

**Waimakariri Land and
Water Solutions
Programme**

**Alternative Pathways
Scenario - Water
Management Options
Assessment**

Report No. R17/xx

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Summary and Key Questions

We have summarised some of the main findings of the Current State, and Current Pathways and Alternative Pathways scenarios groundwater and surface water science work in the table below. For each of the key findings we have posed the key water management questions that need to be answered by the Waimakariri Water Zone Committee. We have presented some possible options for each question, as a starting point for discussion. In some instances there are other options that could be explored and potentially adopted. We acknowledge that further information is likely to be required before some of the questions posed here can be answered by the committee.

Summary	Key question	Possible options
Monitoring results show that nitrate concentrations are elevated in many watercourses, and could increase further in some watercourses according to modelling results.	What is the maximum acceptable nitrate concentration in the main surface watercourses in the Waimakariri Zone?	<ol style="list-style-type: none"> 1. Max 1 mg/L¹ for all watercourses as per COMAR report 2. Courtenay: 2.4 mg/L. Cust Main Drain, Ohoka, lower Silverstream: 3.8 mg/L, 6.9 mg/L Silverstream at Harpers Rd. Cam, Taranaki, Waikuku, Little Ashley, Saltwater Ck: 1 mg/L. Rakahuri at Gorge: 0.1 mg/L. Rakahuri at SH1: 0.4 mg/L. Waimakariri: no change from current (0.05 – 0.1 mg/L) 3. As per option 2, but with max of 6.9 mg/L for Cust Main Drain, Ohoka and Silverstream
Monitoring results show that nitrate concentrations are increasing in the Eyre zone in particular. The risk of nitrate concentrations exceeding the Drinking Water Standard limit (MAV) in water supply wells is likely to increase. Current measured data show median N and MAV exceedance risk as follows: Ashley GAZ: 0.5 mg/l, 0% risk ² Cust GAZ: 7 mg/L, 16% Eyre GAZ 5 mg/L, 5% risk	What mean nitrate concentration and/or nitrate MAV exceedance risk is acceptable – e.g. 5%, 10%, 20%? 10% risk would be equivalent to an average nitrate concentration of 5.65 mg/L	<ol style="list-style-type: none"> 1. CWMS target: N <½ MAV (i.e. 5.65 mg/L) in <u>all</u> drinking water wells by 2040 2. Selwyn Waihora zone: all domestic drinking water to meet national standards, preferably without treatment, within 10 years 3. Hinds zone: annual median groundwater nitrate concentration max 6.9 mg/L. 4. No deterioration from present
	Are well deepening and/or point-of-use treatment by well owners acceptable mitigation options?	<ol style="list-style-type: none"> 1. Yes 2. Obtain feedback from community 3. No

¹ NOF A Band

² Risk of exceeding the Maximum Acceptable Value of 11.3 mg/L nitrate-N

<p>Elevated nitrate concentrations in groundwater and surface water and low flows in spring-fed streams could potentially be addressed by channelling water from the Waimakariri River³ to some of the streams.</p>	<p>Should channelling water from Waimakariri River to some spring-fed streams be explored further, to address elevated nitrate concentration and / or low flows? If so for which watercourses?</p>	<ol style="list-style-type: none"> 1. Silverstream only 2. Silverstream, Ohoka and Cust
<p>Elevated nitrate concentrations in groundwater and surface water and low flows in spring-fed streams could potentially be addressed by managed aquifer recharge (MAR)</p>	<p>Should MAR be explored to address elevated nitrate concentrations in groundwater and surface water and low flows in spring-fed streams? If so, which MAR options should be considered?</p>	<ol style="list-style-type: none"> 1. River recharge (Eyre and possibly Cust) via discharges from water races 2. Infiltration basins 3. MAR via winter irrigation on light soils
<p>Flow declines are projected for some watercourses due to improved irrigation efficiency, climate change and increasing groundwater abstraction</p>	<p>Are further increases in groundwater abstraction acceptable in the Cust, Ashley, Kowai and Loburn GAZs?</p>	<ol style="list-style-type: none"> 1. Maintain current allocation limits 2. Cap allocation at current 3. Reduce current abstraction 4. Develop "Adaptive Management" type limits
	<p>Is the current groundwater allocation limit appropriate in the Eyre GAZ?</p>	<ol style="list-style-type: none"> 1. Maintain current limit 2. Reduce allocation limit 3. Develop "Adaptive Management" type limits
	<p>Should options to increase flows in spring-fed streams be explored further, in order to mitigate effects of improved irrigation efficiency and climate change?</p>	<ol style="list-style-type: none"> 1. Change stream depletion rules 2. Change allocation limits as per above options 3. Stream augmentation/MAR options
<p>Environmental flow releases from a hypothetical Lees Valley water storage scheme could potentially improve low flows in the Ashley River/Rakahuri⁴. The main purpose of the storage scheme would be to provide new irrigation water for around 12,600 ha of land.</p>	<p>Do the projected cultural, environmental and social benefits of a hypothetical Lees Valley water storage scheme outweigh the impacts?</p>	<ol style="list-style-type: none"> 1. Deliberate further during Solutions phase 2. Make recommendation that detrimental effects outweigh benefits 3. Make recommendation in support of scheme, on basis that net effect is positive.
<p>Modelling results provided previously⁵ indicate that the number of unreliable water supply wells could increase by around 40⁶ due to an assumed increase in groundwater</p>	<p>Should the Solutions Programme attempt to address well reliability or should it be left to individual well owners?</p>	<ol style="list-style-type: none"> 1. Leave to well owners 2. Leave to well owners but reduce potential for future declines by capping allocation 3. Investigate MAR options to increase groundwater levels

³ And/or from the Ashley River/Rakahuri, although we have not explored this option

⁴ Environmental flow releases to the lowland streams might also be possible, but we have not explored this option

⁵ Waimakariri Current Pathways Scenario – Groundwater Assessment Results memo dated 15/12/2016

⁶ From around 360 unreliable wells at present to 400 under the Current Pathways Scenario – see Waimakariri Current Pathways Scenario – Groundwater Assessment Results memo dated 14/12/16 for details

abstraction, improved irrigation efficiency and climate change.		
Conservative modelling of the potential impacts of the proposed PC5 PA rule indicates that extra N load could exacerbate nitrate issues and offset gains from GMP	Should the proposed PC5 PA rule be modified for the Waimakariri zone?	<ol style="list-style-type: none"> 1. Assess potential effects using less conservative assumptions on fodder crop areas/N loss 2. Leave PA rule unchanged

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1 Introduction

Environment Canterbury is working with the Waimakariri Water Zone Committee (WWZC) and local community to develop a land and water solutions programme as part of the Canterbury Water Management Strategy (CWMS). Some of the recommendations in the Waimakariri Land And Water Solutions Programme will be used to inform future changes to a Waimakariri sub-regional section of the Canterbury Land and Water Regional Plan (LWRP) They will also inform 'on the ground' actions and together with regulation, will help deliver on the Community Outcomes.

Environment Canterbury provided information to the Waimakariri Water Zone Committee (WWZC) and local community on the current state of the Waimakariri Zone environment via written reports and Zone Committee and community presentations in September and October 2016. This was followed by a second set of reports and presentations on the *Current Pathways Scenario* in November 2016, the purpose of which was to provide an indication of what could happen to the environment if land development and resource management continue along the current trajectory.

This latest report summarises the main findings of a second scenario, referred to as *Alternative Pathways*, which explores the feasibility and potential effects of introducing alternative land and water management options. The focus of this report is water resources: both water quantity and water quality. Other aspects of the environment (e.g. terrestrial and aquatic ecology) are presented in separate reports. The water quality assessments presented in this report cover nitrate only. Other water quality parameters (e.g. sediment, phosphorus and E. Coli) and aquatic ecology are also discussed elsewhere.

2 Water management issues

2.1 Background – Current Pathways Scenario

The water resource component of the *Current Pathways Scenario* considered the individual and combined effects of lag (see explanation below), Good Management Practice, the proposed Plan Change 5 Permitted Activity rules (PC5 PA) and climate change on the following water resource outcomes:

- Groundwater levels and water supply well reliability
- Nitrate concentrations in water supply wells
- Flows in spring-fed streams
- Nitrate in spring-fed streams

The Waimakariri Land and Water Solutions Programme is an iterative process involving a number of stages of technical assessment and community consultation and feedback. This approach allows knowledge and feedback from the community to be incorporated in both the scientific assessment and decision-making process.

The first part of this report provides an update of the *Current Pathways Scenario* assessment, which incorporates knowledge and feedback obtained from the WWZC and local community during the November 2016 community consultation process. A final iteration of the *Current Pathways Scenario* assessment will be undertaken between March and August 2017, incorporating further feedback from and knowledge within the local community, and using more detailed scientific assessment tools.

The Current Pathways scenario evaluates the effects of four “business as usual” components:

1. Time lag: significant land use change has occurred in large areas of the Waimakariri zone in recent years; the full effects of these changes have not yet been seen in groundwater and surface water. The main purpose of this component is to provide estimates of how much nitrate concentrations could increase when they “catch up” with recent land use intensification.
2. Good Management Practice (GMP), as defined in the Matrix of Good Management (MGM). These farm management measures are expected to become mandatory under variation five of the Land and Water Regional Plan (LWRP), when this becomes operational. Our technical

assessment for this component provides an indication of the effect of these measures on groundwater levels, spring-fed stream flow and nitrate concentrations.

3. Plan Change Five Permitted Activity (PC5 PA) rules: the proposed rules would allow for some limited increases in irrigated land area in Orange Nutrient Allocations Zones⁷ (NAZs) and in forage crop areas in both Orange and Red NAZs. We have assessed the maximum potential effect of these increases on groundwater levels, spring fed stream flows and nitrate concentrations.
4. Climate change between 2015 and 2090: The aim of this component is to provide a high level assessment of the effect of rising temperatures and changing rainfall patterns on water resources in the Waimakariri zone.

We have framed this report as an *issues and options* assessment: the updated *Current Pathways Scenario* results highlight the main water resource issues associated with continuance along the current trajectory. The Water Management Options section introduces some of the possible solutions that could be developed to address these issues.

2.2 Current Pathways Scenario assessment update

The results of our first iteration of the *Current Pathways Scenario* assessment were presented to the WWZC in a memo dated 14/12/2016 entitled *Waimakariri Current Pathways Scenario – Groundwater Assessment Results*. The results of this assessment were reality checked against measured data and via discussions with the local community. The comparison of model results to measured nitrate data suggested that modelled nitrate losses from agricultural land were too high. Other information sources suggested that the stocking rates assumed for the nitrate loss modelling were too high. The modelling was therefore revised in December 2016 and January 2017. We presented the revised results to the Waimakariri Farmer Reference Group via a presentation on 2/2/2017 and were provided with additional feedback on land use changes within the zone. The view of the panel members was that extensive recent land use intensification in the Cust Main Drain, Taranaki Stream, Waikuku Creek and Saltwater Creek catchments has not occurred, and hence the potential for significant increases in nitrate concentrations in these watercourses is considered to be limited by the panel members. This view is supported by nitrate trend analysis in the Cust catchment, which shows broadly stable nitrate concentrations. The panel members noted that significant recent land use intensification has occurred in the Eyre River Groundwater Allocation Zone, and on that basis believed that nitrate concentrations could increase significantly in groundwater and in watercourses within or downstream of this zone.

2.3 Issues: nitrate in surface watercourses

Summary

Nitrate concentrations are already above the National Bottom Line limit of 6.9 mg/L in Silverstream at Harpers Road. Nitrate concentrations could potentially exceed this limit over the full length of Silverstream and Ohoka Stream in the long term (several decades into the future) if land development and resource management continue along the current trajectory.

Nitrate concentrations in Cust Main Drain could increase slightly, to around 5 mg/L, if climate change reduces flows in this watercourse.

Nitrate concentrations are not expected to increase significantly in the Cam River, Taranaki Creek, Waikuku Stream and Saltwater Creek, and are expected to stay below the NOF A Band limit, if lag effects are negligible.

Ashley River/Rakahuri nitrate concentrations at the gorge are projected to increase from 0.05 mg/L to 0.11 mg/L. The driver for this increase is an assumed lag between the low degree of land use intensification that has occurred in this catchment, and water quality effects.

The Cultural Health Assessment report (Tipa, 2016) recommends a maximum nitrate target of 1 mg/L (NOF A Band limit) for all of the watercourses assessed in this report.

⁷ See Canterbury Land and Water Regional Plan for definition

Most of the Ashley-Waimakariri plains are defined as a red Nutrient Allocation Zone (NAZ) in the Land and Water Regional Plan. The red classification means that water quality outcomes are not met in this area. The driver for this classification is a strong surface water – groundwater interaction with highly valued spring-fed streams with increasing nutrient concentrations above all guidelines. The Ashley River/Rakahuri catchment is defined as an Orange NAZ, which means that water quality outcomes are classified as being at risk. The Ashley River/Rakahuri is considered to be at the threshold of likely effects with increasing nutrient concentrations and periods of increasing algal growth (Meredith et. al. 2012).

Updated *Current Pathways Scenario* assessment results are summarised in Table 2-1. We have provided two sets of results for the *Current Pathways* assessment: raw model results and a set of adjusted results which assume minimal lag effects in the Cust Main Drain, Taranaki Stream, Waikuku Creek and Saltwater Creek catchments, as per the feedback from the Waimakariri Farmer Reference Group. Further work will be undertaken to ground-truth this feedback during the final phase of the Waimakariri Land And Water Solutions Programme science study.

Most of the results in Table 2-1 are presented as a range to reflect some of the uncertainty associated with inputs to our model.

We have presented the nitrate results graphically in Figure 2-1 and Figure 2-2 for Courtenay Stream, Silverstream, Ohoka Stream and Cust Main Drain.

Figure 2-1 shows the overall adjusted *Current Pathways* assessment results together with current measured nitrate concentrations. The results suggest that nitrate concentrations are likely to remain above 3.8 mg/L (90% aquatic ecology protection level) in all of these watercourses, and could exceed the National Bottom Line (6.9 mg/L) in Courtenay Stream, Silverstream and Ohoka Stream. Nitrate in the Cust Main Drain would exceed 6.9 mg/L if the raw modelling results proved to be correct, but currently available information suggests that this is unlikely (see feedback from Waimakariri Farmer Reference Group in Section 2.2).

Figure 2-2 shows the raw model results for the individual *Current Pathways* elements, to provide an indication of the key drivers for high nitrate concentrations. The effects of climate change (to 2090) are included in the Current Pathways results: the difference between the GMP + PC5PA results is due to the projected effects of climate change. Results indicate that lag is the main driver for the projected increase in nitrate concentrations in Silverstream and Ohoka Stream. The combined effects of climate change and the PC5PA rules are the key driver for the projected 1 mg/L increase in nitrate concentrations in Cust Main Drain.

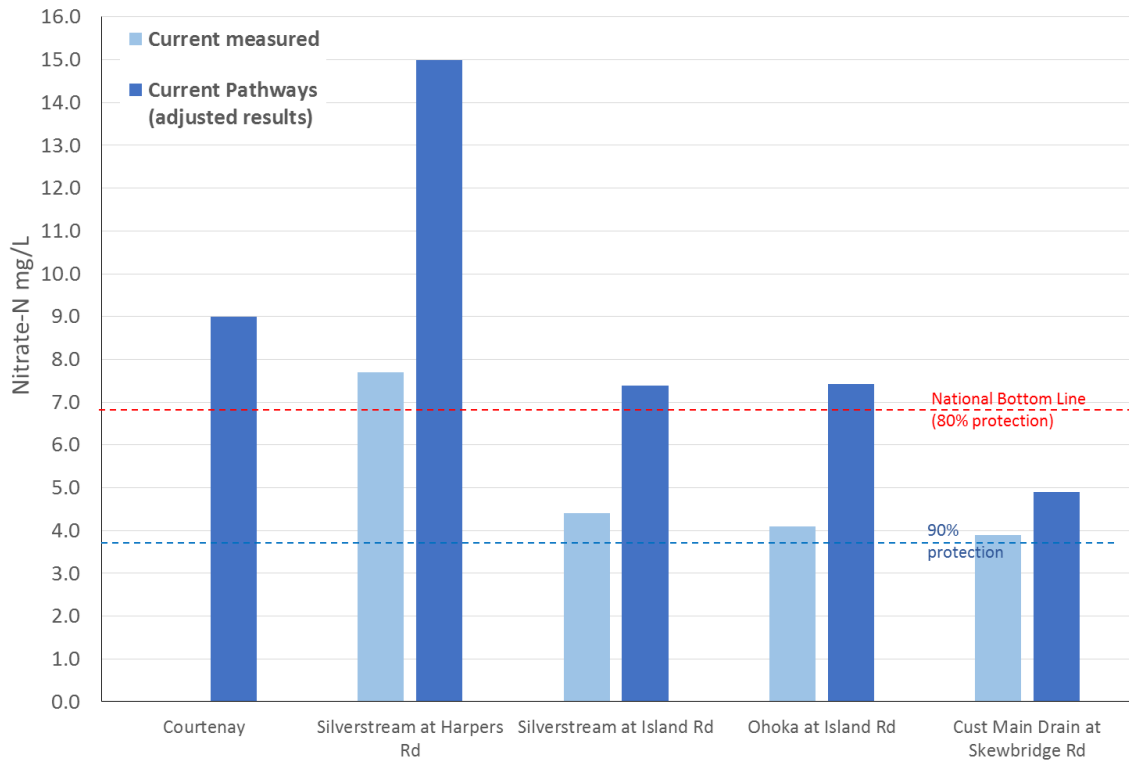


Figure 2-1 Current measured and Current Pathways nitrate – Kaiapoi River tributaries⁸

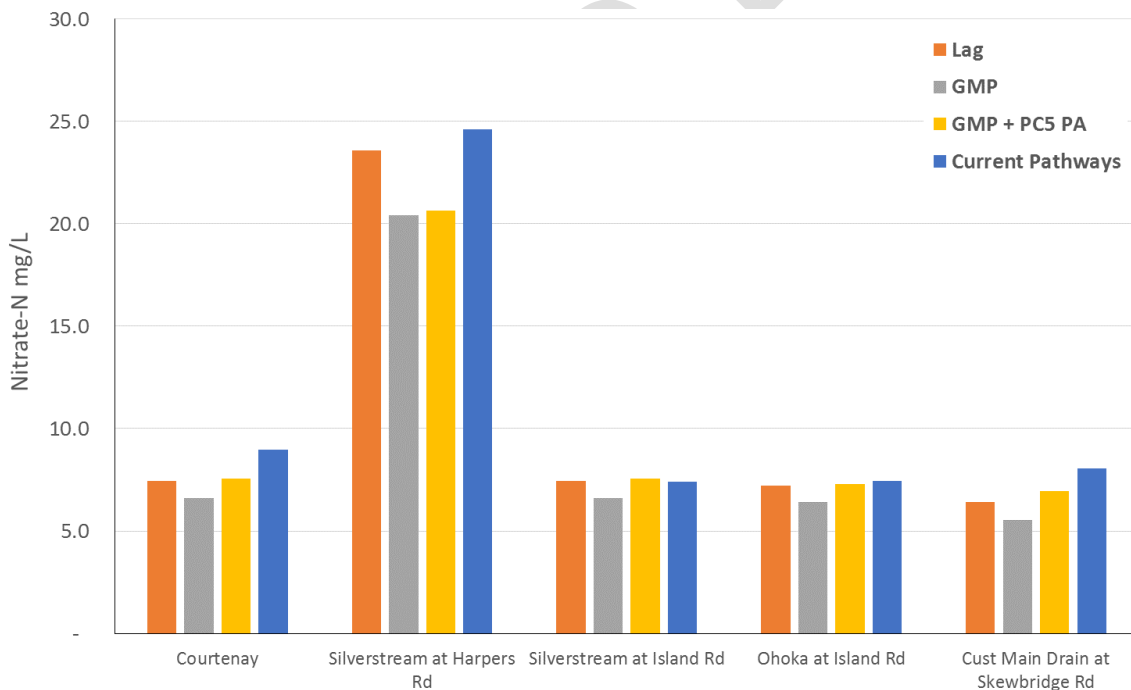


Figure 2-2 Current Pathways elements nitrate – Kaiapoi River tributaries⁸

Current Pathways Scenario adjusted model results for the Ashley Groundwater Allocation Zone (GAZ) streams (Figure 2-3) indicate that nitrate concentrations are likely to remain below the NOF A Band limit of 1.0 mg/L. The raw model results for the individual Current Pathways elements (Figure 2-4) indicate that nitrate could exceed the NOF A Band limit if there is a significant lag between land use

⁸ Excluding Cam River/Ruataniwha

change and water quality impacts. As per the Cust Main Drain, current information suggests that this is unlikely to be the case.

