Draft memo

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To	Waimakariri Zone technical team
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From	Jarred Arthur

Alternative Pathways: assessment of ecosystem effects

An expert panel has been commissioned to provide technical advice for the Waimakariri sub-regional planning process. As part of this work, the panel assessed the likely effects of different scenarios on aquatic ecosystem health. Initially, a 'Current Pathways' scenario (i.e. Good Management Practise (GMP) under a "Business as Usual" approach) assessment was completed and is used as a baseline for comparing and assessing other scenarios for the Waimakariri Zone. The results of the Current Pathways expert panel assessment can be found in an associated memorandum[1].

The expert panel also assessed the effects of an 'Alternative Pathways' scenario on aquatic ecosystem health. The primary focus of the Alternative Pathways scenario is the construction of a new water storage scheme in the upper Ashley River/Rakahuri catchment. This memorandum details the assessment including:

- assumptions of the Alternative Pathways scenario including:
- details of the new water storage reservoir and its application.
- assumptions to be retained from the Current Pathways scenario.
- results of nitrate and flow modelling under both the Current and Alternative Pathways scenarios.
- potential options for stream flow augmentation to reduce stream nitrates in the zone.
- draft minimum flow assessment results for ecological and cultural values in waterways.
- technical metrics assessed by the expert panel.
- assessment methodology used by the panel.
- results of the assessment.

[1] *Current Pathways: background information and ecosystem assessment results* – Environment Canterbury memorandum from Michael Greer to Waimakariri technical team 31/10/2016

Alternative Pathways: new water storage in the upper Ashley River/Rakahuri catchment

Background

Water storage reservoirs can provide a reliable source of water for irrigation and other purposes at times when surface and groundwater levels are low and demand for water use is high. However, additional water storage is often accompanied by changes to land-use and hydrological regimes. For the expert panel to assess the effect of new water storage on aquatic ecosystem health, a number of assumptions needed to be quantified. Specifically, how new water will be used, and what land-use changes will occur.

Key assumptions

New water storage would be constructed in the north of Lees Valley, capturing water from stream in the upper Ashley River/Rakahuri catchment. The following outlines the key assumptions of the water storage scheme.

- The reservoir will cover approximately 1,750 ha of land and have a storage capacity of 115 million m^3.
- The majority of stored water will be used for irrigation.
- A total of 12,600 ha of newly irrigated land will result from the scheme.
- Appendix 1 shows the locations of newly irrigated areas. Land allocated for new irrigation in each sub-unit is as follows:
    - Loburn 3,300 ha
    - Lees Valley 550 ha
    - Cust/Ashley/Eyre 8,750 ha
- Newly irrigated land in Lees Valley will change to dairy support. Newly irrigated land in the Loburn and Cust/Ashley/Eyre areas will change to 50% dairy and 50% dairy support.
- Any changes to existing wetland extent resulting from the reservoir's construction will be offset by the creation of new artificial wetlands.
- Existing nutrient allocation zone (NAZ) rules apply.
- Existing Land and Water Regional Plan (LWRP) stream depletion rules apply across the entire zone.
- A combination of existing and new distribution races will be used to distribute water to newly irrigated areas.
- New distribution races will be constructed such that water loss is minimised (effectively nil loss). Existing race losses is assumed to be 10% of abstracted flow rate across all existing races.
- 20 million m^3 of water that is stored each year will be allocated for environmental flow purposes. This volume equates to 900 L/s of low-flow support in the Ashley River/Rakahuri during the irrigation season.

- Any support for fresh/flood flow provisions will be taken from the same allocation as low-flow support.

Assumptions retained from Current Pathways scenario

The Alternative Pathways scenario retains many of the previous assumptions made under Current Pathways. A summary of these are listed below.

- Nutrient load lags (i.e. those that are “in the post”) are taken into account.
- Stock exclusion is implemented in accordance to the LWRP. This will include any new fencing that needs to be installed due to land-use changes (e.g. change to dairy) resulting from new irrigation.
- Nutrient management of farms follows Matrices of Good Management (MGM) guidelines.
- Riparian management is applied according to Good Management Practises (GMP) (see Current Pathways memorandum for details).
- Population change continues, e.g. increase in urban areas.
- Climate change is realised, e.g. sea level rise.
- Indigenous biodiversity changes.
- Waimakariri District Council drinking water supplies and stormwater systems are adequate and up to standard.

Modelled nitrate and stream flows

New water storage and irrigation will likely result in land-use changes throughout the zone (Appendix 1). As a result, nutrient losses and hydrological regimes will also change. The following details modelling adjustments made to the nitrate and flow forecasting used for Current Pathways assessments. Furthermore, it summarises stream nitrate concentrations and flows as expected from increases in irrigation and water storage. More technical information is available in the Environment Canterbury draft technical report by Etheridge et al. (2017)[2].

<u>Nitrate and flow data updated since Current Pathways assessments</u>

Initial nitrate and flow data estimates, as modelled for the Current Pathways scenario, were later corrected (Appendix 2). This followed some “reality checking” of the Overseer/MGM-based nitrogen load layer against measured groundwater nitrate concentrations and stream nitrogen loads. The checking showed that the stocking rate was likely to be approximately 40% over-estimated. After adjusting the load layer for this, and changing some assumptions around lifestyle blocks, nitrogen loss estimates reduced significantly. In some instances, the

[2] Etheridge, Z., Megaughin, M. and Diettrich, J. (2017) Waimakariri Land and Water Solutions Programme: Alternative Pathways scenario – water management options assessment. Environment Canterbury draft technical report no. R17/xx ISBN 978-1-927210-99-4.

updated Current Pathways nitrate results are quite different from the results assessed by the expert panel previously.

Appendix 2 outlines the revised modelling results for Current Pathways nitrate and flow. Notably, the table details two sets of Current Pathways results: one purely based on modelling and another ("*Current Pathways adjusted model results"*) in which the results have been adjusted based on qualitative information and expert opinion. For example, it is assumed that there is no significant lag effect in the Cust catchment based on anecdotal information and a nitrogen trend analysis. The adjusted model results were treated as the most accurate baseline for the Alternative Pathways expert panel assessment.

Alternative Pathways nitrate and flow data

Modelled nitrate and flow values in Appendix 2 include those predicted as the result of new water storage in the Lees Valley ("*New irrigation"*). The effect of these nitrate concentrations and flows on instream ecosystem health were assessed by the expert panel taking into account the changes made to baseline (Current Pathways) nitrate concentrations. New irrigation results do not account for climate change or PC5PA rules; the latter of which is a Current Pathways assumption not retained by the Alternative Pathways scenario.

It is assumed that storage in the upper Ashley River/Rakahuri catchment will accrue water during the winter months, while providing much of its allocated low flow support during the dry summer months. "*New irrigation*" flow values displayed in Appendix 2 only represent changes as a yearly average and do not account for differences between season (e.g. irrigation and non-irrigation seasons). The magnitude, duration and seasonality of low flow events are important factors to consider when assessing the impact of changing flows on stream ecology. Supplementary flow information (e.g. flow duration curves for the irrigation season) for the Ashley River/Rakahuri was supplied to the expert panel detailing the flows in the Ashley River/Rakahuri. The magnitude or frequency of freshes and flood events in the Ashley River/Rakahuri were not available to be supplied. It may be assumed that fresh flow events will be provided from storage, albeit at the expense of a portion of the low-flow support allocation.

Ashley River/Rakahuri dry reach modelling

Extensive lengths of the Ashley River/Rakahuri dry regularly each year. However, 20 million m^3 of stored water will be allocated for environmental purposes each year (e.g. for low-flow support) and it is expected that the extent of drying in the river will change. A summary of dry reach modelling for the Ashley River/Rakahuri under the different scenarios is summarised in Table 1.

Table 1. *Simulated drying reach lengths in the Ashley River/Rakahuri based on both Current Pathways and Alternative Pathways assumptions.*

Scenario	Average length of drying (km)[1]	Maximum length of drying (km)[2]	Percentage of time dry[3]
Current Pathways	12.2	19.5	2.5 %
Alternative Pathways	11.6	19.5	1.7 %

[1] Based only on those days when river is dry.
[2] Maximum length of drying Ashley River/Rakahuri bed ever simulated.
[3] Comparing the entire river length over time; i.e. for each simulated river length over 20 years and forming a ratio of when the river is and isn't flowing.

Further information may be found in the Etheridge et. al (2017) draft technical report.

Ecological and cultural flow guidelines

Environment Canterbury commissioned external contractors to provide assessments of minimum flows based on ecological[3] and cultural[4] values. Ecological minimum flow values were considered by expert panel members when assessing stream flow effects on instream ecosystems. Appendix 3 summarises the results of both ecological and cultural flow assessments at the time of the Alternative Pathways assessment.

In summary, there is a high risk of over-allocating water throughout the zone. This may increase aquatic community stress levels by lengthening the time that streams and rivers spend at or below minimum flows. It is suggested that the effect of water extraction on flow variability is not of great concern for most lowland spring-fed waterways because flow in spring-fed streams is naturally stable with little variation (Golder Associates 2009). Minimum flow recommendations by Golder Associates (2009) make no suggestion of what proportion of flow should be allocated for abstraction. Waterways Consulting (2017) memorandums make minimum flow and allocation limit recommendations for the Ashley River/Rakahuri at Gorge, and four lowland spring-fed streams not covered by the Golder Associates (2009) report.

[3] Golder Associates (2009) Minimum flows and aquatic ecological values of lower Waimakariri River tributaries. Report prepared for Environment Canterbury. Report no. 07813138.
Ashley River at Ashley Gorge: minimum flow. Waterways Consulting memorandum to Environment Canterbury 13/2/2017.
Taranaki, Waikuku, Saltwater and Little Ashley: minimum flow. Waterways Consulting memorandum to Environment Canterbury 14/2/2017.
[4] Te Ngai Tuahuriri and Tipa & Associates (2017) Cultural health assessments and water management for the Rakahuri – Waimakariri Zone. Draft report supplied to Environment Canterbury.

