toward the Christchurch aquifers.
Limit	Defined in the NPS-FM. The maximum amount of resource use available.
LWRP	(Land and Water Regional Plan: the regional plan for managing freshwater resources in Canterbury. The only regional plan for the Ashley catchment.
Minimum flow	Flow rate in a river at which all takes must cease other than for an individual's reasonable domestic and stockwater use, and for community supply.
NAZ	Nutrient allocation zone: an area set out in LWRP based on current water quality. "Green" = water quality outcomes are being met; "Orange" = water quality outcomes are at risk; "Red" = water quality outcomes not being met.
New take/consent	An application for resource consent to take water that would not replace a previous take.
NPA	Nitrate Priority Area where additional actions and controls are required to reduce nitrate discharges
NPS-FM	National Policy Statement for Freshwater Management. Central Government direction for how freshwater must be managed, regional councils must give effect to it when preparing freshwater plan changes. Requires limits to be set for quality and quantity, and water quality to be maintained or improved. Also sets "bands" in which nitrate concentrations (amongst other attributes) must be maintained.
Over-allocation	Defined in the NPS-FM for both water quantity and quality. In summary, over-allocation is where existing allocation exceeds a limit in the plan or results in outcomes not being met.
Partial restriction regime	Graduated restrictions; designed to prevent flows falling below the minimum flow as a result of abstraction. Existing LWRP policy for rivers in the Ashley River/Rakahuri catchment is to apply a "pro rata" approach. This applies partial restrictions to all users when flows drop to a rate equalling the minimum flow plus the allocation limit.
PC5	Plan Change 5 (Nutrient Management & Waitaki) to the LWRP. Among other things, this plan change introduced "Good Management Practice" into the region-wide rulebook.
Receptor	A receiving water body that could be affected by contamination – e.g. a community water supply well, spring fed stream or estuary
Replacement or renewed take	A resource consent to take water that replaces a previous take.
Scenario	A possible land use configuration modelled to consider how to reach community outcomes. Exploration of alternatives/options/what ifs at whatever scale is useful to support the question being asked.
Stream Depletion Assessment	Estimate of effect of pumping groundwater on a nearby stream. Related to depth, pumping rate, distance from stream and aquifer properties.
Stochastic model	A tool for estimating probability distributions of potential outcomes by allowing for random variation in one or more inputs over time. This type of model addresses uncertainty associated with data. While this approach still relies on underlying model assumptions to generate initial parameter estimates, it more clearly estimates the uncertainty associated with modelling and allows reflection of this in communications.
Stream depleting groundwater take	A take from a well where the water abstracted has been assessed as having a component of river water.
SWAZ	A planning tool for managing surface water abstraction. SWAZs are based on river catchments and each SWAZ has an allocation limit expressed in litres per second and a minimum flow site to manage water takes.

Report term	Definition
Target	Defined in the NPS-FM. Applies in the context of phasing out over-allocation. In summary, means a limit on resource use that is less than current allocation, to be achieved by a stated time in the future.
Nitrate threshold option for waterbodies outside of the Waimakariri Water Zone	Nitrate threshold options provide a point of reference, or a starting point indicating the scale of nitrate reductions that may be needed to enable land users in the Waimakariri Zone to play their part in maintaining the high quality of Christchurch groundwater and the Waimakariri River.
Transfer (of a water take)	Transfer of a consent allowing water to be taken from a well or river/stream. Transfers can be between different people on the same site, or from site to site.
Waimakariri northern tributaries catchment	Area of Waimakariri River catchment within the Waimakariri CWMS zone that drains into the northern side of the Waimakariri River.
WRRP	Waimakariri River Regional Plan: the currently operative regional plan for managing (amongst other things) the taking or diverting of surface water and discharges to surface water in the main stem and tributaries of the Waimakariri River.

1 Introduction and background

1.1 Report purpose and structure

This technical overview report summarises the technical work delivered to the Waimakariri Water Zone Committee (WWZC) by the Environment Canterbury technical team. The WWZC is charged with making recommendations to Environment Canterbury on sustainable management of water resources in the Waimakariri Water Zone (Waimakariri Zone), including water quality and quantity limits, in support of the Canterbury Land and Water Regional Plan (LWRP).

The report assesses the Zone Committee's recommendations for freshwater management against community aspirations and the current regulatory framework, and makes transparent the assumptions, technical work undertaken and uncertainties of the project. Specifically, the report:

- Documents the science work and technical information which informed the WWZC's decision-making process
- Summarises the options assessment process used by the WWZC to develop their recommendations
- Summarises the WWZC recommendations and explains the rationale behind them
- Assesses the extent to which implementation of these recommendations will achieve the WWZC's Community Outcomes.

The report comprises the following sections:

Section 1	Introduction and background
Section 2	Assessment approach
Section 3	Current state description and assessment
Section 4	Scenarios and Freshwater management unit assessments
Section 5	Zone Committee recommendations and assessments
Section 6	Monitoring recommendations
Section 7	Conclusions

1.2 Planning framework

The LWRP gives effect to National and Regional Policy Statements regarding the management of freshwater in Canterbury. This plan has both regional provisions (most recently updated through Plan Change 5) and sub-regional sections to allow for the development of provisions at a finer scale.

The National Policy Statement for Freshwater Management 2017 (NPS-FM) sets out the direction for freshwater quality and quantity management in New Zealand. Regional councils must give effect to the requirements of the NPS-FM when developing statutory plans and plan changes. The NPS-FM requires freshwater quality to be maintained (where it is of good quality) or improved over time (where it does not meet the requirements of the NPS-FM), and includes a national objectives framework (NOF) for achieving this. The NPS-FM also requires engagement with iwi, hapū, and the community in setting freshwater outcomes.

Alongside the regulatory framework is the Canterbury Water Management Strategy (CWMS). The CWMS was formed in 2009 as a collaboration between Canterbury's ten territorial authorities, Environment Canterbury, Te Rūnanga o Ngāi Tahu, industry, key stakeholders, agencies and the community. The vision of the CWMS is "to enable present and future generations to gain the greatest social, economic, recreational and cultural benefits from our water resources within an environmentally sustainable framework." (Canterbury Mayoral Forum, 2009 p.6). The CWMS divides Canterbury into ten

Zones (sub-regional sections). The Zone Committees for each of these ten Zones are the key delivery mechanism for the CWMS. Each Zone Committee has developed a detailed ‘Zone Implementation Programme’ which includes a set of priority outcomes. Although Zone Implementation Programmes are not statutory documents, there is a clear expectation and commitment for the programmes to be implemented, resourced, and given effect to through both regulation (e.g., in regional plans) and on the ground actions.

In the Waimakariri Zone, freshwater management is covered by Section 8 of LWRP which already includes provisions to manage the water resources in the Ashley River/Rakahuri catchment. Plan Change 5 (PC5) to the LWRP addresses water quality issues throughout the Canterbury region and includes new definitions, policies, rules, limits and schedules which require farming activities to operate at “Good Management Practice” (GMP). PC5 provides both the foundation and starting point for managing nutrient losses from farming within the Waimakariri Zone.

The Waimakariri River Regional Plan (WRRP) also has legal effect in part of the Waimakariri Zone, and manages water quantity, water quality and works in river and lake beds. Having two regional plans managing freshwater in the same zone adds unnecessary complexity for the regulator and plan users. This current LWRP plan change provides an opportunity to create a simpler framework by incorporating those parts of the WRRP that apply to the Waimakariri sub-region into section 8 of the LWRP.

The Waimakariri Water Zone Implementation Programme (ZIP) (2013) contains a collection of integrated actions and proposals that give effect to the vision and principals of the CWMS for the zone including eight Priority Outcomes.

The Waimakariri Zone Implementation Programme Addendum (ZIPA), finalised in December 2018, builds on the original ZIP and provides recommendations to guide both the sub-region plan change to section 8 LWRP including actions to be advanced within the Waimakariri Zone and the Waimakariri District Plan as well as non-statutory on-the-ground actions. These recommendations, the Waimakariri sub-region plan change, and the programme of actions are collectively referred to as the Waimakariri Land and Water Solutions Programme. The purpose of the technical work programme has been to firstly inform the detailed development of the Waimakariri Land and Water Solutions Programme by assessing numerous scenarios and options for the WWZC, and to then assess how the finalised programme, particularly the Regional Plan rule recommendations provided in the ZIPA, will achieve the Community Outcomes defined by the WWZC.

1.3 Zone Committee Community Outcomes

The ZIP contains a collection of integrated actions and proposals that give effect to the vision and principals of the CWMS for the zone. The ZIP (2013) contained eight priority outcomes identified by the WWZC. The original priority outcomes were re-visited and re-named Community Outcomes during a series of community meetings held in 2014/12 and in 2016. An additional Community Outcome (**Outcome 9)** was added during the development of the ZIPA (2018).

Outcome 1 – The water quality and quantity of spring-fed streams maintains or improves mahinga kai gathering and diverse aquatic life

Narrative: The habitat, flow and water quality in the spring fed streams supports abundant and diverse aquatic life (including native flora and fauna). Spring fed streams contain safe and plentiful kai for gathering. The flow and visual appearance of the spring fed streams meet aesthetic values and promotes customary use. Plant and animal pest species are managed or eliminated.

Outcome 2 – The Ashley River/Rakahuri is safe for contact recreation, has improved river habitat, fish passage, and customary use; and has flows that support natural coastal processes

Narrative: The river meets national standards for swimmable contact recreation. The habitat and fish passage along the river are improved to encourage more customary use and mahinga kai gathering. Braided river bird populations are protected, and numbers improved. The river mouth and estuary are healthy and functioning.

Outcome 3 – The Waimakariri River as a receiving environment is a healthy habitat for freshwater and coastal species, and is protected and managed as an outstanding natural landscape and recreation resource

Narrative: Flow and water quality are maintained to support and enhance aquatic life. The river mouth is healthy and functioning. The natural braided characteristics of this alpine river are recognised for aesthetic and amenity values. Recreational opportunities, along and on the river, are sustained.

Outcome 4 – The zone has safe and reliable drinking water, preferably from secure sources

Narrative: Community drinking and domestic supplies meet New Zealand drinking water standards. Water supply wells are reliable during drought conditions.

Outcome 5 – Indigenous biodiversity in the zone is protected and improved

Narrative: Protect and improve the indigenous biodiversity, habitat or ecosystems. Plant and animal pest species are managed or eliminated.

Outcome 6 – Highly reliable irrigation water, to a target of 95%, is available in the zone

Narrative: Irrigation water (from both surface and groundwater) reliably supplies water to meet demand when operating within flow and allocation regimes. 100% of the irrigated area can be irrigated 95% of the time. The effects of climate change are considered in the planning and effective long-term management of water and land. Opportunities for water storage are considered.

Outcome 7 – Optimal water and nutrient management is common practice

Narrative: All land and water users' practise management that maximises water use efficiency and minimises inputs of nutrients and pollutants to water. Industry agreed Good Management Practices and Farm Environment Plans are adopted as everyday farm management tools.

Outcome 8 – There is improved contribution to the regional economy from the zone

Narrative: The zone has thriving, and vibrant communities supported by a sustainable local economy based on diverse and productive land and water use. Integrated and sustainable management of the effects of flooding, earthquakes and climate change protects assets and amenities and builds resilience in communities and ecosystems.

Interzone Groundwater Outcome

Outcome 9 – Land and freshwater management in the Waimakariri Water Zone will, over time, support the maintenance of current high-quality drinking water from Christchurch's aquifers

Narrative: Nutrient discharges to groundwater in the Waimakariri zone are managed to maintain the high-quality groundwater resource beneath Christchurch, recognising that nitrate concentrations may increase in the medium term due to the nitrogen load already moving through the system, before reducing in the longer term. This Priority Outcome is in response to recent science investigations which have concluded that a proportion of the Christchurch aquifer system recharge is likely to be derived from north of the Waimakariri River, within the Waimakariri Zone.

2 Assessment approach

2.1 Boundaries

The Waimakariri Zone is in North Canterbury; north of the Waimakariri River. The zone covers 226,662 hectares (ha); from the Waimakariri River north to include the Ashley River/Rakahuri catchment and from the Puketeraki Range in the west to Pegasus Bay in the east (Figure 2-1).

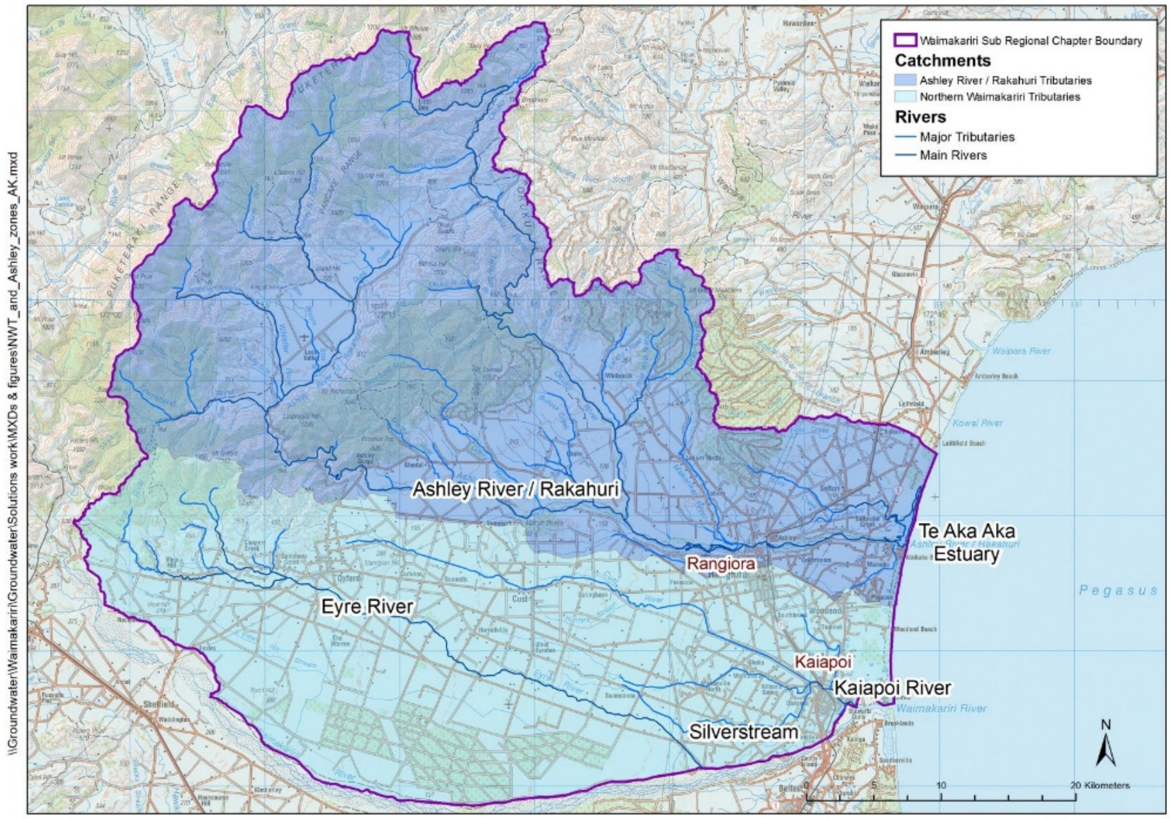

Figure 2-1: Ashley River/Rakahuri tributaries and Waimakariri northern tributaries catchments

The Waimakariri and Rakahuri/Ashley catchments fall within the takiwā of Ngāi Tūāhuriri, one of five primary hapū of Ngāi Tahu. Ngāi Tahu is the collective representation of whānau and hapū who share a common ancestry and are tāngata whenua of Canterbury (and most of the South Island). They hold ancestral and contemporary relationships with the land, water, sites and resources of Canterbury. Mana whenua are whānau or hapū who hold customary authority over the resources of an area or takiwā. Mana whenua is established though whakapapa (ancestral links) to an area and maintained through ahi kā (continuous occupation). With mana whenua status comes the rights and duties of rangatiratanga and kaitiakitanga.

Ngāi Tūāhuriri's duty of kaitiakitanga extends over all natural resources of the catchment; the hapū's interest is not limited to areas or sites identified in plans as wāhi tapu me wāhi taonga. The rivers, streams, lagoons and wetlands have always been important places and a food basket for Ngāi Tūāhuriri. Ngāi Tūāhuriri contend that the Crown's right to govern, as gifted in Article the First, is totally dependent on the honouring of Article the Second. That is, the recognition and protection of the Tribe's resource ownership authority rights, including the rights to use and have access to those resources.

2.2 Indicators and modelling scenarios used

A suite of indicators identified from previous limit-setting processes was matched to Community Outcomes identified by community consultation (Table 2-1). These indicators were tested with and accepted by the WWZC. Due to the challenges in deriving thresholds for meeting/not meeting many of the community outcomes, the technical team used most indicators in relative terms, i.e. relative to current state.

Table 2-1: Key technical indicators used to assess scenarios and WWZC ZIPA recommendations against the Community Outcomes

Community Outcomes	Key technical indicators
1 – Spring-fed streams maintains or improves mahinga kai/aquatic habitat	Aquatic plant and periphyton growth Nitrate toxicity to aquatic fauna Flows and flow durations Safe, diverse, abundant and accessible mahinga kai Diversity and abundance of riparian flora and fauna, wetland flora and fauna, freshwater periphyton and plant species, freshwater invertebrate species, indigenous fish
2 – Ashley River/Rakahuri safe for contact recreation, improved habitat including Te Aka Aka	Presence of cyanobacteria growths *E. coli (*contact recreation) Estuary Trophic level indicator
3 – The Waimakariri River is a healthy habitat and is treated as an outstanding natural landscape and recreation resource	*E. coli* (contact recreation) Supports large variety of indigenous and introduced fish species; plant, bird, invertebrate species. Nuisance algal and occasional toxic cyanobacteria growth issues
4 – Safe and reliable drinking water	Groundwater/drinking water supply nitrate concentrations *E. coli* in drinking water supplies Groundwater levels and drinking water supply (private and community) reliability including during extended dry periods
5 – Indigenous biodiversity protected and improved	Habitat diversity Habitat loss and modification Animal/plant intrusive species
6 – Highly reliable irrigation water	Irrigation availability Minimum flow and partial restrictions conditions
7 - Optimal water and nutrient management is common practice	Implementation of Good Management Practice
8 - Improved contribution to the regional economy: thriving, and vibrant communities supported by a sustainable local economy based on diverse and productive land and water use	Economic indicators – operating profit, GDP, household income, employment Social indicators – Ngā Tūāhuriri values: safe, diverse, abundant and accessible mahinga kai, recreational fishing opportunities
9 - Land and freshwater management in the Waimakariri Zone will support the maintenance of current high-quality drinking water from Christchurch's aquifers	Current and modelled future nitrate concentrations in Christchurch drinking water supplies

Current state was assessed and future scenarios (Table 2-2) were modelled to increase understanding of the Waimakariri Zone, to examine various alternative futures, and to facilitate discussions amongst all parties with an interest in the future management of the zone's water resources. The scope and assumptions for the scenarios evolved as discussions with the WWZC and community progressed. The scenarios were adapted to best support individual work streams. The 'solutions package' as represented by the ZIPA recommendations was also assessed.

Table 2-2: Technical programme scenarios

Scenario	High-level description
Current state	What we see now
Current Pathway	What would happen if we continue with implementation of current plans and on the ground actions. For nitrate management assumes GMP plus 50% uptake of permitted activity allowances.
Alternative pathways	For water quantity management – wide range of parameters and rules options For nitrate management • Current management practise • Good management practise (GMP) • Three beyond baseline GMP nitrate loss reduction options; dryland farming option; winter grazing options
Solutions package assessment	Full implementation of ZIPA recommendations

2.3 Current state assessment and scenario modelling approach

A large-scale multi-disciplinary technical work programme was undertaken between 2015 and 2018 to inform and support the Waimakariri Land and Water Solutions Programme, as illustrated in Figure 2-2.

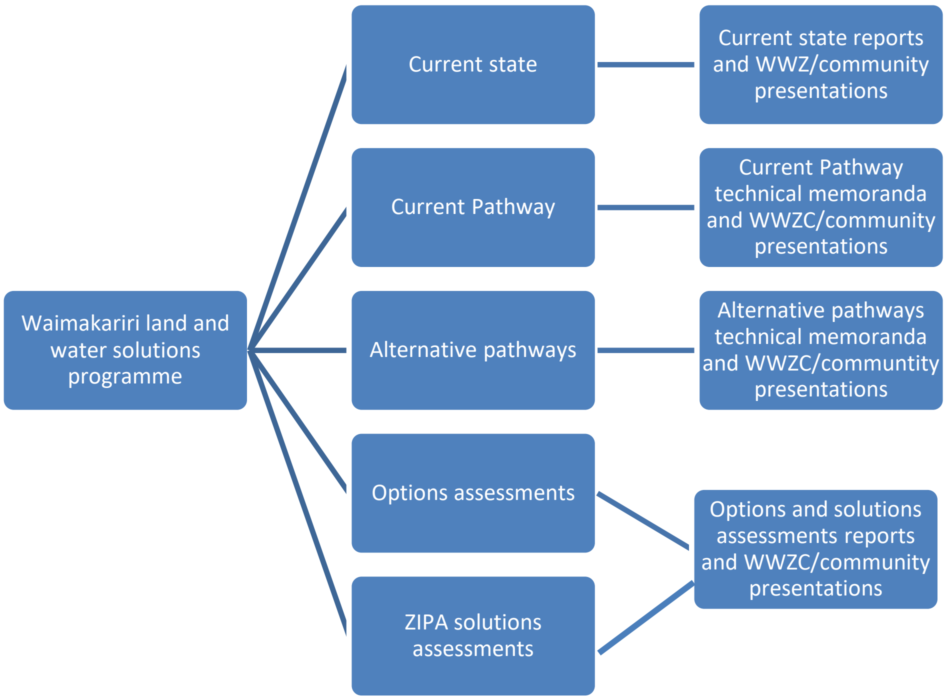

Figure 2-2: Technical work programme process

The Current State work and reports were followed by Current Pathway and Alternative Pathways scenario assessments which have been documented as a series of Options and Solutions Assessment technical reports. These Current State reports and Options and Solutions Assessment technical reports are the key sources of information for much of this Technical Overview report. These technical reports rely on technical analysis and modelling undertaken and reported on throughout the process. A report bibliography is provided in Appendix 1.

The main technical information which underpins this overview report are found in:

- Nitrate Management Options and Solutions Assessment (Kreleger and Etheridge, 2019a)
- Water quality, Aquatic ecology and Biodiversity Options and Solutions Assessment (Arthur *et al.*, 2019)
- Indigenous biodiversity solutions assessment (Grove, 2019)
- Groundwater allocation options and solutions assessment (Etheridge, 2019)
- Surface Water Quantity Options and Solutions Assessment (Megaughin and Lintott, 2019);
- Social Assessment (Sparrow and Taylor, 2019)
- Economic Assessment (Harris, 2019)
- Coastal Protection Area Assessment (Etheridge and Arthur, 2019).

The technical work programme and WWZC were informed by our collaborative science, technical work and community engagement process (Figure 2-3).

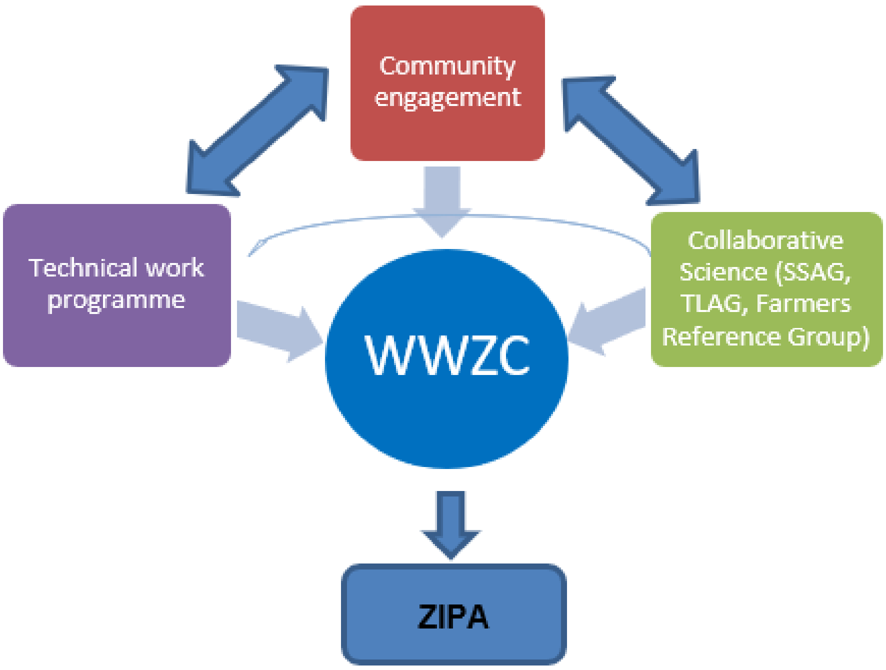

Figure 2-3: ZIPA collaborative development process

The Science Stakeholders Advisory Group (SSAG) provided an opportunity for members of rūnanga, industry, key stakeholders and crown research institutes to be involved with the development and understanding of much of the technical work. The SSAG held periodic (usually twice annually) meetings. In addition to SSAG members, the meetings were attended by select WWZC members, Waimakariri District technical staff and Environment Canterbury technical and planning staff.

The SSAG acted to:

- help identify the key areas of contention that require scientific input.
- help identify key environmental indicators and monitoring priorities.
- identify scientific limitations and provide clarity about the underlying assumptions.
- help achieve consensus on the key science issues facing the zone.
- review and validate the robustness of the data.
- inform the development of policy-making that subsequently flows out of the scientific investigations.

The Technical Lead Advisory Group (TLAG) was formed as a subgroup of the SSAG to provide independent advice/review/gap identification to the Environment Canterbury technical team regarding planning and delivery of some of the main technical information to communities, stakeholders, our governance partners, decision makers and other technical experts. The TLAG was also responsible for communication with stakeholders and partners.

A critical part of this collaborative process included the establishment of a Farmers Reference Group. The main purpose of the group was to consider what can be done at the farm-level in catchments where current nutrient losses and expected losses under GMP do not achieve Community Outcomes. Meetings were generally held every four to six weeks. The group:

- reviewed and agreed financial models for dairy, sheep and beef, dairy support and arable land uses
- reviewed and agreed beyond Baseline GMP[1] nitrate loss mitigation options
- reviewed and agreed economic model inputs and assumptions for beyond Baseline GMP mitigation costs.

Findings were used to inform and support the development of the ZIPA recommendations. Members included farmers in the Waimakariri Zone based on their reputation as respected and influential thought leaders covering the major farm types; farmer members of the WWZC along with industry representatives from DairyNZ, Beef + Lamb NZ; and Foundation for Arable Research.

The terms of reference for the SSAG, TLAG and Farmers Reference Panel are provided in Appendix 2. Community engagement was critical to the success of the land and water solutions programme, both in terms of providing an opportunity for people living within or strongly connected with the Waimakariri Zone to provide and receive information for/from the technical work programme, to inform the WWZC and ultimately for implementation of the programme.

The main purpose of community engagement was to:

- identify what the community (which includes stakeholders and Environment Canterbury governance partners) want to achieve in their catchment
- obtain and consider the views of stakeholders on the development of plan provisions to address issues
- meet the Council's obligations under Schedule 1 of the Resource Management Act 1991 (RMA)
- bring local knowledge into the process.

The engagement included:

- targeted engagement with specific stakeholder groups during ZIPA development. The engagement focussed on the key issues most relevant to the individuals and groups in each catchment
- catchment specific workshops held at milestones in the process (e.g. Current State, Scenarios, pre-draft ZIPA and draft ZIPA) for the Ashley River/Rakahuri and the Waimakariri River northern tributaries catchments
- community drop-in sessions pre-draft and draft ZIPA
- one on one sessions between community members and WWZC members to allow individuals to discuss issues
- zone delivery team face to face with community members.

Key groups for community engagement were:

- Te Ngāi Tūāhuriri,
- Science Stakeholders Advisory Group,
- Farmers Reference Group
- CWMS partners (Waimakariri District Council and Te Rūnanga o Ngāi Tahu [TRONT])
- directly affected water take consent holders
- Ashley River/Rakahuri catchment consent holders

[1] i.e. nitrate reductions that reduce losses to a rate lower than the 2009-2013 baseline period GMP loss rate, as defined in the LWRP

- Waimakariri River tributaries catchment consent holders
- Waimakariri District Council staff
- Waimakariri Irrigation Limited
- Canterbury Water Management Strategy Partners
- water management groups.

Community feedback was provided via:

- written feedback via email or website
- verbal feedback recorded during community workshops, presentations, farmers markets, and targeted engagement sessions.

In some cases, responses to a community survey were initiated by direct contact via email informing of the process and relevant issues.

2.4 Catchment and sub-catchment scale modelling

The Waimakariri Zone has been the subject of extensive investigations and research over the past 50 or more years by regional council, district council, academic institutions, crown research institutions, industry, businesses, environmental groups, consultancies and private individuals.

Catchment and sub-catchment scale modelling used this existing body of knowledge and in some cases expanded it. The work for this project, undertaken between 2015 and 2018, broadly comprised:

- summarising, refining and improving the current understanding of cultural, environmental, social/recreational and economic conditions and documenting our understanding in the Current State reports
- exploring potential future scenarios (Current Pathway and Alternative Pathways) for land and water management options
- assessing the extent to which the ZIPA recommendations will achieve the WWZC's Community Outcomes.

The methodologies used for the technical work are listed below and summarised in the following sections.

- Cultural Health Assessment
- nitrate modelling
- aquatic ecology and biodiversity assessment
- water quantity modelling
- economic modelling
- social impact assessment.

2.4.1 Cultural Health assessment

The current state and future scenarios were explored via a Cultural Health Assessment report (Representatives of Te Ngai Tūāhuriri and Tipa & Associates, 2016). The overall objective of the Cultural Health Assessment was to determine the water management priorities for the Waimakariri – Rakahuri Zone, from the perspective of Manawhenua.

The approach to the report was to:

- provide an overview of some of the water dependent cultural values of the catchment
- identify the characteristics of the waterways of the Ashley that whanau believe will maintain, rehabilitate or restore their values
- outline the results of the health assessments undertaken by whanau at several sites in the lower catchment
- outline the flow preferences of whanau and water requirements

- recommend management priorities to enable waterways to meet the Kaitiakitanga standards in the CWMS.

The study methodology broadly comprised:

- summarising publicly available cultural information pertaining to cultural interests associated with the waterways in the zone
- identifying the extent and/or location of these interests (where possible)
- defining water-related issues of concern to Manawhenua that need to be addressed by Environment Canterbury.

The principal sources of historical information were obtained from written records held by Ngai Tahu. These data were complemented by:

- field assessments using the Cultural Health Index in the Rakahuri undertaken by whanau in December 2013 and in 2015
- flow assessments undertaken by the manawhenua team 2013-2014
- field assessments using the Cultural Health Index in the Waimakariri area undertaken by whanau in 2015.

2.4.2 Nitrate modelling

The purpose of nitrate modelling water to assess the effects of land use on nitrate concentrations in groundwater and then to spring-fed streams. The main elements of the nitrate modelling included how much nitrate seeps into groundwater from land use; where does it go (groundwater recharge zones and flow paths) and changes in concentration along the way (via dilution and attenuation). These are summarised below and further details are provided in Lilburne *et al.* (2019) and Kreleger and Etheridge (2019a). Quantitative uncertainty analysis was undertaken as described in Section 2.5 and further documented in Hemmings *et al*. (2018b).

Nitrate losses from land use
The soil profile nitrate loss modelling comprised generation of a spatially based two-dimensional layer of nitrate losses from all land within the Waimakariri Zone boundaries. The layer combined desk-based land use mapping of climate, soil type with a lookup table of expected nitrogen losses for each farm type (based on the matrix of good management, climate and soil category). This information was subjected to a ground-truthing exercise involving the Farmers Reference Group, Environment Canterbury staff and members of the WWZC. Estimates of nitrate losses from on-site sewage discharges (e.g. septic tanks) were included in the nitrate loss layer. Further details are provided in Lilburne *et al*. (2019).

The modelling included both the soil drainage rate, the nitrogen load in drainage water and hence the nitrate concentration in drainage water. Some of the scenarios include a change in drainage rate and load (e.g. reduced drainage rate and load due to improved irrigation efficiency). For other scenarios (e.g. changes in winter grazing) the drainage rate was assumed to remain constant.

Recharge zone modelling
Knowledge of groundwater recharge zones is critical for determination of where focused nitrate management is required to meet the Community Outcomes. A steady state numerical groundwater model was developed collaboratively between Environment Canterbury and GNS Science (Hemmings *et al*., 2018a), with rolling review and feedback during the model development process provided by a panel of external experts including TLAG members and others not involved in the modelling process.

The model domain included both the Waimakariri - Ashley plains, the Christchurch West Melton aquifer system and a significant proportion of the Selwyn Te Waihora zone, in recognition of previous studies (e.g. Stewart *et al*., 2002) which identified a possible connection and flow path between these aquifers. The model was constructed with an initial (prior) parameter set derived from field data analysis and expert panel (including TLAG members) judgement and was then optimised to achieve the best match between modelled water levels, stream and river flows, and long-term average measured values, whilst deviating from the prior values as little as possible. We used the optimised model to evaluate groundwater recharge zones for the key receptors: the main spring-fed streams and rivers, Waimakariri District Council (WDC) community supply wells, private water supply wells and Christchurch City aquifer.

Dilution
Nitrate concentrations in water draining from the soil profile can be diluted between recharge zone and receptor. The main sources of dilution are leakage of low-nitrate water from the extensive irrigation and stockwater race network within the Waimakariri zone, water losses from the Waimakariri River and Ashley River/Rakahuri and runoff from the foothills on the western edge of the Waimakariri Zone (e.g. Eyre River), which infiltrate to ground on the Waimakariri – Ashley plains. Dilution was simulated by incorporation of these low nitrate water sources, modelling of mixing processes and post-processing the model results using dilution ratio data derived from analysis of water chemistry data.

Attenuation
Groundwater nitrate concentrations can be reduced by microbial processes under favourable biochemical circumstances. These processes are referred to as nitrate attenuation. The nitrate attenuation potential of groundwater is low for the inland areas of the zone and medium/high in the near-coastal area as discussed in Kreleger and Etheridge (2019b).

Consideration of groundwater flow paths is required when translating nitrate attenuation potential to a nitrate attenuation rate. Investigations have suggested that the near-coastal zone anoxic conditions and organic sediments predominantly occur within low permeability sediments, which may be by-passed by most groundwater flow to wells and spring-fed streams. This means that although there is potential for nitrate attenuation, the actual attenuation rate of water flowing to our key receptors could be low. We ran an additional model scenario to explore potential nitrate attenuation in the near-coastal zone (Etheridge and Kreleger, 2019).

2.4.3 Aquatic ecology and biodiversity assessment

Arthur *et al.* (2019) analysed current state and trend water quality and ecosystem health data and examined aquatic values. An expert panel including TLAG members was used extensively throughout the process, primarily to explore how current and future possible management regimes impact water and habitat quality, and overall aquatic ecosystem health. The panel also assessed the likely effect of Plan Change 5 policies and rules relating to stock exclusion on waterway health.

The expert panel developed an inventory (solutions toolbox) of management options for improving waterway health and flows to support achieving the Community Outcomes. The WWZC used this solutions toolbox when discussing and making their ZIPA recommendations for protecting and improving aquatic values. The ZIPA recommendations were then assessed for the improvements they may provide to ecosystem health. Further details are provided in Arthur *et al.* (2019).

2.4.4 Water quantity modelling

Groundwater
The numerical model of the Waimakariri – Christchurch aquifer system (see Etheridge and Hanson, 2019) was used to assess effects on spring-fed stream flows and well reliability from:

- improvements in irrigation efficiency and the associated reduction in groundwater recharge
- higher usage of existing consents
- increased groundwater allocation, up to the current allocation limits.

Surface water
The methodology used to determine flows and water supply reliability under current conditions, a range of alternative management scenarios and under the ZIPA recommendations is described in Megaughin and Lintott (2019). The main components of the methodology were:

- regression analysis to generate a comprehensive set of flow statistics for the main streams and rivers in the zone
- flow record naturalisation (modification of the measurement-based flow record to remove the effects of water abstraction, to estimate flows under “natural” conditions)
- modelling of supply reliability for consented water takes under various management scenarios

- modelling of flows under current and alternative management scenarios through stream depletion analysis and evaluation of minimum flow and allocation limit options.

2.4.5 Economic modelling

The impact of environmental management options on the economy was modelled by Harris (2019) using the information and technical assessments described above (Arthur *et al*., 2019; Kreleger and Etheridge, 2019a; Megaughin and Lintott, 2019; and Lilburne *et al*., 2019). Modelling approach included:

- modelling impacts on farm finances from changes to surface water minimum flows, allocation and partial restrictions with results reported as levels of restrictions over the irrigation season on average, and for events that occur once in every 10 years.
- modelling impacts on farm finance from changes to nitrogen load limits based on information developed in conjunction with Farmers Reference Group and Dairy NZ.
- farm level impacts were provided as per ha annual outcomes by land use, and aggregated impacts for the catchment and zone to estimate impacts on profit, as well as the average changes in GDP, household income and employment.
- costs to private water supplies where nitrate concentrations are likely to exceed the drinking water MAV were estimated assuming that affected households would install under-bench treatment systems (reverse osmosis and ion exchange).
- costs of the proposed strengthening of the stock exclusion rules was estimated using average fencing costs for different land uses, combined with GIS estimated lengths of streams, drains and springheads.

2.4.6 Social impact assessment

The qualitative social impact assessment was undertaken by first conducting a detailed current state social profile for the Waimakariri Zone (Sparrow 2016b). This profile was used as a comparative basis to assess the likely effects of the ZIPA recommendations on the health and social wellbeing of the zone.

The social impact assessment evaluated key social impacts of the ZIPA recommendations based on information and technical assessments described above (Arthur *et al*., 2019; Kreleger and Etheridge, 2019a; Megaughin and Lintott, 2019; Lilburne *et al*., 2019; and Harris, 2019). The impacts assessed included:

- potential amenity effects,
- consequences for outdoor recreation,
- visitor activity and on- and off-farm employment
- likely periphyton and macrophyte conditions that could affect attractiveness for food gathering (mahinga kai)
- swimming, picnicking and passive uses
- the presence of *E. coli*. and cyanobacteria that could affect the health of humans and pets
- the levels of nitrate that compromise drinking water safety.

Finally, it was important to distinguish and comment on the projected social effects from social changes that would have happened in the area anyway, such as from increased urbanisation and further population growth.

Further details of the methodology are provided in Sparrow and Taylor (2019).

2.5 Managing uncertainty

The WWZC were cognisant of the uncertainties inherent in the modelling work and took those uncertainties into consideration when making the ZIPA recommendations.

We have summarised some of the main uncertainties that arose during the Waimakariri Land and Water Solutions Programme in Table 2-3.

Table 2-3: Summary of uncertainty

Technical area	Uncertainty description	Potential impact	Steps taken to address issue
Nitrate modelling	Assessing impact of implementing GMP relative to current management practice	Over/underestimating nitrate concentrations in receptors	Modelling of nitrate losses under CMP and comparison to modelled GMP loss rates (See Lilburne *et al.*, 2019)
	Modelling uncertainty	Over/underestimating nitrate concentrations in receptors	Quantified uncertainty (stochastic modelling);
	Nitrate attenuation in groundwater	Over/underestimating nitrate concentrations in receptors	Investigation of attenuation potential and assessment of actual attenuation likelihood
	Uncertainty associated with OVERSEER®-based soil nitrate loss modelling	Over/underestimating nitrate concentrations in receptors	Completed formal expert judgement elicitation framework (Sheffield Elicitation Framework, Oakley and O'Hagan, 2016) and statistical analysis to approximately quantify uncertainty around catchment-scale modelled nitrogen loss rates, transfer pathways and dilution modelling uncertainty.
Economic modelling	Potential for high variability in profitability figures for land use and the differential between land uses can vary similarly	Limited range of financial returns and nitrate losses resulting in simplistic modelling representing likely complex system	Limited reliance of results to identifying the likely scale of costs and the difficulties of achieving some of the percentage reductions assessed in the scenario analysis.
Groundwater modelling	Modelling uncertainty	Inaccuracy in groundwater system understanding (levels, flow directions etc)	Completed a calibration-constrained[2] Monte-Carlo modelling process to quantify modelling uncertainty. Process provided a set of model realisations which could be used to assess the effects of uncertainty around groundwater recharge, groundwater-surface water interaction, groundwater discharge and aquifer hydraulic properties on model predictions of nitrate concentrations[3].
Water allocation accounting	Uncertainty regarding estimation of stream depletion rates for groundwater takes using desk-top analysis	Possible under-estimation of the actual allocated groundwater volume and over-estimation of surface water allocation.	Communicate uncertainty and possible ways to manage ZIPA response was: i) Proposed plan provisions that allow for renewal of existing groundwater takes in over-allocated catchments. ii) Proposed plan provisions for surface water allocation aim to

[2] Process maintained an acceptable fit (or "calibration") between measured data (groundwater levels, stream flows etc) and modelled values

[3] A detailed discussion of the uncertainty analysis process is provided in Hemmings *et al.* (2018b); a higher-level overview is provided in Kreleger and Etheridge (2019a).

Technical area	Uncertainty description	Potential impact	Steps taken to address issue
			avoid new allocation of surface water where there is potential for this to occur due to the accounting method
Meeting outcomes	Statutory (Regional Plan Rules/Policies) provision not enough to achieve Community Outcomes.	WWZC vision for improvements are not realised	Communicate scenario results and suggest other possible actions ZIPA response was: Inclusion of non-statutory “on-the-ground actions” to help to achieve the required outcomes
Non-statutory actions	Assessing benefits of actions which are voluntary and/or have no funding	Uncertainty regarding implementation	Assess benefits and what could be achieved, and which could deliver the greatest benefit. Communicate assessment and highlight reliance on implementation assumptions

3 Current state description and assessment

3.1 Overview and current state assessment compared to Community Outcomes

The Waimakariri Zone (Figure 2-1) encapsulates two main hydrological catchments:

- Ashley River/Rakahuri, its tributaries and the Ashley Estuary (Te Aka Aka)
- Waimakariri River northern tributaries including the Kaiapoi River and its tributaries (e.g. Silverstream, Ohoka Stream Cust River and Cam River/Ruataniwha).

These catchments along with all groundwater in the zone were recommended by the WWZC as freshwater management units (FMUs). These FMUs were defined based on common hydrological and biophysical characteristics to allow for setting water quantity and quality limits and objectives at an appropriate scale.

The hilly land in the northern and western parts of the zone is drained by high-country streams; the remainder of the zone comprises a gently sloping plain drained by spring-fed streams in the eastern part of the zone, towards the coast. Alluvial sand and gravel deposits dominate the plains, with finer-grained estuarine deposits along the coast. Light and very light soils are found between the Eyre River and the Waimakariri River. The Loburn fan area, areas along the Cust River and the coastal plain are characterised by heavier soils. Hardpan soils, which promote run-off to surface water, are found to the north of the Ashley River/Rakahuri, on the Mairaki Downs and on the hill-country near Oxford.

The Waimakariri - Ashley Plain (i.e. the central part of the zone) is prone to extended dry periods with high evapotranspiration, especially during north-westerly winds. Irrigation demand is high in the summer months when evapotranspiration is well above the average rainfall and there is a large soil moisture deficit. Much of the land in the flat coastal plains in the eastern part is subject to poor drainage and occasional flooding.

Approximately 103,490 ha (40% of land area) in the Waimakariri zone is used to farm sheep and beef. Dairy and dairy support account for 35,000 ha (16% of land area). There are also many small block holdings (lifestyle blocks) encompassing approximately 29,000 ha (12% of land area). Arable land use (5,400 ha) accounts for approximately 2% and forestry (5,800 ha) accounts for 3% of land area. Non-productive land, including native forest, scrub, water, and urban areas is approximately 61,300 ha or 27% of the total land. Irrigated land covers approximately 37,000 ha (16% of land area) (Harris, 2016).