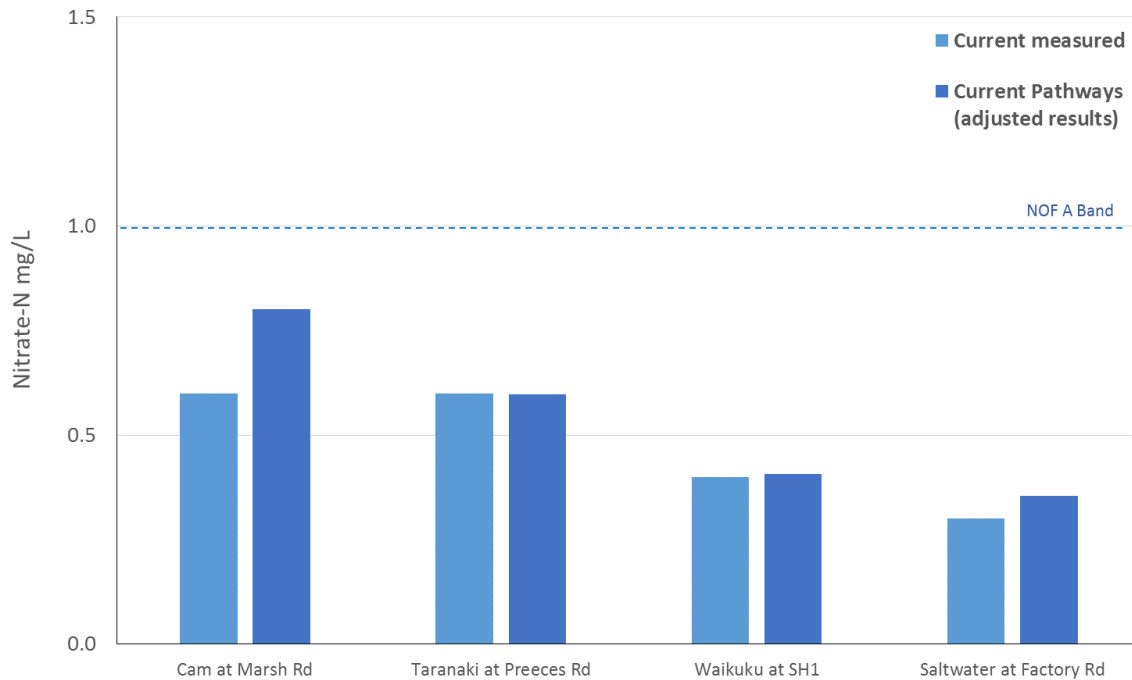


Figure 2-3 Current measured and Current Pathways nitrate – Ashley GAZ streams

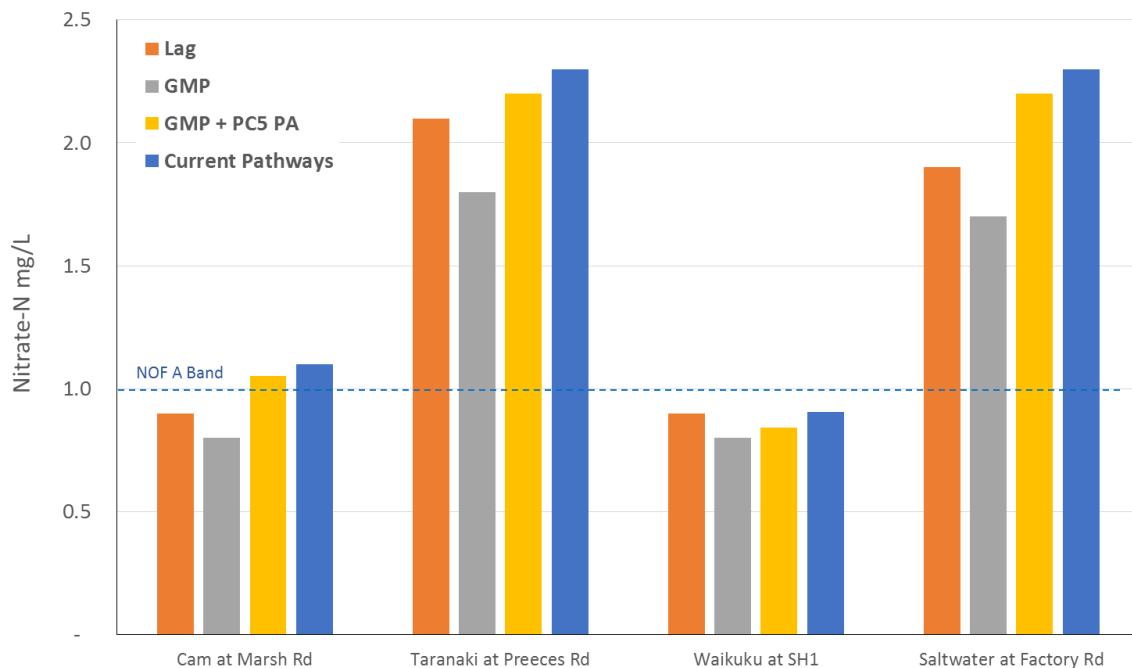


Figure 2-4 Current Pathways elements nitrate – Ashley GAZ streams

The Cultural Health Assessment report (Tipa, 2016) recommends that nitrate concentrations in the watercourses discussed in this report should be maintained within, or reduced to be within, the NOF A Band limit (1 mg/L). A significant reduction in concentrations would be required in Silverstream, Ohoka Stream, Cust River/Main Drain and Courtenay Stream to achieve this.

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Waimakariri Alternative Pathways Scenario Water Management Options Assessment

Table 2-1 Updated Current Pathways Scenario results: nitrate-N (mg/L)

Stream	Site	Current measured	Lag ⁹	Lag + GMP ⁹	Lag + GMP + PC5 PA ⁹	Current Pathways model results ^{9,10}	Current adjusted results ¹¹	Pathways model
Waimakariri	Brooklands Lagoon ¹²	No data	0.7	0.6	0.6	0.6	-	
Kaipoi 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	
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	
Silverstream	Harpers Rd	7.7	23.6	20.4	20.7	24.6	≥15	
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	
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	
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	
Cam	Youngs Rd	0.6	0.8 to 0.9	0.7 to 0.8	1.0 to 1.1	1 to 1.1	0.8	
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	
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	
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	
Ashley	Gorge	0.05	0.11	0.11	0.11	0.11	0.11	
Ashley River	Estuary	No data	1.3	1.2	1.3	1.3	1.3	

⁹ 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)

¹⁰ Includes projected flow reductions associated with climate change plus PC5 PA rules plus GMP

¹¹ 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. E.G. model results project significant nitrate increase in Cust Main Drain, but anecdotal information suggests 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

¹² Based on Waimakariri River flows only – assumes no dilution with seawater.

2.4 Issues: nitrate in water supply wells

Summary

Nitrate concentrations are currently expected to exceed the drinking water standard limit in approximately 100 domestic water supply wells in the Waimakariri zone. This could increase significantly, to over 400 wells, when the projected lag effect between land use change and water quality effects is accounted for. This issue could potentially be exacerbated by the proposed PC5 PA rules. Wells in the Eyre River GAZ are most at risk. The risk to wells in the Cust and Ashley GAZs is much lower.

Nitrate results for community water supply wells follow a similar pattern: the projections suggest that there is a reasonable likelihood that either treatment or development of an alternative (lower nitrate) water supply source could be required for water supply wells within the Eyre River GAZ (e.g. Kaiapoi wells) in the long term. Current results assume no attenuation of nitrate and have not accounted for the effects of climate change. Attenuation could potentially reduce nitrate concentrations whilst climate change could potentially cause further increases (reduced dilution).

We have summarised the revised *Current Pathways Scenario* assessment results for projected nitrate maximum acceptable value (MAV, 11.3 mg/L nitrate-N) in Table 2-2, and provided a more detailed breakdown of the model results for the Cust and Eyre catchments graphically in Figure 2-5 and Figure 2-6. This breakdown indicates that whereas the risk of nitrate MAV exceedances in the Cust River/Main Drain catchment is unlikely to increase significantly, the number of wells in which nitrate exceeds the MAV could increase significantly in the Eyre River catchment. These results align with the feedback from the feedback from the Waimakariri Farmer Reference Group discussed in Section 2.2.

As noted above, the water supply well nitrate results assume no attenuation. This will be addressed during the final iteration of the *Current Pathways Scenario* results, which will be used as a basis for development of the Solutions Programme.

Table 2-2 Risk of nitrate MAV exceedance¹³ in domestic water supply wells

Simulation	Risk of DWS exceedance	No of wells \geq MAV
Current measured	3%	100
Current (after lag)	12 % to 25 %	410 to 820
GMP	10 % to 21 %	320 to 700
GMP + PC5 PA	17 % to 32 %	570 to 1070

¹³ These statistics are generally based on annual groundwater quality surveys undertaken in August and September. Groundwater nitrate concentrations are usually at their highest in these months, and hence the exceedance risk is likely to relate more closely to the annual maximum than the annual average. This means that the risk of DWS exceedance shows the likelihood of nitrate exceeding the MAV on one or more occasions per year.

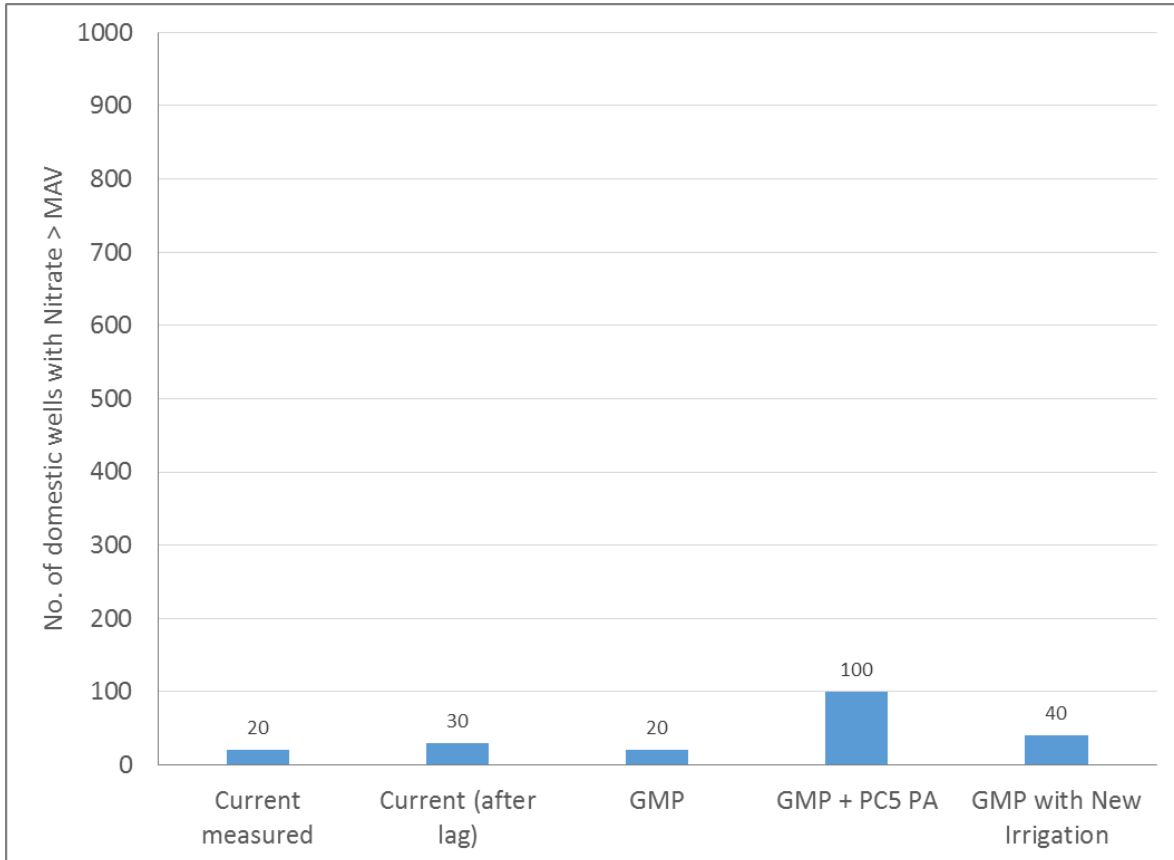


Figure 2-5 No. of domestic wells with nitrate projected to exceed MAV in Cust catchment

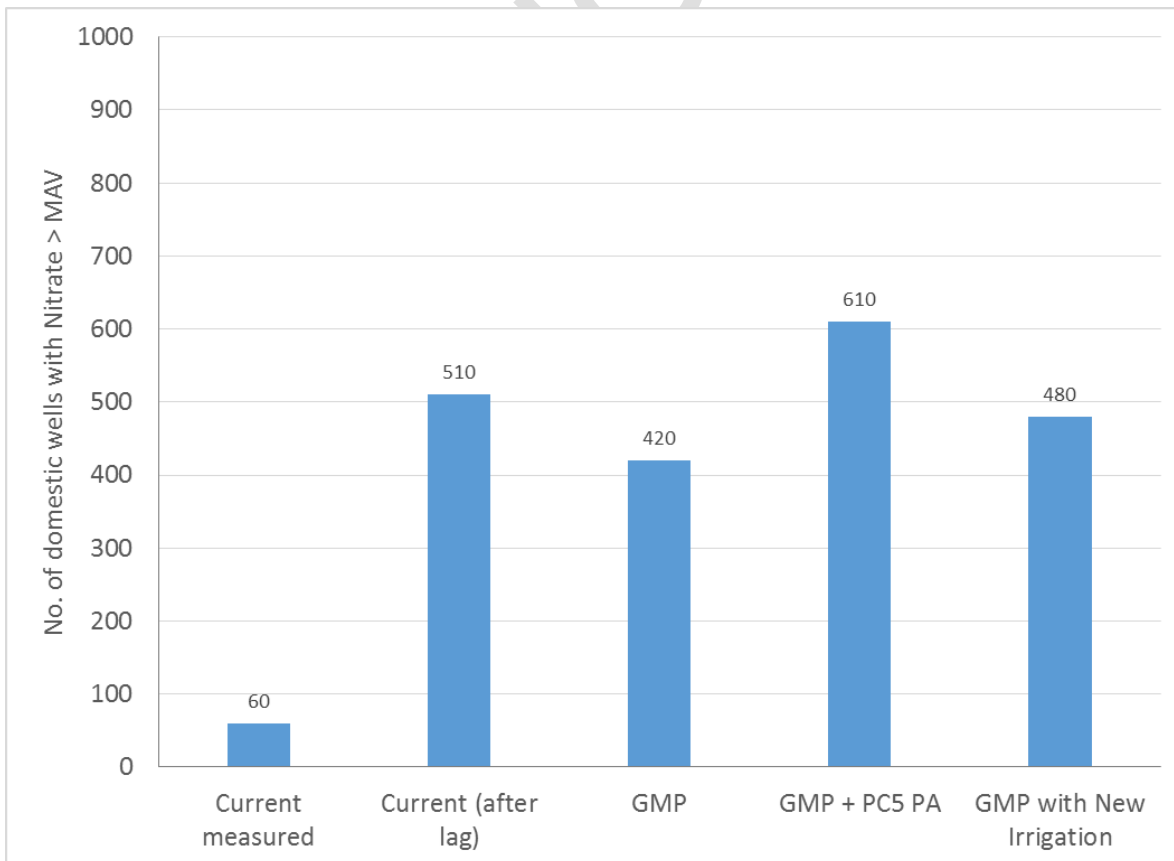


Figure 2-6 No. of domestic wells with nitrate projected to exceed MAV in Eyre catchment

Nitrate results for community water supply wells in the Waimakariri zone are summarised in Appendix 1. We have presented results from the Cust community water supply wells and one of the Kaiapoi town water supply wells graphically in Figure 2-7. The results are presented as a risk that either nitrate treatment or an alternative (low nitrate) water supply source will be required in order to maintain nitrate concentrations below the MAV. The results suggest that risk to the Cust supply well could increase to around 10% due to lag effects. Implementation of GMP is projected to reduce the risk slightly, whilst the PC PA rules could potentially increase the risk to around 15%. Model results suggest that the risk to the Kaiapoi supply wells (located in the Eyre River GAZ) is greater. Lag is the main driver for a projected increased risk from zero at present to around 20%.

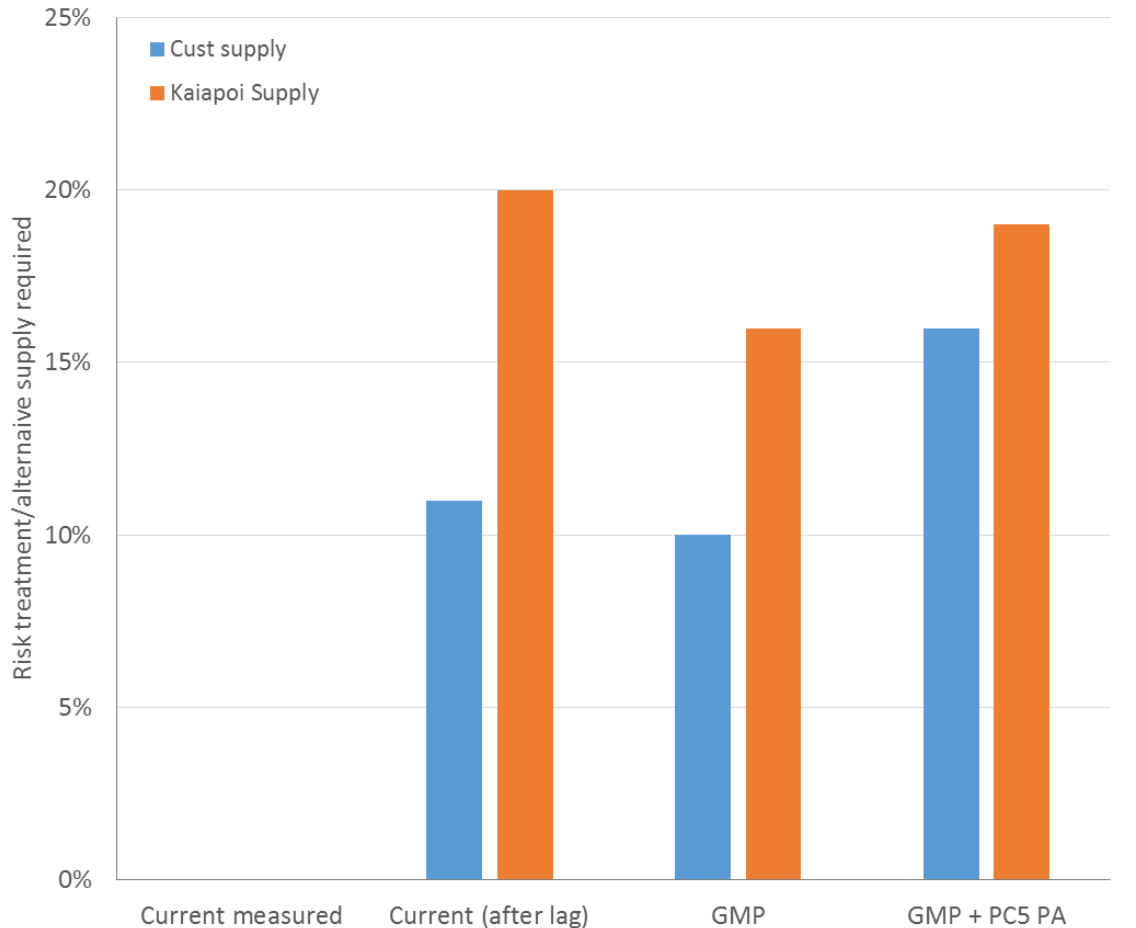


Figure 2-7 Current Pathways Scenario results for Cust and Kaiapoi community supply wells

2.5 Issues: flow in spring-fed streams

Summary

Modelling results indicate that median flows could reduce by around 20% in Silverstream and Ohoka Stream and by 25% in Cust Main Drain, due to the combined effects of improved irrigation efficiency and climate change. Much smaller flow reductions of around 3% are projected for the Ashley GAZ spring-fed streams.