Stream flow augmentation

A second component of the Alternative Pathways scenario examines the feasibility and benefits of stream flow augmentation in the zone. This would be by managed aquifer recharge (MAR) or targeted stream augmentation (TSA). The expert panel assessed flow augmentation independently of any effects associated with new water storage in the upper Ashley River/Rakahuri.

The water volumes for augmenting flow in target streams are detailed alongside other modelled flow values in Appendix 2. The purpose of augmentation is to dilute stream nitrate levels sufficiently to achieve the following concentrations:

- 6.9 mg/L
  - Silverstream at Harpers Road
- 3.8 mg/L
  - Silverstream at Island Road
  - Ohoka River at Island Road
  - Cust Main Drain
- 1.0 mg/L
  - Taranaki Creek at Preeces Road
  - Saltwater Creek at Factory Road

The water source for augmentation in Silverstream, the Ohoka River, and Cust Main Drain would be Waimakariri River water distributed via existing irrigation races. It was assumed that water quality is generally high, however the expert panel also considered the implications of high sediment loads often characteristic of Waimakariri River water. A potential solution to this would be to supply water via MAR, which would filter sediments through the ground.

Deep groundwater is the only feasible place to obtain water for the augmentation of Taranaki and Saltwater Creeks. While the viability of this approach was initially considered by the technical team, it was eventually deemed impractical and not assessed by the expert panel.

Technical metrics

The Waimakariri Water Zone Committee (WWZC) set a series of priority outcomes for the zone. It was the technical team's responsibility to assess the likelihood of these outcomes being met under the Alternative Pathways scenario. The outcomes relevant to the expert panel's ecological assessments are described below:

- The water quality and quantity of spring-fed streams maintains or improves mahinga kai gathering and diverse aquatic life. If this outcome is met will be determined by:
  - Aesthetics
  - Diversity and abundances of aquatic species (including pests)
  - Habitat

- Human health for recreation
- Overall flows plus low flows and minimum flows
- Water quality

- 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. If this outcome is met will be determined by:
    - Estuary assessment
    - Habitat
    - Human health for recreation
    - Overall flows plus low flows and minimum flows
    - Water quality

- 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. If this outcome is met will be determined by:
    - Diversity and abundance of aquatic species
    - Habitat
    - Human health for recreation
    - Social and recreation assessment
    - Water quality

The indicators described above are very broad and there are several metrics nested within “habitat” and “water quality” etc. These metrics need to be assessed to determine if the outcomes will be met under the Alternative Pathways scenario. These metrics can be broken down into three tiers:

- <u>Tier 1</u> metrics are the water quality and habitat parameters that will be directly affected by a change in land and/or water use including riparian management. These are:
    - Ammonia (toxicity)
    - Nitrate (toxicity)
    - Plant available nutrients
    - Sediment deposition
    - Suspended sediment
    - *Escherichia coli*
    - Flow

- <u>Tier 2</u> metrics are the water quality and habitat parameters that will be indirectly affected by a change in land and/or water use including riparian management (i.e. changes resulting from changing Tier 1 metrics). These are:
    - Cyanobacteria cover
    - Fish passage
    - Macrophyte cover
    - Periphyton cover
    - Connectedness

- <u>Tier 3</u> metrics are those that quantify trophic level and other value responses to Tier 1 and 2 changes. These are:
    - Invertebrate community health (QMCI)

- Fish diversity
- Human health risks
- Overall suitability for recreation

Assessment methodology

New water storage and irrigation

As was consistent with the Current Pathways scenario assessment, the expert panel assessed metrics qualitatively. For each sub-catchment unit, expert panel members presented their assessments for each metric using the format in the following example.

Metric: ***E. coli***			**Sub-catchment unit: Mississippi Basin**
Change	**Effect**	**Confidence**	**Justification**
-2 (Large -)	-2 (Strong -)	0 (Not	Change: In an area with low run off and no border dyke irrigation or tile drainage, direct access by stock will be the major source. Complete exclusion of intensively farmed stock should reduce levels. However, sheep farming is widespread in the area and will remain so with little added irrigation and land-use change predicted in the catchment. As these animals will not be excluded, a large improvement is not expected. This change is no different to that expected under the Current Pathways scenario. Effect: Although reductions across the area should be moderate, levels in key bathing sites are already controlled through upstream fencing and are well below guideline levels. Therefore, it is unlikely that the recreational value of actual bathing sites will improve. Confidence: Levels are already low, land use is not expected to increase, and riparian management practices will improve. There is no potential for further degradation but any improvements are unlikely to have an effect.
-1 (Moderate -)	-1 (Moderate -)	1 (Low)	
0 (No/negligible)	**0** **(No/negligible)**	2 (Moderate)	
+1 **(Moderate +)**	+1 (Moderate +)	**3** **(High)**	
+2 (Large +)	+2 (Strong +)		

Current Pathways assessment results were used as a baseline for scoring metric against. Expert panel members' scorings and narratives were collated and summarised to represent both consensus and differing opinions.

Ecological and cultural flows

Minimum flow values for protecting instream ecosystem values were used to assess the effect of changing flow regimes on fish diversity and other appropriate metrics. The expert panel was also given scope to comment on the appropriateness of current and suggested minimum flow values and allocation in the zone. Any comments were detailed in the justification section of scoring sheets.

Stream flow augmentation

The impact of stream flow augmentation on waterway health was assessed independently of new water storage and irrigation effects. Assessments were carried out on Silverstream, the Ohoka River, and Cust Main Drain using the same format as above.

Further information provided to panel.

Much of the background information necessary for the panel to conduct their assessments was supplied during the Current Pathways assessment process. This included maps of the zone's ecological, angling, recreational, cultural, commercial, and amenity values. A number of supporting reports, memorandums, and data summaries were also provided. These included:

- A memorandum detailing the background information and assessment results of the Current Pathways scenario.
- Environment Canterbury draft technical report: Waimakariri Land and Water Solutions Programme: Alternative Pathways Scenario – Water management options assessment.
    - Revised modelled nitrate and flow results under the Current Pathways scenario.
    - Modelled nitrate and flow results under the Alternative Pathways scenario.
    - Details of flow augmentation options in the zone.
    - Other relevant hydrological information.
- Flow duration curves displaying the effect of new water storage on Ashley River/Rakahuri flow during the irrigation season.
- Golder Associates (2009) technical report: Minimum flows and aquatic values of lower Waimakariri River tributaries
    - A background to the assessment methodology of ecological minimal flows for many streams in the Waimakariri Zone.
- Waterways Consulting (2017) minimum flow memorandums
    - Minimum flow modelling assessment methodologies and results for the Ashley River/Rakahuri at the Gorge.
    - Minimum flow modelling assessment methodologies and results for Waikuku Stream, and Little Ashley, Saltwater and Taranaki Creeks.
- Te Ngai Tuahuriri and Tipa and Associates (2016) draft report: Cultural health assessments and water management for the Rakahuri – Waimakariri Zone

- Background information and assessment data for cultural minimum flow recommendations.

- Assessment sheet templates for completion

Results – New water storage and irrigation

Unit 1: Ashley River below the Gorge and the Loburn Fan

Tier	Metric	Change	Effect	Confidence	Description of drivers/effects where applicable
1	Nitrogen	Moderate increase	Moderate negative	Low to moderate	There will be a significant increase in irrigation, particularly in the Loburn Fan, and a change to more intensive land-use practises. A moderate increase in nitrate with an expected move from the NOF A to B band in some waterways (e.g. the Garry and Okuku Rivers). A potential negative effect due to increases in toxicity to invertebrates and fish. Expected increases in problem periphyton and macrophyte growth if N is the limiting nutrient. Possible increases in cyanobacteria. Low to moderate assessment confidence due to a lack of modelling methods. No indication of uncertainty in the predicted changes for nitrate. Some increased confidence expressed by some panel members because modelled nitrate loss values seem realistic for the scale of intensification assumed in the Loburn Fan.
	Phosphorus	Negligible to moderate increase	Negligible to moderate negative	Low to moderate	Contrasting views on the extent of change in P. Some panel members believe that fencing and near-complete stock exclusion under GMP will sufficiently limit P input due to bank erosion and surface runoff. Others believe that 1 m fencing setbacks (as per the assumption) will allow critical source areas to prevail as well as there being a subsurface flow of P. Coupled with new irrigation and land-use intensification, this will result in moderate increases of P within the Loburn Fan. Potential increase in periphyton growth in P-limited waterways. A high uncertainty expressed by some members due to: the unknown role of legacy P in instream sediments; how

					effectively landowners will improve land management to counteract increased losses due to land-use intensification; and a lack of information about surface runoff by-pass flow through riparian setbacks and shallow subsurface P transport. Confidence lessened given the lack of modelled assessment.
	Sediment input	Negligible to moderate increase	Negligible to moderate negative	Low to moderate	The extent and mechanisms of change are consistent with those predicted for P above. Any predicted change will occur in Loburn Fan streams due to land-use intensification, whereas the dominant sediment source for the Ashley River is from higher in the catchment (e.g. Lees Valley). The degree of change will be less than that predicted for P due to mitigation resulting from GMP and a lack of subsurface inputs. There remains to be differences in opinion between panel members due to reasons explained under the P metric above. A moderate confidence is expressed due to the uptake of better land management practises that have already occurred and are likely to occur over the next ten years (e.g. cultivation buffer widths and critical source area protection). Greater stock exclusion requirements for dairy and intensive grazing is likely to reduce bank erosion to a degree. Low confidence because of lack of modelling and specific measures of sediment cover.
	Faecal contamination	Negligible to moderate increase	Negligible to moderate negative	Low to moderate	The extent and mechanisms of change and effect are consistent with those predicted for the P and sediment metrics above. It is presumed that there will be significant bacteria die-off during transport from upstream source areas. Low to moderate levels of confidence due to reasons highlighted under P and sediment input metrics.