There are three irrigation schemes: Waimakariri Irrigation Limited (WIL), Loburn Irrigation Company and the Moy Flat scheme. A map of current land use is provided in Figure 3-1.

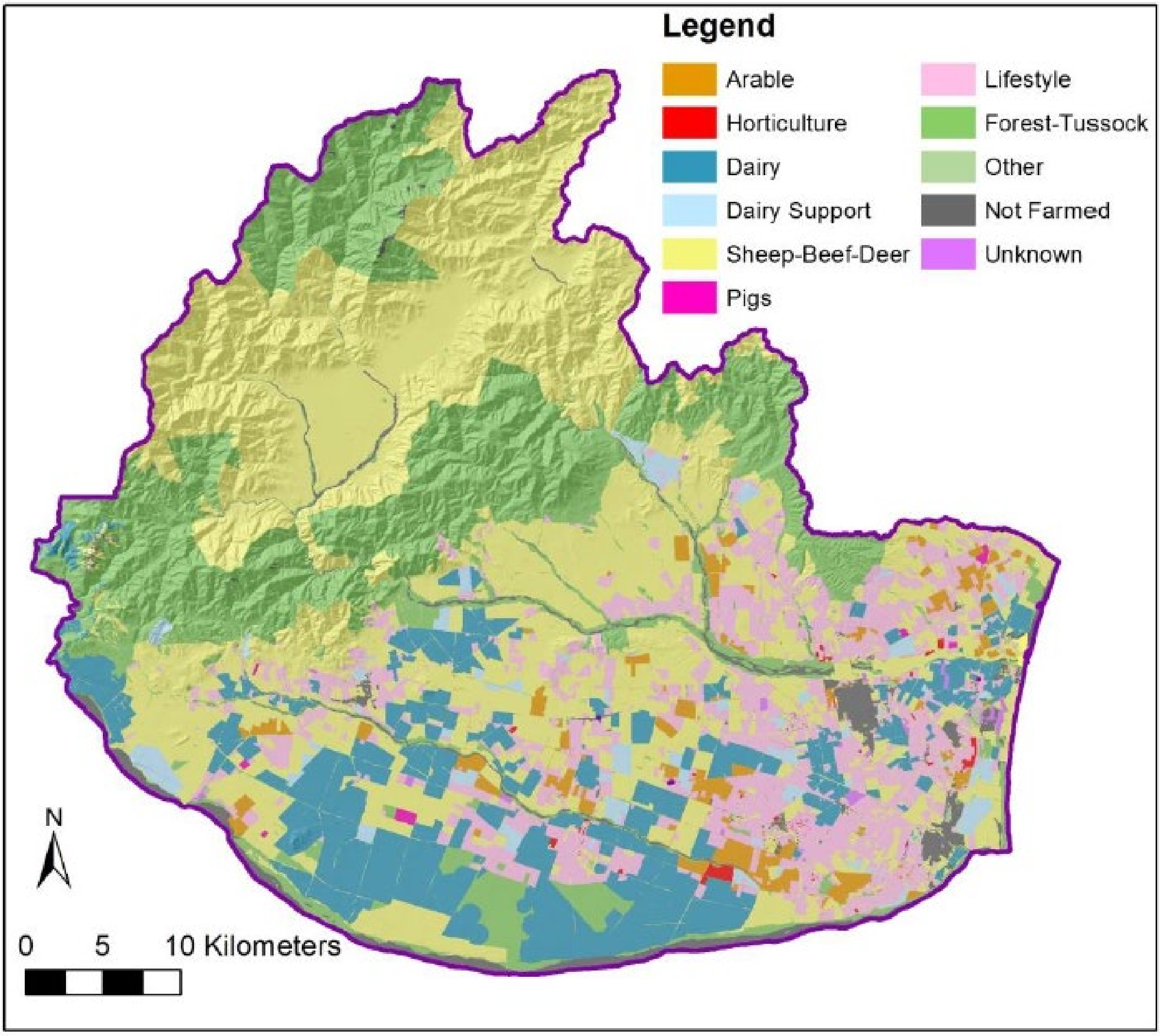

Figure 3-1: Land use at "Current State" as at 2016 (Lilburne *et al.*, 2017)

In this section of the report we summarise the current state of:

- People, economy and employment including Te Ngāi Tūāhuriri Rūnanga
- Environment including water quality, aquatic ecosystems, mahinga kai and stream health, Te Aka Aka, terrestrial ecology and biodiversity and water quantity

We also summarise the current state of point and diffuse nitrogen discharge to land which is a key contaminant affecting multiple outcomes (e.g., water quality, ecosystem health and social and recreational values). These discharges are a relevant indicator of risk of other contaminants that are often generated by the same types of activities that discharge nitrogen. Other important contaminants such as disease-causing microorganisms indicated by *E. coli*, sediment and phosphorus are also addressed.

We have assessed the current state in relation to the Community Outcomes, a summary of which is provided in Table 3-1.

Table 3-1: Community Outcomes and current state summary

Community Outcomes	Current state meets outcomes in:	Current state does not meet outcomes in:	Rationale/key indicator
1 –Spring-fed streams maintains or improves mahinga kai/aquatic habitat	None of the streams	All streams	High fine sediment cover, high nitrate and elevated dissolved reactive phosphorus (DRP) and *E. coli* concentrations in some water courses Low minimum flows and some over-allocation of surface water Poor in-stream habitat, degraded riparian margins, predominance of invasive plant species, declining native flora and fauna populations
2 – Ashley River/Rakahuri safe for contact recreation, improved habitat including Te Aka Aka	Ashley River/Rakahuri at Gorge	Ashley River/Rakahuri main stem Te Aka Aka	Significant cyanobacteria growths in Ashley River/Rakahuri main stem between Rangiora/Loburn Road and SH1 during the summer months Te Aka Aka does not meet requirements for ecosystem, contact recreation and shellfish gathering water quality
3 – The Waimakariri River is a healthy habitat and is treated as an outstanding natural landscape and recreation resource	Waimakariri River except for some indicators at some sites	Gorge and SH1 monitoring sites for nuisance algal and toxic cyanobacteria	Meets outcome for recreational use (one of the highest used salmon and trout fisheries, swimming, yachting, jet boating, kayaking and whitebaiting. Supports large variety of indigenous and introduced fish species; plant, bird, invertebrate species. Nuisance algal and occasional toxic cyanobacteria growth issues in lower river reaches
4 – Safe and reliable drinking water	most drinking water supply wells	around 5% of private wells	Nitrates likely to exceed the drinking water limit in ~90 – 165 private wells and could increase to 270 wells in the future. Elevated nitrate concentration in WDC's Poyntz Rd community drinking water supply well (scheduled for upgrade). Elevated *E. coli* in some shallow private water supply wells.
5 – Indigenous biodiversity protected and improved	some isolated areas	most of the zone	Loss and modification of habitat by deforestation, burning, drainage, cultivation and other development, and new species introductions. Continuing habitat loss and modification, and the impacts of animal and plant pests remain the principal threats to indigenous biodiversity today. Biodiversity loss also prevalent in Te Aka Aka.
6 – Highly reliable irrigation water	deep groundwater takes and some surface water takes currently have no minimum flow conditions	most surface water takes from the Waimakariri River, Ashley River/Rakahuri and most of the	Most surface water and stream-depleting groundwater takes where consent conditions align with current Regional Plan rules have minimum flow and partial restriction conditions which are likely to result in <95% reliability.

Community Outcomes	Current state meets outcomes in:	Current state does not meet outcomes in:	Rationale/key indicator
	and are very reliable	spring-fed streams	
7 - Optimal water and nutrient management is common practice	some locations, where farmers have pro-actively implemented GMP	many locations, where farmers are working towards GMP implementation	Some farmers, and the WIL irrigation scheme, are working hard to implement GMP, which provides rules and guidelines for optimal water and nutrient management. Other farmers are yet to implement the changes required to achieve this outcome.
8 - There is improved contribution to the regional economy: thriving, and vibrant communities supported by a sustainable local economy based on diverse and productive land and water use	Primarily construction, services, manufacturing and farming	Some farming business due to implementation of PC5	Implementation of PC5 is likely to impact on all farm type profitability
9 - Land and freshwater management in the Waimakariri Zone will support the maintenance of current high-quality drinking water from Christchurch's aquifers	N/A	Waimakariri zone	The connection between the Waimakariri and Christchurch aquifer system was not recognised prior to the Waimakariri Land and Water Solutions Programme, thus the current nutrient management approach does not address drinking water quality in Christchurch's aquifers.

3.2 People, economy and employment

3.2.1 Te Ngāi Tūāhuriri Rūnanga

Te Ngāi Tūāhuriri Rūnanga hold manawhenua status over the area covered by the Waimakariri Land and Water Solutions Programme. This status carries with it a responsibility to manage the resources of the area sustainably for future generations (kaitiakitanga) and a duty to care for the physical, ecological and spiritual well-being of the area and its resources.

The cultural health assessment report completed by Representatives of Te Ngai Tūāhuriri and Tipa (2016) describes the eco-cultural character of the rivers with a focus on the Ashley River/Rakahuri. This character is based on the physical environment of the rivers which support resources available to sustain whanau and communities. The report explains that the populations, ecological processes and functioning of the rivers and estuaries are crucial to ensuring the cultural health of the rivers of the Waimakariri – Rakahuri Zone. Te Moemoeā, the vision, for the zone is presented in Figure 3-2.

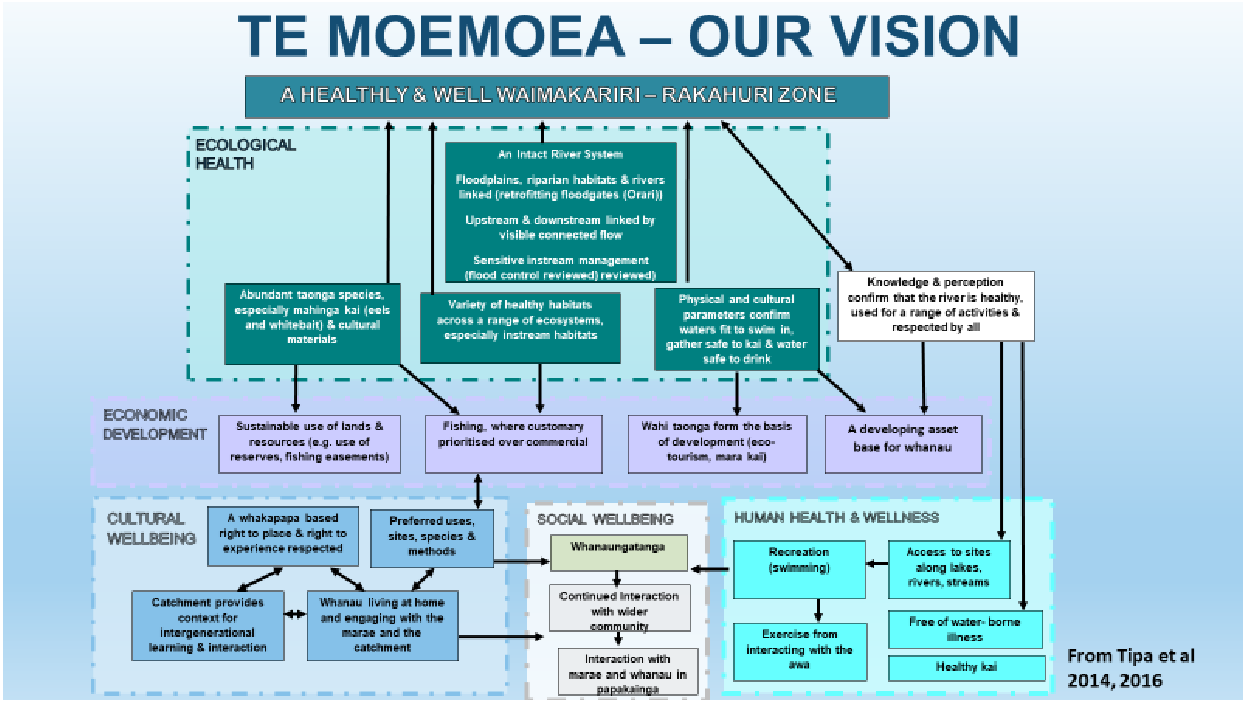

Figure 3-2: **Te Moemoeā "Our Vision for the Zone" (Representatives of Te Ngai Tūāhuriri and Tipa, 2016)**

Cultural health index assessments were undertaken at 13 sites within the Rakahuri catchment and six sites within the Waimakariri River catchment. Assessment results are summarised in Figure 3-3.

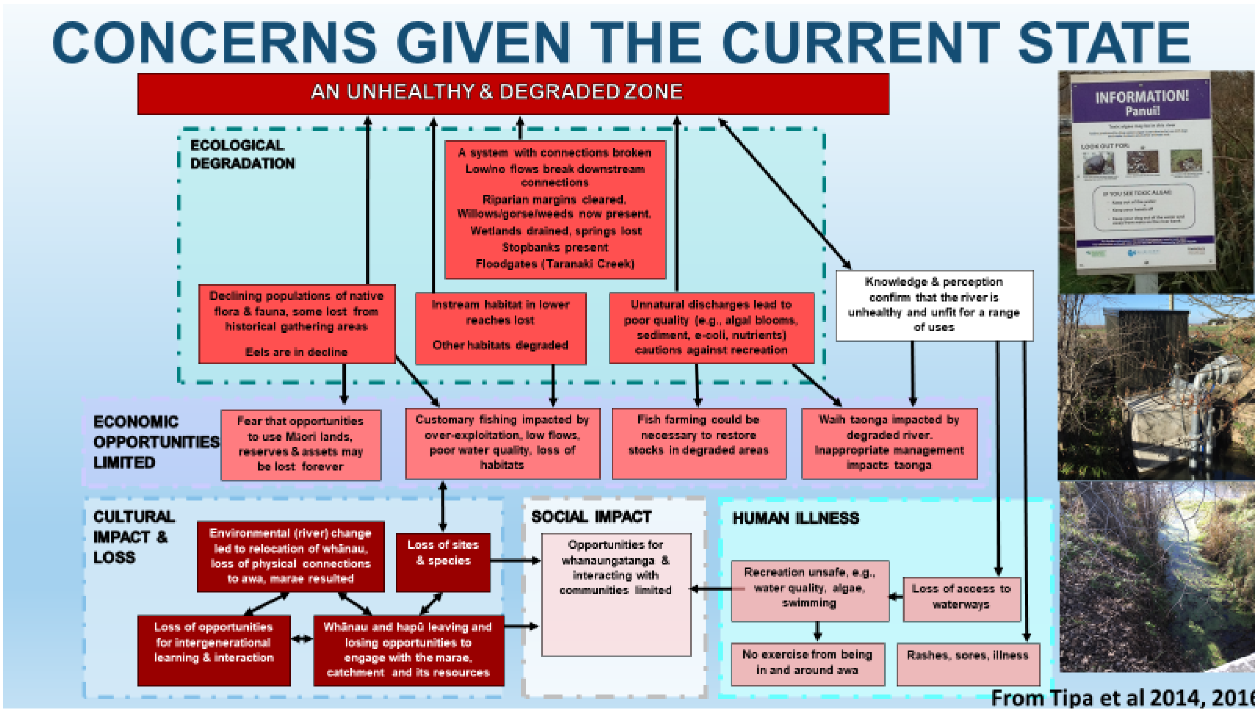

Figure 3-3: **Cultural health assessment current state assessment (Representatives of Te Ngai Tūāhuriri and Tipa, 2016)**

The cultural health assessment concluded that:

- The current state of the Waimakariri zone is unhealthy and degraded
- Native flora and fauna populations are declining, in-stream habitats are degraded and dominated by invasive species. Water quality is poor in most streams and rivers
- Economic opportunities are limited due to declines in customary fishing and declining opportunities for use of Māori lands, assets and reserves
- Cultural, social and health impacts are significant.

The Cultural health assessment report recommendations are provided in Appendix 3.

These conclusions were reinforced during a hui held between Environment Canterbury staff and Ngai Tūāhuriri on 20/6/2018: te rūnanga provided information on degradation of stream health, significant declines in mahinga kai diversity and abundance, and access issues. The major social impacts being experienced by whanau because of this degradation were made clear.

3.2.2 Social/Recreational Assessment

The current estimated population for the Waimakariri District is 60,700. Approximately 77% of the District's population lives in the south-east. The areas to the north and west have a significantly lower population density, with the main settlement, Oxford, currently having a population of just over 2,000. These rural areas are characterised by a substantial number of large farms, some of which are irrigated from the WIL irrigation scheme. The Oxford township provides the focal point for social activity for the rural community to the south-west and west of the District. There are smaller social "hubs", often based around schools and sports facilities, throughout the District that provide the basis for maintenance of community cohesion at a local level. There has been a strong increase in local employment between 2000 and 2017 with a decline in agricultural employment. Approximately 40% of the workforce travels to Christchurch to work (Sparrow 2016b and Sparrow and Taylor, 2019).

The Waimakariri Zone offers a wide range of water-related recreation opportunities. The land adjacent to the lower reaches of the Waimakariri River and Ashley River/Rakahuri has been established as Regional Parks, and enhancement of these areas for recreation is on-going. Much of the land along the coast between the Waimakariri River and the Ashley River/Rakahuri is controlled by the Te Kohaka o Tuhaitara Trust and managed under a 200-year development plan seeking to restore indigenous habitat and enhance recreation opportunities. Nearby beaches are also important recreational places (Waikuku and Kairaki/Pines Beaches) where coastal water quality is directly affected by the river quality depending on wind and tides (Sparrow, 2016a).

Te Aka Aka stands out as an important bird habitat for many species, some of which are migratory, and is of great significance for those interested in observing birds. The lowland streams (both the northern tributaries of the Waimakariri River and the streams that flow into the Ashley River/Rakahuri) provide stream-side recreation opportunities including walking, cycling, picnicking, boating and fishing.

Much of the foothills land and upland streams in the District are controlled by the Department of Conservation, which has developed many tracks and picnic areas that are valued by the community. Heavily used places such as Ashley Gorge and Mt Thomas are located adjacent to streams used for contact recreation such as swimming and paddling.

3.2.3 Economy and employment

The economy of the Waimakariri Zone is primarily focussed on construction and services with a reasonably significant manufacturing base. The relative size of these sectors and the low zonal employment self-sufficiency implies that the district economy is dominated by the activities associated with domiciling people and their families who are supported through work in Christchurch City; especially in the south-east part of the zone (Harris, 2016).

Agricultural activity is the fifth most important employment source in the zone (see Figure 3-4).

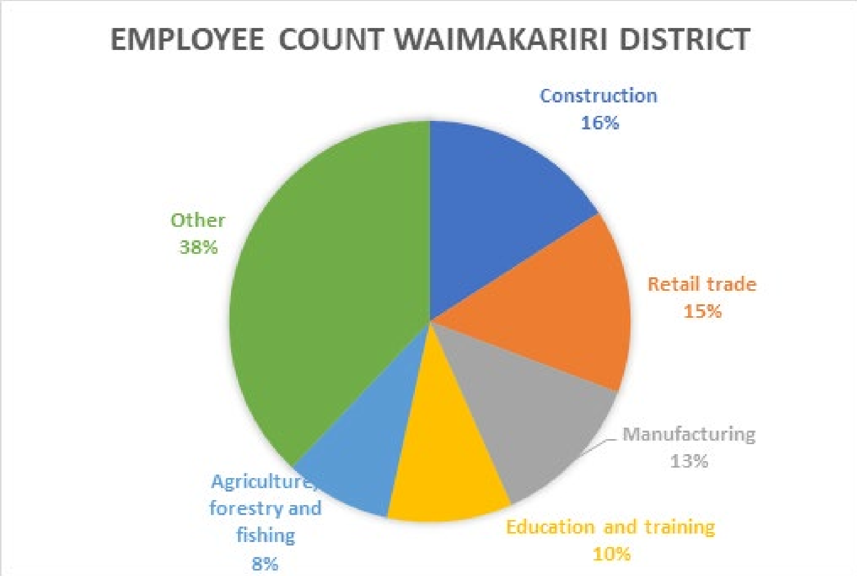

Figure 3-4: Employment per sector (Harris, 2016)

Dairy is the largest contributor to the local agricultural economy, although employment for sheep and beef farming is similar. A smaller land area is used by dairy compared to sheep and beef, and their relative contribution to the farming economy reflects the widespread use of irrigation by dairying and the intensive nature of the activity. Sheep and beef is the largest land-use overall by area. The implications of the sector for local agricultural employment are important because although it has lower returns, the labour use per unit of output is higher. Also, the higher input nature of dairying meaning that it is a major contributor to GDP and household income within the agricultural sector.

Agriculture is the primary user of surface water and groundwater in the catchment. It is the dominant source of both consented and unconsented nutrient discharges. Agricultural processing operations are not a major feature of the district economy, with no large processing plants present, although there are several small operations.

Although there are other water-based activities present in the catchment, such as the salmon hatchery (Salmon Smolt NZ) in the Silverstream catchment, these are not currently major contributors to the zonal economy.

More detailed information on the economy of the zone is provided in Harris (2016, 2019).

3.3 Environment

3.3.1 Water quality

Surface water quality
Surface water quality is a key driver of aquatic ecosystem health, habitat values and mahinga kai health. Critical indicators include dissolved inorganic nitrogen (DIN) (which is composed of nitrate-nitrite nitrogen [NNN] and total ammoniacal nitrogen (NH_4N). High concentrations of nitrate-nitrogen and ammonia can be toxic to aquatic fauna, and at lower concentrations can cause nutrient stimulation of nuisance algae and/or macrophyte growth that can lead to other associated adverse ecological effects. In addition, high concentrations/stream bed coverage of fine sediment, dissolved reactive phosphorus (DRP), and the presence of *E. coli* can be detrimental.

Nitrate
In the Ashley River/Rakahuri FMU, the median NNN concentrations in the hill-fed and spring-fed rivers were below the threshold for the 99% protection of biodiversity from nitrate toxicity with the exception of the spring-fed Taranaki Creek.

In the Kaiapoi (Silverstream), Cust and Ohoka rivers water quality data suggests that there is significant ecological risk from nitrate toxicity with the median NNN concentration at the Kaiapoi River (Silverstream) Harpers Road site exceeding national bottom lines for nitrate toxicity under the NPS-FM.

In the Cam River/Ruataniwha catchment the NNN concentrations were much lower, than in the Kaiapoi, Cust and Ohoka rivers. Although thresholds for the 99% protection of biodiversity were breached in every site in the Cam River/Ruataniwha catchment, 95% protection thresholds were not breached, and it is unlikely that nitrate toxicity is having a significant effect on ecosystem health at these sites.

Runoff contaminants
Suspended and deposited sediments can have a range of direct and indirect negative ecological effects. The LWRP outcome of <15% deposited sediment stream bed cover has been regularly breached in all but four hill-fed sites in the Ashley River/Rakahuri catchment and in all sites in the spring-fed streams. Deposited fine sediment cover is also high in most of the spring-fed streams of the Kaiapoi River catchment.

Elevated concentrations of DRP (along with elevated DIN) in the spring-fed streams of the Ashley River/Rakahuri and Kaiapoi River (Silverstream) catchments are facilitating nuisance macrophyte growth in these streams.

Trends
Statistical analysis of the water quality data identified increasing trends in DIN and NNN concentrations in the Silverstream at Island Road. Decreasing trends in DIN, NNN, NH_4N, DRP, *E. coli* and total suspended solids (TSS) were found in a number of spring-fed streams in both the Waimakariri and Ashley River/Rakahuri catchments, and TSS was also found to be decreasing in the Ashley River/Rakahuri at SH1.

Surface water quality and aquatic ecosystems are generally degraded due to sediment and high nitrate concentrations (e.g. Silverstream at Island Road and Harpers Road). However, many areas still support important ecological values, particularly the upper catchments of spring-fed streams like Silverstream and Cust Main Drain.

More detailed information on the surface water quality of the zone is provided in Greer and Meredith (2019) and Arthur *et al.* (2019).

Groundwater quality
Nitrate
Diffuse and point sources of nitrogen leaching from land use are the main threat to groundwater quality in the Waimakariri zone.

Nitrogen (N) losses from diffuse sources were modelled by Lilburne *et al.* (2019). Modelling results, summarised by GAZ (Table 3-2), indicate that N losses from the Eyre River GAZ make up the majority proportion of the total load. This reflects the predominance of light soils and intensive land use in the GAZ.

Table 3-2: Estimated total nitrate losses (tonnes/year) by sub catchment

Sub-catchment	Current management practice nitrogen losses (tonnes/year)
Ashley River/Rakahuri	86
Coastal wetlands	53
Cust	807
Eyre	3,199
Kowai	89
Lees Valley	319
Loburn	375
Other	97
Total Waimakariri Zone	**5,025**

Estimates of nitrogen and phosphorus contribution to water from authorised point source discharges including community wastewater treatment systems, dairy effluent ponds and approximately 5,500 on-site domestic wastewater treatment systems are provided in Loe and Clarke (2017). The total nitrogen load estimates from these sources represents approximately 2% of total load and is therefore insignificant on a zonal scale.

Groundwater nitrate concentrations are elevated in parts of the Eyre River, Loburn and Cust Groundwater Allocation Zones (GAZs), with nitrate-nitrogen concentrations close to the New Zealand Drinking-water Standard Maximum Acceptable Value (MAV) of 11.3 mg/L (MoH 2005) in some places.

Statistical analysis of nitrate monitoring results from the Waimakariri zone and broader Canterbury plains (Kreleger and Etheridge, 2019a) indicates that nitrate concentrations are currently likely to exceed the drinking water MAV in approximately 160 of the 2,650 private wells within the Waimakariri northern tributaries catchment on some occasions.

Some of the nitrate load from the current land use is likely still moving with groundwater to deeper wells. This lag means that we have not yet seen the full effects of recent (post-2012) land use intensification on water quality. Modelling results presented in Kreleger and Etheridge (2019a) indicate that nitrate concentrations could exceed the drinking water limit in 270 private water supply wells (i.e., approximately 10% of private wells) when groundwater quality equilibrates with current land use.

Nitrate in Waimakariri District Council (WDC) water supply wells are all below the drinking water MAV. Nitrate concentrations exceed 5.65 mg/L (½ MAV) in the Poyntzs Road supply wells; these wells are monitored monthly by WDC and are scheduled for upgrade (Kreleger and Etheridge, 2019a).

Nitrate concentrations are increasing in some parts of the deep Christchurch aquifer; previous studies (e.g. Stewart, 2002) have identified a possible connection between the Waimakariri and Christchurch aquifer systems, which may explain these increases. Our groundwater modelling results showed that the deep Christchurch aquifer system is likely to be recharged from land within the Waimakariri Zone (Etheridge & Kreleger, 2019), and that given lag times, the concentrations are likely to continue to increase for many decades into the future.

E. coli

Microbial contamination of shallow groundwater is common, particularly where light soils are present. Users of shallow private wells are most at risk from pathogens (disease-causing microorganisms), especially near effluent disposal or animal grazing areas. *E. coli* contamination (1 or more count per 100 ml) has been recorded in 25 of 115 tested wells in the Waimakariri Zone (sample data since 13/09/1999). From those 25 wells, only one well was deeper than 50m (with only one sample of 1 count per 100 ml). For the 24 shallow wells (total of 850 samples) 15% of the samples showed 1-10 count, 4.5% 11-2400 count and 0.1% >2400 count per 100 ml.

Pathogen discharge rates can be managed by good design and treatment in wastewater systems, livestock and irrigation management, and careful disposal of animal effluent. Community supply protection zones have been established to provide a mechanism for management of microbiological contamination in water supply well recharge areas.

More detailed information on the groundwater quality of the zone is provided in Scott *et al*. (2016) and Kreleger and Etheridge (2019a).

Naturally occurring contaminants
Naturally occurring contaminants (e.g. iron, manganese and arsenic), which are present in some parts of the Waimakariri zone, were not considered for the Waimakariri Land and Water Solutions Programme.

3.3.2 Aquatic ecosystems

Many of the rivers/streams in the Waimakariri Zone, particularly spring-fed streams, have poor ecological health scores, reflecting poor habitat, poor flow conditions and degraded water quality. This condition reflects the high intensity land use in many parts of the zone as discussed in Greer and Meredith (2016) and Arthur *et al*. (2019). General issues identified include:

- Overland flow pathways of contaminants – sediment, phosphorus, and faecal contamination.
- Accumulated streambed sediment.
- Soluble contaminant input via groundwater – predominantly nitrate but also other contaminants e.g., ammonia.
- Reduction in stream flows due to irrigation efficiency and climate change.
- Increased flow intermittency due to irrigation efficiency and climate change.
- Urban stormwater management.
- Reduced indigenous biodiversity due to pest and weed species.
- Reduced indigenous biodiversity due to habitat loss.
- Barriers to fish passage.
- Climate change resulting in reduced water resources and sea-level rise.

Invertebrate communities are in a degraded state in half of the hill-fed rivers in the Ashley River/Rakahuri catchment and deposited fine sediment is a likely cause of this. Nuisance periphyton and cyanobacteria growths have also been observed in the Waimakariri River.

Although nitrate toxicity is not the most important driver of degraded invertebrate health in the zone's spring-fed streams, the high concentrations in the Silverstream, the Cust Main Drain and the Ohoka River are undoubtedly a contributing factor.

In-stream ecosystem health is susceptible to changing water quality. The water quality of lower reaches in many Waimakariri Zone spring-fed waterways is highly responsive to changing flows, with tidal pooling common. Low flows and tidal pooling can result in long water residence times and stagnation. Water movement and flushing capacity to remove contaminants from the lower reaches of streams are important considerations when setting environmental flow regimes. This is of particular significance for Taranaki Creek and Courtenay Stream, where approximately 1 km of the lower waterway is tidal or impounded behind floodgates.

The lower Kaiapoi River, which occupies a former channel (North Branch) of the Waimakariri River, experiences sustained periods of tidal salinity intrusion to the west of Kaiapoi up to the South Island main trunk railway bridge. This point marks a change from being a tidal freshwater upstream to a tidal and saline influenced waterway downstream. The effects of this saline water intrusion could explain many of the recent observations of degraded water quality and ecology in the lower reach (Meredith, 2018).

Environmental flow regimes

Water resource usage controls are required to maintain flows that protect ecological, cultural, recreational and amenity values. These flow provisions are collectively known as an ‘environmental flow regime’. A simple environmental flow regime uses two management tools:

- a ‘minimum flow’ to manage the effects of abstractions on surface water values at low flow, and;
- an ‘allocation limit’ to preserve the variability of flows, specifically freshes and smaller flood flows.

More detailed information on environmental flow regimes and how they typically work is provided in Appendix 4.

Current minimum flows (i.e., those set in the WRRP and in current consent conditions) are insufficient to allow for macrophyte removal, promote water movement in lower reaches, and protect indigenous taonga species for Waikuku Stream, Little Ashley Creek and Taranaki Creek (Arthur *et al*., 2019). Current minimum flows are insufficient to protect ecological values for all waterways in the Waimakariri River northern tributaries area excluding the Cam River, South, Middle and North Brooks and Cust Main Drain.

Allocation limits are currently very high compared to those suggested by the Proposed National Environmental Standard on ecological flows (MfE, 2008) and water levels, and some streams are ecologically over-allocated. This overallocation impedes the capacity of the stream to provide flushing flows and aquatic communities are likely to be highly stressed for extended periods of time over summer and marginal months due to the river being held at low flows for a long time.

3.3.3 Mahinga kai and stream health summary

In addition to elevated nitrate concentrations and poor environmental flow regimes, runoff contaminant discharges to surface water bodies (both past and present) and stream morphology were identified as key drivers for poor spring-fed stream health and mahinga kai. This results from poor riparian conditions. If managed correctly, riparian vegetation can intercept sediment, nutrients, and pathogens to waterways, and provide habitat and food resources for aquatic communities. Arthur *et al*. (2019) evaluated the relative impact of the predominant surface water contaminants on stream health (and hence mahinga kai) and found that the contaminants which are mainly transported to waterways via surface runoff (referred to as the “runoff contaminants”) are the main driver of poor stream health in some waterways. Nitrate is likely to be the main driver of poor stream health in other waterways, whilst habitat (or lack of) is the key factor for a third sub-set. This information was used by the WWZC, in combination with mapping of the main recharge areas for drinking water supply wells, to understand where reducing nitrate discharges is top priority and where management of runoff contaminants is most important for achieving their mahinga kai and stream health Community Outcomes.

3.3.4 Te Aka Aka (Ashley Estuary)/Coastal Area

The coastal area between the Pegasus Bay sand dunes and State Highway 1 is an important and unique area of the Waimakariri Zone. It encompasses Te Aka Aka and a diversity of habitats including spring-fed streams, wetlands, lagoons and other significant water features. The high diversity of aquatic habitat means that these waterbodies are of high ecological, cultural, recreational and aesthetic value. The area supports a variety of native fish species including eels, inanga, and the critically threatened Canterbury mudfish. It also serves as important nursery, rearing and feeding habitat for a variety of birds. These fish and bird species are taonga and the area is of critical importance for mahinga kai. There are also high biodiversity values associated with wetland flora. Overall, the coastal waterbodies in this area are wahi tapu (sacred waters) to iwi. It is an important recreational area with several popular walkways, fishing and whitebaiting spots, and swimming areas (Arthur *et al*., 2019).

Extensive water quality issues affect the waterbodies that are present within and drain into the coastal area. Runoff contaminants have degraded many of the spring-fed stream and coastal ecosystems. Excessive sediment has smothered stream and estuary beds, impacting the habitat of invertebrates and fish, while high *E. coli* concentrations provide a high risk of infection or illness to public gathering and consuming food or swimming. Other water management issues are also present (e.g. barriers to fish passage and elevated nitrogen levels).

Te Aka Aka receives flows from Ashley River/Rakahuri catchment, the Taranaki Creek Catchment and the Saltwater Creek catchment and has high cultural, social and environmental values. There has been historical habitat loss around the margins of the estuary. The estuary is highly sensitive to nitrate discharges which could result in the proliferation of macroalgae that can have associated eutrophication effects including deoxygenation as well as creating a physical bed environment that increases fine sediment accumulation (Bolton-Ritchie, 2019).

Eutrophication of estuaries is driven by the enrichment of water by nutrients, especially nitrogen and/or phosphorus from land, atmosphere, or adjacent seas, and which leads to increased growth, primary production and biomass of algae, changes in the balance of organisms, and water quality degradation. The response to nutrients is often exacerbated by the presence of muds (lower pore water exchange, increased sediment bound nutrients) and hydrological conditions.

The current state of the estuary was assessed in terms of the water quality classification for this estuary, as described in the Regional Coastal Environment Plan (RCEP) (Environment Canterbury, 2012) (Table 3-3) and the significant issues facing New Zealand estuaries (Table 3-4). The assessment results indicate that there has been habitat loss and that if nutrient concentrations increase there is potential for eutrophication of Te Aka Aka. Sediment deposition could be having an ecological effect, but sediment metal and PAHs concentrations are unlikely to be having an ecological effect, in this estuary. The water quality within Te Aka Aka does not meet the requirements for the water quality classification of Coastal AE and Coastal CR as designated in the RCEP (Environment Canterbury, 2012).

Table 3-3: Water quality outcomes assessment for Te Aka Aka

Regional Coastal Environment Plan coastal water classification	Met	Evidence
Coastal AE water (water quality for aquatic ecosystem health)	No	Near the estuary mouth the NNN, DIN (mostly NNN), DRP, TSS concentrations and turbidity are frequently above water quality standards and guideline values and therefore potentially influencing ecosystem health. For Taranaki Creek flow, the NNN, DIN (mostly NNN), DRP, TSS concentrations, turbidity and DO % concentrations are frequently above/below water quality standards and guideline values and therefore potentially influencing ecosystem health.
Coastal CR water (water quality for contact recreation)	No	Faecal indicator bacteria concentrations, at the site monitored over the summer, frequently exceed MfE/MoH 2003 guideline values for contact recreation. The Suitability for Recreation Grade at this site is POOR.
Coastal SG water (water quality for shellfish gathering)	No	At present the water in Te Aka Aka is not classified as Coastal SG water. The MfE/MoH (2003) standards for faecal coliform concentrations in water, as an indication of shellfish safe to eat, are not being met.

Table 3-4: Ecological outcomes assessment for Te Aka Aka

Estuarine Issue	Occurrence in Te Aka Aka	Evidence
Habitat Loss	Definitely	Straight edges where saltmarsh and freshwater wetland vegetation meet the land.
Eutrophication	Potentially	8.2 ha of macroalgae in December 2013. The NNN and DIN concentrations are frequently above comparison values.
Disease Risk	Possibly	Faecal indicator bacteria concentrations above MfE/MoH 2003 guideline values for contact recreation and shellfish gathering. The source of the faecal contamination is birds and ruminants.
Sedimentation	Possibly	Of total 146.1 ha of non-vegetated sediment, 15.5 ha of very soft mud/sand and 33.3 ha of soft mud/sand in December 2013. These sediments are adjacent to the Saltwater Creek and Taranaki Creek channels and also in upper reaches where water energy is low.
Toxins	Present but unlikely to be having an ecological effect	Recorded metal/metalloid and polycyclic aromatic hydrocarbons (PAHs) unlikely to be having an ecological effect. There are differences between sites and over time in metal/metalloid concentrations. The vehicles travelling along SH1 are the likely source of the PAHs in estuary sediment downstream of SH1.

Intensively farmed land in the vicinity of Te Aka Aka (e.g. winter grazed or heavily stocked) is particularly susceptible to generating the high runoff contaminant discharges to water which adversely impact sensitive waterbodies. Irrigated land can support higher stock numbers than dryland farming; higher stock numbers, all else being equal, are associated with increased runoff contaminant risk. Winter forage crop grazing can also generate significant runoff contaminants loads.

3.3.5 Terrestrial ecology and biodiversity

The Waimakariri Zone contains areas with diverse terrestrial and aquatic habitats supporting indigenous plant and animal species as discussed in Grove (2016; 2019). The zone's landscape changes from a highly developed/modified plains environment to 'less developed' but still modified foothills and inland basins, to the relatively unmodified subalpine-alpine areas. Special features of Waimakariri Zone include:

- Numerous remnants of dry plains kanuka woodland, and the network of lowland-coastal wetlands along Pegasus Bay.
- Braided Waimakariri River and Ashley River/Rakahuri are both internationally significant habitats; they form an ecological link between mountains and sea and support breeding populations of a range of characteristic but threatened birds – wrybill, banded dotterel, black-fronted tern and black-billed gulls.
- Lees Valley inland basin contains regionally-significant wetlands supporting red tussock and sedge-rush vegetation, and dry shrubland-grassland communities on a naturally rare and threatened inland alluvial fan ecosystem.
- Extensive mountain beech forests remain on the frontal ranges and in the headwaters of the Ashley/Rakahuri and Townshend rivers further inland.
- The Ashley River/Rakahuri and Saltwater Creek estuarine areas are listed as meeting the International Union for Conservation of Nature (IUCN) criteria for a wetland of "international importance".

Substantial loss of indigenous biodiversity has occurred due to the loss and modification of habitat by deforestation, burning, drainage, cultivation and other development, and new species introductions. Continuing habitat loss and modification, and the impacts of animal and plant pests remain the principal threats to indigenous biodiversity today. Specific issues include recent (post-1990) loss of wetlands in the foothills and Lees Valley (Grove, 2016).

More detailed information on the terrestrial biodiversity of the zone is provided in Grove (2016; 2019).

3.3.6 Surface water quantity

The Waimakariri Zone surface water hydrology is characterised by:

- The large alpine Waimakariri River along its southern boundary;
- The hill-fed Ashley River/Rakahuri, its tributaries and estuary;
- The hill-fed Cust and Eyre Rivers;
- The groundwater of the Ashley-Waimakariri Plain (Ashley, Eyre, Cust Zones); and
- The spring-fed streams and lagoons near the coast.

A conceptualisation of the zone's hydrology is presented in Figure 3-5. More detailed information on the hydrology of the zone is provided in Megaughin and Hayward (2016).

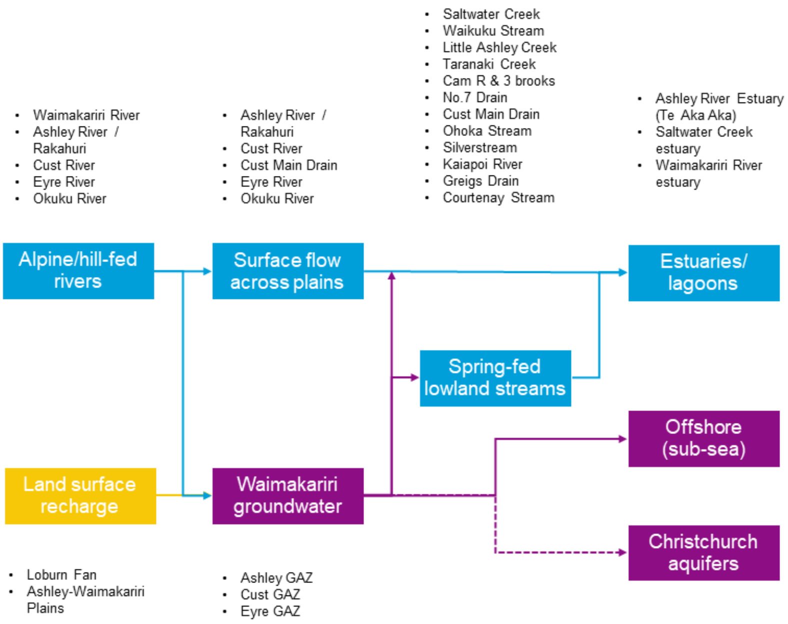

Figure 3-5: Waimakariri zone hydrology conceptualisation (Megaughin and Lintott, 2019)

The Waimakariri River and Ashley River/Rakahuri supply most of the water coming into the zone. Most of their flow comes from high elevation catchments, and in the case of the Waimakariri River, the Main Divide. This water flows out of the hills, across the plains and out to sea, via river mouths. The balance of water available in the zone comes from rainfall directly on the area which recharges aquifers or runs off directly into nearby streams and rivers.

There is a complex pattern of surface flow loss and gain across the plains of the Waimakariri Zone east of the foothills. As these larger rivers exit the hills and flow on to the plains, they lose flow to ground, which recharges the aquifers beneath the plains. The smaller hill-fed rivers such as the Cust, Eyre and Okuku Rivers also recharge the aquifers, although the water they contribute is less than that of the two larger rivers. This natural phenomenon means these rivers are often dry along their mid-reaches in summer.

The water contained in the aquifers flows slowly towards the coast; most returns to the surface via springs, with a proportion abstracted for irrigation and community water supplies. Some groundwater flow discharges offshore. Much of the land to the east of Rangiora, where the small spring-fed streams are located, is reclaimed swamp, and is subject to poor drainage and occasional flooding. There is an extensive land drainage network in this area.

Connected to these systems, to a greater or lesser degree, are the standing waterbodies/wetlands of the zone. Wetlands, swamps, marshes, lagoons and man-made ponds generally have a delicate water balance and changes to any elements of the zone hydrology that are linked to such features will affect those water bodies.

The Waimakariri River is not within the Waimakariri Zone; rather, it is in the Alpine Rivers sub-regional zone, but it is a source of water for two major irrigation schemes in the zone and therefore contributes significant quantities of water into the zone's groundwater (mainly via leakage from the irrigation and stockwater race network). The Waimakariri River is also a receiving water for contaminant discharges within the Waimakariri zone.