Further increases in groundwater abstraction from the Cust, Ashley and Kowai GAZs could cause baseflows in the spring-fed streams to decline. The Cultural Health Assessment report recommends no further allocation of water from Taranaki stream or connected groundwater, that flows in the Cust River should be increased and concludes that flows in Saltwater Creek flows are already too low.

We have assessed the effects of improved irrigation efficiency under GMP and the expected reduction in land surface recharge (LSR) due to climate change on spring-fed stream flows. For the former we

have assumed that implementation of GMP results in a ~15% reduction in LSR, based on Overseer-based soil water budget modelling. This estimate will need to be refined as part of the next phase of work. For the climate change modelling we have used data generated by NIWA under the IPCC3 climate scenario model. The model provides a “middle of the road” type estimate of the potential changes in precipitation and rainfall between the “base period” (1980 – 2000) and two future periods: 2030 – 2050 and 2080 – 2100. The model is based on the A1b carbon emissions scenario and takes the average results from 12 different Global Climate Change models. The climate change projections are therefore not conservative: actual effects could potentially be worse (or better) than these projections. The IPCC3 climate change has been superseded: results from IPCC5 are now available, but more work is required to process these data for the Waimakariri zone. We are planning to finalise our climate change effects assessment during the Solutions phase.

We used the Hargreaves Eto method (Allen et. al., 1998) to estimate the relative change in evapotranspiration for the three climate periods, and applied the results (together with the projected precipitation data) to a simple soil water budget model to estimate change in LSR. We then used our groundwater budgets in the Waimakariri GAZs (modified from Etheridge and Wong, 2016) to estimate what the projected reduction in LSR could mean for spring-fed stream flows. We assumed that runoff from the hill-fed streams (e.g. Eyre River, Coopers Creek) will not reduce significantly due to climate change, based on modelling results provided by NIWA.

Model results are summarised in Table 2-3. The combined GMP and climate change modelling results (Figure 2-8) indicate that median flows could reduce by around 20% in Silverstream and Ohoka Stream and by 25% in Cust Main Drain. Implementation of GMP within the WIL command area accounts for 7 – 10% of these flow reductions.

Much smaller flow reductions of around 3% are projected for the Ashley GAZ spring-fed streams (Figure 2-9 **Error! Reference source not found.**). This is because climate change effects are likely to be lower here: the Ashley River/Rakahuri provides most of the groundwater recharge to this area, and mean Ashley River/Rakahuri flows are not expected to reduce significantly under the current climate change model results. GMP is unlikely to affect flows in these streams because local irrigation water is sourced from wells. This means that the reduction in LSR associated with improved irrigation efficiency will be offset by reduced groundwater abstraction.

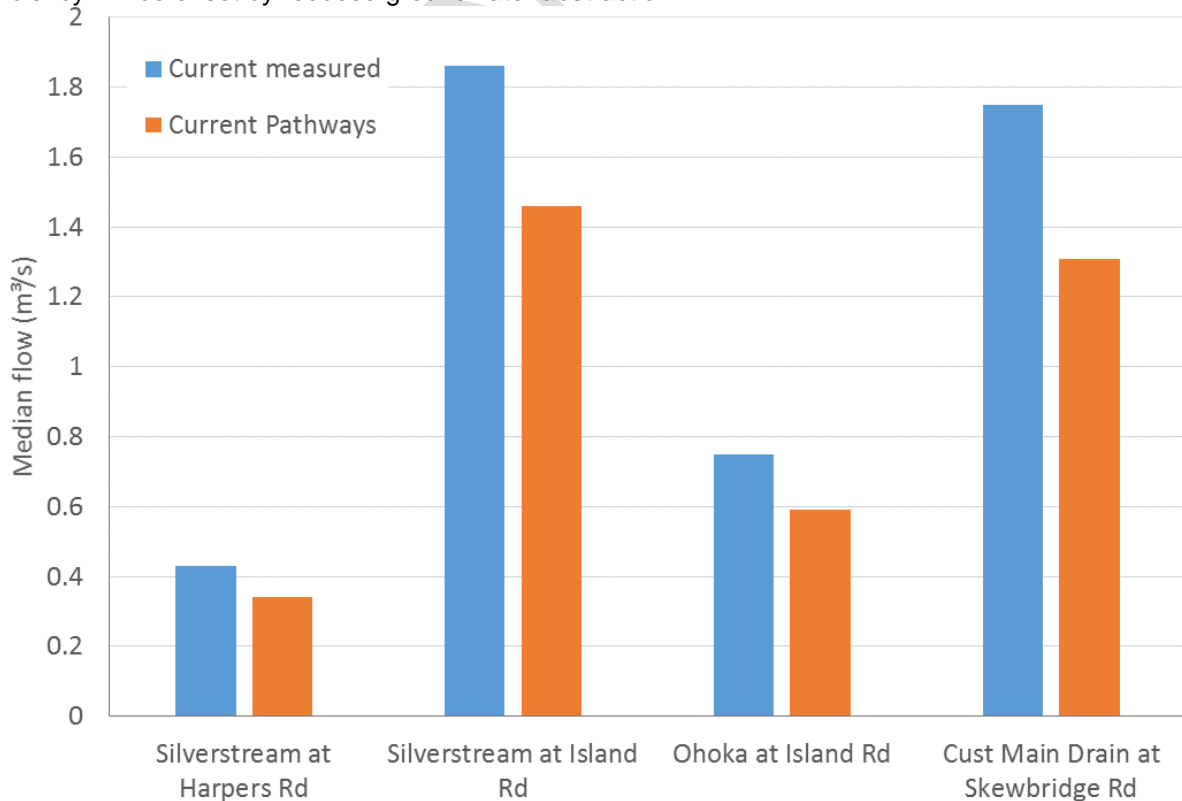


Figure 2-8 Projected *Current Pathways* median flow changes for Silverstream, Ohoka Stream and Cust Main Drain

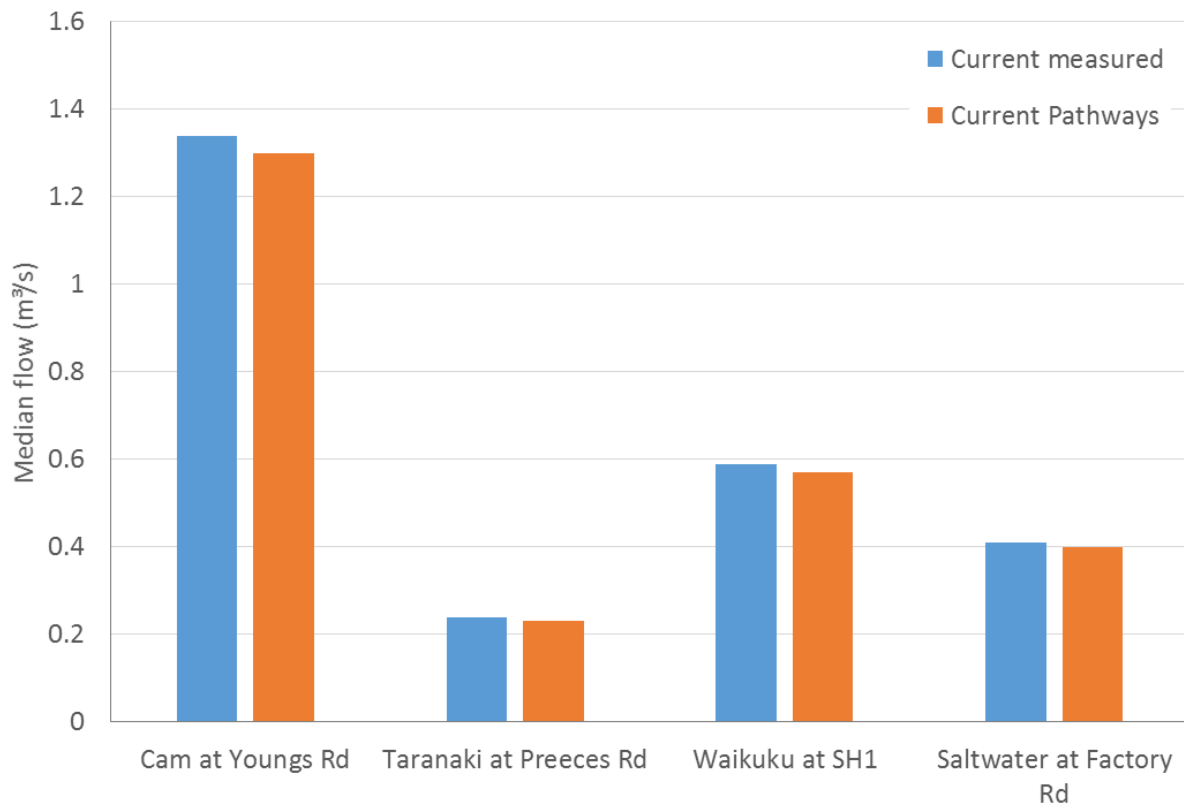


Figure 2-9 Projected *Current Pathways* median flow changes for Cam River, Taranaki Creek, Waikuku Stream and Saltwater Creek

A preliminary assessment of the effects of increasing groundwater abstraction in the Cust and Ashley GAZs was presented in the *Waimakariri Current Pathways Scenario – Groundwater Assessment Results* memo issued to the Waimakariri Water Zone Committee in December 2016. The results indicated that a groundwater level decline of around 0.1 m was possible if abstraction increased by around 300 L/s on average in the Ashley GAZ and 400 L/s in the Cust GAZ. This reduction in groundwater levels could potentially increase the rate of water loss from the Ashley River/Rakahuri, which in turn could exacerbate the duration/frequency/length of drying reaches. The likelihood of this occurring has not been assessed, but some comments were made during a Zone Committee meeting about the limited potential for large increases in groundwater abstraction from the Cust GAZ given the relatively low well yields here..

Further increases in groundwater abstraction from the Kowai, Ashley and Cust GAZs could also cause flows in spring-fed streams to decline. A theoretical assessment undertaken in the above-referenced memo indicated that flows in Saltwater Creek could potentially reduce by over 10% if groundwater abstraction increases in the Kowai GAZ. Baseflows in the Cam River, Taranaki Creek and Waikuku Stream could reduce by around 5-10% if more groundwater is abstracted from the Ashley GAZ, whilst further groundwater takes in the Cust GAZ could, in theory, cause a 15-20 % reduction in baseflows in the Cust River/Main Drain.

The Cultural Health Assessment report (Tipa, 2016) recommends that there should be no further allocation of water from Taranaki stream or connected groundwater, that flows in Saltwater Creek flows are already too low and that flows in the Cust River should be increased.

Waimakariri Alternative Pathways Scenario Water Management Options Assessment

Table 2-3 Current Pathways Scenario flow results

Stream	Site	Current measured		GMP		Current Pathways ¹⁴		
		Mean/ median ¹⁵ m ³ /s	7dMALF (m ³ /s)	Mean/ m ³ /s	median ¹⁵	Mean/ median ¹⁵ m ³ /s	% <u>reduction</u> current from	7dMALF (m ³ /s)
Waimakariri River	Brooklands Lagoon	126.3	N/A	125.8		138.4	-10%	No data
Kaipoi River	Waimakariri confluence	5.7	N/A	5.3		4.5	21%	No data
Courtenay	-	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
Silverstream	Island Rd	1.86	1.35	1.74		1.46	21%	1.19
Ohoka	Island Rd	0.75	0.51	0.70		0.59	21%	0.45
Cust Main Drain	Skewbridge Rd	1.75	0.49	1.55		1.31	25%	0.58
Cam	Youngs Road	1.34	1.19	1.34		1.30	3%	1.19
Taranaki	Preeces Rd	0.24	0.17	0.24		0.23	3%	0.17
Waikuku	SH1	0.59	0.36	0.59		0.57	3%	0.36

¹⁴ Includes projected flow reductions associated with climate change plus PC5 PA rules plus GMP

¹⁵ Mean flow for Waimakariri and Ashley Rivers; median flows for spring-fed streams/rivers

Waimakariri Alternative Pathways Scenario Water Management Options Assessment

Stream	Site	Current measured		GMP		Current Pathways ¹⁴		
		Mean/ median ¹⁵ m ³ /s	7dMALF (m ³ /s)	Mean/ m ³ /s	median ¹⁵	Mean/ median ¹⁵ m ³ /s	% <u>reduction</u> from current	7dMALF (m ³ /s)
Saltwater	Factory Rd	0.41	0.26	0.41		0.40	3%	0.26
Ashley River/Rakahuri	Gorge	12.3	2.04	12.3		12.4	-1%	2.04
Ashley River/Rakahuri	Te Akaaka estuary	No data	No data	18.9		18.8	0%	No data
Garry River	Ashley confluence	0.64	No data	0.64		N/A	N/A	No data
Mount Thomas Stream	Ashley confluence	0.36	No data	0.36		N/A	N/A	No data
Okuku River	Ashley confluence	4.77	No data	4.77		N/A	N/A	No data

2.6 Issues: flows in the Ashley River/Rakahuri

Summary

The Ashley River/Rakahuri regularly dries up in the summer months. Although this is a natural occurrence, it is likely to be exacerbated by groundwater abstractions lowering local groundwater levels and thus increasing the hydraulic gradient between the river and surrounding groundwater. Surface water abstractions are unlikely to have a significant effect on the drying of the river as the majority of surface abstractions must cease prior to the river reaching a flow at which drying occurs. The lack of ki uta ki tai during summer months is a major issue for Te Ngai Tuahuriri Runanga. Tipa (2016) recommends that a visible connected flow is reinstated for the Ashley River/Rakahuri.

In addition to drying, very low flows are also an issue, in particular for nesting birds. The gravel islands formed between river braids are a critical habitat for a number of nesting birds, as are the pools, runs and riffles created between islands which serve as a food source. As low flows dominate, both islands and braid character are lost. The protection of nesting birds on the Ashley River/Rakahuri has been identified as a Priority Outcome by the WWZC.

Previous work undertaken by Environment Canterbury (Etheridge & Wong, 2016, Megaughin & Hayward, 2016) has shown that low flows (and hence the extent / duration of dry reaches) are primarily climate-driven. Dry reaches in the Ashley River/Rakahuri are a natural occurrence in the summer months, the natural losses from the channel above Rangiora being greater than the natural flow leaving the Ashley gorge.

It has been common practice to use a flow at the Ashley Gorge of 2.5 m³/s as the point at which ki uta ki tai (flow connection from mountains to sea) is not likely to occur (Mosley 2001). The 2.5 m³/s value is based on concurrent gaugings and visual observations over a succession of years.

There are no reliable records of the number of days each year that ki uta ki tai does not occur, nor is there a record of the extent of river over which drying occurs. This lack of record limits our ability to assess the effects of future river management options.

To overcome this deficiency, we undertook a model-based analysis of the number of days per year the Ashley River/Rakahuri was likely to be dry. We used the available flow records and groundwater level records to create a model of drying along the river. There is not enough data available to validate the model constructed, therefore its results must be used with caution in the subsequent decision making process. The relative differences between values becomes more important in this case than the absolute values provided.

Figure 2-10 shows the estimated number of days the Ashley River / Rakahuri does not maintain ki uta ki tai under the current conditions and under the *Current Pathways* scenario.

Our modelling suggests that, under the current pathway, drying reduces. The driver for this lies in the climate change work undertaken for the Ashley River/Rakahuri. Climate change predictions currently suggest that the flow in the Ashley River/Rakahuri will increase slightly for the January – May period (Zammit C & Woods R, 2011), which causes in the number of dry days to reduce.

We have not been able to fully explore this proposed effect, and are mindful that a revised climate change data set for New Zealand is now available, but has not be utilised in this work. It is also important that this predicted change be considered in the context of natural climate cycles, such as El Nino-Southern Oscillation (ENSO) and Interdecadal Pacific Oscillation (IPO), which we have not yet be able to do.

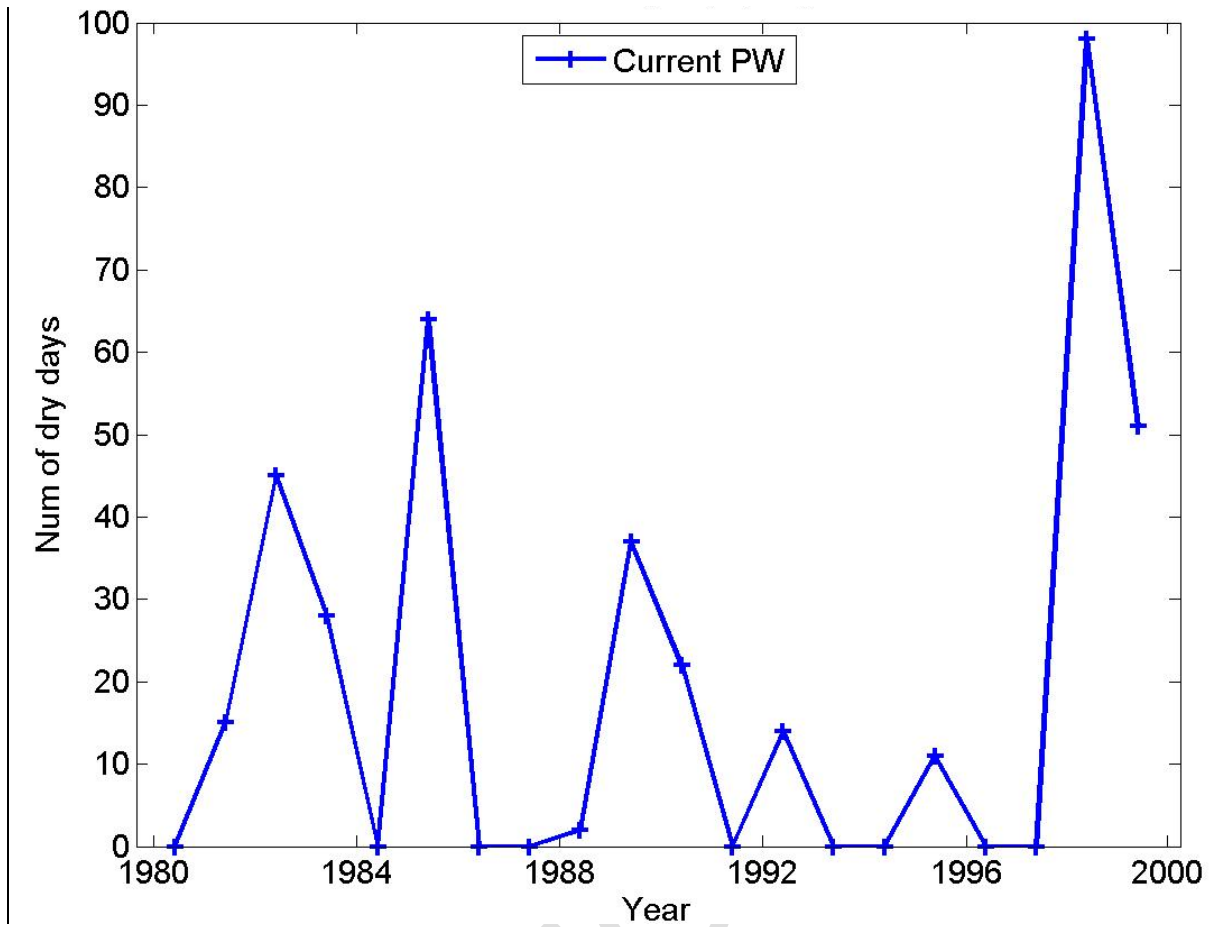


Figure 2-10 Estimate of number of days ki uta ki tai does not occur under the *Current Pathways* scenario – Ashley River/Rakahuri

2.7 Issues: Updating environmental, cultural & recreational flow requirements

Summary

At present uses of flow in the Ashley River/Rakahuri and tributaries, and the lowland spring-fed streams are allocated and controlled by the Waimakariri Regional River Plan (WRRP) and the Land and Water Regional Plan (LWRP). These documents set the allocation blocks and minimum flows on each of the watercourses. These values were set to protect the values placed on each watercourse during the preparation of the WRRP, LWRP and its predecessor the Natural Resources Regional Plan (NRRP).