	Flow	Negligible to moderate increase	Negligible to moderate positive	Low	The flow assessment is based on changes in the Ashley River only. Additional water storage will not impact flow in Loburn Fan streams. The Ashley River will experience a small to moderate reduction in annual median flow. However, a moderate increase in 7dMALF is expected during the irrigation/dry season due to environmental flow releases. A 0.5-0.9 m^3/s flow increase will reduce the number of dry days downstream and should provide for a small improvement in connectivity and fish habitat area. Much of the additional water supplied could be lost to ground relatively quickly though. Confidence is low as no modelling methods or uncertainty has been provided. There would be a significant amount of additional information required to adequately assess the effect or magnitude of effect resulting from a change in flow. No information on any groundwater take reductions or transfers to surface water sources. Limited info on release programme/consistency. No longitudinal flow monitoring (loggers, not spot-gauging) or modelled hydrographs, and the flow connection model does not appear to cover the post-2000 period when much of the intensification and conversion to spray irrigation is likely to have occurred.
2	Plant growth	Moderate increase	Moderate negative	Low	An increase in periphyton is likely because of increasing N and potentially P concentrations. The extent of increase is dependent on nutrient limitation in the streams, but will likely be limited by P and not proportional to the increase is N. A moderately negative effect on aesthetic and ecological values will result if periphyton growth (including cyanobacteria) exceeds guidelines. High uncertainty due to lack of information relating to nutrient and flow metrics.

	Connectedness	Moderate increase	Moderate positive	Low	Flow releases from Lees Valley storage are predicted to slightly reduce the duration of dry periods and the length of drying reaches in the Ashley River. Other waterways, including those in the Loburn Fan, are not affected. Small improvements in fish passage, but of limited benefit overall. Issues around uncertainty are the same as those expressed for the flow metric.
3	Invertebrate community health	Moderate decrease and moderate increase	Negligible	Low	It is predicted that there will be a small benefit to invertebrate health in the Ashley River. This is due to increased habitat margin areas and lower mortality due to decreased drying extents and days. Higher nitrate will have a negative impact on invertebrate communities in Loburn Fan streams due to increased toxicity. Also, a decline in health resulting from increased sediment and periphyton growth should this occur. Flow on effects are likely to be negligible, but there is a low chance of some trophic implications (e.g. as a food source for fish). Confidence is limited by the same constraints as discussed for the Tier 1 and 2 metrics, especially flow.
	Fish diversity	Moderate negative and moderate increase	Negligible	Low	For the Ashley River, there is likely to be an increase in habitat for fish due to increased wetted area, and a reduction in mortality due to a reduced length of dewatered river. The increased duration of connection may also allow for more upstream passage opportunities for migratory species. Higher nitrate will have a negative impact on fish communities in Loburn Fan streams due to increased toxicity. Also, a decline in health due to increased sediment and periphyton growth should this occur. Flow on effects are likely to be negligible, but there is a low chance of some trophic implications.

					Confidence for change in fish community health is largely limited by the same constraints as discussed for the Tier 1 and 2 metrics, especially flow. Improved stock exclusion may possibly improve edge habitat for fish, but there is a low confidence around the response of plant growth and possible impacts on fish diversity. Lack of riparian planting requirements (outside of SDWA requirements) will further restrict improvements in diversity.
	Overall suitability for recreation	Negligible to moderate decrease	Negligible to moderate negative	Low	Overall suitability for recreation is only assessed for the Ashley River. It is difficult to assess most aspects of recreation suitability other than faecal contamination. Though there may be recreational health risks due to cyanobacteria growth (i.e. *Phormidium*). Increased flows in the Ashley may allow some swimming holes to persist for longer during summer, but the benefit likely to be small. May be some increases in fishable water and fish abundance. Confidence of assessment is low. No knowledge or information on other variables that affect 'swimmability' such as turbidity, and *Phormidium* presence and abundance. Environmental flushing flows could clear *Phormidium* growths, but no information on how or if these will be a component of the environmental flow provision.

Unit 2: Lower Ashley Catchment spring-fed streams and coastal wetlands

Tier	Metric	Change	Effect	Confidence	Description of drivers/effects where applicable
1	Nitrogen	Negligible	Negligible	Low	Streams not as closely connected to new irrigation and land-use intensification. No changes in modelled nitrate concentrations when compared to the Current Pathways assessment. Low assessment confidence due to a lack of modelling methods to review. No indication of uncertainty in the predicted changes for nitrate.
	Phosphorus	Negligible	Negligible	Moderate	No change or effect predicted relative to the Current Pathways assessment. No newly irrigated land in the catchment.
	Sediment input	Negligible	Negligible	Moderate	No change or effect predicted relative to the Current Pathways assessment. No newly irrigated land in the catchment.
	Faecal contamination	Negligible	Negligible	Low to moderate	No change or effect predicted relative to the Current Pathways assessment. No newly irrigated land in the catchment.
	Flow	Negligible	Negligible	Low to moderate	No change or effect predicted relative to the Current Pathways assessment.
2	Plant growth	Negligible	Negligible	Low	No change expected from the Current Pathways assessment due to little or no change in P and N.
	Connectedness	Negligible	Negligible	Moderate	No significant change or effect predicted relative to the Current Pathways assessment. Any additional recharge that could occur would be offset by increased irrigation efficiency higher in the catchment. No information that suggests streams in this unit go dry.

Tier	Metric	Change	Effect	Confidence	Description of drivers/effects where applicable
3	Invertebrate community health	Negligible	Negligible	Low to moderate	No change expected in invertebrate community health relative to the Current Pathways assessment.
	Fish diversity	Negligible to small decrease	Negligible to weak negative	Low to moderate	Generally, there is expected to be no change in fish community health relative to the Current Pathways assessment. However, an expression by one panel member that fish diversity may slightly decrease because of legacy N and P from intensification higher in the catchment.
	Overall suitability for recreation	Negligible	Negligible	Low to moderate	No change or effect predicted relative to the Current Pathways assessment.

Unit 3: Kaiapoi Catchment spring-fed streams

Tier	Metric	Change	Effect	Confidence	Description of drivers/effects where applicable
1	Nitrogen	Moderate increase	Moderate negative	Low	Approximately 10% increase in nitrate concentrations predicted at sites in Unit 3. For the Cust Main Drain, there is a predicted increase from a median of 5.1-6.0 to 7.0-8.2 mg/L. This will increase the median nitrate concentration above the NOF bottom line. Potential increase in nitrate toxicity to fish and invertebrates, particularly in Silverstream at Harpers Road. Potential increase in N-limited periphyton growth. Low confidence in assessment due to a lack of modelling methods and no indication of uncertainty in the predicted changes for nitrate. Modelling results being accurate are also dependant on PC5 hearings around MGM land, and how MGM is implemented and enforced. No site-specific information on whether N is the limiting nutrient for plant growth.
	Phosphorus	Negligible	Negligible	Low	No change or effect predicted relative to the Current Pathways assessment. It is presumed that near-complete stock exclusion and fencing setbacks under GMP conditions will minimize bank erosion and limit surface runoff to banks. Newly irrigated areas are distant from the streams in this unit. Confidence is low as there is no information about surface runoff bypass flow through riparian setbacks and shallow subsurface P transport. No information about effects of increased dairy land use on P application. Lack of site-specific evidence as to what streams are P-limited.
	Sediment input	Negligible	Negligible	Low	No change or effect predicted relative to the Current Pathways assessment. Newly irrigated areas are distant from the streams in this unit.

Tier	Metric	Change	Effect	Confidence	Description of drivers/effects where applicable
					No information about sediment in bypass flow from critical source areas. No information about effects of increased dairy land-use on critical source area configuration and size.
	Faecal contamination	Negligible	Negligible	Low to moderate	No change or effect expected relative to the Current Pathways assessment as newly irrigated areas are distant from the streams in this unit. Any change in faecal contamination that could occur would be via groundwater.
	Flow	Negligible	Negligible	Low	No significant change or effect predicted relative to the Current Pathways assessment.
2	Plant growth	Negligible	Negligible	Low	Increased N concentrations are unlikely to affect macrophyte growth as N under the Current Pathways is already likely to be saturating growth. P concentrations are not expected to change much, and therefore N:P ratios are likely to move towards P limitation. Uncertainty is high as there is no site-specific information on the drivers of plant growth. There is also a lack of information about nutrient limitation effects on macrophytes, and the decoupling of water column and sediment nutrient pools.
	Connectedness	Negligible	Negligible	Moderate	Unlikely to be any change as streams in this unit are perennial. Lowland groundwater-fed streams (some with tidal input) are unlikely to shift from perennial to intermittent flow regimes and therefore unlikely to disconnect.
3	Invertebrate community health	Moderate decrease	Moderate negative	Low	Change is likely to be stream-specific due to the effects of nitrate toxicity. Relative to Current Pathways, Silverstream is expected to change minimally, while the Ohoka River will show a moderate decrease in invertebrate community health. These sites are likely to exceed the national bottom line for

Tier	Metric	Change	Effect	Confidence	Description of drivers/effects where applicable
					nitrate toxicity. As a result, there could be negative trophic effects with a shift to mostly nitrate tolerant invertebrate taxa. While there are clear toxicity bandings, confidence from nitrate modelling is low. There are multiple stressor conditions in lowland streams and uncertainty in changes to individual stressors or stressor interactions.
	Fish diversity	Moderate decrease	Moderate negative	Low	Change is likely to be stream-specific due to the effects of nitrate toxicity. Relative to Current Pathways, Silverstream is expected to change minimally, while the Ohoka River will show a moderate decrease in fish community health. These sites are likely to exceed the national bottom line for nitrate toxicity. Nitrate may have an impact on mortality, recruitment and growth rates, and may exclude some species. There is a low level of confidence due to the reasons described in the nitrogen and invertebrate community health metrics above.
	Overall suitability for recreation	Negligible to moderate negative	Negligible to moderate negative	Moderate	There is likely to be a negligible change in 'swimmability' due to a negligible predicted increase in faecal contamination. At most sites, the 95th percentile *E. coli* concentrations are already far above the NPS bottom line for primary contact recreation. However, water quality is predicted to decline and there could be trickle down effects on angling values. Predicted NO^3-N concentrations in the Ohoka River and Cust Main Drain (6.2-8.2 mg/L) are approaching the MAV for drinking water (11.3 mg/L), whereas the modelled concentration for NO^3-N in Silverstream at Harpers Road (21.0 mg/L) exceeds it (this exceedance also applies to the Current Pathways scenario).