Surface water trends
Two distinct changes were noted for the Waimakariri Zone (1972-2016 period):

- Following the commissioning of the WIL scheme in 2000, base flows have increased in some of the lowland spring-fed streams. The increase in base flows is a result of higher groundwater levels associated with increased land surface recharge (from irrigation), water race losses and direct discharge of excess race water to streams. This additional water now forms part of the 'expected' flow regime in spring-fed streams, leaving water users on these streams vulnerable to any changes to the operation/efficiency of the WIL system.
- Ashley River/Rakahuri baseflows appear to be in decline, as recorded at the Gorge recorder above the plains and all water takes. The decline was linked to a reduction in rainfall measured in the catchment during the time period examined. We are uncertain whether this decline will continue, but we expect the site to respond to any climatic changes that occur.

Surface water management regimes
Two operative regional plans cover the Waimakariri zone (Figure 3-6): the LWRP which covers the Ashley River/Rakahuri catchment, and the WRRP which covers all catchments draining to the Waimakariri River.

Sixteen Surface Water Allocation Zones (SWAZ) (Figure 3-6) sit within these plans and provide administrative units for management of surface water.

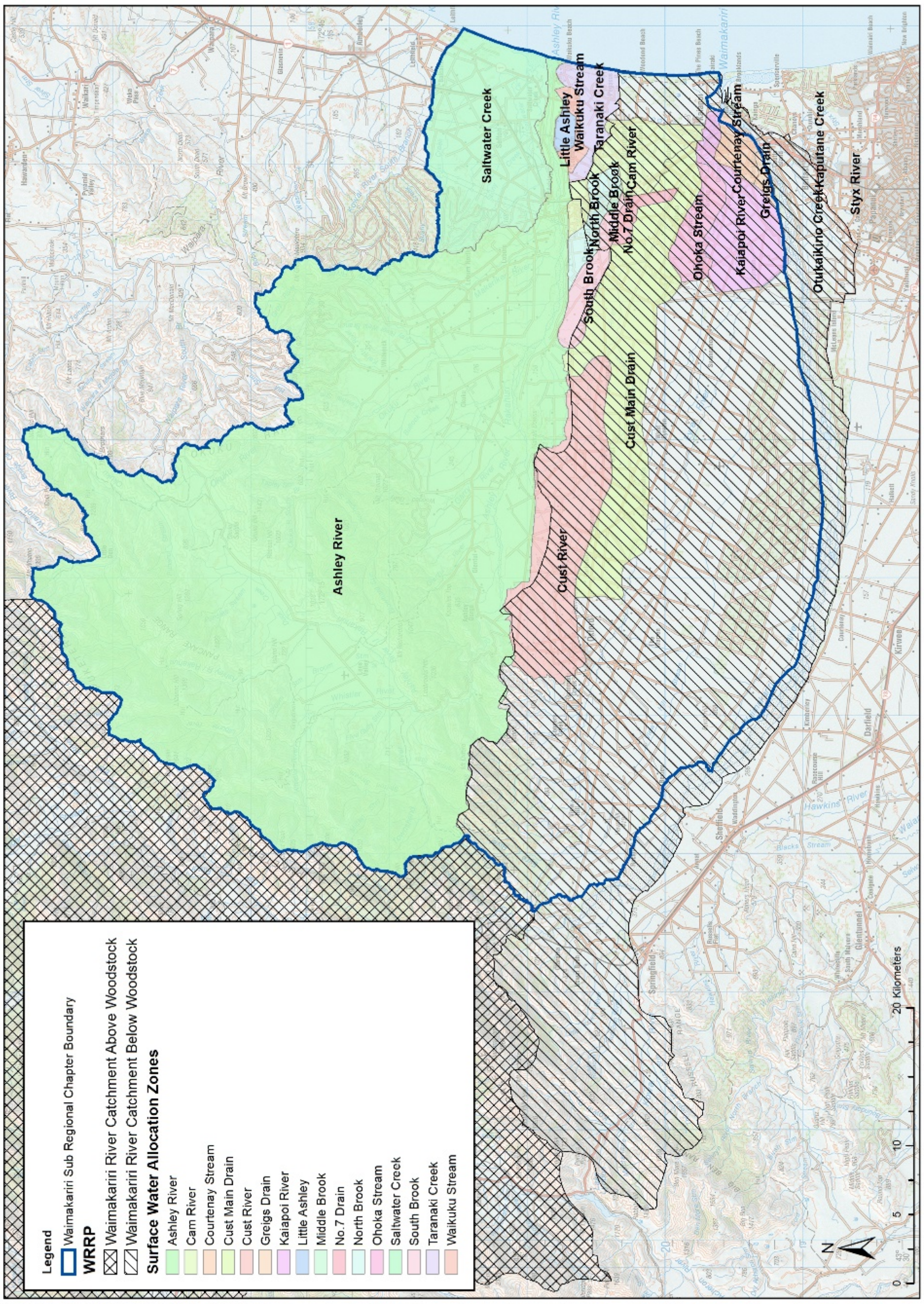

Figure 3-6: Regional Plan and current SWAZ boundaries

For each of these plans, there are two key components of the surface water flow management regime: minimum flow and allocation limits. The minimum flow is the flow in the watercourse that determines when water abstraction must cease, and the allocation limit is the maximum instantaneous rate of take at any one time. The minimum flows and allocation limits for the streams included in the LWRP and WRRP are summarised in Appendix 5.

Both plans also require partial restrictions to be included in consent conditions to prevent flows falling below the minimum flow. Partial restrictions require takes to be reduced gradually once flow falls below a trigger level.

The WRRP (Rule 5.1 (d) (2)) requires pro-rata partial restrictions to be applied to all consented takes. Because of a consent review process undertaken in 2005 for the area covered by the WRRP, most consents in this area include the partial restriction clause.

Existing LWRP policy 4.62 for rivers in the Ashley River/Rakahuri catchment is to apply partial restrictions to prevent the flow in a river falling below the minimum flow. Sub-regional policy 8.4.1 requires partial restrictions to be calculated on a pro-rata basis. Further explanation of environmental flow regimes is provided in Appendix 4.

Surface water allocation accounting
The allocation of water for an individual consent is based on the maximum rate at which water can be abstracted from a waterbody. The total rate of water allocated in a catchment or SWAZ is calculated by adding the consented rates of direct surface water takes and stream depletion rates of all hydraulically connected groundwater. The stream depletion effect is calculated differently under the LWRP and WRRP:

- The LWRP method quantifies the cumulative effect of abstraction on river flow over an irrigation season (pumping at an average 150 day rate and the maximum rate for 7 days) and is applied across most of Canterbury.
- The WRRP method estimates the effect of shallow groundwater takes if pumped at an average 30 day rate. The LWRP method is a more realistic calculation of the depletion effect on rivers over an irrigation season and generally provides a higher level of protection for aquatic habitats.

A Resource Consent Inventory (RCI), which provides the total amount of surface water allocated across the Waimakariri SWAZs, has been completed for the Waimakariri zone (Vattala, 2018) for all consents granted until November 2017. Our summary of the RCI (Table 3-5 and Table 3-6) shows that whilst allocation is available in some catchments, there are several SWAZ which are over-allocated with respect to current plan (LWRP and WRRP) limits. Although there are several reasons for this, the main reason is the upward revision of stream depletion estimates (i.e., the LWRP method has been used), which means that a larger percentage of the groundwater take needs to be counted against the surface water allocation. Currently, there is no opportunity to lower the consented rate of take in this instance and therefore over-allocation takes place occurs.

Under the LWRP 5,301 L/s of surface water allocation is available in established SWAZs (as of November 2017). Consents have been granted to take 3,344 L/s (63%) of this allocation. Most of the remaining available water is C block water which means it could only be taken when the river is at relatively higher flows than is the case for A and B block water. Under the WRRP there is 3,850 L/s of surface water allocation available (as of November 2017); 3,117 L/s (81%) has been granted to water users.

The total consented rate within established SWAZs across both plans is 6,461L/s.

Table 3-5: LWRP RCI summary (as of November 2017)

SWAZ	Allocation Limit	Allocated water	Status
Ashley River / Rakahuri A block	700 L/s	1,095 L/s	Overallocated by 395 L/s
Ashley River / Rakahuri B block	500 L/s	135 L/s	365 L/s allocation available
Ashley River / Rakahuri C block	3,000 L/s	294 L/s	2,706 L/s allocation available
Saltwater Creek	408 L/s	516 L/s	Overallocated by 108 L/s
Taranaki Creek	61 L/s	275 L/s	Overallocated by 214 L/s
Little Ashley Creek	172 L/s	43 L/s	129 L/s allocation available
Waikuku Stream A block	460 L/s	983 L/s	Overallocated by 523 L/s
Waikuku Stream B block	No B block	3 L/s	Overallocated by 3 L/s

Table 3-6: WRRP RCI Summary (as of November 2017)

SWAZ	A block Allocation Limit (L/s)	A block Allocated water (L/s)	A block Allocation Status	B block Allocation Limit (L/s)	B block Allocated water (L/s)	B block Allocation Status
Cam River / Ruataniwha	700 L/s	308 L/s	392 L/s allocation available	No limit	0 L/s	NA
North Brook	200 L/s	160 L/s	40 L/s allocation available	No limit	0 L/s	NA
Middle Brook	30 L/s	29 L/s	1 L/s allocation available	No limit	0 L/s	NA
South Brook	100 L/s	24 L/s	76 L/s allocation available	No limit	0 L/s	NA
Cust River	290 L/s	394 L/s	Overallocated by 104 L/s	No limit	131 L/s	NA
Cust Main Drain	690 L/s	804 L/s	Overallocated by 114 L/s	No limit	0 L/s	NA
No.7 Drain	130 L/s	85 L/s	45 L/s allocation available	No limit	0 L/s	NA
Ohoka Stream	500 L/s	467 L/s	33 L/s allocation available	No limit	0 L/s	NA
Silverstream	1,000 L/s	541 L/s	459 L/s allocation available	No limit	0 L/s	NA
Courtenay Stream	140 L/s	128 L/s	12 L/s allocation available	No limit	0 L/s	NA
Greigs Drain	70 L/s	46 L/s	24 L/s allocation available	No limit	0 L/s	NA

The RCI also provides information on allocation associated with water takes located outside of the documented SWAZ. This only occurs in the WRRP (where the SWAZ map is included in the plan) and because the full plan area is not covered by SWAZ. In total the RCI identified 1,333.5 L/s of allocation outside of the plan SWAZ boundaries (Table 3-7). The consents which make up this allocation have been assessed on a case-by-case basis because of the lack of SWAZ limits.

When this allocation is added to the total consented rate from takes within the SWAZ boundaries the total allocated rate (as of November 2017) is 7,663.5 L/s.

Table 3-7: Non-SWAZ allocation (WRRP) as of November 2017

SWAZ	Plan	Minimum Flow (L/s)	Allocated water	Notes
Eyre River	WRRP	None	557 L/s	No direct surface water takes. Stream depleting takes only, yet no permanent streams exist in area
Coopers Creek	WRRP	None	60 L/s	Public water supply take
Washpen Creek	WRRP	54 L/s	6.5 L/s	Single consent, assigned to a B block
Viewhill Creek	WRRP	None	100 L/s	Single consent, assigned to a B block
Burgess Creek	WRRP	None	186 L/s	No direct surface water takes. Stream depleting takes only,
Old Bed Eyre River	WRRP	None	300 L/s	No direct surface water takes. Stream depleting takes only,
Waimakariri Water Race	WRRP	None	76 L/s	No direct surface water takes. Stream depleting takes only,
Saltwater Creek (Kairaki Creek)	WRRP	None	48 L/s	No direct surface water takes. Stream depleting takes only,

Surface water use
Water usage varies significantly over the irrigation season and between irrigation seasons due to weather patterns and climatic variability. Analysis of metering data indicates that some consents use a large proportion of their consented rate during the peak irrigation season; some consents do not use all their volumes and a small number of consents do not appear to be used at all.

Surface water reliability, minimum flows and allocation limits
Nearly all surface water abstraction in the Waimakariri zone is used for irrigation. Higher minimum flows increase the amount of time water take rates are either partially restricted (i.e. the full consented rate cannot be used; see Glossary for further explanation) or fully restricted (i.e. no water can be taken), and vice-versa. The reduced irrigation associated with higher minimum flows can reduce farm income due to lost production.

Increasing surface water allocation increases productivity and farm income for any newly-irrigated land but reduces the reliability of existing water takes due to the larger overall take causing earlier imposition of partial restrictions and full cease at minimum flows, because minimum flows are reached faster.

3.3.7 Groundwater quantity

Groundwater quantity and trends
The Waimakariri – Ashley Plain is prone to extended dry periods with high evapotranspiration. Irrigation demand is high in the summer months when evapotranspiration is well above the average rainfall and there is a large soil moisture deficit. Land surface recharge (LSR), river losses and losses from the stockwater and irrigation race network all contribute to groundwater recharge. We have estimated that the total volume of groundwater abstracted in a dry year is roughly equal to water losses from the

irrigation and stockwater race network. This means that the race network and the supply of irrigation water from a surface water source plays a vital role in mitigating the effects of groundwater abstraction (Etheridge and Wong, 2018).

Trend analysis undertaken for the Waimakariri Zone Current State Groundwater Quantity report (Etheridge and Wong, 2018) shows that groundwater levels are declining[4] in the Ashley and Kowai and lower part of the Eyre River Groundwater Allocation Zones.

Groundwater allocation
There are five GAZs in the Waimakariri zone: Ashley, Cust, Eyre River, Loburn and Kowai (Figure 3-7). The Ashley GAZ groundwater level declines are likely to be mainly (roughly 70%) caused by climate-driven declines in Ashley River/Rakahuri flows, with increased groundwater abstraction (over the multi-decade record period) making up the balance. Declining Ashley River/Rakahuri flows and Ashley and Kowai GAZ groundwater levels mean that flows in Taranaki Creek, Waikuku Stream and Saltwater Creek are also likely to be declining. Declining groundwater levels in the lower Eyre River GAZ are likely to be reflected in declining flows in the spring-fed streams such as Silverstream. We do not have enough monitoring data for these streams to verify this trend directly, but we know from analysis of stream flow and groundwater level data in the Eyre zone and elsewhere in the region that spring-fed stream flows and nearby shallow groundwater levels are usually strongly correlated (Etheridge, 2019a).

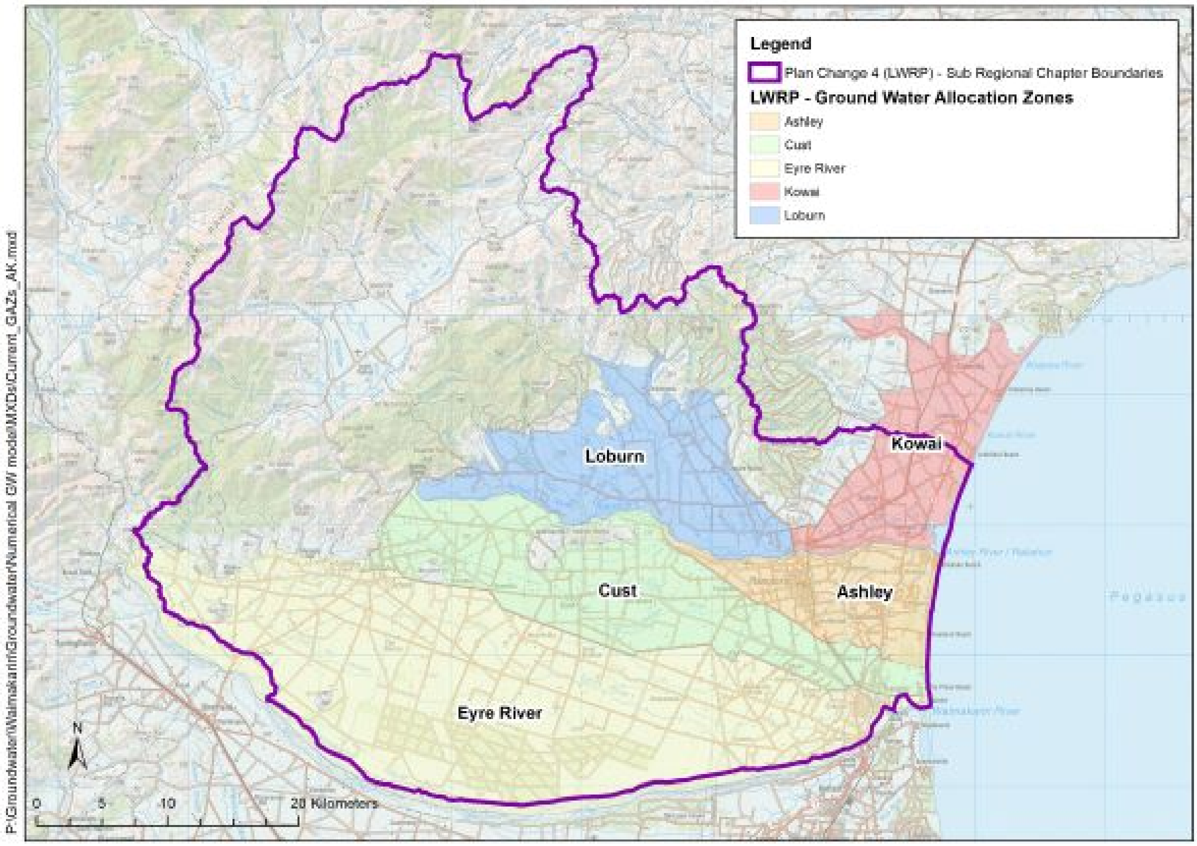

Figure 3-7: Current Waimakariri groundwater allocation zones (GAZs)

The Kowai GAZ straddles the boundary with the Hurunui CWMS Water Zone. Although groundwater allocation has increased significantly in the last decade, allocated volume in the Ashley, Cust, Loburn and Kowai GAZs is currently under the allocation limit. The Eyre River GAZ is fully allocated (Table 3-8). Approximately 70% of the allocated groundwater is used for agriculture with 25% used for community water supply. The current GAZ boundaries do not cover the whole Waimakariri Zone which means that some areas currently have no groundwater allocation limit.

[4] Note that not all records start at the same time – some start in the 1970s, others in the 2000s

Our current estimates of groundwater allocation for each GAZ under two different scenarios as per Vattala (2019) are provided in Table 3-8. Scenario one provides the current allocation based on the consented annual volume specified on consent documents or a volume based on a calculated 212-day annual volume if consents do not have an annual volume. Scenario two derives annual volumes for all groundwater consents by applying the discounting method provided in Schedule 9 of the LWRP to the scenario one annual volume. These two scenarios provide two end points to a range within which the total allocated volume is expected to lie.

Table 3-8: Current groundwater allocation (as of 12 March 2019)

Groundwater Zone	Allocation limit (m^3/year)	Possible range of total allocated[5]
Ashley	29,400,000	35 – 72%
Cust	56,300,000	21 – 40%
Eyre River	99,070,000	76 – 119%
Kowai	17,400,000	39 – 72%
Loburn	40,800,000	0.04 – 2.2%

Water metering data provided by consent holders suggests that on average around 50% of the consented volume was used in 2014-2015, despite this being a very dry year.

3.4 Climate change adaptation

Anthropogenic climate change has caused sea level rise, an increase in mean annual temperatures and changes in weather patterns. These effects are expected to continue to intensify in the future. The scale of effects will depend on whether climate change tipping points are reached (e.g. release of methane from the arctic permafrost) and whether global greenhouse gas emissions continue along their current trajectory. Potential climate change effects on water bodies in the Waimakariri zone include:

- sea level rise effects on Te Aka Aka cultural, ecological and recreational values
- increased groundwater and surface water flooding due to more severe/frequent storms
- increased drought severity/duration
- change in groundwater recharge depending on changes in rainfall.

Bolton-Ritchie and Etheridge (2019) discuss the potential effects of climate change on Te Aka Aka. In summary the potential effects are:

- prolonged inundation of low-lying coastal areas and reduced land drainage
- loss of the coastal barriers such that the area is no longer an estuary
- change in the depth regime within the current estuary
- changes to the water circulation patterns within the estuary
- changes in the sediment composition and distribution within the estuary
- changes to the mixing of freshwater and seawater and hence the salinity regime within the estuary
- saltwater/freshwater interface in the rivers moves further inland
- potential erosion and breach of dunes, stopbanks, landward edge and sand bars at the mouth
- landward displacement of shorelines
- water quality impacts
- threats to infrastructure such as the SH1 bridge at Saltwater Creek, water supplies and wastewater disposal in the low-lying coastal land.

[5] Note that these estimates are currently being revised as part of a Resource Consents Inventory process

3.5 Summary of issues

The current state assessments have highlighted that the following aspects of the Community Outcomes are currently not being met:

1. Mahinga kai and aquatic ecosystems are not meeting outcomes in spring-fed streams, especially in the Silverstream, Cust River/Cust Main Drain, Taranaki Creek, and most of the Ashley River/Rakahuri spring-fed streams due to high nitrate, fine sediment stream bed coverage, invasive plant species, low flows and poor habitat.
2. The Ashley River/Rakahuri main stem below the Gorge is not meeting the WWZC Community Outcomes for contact recreation due to significant cyanobacteria growths in the river; outcomes are not being met in Te Aka Aka due to loss of habitat, nitrate loads and fine sediment discharges.
3. The recreational value of the Waimakariri River is compromised by occasional cyanobacteria blooms in lower reaches.
4. Loss and modification of indigenous biodiversity due to deforestation, agriculture and new species introductions.
5. Safe and reliable drinking water: nitrate concentrations exceed the drinking water limit in ~10% of private water wells; this is expected to increase in the future due to activities already underway in the area.
6. The connectivity between the Waimakariri and Christchurch aquifer systems has been recognised and there is a potential effect on Christchurch groundwater quality.
7. Climate change response: Climate change is causing sea level rise and weather pattern variation and will continue to do so for the foreseeable future, possibly at an accelerating rate. This could affect both the amount of water in the zone and demand/types of water use.

3.6 Indicators, metrics and limits

The objectives of the Waimakariri Land and Water Solutions Programme are embodied within the WWZC Community Outcomes. We use indicators and metrics to measure progress towards these outcomes. Limits are used, amongst other statutory and non-statutory methods to help us achieve the outcomes. For example:

- **Community Outcome 1** states “The water quality and quantity of spring-fed streams maintains or improves mahinga kai gathering and diverse aquatic life”. Contaminant concentrations (e.g. nitrate) are water quality indicators; nitrate is a metric or way of measuring surface water quality. We use a nitrate limit for spring fed streams to help us to maintain or improve nitrate concentrations.
- **Community Outcome 6** states: “Highly reliable irrigation water, to a target of 95%, is available in the zone”. The proportion of time for which water is available for irrigation from a consented surface water (or groundwater) take is both the indicator and metric we use for reliability. Minimum flows are flow rate limits; no water can be taken when stream flow drops to or below the minimum flow. Minimum flow limits are therefore a key factor influencing the reliability of irrigation water.

4 Scenarios and Freshwater management unit assessments

The WWZC considered two broad scenarios: Current Pathway (what happens if we continue with the implementation of current plans) and Alternative Pathways (what happens if we change some aspects of the plans). Each scenario contains a variety of options which were considered individually and in combination for each FMU. The scenario and FMU assessments were undertaken for a wide range of flow, allocation and nitrate limit options and management scenarios to explore the interrelationships between environmental and cultural benefits and economic impacts These assessments were supported by a large amount of technical work completed over several years (2015 to 2018). The assessments were tailored to each FMU and waterbodies within the FMU as needed given variable circumstances. A high-level summary of the options and scenarios considered is provided at the beginning of Appendix 6 followed by details for each option and scenario. The assessments focussed on:

- Nitrate management (nitrate limits and nitrogen loss)
- Runoff contaminant management (sediment, phosphorus and pathogens)
- Aquatic ecology and biodiversity (outcomes)
- Water quantity (minimum flows and water allocation)

Noting that increases in drought frequency and severity are possible under climate change, the water management options considered by the WWZC included some measures which could help to improve drought resilience as follows:

- Increasing minimum flows, reducing water allocation volumes/rates and implementation of existing environmental flow regime rules
- Limiting any increases in new water abstraction from the zone
- Improvements in irrigation efficiency and provision of B Block allocations (where appropriate) for flood harvesting and associated on-farm storage.

The information generated through this process was used by the WWZC to develop the solutions programme contained in the ZIPA recommendations. The assessments informed this process by exploring the extent to which a range of environmental limit options and management strategies achieve or fail to achieve the Community Outcomes. The WWZC was also provided with information on modelling uncertainty. The WWZC's goal was to strike a balance between uncertainty and the need to implement proactive measures to protect environmental receptors (e.g. Christchurch's water supply aquifer) rather than taking a "wait and see" approach; whilst minimising economic impact on farming.

The ZIPA recommendations are summarised in Section 5. Section 5 also contains our assessment of the recommendations against the Community Outcomes.

5 Zone Committee recommendations and assessments

5.1 Overview

This section of the report provides the technical assessment of the extent to which the WWZC Community Outcomes are expected to be achieved through implementation of the ZIPA recommendations. The timeframes required to achieve the outcomes are also discussed.

5.1.1 Key recommendation areas

The ZIPA solutions programme focusses on five key recommendation areas to achieve Community Outcomes. The ZIPA key recommendations are summarised as follows:

Key recommendation area 1 - Improving stream health (Community Outcomes 1, 2, 3 and 5)

1. Prioritise catchments and develop two catchment management plans per year
2. Support for landowners implementing GMP
3. Implement comprehensive monitoring and research programmes
4. Protect and enhance aquatic biodiversity (review waterway management programmes, identify/protect/enhance indigenous species habitat)
5. Protect and enhance aquatic ecosystem health (bank stabilisation, reduction of sediment to spring-fed streams, enhance LWRP stock exclusion rules)
6. Ngāi Tuahuriri values and aquatic ecosystems (work with Ngāi Tuahuriri, Te Rūnanga o Ngāi Tahu and Waimakariri District Council to identify areas of high cultural value and options for protecting these values)
7. Ashley River/Rakahuri and Saltwater Creek catchment (recognise for important natural landscape and ecosystem values)
8. Urban waterways (enhance public education/awareness programmes of urban waterways quality)
9. Support for on-the-ground projects

Key recommendation area 2 - Protecting and enhancing indigenous biodiversity (Community Outcome 5)

1. Implementation of the Canterbury Regional Biodiversity Strategy as applies to the Waimakariri Zone including consideration of climate change and sea level rise impacts
2. Support for Ngāi Tuahuriri values and provide support for Fenton Reserves
3. Work with community groups, landowners/managers to promote awareness and support for on-the-ground actions to protect and enhance indigenous biodiversity

Key recommendation area 3 - Reducing nitrates (Community Outcomes 1, 3, 4, 7, and 9)**:**

1. Staged approach to reduce nitrate losses over time from 1 July 2020 with Baseline GMP[6] as the starting point
2. Propose two water quality management areas: Nitrate Priority Area (NPA) and Runoff Priority Area (RPA) (see Section 5.1.2 for additional details)
3. Nitrate Priority Area: a staged approach to nitrate loss reduction beyond Baseline GMP and investigate/implement "floor" so that low emitters are not required to reduce beyond Baseline GMP).
4. Runoff Priority Area: landowners in this area are not required to achieve beyond Baseline GMP reductions. Expectation is that these landowners will focus on minimizing overland flow of contaminants such as sediment, phosphorus, and pathogens.
5. Permitted activity threshold across entire Waimakariri Zone (reduction of winter grazing threshold)

[6] Baseline GMP is the Overseer-derived nitrogen loss rate estimate for a property based on land use in the 2009-2013 Baseline period operating at Good Management Practice as defined in Plan Change 5 of the LWRP.

6. Nutrient allocation zone rules and sub-regional boundary (use PC5 “red zone” rules for managing nutrients across entire zone and change boundary to include land bordering the Waimakariri River.
7. Nitrate limits for community drinking water supply wells and private water supply wells within the Waimakariri Zone (ZIPA Table 3.2)
8. Nitrate limits for streams and rivers (ZIPA Tables 3.3 and 3.4)
9. Support improvements in monitoring and understanding of system, adaptation to new information and innovation
10. Plan review commencing 2030

Key recommendation area 4 - Managing surface water quantity (Community Outcomes 1 to 8)**:**

1. Reduce and where possible eliminate over-allocation by 2032
2. Apply LWRP rules for partial restrictions and pro-rata restrictions in all SWAZs[7]
3. Apply LWRP methodology to classify stream-depleting groundwater across the Waimakariri Zone
4. Cap allocation limits at current allocated volumes in currently under-allocated SWAZs
5. Remove B allocation blocks from spring-fed rivers
6. Support water user groups
7. Ashley River/Rakahuri catchment (Ashley River/Rakahuri B and C blocks) contain a mahinga kai enhancement purposes block and adopt minimum flow and allocation presented in ZIPA Tables 4.5)
8. Waimakariri tributaries catchment (Cam River/Ruataniwha A block) contain a mahinga kai enhancement purposes block and adopt minimum flow and allocation presented in ZIPA table 4.6)
9. Cust River – investigate potential for enduring flow regime

Key recommendation area 5 - Managing groundwater quantity (Community Outcomes 1, 4, 6, 7, and 8)**:**

1. Allocation limit for under-allocated GAZs (Kowhai, Ashley, Cust and Loburn) to be capped at current allocated volume plus 10% based on current allocated volume for new non-stream depleting takes. Also provides allocation for substitution of existing surface water or stream-depleting groundwater takes for non-stream depleting groundwater takes.
2. Allocation limit for Eyre River GAZ to be capped at current allocated volume. Also provide allocation for substitution of existing surface water or stream-depleting groundwater takes for non-stream depleting groundwater takes.
3. New Lees Valley GAZ with allocation limit to be capped at current allocated volume. Also provide allocation for substitution of existing surface water or stream-depleting groundwater takes for non-stream depleting groundwater takes.

5.1.2 Nitrate Priority Area

The ZIPA recommendations 3.1 – 3.14 (Beyond Baseline GMP nitrate loss reductions in the Nitrate Priority Area [NPA]) comprise ongoing staged reductions in nitrate losses from land with all the following characteristics:

- High nitrate loss rates
- Exclusion of heavy soils
- Located within the source/recharge zones of drinking water supply wells (and/or surface water body) receptors
- Nitrate concentrations in the downgradient receptors do not meet the recommended limits at present and/or are unlikely to do so in the future, after accounting for nitrate loads already consented and/or travelling through the hydrological system towards these receptors (i.e. “in the post”).

[7] Existing LWRP policy for rivers in the Ashley River/Rakahuri catchment is to apply a “pro rata” approach. This applies partial restrictions to all users when flows drop to a rate equaling the minimum flow plus the allocation limit.

Recommendations 3.5 and 3.6 propose beyond Baseline GMP nitrate loss reductions of 15% for Dairy and 5% for all other consented farming activities. Recommendation 3.8 says that these staged reductions should be continued, unless amended in a plan review process, until:

a) the nitrate reductions necessary to achieve the plan limits have been met; or
b) the available science information shows the plan limit is likely to be met in the future without the need for further reductions.

This concept of staged ongoing reductions is illustrated in Figure 5-1.

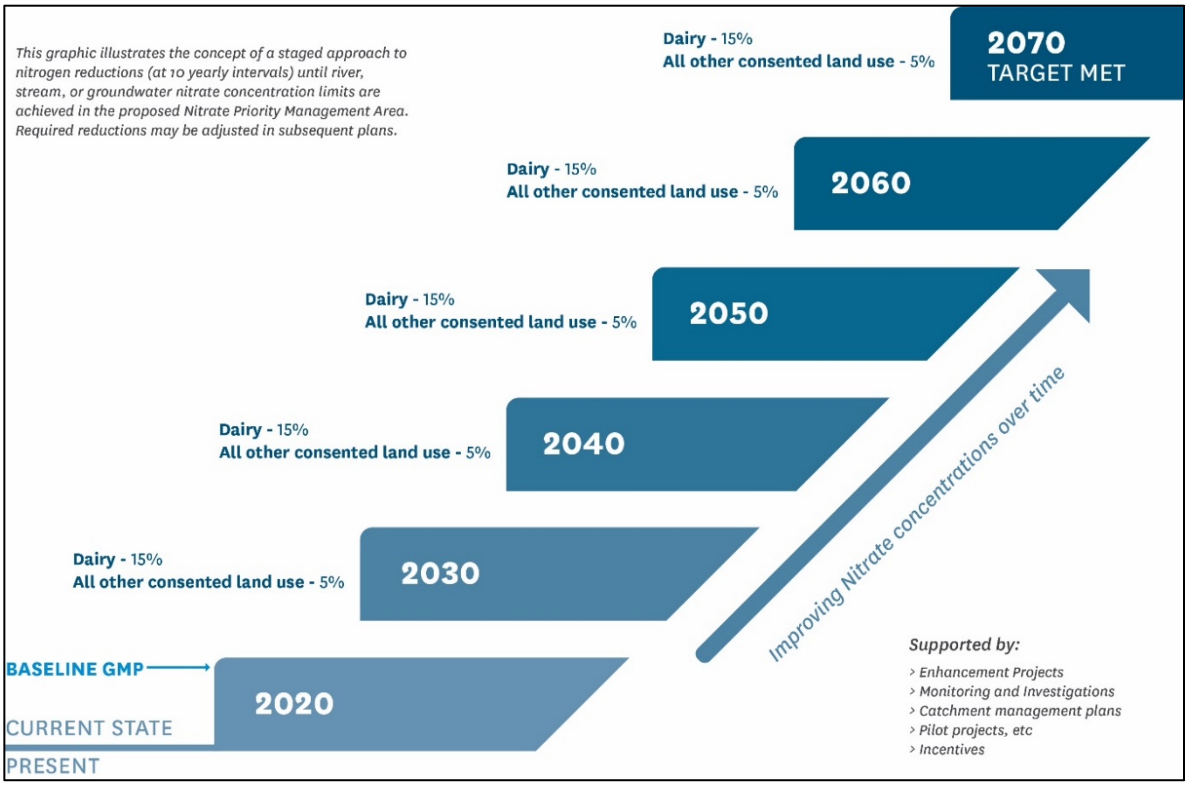

Figure 5-1: Proposed Staged Approach to nitrate reductions[8]

Additional details regarding the description and delineation of the NPA and stages of nitrate reduction are included in Appendix 6 and discussed further in Kreleger and Etheridge, 2019a.

5.1.3 Adaptive management

The WWZC received strong feedback from local stakeholders on the need for an adaptive management approach for nitrate management. Uncertainty over lag times, nitrogen loss rates and the effects of GMP on groundwater and surface water nitrate concentrations were identified as key drivers of the need for adaptive management.

The ZIPA nitrate management recommendations comprise staged reductions in nitrate loss rates over time as illustrated in Figure 5-1, with ten-yearly reviews and more frequent monitoring and science updates.

Environmental monitoring data will be reviewed and modelling will be updated as part of this framework, to assess whether nitrate targets are either being achieved in receiving waters or are likely to be achieved in the future, after accounting for lag times. No further nitrate loss reductions will be required in those catchments where results show that targets are likely to be achieved.

[8] Note that the 2070 data on this figure is for illustrative purposes – it is likely to take longer to meet targets in some areas and less in others, as discussed below.

In parallel, the WWZC has included a range of recommendations to facilitate and support on-the-ground actions, such as MAR. Successful implementation of these actions could reduce the need for beyond Baseline GMP N loss reductions. By combining these actions with improved monitoring, better science knowledge and the adaptive management framework, the Waimakariri Land and Water Solutions Programme will maximise the rate of improvement in cultural and environmental values associated with improving water quality and minimise the economic impact on farming.

5.1.4 Statutory and non-statutory recommendations

The ZIPA recommendations can be broadly classified into those which will be translated into Regional Plan provisions, i.e. the statutory recommendations, and those which rely on non-statutory "on-the-ground actions". Our assessment focuses on the statutory recommendations. However, our results show that implementation of statutory recommendations would not be enough, in some instances, to achieve the Community Outcomes either at all or within several decades. We have therefore also assessed the potential benefits that could be achieved through implementation of the on-the-ground actions, recognising that the latter rely on voluntary actions and/or human and financial resources, with no current commitment to the deployment of these resources.

A comparison of the current plan limits and proposed limits based on the ZIPA recommendations is included in Appendix 8.

5.1.5 Assessment approach

We have structured this solutions assessment as follows:

1. Maintain and improve mahinga kai, water quality and aquatic ecology – Improving stream health (Key recommendation area 1 and 3)
2. Safe and reliable drinking water (Key recommendation areas 3 and 5)
3. Maintain and improve indigenous biodiversity (Key recommendation area 2)
4. Irrigation water supply reliability (Key recommendation areas 4 and 5)
5. Economic sustainability (all recommendation areas)
6. Thriving communities and recreational opportunities (all recommendation areas)
7. Climate change resilience and adaptation (all recommendation areas)

5.2 Maintain and improve mahinga kai, water quality and aquatic ecology - Improving stream health (ZIPA key recommendation areas 1 and 3)

5.2.1 Community Outcomes

Mahinga kai and aquatic ecological health, species diversity and abundance are affected by water quality and habitat, with water quantity being a key factor in the latter. Determination of the extent to which the Community Outcomes 1, 2 and 3 will be met therefore requires an integrated assessment of the ZIPA key recommendation areas 1 and 3 on environmental flow regimes, nitrate and the runoff contaminants and habitat management. Community Outcome 7, which is for optimal water and nutrient management to be common practice, will also help to deliver the goal of maintaining and improving mahinga kai, water quality and aquatic ecology.

5.2.2 Key ZIPA recommendations and assessment summary

The main statutory and non-statutory ZIPA recommendations, the watercourses that are expected to benefit from implementation of these recommendations and the ZIPA recommendations assessment results are summarised in Table 5-1 and Table 5-2. The assessment compared the ZIPA recommendations to current state and to Current Pathway. In some cases (e.g., extended stock exclusion rules) the current state and Current Pathways conditions are the same. For others (e.g., recovering surface water over-allocation) the current state and Current Pathways represent different conditions. The assessment result noted in the table reflects this difference. Details regarding our solutions assessment for mahinga kai, water quality and aquatic ecology are provided on a waterbody-by-waterbody basis in Arthur *et al*. (2019). Details regarding our solutions assessment for stream nitrate concentrations are provided in Appendix 7.

Table 5-1: Summary of ZIPA solutions programme assessment – statutory recommendations

Main ZIPA statutory recommendations[9]	Watercourses affected	Assessment result	Rationale
Extended stock-exclusion rules (1.15, 1.16)	Ashley River/Rakahuri, Te Aka Aka and spring-fed streams	Minor to moderate improvement	Extension of stock-exclusion rules to include all springs and all open drains and artificial watercourses reduces inputs of sediment, phosphorus and *E. coli*.
Beyond Baseline GMP N loss reductions in NPA (3.1, 3.2, 3.5, 3.6, 3.8)	Waimakariri northern tributaries	Minor improvement	Manage periphyton and macroalgal growth and nitrate toxicity effects by maintaining or reducing current nitrate concentrations:
Reduction in PA winter grazing thresholds (3.11)	Ashley River/Rakahuri, Te Aka Aka, spring-fed streams	Minor improvement	Protect watercourses from further declines in health/values due to periphyton and macroalgal growth, nitrate toxicity, and sediment loss associated with expansion of winter grazing
Nitrate limits (3.18)	All	Minor to moderate improvement	Help to maintain or reduce current nitrate concentrations, in combination with reduced PA thresholds and beyond Baseline GMP N loss reductions in NPA. Manage periphyton and macroalgal growth, and nitrate toxicity effects
Increased minimum flows (4.16, 4.18)	Saltwater Creek, Waikuku Stream, Little Ashley Creek, North Brook, South Brook, Cust River, Ohoka Stream, Silverstream, Courtenay Stream, Greigs Drain	Minor to moderate improvement	Improves habitat area and fish passage, and water quality by preserving low flows over a longer period.
Recover over-allocation of surface water (4.1, 4.2)	Ashley River / Rakahuri A Block, Saltwater Creek, Waikuku Stream, Taranaki Creek, Ohoka Stream, Cust Main Drain, Cust River (A block)	No change relative to current pathway (assumes full recovery of over-allocation) Minor to moderate improvement from current state if recovery reduces actual abstraction	Progressively improves capacity of streams to maintain water and habitat quality relative to current state by improving the variability of river flows.

[9] Number in brackets refers to recommendation number in ZIPA

Main ZIPA statutory recommendations[9]	Watercourses affected	Assessment result	Rationale
		rather than "paper" allocation alone	
Reduce surface water allocation limits (4.7)	Ashley River/Rakahuri B and C Blocks, Little Ashley Creek, Cam River / Ruataniwha, North Brook, South Brook, No. 7 Drain, Silverstream, Courtenay Stream, Greigs Drain Eyre River, McIntosh/Kairaki, Upper Eyre River	Improvement relative to Current Pathway, no change relative to current state	Prevents further degradation of water and habitat quality by preventing further takes which would impact on flow variability, habitat availability and stream health.
Extend existing SWAZs and/or introduce new SWAZ to eliminate gaps in environmental flow regime network (4.6)	Eyre River, McIntosh/Kairaki, Upper Eyre River	Minor improvement	Defining SWAZ boundaries for the Macintosh Drain and Kairaki Creek SWAZ and prohibiting surface water and stream-depleting groundwater takes will help to protect this area of high value wetlands and biodiversity. Defining Eyre River and upper Eyre River SWAZ gives surety as to the water available and subsequent effects.
Reduce groundwater allocation limits, expand GAZ boundaries and create new Lees Valley GAZ (5.1-5.7)	Spring-fed streams	No change relative to current state Improvement relative to Current Pathway	Reducing the potential for increased groundwater abstraction will help to maintain current spring-fed stream flows, associated stream values and mahinga kai.
Remove B Block allocation on WRRP spring-fed streams	Cam River / Ruitaniwha, North Brook, Middle Brook, South Brook, No.7 Drain, Ohoka Stream, Silverstream, Courtenay Stream and Greigs Drain	Minor improvement	Preserves small frequencies of intermediate flows in spring-fed streams, which are valuable for small flushing events to maintain water quality and for ecosystem function.
Mahinga kai water allocation for Ashley River/Rakahuri (4.15), Cam River/Ruataniwha and Silverstream	Ashley River / Rakahuri B and C Blocks, Cam River / Ruataniwha A Block and Silverstream	Minor improvement	Improve habitat provisions for tuna, koura and other mahinga kai species.