Since this time work by a number of parties has been undertaken to determine alternative management regimes for the Zone's watercourses. Whilst each of these individual recommendations have their merits the cumulative effects of changes to allocations can be significant, both for the watercourses and the current users. We have presented below a comparison of the existing minimum flows and proposed revised minimum flows. Seven day mean annual low flows (7dMALF) and mean flows are provided for reference.

The Current Pathway 7dMALFs for Ohoka Stream, Cust River, Taranaki Creek and Kaiapoi River (Butchers Bridge) are all greater than the cultural and ecological recommendations, placing these watercourses in a good position to be able to meet the WWZC Priority Outcomes.

The Current Pathway 7dMALFs for Kaiapoi River (Neeves Road), Cam River, Ashley River (Gorge) do not meet the cultural flow recommendations.

The Current Pathway 7dMALF for Waikuku Stream does not meet any the recommendations.

No cultural flow recommendation was made for Saltwater Creek, however it was noted that flows were too low for mahinga kai purposes.

To change the way a particular value (e.g. ecology / cultural importance) is reflected in stream flow, changes must be made to the governing plan. Assessments of what changes could be made on the basis of current ecology and cultural considerations have been undertaken in Golder (2009) and Tipa (2016). Further work is currently being undertaken to assess environmental flows for the Rakahuri at Ashley Gorge, Taranaki Stream, Saltwater Creek and Little Ashley stream.

We have compared these flow targets, and the current plan minimum flows, to the current 7dMALF and the current mean flow (Figure 2-11 - Figure 2-18 below plus Appendix 2). The main findings of this review are summarised below.

In the Ohoka Stream the recommended ecological and cultural flow are higher than the WRRP allocation block minimum flow by 70 L/s and 120 L/s respectively (Figure 2-11). These recommended flows are below both the Current and Current Pathways 7dMALF flow for the stream, however.

Our modelling predicts that the Cust Main Drain will experience a significant change in mean flow under the Current Pathway (Figure 2-12). The ecological recommendation (Golder, 2009) is the same as the WRRP allocation block minimum flow. The cultural recommendation is 170 L/s higher, but this is less than both the Current and Current Pathway 7dMALFs.

The Cam River ecological recommendation is lower than the WRRP minimum flow (Figure 2-13). They are both below the 7dMALF for the Current and Current Pathway situations. The cultural recommendation is 200 L/s higher than the WRRP minimum flow, the Current and Current Pathway mean flows. The existing Cam River minimum flow was set to include an allowance for dilution of wastewater flows which no longer enter the Cam River.

Taranaki Creek was not specified in Tipa (2016) with a cultural flow recommendation. The ecological recommendation is equal to the LWRP minimum flow (Figure 2-14). We do not expect changes in the current pathway mean and 7dMALF.

In the Kaiapoi River/Silverstream (Neeves Road) we have estimated a 270 L/s decrease in 7dMALF flow following the Current Pathway (Figure 2-15). The ecological recommendation is 400 L/s higher than the WRRP minimum flow but both are below the Current Pathway 7dMALF. The cultural recommendation is an additional 200 L/s higher than the ecological threshold. It is lower than the Current 7dMALF however the Current Pathways 7dMALF is 140 L/s below the recommended cultural flow.

The Waikuku Stream falls under the LWRP and has a split minimum flow; 100 L/s from Monday to Friday, and 150 L/s from Saturday to Sunday (Figure 2-16). This is set well below the 7dMALF, which we do not expect to change in the Current Pathways. The cultural recommendation is between 450 and 500 L/s higher than the minimum flow. This value is also higher than the Current and Current Pathways means.

Butchers Bridge on Kaiapoi River/Silverstream was identified as a site of cultural importance in Tipa (2016). There is no difference in flow between this site and Skewbridge/Island Road which is our established monitoring and reporting site on the Kaiapoi River/Silverstream. As such these sites can be considered as being the same for the purposes of flow discussions. The cultural flow recommendation of 600 L/s (Tipa 2016) is well below the Current and Current Pathways 7dMALFs (Figure 2-17).

The Ashley River/Rakahuri minimum flow regime varies throughout the year. Three separate minimum flows are set for the periods; January to July, August to November, and December (Figure 2-18). These minimum flows are between 500 L/s and 2000 L/s higher than the 7dMALF. We do not expect a change in 7dMALF under the Current Pathways. The cultural recommendation is also considerably higher than the 7dMALF, approximately 3000 L/s higher.

We do not expect Saltwater Creek to experience any change in mean or 7dMALF flow under the Current Pathway. No ecological or cultural flow recommendations have been provided in Golder (2009) and Tipa (2016). The LWRP minimum flow is 310 L/s below the Current and Current Pathways 7dMALFs (Figure 2-19).

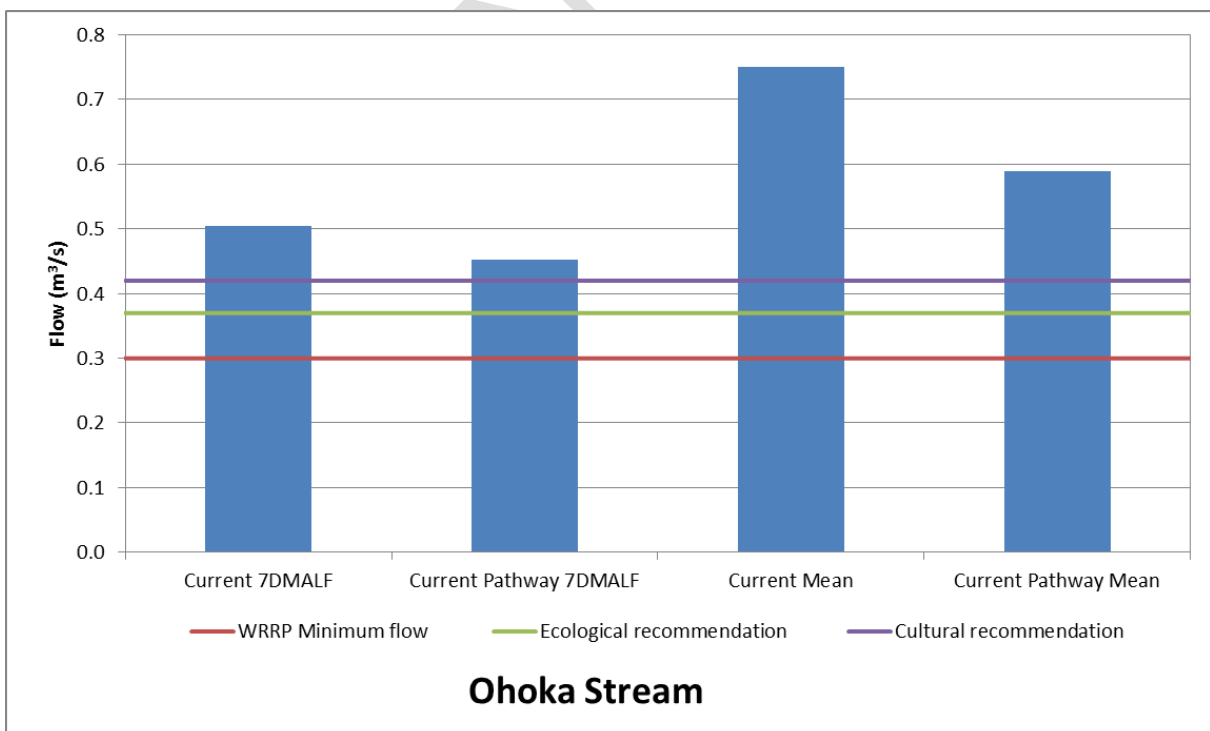


Figure 2-11 Comparison of minimum flows and potential targets for the Ohoka Stream

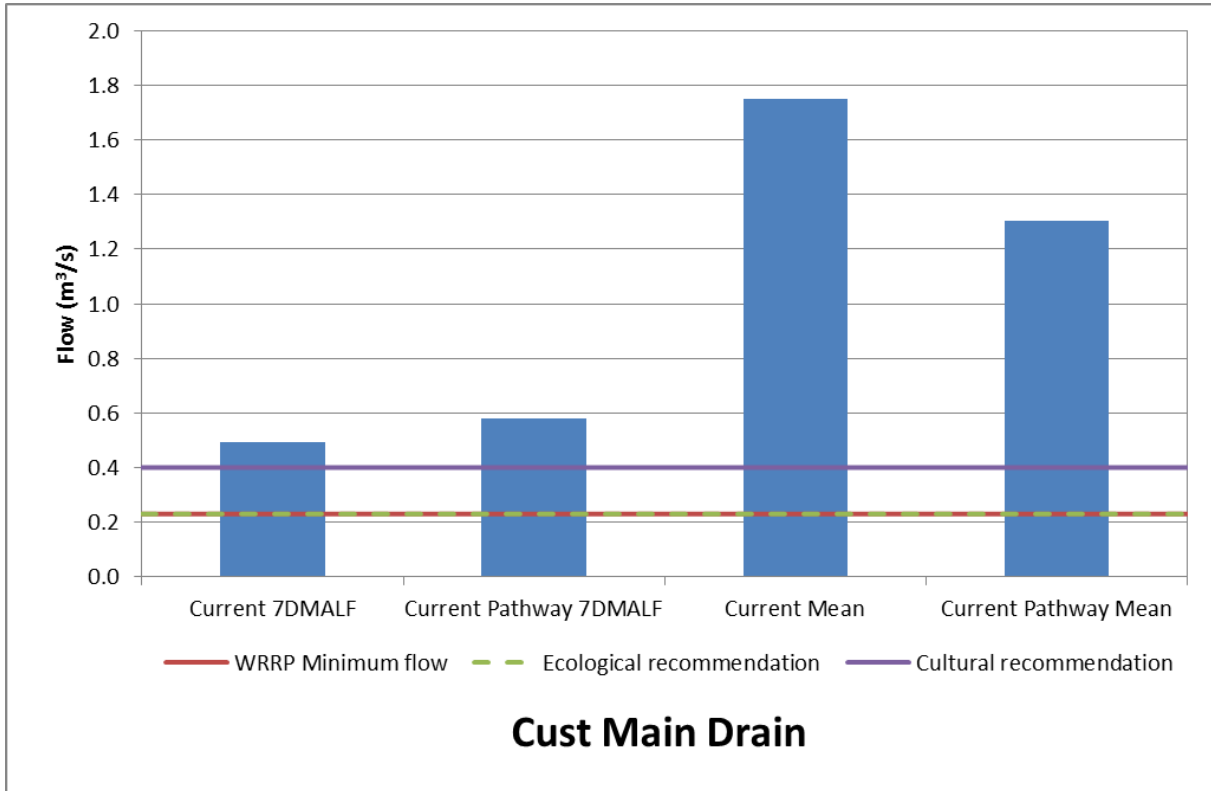


Figure 2-12 Comparison of minimum flows and potential targets for the Cust Main Drain

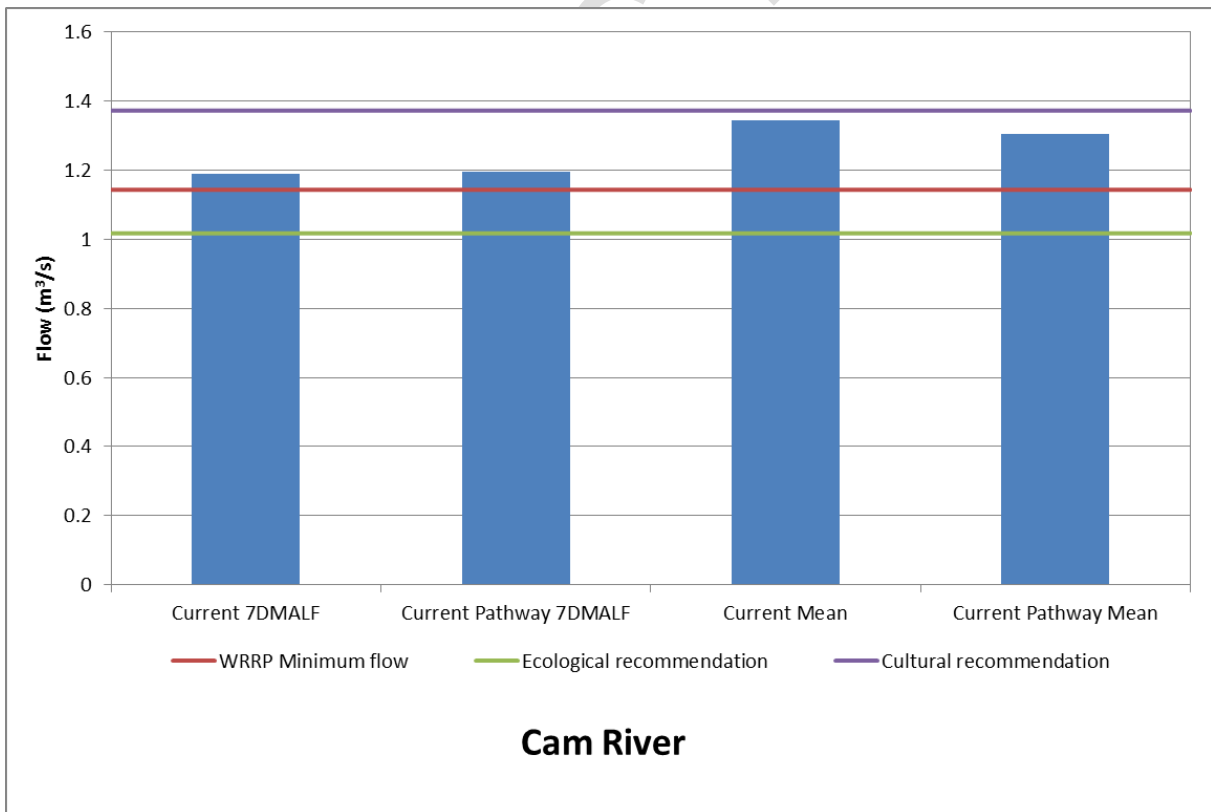


Figure 2-13 Comparison of minimum flows and potential targets for the Cam River

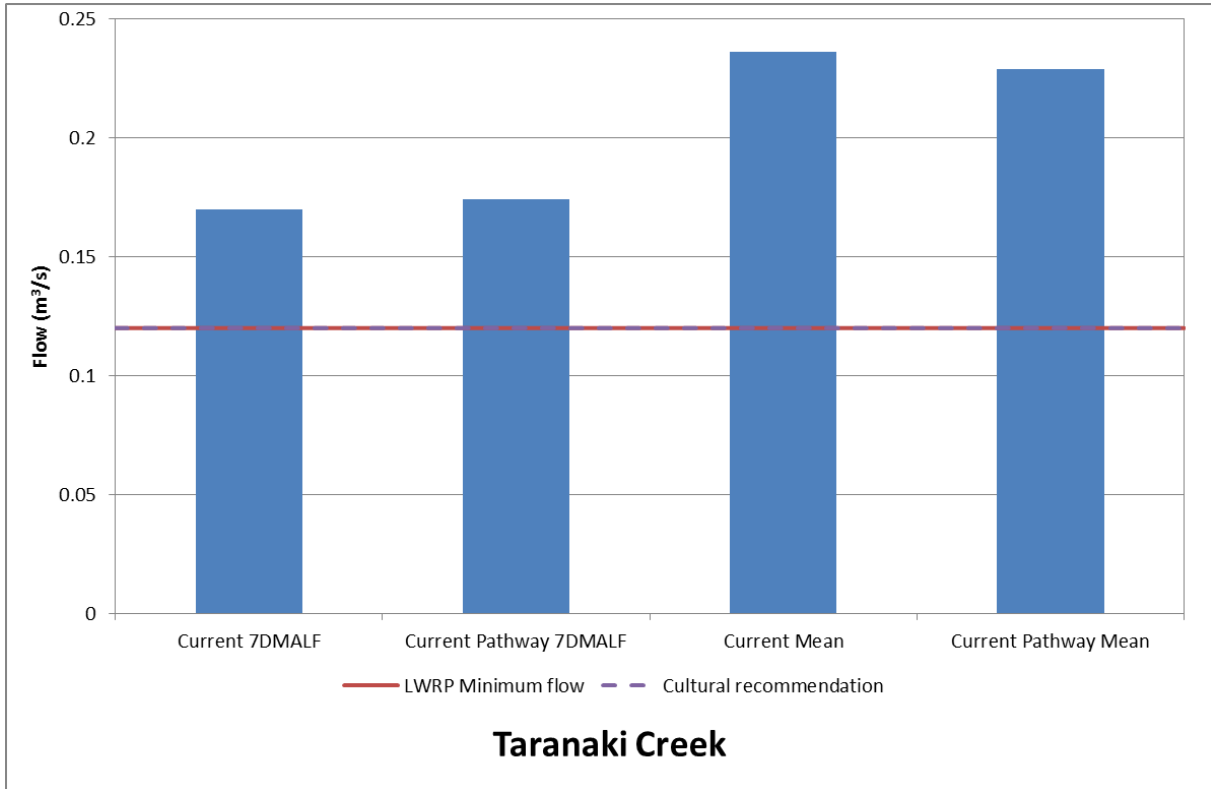


Figure 2-14 Comparison of minimum flows and potential targets for Taranaki Creek

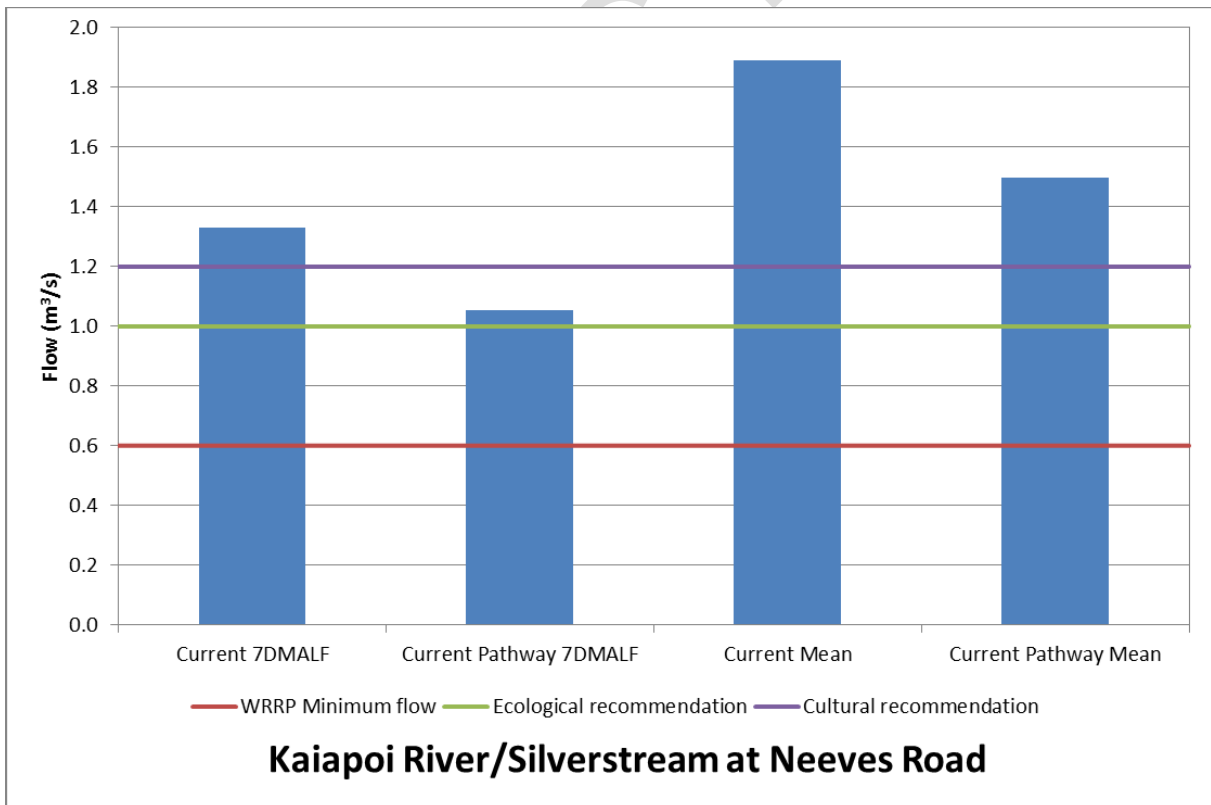


Figure 2-15 Comparison of minimum flows and potential targets for Kaiapoi River/Silverstream at Neeves Road