Unit 4: Upper Eyre and Cust River catchments

Tier	Metric	Change	Effect	Confidence	Description of drivers/effects where applicable
1	Nitrogen	Negligible to moderate increase	Negligible to moderate negative	Low	It is predicted that small increases in nitrate loading will occur in the upper Eyre and Cust Rivers, and View Hill Stream from newly irrigated properties on south side of Eyre River and east of Oxford. Nitrate input to waterways is likely to be limited to surface and shallow subsurface runoff because streams in this area are losing water and not being recharged by the underlying aquifer. Nitrate concentrations are not expected to change for Coopers Creek, Trout Stream, Mounseys Stream, and other hill-fed streams as their catchments will have no new irrigated area. Any effects are unknown as there is no information about the magnitude of change in nitrate. Any effects that do occur are likely to be limited to stream reaches immediately adjacent to irrigated properties. Confidence is very low. There are no modelled predictions for nitrate change and no information is available about nutrient limitation for periphyton growth.
	Phosphorus	Negligible to small increase	Negligible to weak negative	Low	Possibly a small increase in P input from newly irrigated land immediately adjacent to the upper Eyre and Cust Rivers, and View Hill Stream. It is presumed that even localised P input is very low to negligible due to stock exclusion and fencing setbacks. However, there is some concern about overland and groundwater contamination for the more ‘leaky’ soils, but not for the heavier Cust soils. No change expected for other hill-fed streams outside of the newly irrigated area. Negligible trickle down effects on ecological processes likely from small, localised increases in P input. A low likelihood that lower catchments could be affected through groundwater. Confidence is very low due to a general lack of information including that about: surface runoff bypass flow through

Tier	Metric	Change	Effect	Confidence	Description of drivers/effects where applicable
					riparian setbacks and shallow subsurface P transport; effects of increased dairy land use on P input to land; nutrient limitation in periphyton; and the range of soil types and other hydrogeological factors.
	Sediment input	Negligible to small increase	Negligible to weak negative	Low	Possibly a very small increase in sediment input from newly irrigated land immediately adjacent to the upper Eyre and Cust Rivers, and View Hill Stream. It is presumed that even localised sediment input is low due to stock exclusion and fencing setbacks. Effects expected to be confined to localised areas where additional sediment input occurs.
	Faecal contamination	Negligible to small increase	Negligible to weak negative	Low	Predicted change in faecal contamination similar to that assessed in the sediment input metric above. Localised and minimal change.
	Flow	Negligible	Negligible	Low to moderate	The hill-fed streams west of Oxford are not in newly irrigated areas, so will receive no irrigation recharge. Streams in the newly irrigated area are losing water and overlie a deep, poorly confined aquifer. Irrigation recharge in the area will primarily drain vertically to the aquifer, not laterally to stream channels.
2	Plant growth	Negligible to small increase	Negligible	Low	Overall change is expected to be negligible, but increased nutrient concentrations could lead to increased periphyton growth in localised areas. The major limiting factor for periphyton in the newly irrigated area is flow intermittence, which is not likely to change. No responses are expected for hill-fed streams outside of the newly irrigated areas. The is a high level of uncertainty due to predictions about N and P input to stream reaches adjacent to newly irrigated areas.

Tier	Metric	Change	Effect	Confidence	Description of drivers/effects where applicable
	Connectedness	Negligible	Negligible	Low to moderate	No change expected in connectedness due to reasons explained under flow metric.
3	Invertebrate community health	Small decrease to negligible	Negligible	Low	An unpublished 2009-2010 survey of the Upper Cust and Eyre Rivers indicate that median NO^3-N concentrations were below approximately 2 mg/L. This suggests that nitrate toxicity is not a major concern. The small changes in nitrate predicted for stream reaches adjacent to newly irrigated areas should have a minimal effect on the risk of toxicity. Potential small increases in sediment input to stream reaches adjacent to newly irrigated land could have adverse effects on invertebrate community health. However, it is likely that a major limiting factor for invertebrate communities is flow intermittence, and new irrigation is not predicted to alter this. No changes are predicted for streams outside of the newly irrigated area.
	Fish diversity	Small decrease to negligible	Negligible	Low	Fish diversity is expected to undergo a negligible to small decrease due to similar mechanisms described in the invertebrate community health metric above.
	Overall suitability for recreation	Negligible	Negligible	Low	It is unlikely that severely intermittent stream reaches receive much recreational use. Also, given current water quality, and the negligible to small changes expected in tier 2 and 3 metrics under new irrigation, there is unlikely to be a significant change in suitability for recreation.

Unit 5: Ashley River Catchment above the Gorge

Tier	Metric	Change	Effect	Confidence	Description of drivers/effects where applicable
1	Nitrogen	Negligible to moderate increase	Negligible to moderate negative	Low	A small increase in nitrate concentration predicted by modelling feels like an underestimate when 550 ha of land will be converted to dairy support. The Ashley River will receive a substantial proportion of the N source load from this area, soils are free-draining, and denitrification attenuation may be relatively low between the irrigated area and the Lees Valley outlet. The modelled increase in nitrate concentration is well below toxicity levels, but there could be an increase in N-limited periphyton growth (including cyanobacteria). Confidence in the modelled nitrate values is low. No modelling methods have been detailed and there is no indication of uncertainty for the predicted changes. It is difficult to be confident about what the dilution effect will be from the surrounding catchment. There is also no information about nutrient limitation for periphyton growth.
	Phosphorus	Negligible	Negligible	Low	It is presumed that near-complete stock exclusion and fencing setbacks under GMP conditions will minimize bank erosion. The small area of intensified land should further limit P input, however heavier soils in this area may increase the risk of overland flow. Confidence is low as there is no information about surface runoff bypass flow through riparian setbacks and shallow subsurface P transport. No information about the effects of increased dairy land use on P application. Lack of site specific evidence for what streams are P-limited.
	Sediment input	Negligible	Negligible	Low	Little change in sediment input is expected through similar mechanisms as described in P metric above.

Tier	Metric	Change	Effect	Confidence	Description of drivers/effects where applicable
	Faecal contamination	Negligible	Negligible	Low	Little change in faecal contamination is expected through similar mechanisms as described in P metric above.
	Flow	Negligible to moderate increase	Negligible to moderate positive	Low	Stored water supplied for irrigation use during the spring and summer will increase flows in the Ashley River above the irrigation intake. Environmental flows will further increase the 7dMALF below the intake thus providing benefits for fish passage and potentially more habitat for larger fish. However, mid-range flow fluctuations will decrease as winter flows are diverted for storage. Less flow in the non-irrigation season may affect spawning fish success. Overall, there is likely to be a positive effect in the Ashley River during the irrigation season, but not in the winter/autumn. There is more confidence in this unit compared to the lower river as losses to groundwater and water abstraction are reduced/absent. However, confidence remains low as no modelling methods or indication of uncertainty have been provided. It is difficult to predict the effects without a more detailed environmental flow release programme. It is also difficult to determine whether the benefits of increased irrigation season 7dMALF outweighs the consequences of reduced mid-range flow fluctuations.
2	Plant growth	Moderate increase	Moderate negative	Low	The panel believes that predicted increases in nutrient concentrations (particularly N) have been underestimated by modelling. Coupled with a more regulated flow regime in the Ashley River, there is a consensus that periphyton growth could increase with a negative effect on both ecological and aesthetic values. The magnitude of these effects is difficult to establish.
	Connectedness	Negligible	Negligible	Moderate	No change in connectedness is expected as the Ashley River is perennial from Lees Valley to the gorge. Summer 7dMALF

Tier	Metric	Change	Effect	Confidence	Description of drivers/effects where applicable
					is predicted to increase, so connectedness is likely to continue.
3	Invertebrate community health	Negligible	Negligible	Low	The magnitude of change in tier 1 metrics is unlikely to drive a significant change in invertebrate community health. There is uncertainty around flow changes and how this will increase or decrease habitat quality, but overall it is predicted that there will be a small increase in habitat area during summer due to an increased 7dMALF. There is a possible small negative effect of increased periphyton growth on invertebrates except these are difficult to quantify. There is unlikely to be flow on ecological effects.
	Fish diversity	Negligible	Negligible	Low	The magnitude of change in tier 1 metrics is unlikely to drive a significant change in fish diversity. There is uncertainty around flow changes and how this will increase or decrease habitat quality. It is likely that summer 7dMALF will increase because of environmental flow provisions, and augmentation above the irrigation intake. This may increase fish habitat during the summer and increase fish passage.
	Overall suitability for recreation	Negligible	Negligible	Low	There is unlikely to be any considerable increases in faecal contamination and health risks compared to the Current Pathways assessment. There is the possibility that increased flow will be favourable towards larger game fish species and improve angling. Implications for kayaking and rafting are difficult to quantify, but it was suggested that reduced flow fluctuations could be detrimental to both sports (although above the irrigation intake the > 2 m^3/s of flow increase may be favourable). If cyanobacteria growth increases, then this would decrease recreational suitability.

Unit 6: Tidal reaches of the Waimakariri, Kaiapoi and Cam Rivers

Tier	Metric	Change	Effect	Confidence	Description of drivers/effects where applicable
1	Nitrogen	Moderate increase	Negligible to moderate negative	Low	The predicted increase in NO^{3}-N for the Waimakariri River at Brooklands (0.6 to 0.7 mg/L) remains in the NOF A band. The increase in NO^{3}-N for the Kaiapoi River at the Waimakariri River confluence (3.7-4.7 to 4.2-5.4 mg/L) remains in the NOF C band. These changes are unlikely to have major effects on toxicity, but increased N may result in small increases of benthic algae and phytoplankton. Confidence is low as no modelling methods have been detailed and there is no indication of uncertainty for the predicted changes.
	Phosphorus	Negligible to small increase	Negligible to small negative	Low	Probably negligible or small increases in P input from upstream tributaries associated with overland flow from newly irrigated land along the Cust River and Hunters Stream. Otherwise, any P input to tidal reaches associated with the new irrigation would require long-distance groundwater transport. Increases in N likely to have a negligible or small effect on benthic algae and phytoplankton growth. Uncertainty is high. There is no information about: P input to tributaries in newly irrigated areas; P transport in surface or groundwater; or groundwater discharge in tidal reaches.
	Sediment input	Negligible	Negligible	Low	Potentially negligible or very small increases in sediment input from upstream tributaries associated with overland flow from newly irrigated land along the Cust River and Hunters Stream. The newly irrigated land should have minimal sediment loss under GMP due to near-complete stock exclusion and fencing setback rules.