Table 5-2: Summary of ZIPA solutions programme assessment – non-statutory recommendations

Main ZIPA non-statutory recommendations[10]	Watercourses affected	Assessment
Consent review to implement existing LWRP minimum flows and partial restrictions (4.3, 4.14)	Ashley FMU (2026-2027) Waimakariri FMU (2028-2029)	Will prevent streams from being drawn below plan minimum flow levels, and the associated negative outcomes for instream habitat and water quality.
Runoff Priority Management Area designation (3.2), Implement GMP (1.2) + Catchment Management Plans (1.1)	Te Aka Aka, Ashley River/Rakahuri and tributaries	Provides foundation for seeking a funding mechanism to support costly on-the-ground projects that are essential for obtaining improvements in mahinga kai and instream ecosystem health in spring-fed streams, regardless of new statutory provisions.
Mahinga kai, stream health and habitat protection and restoration projects (1.11, 1.12, 1.13, 1.14, 1.20, 1.21, 1.23, 1.26, 1.27, 1.28, 2.7, 2.10, 2.12, 3.25)	Spring-fed streams and Te Aka Aka	Will provide localised improvements to instream and bankside habitats, and remedy barriers to mahinga kai passage (e.g. tide gates that block inanga passage)
Improved water quality and ecological monitoring and research (1.4, 1.6, 1.7, 2.13 3.19)	All water bodies	Improve understanding of state and drivers of ecosystem health. Will fill-in gaps where there is currently very little or no data (e.g. in high valued Lees Valley and Upper Eyre catchments)
Fish passage barrier review (1.8)	Most spring-fed waterways, particularly those with tide and flood gates	Improve migratory passage of native species and salmonids. Mitigation of tide gate barrier will provide short-term benefits to community diversity in streams, which will otherwise be achieved only in the long term.
Nitrate mitigation options study (3.24)	Silverstream, Ohoka Stream, Cust River/Main Drain	Successful implementation of MAR could increase stream flows and habitat area and improve water quality
Support for stream augmentation (4.11)	Cust River/ Cust Main Drain	Stream augmentation using Waimakariri River water via irrigation race network could increase stream flows and habitat area and improve water quality
Consultation on proposed water race modifications (4.12)	Silverstream, Ohoka Stream, Cust River/Main Drain	Maintain current stream flows and water quality benefits associated with clean water losses from current race network
Monitoring of PA water use (4.13)	All spring-fed streams	Monitoring and enforcement of water take rates allowed for as PA could help to maintain or improve stream flows and associated habitat areas

[10] Number in brackets refers to recommendation number in ZIPA

Main ZIPA non-statutory recommendations10	Watercourses affected	Assessment
Environment Canterbury should investigate further actions necessary to reverse degradation of Kaiapoi River (4.20)	Kaiapoi River	Improve all aspects of water quality, and habitat quality and quantity in the Kaiapoi River catchment. Will increase ecosystem, recreation, cultural and aesthetic values.
Establish working group to protect and enhance Ngāi Tūāhuriri, biodiversity and recreational values in Te Aka Aka in the face of climate change and sea level rise (2.12)	Te Aka Aka	Result will be climate change adaptation.
Support industry groups to provide sector, and catchment-specific support to landowners implementing Good Management Practice (1.2)	All waterbodies	Although reduced water abstraction from streams and groundwater under GMP should leave more water available for environmental flows and reduce nitrogen loss rates, improved irrigation efficiency for Waimakariri River-sourced irrigation schemes is likely to reduce groundwater recharge. This may lead to reduced spring-fed stream flows and reduced dilution of nitrate and higher concentrations in some receptors.
Environment Canterbury runs an education campaign (including workshops) promoting good management practice, and proactively checks progress (3.12)		
Environment Canterbury engages with small block owners to increase awareness and uptake of good management practices (1.3)		Improved management of small blocks could reduce water abstraction from surface and groundwater, reduce nitrogen loss rates and reduce the rate of runoff contaminant discharge to waterways.

5.2.3 Solutions assessment

Our solutions assessment results as discussed in Arthur *et al.* (2019) show that the expected catchment-scale benefits of implementation of the statutory ZIPA recommendations on mahinga kai, stream health and water quality fall into three categories:

- maintain Current (e.g. control of the potential for significant deterioration in values via more stringent winter grazing PA rules, introduce nitrate concentration limits for streams)
- minor Improvement (e.g. higher minimum flows, implementation of existing minimum flows and partial restrictions)
- moderate Improvement (e.g. expanded stock exclusion rules).

ZIPA recommendations will improve the way land and water is managed in the Waimakariri Zone by preventing further degradation in aquatic ecosystem health. In particular, there will be a reduction in runoff contaminants (sediment, phosphorus and *E. coli*) and, in the long-term, groundwater nutrients (nitrogen) entering waterbodies. Minimum flows will increase in some streams, and allocation limits decrease, which will mean flows will better maintain the availability of fish and invertebrate habitat and flushing flows. Despite the recommendations of the ZIPA, ecosystem health in Waimakariri Zone waterbodies will likely remain compromised by either poor water quality, lack of habitat availability, or poor physical habitat condition. Much of this will be due to the legacy effects of past land uses such as deposited sediment, channel modification, riparian de-vegetation, and over-allocation leading to high groundwater nutrients and excessive water abstraction.

Protecting waterways from further contamination and degradation is important, and substantial improvements to ecosystem health will require the implementation of on-the-ground projects, coupled with lower nitrate and water allocation limits. Some of the key recommendations which have the potential to deliver a major improvement to aquatic ecosystems include:

- modifying or removing fish barriers to allow migration to upstream reaches (Rec 1.8)
- rehabilitation of wetlands, freshwater and estuarine habitats of threatened species and those of high value to Ngāi Tūāhuriri (Rec 1.11)
- reducing and removing fine sediment and improving mahinga kai species habitat in Taranaki Creek, Cam River/Ruataniwha, Silverstream and Kaiapoi River (Rec 1.21, 1.27)
- managed aquifer recharge (MAR) and stream augmentation (Rec 3.24).

This work will require significant resourcing and funding, the amount of which will likely be proportional to the scale and speed of improvements to ecosystem health. Given the limited availability of such funding currently in the zone, the recovery of aquatic ecosystem health is likely to be slow and/or confined to localised reaches or areas. For example, ZIPA recommendation 3.25 proposes that Environment Canterbury and Waimakariri District Council should explore a funding mechanism and management structure to deliver the significant improvements in mahinga kai, stream health and biodiversity required by Ngāi Tūāhuriri and sought by local communities respectively, over the next five to ten years. The option of a Targeted Ratings District mechanism should be investigated by Environment Canterbury, and industry and government funding sources also should be sought, according to this recommendation. The rough order cost analysis presented in Harris (2019) suggests that if $60M of funding could be secured from these sources over a 10-year period it may be possible to:

- install stock-exclusion fencing with wider set-backs and to plant these set-back areas with native plant species over 2,400 km of stream length
- install 2,500 sediment traps
- re-batter 285 km of stream bank
- remove legacy sediment from 87 km of stream
- pay for management of these rehabilitated areas.

The ecological assessment provided by Arthur *et al.* (2019) shows that these rehabilitation actions have the potential to deliver a significant improvement in mahinga kai diversity and abundance desired required by Ngāi Tūāhuriri over the next 10 years. The WWZC assessed that a rehabilitation project of this scale is critically important for continuation of cultural practices and to mitigate the significant social impact currently being experienced by tangata whenua. The project would also help to deliver Environment Canterbury's organisational priority of achieving a step change in biodiversity.

A Coastal Protection Area (CPA) was proposed in recognition of the important natural resources and values found in the main spring-fed streams, lagoons and wetlands near Te Aka Aka and the Waimakariri coast (Etheridge and Arthur, 2019). We assessed the stream lengths that would benefit from the improved protection and management associated with a requirement to obtain a Resource Consent and produce an audited Farm Environment Plan (FEP) based on potential for increased runoff contamination under PC5PA rules. Further details are provided in Appendix 6.

ZIPA recommendations for greater monitoring in the zone will vastly improve our understanding of the state and drivers of aquatic ecosystem health. This will allow us to measure the effectiveness of regulatory and on-the-ground management methods mentioned in the ZIPA. Education is an important tool for ensuring behaviour that is consistent with protecting the values that these waterbodies have to iwi and communities. The development of funding strategies and encouraging community involvement will be crucial to rehabilitating waterways, wetlands and coastal waterbodies.

5.3 Safe and reliable drinking water

5.3.1 Community Outcomes

Community Outcome 4 seeks to achieve safe and reliable drinking water, preferably from secure sources. Community drinking and domestic supplies should meet New Zealand drinking water standards and water supply wells should be reliable during drought conditions.

Nearly all drinking water in the Waimakariri Zone is sourced from groundwater. There are approximately 2,750 private water supply wells in the zone, supplying water to ~7,150 people. The remaining 53,550 people are supplied by WDC's community water supply wells. This means that resilient groundwater quality management is critical for Waimakariri Zone residents.

Nitrate and *E. coli* are the primary contaminants of concern with respect to provision of safe drinking water in the Waimakariri zone. Although there is a possibility that other contaminants[11] are present in discharges from agricultural land, there is currently no evidence to suggest that these are present or impacting water quality in this area or that specific management controls are required. In addition, managing to reduce nitrate and *E. coli* is likely to also produce some parallel benefit for other contaminants that come from the same or similar sources.

Community Outcome 9 supports the maintenance of current high-quality drinking water from Christchurch's aquifers through appropriate land and freshwater management in the Waimakariri Zone. This outcome recognises the connectivity between the Waimakariri and Christchurch aquifer systems and that nitrate concentrations in the Christchurch aquifer may increase in the medium term due to the nitrate load already moving through the system, before reducing in the long term. Protecting the high quality of Christchurch's groundwater is not only critically important for the 388,000 city residents who rely on this drinking water source; groundwater discharges from the aquifer also maintain flows and water quality in Christchurch's highly-valued spring fed streams.

5.3.2 Key ZIPA recommendations and assessment summary

The main statutory and non-statutory ZIPA recommendations, the receptors that are expected to benefit from implementation of these recommendations and the solutions assessment results are summarised in Table 5-3. Details regarding our solutions assessment for safe and reliable drinking water are provided in Kreleger and Etheridge, 2019a.

[11] e.g. veterinary medicines such as antibiotics and antiparasitic agents and hormones such as synthetic and natural estrogens and androgens

Table 5-3: Solutions assessment summary for drinking water outcome

Main ZIPA statutory recommendations[12]	Effect on outcome relative to Current Pathway	Assessment Result	Notes
Define nitrate limits for groundwater and drinking water supply wells (Rec 3.15)	Minor improvement (short term); significant improvement (long term)	Meeting the recommended nitrate limits will mean that nitrate concentrations in community water supply wells remain well below the drinking water MAV for nitrate of 11.3 mg/L. Achieving a median nitrate concentration of 5.65 mg/L in all private water supply well areas will mean that nitrate concentrations are likely to remain below the MAV in at least 90% of wells.	Implementation of GMP under the Current Pathway scenario is expected to reduce groundwater nitrate concentrations in some areas but may cause an increase in concentrations in areas irrigated with imported water (Waimakariri River source) and where current practice irrigation is inefficient Assessment certainty: moderate
Reduce nitrate concentrations in Nitrate Priority Management Area until targets are met (Rec 3.1 - 3.8)	Minor improvement (short term); significant improvement (long term)	The staged reductions provide a pathway and mechanism by which the nitrate targets can be achieved. In some areas it is likely to take many decades to meet the limits due to lag times and the rate of nitrate reduction that can be achieved by farmers	Assessment certainty: moderate
Reduce winter grazing PA thresholds and strengthen Nutrient Allocation Zone rules to limit potential for further land use intensification (Rec 3.11 and 3.14)	Maintain current	Reducing the potential for further intensification means that limits will be met more quickly. The risk of further deteriorations in water quality is reduced.	Assessment certainty: high
Improve knowledge of nitrate concentrations and trends (Rec 3.16 and 3.19)	Long term improvement	Supports adaptive management at plan review stage in 2030: new information will allow the Nitrate Priority Management Area to be redefined in the future based on improved science information	Assessment certainty: high
Develop on-the-ground actions to address nitrate issues (Rec 3.24)	Potential to achieve significant improvement in some areas	Successful implementation of on-the-ground actions such as Managed Aquifer Recharge would mean that targets are met more quickly in some wells.	Assessment certainty: moderate

[12] Number in brackets refers to recommendation number in ZIPA

Main ZIPA statutory recommendations[12]	Effect on outcome relative to Current Pathway	Assessment Result	Notes
Provision of guidance on minimum wells depths and well head security for new drinking water wells	Minor improvement	Will improve safety and security of new wells. No change for existing supply wells	Assessment certainty: moderate
Cap groundwater allocation at current rates in Eyre GAZ and at current + 10% in other GAZs order to maintain reliability (Rec 5.1 - 5.6)	Minor decline from current; significant improvement from Current Pathway scenario	Additional 10% allocation could, if utilised, cause a small decline in the reliability of shallow wells during drought periods but this potential impact is much less than that which could occur under Current Pathway	Because current allocation limits are much higher than the currently allocated water volume in some of the GAZs, the Current Pathway scenario (which assumes water is allocated up to the current limits) projects a potentially significant reduction in reliability in some wells. The ZIPA recommendations reduce the allocation limits in four allocation zones and hence provide an improvement in reliability relative the Current Pathway scenario[13] Assessment certainty: moderate

[13] Further details regarding groundwater allocation recommendations and assessment results are provided in Appendix 7.

5.3.3 Solutions assessment

The solutions assessment results show that the statutory ZIPA recommendations are expected to:

- help to maintain current nitrate concentrations via the proposed reduction in PA winter grazing allowances;
- achieve a minor short-term improvement and significant long-term improvement in drinking water well nitrate concentrations relative to the Current Pathway scenario by setting groundwater drinking water supply nitrate concentration limits and defining statutory actions to achieve these limits; and
- help to maintain current levels of well reliability by limiting the potential for future increases in groundwater abstraction.

The non-statutory ZIPA recommendations could:

- reduce the time taken to achieve the nitrate limits in water supply wells if MAR is implemented in the recharge areas of private and community water supply wells
- improve safety and security of new private water supply wells by encouraging owners to drill wells sufficiently deep to minimise the risk of microbial contamination; and
- support adaptive management at plan review stage in 2030 by improving knowledge of nitrate concentrations and trends.

Our nitrate modelling assumes zero attenuation in groundwater. Modelling results presented in this section show that it could take a long time to achieve nitrate limits due to a combination of lag times and the associated expectation of future nitrate increases in some wells. These increases will be lower and hence limits achieved more quickly (with smaller beyond Baseline GMP N loss reductions required), if significant nitrate attenuation is occurring. This is discussed further in Kreleger and Etheridge (2019b).

We ran an additional model scenario which accounted for potential nitrate attenuation in the near-coastal zone. The results of this assessment (presented in Etheridge and Kreleger, 2019) show that nitrate loss reductions would be significantly lower for some parts of the Waimakariri Zone (e.g. Cust Main Drain catchment) if the potential nitrate attenuation translates into actual attenuation.

Similar to stream nitrate concentrations, the timeframe within which drinking water supply well nitrate concentration limits could be achieved was an important aspect of the WWZCs deliberations when determining their ZIPA recommendations.

Details of the approximate time taken to meet the recommended nitrate limit in the modelled private water supply well areas (PWSAs) are presented in the Nitrate Management Options and Solutions Assessment Report (Kreleger and Etheridge, 2019a). In summary:

- Nitrate concentrations under Current Pathway will stay beneath the ZIPA limit for eight of the PWSAs (includes approximately 1300 of the total 2650 private water supply wells) so beyond Baseline GMP nitrate reductions are not required.
- Nitrate concentrations may either currently exceed or under Current Pathway exceed the proposed ZIPA limit in 15 of the PWSAs (approximately 1350 wells). Time required to reach the proposed limit ranges from:
  - 50 – 80 years in eight of these areas (Clarkville, Cust, North East Eyrewell, North West Eyrewell, Ohoka, Springbank, Swannanoa and West Eyreton[14]);
  - 80 – 100 years in four areas (Eyreton, North East Eyrewell[14], North West Eyrewell[14] and Swannanoa[14]); and
  - >100 years in three areas (Eyreton[14], Ohoka[14] and Summerhill)

Although, estimated nitrate concentrations may exceed the ZIPA limit (or the drinking water limit) for a given PWSA, nitrate concentrations in individual wells may or may not exceed limits. This is discussed further in Kreleger and Etheridge (2019a).

[14] For deep wells in these areas; shallow wells would meet targets more quickly.

5.4 Maintain and improve indigenous biodiversity

5.4.1 Community outcome

Community Outcome 5 seeks to achieve protection and improvement of indigenous biodiversity in the Waimakariri zone. The outcome recognises that habitat loss and the impacts of introduced species are key threats to the Waimakariri Zone goal of protecting and enhancing indigenous biodiversity.

5.4.2 Key ZIPA recommendations and assessment summary

ZIPA recommendations 2.1-2.13 explicitly relate to the protection and enhancement of indigenous biodiversity. The recommendations seek an integrated catchment management approach to biodiversity protection and improvement, with key agencies, Ngāi Tūāhuriri, landowners and stakeholders working together. The Canterbury Biodiversity Strategy approach is endorsed by the ZIPA, with implementation sought at the zonal scale. The need for mapping of key habitats and species distributions within the zone, identifying priorities and setting clear targets are recognised, as is the need for further investigations and monitoring in areas such as the Ashley Estuary/Te Aka Aka.

Additional recommendations relating to protection/enhancement of biodiversity and health of aquatic (including wetland) ecosystems are contained within 'Improving Stream Health' recommendations 1.7–1.28, 'Reducing Nitrate' recommendations 3.1-3.25 and 'Managing Water Quantity' recommendations 4.1-4.16 and 5.1-5.7.

The 'Improving Stream Health' recommendations placed emphasis on the need for measures to protect biodiversity and ecosystem health by avoiding or minimising contaminant losses to receiving waterbodies (including wetlands – e.g. Rec 1.24). Regulatory measures, such as strengthening LWRP rules around stock exclusion from waterways and springs, were included. Similarly, a planning/regulatory approach was included in recommendations relating to 'Reducing nitrates' and 'Managing water quality' outcomes.

By contrast, recommendations targeted at 'Protecting and enhancing indigenous biodiversity' emphasised non-regulatory measures such as provision of incentives and advisory services, and 'working with willing landowners'.

The main ZIPA recommendations and the solutions package assessment results are summarised in Table 5-4.

Table 5-4: Summary of ZIPA solutions programme assessment – indigenous biodiversity

Main ZIPA non-statutory recommendations[15]	Assessment results
Protection and enhancement of indigenous biodiversity (2.1-2.13)	Non-statutory recommendations support an integrated catchment management approach, endorse Canterbury Biodiversity Strategy approach and recognise need for setting clear targets and further investigation and monitoring. These non-statutory recommendations unlikely on their own to achieve outcome other than on a very localised scale. A combination of an improved planning/regulatory framework at both regional and district plan level, plus substantial new funding to implement the ZIPA's non-statutory recommendations would be required.

5.4.3 Solutions assessment

The solutions assessment provided by Grove (2019) identified two key issues for protecting and enhancing indigenous biodiversity: habitat loss and the impacts of introduced species.

[15] Number in brackets refers to recommendation number in ZIPA

Recommendations 2.1 to 2.14 are ‘non-statutory’ and will not lead to strengthening of the District and Regional Plan provisions for the maintenance and protection of indigenous biodiversity. Therefore, the extent to which they will protect and improve indigenous biodiversity is uncertain and may be negligible unless significant resources are committed to these recommended actions.

Statutory and non-statutory actions are required to achieve Priority Outcome 5. Both District and Regional Plans need the ability to regulate the land use activities that have the potential to adversely impact on the ecosystem health and indigenous biodiversity of terrestrial, wetland and aquatic habitats. The ZIPA includes a number of recommendations to improve/strengthen LWRP provisions which will, if implemented, improve the health of aquatic and some wetland ecosystems. However, no equivalent recommendations are offered to improve/strengthen District Plan provisions in relation to terrestrial ecosystems and biodiversity. Without these District Plan provisions, it is unlikely that Community Outcome 5 will be achieved on anything other than a very localised scale. Whilst the various non-statutory recommendations listed in the ‘Improving Stream Health’ and ‘’Protecting and Enhancing Indigenous Biodiversity’ sections of the ZIPA could potentially achieve some localised biodiversity improvements, the assessment concluded that stronger regulatory controls together with sufficient resourcing of rule implementation and compliance monitoring would be required to achieve Priority Outcome 5 over the wider Zone. With appropriate regulatory baselines to secure habitats, the non-regulatory actions recommended in the ZIPA will be better placed to deliver improved protection and enhancement of biodiversity in the wider sense.

The various statutory/planning-based recommendations to reduce nitrates and manage surface- and groundwater quantity should, if successfully implemented, also contribute to improved stream health and the protection and enhancement of indigenous aquatic biodiversity.

In summary, the assessment is that the ZIPA recommendations are unlikely on their own to achieve Community Outcome 5 and a combination of an improved planning/regulatory framework at both regional and district plan level, plus substantial new funding to implement the ZIPA’s non-statutory recommendations would be required to deliver Community Outcome 5 (Grove, 2019).

5.5 Irrigation water supply reliability

5.5.1 Community outcome

Community Outcome 6 defines a target of 95% reliability for irrigation water in the Waimakariri Zone. The narrative provided by the WWZC for this outcome suggests that it would be achieved if:

1. irrigation water (from both surface and groundwater) reliably supplies water to meet demand when operating within flow and allocation regimes
2. 100% of the irrigated area can be irrigated 95% of the time
3. the effects of climate change are considered in the planning and effective long-term management of water and land
4. opportunities for water storage are considered.

For the purpose of assessing whether this outcome is achieved we have assumed that all ZIPA recommendations have been fully implemented and thus identified over-allocation has been fully recovered.

5.5.2 Key ZIPA recommendations and assessment summary

Our summary of the main ZIPA recommendations and overview of expected outcomes (Table 5-5) identifies both positive and negative outcomes for irrigation water supply reliability. In general, irrigation reliability is improved under these recommendations and will contribute towards meeting Community Outcome 6, although the specific target of 95 % is not met. The Cam, South Brook and Little Ashley catchments showed improvement under the ZIPA recommendations relative to LWRP rules for demand reliability. North Brook, Cust, Cust B block, Ohoka, Silverstream, Greigs, Courtenay and Ashley B block showed a decrease in supply-demand reliability[16] under the ZIPA recommendations relative to LWRP rules:

[16] supply-demand reliability is an assessment of the effects on individual users.

Table 5-5: Summary of ZIPA recommendations and assessment for water take reliability and demand

Main ZIPA recommendations[17]	Watercourses affected	Assessment Result
Cap allocation at current in under-allocated catchments (4.7)	Little Ashley Creek, Ashley River/Rakahuri B and C Blocks, Cam River/Ruataniwha, North Brook, South Brook, No. 7 Drain, Silverstream, Courtenay Stream, Greigs Drain, Upper Eyre River	Capping allocation will help to maintain the reliability of existing water takes because partial restrictions will be triggered at lower flow rates and minimum flows will not be reached as quickly as they would be with more water takes
Implement LWRP partial restriction rules (4.3)	All	No change from Current Pathway scenario, which assumes full implementation of existing Regional Plan rules. Reduction in reliability relative to current state for water takes for which consent conditions have not yet been updated to reflect current Regional Plan rules on partial restrictions.
Apply LWRP schedule 9 stream depletion method (4.4)	Waimakariri FMU streams and river	Negative impact on reliability of those users upon whom new minimum flow and partial restriction conditions are imposed. Results in more equitable division of available water across those depending on a particular stream
Remove B block allocations for spring-fed streams or define new blocks where appropriate (4.5)	Cam River / Ruitaniwha, North Brook, Middle Brook, South Brook, No.7 Drain, Ohoka Stream, Silverstream, Courtenay Stream and Greigs Drain	No impact on current reliability as there are no users. Prevent access in the future and hence removes potential to offset the effects from other plan measures through flood harvesting.
Adopt new minimum flow and allocation limits (4.16)	Saltwater Creek, North Brook, South Brook, Cust River, Ohoka Stream, Silverstream, Courtenay Stream, Greigs Drain	Higher minimum flows will reduce the reliability of surface water takes and those stream-depleting groundwater takes with minimum flow conditions
Review water permits to align with revised environmental flow and allocation regime in 2026-2027 (Ashley catchment and 2028-2029 (Waimakariri catchment) (4.14)	All	As per outcome for implementing LWRP partial restriction rules above
Define sustainable B Block allocation for Cust River (4.22)	Cust River	Preserves reliability of existing block users. Avoids further impacts on stream health and provides future reliability opportunity for new takes.
Extend existing SWAZs and/or introduce new SWAZ to eliminate gaps in environmental flow regime network (4.6)	McIntosh/Kairaki, Upper Eyre River, Eyre River,	Defining SWAZ boundaries for the Macintosh Drain and Kairaki Creek SWAZ and prohibiting surface water and stream-depleting groundwater takes does not affect reliability of current takes.

[17] Number in brackets refers to recommendation number in ZIPA

Main ZIPA recommendations[17]	Watercourses affected	Assessment Result
		Possible future reduction in reliability of current consents within this area if found to be stream-depleting. Defining Eyre River and upper Eyre River SWAZ and setting limit at 0 L/s gives surety as to the water available and subsequent effects. Does not impact current water user's reliability here.
Reduce groundwater allocation limits, expand GAZ boundaries and create new Lees Valley GAZ (5.1-5.7)	N/A (applies to groundwater takes)	Helps to maintain current reliability by limiting new abstraction, which could reduce groundwater levels and hence reliability of wells under drought conditions

5.5.3 Solutions assessment

Background

A significant proportion of irrigated land within the Waimakariri zone is supplied by WIL. The reliability of this supply source relates to the Waimakariri River flow regime, which is beyond the scope of the Waimakariri Land and Water Solutions Programme. Our irrigation reliability solutions assessment therefore excludes the WIL supply.

Our assessment differentiates between irrigation water supply reliability and irrigation demand reliability. Water supply reliability, which considers whether each water take can abstract their allocated volume after accounting for minimum flow restrictions and partial restrictions, is assessed in Megaughin and Lintott (2019). Irrigation supply-demand reliability (an assessment of the effects on individual users) which is evaluated in Harris (2019), takes water supply reliability as a starting point and moderates the reliability assessment based on an irrigation demand assessment. We have therefore presented our solutions assessment in terms of supply reliability and demand reliability. It should be noted that the demand reliability does not deal with cases where a water user has more than one source of water (e.g. a surface water supply and a connection to the WIL scheme).

Because irrigation water storage is currently very limited in the Waimakariri zone, our water supply reliability assessment relates to run-of-river usage only.

Water Supply reliability

Megaughin and Lintott (2019) assessed results of the ZIPA recommendations on water supply reliability against the Current Pathway scenario and found that reliability is generally improved, with only four SWAZs (three in the WRRP area, one in the LWRP) seeing a reduction in available water and therefore reliability. This contributes towards meeting Community Outcome 6, although the specific target of 95 % is not met.

Overall, the Ashley River/Rakahuri catchment shows a very small increase in reliability. This increase is observed in the B and C blocks and is because the allocation block limit for these blocks is reduced. No change in reliability occurs in the A block.

Because there are no changes in management regime between Current Pathway and Solution Assessment in Saltwater Creek and Taranaki Creek, these SWAZs have no change in reliability. A small reduction in reliability is observed in Waikuku Stream because of the increase in minimum flow Monday to Friday (up to 150 L/s from 100 L/s). Little Ashley Creek has the greatest increase in reliability due to the large reduction in block size under the Solution Assessment.

For the Cam River/Ruataniwha and South Brook increases in available water are observed. For the Cam River/Ruataniwha this is due to a reduced allocation limit which improves water access to those in the smaller block. The same is true for South Brook, however the effect is moderated because the minimum flow increases as well.

In North Brook, Cust River and No.7 Drain water availability reduces. This is due to increases in minimum flows and allocation limits remaining fixed.

Cust Main Drain and Middle Brook show no changes in water availability as no management changes are proposed.

For Ohoka Stream, Silverstream, Courtenay Stream and Greigs Drain the Solution Assessment results in an increase in available water, due to a reduction in the allocation limit. For SWAZ which have an increasing in minimum flow the improvement to available water caused by allocation reductions would be reduced, but the outcomes still show a positive outcome.

Demand reliability

Harris (2019) evaluated demand reliability based on his assessment of the severity of restrictions associated with minimum flow limits. Severity is described by the number of days on restriction and the restriction in total volume available. The reliability is given an overall grade based on its volume restriction and the degree to which partial and full restrictions occur as presented in Table 5-6.

Harris (2019) shows that implementation of existing LWRP rules on those consents that have not been renewed or granted since the current rules became operative is likely to cause a significant decline in reliability for some water users. Because these changes have already been mandated by current plan rules, we have focussed on the change in reliability associated with ZIPA recommendations relative to the fully implemented LWRP rules (i.e. equivalent to the Current Pathway scenario).

Table 5-6: Assessment of change in surface water reliability and final reliability as a result of ZIPA recommendations compared to Current Pathway (modified from Harris, 2019)

Catchment	Reliability (based on severity of restriction)	Final reliability
Cam	Much better	Moderate
North Brook	Worse	Poor
Middle Brook	No change	Non-viable[18]
South Brook	Much better	Very good
Cust	Slightly worse	Very poor
Cust B block	Substantially worse	Very poor
Cust Main Drain	No change	Very good
No 7 Drain	No change	Very good
Ohoka	Slightly worse	Good
Silverstream	Slightly worse	Good
Greigs	Slightly worse	Very good
Courtenay	Substantially worse	Poor
Ashley A block	Same	Very poor
Ashley B block	Slightly worse	Very poor
Ashley C Block	Same	Non-viable
Little Ashley	Substantially better	Good
Waikuku	No change	Non-viable
Taranaki	No change	Moderate
Saltwater Creek	No effective change	Non-viable

5.6 Economic sustainability

5.6.1 Community Outcomes

Community Outcome 8 seeks to achieve an improved contribution to the regional economy of the zone. The WWZC narrative associated with this objective describes thriving and vibrant communities supported by a sustainable local economy based on diverse and productive land and water use. Integrated and sustainable management of the effects of flooding, earthquakes and climate change protects assets and amenities and builds resilience in communities and ecosystems. Community Outcome 8 therefore defines both social and economic goals for the Waimakariri zone. We assess the economic aspect in this section and the social component in Section 5.7 Thriving Communities.

5.6.2 Key ZIPA recommendations

The ZIPA recommendations of greatest relevance to economic sustainability are:

- changes to minimum flows and allocation limits, which can affect water take reliability and hence productivity

[18] For run of river irrigation.

- requirements for beyond Baseline GMP nitrate loss reductions, for which capital investment and/or reduced productivity may be required
- reduction in the winter grazing thresholds with associated consenting and regulatory compliance costs
- changes to the stock exclusion rules, with associated fencing costs
- nitrate treatment costs for private water supply well owners.

5.6.3 Solutions assessment

The ZIPA recommendations will incur costs for the farming sector across a range of areas as discussed in Harris 2019. The largest of these are due to the changes to minimum flows, where modelled operating profit reduces from $23 million per annum under current state, to $18.7 million per annum in Current Pathway, and $16.2 million per annum in the ZIPA recommendations (Table 5-7).

Table 5-7: Predicted changes to zone indicators for the farming sector associated with changes to the flow regimes, by scenario (Harris, 2019)

Scenario	On farm Operating profit ($m/annum)	Contribution to Regional GDP from irrigators[19] ($m/annum)	Contribution to Regional Household Income from irrigators ($m/annum)	Contribution to Regional Employment from irrigators (FTE)	Area (ha)
Current	$22.95	$88.25	$43.81	$706.12	11,490
Current Pathways[20]	$18.67	$89.96	$44.55	$713.26	16,515
ZIPA recommendations	$16.20	$67.12	$33.85	$553.76	9,105

Some of these estimated impacts are illusory because they are associated with changes in irrigated area that will not occur due to other considerations. However, it is not currently known how much of the reduction in allocation can be achieved without impacting on irrigators use of water. Additionally, there are some situations where a move to a partial restriction regime under the Current Pathway, and where minimum flows are changed in the ZIPA recommendations, that will lead to real impacts on irrigators. There is therefore potential for actual reduction in economic activity associated with changes to the flows.

The impacts associated with changes to the nutrient management regime are next most important, since these will impact across a range of land uses including dryland. The total reduction will be approximately $5.8 million per annum in operating profit, $5.7 million per annum in regional GDP, $2.8 million per annum in regional household income, and 46 full time equivalent jobs. The majority of these impacts are associated with the dairy sector ($4.9 million out of the $5.8 million in operating profit reduction), which forms a large part of the land that experiences nutrient losses that exceed the threshold at which mitigation is required. These impacts have been calculated using a set of reasonably conservative mitigation assumptions for non-dairy landholders, that may prove to be overestimates if there are other mitigation options available. However, there are also risks that the costs may be higher than has been stated here because some of the larger dairy mitigations were calculated relative to the Environment Canterbury portal GMP estimates, which may not represent the actual GMP figure for a property. If a landholder has already undertaken some of the mitigations used to calculate the curve, the costs of reaching the mitigation target will be higher.

[19] Includes dryland substituted for irrigated land where allocation changes between scenarios.

[20] Under Current Pathway increases in allocation cause an increase in irrigated area, which increases total returns and the model converts this into additional regional activity. In reality much of this additional allocation will not be used because the reliability is too low.

There is likely to be an interaction between the reduction in reliability and nitrate losses, because farms that experience lower reliability or reduced allocation are also likely to have reduced production and reduced nitrate losses. It is unclear how important these interactions will be, but it should be noted that at least part of the costs of flow management changes and nitrate mitigation requirements may not additive.

The ZIPA scenario costs for stock exclusion were calculated as a capital cost, while the costs for a lower Permitted Activity (PA) threshold and drinking water were calculated as net present value (NPV) based on the costs over time. These costs are:

- $4.4 million for stock exclusion including non-intensively farmed cattle but with no buffers in riparian zones,
- $60 million indicatively for biodiversity costings
- $0.77 million for additional compliance costs for the lower PA threshold
- $0.6 million for the additional compliance costs for the Coastal Protection Area
- saving of $0.08 million for drinking water compliance.

If the costs are incurred evenly over the period of the plan (10 years), then converted to an equivalent annual value over 25 years, the annual equivalent costs are:

- $0.25 million per annum for stock exclusion,
- $3.44 million for instream biodiversity enhancement
- $0.13 million for compliance costs with the lower PA threshold
- $0.27 million for the additional compliance costs for the Coastal Protection Area
- $0.27 million for the additional compliance costs for the Coastal Protection Area
- savings of $0.004 million per annum for drinking water treatment.

These costs are significant for the landholders affected, particularly those who are affected by multiple measures (for example a reduction in reliability and a requirement to exclude stock from streams). In the context of the contribution to the regional economy by water-using industries, and to the regional economy overall, the ~ $30 million per annum GDP impact is 6.4% of the $474 million contribution to GDP from the water-using industries, and 2.0% of the $1.57 billion district GDP[21]. These impacts will accrue over a 10-year period, and while they may be noticeable in the rural economy, are unlikely to have a major impact in the context of the regional economy.

Community Outcome 8 seeks to achieve an improved contribution to the regional economy from the zone, with an emphasis on the economic contribution from sustainable and productive land and water use. The assessment undertaken here indicates that there will be a reduction in the economic contribution from the land and water-based industries under both Current Pathway and ZIPA recommendations scenarios. There may be some improvements for industries that rely on high quality water, including the salmon hatchery on Silverstream and recreational and tourism industries.

Our overall solutions assessment for Priority Outcome 8 is therefore that:

- An improved contribution to the regional economy from the farming sector is not expected
- The projected impacts on the farming sector will not impact the regional economy significantly
- The ZIPA recommendations are broadly supportive of the narrative associated with Community Outcome 8

[21] District level estimates of economy are 2016.

5.7 Thriving communities and recreational opportunities

5.7.1 Community Outcomes

Community Outcomes 1, 2, 3, 4 and 8 contain components which support thriving communities and seek to maintain or improve recreational opportunities in the Waimakariri zone:

Outcome 1 – The water quality and quantity of spring-fed streams maintains or improves mahinga kai gathering and diverse aquatic life (improved mahinga kai is critical for reduction on Ngāi Tūāhuriri social impacts; improved aquatic life will create better opportunities for fishing)

Outcome 2 – The Ashley River/Rakahuri is safe for contact recreation, has improved river habitat, fish passage, and customary use; and has flows that support natural coastal processes

Outcome 3 – The Waimakariri River as a receiving environment is a healthy habitat for freshwater and coastal species, and is protected and managed as an outstanding natural landscape and recreation resource

Outcome 4 - The zone has safe and reliable drinking water, preferably from secure sources

Outcome 8 - There is improved contribution to the regional economy from the zone (The zone has thriving, and vibrant communities supported by a sustainable local economy based on diverse and productive land and water use).

5.7.2 Key ZIPA recommendations and assessment summary

The key ZIPA recommendations associated with these outcomes have been discussed in the preceding sections of this report and include controls and actions which seek to:

1. Improve stream/river health (provisions for reducing nitrate and runoff contaminant loading, reduced water allocation and higher minimum flows)
2. Reduce nitrate concentrations in drinking water supply wells
3. Minimise the economic impacts on farming communities associated with the land and water management controls required to achieve 1 and 2 above by using a phased and adaptive implementation approach

The solutions assessment results are summarised in Table 5-8.

Table 5-8: Summary of solutions assessment results for thriving communities and recreational opportunities

Main ZIPA recommendations	Social impact indicators	Assessment result
As per Table 5-1	Ngāi Tūāhuriri values: safe, diverse, abundant and accessible mahinga kai	Improved water quality associated with stock exclusion and lower nitrate concentrations likely to achieve **minor improvement**. Lower PA winter grazing thresholds will reduce the potential for water quality declines associated with higher nitrate loads (**maintain current**) Recovery of over-allocation, capping current allocation and higher minimum flows will help to maintain and improve mahinga kai habitat (**minor improvement**) ZIPA recommendation 3.25 could deliver **significant improvements** in mahinga kai, stream health and biodiversity, if adequate funding is obtained

Main ZIPA recommendations	Social impact indicators	Assessment result
As per Table 5-1	Recreation: fishing opportunities	As above: ZIPA provisions which impact mahinga kai will generally have similar impacts for freshwater fish species and hence recreational fishing opportunities
As per Table 5-1	Recreation: Te Aka Aka ecology	Stronger stock exclusion rules will reduce fine sediment discharges to Te Aka Aka Lower PA winter grazing thresholds will reduce the potential for water quality declines associated with higher nitrate loads
As per Table 5-3	Health: safe drinking water	Maintain current and achieve minor short-term improvement, significant long-term improvement
As per Section 5.6.2	Thriving communities: rural economy	Changes to minimum flows, with a potentially significant reduction in operating profit

5.7.3 Solutions assessment

Our solutions assessment results for thriving communities and recreational opportunities indicate that the statutory ZIPA recommendations are likely to deliver minor short to medium term improvements in the key social impact indicators; some indicators (safe drinking water) are likely to improve significantly in the long term. The non-statutory measures, particularly ZIPA recommendation 3.25 recommending Environment Canterbury and Waimakariri District Council explore a funding stream and management structure to deliver the significant improvements in stream health and biodiversity, and mahinga kai diversity and abundance for the Waimakariri Zone over the next 5-10 years. This will have the potential to deliver a significant improvement in some of the key indicators if an adequate funding source is secured (e.g. via a Targeted Ratings District, central government funding and/or industry funding).

5.8 Climate change resilience and adaptation

5.8.1 Community Outcomes

The narrative provided by the WWZC for Community Outcome 6 suggests that it would be achieved if, among other things, the effects of climate change are considered in the planning and effective long-term management of water and land.

5.8.2 Key ZIPA recommendations and assessment summary

The ZIPA recommendations include several recommendations which seek to mitigate some of the potential effects of climate change such as:

- Capping allocation limits
- Increasing minimum flows in some streams and implementing existing environmental flow regime rules
- Investigating the vulnerability of Te Aka Aka to rising sea levels

A region-wide climate change vulnerability assessment is required to help Canterbury's communities prepare for intensifying climate change over the coming years. This vulnerability assessment will help to identify adaptation priorities and support development of a dynamic adaptation pathway towards climate change impact mitigation for the Waimakariri zone.

The solutions assessment results are summarised in Table 5-9.

Table 5-9: Climate change adaptation solutions assessment

Climate change risk	ZIPA recommendation	Assessment results
Increase drought frequency/severity	Cap groundwater and surface water allocation at/close to current volumes for under-allocated catchments	Impacts of any increase in drought frequency/severity on existing water takes will not be exacerbated by further exploitation of the finite water resource Lower reliability for abstractors
	Increase minimum flows in some streams Implement existing environmental flow regime rules via review of water permits in 2026-2027 (Ashley catchment and 2028-2029 (Waimakariri catchment)	Improve resilience of aquatic ecosystems to potential increases in drought frequency
	Improvements in irrigation efficiency and provision of B Block allocations (where appropriate) for flood harvesting and associated on-farm storage	Maintain resilience of irrigation water takes to increasing climate stresses
Sea level rise	Investigate vulnerability of Te Aka Aka to rising sea levels Establish working group of partners and key agencies to develop a strategy and programme to protect and enhance Ngāi Tūāhuriri, biodiversity and recreational values	Facilitate maintenance and, where possible, improvement of Te Aka Aka values in the face of current pressures, climate change and rising sea levels

5.8.3 Solutions assessment

Our solutions assessment results indicate that:

- Climate change is causing sea level rise and weather pattern variation and will continue to do so for the foreseeable future, probably at an accelerating rate.
- Although the vulnerability of water resources and aquatic ecosystems in the Waimakariri zone to climate change and sea level rise have not yet been evaluated, a number of water management options for maintaining or improving resilience/reducing vulnerability to climate change stresses were considered. The actions required to determine the vulnerability of Te Aka Aka to rising sea levels were also evaluated.
- Increasing minimum flows, reducing water allocation volumes/rates and implementation of existing environmental flow regime rules could improve the resilience of aquatic ecosystems to potential increases in drought frequency.
- Limiting any increases in new water abstraction from the zone would mean that the impacts of any increase in drought frequency/severity on existing water takes will not be exacerbated by further exploitation of our finite water resource.
- Improvements in irrigation efficiency and provision of B Block allocations (where appropriate) for flood harvesting and associated on-farm storage will help to maintain the resilience of irrigation water takes to increasing climate stresses.
- A comprehensive assessment of vulnerability and adaptation options would help to identify where additional climate change mitigation and adaptation actions could be undertaken, but this regional-scale study is beyond the scope of the Waimakariri Land and Water Solutions Programme.
- Adaptive management approach for nitrate management and plan review cycle will enable adjustment to flow and nutrient management as more certainty regarding climate change is gained.

Adaptation options
Adaptation options for the effects of climate change on Te Aka Aka and freshwater resources are discussed further in the following section.

Te Aka Aka
Bolton-Ritchie and Etheridge (2019) concluded that science investigations are required to determine the likely extent and magnitude of possible climate change impacts in and adjacent to the estuarine area.

The recommended investigations are:

- measure the current height of the dunes and the potential effect of different sea level scenarios on dune and shoreline stability.
- map the current height of the estuary bed to determine the likely changes in the extent of saltmarsh vegetation and intertidal flat with different heights of sea level rise within the estuary (as we know it at present).
- use a dynamic model to map the potential extent of land inundation through sea level rise in the Te Aka Aka area.

The results of such investigations would inform the rūnanga, the wider community and local and regional authorities about the issues. The information collected on the extent and magnitude of issues could then form the basis for robust conversations, development of options and decision-making on how to maintain Te Aka Aka as a functioning estuary, to inform the proposed future revision of the Regional Coastal Environmental Plan.

Freshwater resources
Increasing minimum flows, reducing allocation and implementation of existing minimum flow and partial restriction rules would mean that higher stream flows are maintained under drought conditions, thereby increasing the resilience of the hydrological system to the potential increase in drought frequency. Conversely, these environmental flow regime changes will increase the vulnerability of irrigated farmland to drought conditions. Improvements in irrigation efficiency and development of on-farm storage would offset this increased vulnerability. The latter could be facilitated by provision of B Block allocations for those Waimakariri zone streams with a flow regime that can support flood-harvesting without causing significant adverse effects on stream health.

Capping surface water and groundwater allocation at or close to the current consented volume will prevent erosion of the benefits of the above flow regime changes on stream health resilience. Limiting the potential for future increases in groundwater and surface water abstraction will also avoid exacerbation of climate-driven stresses on existing water takes.

Further work is required to assess the vulnerability of spring-fed streams, rivers and groundwater resources to our changing climate. Development of options to adapt to climate change would be premature without a better understanding of vulnerability. However, climate change impacts can be mitigated to some degree by increasing water resource resilience to drought conditions.

Managed Aquifer Recharge (MAR) can reduce the vulnerability of Waimakariri zone water resources by increasing the amount of water stored in the aquifer (using Waimakariri River water) outside of the irrigation season. This enhanced storage would help to maintain groundwater levels and flows in spring-fed streams which would, in turn, improve stream health resilience, the reliability of irrigation water takes and hence the rural economy. Careful investigation, design and management of MAR is required to mitigate groundwater-driven flooding risk.