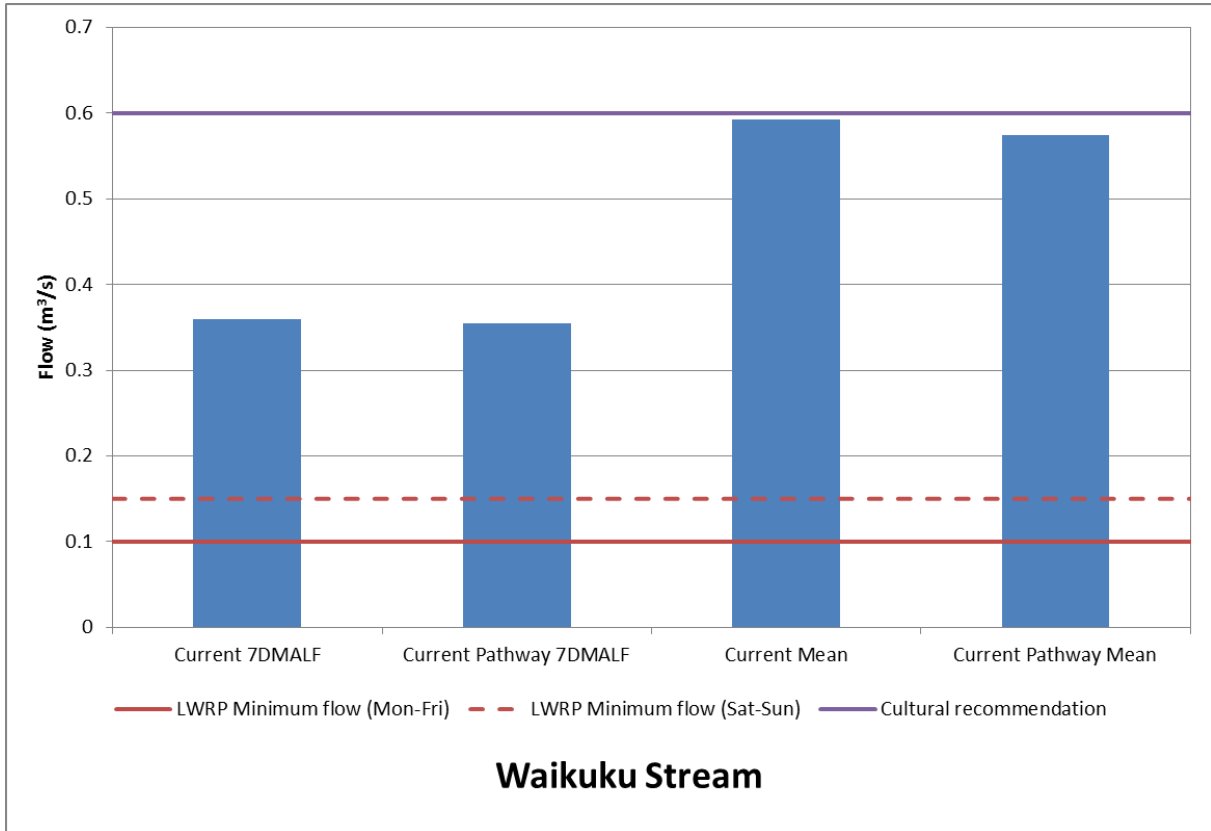


Figure 2-16 Comparison of minimum flows and potential targets for the Waikuku Stream

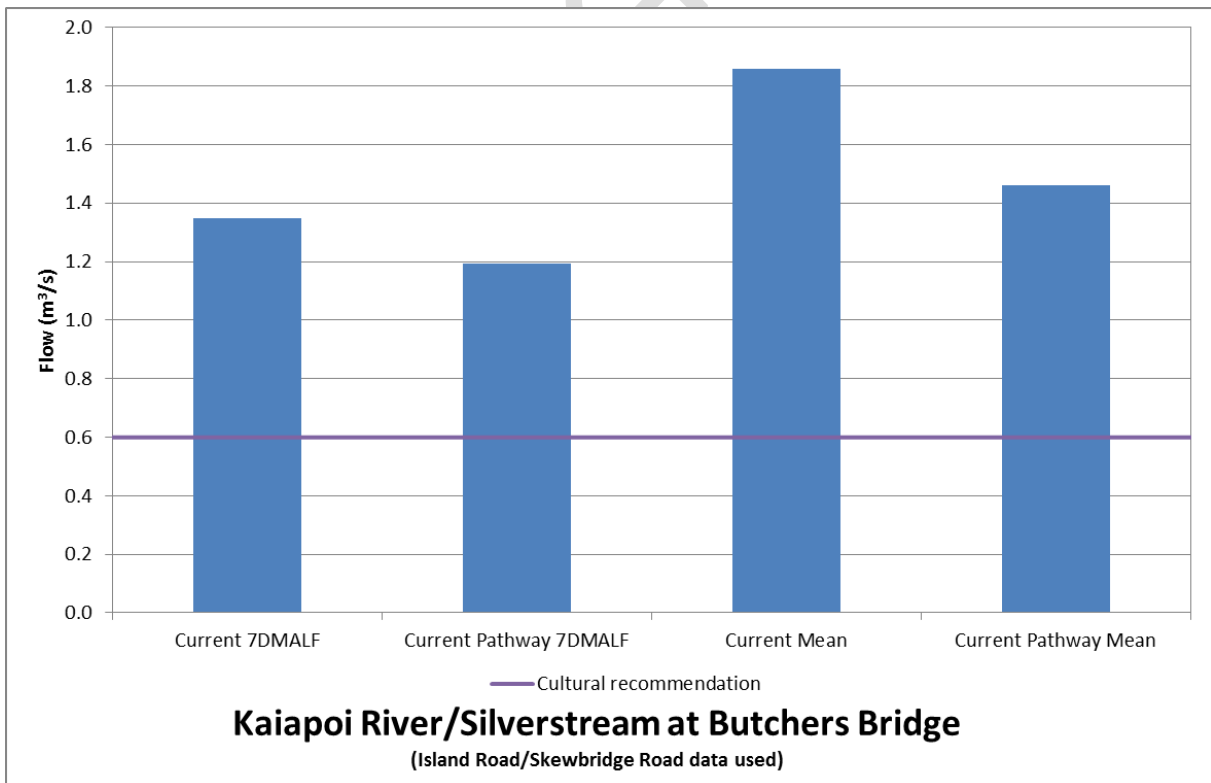


Figure 2-17 Comparison of minimum flows and potential targets for Kaiapoi River/Silverstream at Butchers Bridge (Island Road/Skewbridge Road data used)

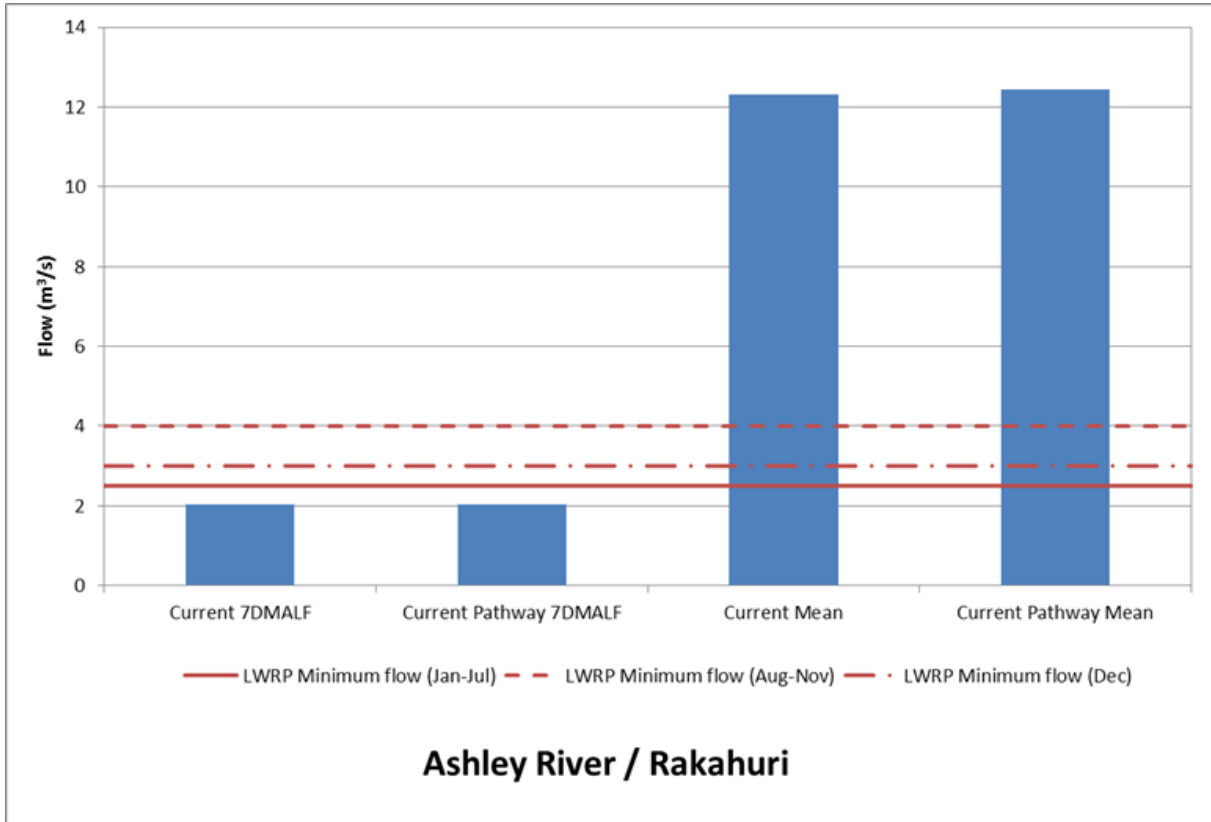


Figure 2-18 Comparison of minimum flows and potential targets for the Ashley River/Rakahuri

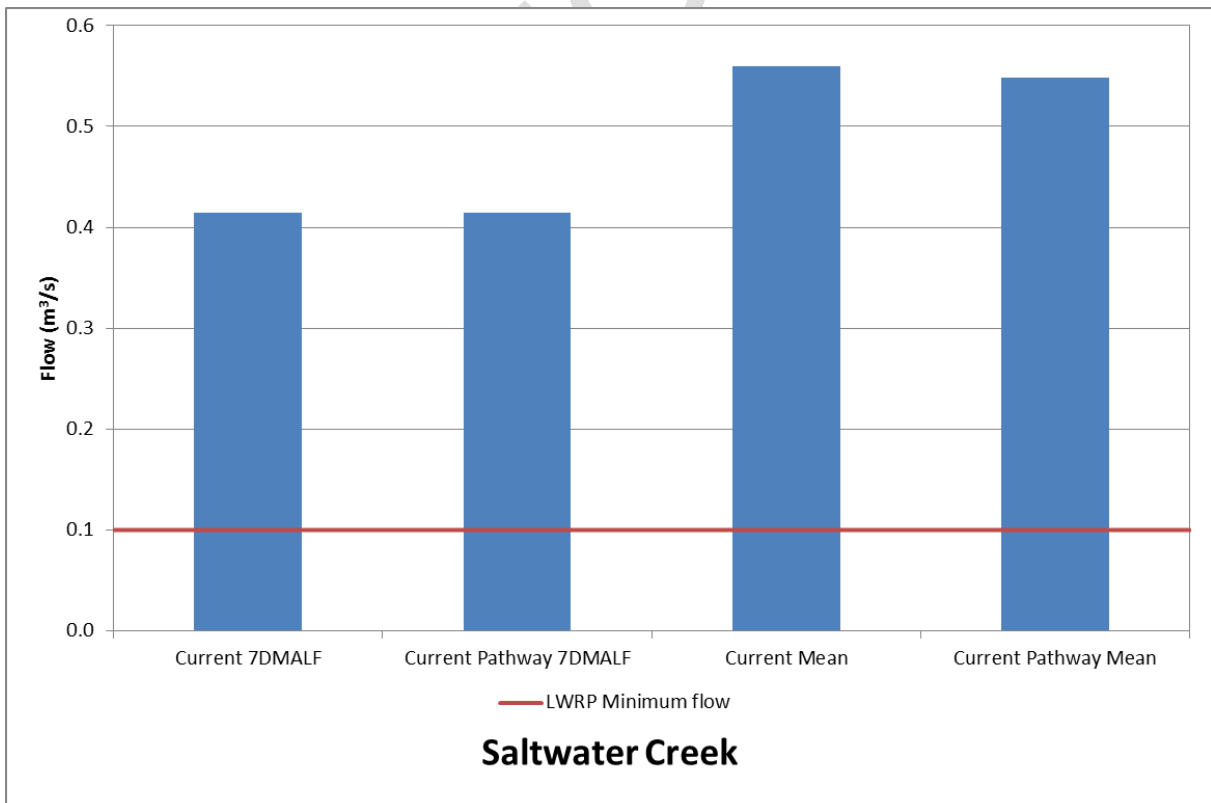


Figure 2-19 Comparison of minimum flows and potential targets for Saltwater Creek

3 Water management options

We have identified a number of water management options under the *Alternative Pathways* scenario that could be utilised to mitigate the issues identified above. These management options need to be considered in the broader range of available management options, many of which do not relate directly to the management of the water resource (e.g. advanced mitigation of nitrate losses from farm land). The options we have considered are:

1. A new water storage scheme in the Lees Valley to provide water for both irrigation and for environmental outcomes
2. Augmentation of specific watercourses where issues have been identified, using available sources of clean water for dilution.
3. Recharge of aquifers using Waimakariri River water, with the intent of boosting spring-fed stream flows and improving water quality in spring-fed streams and supply wells.

We have presented the above options at a high-level, to provide an indication of which ones may be suitable for analysis as part of the Solutions Package, and which have a very low likelihood of achieving the desired outcomes.

3.1 Hypothetical Lees Valley water storage scheme

3.1.1 Hypothetical scheme overview

To explore how community outcomes for the Ashley River / Rakahuri and the wider zone could be met we developed a model of a hypothetical large offline storage scheme (not a main stem storage) and resulting new irrigation. The key attributes of the scheme were:

- 12,600 ha total of new irrigated land. Additional irrigated area - Loburn (3,300 ha), Lees Valley (550 ha) and Cust/Ashley/Eyre (8,750 ha)
- New irrigated area in the Lees Valley changes land use to dairy support; New irrigated area Loburn and Cust/Ashley/Eyre changes to 50/50 dairy and dairy support.
- Combination of new distribution and existing races required as a result of the new irrigated areas, but any new distribution would be constructed such that losses are minimised (effectively 0 % losses).
- 20 million m³/year water stored for environmental purposes
- Environmental water applied at 900 L/s during irrigation season to provide low flow support to Ashley River/Rakahuri.
- Environmental water releases could be skewed to other periods (e.g. during fish spawning), but we did not consider this
- Support for fresh/flood flow augmentation could also be undertaken, but would be taken from same allocation as low flow support. We have not evaluated this option at this time.

This model was used to assess impacts on the flow regime of the Ashley River/Rakahuri and the effects of the new irrigation area on groundwater and surface water nitrate concentrations.

3.1.2 New Irrigation: effects on flows

We have assumed that environmental flow releases to the Ashley River/Rakahuri are for environmental benefit only, and that Ashley River/Rakahuri water take reliability remains unchanged. Model flow statistics (Table 3-1) suggest that annual mean flows would reduce by around 2 m³/s at Ashley Gorge if such a scheme was developed. Low flows (7dMALF) could increase by around 200 L/s.

In irrigation season (when we have set environment top-up to occur) the 7dMALF is increased by 500L/s, whilst out of season it is reduced by 800 L/s. The increase is somewhat offset by the effects of climate change (lower flows at the very low flow level), however, we consider further analysis of this is required to determine the appropriateness of this pattern

It is worth noting that the scheme we are proposing does not alter the total water resource of the catchment; the modelled scheme collects water during high-mid flows and provides a top-up during low flow. Therefore, to provide increased flows in one part of the year flow must be decreased in another part of the year. In addition, water is also exported for irrigation, avoiding the Ashley Gorge flow monitor, which further reduces the flow statistics.

Table 3-1 Ashley River/Rakahuri flows with/without storage scheme

Site	Period	Current	Current with scheme	Future with scheme
		<i>Mean flow (m³/s)</i>		
Ashley Gorge	Full year	11.5	9.4	9.9
	Irrigation season	10.4	8.9	8.7
	Non-irrigation season	13.5	10.5	12.2
SH1	Full year	5.69	-	4.81
		<i>7dMALF* (m³/s)</i>		
Ashley Gorge	Full year	2.2	2.4	2.1
	Irrigation season	2.2*	2.7*	2.3*
	Non-irrigation season	3.4*	2.6*	3.0*
SH1	Full year	0.4	-	0.5

* The terminology 7DMALF is not strictly applicable for analysis of irrigation season and non-irrigation season as it is an annual statistic. The term has been preserved here in the interests of simplicity – what is represented by the figures is the mean of the 7-day low flow periods in the season of interest.