Tier	Metric	Change	Effect	Confidence	Description of drivers/effects where applicable
					Confidence is low as there is no information about sediment input to tributaries in newly irrigated areas, or about sediment transport to tidal reaches.
	Faecal contamination	Negligible	Negligible	Low	Change and effect is similar to that expressed in sediment metric above.
	Flow	Negligible	Negligible	Low to moderate	No significant change or effect predicted relative to the Current Pathways assessment.
2	Plant growth	Moderate increase	Moderate negative	Low	Benthic algae and phytoplankton production may be enhanced by the predicted increase in N. Possible minor effects on ecological responses associated with algal growth and decomposition (e.g., altered trophic dynamics and/or hypoxia). Uncertainty is high due to a lack of information about nutrient limitation effects on benthic algae and phytoplankton, and the coupling of water column and sediment nutrient pools.
	Connectedness	Negligible	Negligible	Moderate	Groundwater-fed river reaches, particularly those below the head of tide, are very unlikely to shift from perennial to intermittent flow. Therefore, connectedness is likely to remain the same.
3	Invertebrate community health	Moderate decrease	Negligible to moderate negative	Low	There could be a minor change in invertebrate composition and/or abundance as a response to the increased productivity of benthic algae and phytoplankton. However, confidence is very low due to uncertainty in nutrient loading, algal responses to nutrient loads, and invertebrate community responses to changes in algal growth.
	Fish diversity	Moderate decrease	Moderate negative	Low	There could be a minor change in fish diversity composition and/or abundance as a response to the increased

Tier	Metric	Change	Effect	Confidence	Description of drivers/effects where applicable
					productivity of benthic algae and phytoplankton. However, confidence is very low due to uncertainty in nutrient loading, algal responses to nutrient loads, and invertebrate community responses to changes in algae. Other potential factors which may affect diversity include poor clarity and nitrate toxicity, although these are expected to be very small if at all prevalent.
	Overall suitability for recreation	Moderate decrease	Moderate negative	Low	A negligible change in 'swimmability' is expected due to a negligible to very small predicted increase in faecal contamination. However, algal blooms, smells and water discolouration must be considered especially in coastal areas. It is predicted that there will be minimal trickle down effects on angling values. If increased NO3-N concentrations do stimulate phytoplankton growth (include toxic algae) then shellfish safety for consumption may be reduced. There is a high level of uncertainty around the changes in bacterial input upstream and in bacterial die-off in transport from these sources. High uncertainty in algal responses to increased nitrate concentrations and no indication of uncertainty in the predicted nitrate concentration values.

Results – Flow augmentation

Cust Main Drain

Tier	Metric	Change	Effect	Confidence	Description of drivers/effects where applicable
1	Nitrogen	Moderate decrease	Moderate positive	Low	Dilution by flow augmentation can potentially reduce the median NO^3-N concentration by 20-25%. This predicted reduction could reduce potential toxicity as the target concentration (3.8 mg/L) would correspond to the NOF 80% protection value. It could also reduce N-enhanced algal and/or macrophyte growth. Dilution will not reduce N loading to Kaiapoi River and estuary. The confidence of this assessment is low due to there being no indication of certainty about current median NO^3-N values. There is substantial uncertainty about the prospect for flow augmentation in Cust Main Drain. There is no information about seasonal variation in current NO^3-N concentrations, but dilution may be most valuable during irrigation season. The assumption is made that NO^3-N concentration in race water is near zero.
	Phosphorus	Moderate decrease	Moderate positive	Low	A possible reduction in P concentrations, particularly in P fractions that are dominated by riverine inputs from upstream. The effects on dissolved P that enters the Cust Main Drain via river recharge will be smaller. No change predicted for input from localised sources including bank erosion and overland flow. Reduced P concentrations may reduce P-enhanced algae and macrophyte growth. Dilution will not reduce P loading to Kaiapoi River and estuary. A low level of certainty in current P concentrations, which is exacerbated by uncertainty in the effects of dilution.

	Sediment input	Negligible to moderate increase	Moderate negative to Negligible	Moderate	It is predicted that an increase in flow could reduce suspended sediment concentrations from upstream sources, but this reduction would be offset by the additional sediment originating from the Waimakariri River and transported via irrigation races to the Cust Main Drain. The net effect could be an increase in sediment loading. Augmented flows will not affect localised sediment sources and input from overland flow and bank erosion. A minimal to moderate negative effect on ecological and cultural values is predicted if sediment load does increase. There is a moderate level of confidence that TSA would increase total sediment source load. However, there is no information about the transient storage of increased sediment. Uncertainty exists around which method of augmentation will be used. TSA may increase fine sediment input from glacial flour in Waimakariri River water, however sediment should be removed via filtering if MAR is used.
	Faecal contamination	Negligible	Negligible	Low	A possible small reduction in faecal bacteria concentrations due to dilution of bacteria sourced from upstream. The effect of increased median flow will be partially or wholly offset by bacteria input from irrigation races. As with other contaminants, dilution may reduce bacteria concentrations but will not reduce loading (and could increase it). A minimal or negligible effect is predicted to result from a minimal change in bacteria input. Assessment confidence is low as there is no information about current faecal bacteria concentrations (median or variation) in either the Cust Main Drain or in the augmentation water sourced from irrigation races. However, irrigation water is assumed to contain a low level of faecal contamination.

	Flow	Moderate increase	Moderate positive	Low	Projected median flow would increase by 30-40%. Potential dilution effects for water quality are as discussed for the metrics above. An increased flow may also improve hydraulic habitat quality in augmented reaches. Confidence is low as no methods have been sighted for NO^3-N modelling and there is no indication of uncertainty in the predicted changes from the GMP + Lag (i.e. Current Pathways) scenario to the new irrigation (i.e. Alternative Pathways) scenario.
2	Plant growth	Negligible	Negligible	Low	A possible reduction in NO^3-N concentration may reduce N supplies to algae and macrophytes. However, a reduced NO^3-N concentration to a target of 3.8 mg/L is still likely to be saturating for growth. No effect is expected on algae and macrophyte growth. Confidence is low due to a lack of information about nutrient limitation effects on macrophytes, decoupling of water column and sediment nutrient pools, and current macrophyte abundance.
	Connectedness	Negligible	Negligible	High	There is a high level of confidence that there will be no change or effect as the Cust Main Drain is perennial.
3	Invertebrate community health	Moderate positive	Negligible	Low	A predicted slight reduction in toxicity resulting from a reduction in the median NO^3-N concentration from 4.9 to 3.8 mg/L. This could lead to the presence or increased abundance of NO^3-N sensitive invertebrate taxa. A possible positive effect on the quality of invertebrates as a food source for fish, but these benefits are probably minimised in lowland groundwater-dominated streams by poor habitat quality for both invertebrates and fish.

					There is high uncertainty about toxicity effects on invertebrate diversity. No information about variation in NO^3-N concentrations that could affect acute toxicity. In combination with the relatively small reduction in the median NO^3-N concentration, this makes the effects at the invertebrate community level very uncertain.
	Fish diversity	Moderate increase	Negligible	Low	A predicted slight reduction in toxicity resulting from a reduction in the median NO^3-N concentration from 4.9 to 3.8 mg/L. This could lead to the increased abundance of NO^3-N sensitive fish taxa. Minimal direct effect of a reduction in NO^3-N toxicity on fish diversity. Any benefits would probably be further reduced in lowland groundwater-dominated streams by poor habitat quality for both invertebrates and fish. There is high uncertainty about toxicity effects on fish diversity. No information about variation in NO^3-N concentrations that could affect acute toxicity. In combination with the relatively small reduction in the median NO^3-N concentration, this makes the effects at the fish community level very uncertain.
	Overall suitability for recreation	Negligible	Negligible	Low	A possible minor reduction in the risk of faecal microbial infection due to dilution of bacterial loading from upstream. However, no effect on localised sources of bacteria so beneficial effects expected to be very small. Possibly very small improvements in amenity and natural character values associated with a projected 30-40% increase in flow. Confidence is low as there is no information about current faecal bacterial input from augmentation water coming from irrigation scheme races; effects of dilution by augmentation water on bacteria die-off; or relationships between median flow and natural character and other social values.

Ohoka River

Tier	Metric	Change	Effect	Confidence	Description of drivers/effects where applicable
1	Nitrogen	Large decrease	Strong positive	Low	Dilution by flow augmentation can potentially reduce the median NO^3-N concentration by 50%. This predicted reduction would shift the median NO^3-N concentration from the NOF D band to C band, thereby reducing potential toxicity effects. It could also reduce N-enhanced algae and/or macrophyte growth. Dilution will not reduce N loading to Kaiapoi River and estuary. The confidence of this assessment is low due to there being no indication of certainty about current median NO^3-N values. There is substantial uncertainty about the prospect for flow augmentation in the Ohoka River. The capacity in the Ohoka River for conveying additional flow has not been assessed. There is no information about seasonal variation in current NO^3-N concentrations, but dilution may be most valuable during irrigation season. The assumption is made that NO^3-N concentration in race water is near zero.
	Phosphorus	Moderate decrease	Moderate increase	Low	A possible reduction in P concentrations, particularly in P fractions that are dominated by riverine inputs from upstream. The effects on dissolved P that enter the Ohoka River via river recharge will be smaller. No change predicted for input from localised sources including bank erosion and overland flow. Reduced P concentrations may reduce P-enhanced algae and macrophyte growth. Dilution will not reduce P loading to the Kaiapoi River and estuary. A low level of certainty in current P concentrations, which is exacerbated by uncertainty in the effects of dilution.
	Sediment input	Negligible to Moderate increase	Moderate negative to Negligible	Moderate	It is predicted that doubling flow could reduce suspended sediment concentrations from upstream sources, but this reduction would be offset by the additional sediment

Tier	Metric	Change	Effect	Confidence	Description of drivers/effects where applicable
					originating from the Waimakariri River and transported via irrigation races to the Ohoka River. The net-effect could be negligible or an increase in sediment loading. Augmented flows will not affect localised sediment sources and input from overland flow and bank erosion. A minimal to moderate negative impact on ecological and cultural values is predicted if sediment load does increase. There is a moderate level of confidence that flow augmentation would increase total sediment source load. However, there is no information about the transient storage of increased sediment. Uncertainty exists around which method of augmentation will be used. TSA may increase fine sediment input from glacial flour in Waimakariri River water, however sediment should be removed via filtering if MAR is used.
	Faecal contamination	Moderate decrease	Moderate positive	Low	A possible reduction in faecal bacteria concentrations due to dilution of bacteria sourced from upstream. No change predicted in input from localised sources including bank erosion and overland flow. Presume that effects of faecal contaminants are highest near sources due to bacteria die off. Dilution will not change localised sources. Assessment confidence is low as there is no information about current faecal bacteria concentrations (median or variation) in either the Ohoka River or in the augmentation water sourced from irrigation races. However, irrigation water is assumed to contain a low level of faecal contamination.
	Flow	Large increase	Moderate positive	Low	Median flow will increase. Potential dilution effects for water quality are as discussed for the metrics above. An increased flow may also improve hydraulic habitat quality in augmented reaches.