Management of flooding risk is beyond the scope of the Waimakariri Land and Water Solutions Programme; this matter is addressed via Environment Canterbury's floodplain management programme and Waimakariri District Council's Natural Hazard Management plan.

6 Monitoring recommendations

Improving environmental monitoring was identified as a high priority by the WWZC, stakeholders and members of the community throughout the Waimakariri Land and Water Solutions Programme.

Several critical data and knowledge gaps were identified during modelling, data analysis and discussions with stakeholders and community members during the consultation process. The WWZC recognised that addressing these gaps will be crucial for:

- tracking the efficacy of the ZIPA recommendations through time;
- achieving the Community Outcomes;
- the continued engagement of partners and key stakeholders in the implementation programme; and
- facilitating adaptive management

The ZIPA contains several recommendations for improved environmental monitoring, key of which are summarised in Table 6-1.

Table 6-1: Key monitoring recommendations

ZIPA recommendation	Expected outcome
Development of a comprehensive monitoring plan for the zone (Rec 1.4) including: • State of the takiwā, including mahinga kai; • Aquatic plant, invertebrate and fish community health; • Critical contaminant source areas • Bathing site health (including the addition of swimming site to Schedule 6 of the LWRP); • Emerging contaminants (e.g. endocrine disruptors); • Tidal waterbodies, including sediment deposition, salt water intrusion and the effects of sea level rise; and • Urban water quality and ecosystem health.	Improved understanding of state and drivers of aquatic ecosystem health, particularly in areas with no or little data that are highly valued e.g. hill-fed catchments of Ashley/Rakahuri, Cust, and Eyre River catchments, and Lees Valley waterbodies. Improved long-term management of drinking water quality via better knowledge of risks.
Investigations and monitoring to improve understanding of the Waimakariri Zone groundwater system and its connection with the Christchurch aquifer and spring-fed streams. Updated science assessment in 2025 (3.19)	Reduce current uncertainty over future nitrate concentrations in streams and groundwater
Develop a programme for testing and reporting of water quality in private drinking water supply wells (3.16)	Improved knowledge of private well water quality leading to better protection of human health
Monitoring of permitted surface water takes (4.13) and groundwater irrigation takes (5.8) for compliance with limits in the LWRP	Improved water use efficiency on small blocks with PA water takes. Reduced groundwater and surface water abstraction. Resolve widespread concerns over excessive water use on small blocks.

The WWZC will also develop a 5-year work programme to oversee and evaluate progress in implementing their recommendations. The following approach is proposed in the ZIPA:

2019-2021 Solutions Programme – Establishment stage

- Initial catchment management plans underway
- Actions which can be implemented immediately underway
- Establishment of Water User Groups
- Funding plan for implementation of the programme

2021-2025 Solutions Programme – 5-year priorities stage 1

- A set of priorities to be achieved by 2025 will be prepared and monitored over a five-year period, to 2025.

2026-2030 Solutions Programme – 5-year priorities stage 2

- Based on a review of progress made by 2025, a revised set of priorities will be prepared to guide progress over the following 5 years, to 2030.

7 Conclusions

The Waimakariri Zone Committee (WWZC) identified a set of nine Community Outcomes for the Waimakariri Zone. In summary, the outcomes seek to:

1. Maintain and improve mahinga kai, water quality and aquatic ecology
2. Provide for safe and reliable drinking water
3. Maintain and improve indigenous biodiversity
4. Support social and economic sustainability and thriving communities
5. Promote climate change resilience and adaptation

Our assessment of the Current State of the Waimakariri zone identified the following main issues:

- Significant degradation of mahinga kai diversity, abundance and quality, causing major social impacts on Ngāi Tūāhuriri
- Poor water quality and habitat in spring-fed streams causing poor stream health and aquatic biodiversity
- Recreational opportunities compromised by water quality issues such as cyanobacteria blooms in the Ashley River/Rakahuri and impacts of poor stream health on sports fisheries
- Water quality issues and loss of habitat in Te Aka Aka (Ashley Estuary) with associated ecological, cultural and recreational impacts
- Substantial loss of indigenous biodiversity due to past activities; ongoing threats due to continuing habitat loss and modification and animal and plant pest invasion
- Nitrate concentrations exceeding drinking water limits in ~10% of private supply wells, with further increases likely in the future due to lag effects
- Likelihood of connectivity between Waimakariri and Christchurch aquifer system not previously well-understood; risk of long-term nitrate concentration increases in Christchurch aquifer due to intensive land use in Waimakariri zone

The WWZC recognised the conflict between maintaining and growing output from the rural economy and achieving their cultural and environmental Community Outcomes. Environment Canterbury staff worked with the committee, stakeholders and the local community to evaluate a range of options which sought to achieve their Community Outcomes. Finding the balance between environmental, social and economic outcomes which best aligns with community and stakeholder values was a major component of the WWZC's work. The options and scenarios assessment supported this balance-striking process by exploring the extent to which a range of environmental limit options and management scenarios achieve/fail to achieve the Community Outcomes.

The WWZC used information from the Current State analysis, Current Pathway and Alternative Pathways assessment process and community and stakeholder consultation to develop a set of recommendations for statutory and non-statutory actions. These are provided in their Zone Implementation Programme Addendum (ZIPA).

The WWZC recognised that implementation of statutory recommendations would not be enough, in some instances, to achieve the Community Outcomes either at all or within several decades. Thus, the WWZC considered the potential benefits that could be achieved through implementation of the on-the-ground actions, recognising that the latter rely on voluntary actions and/or human and financial resources, with no current commitment to the deployment of these resources.

The main recommendations for statutory measures (i.e. to include in regional plan provisions) and their expected outcomes are:

- Definition of nitrate limits for surface and groundwater: these will drive water quality improvements in nitrate-degraded water bodies and help to maintain current concentrations elsewhere

- Delineation of a Nitrate Priority Area in which significant nitrate loss rate reductions are required: this management regime will reduce nitrate concentrations in groundwater and in those surface water courses in which reducing concentrations is first priority for stream health and mahinga kai improvement
- Reduction in the allowance for unconsented winter grazing throughout the zone: this will reduce the risk of significant further water quality degradation, particularly in sensitive water bodies like Te Aka Aka
- Delineation of a Coastal Protection Area which will afford additional protection (via lower Permitted Activity (PA) thresholds driving the requirement for more land use consents and hence FEPs) for main spring-fed streams and coastal lagoons and wetlands near the Waimakariri coast which are particularly susceptible to runoff contaminant discharges
- Increased minimum flows and recovery of over-allocation in some streams: this will improve stream health and mahinga kai but reduce the reliability of some existing water takes
- Cap allocation limits at or close to current rates/volumes: this will prevent further ecological and mahinga kai degradation and maintain the reliability of existing water takes
- Strengthen stock exclusion from waterways rules: this will improve stream water quality, habitat and mahinga kai

Our solutions assessment indicates that implementation of the statutory actions will help to achieve most of the WWZCs Community Outcomes by maintaining current values in some instances and delivering improvements over time elsewhere.

The ZIPA non-statutory recommendations and their expected outcomes include:

- Removal or optimisation of fish barriers (e.g. tide gates) to reduce impediments to fish migration and spawning: improve mahinga kai, aquatic ecology and recreation opportunities

- Support for stream augmentation and managed aquifer recharge projects to reduce nitrate concentrations and improve stream flows: improve mahinga kai and aquatic ecology and improve drinking water quality

- Produce Catchment Management Plans for each surface water catchment: this will define management goals for each catchment to improve stream health and mahinga kai

- Establish a working group to protect and enhance Ngāi Tūāhuriri, biodiversity and recreational values in Te Aka Aka in the face of climate change and sea level rise: This group will develop an adaptive management plan to maintain and improve Te Aka Aka values as sea levels rise and our climate changes

All these actions could, if adequately resourced and successfully implemented, help to protect current ecological and cultural values and deliver moderate improvements.

The WWZC also recommended that the option of a Targeted Ratings District should be investigated by Environment Canterbury, and that industry and government funding sources should be sought, to improve stream health, biodiversity and mahinga kai. This recommendation recognises the fact that a major part of the significant degradation of mahinga kai and the associated major social impact on Ngāi Tūāhuriri have been driven by historical land use, drainage and management practices. It also recognises that these issues are not easily remedied by regional plan rules. Sediment removal and installation of sediment traps, stream bank re-battering and riparian planting with increased set-backs would be the main stream restoration actions required to address these legacy issues. Our analysis indicates that a major improvement in stream health and mahinga kai could be achieved by an adequately funded stream restoration programme and that securement of funding from the sources listed above is the best pathway towards this.

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Terrestrial biodiversity	Dodson, M. 2017: Biodiversity Issues and Options. Environment Canterbury presentation to Waimakariri Water Zone Committee. File reference: C19C/81387.

Discipline	Report
Terrestrial biodiversity	Grove, P. 2019: Waimakariri land and water solutions programme: Biodiversity solutions assessment. Environment Canterbury Memorandum. File reference: C19C/96592.
Water quantity (surface water and GW)	Vattala, D. 2019: Resource consent inventory for Waimakariri land and water solutions programme (version 2). Environment Canterbury Report R19/10.

APPENDIX 2: SSAG, TLAG and Farmers Reference Group Terms of Reference

A2.1 Terms of reference

WAIMAKARIRI SCIENCE STAKEHOLDER ADVISORY GROUP – TERMS OF REFERENCE

1.0 Introduction

The Waimakariri Canterbury Water Management Strategy (CWMS) zone is scheduled to commence its limit-setting process in June 2016, with the expectation of notifying a plan in June 2018. As part of the development of a sub-regional plan for the zone, Environment Canterbury have committed to developing a collaborative process around the design and delivery of science including establishing a Science Stakeholder Advisory Group (SSAG).

2.0 What is the purpose and functions of the SSAG?

- Build stakeholder involvement and confidence in the science carried out for the Waimakariri sub-regional process.
- Help to identify the key issues of contention that require scientific input.
- Help to identify key environmental indicators and monitoring priorities, including short and long opportunities.
- Identify scientific limitations and provide clarity about the underlying assumptions.
- Help to achieve consensus on the key science issues facing the zone.
- Review and validate the robustness of the data.
- Inform the development of policy-making that subsequently flows out of the scientific investigations.

3.0 What does success look like?

- That the stakeholders involved in the SSAG endorse the science underpinning the catchment limit setting process in the Waimakariri zone.
- That key stakeholders feel that they have had the opportunity to be involved in the development of the sub-regional plan.

4.0 Out of scope

- Relitigate the recommendations in the ZIP and LWRP.
- Policy and value debates.

5.0 Membership

- Beef and Lamb
- BRAID/Ashley River Care Group
- Canterbury District Health Board
- Canterbury University
- Dairy NZ
- Deer NZ
- Department of Conservation
- Foundation for Arable Research
- Federated Farmers
- Fish and Game
- Forest and Bird
- Irrigation NZ
- Ngâi Tahu Farming
- Lincoln University Silverstream River Care Group
- Te Kohaka o Tuhaitara Trust
- Te Rûnanga o Ngâi Tahu
- Tuahiwi Marae
- Whitewater NZ

- Waimakariri Irrigation Limited

6.0 Meetings

- Environment Canterbury offices or at stakeholders
- 6-8 weeks.

TECHNICAL LEAD ADVISORY GROUP (TLAG) – TERMS OF REFERENCE

Environment Canterbury Regional Council
Kaunihera Taiao ki Waitaha

Project plan

General Information

Project Title	Technical Lead Advisory Group (TLAG) (Waimakariri)		
Author	Matt Dodson	**Date**	25 August 2015 (updated 9 May 2016)
Initiating business unit	Groundwater Science	**Cost centre**	P023500 EMG906
Project start	1 June 2015	**Project finish**	30 June 2016
Portfolio	Canterbury Water Management Strategy (CWMS)	**Portfolio Director**	Ken Taylor
Programme	RMA water framework	**Programme Manager**	Christina Robb

Project description

Objectives

Provide independent advice to the Technical Lead for the Waimakariri limit-setting process on planning and delivery of technical information. The technical information is to be used by communities, stakeholders, decision makers and other technical experts. Current state information will be delivered by mid-2016.

TLAG Members

Member	Discipline
Greg Burrell	Aquatic ecology/ water quality
Lee Burbery	Groundwater quality
Peter Callander	Hydrogeology
Seth Laurenson	Soil Scientist

Constraints

The funding for the TLAG is limited to 11 full working days to be billed over the period 17 August 2015 to 30 June 2016.

In scope: high level requirements

- Using the Waimakariri Zone Committees priority outcomes as a guide, review the technical work being planned by Technical Team and identify potential gaps.

- Identify priorities for technical work from Waimakariri Zone Committee and Science Stakeholder Advisory Group (SSAG) and help prioritise the gap filling. Prioritisation of the potential projects will be based on:
  - available budget
  - likelihood of being completed before mid-2016
  - output/ results likely to significantly improve the technical assessments
  - output/ results likely to significantly reduce uncertainly.
- Review the methodologies proposed by the Technical Team and provide suggestions, if required.
- Review or identify and comment on major assumptions.
- Identify key areas of uncertainly.
- If there is disagreement between TLAG members and/ or the Technical Lead/ Team, devise a strategy that can be used to address the disagreement.
- Document the process after each phase via brief memos. Environment Canterbury will assist with the drafting of the memo in order to reduce time constraints on the TLAG members.

Out of scope

- Policy debates and advocacy
- Day to day management of the Technical Team
- Undertaking the technical work

Deliverables

1. Attend Waimakariri Zone Committee meeting
2. Attend SSAG workshop
3. Attend Technical Team meeting(s)
4. Summary memo's at the end of the financial year (drafted by Environment Canterbury)

Project approach

Following the discussions at the start up meeting (17 August 2015) TLAG members and the Technical Lead decided on a three phase approach. The main tasks of the phase one and two have been determined. The Technical Lead, in conjunction with the TLAG, will scope the third phases after the completion of the first phase.

Phase 1: Review and gap identification:

- Meeting with the Technical Team where they will present work plans
- Attend a Waimakariri Zone Committee meeting to identify their priorities and the major questions
- Attend a SSAG workshop to identify their priorities and the major questions

Phase 2: Provide feedback on potential gaps and advice on technical approach:

- Attend TLAG review session

- Attend model conceptualisation workshop

Phase 3: Ongoing technical guidance and review

Project management plan documents

Communication management

The members of the TLAG requested that all correspondence from the Waimakariri Zone Committee, SSAG and Technical Team be directed through the Technical Lead.

Change management

While any project team member may suggest a variation to the project, such suggestions shall be made to Technical Lead who will then make a recommendation for consideration to the project owner.

Resources

Any suggested variations in the allocation of human or financial resources shall be assessed by the Technical Lead who shall recommend a response for consideration and approval by the project owner or project sponsor.

Scope and schedule

Any suggested variations in the project scope or schedule shall be discussed with the affected project team members and recommendations made by the Technical Lead to the project owner or project sponsor.

Reporting and control

Project meetings

No	Meeting	Date	Scope	Attendance
1	Start-up meeting	17 August 2015	Provide overview of the process and plan TLAG work programme	TLAG Zone Facilitator Technical Lead
2	Technical Team briefing meeting	7 and 11 September	Technical Team present work plans to TLAG	TLAG Technical Team

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				Technical Lead
3	Waimakariri Zone Committee	5 October. Typically 3:30 pm to 7:30 pm	Review of the priority outcome narratives and identification of the big questions. Discussion lead by Zone Facilitator and Technical Lead	TLAG Zone Facilitator Technical Lead Waimakariri Zone Committee
4	SSAG workshop	16 October, 3 pm to 5 pm	Field trip Discussion focusing on SSAG science priorities	TLAG SSAG Zone Facilitator Technical Lead Waimakariri Zone Committee
5	TLAG review session	29 October 2015	Review of work plans and recommendations	TLAG Zone Facilitator Technical Lead
6	Model conceptualisation workshop	15 December 2015	Review conceptual model prior to construction of the hydrological model	TLAG Zone Facilitator Technical Lead
7	TLAG review session (2)	25 January 2016	Review of work plans and recommendations	TLAG Zone Facilitator Technical Lead
8	TLAG planning meeting	7 June 2016	Planning work programme for the next FY	TLAG Zone Facilitator Technical Lead
9	Other meetings and workshops as required	Various	Various	Various

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Project reporting

The Technical Lead is to provide the project sponsor and project owner with a monthly written update as required, clearly identifying progress against milestones and current issues.

WAIMAKARIRI FARMERS REFERENCE GROUP – TERMS OF REFERENCE

1.0 Introduction

The farmers reference group was established in 2017 by inviting lead farmers, industry representatives. and Waimakariri Water Zone Committee members to meet. The group was initially used to field-validate resource data – irrigation, land use, trends (e.g. cow wintering) etc. From 2017 to 2018, the group was used to generate and evaluate data on costs and benefits of mitigating nitrogen loss beyond GMP.

2.0 What is the purpose and functions of the Farmers Reference Group?

- Evaluate the potential for going beyond GMP as per booklet + proxies
- Use MGM files
- Must be capable of modelling in OVERSEER®
- Must be feasible
- Use existing information where available P21 x2, Forages for Reduced N Leaching project
- Full transparency
- Seek consensus

3.0 Out of scope

- Relitigate the recommendations in the ZIP and LWRP.
- Policy and value debates.

4.0 Membership

- Beef and Lamb
- Ngâi Tahu Farming
- DairyNZ
- Foundation for Arable Research
- Federated Farmers
- Waimakariri Irrigation Limited
- WWZC members
- Local famers

5.0 Meetings

- Quarterly as needed

APPENDIX 3: Cultural Health Assessment report recommendations

A3.1 Cultural Health Assessment report

The Cultural Health Assessment report states that the catchments of the Waimakariri zone should be restored as mahinga kai in order to meet Te Moemoea (our vision). This requires:

1. Water flows in rivers are increased, especially lowland streams. A visible connected flow – ki uta ki tai - is reinstated for the Rakahuri (see recommendations for flows at Ashley Gorge and SH1)
2. Flow variability (especially higher flushing flows seasonally) to trigger and restore passage for migratory native fish species
3. Allocation of water for cultural purposes is to be put in place for all streams where an allocation regime exists. In the first instance an allocation is to be made for the Rakahuri and the Cam.
4. Unless there is “new water” and until there are allocations for cultural purposes, there is to be no further allocation of water for irrigation from waterways in the zone
5. Water quality protected where it is currently high, and where degraded improved to drinkable quality, especially the Taranaki Creek, Cam, Kaiapoi and Rakahuri (see the band recommendations for these streams).
6. Increased native fish populations is a priority, especially mahinga kai species. See recommendations for some streams that specific species are to be provided for.
7. Needs of indigenous fish species are prioritised over exotic fish species.
8. Improve water quality so whanau are able to gather resources, play and enjoy themselves in the Rakahuri, the Cam and in the estuaries of North Canterbury
9. Instream habitats restored with provision made in the sub regional plan for the installation of artificial habitats in the short term
10. No algal blooms in the lower reaches of any streams.
11. Drains are to be recognised as substitute habitats and managed as waterways.
12. Streams fenced off and stock excluded – a priority for springheads and the lowlands.
13. Water security (quantity and quality) for the marae and papakāinga at Tuahiwi
14. Taranaki Creek is to be the site of a whole of catchment enhancement programme; the Cam is to be restored; and the Rakahuri Gorge protected from damming. Rakahuri and Cam flow regimes are to be revisited (higher with seasonal variations).
15. Water quality in the lagoons of Saltwater/ Rakahuri/ Kaiapoi is improved.
16. Levels in the springs in the lower reaches are identified and protected & don’t run dry (e.g. Little Ashley)
17. Floodgates at Taranaki Creek, Courtenay & Cam are retrofitted to restore the indigenous fishery
18. Use of reserves and easements enabled by improved access, restoration, improved flows, good water quality, increased abundance of species, and allocations of water for cultural purposes.
19. All spring heads are mapped, protected with a buffer around them, and statutory protective provisions put in place.

20. Species gathered by whanau are free of heavy metal contamination and safe to eat.
21. Environment Canterbury engineers change their practices to include protection of instream functioning
22. Discuss with whanau opportunities to restore Harris's Creek; and Smarts Road Creek
23. The following minimum flows are recommended

River	Whanau flow preference for flow	Comparisons
Northbrook	590l/s	Higher minimum flow than current minimum flow in WRRP
Middlebrook	50l/s	Current minimum flow in WRRP
Greigs Drain	230 l/s	Current minimum flow in WRRP, higher than new figure recommended.
No. 7 drain	60 l/s	This is the current minimum flow, and is what is recommended
Ohoka	420 l/s	Higher than the current WRRP, and higher than minimum flow that is recommended.
Ashley River Gorge	Visible connected flow – ki uta ki tai - with variability	Significantly higher minimum flow than current minimum flow in WRRP
Ashley River SH1	Visible connected flow – ki uta ki tai - with variability	Significantly higher minimum flow than current minimum flow in WRRP. The suggestion of a step up is a new concept.
Saltwater Creek		
Cam River	1.2 cumec	This is higher than the current figure that is in the WRRP. The concept of a step-up is new.
Taranaki Creek (Preeces)	At least 120l/s	
Silverstream	600l/s	
Southbrook	170l/s	
Okuku River	650l/s	Higher than current minimum that is attached to consents.
Garry River	100l/s at Birch Hill	
Leggats Creek	At least 90% of 7dMALF	
Little Ashley	50l/s	Current, minus the compromise to 30l/s for a set number of days per month
Kaiapoi Stream	1.2 cumecs	Higher than recommended.
Waikuku Stream	600l/s	
Cust	400l/s	
Courtenay	400l/s	

24. If the rūnanga does agree to "new water" in the zone, the rūnanga reserves the right to ask for all minimum flows to be increased.

APPENDIX 4: Introduction to environmental flow regimes

A4.1 Introduction to environmental flow regimes

Mahinga kai and stream health considerations

Protecting cultural, recreational and amenity values is also key when managing water use and flows in the Waimakariri Zone. Indigenous flora and fauna evolve and adapt to habitats provided by natural flow regimes in streams and rivers. The availability and quality of these habitats, however, are typically increasingly compromised as more and more water is abstracted. Water resource usage controls are required to achieve flows that protect ecological, cultural, recreational and amenity values. These flow provisions are collectively known as an 'environmental flow regime'. A simple environmental flow regime uses two management tools:

- a 'minimum flow' which requires the abstraction of water to cease at a given threshold, set to protect some or all of the values associated with the waterway, and;
- an 'allocation limit' which limits the total amount of water which can be taken from a waterway. This maintains some of the natural flow variability of the waterway.

Low flows can prevent fish passage by exacerbating the spatial and temporal extent of drying reaches and reduce available habitat for resident and spawning populations. Low flows can also degrade water quality by:

- increasing water temperatures;
- decreasing point-source contaminant dilution potential;
- altering water pH;
- increasing diurnal fluctuations in dissolved oxygen concentrations; and,
- reducing sediment transport.

The above water quality effects can have multiple physiological and behavioural outcomes for aquatic species, and cause shifts in aquatic community assemblages. The indirect ecosystem effects of low flows on aquatic communities can include:

- an increased risk of nitrate toxicity to flora and fauna;
- increased nuisance algal and aquatic plant growths;
- reduced habitat refugia in bed substrates resulting from excessive bed siltation; and
- increased invertebrate and fish mortality resulting from depleted dissolved oxygen levels and excessive water temperatures.

All of these effects reduce the quality, abundance and diversity of mahinga kai species.

Neither a minimum flow nor an allocation limit should be considered independently of one another when setting an environmental flow regime. Each function in different ways, but also complement one another to protect instream values.

A minimum flow should be set high enough to guarantee that abstraction will not occur at times when flow is at or below that which provides a minimum amount of viable habitat for a species, even though the flow may still fall below that minimum during naturally dry climatic periods. It should also provide refuge for invertebrates and fish until higher flows return. An allocation limit requires setting a low enough value that promotes flow variability. This limits the time spent at low flow conditions and the amount of compounding environmental stress a stream community suffers.

The higher an allocation limit is, the longer a stream is likely to spend at a minimum flow level. Lower allocation limits are arguably more important for hill-fed rivers like the Ashley River / Rakahuri, which is naturally highly variable and highly dependent on freshes and floods to turn-over the river bed, remove algal growths, provide fish passage, and maintain braided river function and character. Spring-fed waterways are naturally less variable, but still rely on smaller flood flows to flush contaminants. Minimum flow and allocation limits must therefore be considered collectively when ensuring the low flow protection of instream values. The effect of an excessive allocation limit can be mitigated to some extent by setting a higher and more conservative minimum flow. This is likely to be the case in the Waimakariri Zone, where many streams are over-allocated or have large allocation limits. Likewise, the effect of a low minimum flow can be offset to some degree by a more constrained allocation limit.

Water take reliability considerations

Nearly all surface water abstraction in the Waimakariri zone is used for irrigation. Higher minimum flows increase the amount of time water take rates are either partially restricted (i.e. the full consented rate cannot be used; see Glossary for further explanation) or fully restricted (i.e. no water can be taken), and vice-versa. The reduced irrigation associated with higher minimum flows reduces farm income due to lost production.

If additional water is available, increasing surface water allocation can increase the productivity and farm income for any newly irrigated land but reduces the reliability of existing water takes due to partial restrictions. Partial restrictions are initiated when stream flow rates fall to a rate equal to the minimum flow plus the total allocated flow rate, as explained in the Glossary. Higher allocated volumes mean that the stream flow rate at which partial restrictions begin is higher and hence water takes are on partial restriction for a higher proportion of the time. Conversely, lower allocated volumes can increase the reliability of existing surface water takes. This means that recovering unused[22] over-allocation can improve the reliability of existing water takes but could mean, perversely, that more water is actually taken from the stream. Recovering over-allocation as a "paper-based" exercise only, could therefore have a negative impact on stream health and mahinga kai but a positive impact on farm productivity and income. Conversely, not recovering over-allocation could lead to future actual use of that currently unused portion, resulting in worse outcomes than those ones described here.

[22] Environment Canterbury staff and the WWZC received feedback during several community meetings on this matter: this anecdotal information suggests that many consent holders are never using their full allocation, and some consents are not used at all.

APPENDIX 5: Current surface water quantity management regimes

A5.1 Current surface water quantity management regimes

LWRP Surface Water Allocation Zones

SWAZ	Minimum Flow	Allocation Limit
Ashley River / Rakahuri A block	2,500 L/s (Jan-Jul), 4,000 L/s (Aug-Nov), 3,000 L/s (Dec)	700 L/s
Ashley River / Rakahuri B block	3,200 L/s (Jan-Jul), 4,700 L/s (Aug-Nov), 3,700 L/s (Dec)	500 L/s
Ashley River / Rakahuri C block	6,000 L/s	3,000 L/s
Saltwater Creek	100 L/s	408 L/s
Taranaki Creek	120 L/s	61 L/s
Little Ashley Creek	50 L/s (30 L/s for 4 days each month)	172 L/s
Waikuku Stream	100 L/s Mon-Fri (150 L/s Sat-Sun)	460 L/s

WRRP Surface Water Allocation Zones

SWAZ	A block Minimum Flow (L/s)	A block Allocation Limit (L/s)	B block Minimum Flow (L/s)	B block Allocation Limit (L/s)
Cam River / Ruataniwha	1000 L/s	700 L/s	1,700 L/s	No limit
North Brook	530 L/s	200 L/s	730 L/s	No limit
Middle Brook	60 L/s	30 L/s	90 L/s	No limit
South Brook	140 L/s	100 L/s	240 L/s	No limit
Cust River	20 L/s	290 L/s	310 L/s	No limit
Cust Main Drain	230 L/s	690 L/s	920 L/s	No limit
No.7 Drain	60 L/s	130 L/s	190 L/s	No limit
Ohoka Stream	300 L/s	500 L/s	800 L/s	No limit
Silverstream	600 L/s	1,000 L/s	1,600 L/s	No limit
Courtenay Stream	260 L/s	140 L/s	400 L/s	No limit
Greigs Drain	150 L/s	70 L/s	220 L/s	No limit

APPENDIX 6: FMU Scenario and options assessment

A6. FMU Scenario assessments

A6.1 Overview

Potential management strategies for water quality, stream health (aquatic ecology) and biodiversity were assessed under several different scenarios, sometimes with a range of options for a given scenario.

A summary of the technical assessments is provided below.

A6.1.1 Water quality and stream health

The LWRP contains region-wide water quality and ecological health outcomes for rivers and lakes. These are set to achieve Plan objectives for freshwater in Canterbury. The LWRP also sets water quality limits, and targets for where limits are over-allocated.

The primary focus for water quality and stream health limits and targets was nitrate due to impacts from toxicity. We also considered runoff contaminants (sediment, phosphorus, and pathogens). We explored a range of limit options including:

- Current measured
- National Bottom Lines/Drinking water MAV
- Fisheries protection (streams)
- Periphyton/nuisance algal growth
- COMAR

The limit/target options were then considered under two scenarios: Current Pathway and Alternative Pathways. The Current Pathway assessment found that:

- Implementation of GMP is expected to achieve outcomes in Ashley River/Rakahuri catchment spring-fed streams and Cam River/Ruataniwha if future land use intensification is prevented.
- Nitrate limits are above guidelines for nuisance periphyton, including toxic algal blooms, which currently impact Ashley River/Rakahuri recreation, benthic biodiversity and mahinga kai values

The Alternative Pathways assessments found that:

- Significant beyond Baseline GMP nitrogen loss reductions required to meet outcomes in some streams and wells in the Waimakariri Northern tributaries FMU
- Will take longer to achieve nitrate limits under lower reduction rates (e.g. 10% beyond Baseline GMP).
- Farm economic impacts could be significant for nitrate loss reduction rates above 10% for dairy and <5% for other farm types.
- Sediment removal required to improve habitat for mahinga kai species and broader stream health
- Reducing the PA thresholds for winter grazing will help to protect sensitive waterbodies
- Current stock exclusion rules need to be strengthened to improve stream health and mahinga kai
- Christchurch aquifer ‘threshold’ nitrate concentration to protect 90% of sensitive aquatic species

The WWZC ZIPA recommendations included:

- **Streams:** Varies depending on current concentrations and expected lag times. Maintain current nitrate concentrations where low, National Bottom Line where current concentration is above that limit. Stay within NPS band.
- **Drinking water wells**: ½ MAV for nitrate
- **Christchurch aquifer:** threshold 20% N loss reduction required. Can be achieved without land use change and by using currently available N loss mitigation options.

NPS-FM required water quality to be maintained or improved. Current state or recent investigative data (2011-2016) was used to set limits for contaminants other than nitrates (e.g., DIN, DRP, ammoniacal nitrogen) to ensure compliance with this objective. If data indicated an overallocation of contaminants compared to NPS-FM NOF national bottom lines, NPS-FM bottom lines were set as the target. Where freshwater outcomes were not being met as a direct result of excessive nutrients in a river of lake, more stringent limits were considered. Further details regarding setting water quality limits is provided in Arthur (2019).

A6.1.2 Management areas for water quality and stream health

We worked with the WWZC, stakeholders, community and partners to identify management options which could achieve the water quality and stream health limits considered by the WWZC These strategies focussed on defining management areas for nitrate and runoff contaminants.

We explored a range of nitrate management scenarios including several refinements under the Current Pathway scenario (e.g., GMP (no PA uptake), PC5PA (full uptake of PA), Current Pathway (50% uptake of PA). The Alternative Pathways scenario included three Beyond Baseline GMP:

- **10% beyond Baseline GMP** – all consented land use reduce nitrate losses 10% beyond Baseline GMP
- **20 kg/ha + 10% beyond Baseline GMP** – all consented land use reduce nitrate losses 10% beyond Baseline GMP if their nitrate loss at any stage is more than 20 kg/ha.
- **20 kg/ha + 10 & 20% beyond Baseline GMP** – Dairy reduce nitrate losses 20% and all other consented 10% beyond Baseline GMP if their nitrate loss at any stage is more than 20 kg/ha.

The range of scenarios explored for runoff contaminant and stream health management included improving riparian health and the management of critical source areas of sediment.
The assessments found that:

- Ashley River/Rakahuri catchment current low nitrate concentrations not expected to increase significantly under Current Pathway
- Waimakariri northern tributaries FMU nitrate concentrations either currently exceed or are expected to do so under Current Pathway
- Mahinga kai, stream health and biodiversity will be somewhat worse under Current Pathway and better under nitrate loss reduction scenarios in the proposed Nitrate Priority Area (see section 5).

The WWZC ZIPA recommendations (details provided in Section 5) included:

- Establish a nitrate management area (Nitrate Priority Area [NPA])
- Runoff contaminant and stream health – solutions toolbox (fencing etc) addressed under the proposed Runofff Priority area (RPA)
- Mahinga kai (riparian buffers, stock exclusion, plantings, pre-treatment of discharges, minimum setbacks for springs, cultural health assessments for major schemes.
- Te Aka Aka – Proposed Coastal Protection Area (CPA) based on potential for increased runoff contamination under PC5PA rules.

A6.1.3 Surface water FMUs minimum flow and allocation limits

A number of range of scenarios and options under these scenarios were explored for minimum flows for Ashley River/Rakahuri FMU and Waimakariri River tributaries FMU. These included:

- Current Pathway (full implementation of LWRP/WRRP):
- recommendations in the cultural health assessment report
- ecological minimum flow
- Bespoke (some water ways) compromise between LWRP cultural and ecological) for Ashley River/Rakahuri FMU

Allocation limits were considered using a range of scenarios for the Ashley River/Rakahuri and Waimakariri River FMUs. These included:

- Current Pathway full implementation of the LWRP/WRRP allocation limits which reflect status as in the early 2000s and means all rivers in Ashley River/Rakahuri catchment are over allocated except Little Ashley Creek and B and C blocks of Ashley/River Rakahuri
- recommendations in the cultural health assessment report
- Cap at current allocated volume
- Reduce LWRP allocation limit by a feasible amount over time
- Ecological allocation
- Cultural allocation
- Phasing out overallocation (both FMUs) including switch to deep groundwater, allocation based on actual use, percent reduction/restriction of site to site water transfers in replacement consents and voluntary surrender/nonrenewal of lapsed consents

A range of options was selected for community consultation during the development of the ZIPA recommendations. The final ZIPA recommendations include (details provided Section 5):

- Ashley River/Rakahuri FMU minimum flows: no change from LWRP limit
- Ashley River/Rakahuri FMU allocation limits: no change from LWRP adjusted limits
- Waimakariri northern tributaries FMU minimum flows ranged from no change from WRRP limit to increasing minimum flow limits from 2027 with future goals
- Waimakariri northern tributaries FMU allocation limits ranged from no change to reduction to current allocation levels

A6.1.4 Groundwater FMU allocation

Scenarios explored included Current Pathway and options within that scenario to 1) cap at current allocated volume; 2) cap at current plus an extra amount to help address surface water overallocation 3) cap at current plus extra to help address surface water overallocation extra amount for new takes.

The Current Pathway assessments found that there was potential for a decline in some flows in spring-fed streams, decline in groundwater levels in the lower Eyre River GAZ, and reduced water supply well reliability

The WWZC recommendations (details provided in Section 5) provided for a cap at current cap allocated volume in the Eyre River GAZ (fully allocated) and at current plus extra to help address surface water overallocation and/or extra amount for new takes in other GAZs.

A6.1.5 Climate change adaptation scenario

Options explored to address climate change adaptations included: increasing minimum flows, reducing allocation, limiting new takes, and making improvements in irrigation efficiency.

The assessments found that Te Aka Aka is vulnerable to sea level rise there is potential for weather pattern variability (e.g. drought) to stress aquatic ecosystems.

The WWZC ZIPA recommended additional science investigations of vulnerability of Te Aka Aka and spring-fed streams, rivers and groundwater resources to climate change (details provided in Section 5).

Details regarding the water quality and quantity limit options and management scenarios that were explored are provided below followed by the results of the technical assessments.

A6.2 Scenarios and options description

A6.2.1 Water quality limit options

Nitrate limits options

Nitrate limits are a key driver in achieving the WWZC Community Outcomes as discussed in Kreleger and Etheridge (2019a). A rigorous evaluation of nitrate limit options and their implications for environmental health and economic impact on farming was undertaken recognising the importance of these limits. The nitrate limit options considered by the committee are summarised in Table A6-1 (streams and groundwater), Table A6-2 (Christchurch aquifer) and Table A6-3 (Waimakariri River). The limit options were then used to support delineation of water quality management areas.

Table A6-1: Nitrate limit options for streams and groundwater in the Waimakariri Zone

Waterbody	Option name	Basis	Nitrate- N limit (mg/L)
Streams	Current measured	Maximum measured annual median	Varies
	National Bottom Line	Statutory obligation where concentrations already exceed 6.9 mg/L (or where concentrations are currently in NPS-FM C band, but are projected to rise above this)	6.9
	Fisheries protection	90% species protection with increased protection for salmonid spawning and rearing. This figure is within C band (2.4 – 6.9).	3.8
	B band	Top of the B band. Statutory obligation to maintain within this figure if current concentrations are in B band now. Also 95% species protection.	2.4
	COMAR	Cultural Health Assessment report recommendation. Top of A band. Also 99% species protection	1.0
Ashley River/Rakahuri main stem	Current measured	No deterioration from present	0.3 (Ashley River/Rakahuri at SH1)
	Periphyton control	Reduce proliferation of nuisance algal growth	0.1
Te Aka Aka	Maintenance of Te Aka Aka trophic state	Maintain current trophic state of Band B[23]. Ecological communities slightly impacted by additional algal growth due to elevated nutrient levels	refer to limits for Ashley River/Rakahuri catchment
Groundwater	Shallow well protection – Waimakariri tributaries catchment	Maximum annual average concentration in shallow wells at which peak seasonal concentrations are likely to be < drinking water limit (11.3 mg/L)	7.1
	Current measured	Spatially averaged current measured nitrate-N concentration in Waimakariri River northern tributaries catchment monitoring wells from 2014 – 2017	4.1
		Spatially averaged current measured nitrate concentration for the Ashely and Kowai GAZs monitoring wells from 2014-2017	0.8
	LWRP	5.65 mg/L spatially averaged over area	5.65

[23] Robertson *et al.*2016a and 2016b) New Zealand estuary trophic index (ETI). Thresholds for various indicators used to classify an estuary into one of four eutrophication bands (A – minimal; B – moderate; C-high; D – very high)

The WWZC and Christchurch West Melton Zone Committees discussed a range of possible nitrate threshold options for the Christchurch aquifer. The WWZC also discussed possible thresholds for the Waimakariri River. The purpose of the nitrate threshold options for the Christchurch aquifer and Waimakariri River is to provide a point of reference, or a starting point, to indicate the scale of nitrate reductions that may be needed to enable land users in the Waimakariri Zone to play their part in maintaining the high quality of Christchurch groundwater; the same logic applies to the Waimakariri River. These threshold limits differ from those considered for water bodies within the Waimakariri Zone which are firm recommendations for nitrate concentrations that could be used as limits and should be achieved in surface water and groundwater/drinking water supply wells.

Table A6-2: Nitrate limit options for Christchurch aquifer

Nitrate threshold option (mg/L N)	Rationale
0.6	Average current measured concentration in deep Christchurch aquifer
1.0	NPS-FM A Band limit: protects 99% of aquatic species. Recognises that groundwater from deep Christchurch aquifer likely to ultimately discharge to spring-fed streams
2.4	NPS-FM B Band limit: protects 95% of aquatic species. Recognises spring-fed stream connectivity as above.
3.8	Protects 90% of sensitive aquatic species. Recognises spring-fed stream connectivity as above.

Table A6-3: Nitrate limit options Waimakariri River

Waterbody	Option name	Basis	Nitrate- N limit (mg/L)
Waimakariri River	Current measured	No deterioration from present	0.2 (Waimakariri River at SH1) and 0.1 (Waimakariri River at Gorge
	Periphyton control	Reduce proliferation of nuisance algal growth	0.1

Other contaminants
Limit options for the broader suite of water quality contaminants, such as phosphorus, sediment and *E. coli* are discussed in Arthur (2019). The options considered were: maintain the LWRP region-wide limits or develop bespoke limits for the Waimakariri zone based on consideration of local conditions and values.

A6.2.2 Water quality management scenarios

Our current state and water quality trends analysis showed that high and/or increasing nitrate concentrations are a significant issue in some areas of the Waimakariri Zone but not in others. Some areas are of critical importance for Ngāi Tūāhuriri and runoff contaminants and legacy sediment issues are impacting stream health and mahinga kai in some of these areas. We presented several water quality management area scenarios to the WWZC to assist with management of the various issues.

Nitrate management scenarios
The first key objective of the scenario assessment was to determine whether the current management regime (or a variant thereof) is likely to achieve the nitrate limits proposed by the WWZC, when fully implemented. The Good Management Practice, PC5PA (Plan Change 5 Permitted Activity) and Current Pathway scenarios described below served this purpose.

The second objective was to explore a range of alternative nitrate management scenarios, referred to as Alternative Pathways, which provide for greater rates of nitrate loss reduction. We also considered dilution-based options: Managed Aquifer Recharge and stream augmentation.

The nitrate management scenarios we evaluated are described in Table A6-4.

Table A6-4: Nitrate management scenarios

Management Scenario	Summary/Assumptions
Good Management Practice (GMP)	Industry-agreed good management practices for nutrient management fully implemented; Land use remains as per 2015 land use mapping, except for consented but unimplemented (as of 2015) land use consents, which are assumed to be fully utilised (e.g. the Ngai Tahu Te Whenua Hou/Eyrewell Forest conversion); The impacts of nutrient loads "in the post" are realised No land use intensification. Land use intensification allowed for under PC5 of the LWRP (which allows for limited areas of winter grazing and irrigation as a permitted activity [PA]) is <u>excluded</u>.
Current Management Practice (CMP)	Estimates nitrate loads prior to full implementation of GMP. Assumptions as per GMP above, bar the first point
PC5PA	Same assumptions as GMP other than allows for full uptake of the LWRP (post Plan Change 5) PA allowances for winter grazing and irrigation.
Current Pathway	Same assumptions as the PC5PA scenario, except for allowing for a 50% uptake of the PC5PA winter grazing and irrigation allowances.
Alternative Pathways[24]	Three 'beyond Baseline GMP' [25]nitrate loss reduction options for consented land use under which nitrate losses are reduced by 10% or 20% for specified land uses every 10 years under a staged or adaptive approach as follows: • Dairy 10% beyond Baseline GMP: land use classified as "dairy" and "dairy-support" reduce nitrate-nitrogen losses by 10% beyond Baseline GMP; • 15 kg/ha 10% beyond Baseline GMP: all land use categories reduce nitrate-nitrogen losses by 10% beyond GMP if their nitrate-nitrogen loss at any stage exceeds 15 kg/ha/year. • Dairy 20% beyond Baseline GMP: land use classified as "dairy" and "dairy-support" reduce nitrate-nitrogen losses by 20% beyond Baseline GMP; A dryland farming option for the Christchurch aquifer recharge area within the Waimakariri Zone: • Average nitrogen losses are reduced to 8 kg/ha per year by 2050 (which is roughly equivalent to the expected N loss rate from low intensity dryland farming). • Provides information on the costs and benefits of a highly restrictive nitrate management regime for the modelled Christchurch aquifer recharge zone within the Waimakariri zone. Winter grazing options: • Four winter grazing/forage crop management options (i.e. variations of the PC5PA rules). • Potential nitrogen loads and number of consents that would be required under a range of PA threshold options, e.g. a 25% reduction and 50% reduction in the threshold. Further information on these options is provided in Etheridge *et al.* (2019).

[24] Alternative Pathway scenario was only assessed for the Waimakariri River catchment located within the Waimakariri Zone: The scenario was not assessed for the Ashley River/Rakahuri catchment because nitrate concentrations are much lower here and the WWZC did not consider that beyond Baseline GMP N loss reductions were required.