A hypothetical storage would be able to provide environmental releases. In the modelling we have undertaken, this release has been a base-flow top-up during irrigation season. The intent of this is to minimise the occurrence of drying reaches, and to support bird habitat within the braided channel. The environment releases could also be managed in different ways. For instance the base flow support could be held back early in the irrigation season so that higher flows could be provided around critical periods such as fish migration periods or when the river is more likely to be dry. Alternatively the water could be released as a fresh/flood top-up which would assist in the scouring of the bed. These options can be explored during the Solutions work phase, if necessary.

Our analysis gives an indication of the potential benefit of a storage scheme on the number of days per year on which the Ashley River/Rakahuri has dry reaches (Figure 3-1). Results suggest that a potentially significant reduction in dry days could, in theory, be achieved. We would need to undertake further analysis to determine the extent and frequency of occurrence of these days.

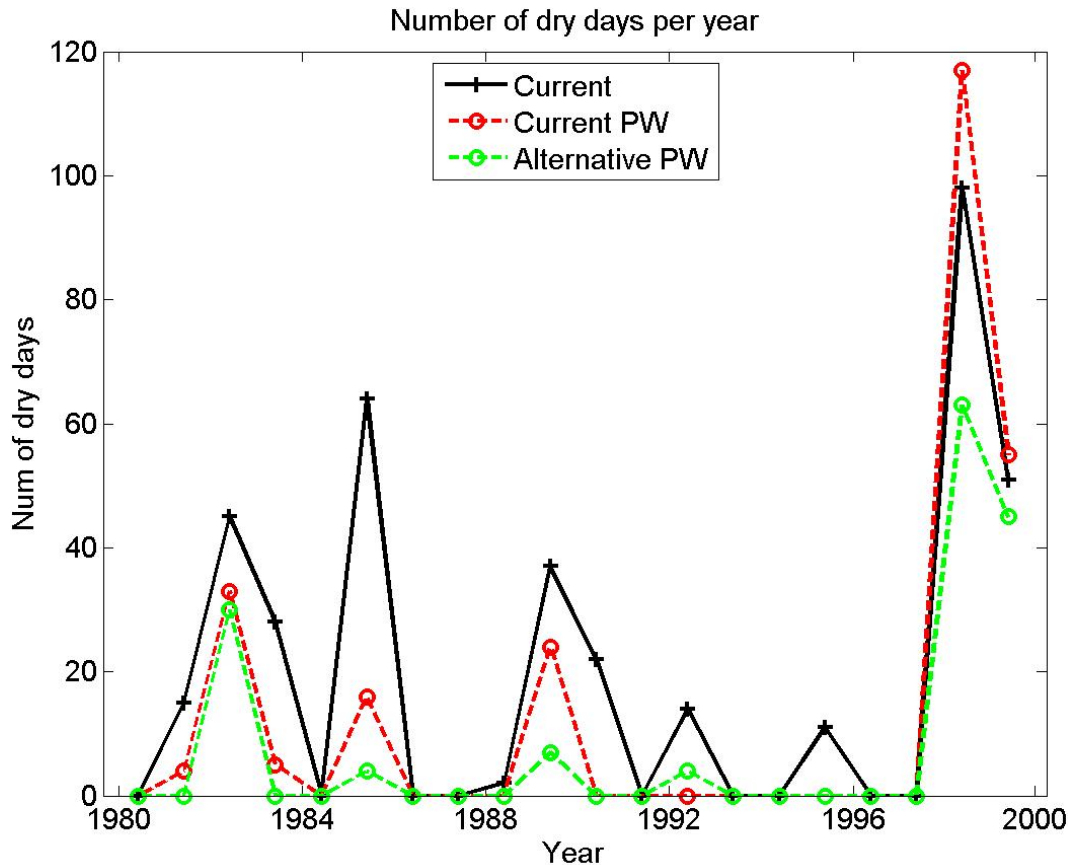


Figure 3-1 Number of dry days on the Ashley River/Rakahuri

3.1.3 New Irrigation: Other effects

Summary of recreational effects

- Flows at Ashley Gorge campsite increase by maximum of 900 L/s in summer hence no adverse effects for swimming – may help support swimming at times of diminishing flows
- On the assumption that irrigation water is conveyed via the Ashley Gorge, and removed above the campsite, flows will be larger in the gorge during the irrigation season, and lower during non-irrigation season when water is being abstracted to refill the reservoir.
 - Higher summer flows may impact traditional uses in the gorge.
 - Higher summer flows will impact the opportunity window available to kayakers at mid-low flows
 - Lower winter flows will impact the opportunity window available to kayakers at mid-low flows
 - No significant impact on kayakers would be envisaged at high flow as our intake capacities are relatively small, and would likely be shut during floods to prevent gravel ingestion
- Recreational flows below the Gorge campsite would be enhanced by a raise in low flows during irrigation season which would support a small benefit to jet-boaters and amenity users.

Summary of Ashley River/Rakahuri and Te Akaaka estuary flushing flow effects

- The scheme as hypothesised here would have no significant effect on flood flows. Firstly the assumed intake capacities are relatively small in comparison to flood flows, and secondly the intakes would likely be closed during floods for any scheme, to prevent gravel ingestion as noted above.
- As we noted above there is the potential for the environmental contribution from the storage to be used to increased fresh/flood flows. This would need to be explored during the Solutions work phase if it is of interest.

Summary of Loburn fan stream flow effects

- We have assumed that there will be negligible effects on stream flows of the Lowburn fan due to high irrigation efficiency, and the relatively much larger large hill-fed catchment area for these streams

Summary of lower plains spring-fed stream flows effects

- Model results suggest negligible effects on spring-fed stream flows because we have assumed very high efficiency irrigation, so losses are very limited

3.1.4 New Irrigation: effects on nitrate

Nitrate concentrations in groundwater and spring-fed streams would increase if the irrigated land areas were increased as per the assumptions of the New Irrigation option (3,300 ha increase in the Loburn Fan area, 550 ha in Lees Valley and 8,750 ha in the Cust/Ashley/Eyre).

Our model results for nitrate concentrations in Silverstream, Ohoka Stream and Cust Main Drain (Figure 3-2) suggest that modest increases (0.5 – 0.8 mg/L) could occur. Nitrate in the Cust Main Drain could potentially increase by 2 mg/L. It should be noted that these results were not adjusted to incorporate the suggestions that lag effects are minimal in the Cust Main Drain, and should therefore be viewed in terms of the changes in nitrate concentrations (between GMP and New Irrigation) rather than absolute concentrations.

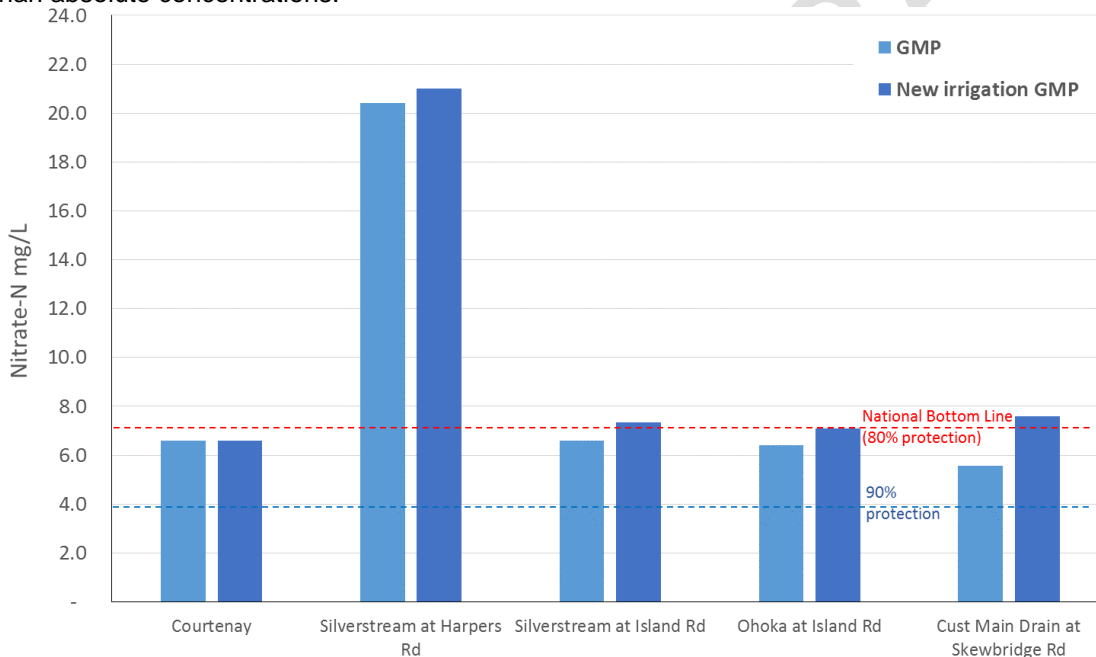


Figure 3-2 Projected nitrate effects for Silverstream, Ohoka Stream and Cust Main Drain

Model results for northern Ashley River/Rakahuri tributaries (Figure 3-3 and Table 3-2) show increases in nitrate concentrations of 1.1 mg/L for Garry River, 1.8 mg/L for Mount Thomas Stream and 0.3 mg/L for the Okuku River. These results have also not been ground-truthed because measured data for these watercourses is very limited, and should therefore again be considered in terms of change between the GMP results and New Irrigation results. Available measured nitrate data are also plotted for reference, but these are not necessarily representative of the current long term mean at these locations. In the event that the current measured nitrate data are representative (and the model results are accurate), the nitrate concentration increases in Garry River and Mount Thomas Stream could exceed the NOF A Band limit. It should be noted that our confidence in these model results is lower than for other streams because the Loburn Fan hydrological system has not been studied in the same level of detail as other parts of the Waimakariri zone.

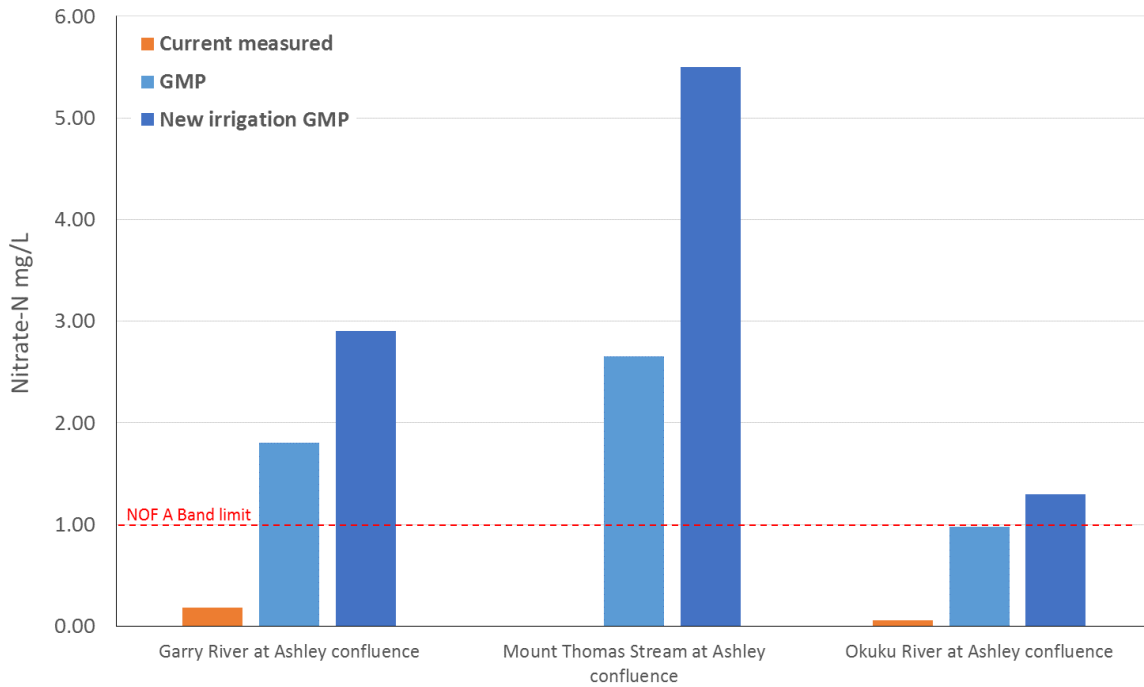


Figure 3-3 Projected nitrate effects for Garry River, Mount Thomas Stream and Okuku River

Nitrate concentration results for all assessment sites summarised in Table 3-2 indicate that nitrate concentrations could also increase slightly in the Waimakariri River due to the projected additional 200 T/year N load associated with the new irrigated area. A small (0.01 mg/L) nitrate concentration is projected for the Ashley Gorge, and hence the 22 T/year increase in N load associated with irrigation of 550 ha of land in the Lees Valley would be unlikely to impact nitrate concentrations in the upper Ashley River/Rakahuri significantly. A more significant concentration increase is projected at the Ashley estuary/Te Akaaka due to nitrate discharges from the assumed 3,300 ha of irrigated land on the Loburn Fan.

Table 3-2 Model nitrate concentrations (mg/L N) for hypothetical New Irrigation scheme

Stream	Site	Current measured	Lag + GMP ⁹	New irrigation ¹⁶
Waimakariri	Brooklands Lagoon ¹⁷	No data	0.6	0.7
Kaipoi River	Waimakariri confluence	No data	3.7 to 4.7	4.2 to 5.4
Courtenay	-	No data	5.6 to 7.2	No change
Silverstream	Harpers Rd	7.7	20.4	21.0
Silverstream	Island Rd	4.4	5.6 to 7.6	6.2 – 8.5
Ohoka	Island Rd	4.1	5.6 to 7.2	6.2 – 8.0
Cust Main Drain	Skewbridge Rd	3.9	5.1 to 6.0	7.0 to 8.2
Cam	Marsh Rd	0.6	0.7 to 0.8	No change
Taranaki	Preeces Rd	0.6	1.6 to 1.7	No change
Waikuku	SH1	0.4	0.7 to 0.8	No change
Saltwater	Factory Rd	0.3	1.5 to 1.6	No change
Ashley	Gorge	0.05	0.11	0.12

¹⁶ Comparable to GMP results – does not account for PC5 PA rules or climate change

¹⁷ Based on Waimakariri River flows only – assumes no dilution with seawater.

Stream	Site	Current measured	Lag + GMP ⁹	New irrigation ¹⁶
Ashley River	Estuary	No data	1.2	1.5
Garry River ¹⁸	Ashley confluence	0.18	1.8	2.9
Mount Thomas Stream ¹⁸	Ashley confluence	No data	2.7	5.5
Okuku River ¹⁸	Ashley confluence	0.06	1.0	1.3

3.1.5 New Irrigation assessment summary

We have summarised the projected positive and negative effects of the hypothetical water storage and irrigation scheme in Table 3-3. These results do not provide a complete assessment of the potential impact of such a scheme; e.g. effects on terrestrial and aquatic ecology and recreation are discussed elsewhere.

Table 3-3 New Irrigation assessment summary

Positive effects	Negative effects
Number of Ashley River/Rakahuri dry reach days reduces	Nitrate concentrations increase in northern Ashley tributaries, and could breach NOF A Band. Nitrate concentrations increase in Ashley estuary, Cust Main Drain, Ohoka Stream and Silverstream. Increased risk of exceeding National Bottom Line in latter 3 watercourses.
Improved local economy	Flushing flows in Ashley River/Rakahuri and estuary/Te Akaaka reduced due to storage reservoir
Potential benefit to swimming at Ashley Gorge Campsite	Mean flow in Ashley River/Rakahuri reduced
Positive and negative potential changes to opportunity window for kayaking in the gorge (dependant on skill level)	

¹⁸ Current measured nitrate in Garry River. Mount Thomas Stream and Okuku River based on only two years of sampling during very dry conditions. Unlikely to be representative of longer term average. Flow data also lacking for lower reaches of these watercourses, so results should be considered as relative change between GMP and new irrigation scenarios only.

3.2 Water resource augmentation options

Summary

Additional clean water could be channelled from the Waimakariri River (or the Ashley River/Rakahuri if Lees Valley scheme water is not to be used for instream purposes on the Ashley River/Rakahuri) to surface water and groundwater in order to reduce nitrate concentrations (by dilution) and improve flows in the spring-fed streams.

This flow augmentation could be implemented as stream augmentation and/or as managed aquifer recharge (MAR).

Our initial feasibility analysis suggests that direct stream augmentation could potentially be feasible for Silverstream, Ohoka Stream and Cust River/Main Drain. A significant volume of clean dilution water would be required to achieve the assumed target nitrate concentrations in the lower reaches of Silverstream in particular based on the Current Pathways nitrate concentration projections. Water quality and flow improvements associated with direct augmentation would be limited to the channel into which water is discharged. Water quality and flow in other channels/tributaries, and in groundwater, would not improve. A number of key feasibility questions remain unanswered and would need to be addressed under the Solutions work phase if the Zone Committee wish to explore this option further. The availability of irrigation race capacity to channel water to these streams over the irrigation summer could be a fatal flaw for this option.

Our assessment suggests that there are unlikely to be any viable options for augmentation of Taranaki Stream and Saltwater Creek. Information provided in previous sections of this report points to a low likelihood that nitrate mitigation will be required for these watercourses, however, in order to meet the NOF.

MAR through discharge of Waimakariri River water to the Eyre River bed via the irrigation races in the off season is likely to be the most easily achieved augmentation option, although further feasibility assessment work is still required (e.g. consent for additional water abstraction from the Waimakariri River). The water quality benefits of Eyre River MAR would likely be limited to within 1.5 km either side of the river channel, thus benefiting Ohoka Stream but probably not improving water quality in Cust Main Drain and Silverstream significantly. Flow and groundwater level increases would be more widespread than water quality improvements.

The feasibility of irrigating well drained soils over winter in the WIL command area could be explored further. This approach could potentially provide more widespread water quality improvements, but a number of critical feasibility questions would need to be addressed before the potential benefits of this option are analysed in any detail.

3.2.1 Augmentation as a solution

Elevated nitrate concentrations in groundwater and surface water and low/declining stream flows could potentially be mitigated by discharging low-nitrate water either directly to the affected stream reach (Stream Augmentation), or to ground upstream of the area of concern (managed aquifer recharge [MAR]). We have undertaken an initial high level feasibility assessment of both of these options.

3.2.2 Target outcome assumptions

We have generally used the adjusted Current Pathways model results for the augmentation feasibility assessment because these results provide our current best estimate of potential mitigation requirements. Although our adjusted model results suggest that nitrate in Taranaki Stream and Saltwater Creek is unlikely to exceed the NOF A Band limit (1 mg/L), we have also looked at possible augmentation options for these watercourses in order to determine whether this would be feasible if nitrate concentrations did increase significantly (up to the raw model projected values: these are the values used in Table 3-4 below). It should be noted that we are not suggesting that augmentation necessarily *should* be undertaken for the watercourses we have looked at: the purpose of this

assessment is to consider what is possible and what is unlikely to be achievable, in order to provide information for the Zone Committee's decision-making process.

A decision is yet to be made on the maximum acceptable nitrate concentration in each of the surface watercourses. We have therefore selected tested targets (upper limits) based on the requirements of the National Policy Statement for Freshwater Management (2014): the National Bottom Line limit (6.9 mg/L), the 80% protection value (3.8 mg/L) and the NOF A Band limit (1 mg/L), as per Table 3-4. Figure 3-4 shows the sites for which we have assessed augmentation feasibility.