Tier	Metric	Change	Effect	Confidence	Description of drivers/effects where applicable
					Confidence is low as no methods have been sighted for NO^{3}-N modelling and there is no indication of uncertainty in the predicted changes from the GMP + Lag (i.e. Current Pathways) scenario to the new irrigation (i.e. Alternative Pathways) scenario.
2	Plant growth	Negligible	Negligible	Low	A possible reduction in NO^{3}-N concentration may reduce N supplies to algae and macrophytes. However, a reduced NO^{3}-N concentration to a target of 3.8 mg/L is still likely to be saturating for growth. No effect is expected from slight changes in algae or macrophyte growth. Confidence is low due to a lack of information about nutrient limitation effects on macrophytes, decoupling of water column and sediment nutrient pools, and current macrophyte abundance.
	Connectedness	Negligible	Negligible	High	There is a high level of confidence that there will be no change or effect as the Ohoka River is perennial.
3	Invertebrate community health	Moderate positive	Negligible	Low	A predicted slight reduction in toxicity resulting from a reduction in the median NO^{3}-N concentration from 7.4 to 3.8 mg/L. This could lead to the increased abundance of NO^{3}-N sensitive invertebrate taxa. A possible positive effect on the quality of invertebrates as a food source for fish, but these benefits are probably minimised in lowland groundwater-dominated streams by poor habitat quality for both invertebrates and fish. There is high uncertainty about toxicity effects on invertebrate diversity. No information about variation in NO^{3}-N concentrations that could affect acute toxicity. In combination with the relatively small reduction in the median NO^{3}-N

Tier	Metric	Change	Effect	Confidence	Description of drivers/effects where applicable
					concentration, this makes the effects at the invertebrate community level very uncertain.
	Fish diversity	Moderate positive	Negligible	Low	A predicted slight reduction in toxicity resulting from a reduction in the median NO^3-N concentration from 7.4 to 3.8 mg/L. This could lead to the increased abundance of NO^3-N sensitive fish taxa. Minimal direct effects of a reduction in NO^3-N toxicity on fish diversity. Possible trophic effects. Any benefits would probably be further reduced in lowland groundwater-dominated streams by poor habitat quality for both invertebrates and fish. There is high uncertainty about toxicity effects on fish diversity. No information about variation in NO^3-N concentrations that could affect acute toxicity. In combination with the relatively small reduction in the median NO^3-N concentration, this makes the effects at the fish community level very uncertain.
	Overall suitability for recreation	Moderate increase	Moderate positive	Low	A possible minor reduction in the risk of faecal microbial infection due to dilution of bacterial loading from upstream. However, no effect on localised sources of bacteria, so beneficial effects expected to be very small. Possibly very small improvements in amenity and natural character values associated with projected increase in flow. Unlikely that any sites will shift to 'swimmable'. Confidence is low as_there is no information about current faecal bacterial input from augmentation water coming from irrigation scheme races; effects of dilution by augmentation water on bacteria die-off; or relationships between median flow and natural character and other social values.

Silverstream

Tier	Metric	Change	Effect	Confidence	Description of drivers/effects where applicable
1	Nitrogen	Large decrease	Moderate positive	Low	Dilution by flow augmentation can potentially reduce the median NO^3-N concentration by 50%. This predicted reduction would shift the median NO^3-N concentration from the NOF D band to C/D band boundary, and could reduce toxicity. It could also reduce N-enhanced algae and macrophyte growth. Dilution will not reduce N loading to the Kaiapoi River and estuary. The confidence of this assessment is low due to there being no indication of certainty about current median NO^3-N values. There is substantial uncertainty about the prospect for flow augmentation in Silverstream. The capacity in the Silverstream channel to convey target flow levels (0.7 m^3/s at Harpers Rd and 2.8 m^3/s at Island Rd) has not been assessed. There is no information about seasonal variation in current NO^3-N concentrations, but dilution may be most valuable during irrigation season. The assumption is made that NO^3-N concentration in race water is near zero.
	Phosphorus	Moderate decrease	Moderate positive	Low	A possible reduction in P concentrations, particularly in P fractions that are dominated by riverine inputs from upstream. The effects on dissolved P that enter Silverstream via river recharge will be smaller. No change predicted for input from localised sources including bank erosion and overland flow. Reduced P concentrations may reduce P-enhanced algae and macrophyte growth. Dilution will not reduce P loading to the Kaiapoi River and estuary. A low level of certainty in current P concentrations, which is exacerbated by uncertainty in the effects of dilution.
	Sediment input	Moderate increase	Moderate negative to negligible	Moderate	Augmentation water sourced from the Waimakariri River will have some fine suspended sediment (and higher levels if

Tier	Metric	Change	Effect	Confidence	Description of drivers/effects where applicable
					abstracted at moderate to high flow levels). Augmentation should increase sediment load, but it is presumed that the dilution effect of doubling flow will cancel the effect of this. If sediment concentrations do increase, it may have negative effects on ecological and cultural values. There is a moderate level of confidence that flow augmentation would increase total sediment source load. However, there is no information about the transient storage of increased sediment. Uncertainty exists around which method of augmentation will be used. TSA may increase fine sediment input from glacial flour in Waimakariri River water, however sediment should be removed via filtering if MAR is used.
	Faecal contamination	Moderate decrease	Moderate positive	Low	A possible reduction in faecal bacteria concentrations due to dilution of bacteria sourced from upstream. No change predicted in input from localised sources including bank erosion and overland flow. Presume that effects of faecal contaminants are highest near sources due to bacteria die off. Dilution will not change localised sources. Assessment confidence is low as there is no information about current faecal bacteria concentrations (median or variation) in either Silverstream or in the augmentation water sourced from irrigation scheme races. However, irrigation water is assumed to contain a low level of faecal contamination.
	Flow	Large increase	Moderate positive	Low	Flow augmentation would approximately double median flows at Harpers and Island Roads. Potential dilution effects for water quality are as discussed for the metrics above. An increased flow may also improve hydraulic habitat quality in augmented reaches.

Tier	Metric	Change	Effect	Confidence	Description of drivers/effects where applicable
					Confidence is low as no methods have been sighted for NO^{3}-N modelling and there is no indication of uncertainty in the predicted changes from the GMP + Lag (i.e. Current Pathways) scenario to the new irrigation (i.e. Alternative Pathways) scenario.
2	Plant growth	Negligible	Negligible	Low	A possible reduction in NO^{3}-N concentration may reduce N supplies to algae and macrophytes. However, reduced NO^{3}-N concentrations to targets of 6.9 mg/L (Harpers Rd) and 3.8 mg/L (Island Rd) are still likely to be saturating for growth. No effect is expected from slight changes in algae or macrophyte growth. Confidence is low due to a lack of information about nutrient limitation effects on macrophytes, decoupling of water column and sediment nutrient pools, and current macrophyte abundance.
	Connectedness	Negligible	Negligible	High	There is a high level of confidence that there will be no change or effect as Silverstream is perennial.
3	Invertebrate community health	Moderate increase	Negligible	Low	A predicted slight reduction in toxicity resulting from a reduction in median NO^{3}-N concentration. This could lead to the increased abundance of NO^{3}-N sensitive invertebrate taxa. A possible positive effect on the quality of invertebrates as a food source for fish, but these benefits are probably minimised in lowland groundwater-dominated streams by poor habitat quality for both invertebrates and fish. There is high uncertainty about toxicity effects on invertebrate diversity. No information about variation in NO^{3}-N concentrations that could affect acute toxicity. In combination with the relatively small reduction in the median NO^{3}-N

Tier	Metric	Change	Effect	Confidence	Description of drivers/effects where applicable
					concentration, this makes the effects at the invertebrate community level very uncertain.
	Fish diversity	Moderate increase	Negligible	Low	A predicted slight reduction in toxicity resulting from a reduction in median NO^3-N concentration. This could lead to the increased abundance of NO^3-N sensitive fish taxa. Minimal direct effects resulting from a moderate reduction in NO^3-N toxicity on fish diversity. Possible trophic effects. Any benefits would probably be further reduced in lowland groundwater-dominated streams by poor habitat quality for both invertebrates and fish. There is high uncertainty about toxicity effects on fish diversity. No information about variation in NO^3-N concentrations that could affect acute toxicity. In combination with the relatively small reduction in the median NO^3-N concentration, this makes the effects at the fish community level very uncertain.
	Overall suitability for recreation	Moderate increase	Moderate positive	Low	A possible minor reduction in the risk of faecal microbial infection due to dilution of bacterial loading from upstream. However, no effect on localised sources of bacteria so benefit expected to be small. Possibly small improvements in amenity and natural character values associated with projected increase in flow. Unlikely that any sites will shift to 'swimmable'. Confidence is low as there is no information about current faecal bacterial input from augmentation water coming from irrigation scheme races; effects of dilution by augmentation water on bacteria die-off; or relationships between median flow and natural character and other social values.