[25] Baseline GMP refers to the Overseer-derived N loss rate estimate for a property based on land use in the 2009-2013 Baseline period operating at Good Management Practice (as defined in Plan Change 5 of the LWRP). Many farmers need to reduce their nitrogen loss rates to achieve Baseline GMP. Going beyond Baseline GMP means reducing loss rates further by a certain percentage of the Baseline rate.

Management Scenario	Summary/Assumptions
Managed Aquifer Recharge and stream augmentation	Managed Aquifer Recharge (MAR) is a proven tool for increasing groundwater storage to sustain spring-fed stream flows and improve water take reliability. Environment Canterbury has been working with consultants and local partners in the Hinds catchment in south Canterbury over the last few years to investigate the feasibility of MAR for reducing groundwater and downgradient spring-fed stream nitrate concentrations. Results to date have shown lower nitrate concentrations in groundwater adjacent to and downstream of the MAR trial site and have tracked the progress of a plume of clean water moving towards the spring-fed streams. Further investigations are underway in the Hinds area to design a catchment-scale MAR scheme which will aim to achieve a widespread improvement in groundwater and surface water quality and flows and levels. MAR could potentially be implemented in the Waimakariri zone as a nitrate mitigation tool; this option was discussed by the WWZC. Stream augmentation has also been used to enhance natural flows and reduce contaminant concentrations in many locations in New Zealand and across the world.

In addition, a Coastal Protection Area (CPA) was proposed in recognition of the important natural resources and values found here (Etheridge and Arthur, 2019). The area encapsulates the main spring-fed streams, lagoons and wetlands near the Waimakariri coast.

We assessed the stream lengths that would benefit from the improved protection and management associated with a requirement to obtain a Resource Consent and produce an audited Farm Environment Plan (FEP) for several different consenting threshold options.

A6.2.3 Surface water flow minimum flow options

The following tables (Table A6-5 and Table A6-6) describe potentially feasible options for Ashley River/Rakahuri and Waimakariri River northern tributaries FMUs minimum flows. A detailed explanation of how the cultural and ecological minimum flows were derived is provided in the Cultural Health Assessment report (Representatives of Te Ngai Tūāhuriri and Tipa 2016) and Arthur *et al.* (2019) respectively.

Table A6-5: River minimum flow options for Ashley River/Rakahuri FMU

Option	Summary
LWRP minimum flow **(Current Pathway)**	Section 8 of the LWRP sets out minimum flows for rivers in the Ashley River/Rakahuri catchment. However, these have yet to be implemented on many river and stream depleting groundwater take consents in the catchment. This option would affect consents upon renewal that are not already aligned with the LWRP only. Importantly, this would happen regardless of the ZIPA process as the LWRP is the operative plan for the catchment.
Cultural	This option presents the minimum flows recommended in the Cultural Health Assessment report. In some cases, the Cultural Health Assessment recommendations align with the LWRP, while in others a different minimum flow has been sought.
Ecological	This option presents the ecological minimum flow recommendations, derived from ecological assessment of each waterway. As for the Cultural, the ecological flow recommendations sometimes align with the LWRP while in other cases a higher minimum flow is recommended.
Bespoke	For some waterbodies, options were developed with the Zone Committee which were a compromise between the LWRP, and the ecological and Cultural flows.

Table A6-6: River minimum flow options for Waimakariri River catchment

Option	Summary
WRRP minimum flows (**Current Pathway**)	Part 2, Section 5 of the WRRP sets out minimum flows for the tributaries of the Waimakariri River within our zone. This option would apply those minimum flows where they do not already form part of consent conditions. ***Note:*** *most groundwater and surface water consents in this area align with the WRRP because a review was done from 2005 onwards to assess compliance with (amongst other things) the standards and terms of Rule 5.1 on surface water and hydraulically connected groundwater takes. The review included a desktop assessment of the stream depletion and applying minimum flow conditions to qualifying groundwater and surface water consents.*
Cultural	This option presents the minimum flows recommended in the Cultural Health Assessment report. In some cases, the Cultural Health Assessment report recommendations align with the WRRP, while in others a different minimum flow has been sought.
Ecological	This option presents the ecological minimum flow recommendations, derived from ecological assessment of each waterway. As for the Cultural, the ecological flow recommendations sometimes align with the WWRP while in other cases a higher minimum flow is recommended.

The following table (Table A6-7) describes the options for implementation of the minimum flow limit options.

Table A6-7: Options for when to apply minimum flows

Options	Summary
Impose minimum flows after expiry date of existing consents (**Current Pathway)**	This option sees the minimum flow imposed on all relevant water take consents upon expiry and replacement.
Review existing consents prior to expiry	This option sees all consents within the catchments (or a subset that affect a particular waterbody) “called in” for a consent review at a future date to align them with the LWRP’s for Ashley River/Rakahuri and with the WRRP for Waimakariri River catchments minimum flows where they don’t already.
Deferred date for any increases to minimum flow (or where partial restrictions are not yet in force)	This option sees a later date for when any increases to minimum flows would apply. It could work in combination with either of the options above.

A6.2.4 Surface water allocation options

Current surface water allocation in some Waimakariri zone watercourses exceeds the current allocation limits. Table A6-8 describes the potentially feasible options for river allocation limits that were explored by the WWZC. Further information on allocation limits for protecting in-stream values is provided in Arthur *et al.* (2019) and Megaughin and Lintott (2019).

Table A6-8: Options for surface water allocation limits

Option	Summary
LWRP/WRRP allocation limit **(Current Pathway)**	This option retains existing LWRP/WRRP allocation limits, which reflect the state of allocation in the early 2000s. This would confirm all rivers in the Ashley River/Rakahuri FMU are over-allocated, except Little Ashley Creek and the "B" and "C" blocks of the Ashley River/Rakahuri.
Cap at current allocation	This option would see the A block allocation limit aligned with the estimated total amount of water that has already been allocated (based on the combined maximum rates of take of existing consents).
Reduce the LWRP allocation limit by a feasible amount over time	This option reduces the LWRP allocation limit (by a certain year in the future) to an amount the WWZC considered achievable given the options available (see options for phasing out river over-allocation in Table A6-9 below).
Ecological allocation	This option would introduce an allocation limit to fully protect stream ecology based on expert knowledge of stream values. It is based on 30% $7dMALF^{natural}$[26] for streams with a mean flow less than 5 m^3/s.
Cultural allocation	The Cultural Health Assessment report recommends a cultural allocation of water from rivers in this zone, without specifying what that amount should be.
More science to determine appropriate allocation limits	Under this option, further investigations would be undertaken by Environment Canterbury to better understand what allocation limits "should be" to provide for instream values in spring-fed streams.

The following table describes the potentially feasible options for phasing out over-allocation which were explored by the WWZC. These only apply if an allocation option is selected that results in a reduction in allocation.

Table A6-9: Options for phasing out river over-allocation

Option	Summary
Switch to deep groundwater	This option enables river takes and stream depleting groundwater takes to switch to deep groundwater. This reduces direct pressure on stream flows. A condition of access to deep groundwater would be the surrender of the river take or stream depleting groundwater take. A portion of the remaining groundwater allocation would be ring-fenced for this purpose only. A timeframe by which this option "closes" could be added to spur action. This is an option that has been supported by farmers in the Selwyn, Hinds and South Coastal Canterbury areas.
% reduction in allocation	The LWRP provides a region-wide default position if methods to reduce over-allocation are not specified in the sub-region section of the plan[27]. Replacement consents receive no more than 90% of the previous consented rate, but this can be moderated depending on the efficiency of existing water use.
Restrict Site to Site Water Transfers	The LWRP already contains policy for the Ashley River catchment that there shall be no transfers of river water takes in the catchment above SH1. This option could extend this to transfers of river water takes anywhere in the catchment and prohibit all transfers entirely. Alternatively, it could restrict transfers by requiring a percentage of transferred water is returned to the environment e.g. the percentage surrender matches the percentage of over-allocation.

[26] See Glossary for explanation
[27] LWRP Policy 4.50

Option	Summary
	In addition, the option could include prohibiting the transfer of any unexercised water permit, or of any unused water based on actual use records.
Lapsed, surrendered, not renewed consents	This option avoids the reallocation of consents that lapse (unexercised within 3 years)[28], are surrendered, and expire and are not renewed.
Voluntary surrender of consents	This option asks consent holders if there are any active consents that are not being exercised they are willing to surrender prior to their expiry. Any surrendered water would not be reallocated and would allow the 'productive' water use in the zone to continue.
Allocation based on actual water use data	This option determines allocation for replacement takes based on actual use data (records of past use). This is already a consideration under Schedule 10 of the LWRP, but this option would make it the method for determining allocation.
Back up municipal supply wells	This option excludes non-concurrent stream depleting "back up" community supply wells from the allocation total. This is on the basis that the wells are rarely used and when they are it is for short periods of time.
Resource consent reviews	Several the options above could be implemented upon application for replacement resource consents or via consent review.

A6.2.5 Groundwater allocation options

The following table summarises the options for groundwater allocation limits which were considered by the WWZC. Because there is no over-allocation of groundwater in the zone and the WWZC did not see a compelling reason to reduce current groundwater allocation, options for reducing allocation were not considered.

Table A6-10: Options for groundwater allocation limits (all GAZs)

Options	Summary
LWRP groundwater allocation limits **(Current Pathway)**	This option would retain the LWRP allocation limits for all GAZs.
Cap at current allocation	This option would cap groundwater at current allocation.
Cap at current & + an amount ring-fenced for switches	This option would also cap at current allocation, plus an extra amount to help address over-allocation of rivers. This extra amount would allow existing surface water takes and stream depleting groundwater takes to access deep groundwater (with a condition of that access that they surrender their existing takes).
Cap at current & + an amount an amount ring-fenced for switches + a nominal extra amount	This option is identical to the above option, plus a nominal further amount. This could provide for some new takes.

Some parts of the Waimakariri Zone are currently outside of the existing GAZs and therefore have no allocation limit. The committee considered the possibility of extending GAZ boundaries and defining a new GAZ for Lees Valley.

[28] LWRP Policy 4.73

A6.2.6 Runoff contaminant and stream health management options

Stream health and runoff contaminant management options were explored via an expert panel. The panel developed a “solutions toolbox” of options for improving ecosystem health in the zone; the main elements were improving riparian health and the management of critical source areas of sediment (e.g. drains and bank erosion points).

The management options identified included:

- fencing waterways with a setback (e.g. 3 m or greater) from the top of stream banks;
- extensively planting of riparian margins and implementing weed control within these setbacks;
- providing additional setback protection, and/or installing sediment traps and/or wetlands at the base of critical source areas draining into streams and rivers;
- re-battering excessively steep banks that are prone to collapse;
- mechanically removing legacy bed sediment from streams (e.g. sediment traps, dredging and/or sand-wanding); and,
- removing or mitigating fish passage barriers.

A6.2.7 Climate change adaptation

Noting that increases in drought frequency and severity are possible under climate change, the water management options considered by the WWZC included some measures which could help to improve drought resilience as follows:

- Increasing minimum flows, reducing water allocation volumes/rates and implementation of existing environmental flow regime rules
- Limiting any increases in new water abstraction from the zone
- Improvements in irrigation efficiency and provision of B Block allocations (where appropriate) for flood harvesting and associated on-farm storage.

A6.3 Scenarios and options assessment

A6.3.1 Water quality limit options assessment

Nitrate limits assessment
The main components of our nitrate limit options assessment, information sources and some key findings are summarised in Table A6-11. The current nitrate concentrations and trends component is addressed in Section 3 and Kreleger and Etheridge (2019a) and is not discussed further here. The remaining components are discussed in the subsequent sections of this report.

Table A6-11: Options assessment

Component	Reference source	Key findings
Management areas		
Delineate three management areas of the zone where different actions are required to achieve environmental outcomes	Kreleger and Etheridge (2019a) and Etheridge and Arthur (2019)	While runoff contaminants are a key driver for stream health in many parts of the zone, reducing nitrate concentrations are top priority within some areas: these areas have been designated the Runoff Priority Area and Nitrate Priority Area respectively. Additional land management actions are required to help protect the high ecological, cultural, recreational and aesthetic values found in the Te Aka Aka, coastal lake and lagoon and Ashley catchment spring-fed streams. This area is encapsulated within the Te Aka Aka and Coastal Protection Area

Component	Reference source	Key findings
Current state and trends		
Review current nitrate concentrations and trends	Kreleger and Etheridge (2019)a Greer and Meredith (2019) Scott *et al*. (2016)	Nitrate concentrations elevated in Kaiapoi River (Silverstream) Cust River Main Drain and Ohoka Stream. Silverstream nitrate trending upwards. High and increasing groundwater nitrate concentrations in some parts of Waimakariri zone. Low but increasing nitrate in deep Christchurch aquifer. Nitrate concentrations > MAV in some private wells. Relatively low in Ashley River/Rakahuri catchment spring fed streams
Current Pathway scenario assessment		
Evaluate lag times and use groundwater model to estimate steady state nitrate concentrations under current management regime	Kreleger and Etheridge (2019a)	Lag times are very long for Christchurch aquifer, long for many Waimakariri zone wells especially those impacted by recent (post 2012) land use intensification, moderate for Kaiapoi River tributary spring fed streams and generally short for the Ashley River/Rakahuri tributaries. Nitrate concentrations are expected to increase significantly in some watercourses and wells due to lag times. It would be extremely challenging to maintain current nitrate concentrations in the face of these lag times. Modelling results show wide uncertainty range.
Nitrate limits options assessment		
Determine magnitude of beyond Baseline GMP N loss reductions required under various nitrate limit options, giving due consideration to modelling uncertainty	Kreleger and Etheridge (2019a) Etheridge (2019b)	Implementation of GMP is expected to achieve NPS-FM A Band in Ashley River/Rakahuri catchment spring-fed streams and Cam River/Ruataniwha if future land use intensification is prevented. Significant beyond Baseline GMP N loss reductions required to meet National Bottom Line in Silverstream and possibly Kaiapoi River. Significant loss reductions required to reduce nitrate toxicity effects in Ohoka Stream and Cust River/Main Drain and nitrate concentrations in private supply wells. Significant reductions also likely to be required if half MAV target set for WDC community supply wells
Evaluate economic impact on farming associated with each limit option	Etheridge (2019b) Harris (2019)	Farm economic impacts could be significant for N loss reduction rates above 10% for dairy and <5% for other farm types. Dairy farming operations unlikely to be viable for average farms under 30%+ N loss reduction rates, particularly if changes implemented over 10 years

Component	Reference source	Key findings
Assess environmental benefits of each nitrate limit option	Arthur *et al.* (2019) Kreleger and Etheridge (2019a)	Nuisance periphyton, including toxic algal blooms, currently impact Ashley River/Rakahuri recreation, benthic biodiversity and mahinga kai values [29]. Fisheries in Silverstream, Kaiapoi River, Ohoka Stream and Cust River/Main Drain likely to be degraded due to nitrate toxicity. Reducing concentrations could help fisheries to recover. Reducing groundwater nitrate concentrations would reduce health effect risks for private water supply well users Use of half MAV target for WDC wells would provide certainty that nitrate will be below the MAV and avoid additional sampling and reporting requirements required under NZ Drinking Water Standards
Alternative Pathways assessment		
Evaluate how quickly nitrate limits could be achieved and the farm economic impact under a range of beyond Baseline GMP N loss reductions. Assess costs and benefits of different PA rules Assess actions required to improve health of streams with legacy sediment issues and poor habitat	Kreleger and Etheridge (2019a)	It will take longer to achieve nitrate limits under lower reduction rates (e.g. 10% beyond Baseline GMP). Reducing nitrate losses from dairy and dairy support land by 20% could have a significant economic impact on farming. Reducing the PA thresholds for winter grazing will help to protect sensitive waterbodies A comprehensive stream rehabilitation programme would be required to remove sediment accumulations from past and present land use activities and to re-batter streams to improve habitat for mahinga kai species and broader stream health. Current stock exclusion rules need to be strengthened to improve stream health and mahinga kai

Other contaminants limits assessment
Waimakariri Zone-specific freshwater outcomes, and water quality limits and targets were determined using the revised draft tables as detailed in Hayward *et al.* (2019) as a guideline. Numeric and narrative freshwater outcomes were developed for rivers and lakes as follows.

Rivers
For the most part, proposed default freshwater outcome values, as per Hayward *et al.* (2019), were adopted for all river types with the exception of those relating to human health for recreation in spring-fed streams. Spring-fed plains rivers in the Waimakariri Zone are valued for primary contact recreation activities and mahinga kai gathering. Likewise, spring-fed waters and the receiving environment of the estuary are extensively used for mahinga kai gathering. It is desired by community and iwi that these waterbodies are safe for recreation, and for mahinga kai gathering and food consumption. Outcomes for suitability for recreation grade (SFRG), *E. coli* and cyanobacteria are therefore set in line with more stringent National Policy Statement for Freshwater Management (NPSFM - MfE, 2017) and MfE (2003)[30] guidelines for these waterbodies than those presented by Hayward *et al.* (2019).

[29] Nitrate limits are above guidelines for preventing nuisance algal growths for protecting trout habitat and angling values and benthic biodiversity.

[30] *Microbiological water quality guidelines for marine and freshwater recreational areas.*

Lakes
All Tūtaepatu Lagoon freshwater outcomes are consistent with proposed defaults as per Hayward *et al.* (2019). There is little reason to justify why these should be different, and there is very little monitoring data or information available for this waterbody.

For Lake Pegasus, some outcomes were set in consideration of the requirements of the Lake developer's (Todd Property Pegasus Town Ltd) resource consents (consent no. CRC135321-CRC135323). Trophic Level Index (TLI) and chlorophyll-a outcome values are the same as proposed in Hayward *et al.* (2019) for artificial lakes and are also consistent with the consent requirement of no algal blooms in the lake. Lake Pegasus was developed primarily for use for secondary contact recreation activities (e.g. kayaking and sailing), not primary contact recreation (i.e. swimming). Despite this, swimmers have used the lake and full-immersion sporting events (e.g. triathlon) have been organised to use the lake as a venue. Current *E. coli* levels in the lake are low and the suitability for SFRG is 'Very Good' (Arthur *et al*., 2019). Therefore, the lake is comfortably meeting its outcomes related to microbial water quality.

Proposed water quality management areas
The Waimakariri Zone was divided into three areas for management purposes:

- Nitrate Priority Area (NPA), where beyond Baseline GMP N loss reductions are required
- Runoff Priority Area (RPA) where runoff contaminants are likely to be having the greatest effect on stream health (noting that beyond Baseline GMP N loss reductions may ultimately be required here) covers entire Waimakariri water zone

  Te Aka Aka and Coastal Protection Area (CPA) where additional land management actions are required to help protect the high ecological, cultural, recreational and aesthetic values found here.

The drivers for and delineation of these zones and potential management controls are discussed further below and in Kreleger and Etheridge (2019a) [NPA and RPA] and Etheridge and Arthur (2019) [CPA]. Figure A6-1 shows the area boundaries.

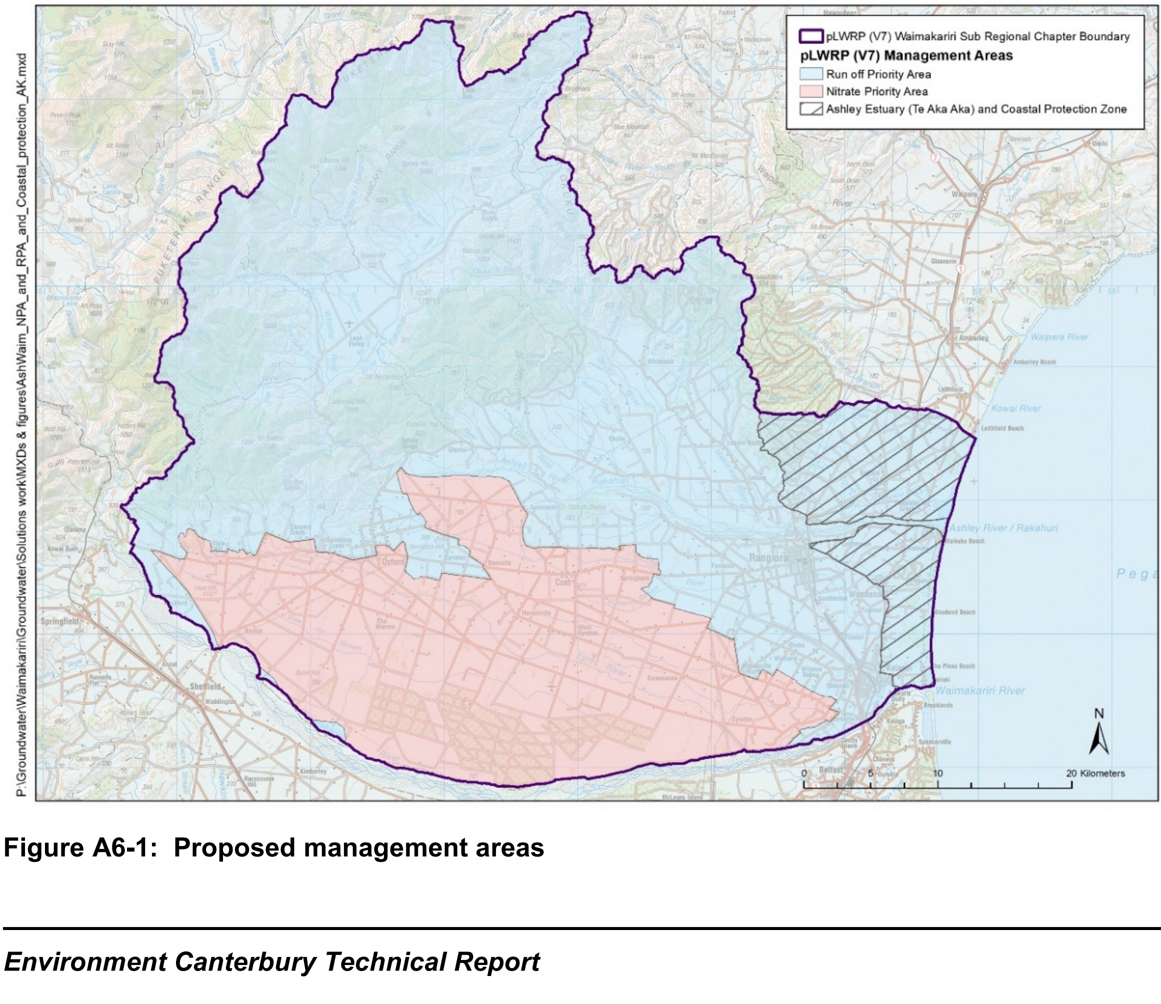


Figure A6-1: Proposed management areas

Nitrate Priority Area (NPA)
Kreleger and Etheridge (2019a) explain that the NPA encapsulates most of the surface water and groundwater receptors where nitrate concentrations currently exceed the nitrate limits recommended in the ZIPA (these are discussed later in this report) and/or are expected to do so after accounting for lag effects. Implementation of beyond Baseline GMP N loss reductions will be required here, options for which are discussed later in this section of the report.

Runoff Priority Area (RPA)
Arthur *et al.* (2019) explain that:

1. phosphorus, sediment and pathogens, which mainly enter surface waters via runoff pathways, are the key drivers for stream health (and hence mahinga kai quality, diversity and abundance) in many of the Waimakariri zone surface watercourses; and that
2. managing land use activities to reduce the influx of these contaminants will help to maintain current values; but that
3. past activities have caused an accumulation of sediment and phosphorus in many spring-fed streams; these would have to be removed in order to achieve a significant improvement in stream health.

Our technical assessments therefore concluded that a comprehensive stream rehabilitation programme would be required to improve mahinga kai, aquatic ecology and biodiversity in these watercourses, most of which are located within the RPA. We discuss this further below.

Te Aka Aka – Coastal protection area (CPA)
The CPA was delineated in recognition of the important natural resources and values found here. The area encapsulates the main spring-fed streams, lagoons and wetlands near the Waimakariri coast.

Intensively farmed land (e.g. winter grazed or heavily stocked) is particularly susceptible to generating the high runoff contaminant discharges to water which adversely impact sensitive waterbodies. Irrigated land can support higher stock numbers than dryland farming; higher stock numbers, all else being equal, are associated with increased runoff contaminant risk. Winter forage crop grazing can also generate significant runoff contaminants loads. Etheridge and Arthur (2019) therefore identified irrigation and winter grazing (as defined in the LWRP) as high-risk activities in the CPA and explored options for stricter management via Farm Environment Plan (FEP) requirements. They also explored options using property area as a threshold for requiring a Resource Consent and audited FEP, in recognition of the fact that irrigated land and winter grazing are not the only activities which can impact on natural resources in the coastal area. The assessment evaluated the increase in stream length protected and the number of additional Resource Consents that would be required under each option to provide an indication of environmental benefits and farm economic impacts.

The results highlight the trade-off between the number of consents required (and associated financial and administrative burden on the farming community) and the stream lengths which benefit from improved protection. Option 1 requires property areas >5 ha with > 0.5 ha of winter grazing or >0.5 ha of irrigation to produce an audited FEP. This option would protect an additional 152 km of streams whilst requiring a relatively modest increase in the number of consents (65) relative to the current Regional Plan rules.

Full details are provided in Etheridge and Arthur (2019).

Current Pathway nitrate management scenario assessment

Ashley River/Rakahuri FMU
We do not expect the currently low nitrate concentrations to increase significantly in the Ashley River/Rakahuri FMU under Current Pathway scenario due to lag effects because there has been limited recent land use intensification and the age of water in these receptors is generally quite young (e.g. a few years old, on average). Although groundwater drawn from the deeper water supply wells (e.g. Pegasus Town) is much older, our modelling results suggest that nitrate concentrations in these wells is unlikely to exceed the preferred nitrate limits.

Modelling results for Te Aka Aka estuary (see Kreleger and Etheridge, 2019) indicate that successful implementation of GMP is expected to reduce nitrogen discharges to the estuary by around 8%. The land use intensification that can occur as a Permitted Activity (PA) under the LWRP (PC5) could offset this entirely and potentially cause a nitrate discharge increase in excess of 20% if the PA allowances are fully utilised by all eligible landowners. Te Aka Aka is a valued cultural, ecological and recreational resource and is highly sensitive to nitrate contamination. Increased nitrate discharges could have a meaningful negative impact on values. This is discussed further in Bolton-Ritchie (2019).

The PA rules assessment (see Kreleger and Etheridge, 2019a) shows that the PA rules also allow for a potentially significant increase in the nitrogen loss rates to several other sensitive water bodies in the Ashley catchment. Winter grazing is the main source of this potential increase.

Waimakariri River northern tributaries FMU
Nitrate concentrations in all surface water courses in the Waimakariri River northern tributaries FMU either currently exceed the committee's preferred limits or are expected to do so under the Current Pathway model projections. Projected increases are mainly driven by the arrival of nitrate which is already in the groundwater system but has not yet arrived at key receptors. The additional winter grazing and to a lesser degree irrigation-based intensification that can occur as a PA under PC5 has the potential to increase nitrate concentrations significantly in some areas.

The analysis of groundwater quality monitoring data presented in Kreleger and Etheridge (2019a) suggests that nitrate concentrations are likely to either occasionally or consistently exceed the drinking water limit in somewhere between 90-165 of the ~2,750 private water supply wells in the Waimakariri northern tributaries catchment. Our Current Pathway modelling results suggest that nitrate concentrations have the potential to exceed the MAV in 270 private wells in the future.

Kreleger and Etheridge (2019a) explain that the half MAV threshold (5.65 mg/L) is currently being achieved in 10 of the 12 main WDC community supply wells included in our modelling. Nitrate concentrations in the Poyntzs Road supply well consistently exceed 5.65 mg/L at present. Our modelling results for the Current Pathway scenario suggest that nitrate concentrations have the potential to consistently exceed 5.65 mg/L in seven of the main water supplies. Lag times are the main driver for increase, but the additional intensification which could occur as a PA under PC5 is again a significant factor for the modelled increases in some water supply wells.

Christchurch aquifer
Groundwater modelling results for the Christchurch aquifer indicate that nitrate concentrations are likely to increase from an average current measured concentration of 0.6 mg/L in the deep aquifer beneath the city to ~5 mg/L under the Current Pathway scenario. Because groundwater flow velocities in the deep aquifer beneath the city are very low, the projected increase is expected to occur over many decades and potentially centuries. More detailed discussion is provided in Kreleger and Etheridge (2019a).

Nitrate limits options assessment further details

Waimakariri zone receptors
Details regarding nitrate limit options, key WWZC decision factors and the limits recommended in the ZIPA for surface water and groundwater receptors in the Waimakariri zone are summarised in Table A6-12 and Table A6-13 respectively.

Table A6-12: Nitrate limit options assessment for surface water

Waterbody	Nitrate limit options	Key decision factors	Recommended limit
Ashley River/Rakahuri at Gorge	0.1, 0.2 mg/L	Nuisance periphyton, including toxic algal blooms, currently impact recreation, benthic biodiversity and mahinga kai values[31]. Most of nitrogen load in the catchment is sourced from low intensity land use. Widespread land use change would be required to reduce concentrations, with significant farm economic impacts.	0.2 (maintain current)
Ashley River/Rakahuri at Gorge	0.1, 0.3 mg/L		0.3 (maintain current)
Te Aka Aka	Maintain current eutrophication risk band[32] Lower eutrophication risk band	Te Aka Aka highly valued natural and cultural resource and highly sensitive to nitrate. It is vulnerable to increased eutrophication and degradation. Most of nitrogen load in the sourced from low intensity land use. Widespread land use change would be required to reduce load with significant farm economic impacts.	Maintain current
Saltwater Creek, Waikuku Stream, Taranaki Creek	Current measured (varies) 1.0 mg/L	Culturally significant landscape and waterbodies. Current concentrations low in terms of nitrate toxicity, but exceeds guidelines for nuisance instream plant growths. 1.0 mg/L limit provides for 99% species protection for nitrate toxicity effects.	1.0 mg/L
Silverstream at Harpers Road	1.0, 2.4, 3.8, 6.9 mg/L	Current concentrations very high and expected to increase further (lag effects). Significant toxicity effects (<80% species protected), particularly for salmonids. Major nitrate loss reductions required to achieve a national bottom line of 6.9 mg/L with significant farm economic impacts.	6.9 mg/L
Silverstream at Island Road	1.0, 2.4, 3.8, 6.9 mg/L	Current concentrations high and expected to become very high (lag effects). Significant toxicity effects on aquatic fauna. Major nitrate loss reductions could ultimately be required to achieve 6.9 mg/L with significant farm economic impacts.	6.9 mg/L
Courtenay Stream	1.0, 2.4, 3.8 mg/L	Current concentrations expected to increase due to lag effects. 3.8 mg/L would maintain current nitrate toxicity levels and protect 90% of aquatic species.	3.8 mg/L
Ohoka Stream	1.0, 2.4, 3.8, 6.9 mg/L	Valued trout fishery currently impacted by elevated nitrate. Reduction from current (4.5 mg/L) to 3.8 mg/L would reduce toxicity impacts but is likely to have significant impacts on farm economics.	3.8 mg/L
Cust Main Drain	1.0, 2.4, 3.8, 6.9 mg/L	High value fishery currently impacted by nitrate toxicity and toxic algal growths.	3.8 mg/L

[31] Nitrate limits are above guidelines for preventing nuisance algal growths for protecting trout habitat and angling values and benthic biodiversity.

[32] Robertson *et al.*2016a and 2016b) New Zealand estuary trophic index (ETI). Thresholds for various indicators used to classify an estuary into one of four eutrophication bands (A – minimal; B – moderate; C-high; D – very high)

Waterbody	Nitrate limit options	Key decision factors	Recommended limit
		Reduction from current (4.7 mg/L) to 3.8 mg/L would reduce toxicity impacts but does not affect nuisance periphyton growth. Scale of N loss reductions mean that impacts on farm economic could be significant	
Cam River / Ruataniwha	1.0 mg/L	Culturally significant landscape and waterbody. Current concentrations low in terms of nitrate toxicity but exceeds guidelines for nuisance instream plant growths. 1.0 mg/L limit provides for 99% species protection for nitrate toxicity effects.	1.0 mg/L

Table A6-13: Nitrate limit options assessment for groundwater receptors

Waterbody	Options	Key decision factors	Recommended limit (mg/L)
Groundwater	• 7.1 mg/L • Current Measured • 5.65 mg/L (half MAV)	No. of private wells in which nitrate concentrations exceed MAV Potential for future increases due to lag Additional sampling and reporting requirements for WDC if nitrate > 5.65 mg/L Impacts on farm economics	Private water supply wells median 5.65 mg/L Community water supply wells 5.65 mg/L max

Christchurch aquifer

We evaluated the beyond Baseline GMP nitrate loss reduction required in the Christchurch aquifer recharge area for the various Christchurch nitrate thresholds using our groundwater modelling results. All thresholds considered by the WWZC and Christchurch West Melton Zone Committee are lower than the 5.65 mg/L (50% of the drinking water limit) threshold at which drinking water suppliers are required[33] to undertake monthly nitrate sampling and submit annual results to the Drinking Water Assessor for review.

The main outcomes of this were:

- Comprehensive land use change, to a low intensity activity such as forestry, would be required to achieve the 0.6 mg/L threshold. Nitrate concentrations are expected to increase above this value due to loads “in the post”, even if all N losses ceased immediately.
- The 3.8 mg/L threshold aims to maintain nitrate concentrations in Christchurch’s spring-fed streams, recognising that some attenuation may occur between the deep aquifer and spring discharge locations, and that deep groundwater is only one component of the spring-fed stream flows. Low nitrate water seepages from the Waimakariri River make up a significant proportion of the Avon River flows, for instance.

[33] Under the New Zealand Drinking Water Standards

Table A6-14: Nitrate limit options assessment for Christchurch aquifer

Nitrate threshold option (mg/L N)	Rationale	Evaluation
0.6	Average current measured concentration in deep Christchurch aquifer	Modelling results indicate that an average nitrate loss reduction of around 90% could be required to achieve this. This could necessitate conversion of the whole Christchurch aquifer recharge area to forestry. Nitrate concentrations are expected to increase even if a forestry conversion was implemented immediately due to nitrogen loads already “in the post”.
1.0	NPSFM A Band limit: protects 99% of aquatic species. Recognises that groundwater from deep Christchurch aquifer likely to ultimately discharge to spring-fed streams	An average N loss reduction of 80% is likely to be required to achieve this target. Assessment results indicate that conversion of all irrigated land to low intensity sheep and beef farming and forestry could be necessary to achieve this limit. As per the option above, nitrate concentrations may still increase beyond this value due to loads “in the post”.
2.4	NPSFM B Band limit: protects 95% of aquatic species. Recognises spring-fed stream connectivity as above.	An average N loss reduction of 50% is likely to be required to achieve this target. This could potentially be achieved with less severe land use change, or potentially over a long period without land use change if new nitrate loss mitigation solutions are developed
3.8	Protects 90% of aquatic species. Recognises spring-fed stream connectivity as above.	20% N loss reduction required. Can be achieved without land use change and by using currently available N loss mitigation options.

Both Zone Committees considered that use of a 3.8 mg/L threshold to define the beyond Baseline GMP N loss reductions required in the Christchurch aquifer recharge area within the Waimakariri zone would strike the best balance between modelling uncertainty, the need to implement proactive measures to protect Christchurch’s water supply aquifer and minimising economic impact on farming.

Water quality management options assessment
We have used the Likert (1932) response scale to summarise the overall expected outcomes of the nitrate management options assessment (Table A6-15) over a 20-year timeframe. Consideration of the timeframe is important because the nitrate loss reductions would be applied in 10-year stages until limits are achieved. This means that the higher reduction rates would achieve the limits more quickly than the lower rates. We have also ignored lag effects in this simple assessment overview and have not discussed the changes between current measured nitrate concentrations and Current Pathway concentrations. These matters are addressed in Kreleger and Etheridge (2019a). We have not included Managed Aquifer Recharge and Stream Augmentation in the summary assessment.

Table A6-15: Nitrate management options assessment summary

Outcome	Current Pathway vs. Current State	Alternative Pathways vs. Current Pathway			
		Consented 10% beyond GMP	20 kg/ha 10% beyond GMP	Dairy 20% beyond GMP	Lower PA thresholds
Mahinga kai, stream health & biodiversity	Somewhat worse	Slightly better	Slightly better	Somewhat better	Somewhat better
Drinking water quality	Somewhat worse	Slightly better	Slightly better	Somewhat better	Somewhat better
Economic impact on farming	Neutral to somewhat worse	Slightly worse	Slightly worse	Somewhat worse	About the same

Our broader water quality management options assessment concludes that:

- Current management regimes around riparian management and stock exclusion are unlikely to resolve poor ecosystem health
- Strengthening of the LWRP stock exclusion rules will be required to improve stream health and mahinga kai
- A comprehensive stream rehabilitation programme will be required to address legacy stream habitat and sediment accumulation issues and to achieve the significant improvement in mahinga kai health, diversity and abundance within a generation required by Ngāi Tūāhuriri

Beyond Baseline GMP nitrate reduction options
We assumed that the 'beyond Baseline GMP' loss rate reductions would continue to be applied every 10 years until the surface water and groundwater nitrate limits recommended by the WWZC are met. Our data analysis and WWZC discussions identified that:

- It will take longer to achieve nitrate limits under lower reduction rates (e.g. 10% beyond Baseline GMP). Higher reduction rates were required to achieve Community Outcomes within an acceptable time frame.
- Reducing nitrate losses from dairy and dairy support land by 20% could have a significant economic impact on farming.
- Inclusion of a low nitrate-emitter threshold, or floor below which further nitrate loss reductions would not be required, would increase the time taken to achieve nitrate limits slightly, but would improve the practicality and equity of the ultimate nitrate management solution and hence the level of engagement by the farming community. This is because farmers making a relatively minor contribution to nitrate pollution would not be required to reduce their loss rate: the focus would be on those making the greatest contribution per hectare of land to the overall nitrate load.
- The estimates of the costs of reducing nitrate losses were generated using data developed with the Farmers Reference Group and Dairy NZ. A range of mitigation options were considered by the group for dairy, and these were translated into a curve of abatement costs using regression analysis. No specific mitigations beyond GMP were found for other industries, and the costs of reducing nitrate losses for these operations was estimated by removing enough land from production to achieve the required abatement and replacing it with forestry. These costings are also conservative because there may be other options available to landholders that have not been investigated by the group, and because technological change over time may increase the range of options available. These abatement costs were aggregated to provide estimated impacts on profit, land value, regional GDP, household income, and employment.
- Cost impacts for drinking water supplies occur only for private wells where nitrate concentrations are likely to exceed the drinking water standard No community supplies are expected to exceed this threshold. As no alternative supplies (such as lower nitrate deep groundwater) are likely to be available for these private wells, the costs of ensuring a safe water supply were estimated assuming that under-bench treatment systems (reverse osmosis and ion exchange) were utilised by affected households.
- The additional cost of the proposed strengthening of the stock exclusion rules was estimated using average fencing costs for different land uses, combined with GIS estimated lengths of streams, drains and springheads in consented and non-consented land uses. Data from Environment Canterbury stream walk monitoring was used to account for the lengths of streams already fenced or where stock exclusion is not required.

The assessment results for projected nitrate concentrations over time in the deep aquifer beneath central Christchurch indicate that increasing the 'beyond Baseline GMP" loss rate provides small improvements to the peak concentration (which is modelled to be <5.65 mg/L. These improvements won't be realised for a long time and may have significant economic impact on farming due to significantly higher N loss reduction rates.

Winter grazing PA rules
Three alternative winter grazing PA thresholds were considered: reducing the allowance to 5% of a property up to a maximum of 50 ha of winter grazing, lowering the current (PC5) thresholds by 25% and

lowering the thresholds by 50%. The 5% option would reduce the potential for increased nitrogen discharges by the greatest amount but could drive the need for many new consents with associated costs for farming. Further details are provided in Kreleger and Etheridge (2019a).

Managed Aquifer Recharge and stream augmentation
Managed Aquifer Recharge (MAR) and stream augmentation could potentially be used as complimentary technologies to address nitrates in surface water and groundwater.

A successful pre-MAR infiltration trial has been completed in the Silverstream catchment (see Kreleger and Etheridge, 2019a); the trial is currently being extended into a MAR trial which has the potential to reduce the time taken to achieve the Silverstream and Kaiapoi River nitrate limits and the associated beyond Baseline GMP N loss reduction requirement significantly. Nitrate concentrations in water supply wells downgradient of the MAR trial site are also likely to reduce.

Megaughin and Lintott (2019) explain that Cust River (and hence Cust Main Drain) is already being informally augmented by discharges from the Waimakariri Irrigation Limited and stockwater race network. Current Regional Plan Rules include provisions for further augmentation. The median flow of the Cust Main Drain is approximately 1 m^3/s; further augmentation with 0.2 m^3/s of low nitrate Waimakariri River water via the race network, for instance, could reduce nitrate concentrations by 20% which would reduce the beyond Baseline GMP N loss requirement by 50%.

Although more work is required to demonstrate feasibility, commit funding and develop a governance mechanism to deliver stream augmentation and MAR; the work already completed and infrastructure that is already in place mean that there is a genuine potential for achieving nitrate limits more quickly, with fewer stages of beyond Baseline GMP N loss reductions, via on-the-ground actions.

A6.3.2 Surface water flow management regime - minimum flow options assessment

Water take consents in the Waimakariri River catchment were reviewed in circa 2005 and hence most of the consents here are aligned with current plan rules. No such review has been undertaken for the Ashley River /Rakahuri catchment and hence there is a significant difference between Current State and Current Pathway (full implementation of current plan rules) here in terms of stream flows and water take reliability.

The LWRP rules including stream depletion effects assessment apply to the Ashley River/Rakahuri FMU. The stream depletion effects associated with groundwater abstraction within the Waimakariri northern tributaries FMU are currently managed using the WRRP rules. Transition to the LWRP method would mean that more groundwater takes will be classified as stream-depleting. The reliability of any newly identified stream-depleting takes may reduce because they will have a minimum flow imposed at times of low flow, whereas previously the abstraction would have been unrestricted.

Currently there are 89 groundwater consents and 84 surface water consents with a minimum flow condition on their consents, totalling 173 consents. Under the Current pathway this increases to 206 consents in total.

Full implementation of current plan rules will mean that less water is taken from surface water and groundwater under low flow conditions. This will improve stream health and mahinga kai to some degree, but will reduce the reliability of those water takes which are not aligned with current plan rules. As per nitrate options assessment, minimum flows options were assessed relative to the Current Pathway scenario, but the WWZC considered the various minimum flow and allocation limits options in the context of the benefits and impacts on stream health and farm economics respectively associated with changes from current state to Current Pathway.

Decision factors
The WWZC considered the following when evaluating minimum flow options:

- The current poor state of mahinga kai in the Waimakariri zone, and the extent to which higher minimum flows could improve this;
- The impact of higher minimum flows on farm economics;
- The ecological and water quality benefits of higher minimum flows; and

- The cumulative impact for water users with consents that do not yet comply with the current operative plans and would need to make a 'double jump' upon consent expiry to reach the revised minimum flows, as explained above.

The impacts of the different minimum flow options on water take reliability and farm economics are discussed in Megaughin and Lintott (2019) and Harris (2019).

A6.3.3 Minimum flow options assessment

We have summarised the minimum flow options assessment for each Waimakariri Zone watercourse in Table A6-16 and Table A6-17. The tables provide the following options:

1. **Discussion options:** Minimum flow options that Environment Canterbury staff presented to the WWZC for consideration (see Megaughin and Lintott., 2019 and Arthur *et al.*, 2019 for further details),
2. **Consultation options**: The options selected by the WWZC for discussion with stakeholders and the community during the consultation process
3. **Recommended option**: The final option recommended by the committee in the ZIPA for implementation via Regional Plan rules. The WWZC rationale for their recommended option is also summarised.