Table 3-4 Target outcomes (annual median nitrate concentrations)

Waterbody	Location	Max nitrate target (mg/L NO ₃ -N)	Assumed nitrate-N (mg/L)
Silverstream/ Kaiapoi River	Harpers Road	6.9	15
	Island Road	3.8	7.4
Ohoka Stream	Island Road	3.8	7.4
Cust Main Drain	Skewbridge Road	3.8	4.9
Taranaki Stream	Preeces Road	1.0	2.3
Saltwater Creek	Factory Road	1.0	2.3

To achieve these thresholds additional water would need to be provided to the target watercourses. As dilution of nitrate is the focus of this action, the additional water supplied must have very low concentrations of nitrogen, otherwise it would not be able to offer dilution. To meet our hypothetical targets, clean augmentation water would need to be supplied at various rates, depending on the target watercourse (Table 3-5). The water can be supplied via one of two methods; direct stream augmentation or managed aquifer recharge. The feasibility of augmentation using these methods is assessed for each watercourse in the next sections of this report.

Table 3-5 Assumed augmentation requirement

Target watercourse	Site	Median flow ¹⁹ (m ³ /s)	Required flow increase (factor)	Total instream flow (m ³ /s)	Dilution water required (m ³ /s)
Silverstream/ Kaiapoi River	Harpers Road	0.34	2.2	0.7	0.4
	Island Road	1.46	1.9	2.8	1.4
Ohoka Stream	Island Road	0.59	2.0	1.2	0.6
Cust Main Drain	Skewbridge Road	1.31	1.3	1.7	0.4
Taranaki Creek	Preeces Road	0.23	2.3	0.5	0.3
Saltwater Creek	Factory Road	0.4	2.3	0.9	0.5

¹⁹ Based on Current Pathways flow results

Waimakariri Alternative Pathways Scenario Water Management Options Assessment

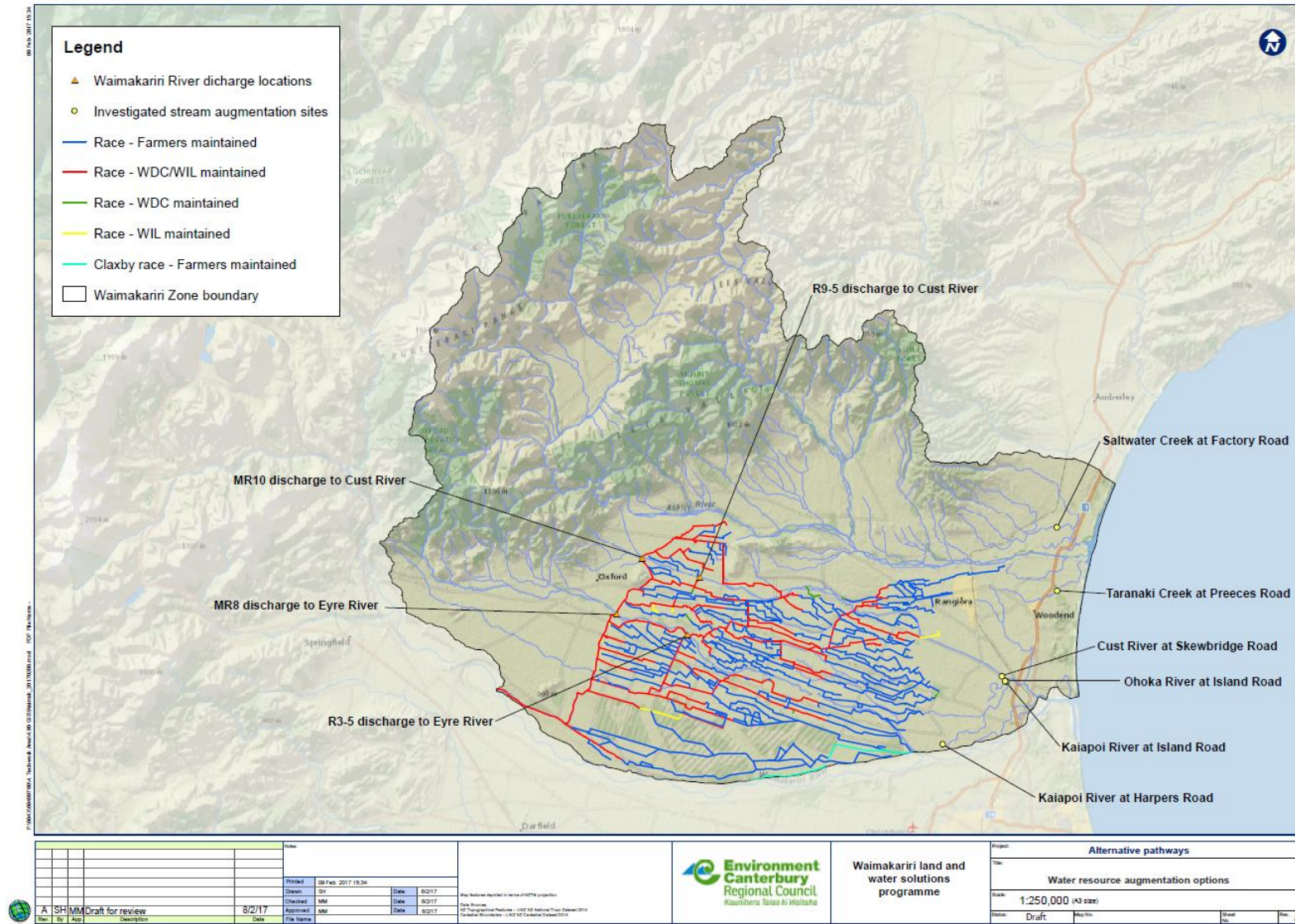


Figure 3-4 Water resource augmentation options map

3.2.3 Stream augmentation feasibility assessment

Silverstream / Kaipoi River (Harper Road and Island Road)

The *Current Pathways* model flow rates are 0.34 m³/s at Harpers Road and 1.46 m³/s at Island Road. We have estimated nitrogen concentrations of 15 mg/L and 7.4 mg/L at these flows respectively. The assumed target nitrogen concentrations for these sites are the 6.9 mg/L and 3.8 mg/L.

Dilution flows of 0.4 m³/s and 1.4 m³/s would be required to meet these targets at Harpers Road and Island Road respectively. To achieve the requisite dilution rates we have assumed that the dilution water has no significant nitrogen concentration.

We have reviewed potential sources of dilution water for Silverstream/Kaiapo River (Table 3-6) and determined that this is limited to the supply of Waimakariri River water, via Claxby Irrigation Limited infrastructure and a new siphon and pipeline. Mixing of Waimakariri River water with spring-fed stream water could be a cultural concern. If this is the case, construction of infiltration basins upstream of the target surface watercourses could be included, although this could add significant costs to the solution.

Table 3-6 Silverstream / Kaiapo River augmentation options summary

Source	Comments
Shallow groundwater	Excluded from consideration - concerns around the long term quality (nitrogen concentrations) of this source
Deep groundwater	Excluded from consideration - concerns around the long term quality (nitrogen concentrations) of this source
Local surface water	Excluded from consideration - none available / fully allocated
Waimakariri River (direct)	Excluded from current consideration - construction of a new intake and providing for its ongoing maintenance could be prohibitively expensive
Water race	Potential use of Claxby Irrigation Limited intake and conveyance infrastructure and new infrastructure (siphon below Eyre River Diversion, 1 km 675 mm dia pipeline & potential soakhole close to stream head)

Notes	
1	The required flow is significant in relation to the size of existing infrastructure and additional infrastructure required
2	The ability for the Silverstream/Kaiapo River channel to accept 1.4 m ³ /s at mean flow is uncertain
3	Significant costs would be involved in establishing a link between Claxby infrastructure and the discharge site at the required capacity
4	Creating a soakhole which can discharge water to the ground before it reaches Silverstream would be problematic at the required capacity.
5	Water take of ~ 1 m ³ /s would require allocation from Waimakariri River
6	Landowners affected by this proposal appear to be agricultural and limited to a couple of entities only

Claxby Irrigation Limited have undertaken a modernisation program, converting from border-dyke to modern irrigation techniques. This has reduced their water demand and they have been able to transfer some of their allocation to other users. This provides us with a working-assumption that there is spare capacity at their intake, and main distribution races to convey water for augmentation. Note that we have not discussed this option with Claxby Irrigation: this would need to be the next step if this option is considered further.

Our augmentation concept would use the existing intake and main race to collect and convey water from the Waimakariri River to the upper reach of Silverstream. Additional / upgraded races would be required for approximately 16 km to convey this water to the Eyre River Diversion. A new siphon under the diversion channel, followed by 1 km of new 760 mm diameter pipe would be required to convey the water via gravity to a disposal point. It is possible that water would need to be discharged to

ground via soakage trench in the vicinity of Harpers Road from which point it would flow into the stream. The alternate option is direct discharge to the watercourse at the same location.

At Harpers Road the current mean flow is $0.43 \text{ m}^3/\text{s}$, generating an approximate water depth of 250 mm in the channel (mannings equation, assumes no downstream hydraulic control). Adding the requisite dilution flow required would increase the water depth at the current mean flow to 600 mm. At Island Road the current mean flow is $1.86 \text{ m}^3/\text{s}$; the dilution flow would increase the total flow to $3.26 \text{ m}^3/\text{s}$. We have not been able to approximate expected flow depths at Island Road. Further investigations are critical to determine whether such an increase in flow would prove problematic over the length of the stream.

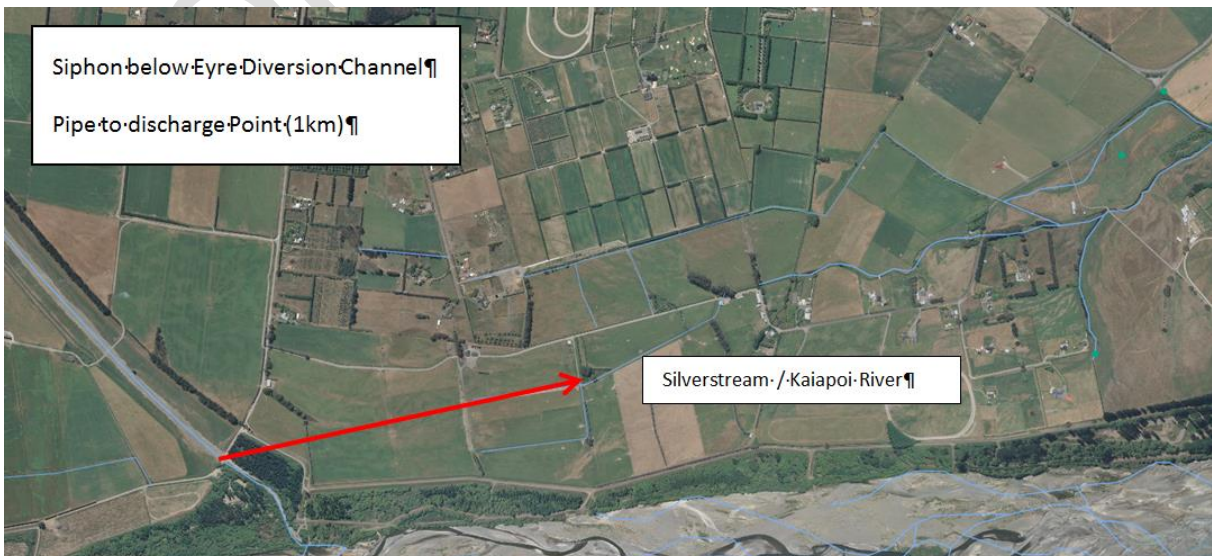
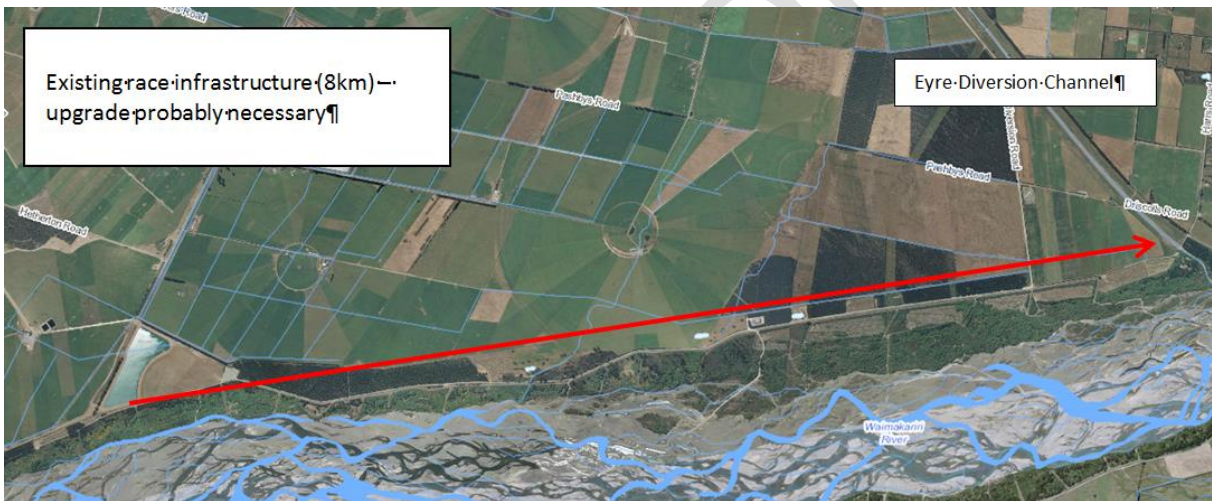
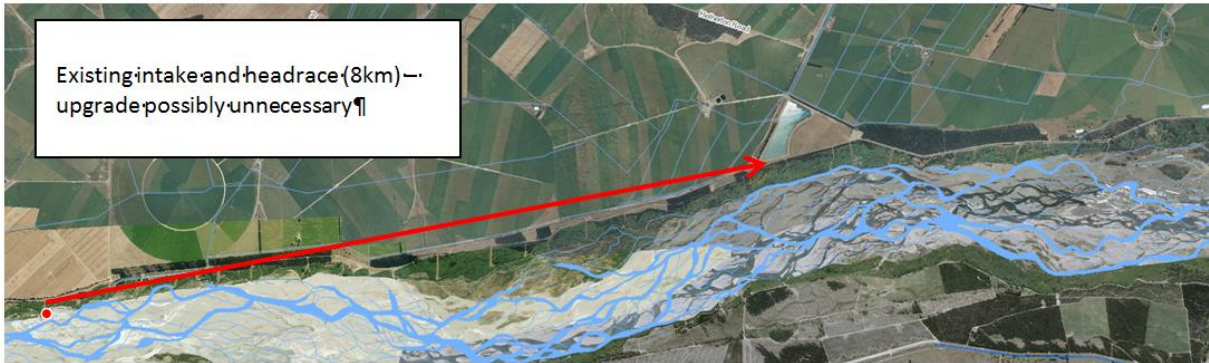


Figure 3-5 Possible supply route to Silverstream/Kaiapoi River

Ohoka Stream (Island Road)

A dilution flow of 0.6 m³/s would be required at Island Road to achieve the assumed nitrate target for this stream. We have reviewed potential sources of water (Table 3-7) and have determined that a combination of water race, Cust River/Main Drain and a new pump/pipeline could offer a source of water to augment Ohoka Stream, although water may not be available over the summer which compromises the benefits of this option significantly.

Table 3-7 Ohoka Stream summary

Source	Comments
Shallow groundwater	Excluded from consideration - tied to nearby stream flows and therefore use of this as a source may exacerbate low-flow condition in the target watercourse(s). High nitrate concentrations also an issue.
Deep groundwater	Excluded from consideration - concerns around the long term quality (nitrogen concentrations) of this source
Local surface water	Excluded from consideration - none available / fully allocated
Waimakariri River (direct)	Excluded from consideration - too distant from target watercourse
Water race	<p>Option 1: Waimakariri Irrigation Limited water race network terminates at Ohoka Stream and, at times of high flow in the network resulting from rainfall, will discharge into the stream. Theoretically this connection could be used to supply dilution water to Ohoka Stream. On inspection we found that race capacities in the area (R3J-4A, R3I-5, R2K-8) are very limited. No inspection of culverts was undertaken, but discussions with WIL and WDC indicate that culverts are generally small and no spare capacity exists. The limited available capacity creates an issue for conveyance of up to 600 L/s of additional flow. This issue is exacerbated by the large number of properties (lifestyle blocks) through which the races pass; gaining agreement for infrastructure improvements from so many private landowners has proven very challenging in the past (Brett Painter pers comms).</p> <p>Option 2: A discharge of water from Waimakariri Irrigation Limited race R9-5 into the Cust River. The river here is characterised as a gaining reach (Farrow, 2016) and therefore discharged water would remain in the channel. At Bradleys Road on the Cust Main Drain a pump would be required to remove 600 L/s and pipe it along Bradleys Road to the Ohoka Stream. This would not improve water quality in branches of Ohoka Stream further south (Figure 3-6). Note: The race network is known to operate at full capacity for much of the summer, hence there would only be spare capacity in the existing network May – November</p>

Notes	
1	We have not undertaken an assessment of the available capacity within the Cust Main Drain, however have assumed that it would be sufficient to convey an additional 600 L/s (+400 L/s for Cust Main Drain itself) without issue.
2	We have not undertaken checks on Ohoka Stream to confirm whether culverts and constructed channels have sufficient capacity to convey the additional flow without causing flooding issues.

Cust Main Drain (Skewbridge Road)

A dilution flow of 0.4 m³/s would be required at Skewbridge Road to achieve the assumed nitrate target for this stream. We have reviewed potential sources of water (Table 3-8) and have determined there is a potential source of water via the Waimakariri Irrigation Limited infrastructure, to undertake augmentation (as per the Ohoka Stream option discussed above). Also as per Ohoka, water may not be available over the summer which compromises the benefits of this option significantly.

Table 3-8 Cust Main Drain summary

Source	Comments
Shallow groundwater	Excluded from consideration - tied to nearby stream flows and therefore use of this as a source may exacerbate low-flow condition in the target watercourse(s)
Deep groundwater	Excluded from consideration - concerns around the long term quality (nitrogen concentrations) of this source
Local surface water	Excluded from consideration - none available / fully allocated
Waimakariri River (direct)	Excluded from consideration - too distant from target watercourse
Water race	Waimakariri Irrigation Limited conveyance infrastructure located to the west. We consider it possible that a bywash structure from the WIL network at Bennets Road from race R9-5 could provide a suitable location of provision of dilution flow (Figure 3-4). The flow rate however is significant in terms of the infrastructure present. It is possible that significant upgrades to races, and in particular culverts, would be required to deliver the required water to this location. The race network is known to operate at full capacity for much of the summer, hence there would only be spare capacity in the existing network May – November.

Notes	
1	We have not undertaken an assessment of the available capacity within the Cust Main Drain, however have assumed that it would be sufficient to convey an additional 400 L/s without issue.