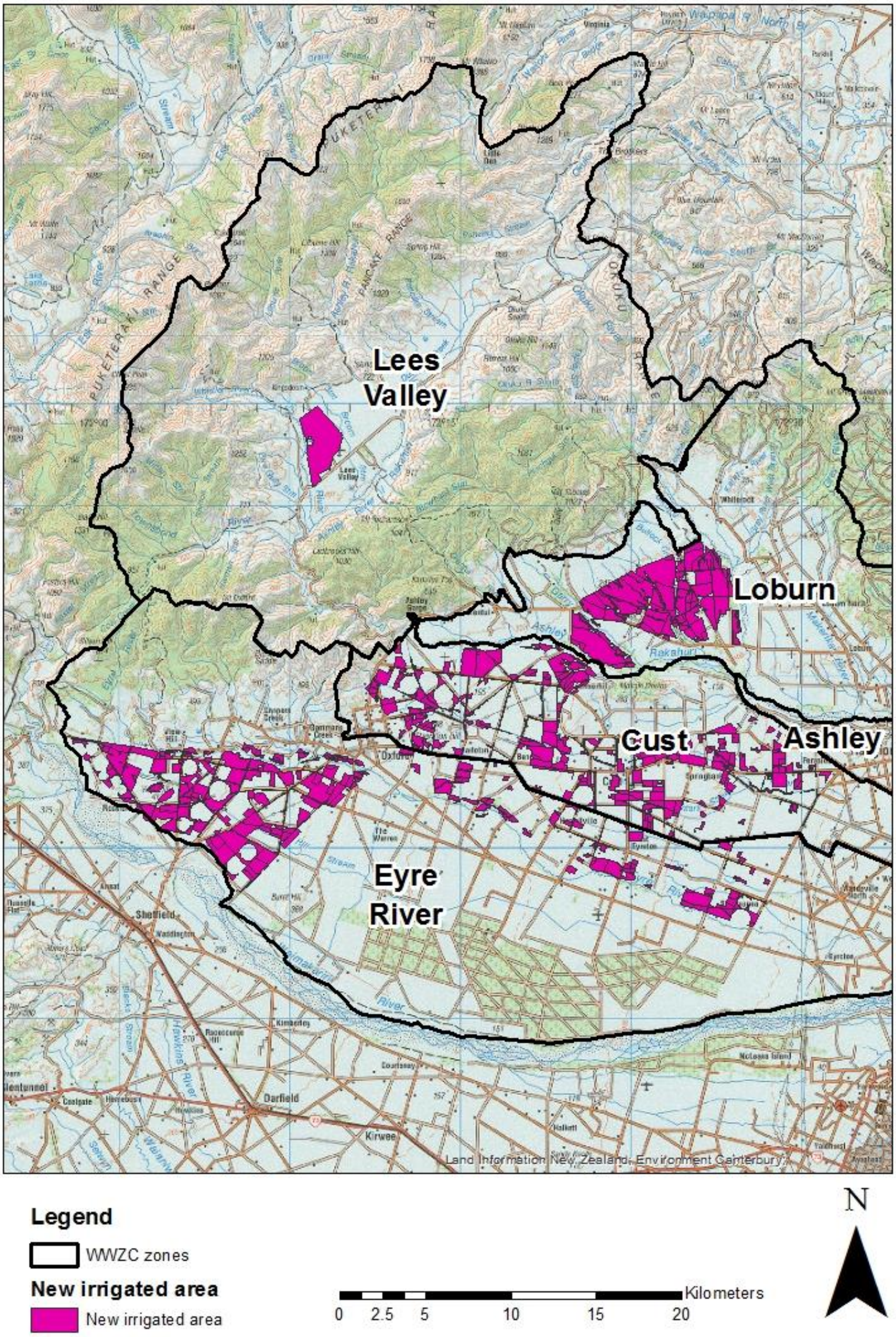
Taranaki and Saltwater Creeks

The expert panel did not assess the effect of flow augmentation on Taranaki Creek or Saltwater Creek. Feasibility studies have found that augmenting these streams is not viable.

Results – Ecological and cultural flow guidelines

Due to time constraints and a lack of information, ecological and cultural minimum flow guidelines have not been assessed. The assessment of these were deferred to a later date.

Appendix 1: Areas of new irrigation under Alternative Pathways scenario



Appendix 2: Modelled nitrate and flow results

Average nitrate-N results (mg/L)

Stream	Site	Current measured	Lag[5]	Lag + GMP[5]	Lag + GMP + PC5 PA[5]	Current Pathways model results[5,6]	Current Pathways adjusted model results[7]	New irrigation[8]
Waimakariri	Brooklands Lagoon[9]	No data	0.7	0.6	0.6	0.6	-	0.7
Kaiapoi River	Waimakariri confluence	No data	4.0 to 5.1	3.7 to 4.7	4.4 to 5.6	5.2 to 6.7	5.9	4.2 to 5.4
Courtenay	-	No data	6.3 to 8.1	5.6 to 7.2	6.4 to 8.2	7.6 to 9.8	6.9	No change
Silverstream	Harpers Rd	7.7	23.6	20.4	20.7	24.6	≥15	21.0
Silverstream	Island Rd	4.4	6.3 to 8.6	5.6 to 7.6	6.4 to 8.2	6.5 to 8.4	7.4	6.2 – 8.5
Ohoka	Island Rd	4.1	6.3 to 8.1	5.6 to 7.2	5.9 to 8.2	5.8 to 8.1	7.0	6.2 to 8.0
Cust Main Drain	Skewbridge Rd	3.9	5.9 to 6.9	5.1 to 6.0	6.4 to 7.5	7.5 to 8.6	4.9	7.0 to 8.2

[5] Range of nitrate estimates is based on range of estimates for denitrification rates (e.g. 5 – 20% denitrification for groundwater discharging to Cust Main Drain).

[6] Includes projected flow reductions associated with climate change plus PC5 PA rules plus GMP.

[7] Results adjusted for "expert-judgement" where appropriate, based on data from other high nitrate streams, anecdotal information on land use change and nitrate trend analysis. For example, model results project a significant nitrate increase in Cust Main Drain, but anecdotal information suggests that recent land use intensification has been limited and nitrate trend analysis shows no upward trend. Cust Main Drain adjusted nitrate result therefore assumes no lag, i.e. current measured = lag result.

[8] Comparable to GMP results – does not account for PC5 PA rules or climate change.

[9] Based on Waimakariri River flows only – assumes no dilution with seawater.

Stream	Site	Current measured	Lag[5]	Lag + GMP[5]	Lag + GMP + PC5 PA[5]	Current Pathways model results[5,6]	Current Pathways adjusted model results[7]	New irrigation[8]
Cam	Marsh Rd	0.6	0.8 to 0.9	0.7 to 0.8	1.0 to 1.1	1 to 1.1	0.8	No change
Taranaki	Preeces Rd	0.6	1.9 to 2.0	1.6 to 1.7	2.0 to 2.1	2.1 to 2.2	0.6	No change
Waikuku	SH1	0.4	0.8 to 0.9	0.7 to 0.8	0.8 to 0.8	0.8 to 0.9	0.4	No change
Saltwater	Factory Rd	0.3	1.7 to 1.8	1.5 to 1.6	2.0 to 2.1	2 to 2.1	0.4	No change
Ashley	Gorge	0.05	0.11	0.11	0.11	0.11	0.11	0.12
Ashley River	Estuary	No data	1.3	1.2	1.3	1.3	1.3	1.5
Garry River[10]	Ashley confluence	0.6	0.8 to 0.9	0.7 to 0.8	1.0 to 1.1	1 to 1.1	0.8	2.9
Mount Thomas[10] Stream	Ashley confluence	0.6	1.9 to 2.0	1.6 to 1.7	2.0 to 2.1	2.1 to 2.2	0.6	5.5
Okuku River[10]	Ashley confluence	0.4	0.8 to 0.9	0.7 to 0.8	0.8 to 0.8	0.8 to 0.9	0.4	1.3

[10] Current measured nitrate in Garry River, Mount Thomas Stream, and Okuku River is based on only two years of sampling during very dry conditions. This is, unlikely to be representative of longer term averages. Flow data is also lacking for lower reaches of these watercourses, so results should be considered as relative change between GMP and new irrigation scenarios only.

Flow results

Stream	Site	Current measured		GMP	Current Pathways[11]			New irrigation[12]	Flow augmentation[13]	
		Mean/ median[14] m³/s	7DMALF (m³/s)	Mean/ median[14] m³/s	Mean/ median[14] m³/s	% reduction from current	7DMALF (m³/s)	Mean/ median[14] m³/s	Mean/ median[14],[15] m³/s	Flow increase m³/s
Waimakariri River	Brooklands Lagoon	126.3	N/A	125.8	138.4	-10%	No data	No change	N/A	N/A
Kaiapoi River	Waimakariri confluence	5.7	N/A	5.3	4.5	21%	No data	No change	-	1.9
Courtenay	-	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Silverstream	Harpers Rd	0.43	0.20	0.40	0.34	21%	0.19	No change	0.73	0.4 (117%)
Silverstream	Island Rd	1.86	1.35	1.74	1.46	21%	1.19	No change	2.46	1 (68%)
Ohoka River	Island Rd	0.75	0.51	0.70	0.59	21%	0.45	No change	0.96	0.4 (63%)

[11] Includes projected flow reductions associated with climate change plus PC5 PA rules plus GMP.

[12] Comparable to GMP results – does not account for PC5 PA rules or climate change.

[13] Exploratory scenario based on additional clean flow required to reduce Current Pathways nitrate result to 6.9 mg/L (Silverstream at Harpers Rd), 3.8 mg/L (Silverstream at Island Rd, Ohoka at Island Rd, Cust Main Drain) and 1.0 mg/L (Taranaki at Preeces Rd, Saltwater at Factory Rd). Uses same flow stats as new irrigation results.