A more detailed assessment of the minimum flow options is provided in Megaughin and Lintott (2019). Delayed implementation (e.g. until 2025 or 2027) of minimum flows has been proposed for some watercourses with higher minimum flow recommendations. The WWZC recommended these delays to provide time for consent holders to prepare and adapt and to allow time for more monitoring of water ways, whilst providing a clear direction to consent holders of the need for change. The expiry date of existing consents was also a factor for some waterways.

Table A6-16: Minimum flow options assessment summary: Ashley River/Rakahuri catchment

Watercourse	Discussion options	Consultation options	ZIPA recommendation	Rationale
Ashley River / Rakahuri A Block	Current consents Min. flow varies per consent LWRP / ecological 2500 L/s (Jan-Jul) 4000 L/s (Aug-Nov) 3000 L/s (Dec) Cultural To allow connected flow from mountain to sea (no specific flow given)	LWRP / ecological 2500 L/s (Jan-Jul) 4000 L/s (Aug-Nov) 3000 L/s (Dec)	No change: 2500 L/s (Jan-Jul) 4000 L/s (Aug-Nov) 3000 L/s (Dec)	Current minimum flow was maintained to prevent abstraction exacerbating the occurrence of drying in downstream reaches. This is to protect benthic ecology and native fish passage, and remains the key driver.
Ashley River / Rakahuri B Block	LWRP 3200 L/s (Jan-Jul) 4700 L/s (Aug-Nov) 3700 L/s (Dec) Ecological 4000 L/s (Jan-Jul) 5500 L/s (Aug-Nov) 4500 L/s (Dec)	LWRP 3200 L/s (Jan-Jul) 4700 L/s (Aug-Nov) 3700 L/s (Dec)	No change: 3200 L/s (Jan-Jul) 4700 L/s (Aug-Nov) 3700 L/s (Dec)	Ecological option increases current minimum flows to provide a "gap" of 800 L/s between the top of "A" allocation block and start of "B" allocation block Any increase to the minimum flow would have significant impacts upon the already poor reliability

Watercourse	Discussion options	Consultation options	ZIPA recommendation	Rationale
				of takes. Higher minimum flow would allow for small fresh flows (protects native fish passage and provides salmonid passage)
Ashley River / Rakahuri C Block	LWRP 6000 L/s	LWRP 6000 L/s	No change: 6,000 L/s	Any increase to the minimum flow would have significant impacts upon the already poor reliability of takes.
Saltwater Creek (Sefton)	Current consents Min. flow varies per consent LWRP 100 L/s Ecological/Cultural 148 L/s	LWRP 100 L/s Ecological/ Cultural 148 L/s	No change: 100 L/s From 2032: 148 L/s	Very few partial restrictions currently exist on consents in this catchment; implementation of these will have a large impact on water take reliability. WWZC felt that the cumulative effect of this and a higher minimum flow would impact users too much. A higher minimum flow is proposed for 2032 to give users time to prepare and adapt. The partial restrictions will keep more water in the river / prevent it from being drawn below the minimum flow.
Waikuku Stream	Current consents Min. flow varies per consent LWRP 100 L/s (Mon-Fri), 150 L/s (Sat-Sun) LWRP fixed 150 L/s (Mon-Sun) Ecological 250 L/s Cultural 600 L/s	LWRP fixed 150 L/s (Mon-Sun)	From 2025: 150 L/s Future goal: 250 L/s	Waikuku Stream is an important contributor to Ashley Estuary (Te Aka Aka), supports salmonid spawning, and is a refuge for fish in times of low flow in the Ashley River/Rakahuri. The minimum flow has been increased on weekends to be 150 L/s at all times. Subject to monitoring, the Zone Committee would like consideration given to increasing the minimum flow to 250 L/s as a future goal for the next plan

Watercourse	Discussion options	Consultation options	ZIPA recommendation	Rationale
				change. This is a non-statutory goal and would provide depths for salmon passage.
Little Ashley Creek	Current consents Min. flow varies per consent LWRP 50 L/s 30 L/s (4 days/month) LWRP single/ Cultural - 50 L/s Ecological 70 L/s	LWRP single/ Cultural - 50 L/s	From 2025: 50 L/s	The variable minimum flow allowed flood irrigation to occur. This outdated irrigation technique is no longer practiced in the catchment and so the rule is not required.
Taranaki Creek	Current consents Min. flow varies per consent LWRP / Cultural 120 L/s Ecological 158 L/s	LWRP / Cultural 120 L/s	No change: 120 L/s	Cultural recommendation was for the minimum flow to stay at 120 L/s. A small benefit will be seen when existing consents are brought up to this standard.

Table A6-17: Minimum flow options assessment summary: Waimakariri catchment

Watercourse	Minimum flow options	Consultation options	ZIPA recommendation	Rationale
Cam River / Ruataniwha	WRRP 1,000 L/s Ecological 890 L/s Cultural 1,200 L/s	WRRP 1,000 L/s Cultural 1,200 L/s	No change: 1,000 L/s Future goal: 1,200 L/s	The minimum flow was originally set to dilute sewage discharges from Rangiora. It is higher than a ‘minimum standard’ for an ecological flow recommendation. That said there are significant issues with the river which would be made worse by lowering the minimum flow. The Committee have recommended to keep it as its current level but would like to see it increased in the long term to meet cultural values. The future goal is a non-statutory target.
North Brook	WRRP / ecological 530 L/s Cultural 590 L/s	WRRP / ecological 530 L/s Cultural 590 L/s	From 2027: 560 L/s Future goal: 590 L/s	Minimum flow increased to improve the habitat available in the river during low flows. WWZC felt the cultural flow was too high so decided on a mid-point between the options. The

Watercourse	Minimum flow options	Consultation options	ZIPA recommendation	Rationale
				future goal is a non-statutory aspiration
Middle Brook	WRRP 60 L/s Ecological 25 L/s Cultural 50 L/s	WRRP 60 L/s	No change: 60 L/s	The flow regime is not being changed for this SWAZ. Minimum flow already set above low flows that occur naturally and therefore provides ample protection for the ecosystem.
South Brook	WRRP / ecological 140 L/s Cultural 170 L/s	WRRP / ecological 140 L/s Interim step 155 L/s	From 2027: 155 L/s Future goal: 170 L/s	Minimum flow increased to a high level of habitat protection to improve the habitats available in the river during low flows for mahinga kai by moving towards the Cultural minimum flow. The future goal is a non-statutory target.
Cust River	WRRP 20 L/s Cultural / Ecological 64 L/s	WRRP 20 L/s Cultural / Ecological 50 L/s Interim step 100 L/s MF reassessment *60 L/s	From 2027: 60 L/s	Chosen management regime based on flows which ignore the bywash water added by Waimakariri Irrigation Limited.
Cust Main Drain	WRRP / Ecological 230 L/s Cultural 400 L/s	WRRP / Ecological 230 L/s Trout protection 270 L/s	No change: 230 L/s	Minimum flow to be kept the same as the current regime as provides protection for native fish habitat. Current state of Cust Main Drain is relatively good.
No.7 Drain	WRRP / cultural 60 L/s Ecological 130 L/s	WRRP / cultural 60 L/s Ecological 130 L/s Interim step Rate not specified	No change: 60 L/s	Minimum flow is to be kept the same as the current regime. Economic effects of increased minimum flows were considered to be too great.
Ohoka Stream	WRRP 300 L/s Ecological 470 L/s Cultural 420 L/s	WRRP 300 L/s Cultural 420 L/s	From 2027: 420 L/s	Minimum flow is to be increased to a level which meets Rūnanga recommendations and which better protects the ecology of the stream.
Silverstream	WRRP	WRRP	From 2027: 900 L/s	Minimum flow is to be increased to a level which

Watercourse	Minimum flow options	Consultation options	ZIPA recommendation	Rationale
	600 L/s Ecological 1,150 L/s Cultural 1,200 L/s	600 L/s Salmon passage 900 L/s Cultural 1,200 L/s	Future goal: 1,200 L/s	better protects the ecology of the stream. Subject to monitoring, the Zone Committee would like consideration given to increasing the minimum flow to 1200 L/s as a future goal for the next plan change. This would further increase the protection for instream ecology and increasing contribution to the Kaiapoi River during low flows. The future goal is a non-statutory target.
Courtenay Stream	WRRP 260 L/s Ecological 330 L/s Cultural 400 L/s	WRRP 260 L/s Ecological 330 L/s Cultural 400 L/s	From 2027: 330 L/s Future goal: 400 L/s	Minimum flow is to be increased to a level which better protects the ecology of the stream. Subject to monitoring, the Zone Committee would like consideration given to increasing the minimum flow to 400 L/s as a future goal for the next plan change, further increasing the protection for instream ecology and increasing contribution to the Kaiapoi River during low flows. The future goal is a non-statutory target.
Greigs Drain	WRRP 150 L/s Ecological/Cultural 230 L/s	WRRP 150 L/s Ecological/Cultural 230 L/s	From 2027: 230 L/s	Minimum flow is to be increased to a level which better protects the ecology of the stream.
McIntosh/Kairaki	N/A	N/A	N/A	New SWAZ to manage takes. Any new takes limited to groundwater takes with no significant effect on surface water system of lagoons, wetlands and streams (Stream depletion classification = Low[34])
Eyre River	N/A	N/A	N/A	Area with many intermittently flowing streams. All current takes are groundwater takes as surface water is often not available during summer. No new surface water takes to be permitted.

[34] As defined in Schedule 9 of the LWRP

Watercourse	Minimum flow options	Consultation options	ZIPA recommendation	Rationale
Upper Eyre River	N/A	N/A	54 L/s	Minimum flow is to be kept the same as the current regime.

A6.3.4 Surface water allocation options assessment

The allocation regime for the four spring-fed streams in the Ashley catchment have an additional layer of complexity. During the original notification process for the LWRP an issue was raised regarding the allocation limit for Saltwater Creek, Waikuku Stream, Little Ashley Creek and Taranaki Creek. It was found that the allocation limit for these streams had been set by summing the average rate of take of the existing consents. The standard practice at the time was to sum the instantaneous rate of take for the existing consents. Using the average approach generated allocation limits which were lower than they would have been if the standard method was used. Environment Canterbury undertook to fix this error when the LWRP became operative, and the current regional plan variation process is being used as the vehicle to do so.

As such, rather than considering the current LWRP allocation limit as an option, the LWRP adjusted allocation limit is considered alongside the other options. This adjusted figure was derived from literature produced when the original LWRP limit was set.

Under the LWRP there are no B blocks on the spring-fed streams. B blocks are generally incompatible with the hydrological character of spring-fed streams, and the WWZC was of the opinion that B blocks should not be pursued on these streams.

Table A6-18: Allocation options assessment summary: Ashley catchment

Watercourse	Allocation limit options	Consultation options	ZIPA recommendation	Rationale
Ashley River / Rakahuri A Block	<u>Current allocation</u> 1082 L/s <u>LWRP</u> 700 L/s	<u>LWRP</u> 700 L/s	<u>No change:</u> 700 L/s	Allocation block is over-allocated; focus on recovery of over-allocation.
Ashley River / Rakahuri B Block	<u>Current allocation</u> 139 L/s <u>LWRP</u> 500 L/s <u>Current allocation + mahinga kai allocation</u> Value tbc	<u>Current allocation + mahinga kai allocation</u> Value tbc	<u>From 2019:</u> Current allocation + mahinga kai enhancement allocation equal to 50 % of the available allocation at plan notification date.	The allocation size is being reduced to minimise the risk to flow variability in the future. An allocation for mahinga kai enhancement is proposed. While anyone could seek consent to take this water, it would need to be for mahinga kai enhancement, and co-managed by Environment Canterbury and Ngāi Tūāhuriri Rūnanga.
Ashley River/Rakahuri C Block	<u>Current allocation</u> 293 L/s <u>LWRP</u> 3,000 L/s <u>Current allocation +</u>	<u>Current allocation + mahinga kai allocation</u> Value tbc	<u>From 2019:</u> Current allocation + mahinga kai enhancement allocation equal to 50 % of the available allocation at plan notification date.	The reduction in the B block allocation limit provides a gap between the B and C blocks. It is being reduced to minimise the risk to flow variability in the future. An allocation for mahinga kai enhancement is proposed as per the B block

Watercourse	Allocation limit options	Consultation options	ZIPA recommendation	Rationale
	mahinga kai allocation Value tbc			
Saltwater Creek	Current allocation 550 L/s LWRP adjusted 417 L/s Feasible limit < LWRP adjusted allocation Value tbc	LWRP adjusted 417 L/s Feasible limit < LWRP adjusted allocation Value tbc	From 2019: 417 L/s	Allocation limit was not reduced given the significant work required to recover over-allocation. If any gains can be made in removing allocation from the system then this should not be reallocated, maximising the benefits to the stream, and to the Ashley Estuary (Te Aka Aka)
Waikuku Stream	Current allocation 1,033 L/s LWRP adjusted 831 L/s Feasible limit < LWRP adjusted Value tbc	LWRP adjusted 831 L/s Feasible limit < LWRP adjusted Value tbc	From 2019: 831 L/s	Allocation limit was not reduced given significant work to recover over-allocation. If any gains can be made in removing allocation from the system then this will not be reallocated, maximising the benefits to the stream, and to the Ashley Estuary (Te Aka Aka).
Little Ashley Creek	Current allocation 63 L/s LWRP adjusted 344 L/s	Current allocation 63 L/s	From 2019: 63 L/s	Significant water remains available in the allocation block, yet no areas of land are available to irrigate within the catchment. The creek is a contributor of flow to Waikuku Stream and Ashley Estuary (Te Aka Aka) and hence the Committee have capped the allocation to avoid adverse effects from future use.
Taranaki Creek	Current allocation 274 L/s LWRP adjusted 149 L/s	LWRP adjusted 149 L/s	From 2019: 149 L/s	Allocation limit was not reduced given significant work to recover over-allocation. If any gains can be made in removing allocation from the system then this will not be reallocated, maximising the benefits to the stream, and to the Ashley Estuary (Te Aka Aka).

The WWZC considered that, given the current degraded nature of the rivers and streams in the Waimakariri catchment, no more water should be taken. In NPS-FM language this allows the current state of streams and rivers to be maintained. The WWZC's decision was to reduce allocation limits to the water allocated on the date of plan notification, nominally June 2019. This approach does not allow a definitive number to be put on the allocation limit at this time, as it is subject to applications for consent to take water which are lodged up to June 2019. As such the number provided in the table below may differ from those discussed in the solutions assessment, and for those ultimately adopted in the plan. The above does not apply to SWAZ which are currently over-allocated. In this case the WWZC decided that the allocation limit should be retained, and effort focused on recovery of the over-allocation.

Table A6-19: Allocation options assessment summary: Waimakariri catchment

Watercourse	Allocation limit options	Consultation options	ZIPA recommendation	Rationale
Cam River / Ruataniwha A block	WRRP 700 L/s Current allocation (adjusted to LWRP stream depletion method) 155 L/s Ecological 311 L/s	WRRP 700 L/s Current allocation (adjusted to LWRP stream depletion method) 155 L/s	From 2019: 350 L/s + An allocation for mahinga kai enhancement shall be available equal to 50 % of the available allocation at date of plan notification.	The allocation block is to be reduced to current allocation levels, to prevent further degradation of the river, without impacting current water users. An allocation for mahinga kai enhancement is proposed. While anyone could seek consent to take this water, it would need to be for mahinga kai enhancement, and co-managed by Environment Canterbury and Ngāi Tūāhuriri Rūnanga.
North Brook	WRRP 200 L/s Current allocation (adjusted to LWRP stream depletion method) 269 L/s Ecological 183 L/s	WRRP 200 L/s Current allocation (adjusted to LWRP stream depletion method) 269 L/s	No change: 200 L/s	Current limit retained and over-allocation to be recovered.
Middle Brook	WRRP 30 L/s Current allocation (adjusted to LWRP stream depletion method) 29 L/s Ecological 8 L/s	WRRP 30 L/s	No change: 30 L/s	The flow regime is not being changed for this SWAZ because any changes would have a large impact on viability of the water take.
South Brook	WRRP 100 L/s Current allocation (adjusted to LWRP stream	WRRP 100 L/s Current allocation (adjusted to LWRP stream	From 2019: 38 L/s	The allocation size is being reduced to minimise the risk to flow variability in the future.

Watercourse	Allocation limit options	Consultation options	ZIPA recommendation	Rationale
	depletion method) 38 L/s Ecological 47 L/s	depletion method) 38 L/s Ecological 47 L/s		
Cust River A Block	WRRP 290 L/s Current allocation (adjusted to LWRP stream depletion method) 427 L/s Ecological 54 L/s	WRRP 290 L/s Current allocation (adjusted to LWRP stream depletion method) 427 L/s	No change: 290 L/s	The A block allocation is over-allocated and so efforts are to be focused on reducing the over-allocation. If these efforts result in reductions of allocation below the limit, then no new consents should be issued. This keeps the returned water in the river.
Cust River B Block	Cap at current allocated water (132 L/s) Alternate options being investigated	Cap at current allocated water (132 L/s) Alternate options based on reliability impact and residual flow analysis	Cap at current	B Block allocation limit is currently 'unlimited', limit required on all allocation blocks to comply with NPS-FM 2017 Large A block allocation means that low flows occur for long periods. Any increase in B block allocation would exacerbate an already pressured system
Cust Main Drain	WRRP 690 L/s Current allocation (adjusted to LWRP stream depletion method) 876 L/s Ecological 90 L/s	WRRP 690 L/s Adopt a lower value over time (no value was provided)	No change: 690 L/s	The A block allocation is over-allocated and so efforts are to be focused on reducing the over-allocation. If these efforts result in reductions of allocation below the limit, then no new consents will be issued. This keeps the returned water in the river
No.7 Drain	WRRP 130 L/s Current allocation (adjusted to LWRP stream depletion method) 69 L/s Ecological 44 L/s	WRRP 130 L/s Current allocation (adjusted to LWRP stream depletion method) 69 L/s	From 2019: 69 L/s	The allocation size is being reduced to minimise the risk to flow variability in the future.

Watercourse	Allocation limit options	Consultation options	ZIPA recommendation	Rationale
Ohoka Stream	WRRP 500 L/s Current allocation (adjusted to LWRP stream depletion method) 458 L/s Ecological 199 L/s	WRRP 500 L/s Current allocation (adjusted to LWRP stream depletion method) 458 L/s	No change: 500 L/s	This SWAZ is currently under-allocated but a change from the WRRP to the LWRP stream depletion regime is predicted to result in this catchment becoming over-allocated.
Silverstream	WRRP 1000 L/s Future allocation (adjusted to LWRP stream depletion method) 449 L/s Ecological 479 L/s	WRRP 1000 L/s Future allocation (adjusted to LWRP stream depletion method) 591L/s	From 2019: 591 L/s	The allocation size is being reduced to minimise the risk to flow variability in the future.
Courtenay Stream	WRRP 140 L/s Current allocation (adjusted to LWRP stream depletion method) 143L/s Ecological 108 L/s	Current allocation (adjusted to LWRP stream depletion method) 143L/s	From 2019: 140 L/s	The allocation size is being reduced to minimise the risk to flow variability in the future.
Greigs Drain	WRRP 70 L/s Current allocation (adjusted to LWRP stream depletion method) 24 L/s Ecological 83 L/s	Current allocation (adjusted to LWRP stream depletion method) 24 L/s	From 2019: 52 L/s	The allocation size is being reduced to minimise the risk to flow variability in the future.
McIntosh/Kairaki	Groundwater only 0 L/s	Groundwater only 0 L/s	Groundwater only 0 L/s	To protect the important wetland/ lagoon complex here the Zone Committee propose no surface water be available for allocation. Groundwater takes are

Watercourse	Allocation limit options	Consultation options	ZIPA recommendation	Rationale
				permitted, so long as they have a Low[35] stream depletion effect.
Eyre River	Groundwater only 0 L/s	Groundwater only 0 L/s	Groundwater only 0 L/s	This area has no permanently flowing waterways and hence assigning of a surface water block is problematic. It is proposed that there be no surface water block available in this SWAZ. All takes would be assigned to the groundwater allocation block.
Upper Eyre River	Current allocation (adjusted to LWRP stream depletion method) 99.5 L/s Current allocation + headroom (tbc) Allocation on a consent by consent basis	Current allocation (adjusted to LWRP stream depletion method) 99.5 L/s	89.5 L/s	The allocation size is being reduced to minimise the risk to flow variability in the future and will be capped at the current level of allocation.

A6.3.5 Groundwater allocation options assessment

Introduction

Current groundwater allocation limits allow for further allocation of groundwater from the Ashley, Kowai, Loburn, and Cust GAZs. In addition to this, groundwater consent holders in the Waimakariri Zone generally only use a relatively small proportion of their allocated volume (e.g. 40-50%)[36]. Groundwater abstraction rates could therefore also potentially increase without any additional water being allocated, if consent holders consistently start to use a higher proportion of their consented volume.

Increased irrigation efficiency associated with implementation of GMP is expected to mean that less Waimakariri River water will be applied via irrigation (e.g. the WIL scheme) to the land within the Waimakariri River tributaries catchment, and this will reduce drainage to and recharge of the aquifer system. Groundwater levels and flows in some of the spring-fed streams are likely to decline as a result.

Current Pathway Groundwater modelling

The effects of groundwater abstraction on stream flows and well reliability were modelled under four scenarios described in Table A6-20 and discussed in detail in Etheridge 2019a.: The Loburn GAZ and Lees Valley were not modelled because insufficient data were available to undertake a useful quantitative assessment here. Our assessment of the effects of increased abstraction (see below) are based on knowledge of the connectivity between these aquifers and the Ashley River/Rakahuri.

[35] As per Schedule 9 of the LWRP
[36] See Etheridge and Wong (2018)

Table A6-20: Model scenarios

Scenario name	Description	Purpose
GMP	Irrigation efficiency assumed to increase by 20%	Evaluate the effects of increased irrigation efficiency associated with implementation of GMP.
Full abs	Full abstraction. Assumes all consented wells use 100% of consented volume. Excludes Permitted Activity water takes (e.g. domestic and stockwater)	Explores potential effects of increased abstraction within current consent limits. This scenario could potentially eventuate as a result of climate change, for instance, if drought length and severity increases.
Full abs allo	Full abstraction, full allocation. Assumes all consented wells use 100% of consented volume in all GAZs except for Loburn, which is not included in the model. There is also currently no GAZ for Lees Valley, so the effects of any additional abstraction from this area have not been assessed. The additional allocation volume is taken from existing consented wells in the model (i.e. modelling assumes same spatial distribution of abstraction as current). Excludes PA takes.	Explores the maximum likely effects of groundwater abstraction that could potentially occur under current LWRP rules
Full allo cur use	Full allocation at current usage rates. As per Full_abs_allo scenario but assumes consent holders use same % of consent volume (e.g. 43%) as currently used	Assesses the effects of increased groundwater allocation up to the current LWRP limits, assuming usage rates remain the same as present (assumes no increase in water usage due to climate change etc.)

Current Pathway scenario modelling results

Eyre River, Ashley, Cust and Kowai GAZs

Our modelling results indicate that flows in some of the spring-fed streams within these GAZs could decline significantly if further water is allocated and/or if groundwater abstraction increases within the current allocated volume. Implementation of GMP could also cause significant declines in flows.

Groundwater levels in the lower Eyre GAZ are currently declining in some areas. Flows in some of the spring-fed streams are also likely to be declining, e.g. Silverstream. The main driver for this trend is likely to be a combination of climate, which has been dryer in the upper parts of the catchment for the last few decades, improved irrigation efficiency (conversion of border dyke to spray irrigation on the land upgradient of Silverstream) and increased groundwater abstraction. Further allocation of water, higher usage rates and/or improved irrigation efficiency for Waimakariri River-fed irrigation schemes could exacerbate this situation.

Increased groundwater abstraction could also reduce the reliability of water supply wells, if this caused groundwater levels to periodically fall below the pump intake level. We used the percentage of wells that could potentially be unreliable in a 1/20 year drought to assess whether the reliability component of Priority Outcome 4 is likely to be achieved for water wells located between the Ashley River/Rakahuri and Waimakariri River. Results showed that:

- Up to 20% of wells could potentially be unreliable in a 1/20 year drought at present
- This could increase to around 25% if water was allocated up to the current allocation limits and if all consent holders consistently abstracted their full consented volumes.

- Reliability would only reduce marginally (by a few percentage points) under the full allocation scenario if all consent holders consistently abstracted their currently consented flow rates or if they consistently took their full consented volume.

This is discussed further in Etheridge and Hanson (2019).

Loburn Fan and Lees Valley
Although we were unable to model higher groundwater abstraction scenarios for the Loburn Fan GAZ and in Lees Valley, we know that well yields are very low here. The Loburn Fan current allocation limit is based on a modelling method which is not well-suited to the local conditions and significantly over-estimates the sustainable yield of the aquifer. Both the Loburn Fan and Lees Valley drain to the Ashley River/Rakahuri; so any groundwater taken here will reduce the discharge to and flow in the Ashley River/Rakahuri by the corresponding amount. Although increased abstraction could result in some economic benefits associated with increased productivity, the low flows and associated water quality issues in the Rakahuri don't support the Community Outcomes. Megaughin and Lintott, 2019 discuss declining flows in the Ashley River/Rakahuri and Arthur *et al.* (2019) discuss the water quality issues. Given that well yields are very low here, the cost and likelihood of any significant increase in groundwater abstraction would be high and low respectively.

A6.3.6 Mahinga kai and stream health restoration options assessment

Our current state assessment and modelling of nitrate trends in the zone identified multiple drivers of poor ecosystem and hence mahinga kai health including:

- high nitrogen concentrations, resulting in toxin-induced and periphyton/plant growth effects
- current stream flows are insufficient for provision of aquatic habitat and fish passage, to maintain water quality and to reduce community stress
- poor riparian management.

The nitrate limits, minimum flows, and surface water allocation limit options required to protect instream ecosystem and mahinga kai values were explored with the WWZC as discussed in the preceding sections of this document.

In addition to elevated nitrate concentrations and poor environmental flow regimes, runoff contaminant discharges to surface water bodies (both past and present) and stream morphology were identified as key drivers for poor spring-fed stream and mahinga kai health. This results from poor riparian conditions which, if managed correctly, can intercept sediment, nutrients, and pathogens to waterways, and provide habitat and food resources for aquatic communities.

An expert panel was used to assess the likely effect of new (Plan Change 5[37]) and existing regional policies and rules relating to stock exclusion on waterway health. The assessment concluded that current management regimes around riparian management and stock exclusion are unlikely to resolve poor ecosystem health.

The expert panel was again convened to discuss and construct a prioritised list of management options for mitigating ecosystem health issues in the zone. These issues included:

- Overland flow pathways of contaminants – sediment, phosphorus, and faecal contamination.
- Accumulated streambed sediment.
- Soluble contaminant input via groundwater – predominantly nitrate but also other contaminants e.g., ammonia.
- Reduction in stream flows due to irrigation efficiency and climate change.
- Increased flow intermittency due to irrigation efficiency and climate change.
- Urban stormwater management.
- Reduced indigenous biodiversity due to pest and weed species.
- Reduced indigenous biodiversity due to habitat loss.
- Barriers to fish passage.

[37] New at that time; PC5 has since become operational

- Climate change resulting in reduced water resources and sea-level rise.
- The common themes identified in the "solutions toolbox" for improving ecosystem health were improving riparian health and the management of critical source areas of sediment (e.g. drains and bank erosion points). Options included:
- fencing waterways with a setback (e.g. 3 m or greater) from the top of stream banks;
- extensively planting of riparian margins and implementing weed control within these setbacks;
- providing additional setback protection, and/or installing sediment traps and/or wetlands at the base of critical source areas draining into streams and rivers;
- re-battering excessively steep banks that are prone to collapse;
- mechanically removing legacy bed sediment from streams (e.g. sediment traps, dredging and/or sand-wanding); and,
- removing or mitigating fish passage barriers.

The Zone Committee explored options for strengthening the current stock exclusion rules for the zone as detailed in the LWRP. Extensive discussion weighed the practicality and benefit of enforcing stock exclusion for different waterbody types (e.g. springs, wetlands, spring-fed streams and drains, high-country waterbodies, and irrigation and stock water races) of variable flow intermittencies (perennial, intermittent or ephemeral), and for different stock types (intensively versus extensively farmed cattle, deer, pigs, sheep and horses) and setback distances (e.g. 1-20 metres from the top of the waterway bank). The key conclusions of the WWZC discussions were:

- controlling stock impacts on spring-fed plains streams and rivers will have little benefit unless the arterial route of contaminants are controlled from drains and artificial watercourses that flow to streams and rivers;
- it is unreasonable to require land owners to fence watercourses without water in them, and it is better to manage these under existing (Jarred?) farm environment plan provisions for managing critical source areas;
- springs are tapu, hold special ecosystem and biodiversity values, and are the source of spring-fed streams so therefore require protection;
- no fixed distance for setbacks is appropriate for all situations or environments;
- heavy stock (particularly cattle) cause bank and streambed damage regardless of how intensively they are farmed;
- the seabed sediment in Te Aka Aka is degraded, i.e. muddy, in the inflow areas of spring-fed streams;
- on-the-ground actions will be required to improve bank structure and remedy legacy sediment from past land use activities; and,
- popular bathing areas are not recognised in Schedule 6 of the LWRP, which contains special provisions for stock exclusion to prevent faecal contamination and health risks in swimming areas.

The Zone Committee recommended extending stock exclusion provisions of the LWRP to springs, drains and artificial watercourses flowing to plains streams and rivers, and all farmed cattle in order to improve the health of instream ecosystems. They also recommended the inclusion of six bathing sites in Schedule 6 of the LWRP.

In addition to regulatory controls, the Zone Committee explored catchment management plans as a mechanism to initiate instream and riparian habitats projects, to improve mahinga kai and aquatic biodiversity in the zone. These plans are focused on sub-catchment level initiatives to educate and engage community and landowners and to secure resources for enhancement projects. Improvement of fish passage through lowland structures such as tide gates to improve mahinga communities would be one such project.

Harris (2019) analysed the rough order costs of fencing, planting, re-battering of collapsed banks and steep banks, sediment removal, and sediment traps using case studies with available stream walk data on the biodiversity restoration work required. The analysis indicates that the total cost of undertaking all of these items would be in the order of $60 million. This includes all of the Ashley and Waimakariri tributary spring-fed streams (excluding drains). The largest part of the costs is for planting, re-battering of steep slopes, and sediment traps. Costs do not include ongoing operating costs. For some of these items the operating costs would be considered within the normal purview of farm operation – for example fencing maintenance. Retired areas and plantings could require weed control in the future depending on how well they were created, and wetlands may require removal of material. Sediment traps require regular clearance of material for effective ongoing operation.

Such measures would be required to achieve the iwi outcome of a significant improvement to mahinga kai within a generation. This is desired so that iwi may continue cultural teachings and practices, which may otherwise be lost between generations, and to mitigate the significant social impact currently being experienced by tangata whenua.

APPENDIX 7: ZIPA recommendations and assessments further details

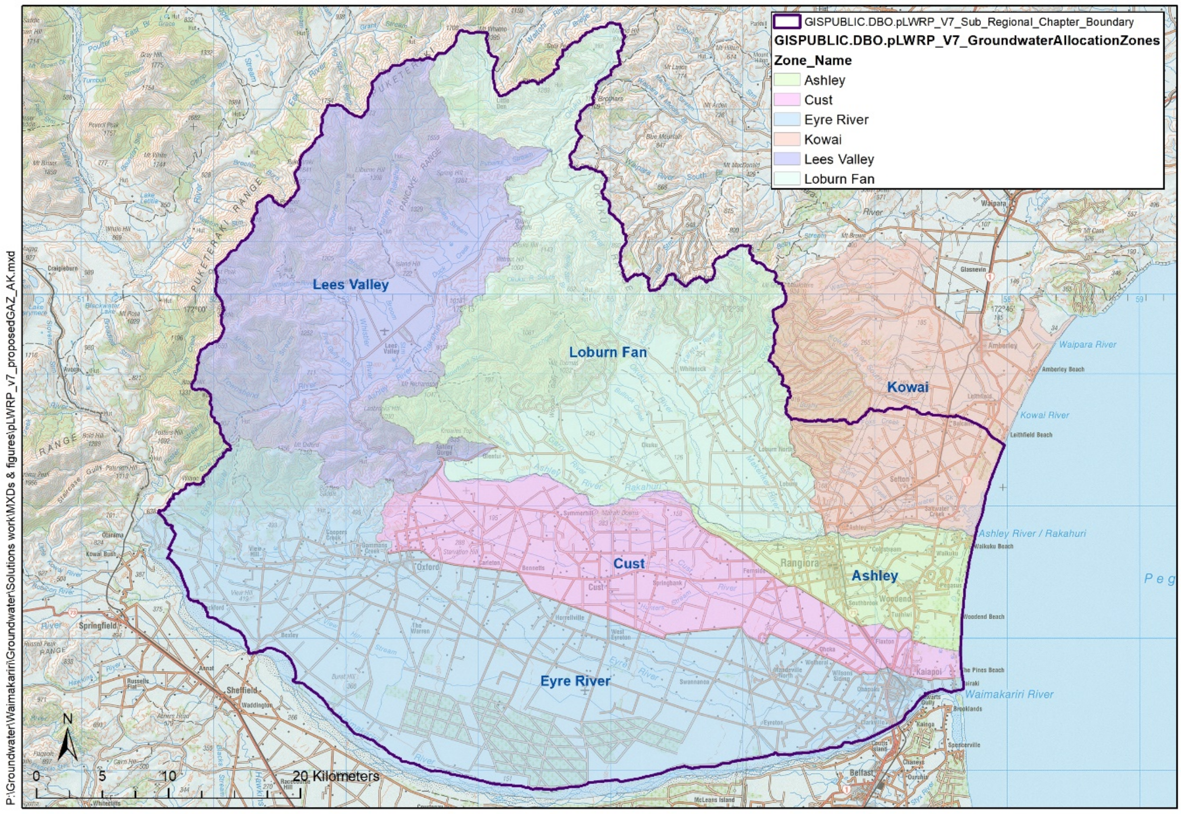
A7. ZIPA recommendations and assessment further details

A7.1 Groundwater allocation

The ZIPA includes the following recommendations for groundwater allocation:

GAZ	Recommended allocation limit	Rationale
Kowai	Current allocated volume + 10% for additional takes that are not stream-depleting.	Reduces potential for future increases in groundwater abstraction. Reduces the potential for further declines in Saltwater Creek and local groundwater levels due to new abstraction. Supports current reliability of existing water takes.
Ashley	Current allocated volume plus an amount to enable switches from surface water to groundwater in SWAZs where surface water is over-allocated (such as Ashley River/Rakahuri A Block, Taranaki Creek, Waikuku Stream, Saltwater Creek and Little Ashley Creek) + 10% for additional takes that are not stream-depleting	Reduces potential for future increases in groundwater abstraction. Reduces the potential for further declines in spring-fed streams and local groundwater levels due to new abstraction. Assists with ZIPA recommendations to recover overallocated surface water Supports current reliability of existing water takes.
Loburn	Current allocated volume + 10% for additional takes that are not stream-depleting.	Reduces potential for increase in groundwater abstraction which could exacerbate low flows in the Ashley River/Rakahuri and may result in increased duration, frequency and length of dry reaches.
Cust	Current allocated volume plus an amount to enable switches from surface water only for SWAZs where surface water is over allocated (e.g. Cust River A Block, Cust Main Drain) + 10% for additional takes that are not stream-depleting.	Full usage of the current allocated volume could cause flows in Ohoka Stream, Cust River and Cust Main Drain to reduce by more than 10%. Improved irrigation efficiency (GMP) is expected to cause flows in the Cust River and Cust Main Drain to decline by 16% and 12% respectively. Assists with ZIPA recommendations to recover overallocated surface water
Eyre River	No new allocation	Fully allocated
Proposed Lees Valley	Create GAZ Current allocated volume + 10% for additional takes that are not stream-depleting.	Move from unmanaged to managed groundwater abstraction. Increased groundwater abstraction from the Lees Valley area could have a significant effect on low flows in the Ashley River/Rakahuri

The proposed GAZ boundaries are shown below.



The groundwater allocation limits for each GAZ are presented below.

GAZ	Current allocation limit (m³/year)	ZIPA-based allocation limit (m³/year)	Transfer (T) Block (m³/year)
Ashley	29,400,000	11,349,884	18,050,116
Cust	56,300,000	13,247,877	29,088,946
Eyre River	99,070,000	75,326,541	23,743,459
Kowai	17,400,000	7,425,638	9,202,867
Loburn	40,800,000	16,046	N/A
Lees Valley	N/A	25,102	N/A

Under our Regional Plan (LWRP) rules a proportion of stream-depleting groundwater take allocated volume is assigned to the stream and the remainder to the groundwater unit. This proportion is based on the estimated stream depletion rate for each groundwater take, in accordance with the LWRP Schedule 9 rules. Whilst site-specific stream depletion assessments have been undertaken for some groundwater takes in the Waimakariri zone, no such assessments have been undertaken for many. We estimated stream depletion rates for these takes using a generic set of aquifer properties, based on local aquifer property data held within our database. The parameters used in our stream depletion assessments may be conservative (i.e. overestimate the stream depletion rate). This means that a higher proportion of the existing groundwater take consented volumes could be allocated to surface water, and a lower proportion to groundwater, than may ultimately be the case when site-specific stream depletion assessments are undertaken. The knock-on effect of this is that more accurate stream depletion assessments in the future could lead to designation of some of the GAZs as over-allocated.

This issue could be addressed by including plan provisions which allow for renewal of existing groundwater takes even when the GAZ is over-allocated.

Our modelling results show that reducing current allocation limits will help to avoid the significant reduction in spring-fed stream and river flows and declines in shallow water supply well reliability that could potentially occur if groundwater continues to be allocated up to the current allocation limits.

Provision of T Blocks, which allow for the transfer of surface water and stream-depleting groundwater in over-allocated surface water catchments will help to recover the over-allocation. Whilst the T block theoretically allows for more groundwater allocation in large parts of the Waimakariri zone, the effects of this allocation increase are expected to be beneficial for stream flows because the transfer is only available from surface water takes and stream depleting wells to wells which do not deplete stream flows significantly over the course of an irrigation season. A well interference assessment will be required as per Schedule 12 of the LWRP, which means that the reliability of existing wells will be protected.

MAR could improve well reliability and stream flows in some areas, by enhancing groundwater storage over winter such that more is available over subsequent dry periods when aquifers are depleted by natural drainage and groundwater abstraction.

Currently, the GAZ boundaries do not cover the entire zone leaving some areas outside of a GAZ. By extending the current GAZ boundaries a clearer and more robust groundwater management regime can be provided by including all areas within an allocation zone. Further details are provided in Etheridge (2019a).

A7.2 Nitrate concentration limits

Table A7-1 and Table A7-2 summarise current measured, projected Current Pathway and the ZIPA recommendations for surface water nitrate concentration limits in the Ashley River/Rakahuri FMU and Waimakariri northern tributaries FMU. We do not expect nitrate concentrations to increase for those watercourses in which the recommended Plan Limit nitrate concentrations are higher than Current Pathway and current state values because current Regional Plan rules and other ZIPA recommendations place strict limitations on future land use intensification.

For the Ashley River/Rakahuri and tributaries the ZIPA recommended limit is meant to provide no deterioration from present and aligns with limits recommended in the Cultural Health Assessment report.

Table A7-1: ZIPA Recommended nitrate limits for Ashley River/Rakahuri and tributaries

Watercourse	Current concentration (mg/L)	Current Pathway concentration (mg/L)	ZIPA Recommended Limit (mg/L)
Saltwater Creek	0.7	0.8	1.0
Waikuku Stream	1.2	1	1.0
Taranaki Creek	1.2	1.1	1.0
Little Ashley Creek	N/A	N/A	1.0
Ashley River/ Rakahuri at Gorge	0.2	0.2	0.2
Ashley River/Rakahuri at SH1	0.3	0.3	0.3

For the Waimakariri River and tributaries within the Waimakariri Zone, a comparison of current concentrations and projected Current Pathway concentrations to the ZIPA recommended limit shows the magnitude of nitrate concentration reductions that we expect the ZIPA recommendations to ultimately achieve in some waterways.

Table A7-2: ZIPA Recommended nitrate limits for Waimakariri River and tributaries

Watercourse	Current concentration (mg/L)	Current Pathways concentration (mg/L)	ZIPA Recommended Limit (mg/L)	Future goal (mg/L)
Silverstream at Harpers Rd	9.4	13.8	6.9	3.8
Silverstream at Island Rd	5.4	9.5	6.9	3.8
Courtenay Stream	3.1	4.7	3.8	-
Ohoka Stream	4.5	7.0	3.8	-
Cust Main Drain	4.7	6.2	3.8	-
Cam River / Ruataniwha	1.5	1.2	1.0	-
Waimakariri River at SH1	0.2	N/A	0.2 (threshold)	0.1 (threshold)

Although the WWZC made a recommendation for a nitrate limit for the Waimakariri River in the ZIPA, the intention of this limit was similar to the nitrate concentrations thresholds recommended for the Christchurch aquifer. These thresholds are not a proposed limit; they are intended to provide an indicative concentration which can be used to show the scale of nitrate reductions that may be needed to enable land users in the Waimakariri zone to support Priority Outcome 9 (play their part in maintaining the high quality of Christchurch groundwater).

A7.3 Solutions assessment results for stream nitrate concentrations

Nitrate concentrations in the Ashley River/Rakahuri tributaries either currently meet the proposed limits or are expected to do so in the near future, following implementation of GMP.

Our summary of nitrate modelling results for the Waimakariri River northern tributaries (Table A7-3) shows that whilst it could potentially take a long time to meet the proposed nitrate concentration limits in the Waimakariri River tributaries, there is significant uncertainty around the rate of change. The uncertainty is indicted by the figures in brackets which show 5th and 95th percentile estimates.

The time needed to meet the proposed nitrate concentration limits is illustrated by the plot of modelled nitrate concentrations over time in Figure A7-1 for Silverstream (Harpers Rd). The modelled concentrations account for the lag time between changes in land use/intensity (and associated nitrate losses to ground) and the full effects of these changes being seen in the receiving waters; the ZIPA Solutions plots also account for the ongoing staged reductions shown in Figure A7-1. The nitrate concentration limits recommended by the WWZC are marked on the figures. Our uncertainty analysis results (illustrated by 5th, 50th and 95th percentile lines) show that while nitrate concentrations have the potential to increase significantly from current measured values, this is not a given.

Table A7-3: ZIPA recommendations nitrate modelling results for Waimakariri River tributaries

Stream	ZC limit (mg/L)	Current Pathway nitrate-N (mg/L)	Reduction needed (%)	Target reached (years)
Kaiapoi River at Harpers Rd	6.9	13.8 (7.7-20.3)	50 (10-66)	45 (15-155)
Kaiapoi River at Island Rd	6.9	9.5 (5.7-13.5)	27 (0-49)	35 (0-55)
Courtenay Stream	3.8	4.7 (3.2-6.6)	19 (0-42)	30 (0-55)
Ohoka Stream	3.8	7.0 (4.2-10.0)	46 (10-62)	70 (20-95)
Cust Main Drain	3.8	6.2 (3.7-9.2)	39 (0-59)	75 (0-110)
Cam River / Ruataniwha	1.0	1.2 (0.8-1.9)	17 (0-47)	1.2 mg/L* (0.8-1.8 mg/L*)

Red – concentration exceeds ZC limit. Uncertainty analysis Figures in brackets show 5th and 95th percentile estimates. Target reached in “0” years means nitrate concentration will always be below ZC limit

* Nitrate concentration unlikely to be achieved by ZIPA recommendations. No further nitrate reductions for this receptor after first stage ZIPA recommendations (under which N loads reduce due to PA rule changes), as the recharge area for this receptor is outside the NPA; therefore, no beyond GMP baseline reductions occur in subsequent stages.

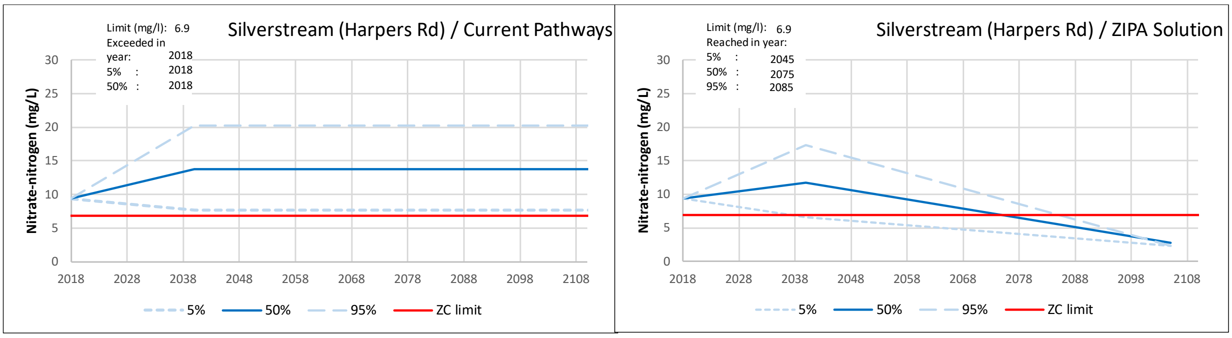


Figure A7-1: Modelled nitrate concentrations over time for selected spring-fed streams

A7.4 Further detail explaining solutions reached for the issue of nitrate in water supplies and the Christchurch aquifer

The potentially long timeframes required to meet the limits in some of the PWSAs relate to both:

- the lag time between reducing nitrate losses from the soil root zone and the arrival of this lower nitrate drainage water at downgradient water supply wells; and
- the rate at which nitrate losses are reduced.

These points are illustrated in the graphs below, which provide indicative plots of nitrate concentrations over time under the Current Pathway scenario and under the ZIPA recommendations. As per the stream nitrate model results plots in A6.3.1, the plots include the median model nitrate projections and an uncertainty envelope constrained by the 5th and 95th percentile steady state model nitrate results.

The long lag times are shown in the Current Pathway plots, with nitrate concentrations projected to reach equilibrium after ~65-120 years.

The wide uncertainty range over future nitrate concentrations is shown by the difference between the 5th and 95th percentile model results. Under the best plausible case scenario (5th percentile model results), nitrate concentrations will remain below the ZIPA limit in all the PWSAs except one: Eyreton. It is expected to take a long time (~70 years) to achieve the limit for Eyreton. Measured nitrate concentrations in the Eyreton area are currently high (e.g. ~10 mg/L) and a number of private well owners have raised concerns about concentrations exceeding the drinking water limit in their wells. The model projections of high nitrate concentrations here, with a significant reduction in nitrate discharges in the upstream area being required to achieve the limits, are therefore supported by measurement and anecdotal information. The likelihood of nitrate concentrations exceeding the drinking water limit in private wells elsewhere in the Waimakariri zone, with a long period of beyond Baseline GMP reduction required to achieve the ZIPA limit, is less clear. ZIPA recommendation 3.19 proposes that Environment Canterbury make resources available to improve understanding of nitrate concentrations in private supply wells. This recommendation aims to reduce the current level of uncertainty over nitrate concentrations and trends in the large number of private water supply wells within the Waimakariri zone.

Recommendation 3.24 supports investigation and assessment of on-the-ground actions such as MAR to address nitrate issues. We explained in Section A6.3.1 that a MAR investigation is currently underway in the area upstream of Silverstream, i.e. in the Eyreton PWSA, and that the results to date have demonstrated that it is possible to infiltrate a significant quantity of clean water into the aquifer here at relatively low cost. Upscaling the current investigation into a MAR scheme could help to reduce nitrate concentrations in private wells much more quickly that the beyond Baseline GMP staged nitrate loss reductions alone.

The ZIPA does not recommend extension of private water supply wells into the deeper part of the aquifer as a solution to elevated nitrate concentrations. This is because deep groundwater nitrate concentrations are already high in some parts of the Waimakariri zone and are expected to increase over time due to lag effects. Increased abstraction from the deep aquifer via private wells would accelerate this rate of increase.

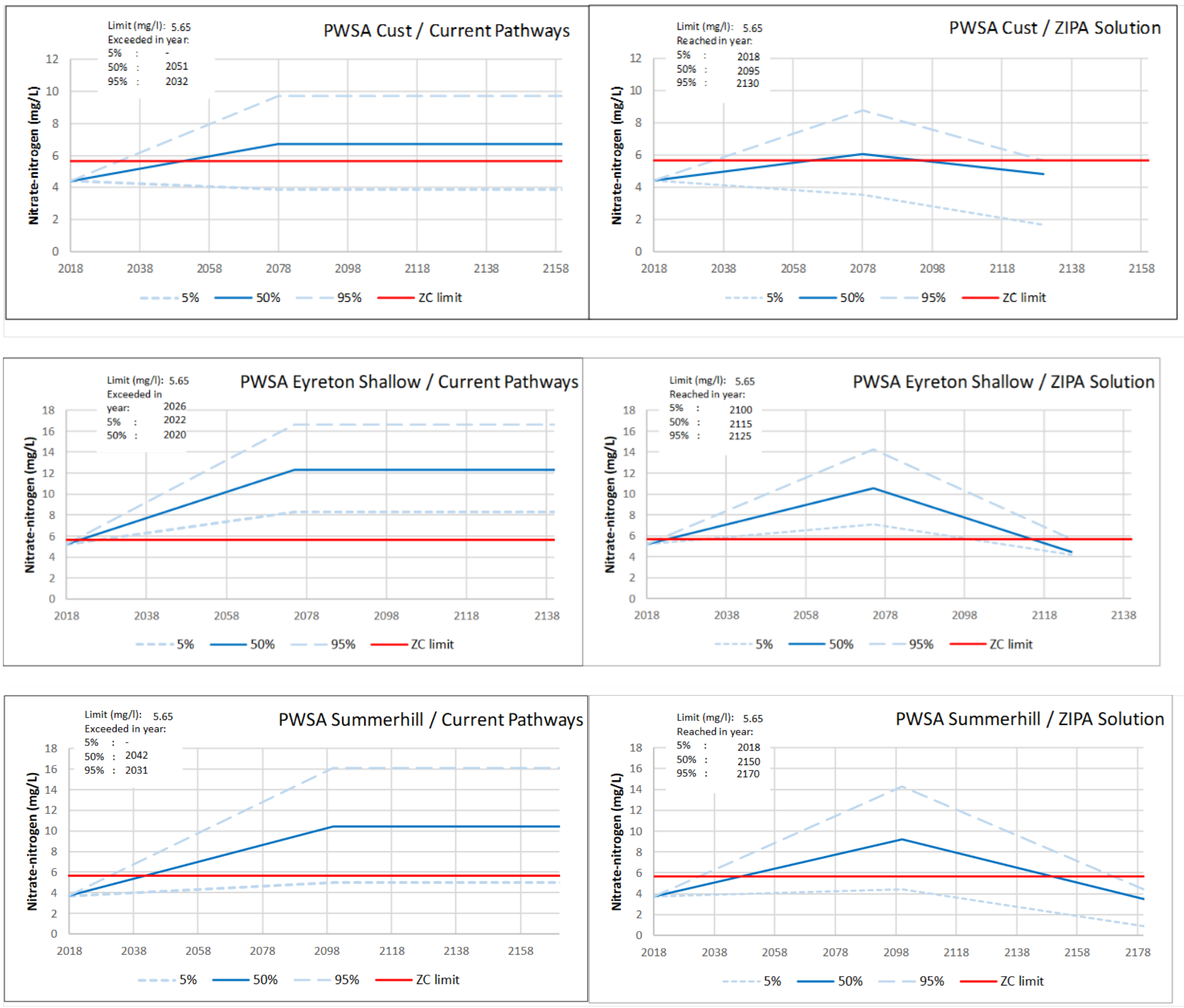


Figure A7-2: Indicative nitrate concentration plots for three PWSAs

A7.5 Nitrate in community water supply wells

Modelling projections of when the ZIPA limit for community supply wells is likely to be achieved (Table A7-4) range from zero years, for those wells that are currently below and expected to stay below the limit, to 125 years. The long durations primarily relate to the long groundwater travel times between recharge areas and the deep parts of the aquifer tapped by many of these wells. This is illustrated more clearly in the plots of modelled nitrate concentration over time presented in Kreleger and Etheridge (2019a), one of which (Kaiapoi wells) is reproduced in Figure A7-3 below. Nitrate concentrations are not expected to be within the ZIPA limit until 2150 under the 50th percentile model results, with a 30 year period (2120 – 2150) during which the 5.65 mg/L limit is likely to be exceeded. Although this duration could potentially be reduced to some degree by increasing the beyond Baseline GMP N loss reduction rates required for land users in the community water supply well recharge areas, the WWZC did not consider that this would strike the best balance between achieving their environmental and economic outcomes, particularly given the significant uncertainty range apparent in the 5th and 95th percentile model results which is clearly illustrated in Figure A7-3.

Table A7-4: Nitrate-N modelling results for WDC wells

Supply area	Current Pathway (mg/L)	Lag time (year)	Beyond Baseline GMP N loss reduction needed (%)	Time taken to reach target (years)
Cust	6.4 (3.9-9.1)	100	12 (0-38)	110 (0-140)
Fernside	5.5 (2.9-8.0)	20	0 (0-29)	0 (0-7.35 mg/L*)
Kaiapoi	6.8 (3.3-10.8)	100	17 (0-48)	120 (0-150)
Kairaki	5.4 (3.3-7.9)	100	0 (0-28)	0 (0-135)
Mandeville	8.1 (5.1-11.7)	42	30 (0-52)	75 (0-100)
Ohoka	7.7 (4.7-11.1)	88	27 (0-49)	120 (0-150)
Oxford Urban	3.0 (1.5-6.2)	70	0 (0-9)	0 (0-80)
Pegasus	3.2 (1.1-6.4)	100	0 (0-12)	0 (0-165)
Poyntzs Road	7.3 (4.6-10.9)	45	23 (0-48)	30 (0-150)
Rangiora	7.4 (3.2-11.9)	100	24 (0-53)	125 (0-160)
Waikuku	1.9 (1.1-3.4)	6	0 (0-0)	0 (0-0)
West Eyreton	5.8 (3.6-8.4)	66	3 (0-33)	70 (0-105)

Purple – concentration exceeds ZC limit

Red – concentration exceeds MAV

Target reached in "0" years means nitrate concentration will always be below ZC limit

* Nitrate concentration unlikely to be achieved by ZIPA recommendations. No further nitrate reductions for this receptor after first stage ZIPA recommendations (under which N loads reduce due to PA rule changes), as the recharge area for this receptor is outside the NPA; therefore, no beyond GMP baseline reductions occur in subsequent stages.

Nitrate-N concentrations in the Tuahiwi Marae supply well are currently low and are expected to stay well below 5.65 mg/L under the Current Pathway scenario.

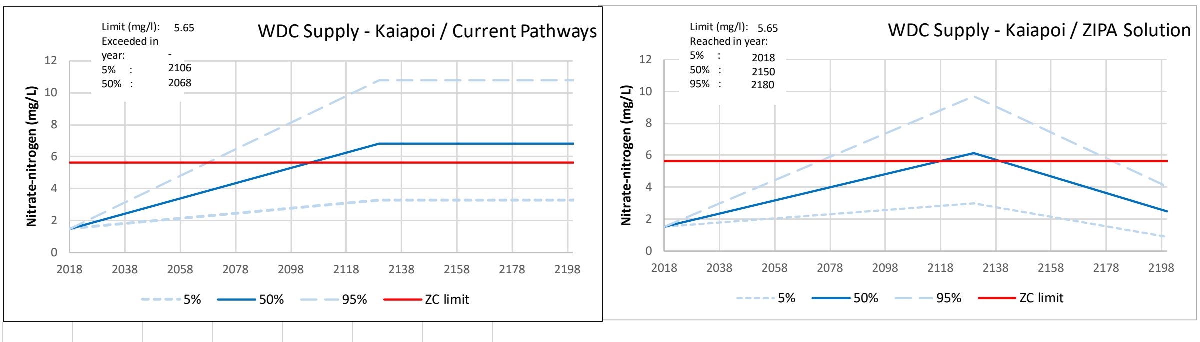


Figure A7-3: Modelled nitrate concentrations over time in Kaiapoi water supply wells

A7.6 Nitrate in the Christchurch aquifer

Model results for the ZIPA solution plotted in Figure A7-4 show that implementation of the ZIPA nitrate management recommendations is expected to reduce the rate of nitrate concentration increase in the city aquifer and to ultimately reduce concentrations to below the 3.8 mg/L threshold recommended by the WWZC.

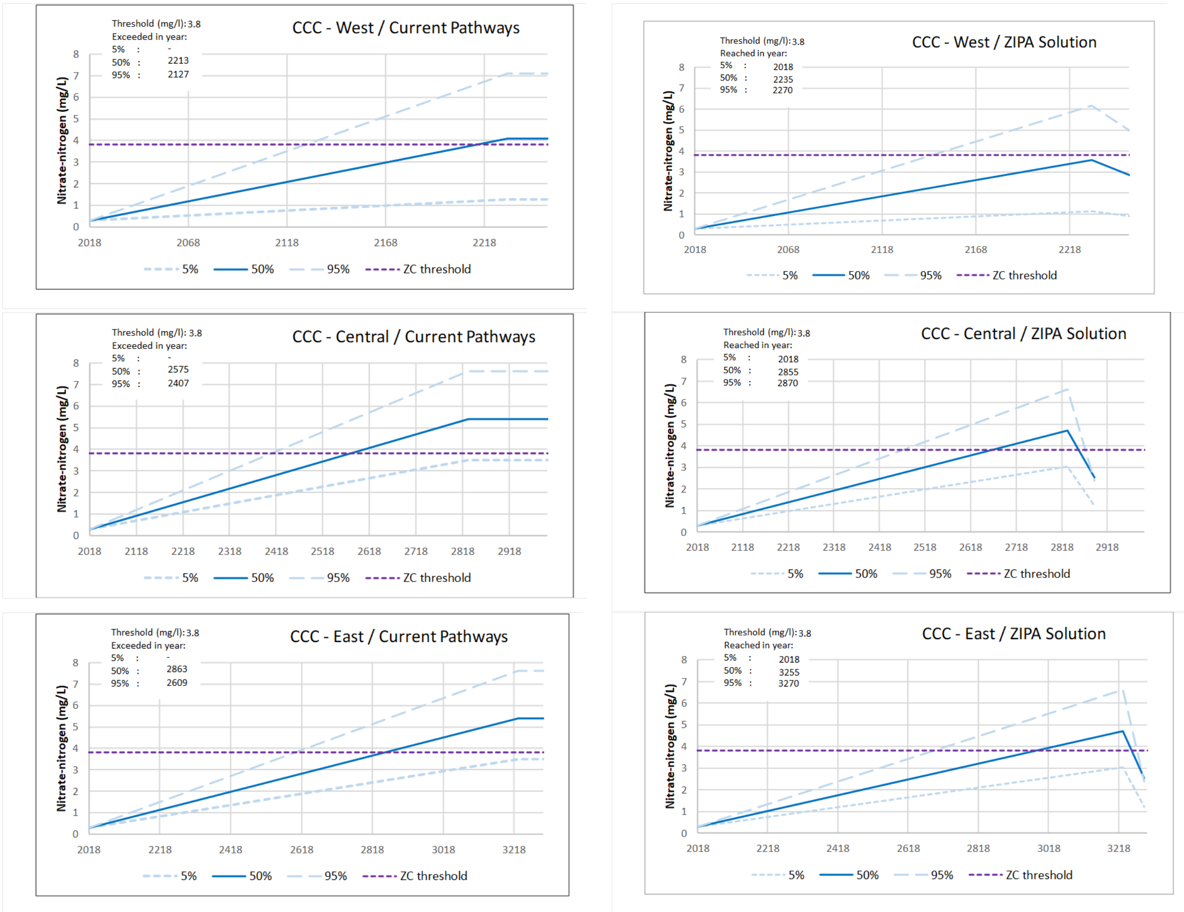


Figure A7-4: Modelled nitrate concentrations over time in western, central and eastern areas of the deep Christchurch aquifer system

APPENDIX 8: Current plan limits compared to ZIPA recommendations

A8.1 Freshwater outcomes for Waimakariri Water Zone rivers and lakes

Table A8-1: Proposed freshwater outcomes for Waimakariri Water Zone rivers. Values highlighted in grey cells are the same as the proposed region-wide default values as presented in Hayward *et al.* (2019). Red text are default values in the current version of Table 1a of the LWRP; green text are proposed default values in Hayward *et al.* (2019); and blue cells and text are proposed changes to attributes and values (respectively) for Section 8 (Waimakariri Zone) of the LWRP.

Freshwater Management Unit	River type	Ecological Health Attributes			Macrophyte Attributes		Periphyton Attributes		Siltation Attribute	Human Health for Recreation Attribute				Cultural Attribute
		QMCI[38] [min score]	Dissolved oxygen [min % saturation]	Temperature [max] [°C]	Emergent macrophytes [max cover of bed] (%)	Total macrophytes [max cover of bed] (%)	Chlorophyll a [mg chl-a/m²]	Filamentous algae >20mm [max cover of bed]	Fine sediment <2mm diameter [max cover of bed] (%)	SFRG[39]	*E.coli* [*E.Coli* /100mL] Median [40] [cfu/100ml]	95th percentile[4] [cfu/100ml]	Cyanobacteria mat cover [max % cover of bed]	
Ashley River / Rakahuri	Natural state waterbodies	Rivers are maintained in their natural state												
	Alpine - upland	6	90	20	No value set		50	10	10	Good	130	540	20[41]	Freshwater mahinga kai species sufficiently abundant for customary gathering, water quality is suitable for their safe harvesting, and they are safe to eat.
	Hill-fed - upland								15	Good			20[41]	
	Hill-fed - lower						200	30		Good to Fair	130	1000	~~50~~ ~~50~~ 20[41]	
	Spring-fed - plains	5	70		30	50			20	No value set	~~260~~ 130[42]	~~1200~~ 1000[42]	~~50~~ ~~50~~ 20[41]	
Northern Waimakariri Tributaries	Natural state waterbodies	Rivers are maintained in their natural state												
	Hill-fed - Upland	6	90	20	No value set		50	10	15	Good	130	540	20[41]	Freshwater mahinga kai species sufficiently abundant for customary gathering, water quality is suitable for their safe harvesting, and they are safe to eat.
	Hill-fed - Lower						200	30		Good to Fair	130	1000	20[41]	
	Spring-fed Plains	5	70		30	50			20	~~No value set~~ ~~No value set~~ Good to Fair[43]	~~260~~ 130[42]	~~1200~~ 1000[42]	~~50~~ ~~50~~ 20[41]	
	Spring-fed Plains - urban	~~3.5~~ 4.5			30	60			30	No value set	~~260~~ 130[42]	~~1200~~ 1000[42]	~~50~~ ~~50~~ 20[41]	

[38] QMCI = Quantitative macroinvertebrate community index.

[39] SFRG = Suitability for Recreation Grade as per *Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas* (MfE, 2003).

[40] To be determined from a minimum of 60 samples collected over 5 years on a monthly basis.

[41] Consistent with MfE (2009) 'surveillance level' guideline for protecting human health for recreation.

[42] Consistent with NOF band B for protecting human health for recreation. Important for minimising human health risks associated with swimming, and mahinga kai gathering and consumption.

[43] Spring-fed plains waterways in this FMU are valued by the community for swimming (e.g. Cam River at Bramleys Rd, and Kaiapoi River (Arthur *et al.*, 2019)). The outcome is set consistent with an SRFG recommended by MfE (2003) for protecting human health associated with primary contact recreation.

Table A8-2: Proposed freshwater outcomes for Waimakariri Water Zone lakes. Values in grey are the same as the proposed region-wide default values as presented in Hayward *et al.* (2019). Red text are default values in the current version of Table 1a of the LWRP; green text are proposed default values in Hayward *et al.* (2019); and blue cells and text are proposed changes to attributes and values (respectively) for Section 8 (Waimakariri Zone) of the LWRP.

Freshwater Management Unit	Lake type	Lake	Ecological Health Attribute				Eutrophication Attribute			Visual Quality Attribute	Human Health for Recreation Attribute				Cultural Attribute
			Dissolved oxygen (min saturation) [%]		Temperature [max] [°C]	Lake SPI[1] [min grade]	TLI[44] [maximum annual average]	Chlorophyll a		Colour	Cyanobacteria [either mm³/L or cells/mL] [max value]	E. coli [E. Coli /100mL]		SFRG[45]	
			Minimum Hypolimnion	Minimum Epilimnion				Maximum annual average* [µg/L]	Annual maximum [µg/L]			Median[46] [cfu/100ml]	95th percentile[46] [cfu/100ml]		
Ashley River / Rakahuri	Artificial – other	Lake Pegasus	~~20~~ ~~20~~ 70[47]	~~Suitable for the purpose of the lake~~ ~~Suitable for the purpose of the lake~~ 90[47]	~~Suitable for the purpose of the lake~~ ~~Suitable for the purpose of the lake~~ 19[48]	~~Suitable for the purpose of the lake~~ ~~Suitable for the purpose of the lake~~ n/a[49]	4.0[50]	5	25[51]	Natural colour not degraded more than five Munsell Units	~~10 or 1.8 mm3/L of potentially toxic cyanobacteria~~ 10 or 0.5 mm3/L of potentially toxic cyanobacteria[52]	130[53]	~~1200~~ 540[53]	~~Suitable for the purpose of the lake~~ ~~Suitable for the purpose of the lake~~ Good[54]	Freshwater mahinga kai species sufficiently abundant for customary gathering, water quality is suitable for their safe harvesting, and they are safe to eat.
	Coastal lake	Tūtaepatu Lagoon	70	90	19	Moderate	~~6.0~~ 5.0	12	60		10 or 1.8 mm3/L of potentially toxic cyanobacteria[55]	130	1200	No value set	

[44] Trophic level index

[45] SFRG = Suitability for Recreation Grade as per *Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas* (MfE, 2003).

[46] To be determined from a minimum of 60 samples collected over 5 years on a monthly basis.

[47] Condition 8c of the Lake Pegasus consent requires there to be no persistent seasonal stratification in the lake leading to oxygen depletion. Value is set to be consistent with other lake types as per the proposed region-wide default values (Hayward *et al.*, 2019). Currently stratification is occurring, and solutions are being sought to remedy this.

[48] Value is set to be consistent with other lake types as per the proposed region-wide default values (Hayward *et al.*, 2019).

[49] Knowledge of the macrophyte community is poor for Lake Pegasus and macrophyte condition is not relevant for the purpose of the lake (which is primarily for secondary contact recreation activities).

[50] Currently the lake is more consistent with hypertrophic conditions but reaches supertrophic in the summer months with cyanobacteria blooms. Aim for a maximum TLI consistent with mesotrophic conditions and infrequent cyanobacteria blooms.

[51] Seasonally high blooms of cyanobacteria occur in Lake Pegasus; however consent requirements are such that blooms should not occur. Outcome value is consistent with proposed region-wide default value (Hayward *et al.*, 2019) and NOF band B (MfE, 2017).

[52] Consistent with: 'Alert' level guideline as per "New Zealand Guidelines for Cyanobacteria in Recreational Fresh Waters – Interim Guidelines" (MfE, 2009); and proposed region-wide default value (Hayward *et al.*, 2019).

[53] Outcome value is well within monitored *E. coli* levels over summer (Arthur, 2019) and consistent with NOF band A (MfE, 2017).

[54] The Pegasus Lake and ECMA Management Plan (Golder Assoc., 2016) states that the lake and its waters purpose are primarily to be used for secondary contact recreation activities such as kayaking and sailing. However, the site is monitored as part of Environment Canterbury's primary contact recreation water quality monitoring programme (Arthur, 2019) and full immersion activities are known to take place in the lake. Pegasus lake currently contains a provisional (i.e. 4 year) SFRG of 'very good' (Arthur, 2019) so outcome is being met.

[55] Consistent with: 'Action' level guideline as per "New Zealand Guidelines for Cyanobacteria in Recreational Fresh Waters – Interim Guidelines" (MfE, 2009); and proposed region-wide default value (Hayward *et al.*, 2019).

Table A8-3: Water quality limits (white cells) and targets (underlined, bold text) for Waimakariri Water Zone rivers. There shall be no deterioration of water quality beyond limits or water quality will improve to meet water quality targets by a specified target date (to be defined in the plan). Values in grey cells are the same as the proposed region-wide default values as presented in Hayward *et al.* (2019). Red, crossed-out text are default values in Schedule 8 of the current version of the LWRP; green, crossed-out text are proposed default values in Hayward *et al.* (2019); and blue cells and text are proposed changes to attributes and values (respectively) for Section 8 (Waimakariri Zone) of the LWRP.

Freshwater Management Unit	River type	Representative River name and measurement location	NZTM2000 Map Reference		Dissolved Inorganic Nitrogen (DIN)[56,57] [5-year median[58]] [mg/L]	Dissolved Reactive Phosphorus (DRP)[57] [5-year median[58]] [mg/L]	Nitrate-Nitrogen[59]		Ammoniacal Nitrogen[60]	
			Easting	Northing			Annual median[61] [mg/L]	Annual 95th percentile[62] [mg/L]	Annual median[58] [mg/L]	Annual maximum[58] [mg/L]
Ashley River / Rakahuri	Hill-fed Upland	Ashley River / Rakahuri at Gorge	1537355	5213583	0.06	0.002	~~N/A~~ ~~N/A~~ 0.2	~~N/A~~ 0.5	~~0.03~~ 0.01	~~0.05~~ 0.07
	Hill-fed - Lower	Ashley River / Rakahuri at SH1	1574736	5208399	0.18	0.004	~~N/A~~ ~~N/A~~ 0.3	~~N/A~~ 0.6	~~0.03~~ 0.01	~~0.05~~ 0.02
	Spring-fed Plains	Taranaki Creek at Preeces Rd	1574757	5208291	0.55	0.013	~~3.8~~ ~~3.8~~ 1.0[63]	~~5.6~~ 1.5	~~0.24~~ 0.03	~~0.40~~ 0.07
		Waikuku Creek at SH1	1574465	5206975	0.44	0.008	~~3.8~~ ~~3.8~~ 1.0[63]	~~5.6~~ 1.5	~~0.24~~ 0.02	~~0.40~~ 0.03
		Saltwater Creek at Factory Rd	1574730	5210832	0.30	0.016	~~3.8~~ ~~3.8~~ 1.0	~~5.6~~ 1.5	~~0.24~~ 0.03	~~0.40~~ 0.13
		Little Ashley Creek at SH1	1574507	5207281	0.20	0.026	~~3.8~~ ~~3.8~~ 1.0	~~5.6~~ 1.5	~~0.24~~ 0.04[64]	~~0.40~~ 0.17[64]
Northern Waimakariri Tributaries	Hill-fed lower	Cust River at Tippings Rd[65]	1547647	5205419	n/a	0.008	~~N/A~~ ~~N/A~~ **3.8**[66]	~~N/A~~ 6.4	~~0.03~~ 0.02	~~0.05~~ 0.12
	Spring-fed plains	Cust Main Drain at Skewbridge Rd	1569938	5197879	n/a	0.023	**3.8**	~~5.6~~ 6.4	~~0.24~~ 0.02	~~0.40~~ 0.16
		Cam River / Ruataniwha at Bramleys Rd	1570577	5200988	0.66	0.008	~~3.8~~ ~~3.8~~ **1.0**	~~5.6~~ **1.5**	~~0.24~~ 0.02	~~0.40~~ 0.05
		Ohoka Stream at Island Rd	1570219	5197465	n/a	0.015	**3.8**	~~5.6~~ 6.4	~~0.24~~ 0.02	~~0.40~~ 0.16
		Silverstream at Harpers Rd	1564806	5191961	n/a	0.002	~~3.8~~ ~~3.8~~ **6.9**	~~5.6~~ **9.8**	~~0.24~~ 0.01	~~0.40~~ 0.02
		Silverstream at Island Rd	1570316	5197431	n/a	0.008	~~3.8~~ ~~3.8~~ 6.9	~~5.6~~ 9.8	~~0.24~~ 0.02	~~0.40~~ 0.09
		Courtenay Stream at Neeves Rd	1571355	5194431	n/a	0.030[67]	3.8	~~5.6~~ 6.4	0.24[68]	0.40[68]

56 Limit only assigned if controlling for nuisance periphyton or macrophyte growth, or macroalgae growth in Te Aka Aka as a receiving environment. Not applicable (n/a) applied as a "value" when controlling for the effects of nitrate toxicity (i.e. nitrate-nitrogen limit or target is >1.0 mg/L).

57 Neither the current version of the LWRP or Hayward *et al.* (2019) contain DIN or DRP limits for rivers.

58 Unless otherwise stated, based on 2011-2016 current state data as per Greer and Meredith (2016), limited Environment Canterbury monitoring data, or NIWA investigation data (NIWA, 2016).

59 Current version of LWRP only contains a default nitrate toxicity (annual median) limit for spring-fed plains and spring-fed plains urban streams.

60 Based on pH 8 and temperature 20°C.

61 With the exception of the Cust River at Tippings Rd, nitrate-nitrogen limits (annual median) were recommended in the Waimakariri Zone Implementation Plan Addendum (ZIPA) based on modelling data and extensive WWZC discussions. See Etheridge and Kreleger (2019) for more detail.

62 For sites with annual median nitrate-nitrogen limits ≥ 1.0 mg/L, annual 95th percentile limits are based on NOF toxicity band thresholds that correspond with the relevant NOF annual median limit set for each site (MfE, 2017). For sites with annual median nitrate-nitrogen limits < 1.0 mg/L, annual 95th percentile limits are based on current state 95th percentile Hazen values from data collected between 2011-2016.

63 Considered a limit based on current state maximum annual median between 2011-2016 being less than this value. Waimakariri ZIPA quotes a higher maximum annual median based on 2008-2018 data, which is greater than this value.

64 Limited monitoring data for Little Ashley Creek between 2011-2016. Limit based on overall 5-year median value (for annual median limit) or 5-year maximum value (for annual maximum limit).

65 No long-term water quality monitoring is current undertaken in the Cust River at Tippings Rd. The site is a physically and ecologically different to the Cust Main Drain site, and it is therefore recommended that limits are set here. DRP and ammoniacal nitrogen limits are based on NIWA 2012-2016 monitoring of Cust River at Bennetts Bridge, approx. 4 km upstream of Tippings Rd site (Jellyman and Sinton, 2016).

66 Limit based on the same Waimakariri ZIPA limit of Cust Main Drain. The site shares the similar up-gradient catchment source area for nitrogen loading as Cust Main Drain, both are at times connected, and the site is valued as a brown trout fishery.

67 No monitoring data for Courtenay Stream at Neeves Rd. Conservative limit based on current state of other spring-fed plains streams in WWZ and limited monitoring taken from Courtenay Stream above floodgates.

68 No monitoring data for Courtenay Stream at Neeves Rd. Limit based on NOF band B (MfE, 2017) for ammonia toxicity, which corresponds with that recommended in the Waimakariri ZIPA for nitrate-nitrogen toxicity at the site.

Table A8-4: Water quality limits (white cells) and targets (underlined, bold text) for Waimakariri Water Zone <u>lakes</u>. There shall be no deterioration of water quality beyond limits or water quality will improve to meet water quality targets by a specified target date (to be defined in the plan). Values in grey cells are the same as the proposed region-wide default values as presented in Hayward *et al.* (2019). Red, crossed-out text are default values in Schedule 8 of the current version of the LWRP; green, crossed-out text are proposed default values in Hayward *et al.* (2019); and blue cells and text are proposed changes to attributes and values (respectively) for Section 8 (Waimakariri Zone) of the LWRP.

Freshwater Management Unit	Lake type	Lake name and measurement location	<u>NZTM2000 Map Reference</u>		Total phosphorus (mg/L)[69]	Total Nitrogen[69] [mg/L]	Ammoniacal Nitrogen concentration[70] (mg/L)	
			<u>Easting</u>	<u>Northing</u>	Annual average[71]	Annual average[71]	Annual median	Annual maximum
Ashley River / Rakahuri	Artificial – other	Lake Pegasus[72]	1575421	5204960	~~0.020~~ ~~0.020~~ **<u>0.05</u>**[73]	~~0.340~~ ~~0.340~~ **<u>0.750</u>**[73,74]	~~1.3~~ 0.03[75]	~~2.2~~ 0.05[75]
	Coastal lake	Tūtaepatu Lagoon[76]	1576209	5204897	~~0.096~~ **<u>0.05</u>**[73]	~~1.560~~ **<u>0.800</u>**[73]	~~1.3~~ 0.03[75]	~~2.2~~ 0.05[75]

[69] Numeric freshwater objective to achieve trophic outcomes for the lake.

[70] Based on pH 8 and temperature of 20ºC

[71] Metric of annual average for total phosphorus and total nitrogen consistent with that represented in proposed default LWRP limits (Hayward *et al.*, 2019), but NPSFM NOF attribute states are measured as annual medians (MfE, 2017).

[72] Limited monitoring with available data collected between 2017-2018 by Golder Assoc. (2018). Lake Pegasus limits referenced against NOF attribute states for seasonally stratified lakes.

[73] Annual average limit consistent with NOF national bottom line (annual median) (MfE, 2017).

[74] Higher than proposed default LWRP limit (Hayward *et al.*, 2019) because Lake Pegasus total nitrogen levels are high due to groundwater influences. Core groundwater recharge area with nitrogen loading is the Cust area, which requires multiple stages of beyond Good Management Practise (GMP) nitrogen load reductions as part of Waimakariri ZIPA recommendations (see Etheridge and Kreleger, 2019).

[75] Consistent with NPSFM NOF band A (MfE, 2017), which protects 99 percent of species from the effects of ammonia toxicity. Limited data for each lake so not appropriate to set limit based on current state.

[76] Limited monitoring with only 3 samples collected between 2015-2016 by Environment Canterbury. Tūtaepatu Lagoon limits referenced against NOF attribute states for polymictic lakes.

A8.2 Environmental flow regimes – surface water

Table A8-5: ZIPA recommendations minimum flows and allocation Ashley River/Rakahuri FMU (strikeout text where ZIPA recommendations differ from current plan limits)

River or stream (see Planning Maps)	Minimum flow site	Minimum flow for A permits (L/s)[1]		Allocation limit for A permits (L/s)	Minimum flow for B permits (L/s)	Allocation limit for B permits (L/s)	Minimum flow for C permits (L/s)	Allocation limit for C permits (L/s)
		From 28 June 2019	From 01 January 2032					
Ashley River/Rakahuri	Ashley Gorge (recorder)	2,500 (Jan-Jul), 4,000 (Aug-Nov), 3,000 (Dec)	2,500 (Jan-Jul), 4,000 (Aug-Nov), 3,000 (Dec)	700	3,200 (Jan-Jul), 4,700 (Aug-Nov), 3,700 (Dec)	~~500~~ 135	6,000	~~3,000~~ 494
Waikuku Stream	Waikuku Beach Road	150	150	~~460~~ 831	No B allocation	No B allocation	No C allocation	No C allocation
Little Ashley Creek	State Highway 1	50	50	~~172~~ 43	No B allocation	No B allocation	No C allocation	No C allocation
Taranaki Creek	Preeces Road	120	120	~~61~~ 149	No B allocation	No B allocation	No C allocation	No C allocation
Saltwater Creek (Sefton)	Toppings Road	100	~~100~~ 148	~~408~~ 417	No B allocation	No B allocation	No C allocation	No C allocation

Table A8-6: ZIPA recommendations minimum flows and allocation Waimakariri River northern tributaries FMU (strikeout text where ZIPA recommendations differ from current plan limits)

River or stream (see Planning Maps)	Minimum flow site	Minimum flow for A permits (L/s)[1]		Allocation limit for A permits (L/s)	Minimum flow for B permits (L/s)		Allocation limit for B permits (L/s)
		From 28 June 2019	From 01 January 2027		From 28 June 2019	From 01 January 2027	
Cam River / Ruataniwha	Youngs Road (recorder)	1000	1000	~~700~~ 350	~~1,700~~ No B allocation	~~1,700~~ No B allocation	~~No limit~~ No B allocation
North Brook	Marsh Road	530	~~530~~ 560	200	~~730~~ No B allocation	~~730~~ No B allocation	~~No limit~~ No B allocation
Middle Brook	Marsh Road	60	60	30	~~90~~ No B allocation	~~90~~ No B allocation	~~No limit~~ No B allocation
South Brook	Marsh Road	140	~~140~~ 155	~~100~~ 38	~~240~~ No B allocation	~~240~~ No B allocation	~~No limit~~ No B allocation
Cust River	Oxford Road	20	~~20~~ 60	290	310	~~310~~ 350	~~No limit~~ 131
Cust Main Drain (recorder)	Threlkelds Road	230	230	690	~~920~~ No B allocation	~~920~~ No B allocation	~~No limit~~ No B allocation
No.7 Drain	Hicklands Road	60	60	~~130~~ 69	~~190~~ No B allocation	~~190~~ No B allocation	~~No limit~~ No B allocation
Ohoka Stream	Island Road	300	~~300~~ 420	500	~~800~~ No B allocation	~~800~~ No B allocation	~~No limit~~ No B allocation
Silverstream	Neeves Road	600	~~600~~ 900	~~1,000~~ 591	~~1,600~~ No B allocation	~~1,600~~ No B allocation	~~No limit~~ No B allocation
Courtenay Stream	Neeves Road	260	~~260~~ 330	140	~~400~~ No B allocation	~~400~~ No B allocation	~~No limit~~ No B allocation

River or stream (see Planning Maps)	Minimum flow site	Minimum flow for A permits (L/s)[1]		Allocation limit for A permits (L/s)	Minimum flow for B permits (L/s)		Allocation limit for B permits (L/s)
		From 28 June 2019	From 01 January 2027		From 28 June 2019	From 01 January 2027	
Greigs Drain	Greigs Road	150	230	~~70~~ 52	~~220~~ No B allocation	~~220~~ No B allocation	~~No limit~~ No B allocation
Upper Eyre River	Trigpole Road	54	54	89.5	No B allocation	No B allocation	No B allocation
Eyre River	No minimum flow site	-	-	No surface water allocation	-	-	No surface water allocation
McIntosh / Kairaki	No minimum flow site	-	-	No surface water allocation	-	-	No surface water allocation

Notes:

The ZIPA recommendations are Zone Committee's recommendations for how the proposed Plan Change 7 should be written. Through the development of the ZIPA recommendations the Zone Committee settled on a number of guiding principles which they used to set allocation limits and minimum flows. These are provided below as they show the intent of what the committee were seeking to achieve through the numbers they have recommended.

- For SWAZ which are currently under-allocated the committee adopted a 'cap at current' allocation approach to setting allocation limits. This recognised that the stream values are degraded by the current level of allocation, and to leave further allocation available would be to risk further degradation. By capping the allocation the Zone Committee intended to also halt the degradation.
- For SWAZ which are currently over-allocated the committee recommended that the allocation limit be kept at the existing level, and that efforts should be focused on recovering the over-allocation. It was the intent of the committee that any water recovered below the allocation limit should not be available for re-use.
- Minimum flows were adopted on a SWAZ by SWAZ basis. The committee used the cultural and ecological recommendations as starting points and took careful consideration of the effects on supply reliability of adopting new minimum flows.

The minimum flows and allocation limits have been selected by the Zone Committee to manage surface water quantity in balance with the many other competing outcomes considered; such outcomes include water supply reliability, cultural use, ecological requirements and recreation / amenity value.

The approach taken by the Zone Committee in deciding allocation limits was to cap at the current level of allocation for any catchment which was not fully allocated at the time this work was undertaken. In the options assessment and solution assessment 'cap at current' was taken to be the allocation as at November 2017, the date of the Resource Consent Inventory (Vattala, 2019). Since November 2017 the consent inventory has changed because of new consents being granted, conditions changed and consents expiring. To determine what the 'Cap at Current' allocation limit for the plan is to be a reassessment of the Resource Consent Inventory was required.
Currently the SWAZs in the WRRP have B blocks with no limit (i.e. unlimited). The current minimum flow for the B blocks is positioned directly above the A block (a stacked block system). This prolongs flatlining if the river flow and does not represent current best practice. To comply with the National Policy Statement for Freshwater Management 2014 (amended 2017) a limit is required on all allocation blocks

A8.3 Groundwater allocation limits

Table A8-7: ZIPA recommendations for groundwater allocation

Groundwater Zone	Current allocation limit (m^3/year)	ZIPA-based allocation limit (m^3/year)
Ashley	29,400,000	11,349,884
Cust	56,300,000	13,247,877
Eyre River	99,070,000	75,326,541
Kowai	17,400,000	7,425,638
Loburn	40,800,000	16,046
Proposed Lees Valley	No limit	25,102

Notes:

The Waimakariri Water Zone Committee (WWZC) have recommended (via their Zone Implementation Programme Addendum [ZIPA]) that no further groundwater should be allocated in the Eyre River GAZ and that groundwater allocation limits for the remaining GAZs should be capped at the current allocated volume + 10%.
A new GAZ is suggested for the Lees Valley area and extension of the existing GAZ boundaries, to coincide with the hydrological catchment boundaries, is proposed.

A8.4 Water quality limits – nitrate

Table A8-8: ZIPA recommendations for water quality limits - nitrate

Receptor	DWS-NZ (mg/L)[77]	ZC limit[78] (mg/L)	Indicator	Future goal (mg/L)
Private water supply wells	11.3	5.65	At least 50% of all samples collected from each private supply well area should meet the limit	All private drinking water supply wells should meet the Nitrate-nitrogen Drinking Water Standards at all times
Community water supply wells Waimakariri District Council	11.3	5.65	100% of all samples collected from community supply wells should meet the limit, recognising that it may take some time to achieve this	N/A
Christchurch deep aquifer	11.3	3.8 (indicative threshold)	Average nitrate-nitrogen concentration in all samples collected from wells >80 m deep should be less than the limit	1.0

Table A8-9: Proposed nitrate limits by the zone committee for surface water

Receptor	ZC limit (mg/L)	Indicator[79]	Future goal (mg/L)
Silverstream[80] at Harpers Road	6.9	Annual median concentration should reduce to below this limit over time	3.8
Silverstream[80] at Island Road	6.9	Annual median concentration should remain below this limit	3.8
Courtenay Stream	3.8	Annual median concentration should remain below this limit	-
Ohoka Stream	3.8	Annual median concentration should reduce to below this limit over time	-
Cust Main Drain	3.8		-
Cam River / Ruataniwha	1.0		-

[77] New Zealand Drinking Water Standard Maximum Acceptable Value (MAV)
[78] For the Christchurch Aquifers the limit is referred to as "threshold"
[79] Based on current measured nitrate concentrations
[80] The upper reaches of the Kaiapoi River, e.g. the section of watercourse from the springheads to the three streams confluence, is commonly referred to as Silverstream.

Receptor	ZC limit (mg/L)	Indicator[79]	Future goal (mg/L)
Cam River / Ruataniwha	1.0	Annual median concentration should reduce to below this limit over time	-
Saltwater Creek	1.0	Annual median concentration should remain below this limit	-
Waikuku Stream	1.0	Annual median concentration should reduce to below this limit over time	-
Taranaki Creek	1.0		-
Little Ashley Creek	1.0	Annual median concentration should remain below this limit	-
Ashley River/Rakahuri at Gorge	0.2		-
Ashley River/Rakahuri at SH1	0.3		-
Waimakariri River at SH1	0.2 (indicative threshold)	Waimakariri zone plays its part in preventing deterioration on Waimakariri water quality	0.1

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