[14] Mean flow for Waimakariri and Ashley Rivers; median flows for spring-fed streams/rivers.

[15] Flow after augmentation.

Stream	Site	Current measured		GMP	Current Pathways[11]			New irrigation[12]	Flow augmentation[13]	
		Mean/ median[14] m^3/s	7DMALF (m^3/s)	Mean/ median[14] m^3/s	Mean/ median[14] m^3/s	% reduction from current	7DMALF (m^3/s)	Mean/ median[14] m^3/s	Mean/ median[14],[15] m^3/s	Flow increase m^3/s
Cust Main Drain	Skewbridge Rd	1.75	0.49	1.55	1.31	25%	0.58	No change	1.80	0.5 (38%)
Cam	Marsh Rd	1.34	1.19	1.34	1.30	3%	1.19	No change	1.30	N/A
Taranaki	Preeces Rd	0.24	0.17	0.24	0.23	3%	0.17	No change	0.38	0.1 (65%)
Waikuku	SH1	0.59	0.36	0.59	0.57	3%	0.36	No change	N/A	N/A
Saltwater	Factory Rd	0.41	0.26	0.41	0.40	3%	0.26	No change	0.64	0.2 (60%)
Ashley River/Rakahuri	Gorge	12.3	2.04	12.3	12.4	-1%	2.04	12.21	N/A	N/A
Ashley River/Rakahuri	Te Akaaka Estuary	No data	No data	18.9	18.8	0%	No data	17.9[16]	N/A	N/A
Garry River	Ashley confluence	0.64	No data	0.64	N/A	N/A	No data	0.66	N/A	N/A
Mount Thomas Stream	Ashley confluence	0.36	No data	0.36	N/A	N/A	No data	0.40	N/A	N/A
Okuku River	Ashley confluence	4.77	No data	4.77	N/A	N/A	No data	4.80	N/A	N/A

[16] Includes climate change effects to 2050.

Appendix 3: Ecological and cultural minimum flows

Plan	Water course	Minimum flow site location	7MALF (L/s)	WRRP minimum flow (L/s)	Ecological minimum flow proposal (L/s)	Justification	% difference from WRRP	Whanau minimum flow preference (L/s)	Justification *Te Ngai Tuahuriri & Tipa Associates (2016)*	% difference from WRRP
WRRP	North Brook	Marsh Road	622[1]	530	530	Reasonable high protection of instream values (habitat/passage) for salmonids/eels[1]	0%	590	-	11%
	Middle Brook	Marsh Road	31[1]	60	30	Habitat is limiting at 7dMALF for site therefore little benefit in higher flows for species present[1]	-50%	50	-	-17%
	Greigs Drain	Greigs Drain Road	60[2]	150	230	Habitat protection for adult and juvenile brown trout[1]	53%	230	-	53%
	No. 7 Drain	Main Drain Road Culvert	67[1]	60	60	Provides suitable depth and adequate protection of aquatic habitat for native and juvenile salmonid fish species[1]	0%	60	-	0%
	Ohoka Stream	Kaiapoi River confluence	505[2]	300	365	Slight increase required to protect salmonid and native fish habitat[1]	22%	420	-	40%
	Cam River	Youngs Road	1,010	1000	890	Lower minimum flow would still provide a high level of protection for adult brown trout habitat. If salmonid spawning, juveniles and native fish were drivers here, a minimum flow of 670 L/s would be required[1]	-11%	1200	Cultural allocation of water, water quality restoration, restore indigenous fish, sustain full range of native fish species	20%
	South Brook	Marsh Road	171[1]	140	120-140	Based on trout protection a small reduction would not change outcomes with adequate habitat protection. If salmonid spawning was a driver a minimum flow of 210 L/s would be required. Autumn/winter minimum flow of 60-100 L/s sufficient for passage of adult trout and trout spawning habitat [1]	-14%	170	Protect spring fed stream, sustain the full range of native fish species	21%
	Kaiapoi River	Neeves Road	1,350[2]	600	1000	900 L/s required for salmonid passage, 1000 L/s would protect habitat for adult brown trout, large eels and other native fish[1]	67%	1200	Water quality in lagoon, sustain the full range of native fish species	100%
	Cust River	Rangiora-Oxford Road	300	20	120	Current minimum provides poor habitat protection. A minimum flow of 120L/s provides adequate protection for juvenile trout habitat. Minimum flow of 60-100 L/s would adequately protect habitat for eels and other native fish[1]	500%	-	-	-
	Cust Main Drain	Threlkelds Road	492	230	230	Current minimum flow provides a good level of protection of the habitat available for juvenile brown trout and native fish. Minimum flow of 280 L/s could be used in autumn/winter if adult trout passage is driver[1]	0%	400	Protect spring fed system, sustain the full range of native fish species -	74%
	Courtenay Stream	Main North Road	332[1]	260	350	Additional protection would provide adequate habitat for adult brown trout, large longfin eels and other native fish[1]	35%	400	Restore indigenous fish, sustain the full range of native fish species	54%

Plan	Water course	Minimum flow site location	7MALF (L/s)	LWRP minimum flow (L/s)	Ecological minimum flow proposal (L/s)	Justification	% difference from LWRP	Whanau minimum flow preference (L/s)	Justification *Te Ngai Tuahuriri and Tipa & Associates (2016)*	% difference from LWRP
LWRP	Little Ashley Creek	Ashley River/Rakahuri at SH1	96	50 L/s 30 L/s for 4 days each month	67[4]	Maintain water volume to reduce potential for low DO events and ensure that macrophyte abundance does not block full channel. Provide habitat in shaded shallow water reaches (if/when present)	34%	50	Spring levels protected, protect eels	0% 67%
	Waikuku Stream	Waikuku Stream, Waikuku Beach Road	355	100 L/s Mon-Fri 150 L/s Sat-Sun	228[4]	Fish passage, salmonid habitat, large eel habitat, sediment flushing to protect salmon spawning habitat, reduce macrophyte abundance	128% (Mon-Fri) 52% (Sat-Sun)	600	Sustain the full range of native fish species, especially inanga and eels	500% (Mon-Fri) 300% (Sat-Sun)
	Saltwater Creek	Saltwater Creek, Toppings Rd	260[3]	100	208[4]	Protect riffle habitat and riffle dwelling species. Will then provide for run and pool dwelling species too		-	Sufficient to sustain the full range of native fish species, inanga (including inanga spawning sites) and eels	-
	Taranaki Creek (Preeces)	Taranaki Creek, Kaiapohia monument	174[2]	120	122[4]	Provide habitat and maintain water volume, protection of diverse fish fauna. Note, some expectation of increasing shade and habitat conditions to improve as revegetation planting takes effect	1.6%	120	Catchment enhancement programme, water quality, restore indigenous fish, koura and inanga, spawning habitat is to be protected	0%
	Silverstream	Silverstream weir	559	-	-	No recent studies available	-	600	Protect spring fed stream, sustain the full range of native fish species	-
	Ashley River/ Rakahuri Gorge	Ashley at Gorge	2040	2500 Jan-Jul 4000 Aug-Nov 3000 Dec	1840[4]	Provide fish passage and maintain riffle habitat, salmon habitat, native fish species habitat including longfin eel, torrentfish, bluegill bully and galaxiids, provision of freshes required to provide temporary migratory paths and connect drying reaches of riverbed	-26% (Jan-Jul) -54% (Aug-Nov) -39% (Dec)	5000 (with variability)	Increased water flow (ki uta ki tai), cultural allocation of water, water quality, enable sufficient swimming depth, sufficient depth non-motorised water craft	100% (Jan-Jul) 25% (Aug-Nov) 67% (Dec)
	Ashley River/ Rakahuri SH1	-	102	-	-	No recent studies available	-	Visible connected flow (with variability)	Increased water flow (ki uta ki tai), cultural allocation of water, water quality	-

[1] Value from Golder (2009)

[2] Estimate from regression analysis of lowland/spring-fed sites

[3] 7MALF based on flow data obtained from Factory Road, downstream of the Toppings Road minimal flow site

[4] Value from Waterways Consulting memorandums and/or tables

Plan	Water course	Minimum flow site location	7MALF (L/s)	Consent minimum flow (L/s)	Ecological minimum flow proposal (L/s)	Justification	% difference from consent	Whanau minimum flow preference (L/s)	Justification *Te Ngai Tuahuriri & Tipa Associates (2016)*	% difference from consent
No Plan	Okuku River	Fox Creek	446	543	-	No recent studies available	-	650	Protect koura, kakahi and freshwater shrimp.	20%
	Garry River	Birch Hill Road Bridge	102	-	-	No recent studies available	-	100	Sufficient for long fin eels	-
	Leggats Creek	-	-	-	-	No recent studies available	-	At least 90% of 7DMALF	Protect spring fed stream	-

Ashley River flow regime (Mosely, 2001)

- Minimum flows above 2.5 m^3/s to maintain:
  - Preferred habitat for food-production required by birds (August to Jan/Feb).
  - Optimum habitat for as many fish species as possible (year round).
  - Quality of angling.
  - Minimal passage depth for upstream migration of salmonids (November to March).
  - Flowing water throughout the length of the river for amenity (recreational) purposes.
- For upstream migration of salmonids, a flow of 3-4 m^3/s is desirable.
- To maintain continuous flow (or at least a series of pools) - i.e. a discharge of 2.5 m^3/s at the gorge.
- To maintain overall appearance of the river (braided, broad gravel bed), maintain frequency and magnitude of floods.
- To minimise nuisance growth of periphyton, maintain the frequency and magnitude of flood events >30 m^3/s, and maintain low flows as high as possible.

* Note that a revised, but draft minimum flow of 1.84 m^3/s (based on 90% 7dMALF) is provided by Waterways Consulting in the table above (see memorandum for more detail).

References:

1. Te Ngai Tuahuriri and Tipa & Associates (2016) Cultural Health Assessments & Water Management for the Rakahuri – Waimakariri Zone (working draft).
2. Golder (2009) Minimum Flows and Aquatic Ecological Values of Lower Waimakariri River tributaries.
3. Mosely (2001) Ashley River: Flow management regime. Report No. U01/4. Environment Canterbury.