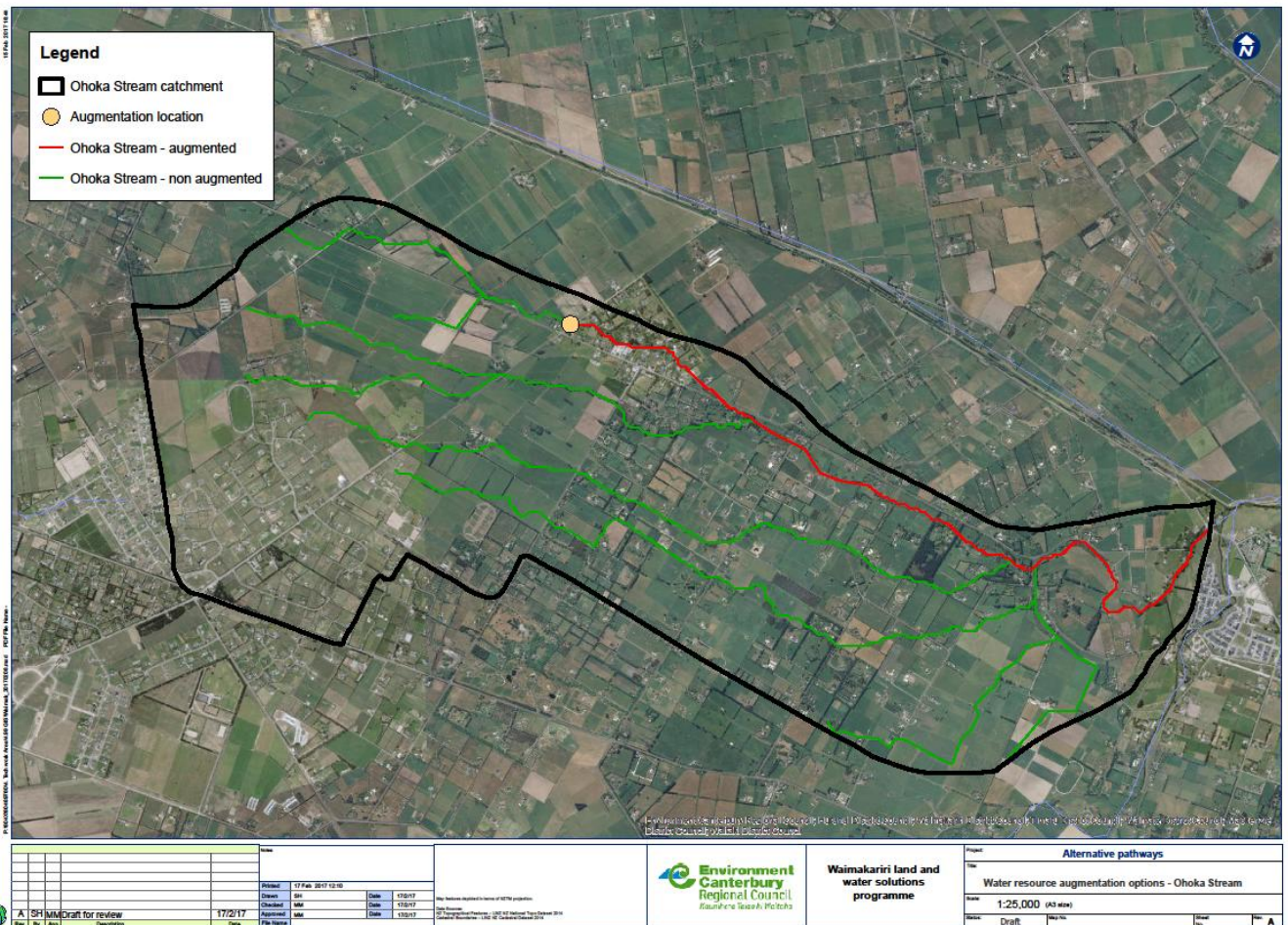


Figure 3-6 Reaches of Ohoka Stream to benefit from augmentation

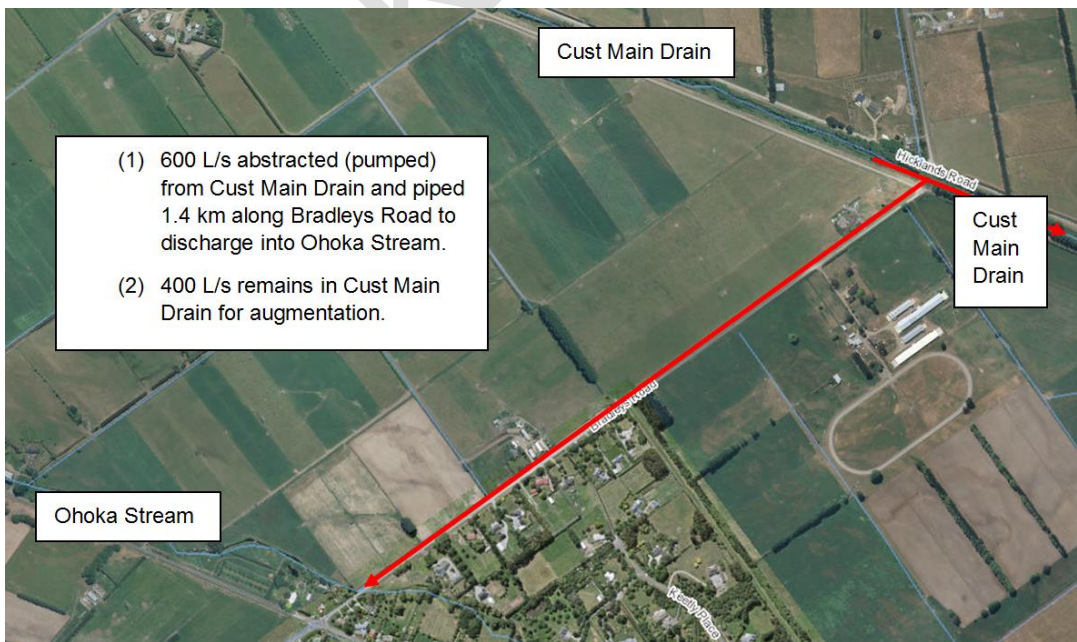
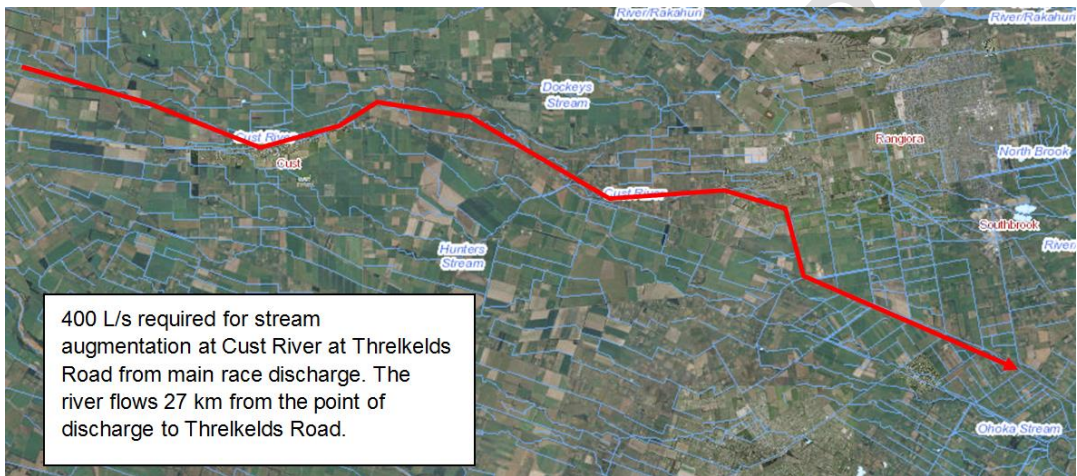
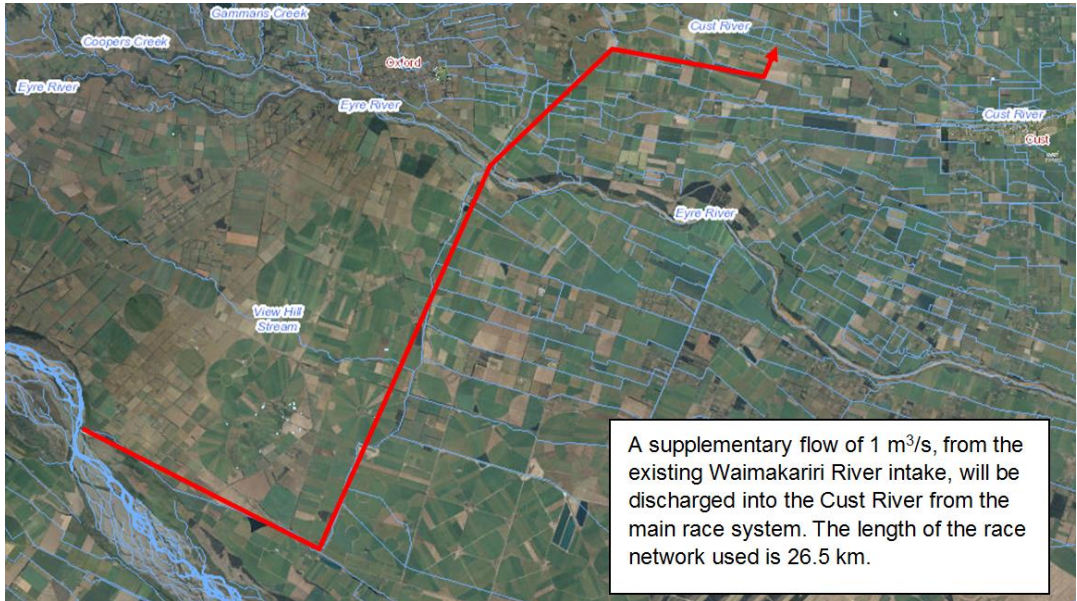


Figure 3-7 Supply route to Ohoka Stream and Cust Main Drain

Taranaki Creek (Preeces Road)

A dilution flow of 0.3 m³/s would be required at Preeces Road to achieve the assumed nitrate target for this stream. We have reviewed potential sources of water (Table 3-9) and have determined there are no viable sources of water to undertake augmentation.

Table 3-9 Taranaki Creek summary

Source	Comments
Shallow groundwater	Excluded from consideration - tied to nearby stream flows and therefore use of this as a source may exacerbate low-flow condition in the target watercourse(s)
Deep groundwater	Excluded from consideration - shown in the past (by potable water supply investigations at Pegasus Township) to contain high levels of metals such as iron and manganese
Local surface water	Excluded from consideration - none available / fully allocated
Waimakariri River (direct)	Excluded from consideration - too distant from target watercourse
Water race	Excluded from consideration - none available

Saltwater Creek (Factory Road)

A dilution flow of 0.5 m³/s would be required at Factory Road to achieve the assumed nitrate target for this stream. We have reviewed potential sources of water (Table 3-10) and have determined there are no viable sources of water to undertake augmentation.

Table 3-10 Saltwater Creek summary

Source	Comments
Shallow groundwater	Excluded from consideration - tied to nearby stream flows and therefore use of this as a source may exacerbate low-flow condition in the target watercourse(s)
Deep groundwater	Excluded from consideration - very low yields evident in existing bores (Figure 3-8)
Local surface water	Excluded from consideration - none available / fully allocated
Waimakariri River (direct)	Excluded from consideration - too distant from target watercourse
Water race	Excluded from consideration - none available

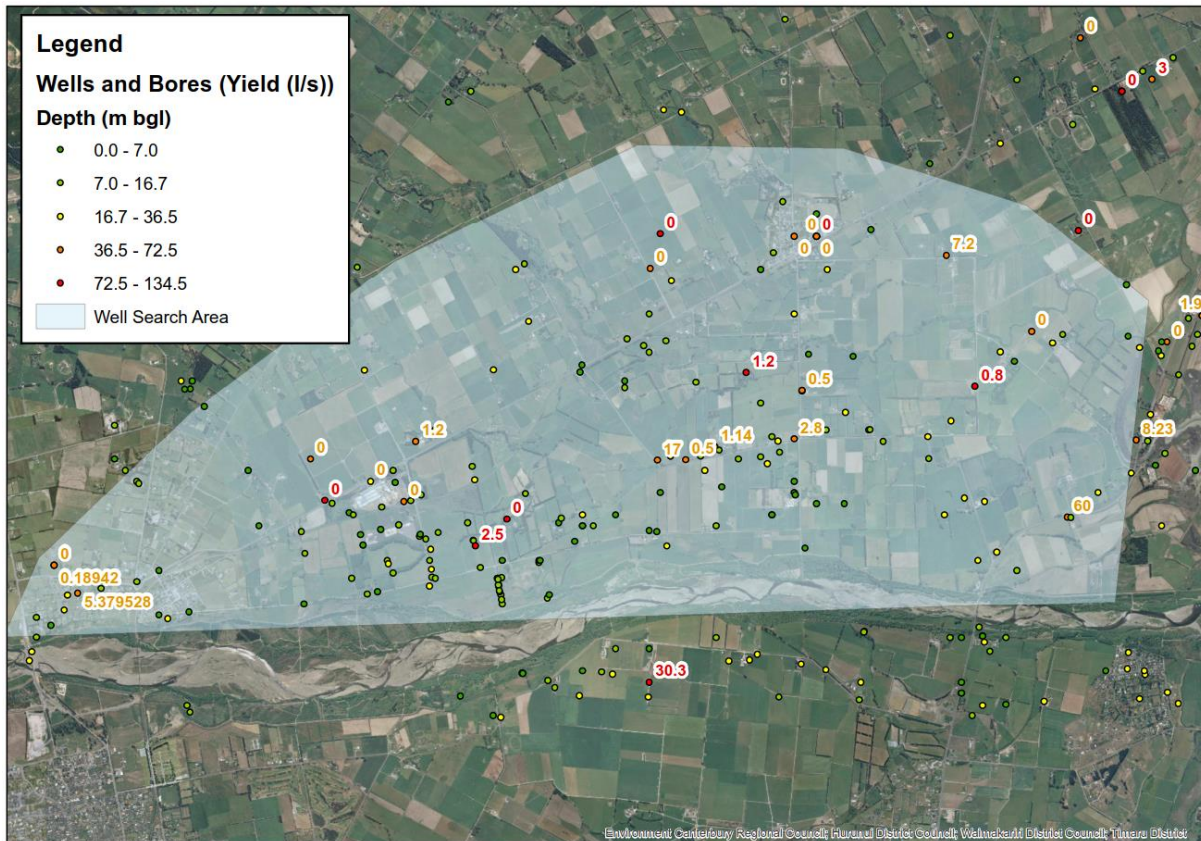


Figure 3-8 Existing groundwater well yields around Saltwater Creek

3.2.4 Managed aquifer recharge feasibility assessment

Overview

Managed aquifer recharge can be undertaken to increase the water level within an aquifer system in order to improve well reliability, and to improve groundwater quality and flows and water quality in spring-fed streams connected to the aquifer. This contrasts with the concept of stream augmentation, which seeks to increase flow in a specific watercourse by direct discharge to the watercourse (or into nearby permeable ground with a strong hydraulic connection to the watercourse).

The following factors need to be considered when assessing the feasibility of a MAR scheme:

- Where MAR water will be transported to, and how far it will disperse (laterally and vertically) in the aquifer
- The extent and degree of groundwater quality improvement downgradient of the MAR location
- Where the recharge water will re-emerge and how much it will improve flow and water quality in spring-fed streams
- The amount and timing of groundwater level increases in response to MAR (e.g. will effects be short-lived, or persist for long periods and therefore potentially exacerbate flooding risk?)

MAR via river recharge

There are two obvious locations where MAR could be undertaken in the Waimakariri zone, The Cust River at MR10 and the Eyre River at MR8 / Warren Road and R3-5 / Wolffs Road). These locations are appropriate because outlets from the water race system to the rivers already exist. They are also sufficiently close to the head of the distribution system for capacities to be able to supply relatively large water flows (cumecs, rather than litres/sec). The Warren Road and Wolffs Road sites are located approximately 20 km and 25 km upstream of the headwaters of Silverstream and Ohoka Stream respectively.

The Eyre River has been assessed as a 'losing river' between Oxford and the Waimakariri River (Farrow, 2016) hence it is suitable for use in aquifer recharge. A pilot recharge study has been

undertaken in the Eyre River and is documented in Callander P and Steffens C (2007). In this study 2.7 m³/s was discharged into the Eyre River at Warren Road for a month. Although this produced significant level rise in the surrounding groundwater, the study did not examine the effects on groundwater levels in the vicinity of, or flows within, the lowland watercourses we are currently interested in.

Farrow (2016) assessed the Cust River as losing as far as Carlton Road Bridge, and then generally gaining thereafter. Carlton Road Bridge is 2 km downstream of the potential discharge site from race MR10. The Carlton Road bridge location is used as the separation between losing and gaining reaches more for its accessibility than it being the specific point of change. We would need to further explore this to assess whether there is sufficient distance after the assumed discharge point for recharge to occur. A key question would be whether increasing flows in the Cust River would cause a significant increase in the rate of groundwater recharge. This is by no means certain and would need to be considered further if this option is selected for more detailed evaluation during the Solutions work phase.

Further studies would need to be undertaken to assess the impact on groundwater quality and flows and water quality in our target watercourses as a result of discharges to these rivers. However, on a first principles basis we would not expect enhanced river recharge to improve groundwater quality over a wide area. The lateral dispersivity of solute transport in the Waimakariri plains aquifer system is likely to be low, and on this basis we would expect the area of the clean water 20-25 km below the recharge point to be limited to 1-2 km either side of the flow line. This assertion is supported by nitrate monitoring data, which show that low nitrate concentrations occur up to 1.5 km either side of the Eyre River. This suggests that Eyre River MAR could improve water quality in Ohoka Stream (and may explain why nitrate concentrations in Ohoka Stream are lower than Silverstream), but would be unlikely to reduce nitrate concentrations in the upper reaches of Silverstream. Nitrate concentrations in drinking water wells within the Eyre River corridor would reduce, but nitrate concentrations outside of this area would likely remain high. Similarly, increasing recharge to the Cust River would be unlikely to result in significant water quality improvements much beyond the Cust Main Drain.

During the shoulders of irrigation season there is little capacity in the water race network, even the main races. Available capacity is dependent on the soil moisture conditions, which vary year to year. During the main irrigation season (December – April) there is no spare capacity within the water race network (pers com WIL). This leaves the only dependable period for use of these races as non-irrigation season. During this time water is still conveyed to refill storage, and to provide stock water, but this demand is relatively small. Routine maintenance is also undertaken at this time and so there may be periods of race closures during winter.

For either scheme to proceed we would need to carefully consider the effects of increasing the groundwater level in such a wide area. There are risks around increased flooding which we would need to consider, and consenting of an ongoing take from the Waimakariri River would also need to be resolved.

MAR via infiltration basins

MAR is often undertaken via purpose-built infiltration basins. The advantage of this approach is that recharge could, in theory, be targeted in areas with particular issues, e.g. directly upstream of Silverstream, or in areas with deteriorating groundwater quality. This advantage is offset by the cost of constructing and maintaining the basins and the loss of return from the land on which basins are built. Conveyance of water to the basins and the availability of Waimakariri River water would also need to be considered and costed.

MAR via irrigation infrastructure

A third MAR option is to run existing irrigation infrastructure (e.g. centre pivots) on land with well-drained soils over winter, in order to increase aquifer recharge. The benefits of this approach would be low cost (relative to infiltration basins) because no new infrastructure is required and the ability to apply recharge (and hence deliver water quality improvements) over a much wider area. Key feasibility questions to address would be the additional rate of nitrogen leaching associated with the increased

recharge, and practicality from a farm management perspective. We are not aware of any previous studies or trials having been undertaken to assess the feasibility of this option.

3.3 Domestic water supply well deepening

Well deepening could be undertaken to address elevated nitrate concentrations in water supply wells. The rationale for this is that the water at depth is likely to comprise a higher ratio of low nitrate hill-fed streams water, recharging the inland plains aquifer system.

Our model results (Table 3-11) suggest that this approach could reduce, but not eliminate, the risk of exceeding the MAV for nitrate. Considering the GMP model results for instance, the data in Table 3-11 suggest that the number of wells with nitrate above the MAV could potentially increase from 100 (current estimate) to 500. Deepening these wells (to an average depth of around 90 m) would reduce the number of wells with nitrate above the MAV to around 200. This means that 200 well owners could potentially invest a significant amount of money in well deepening and still draw water with nitrate above the MAV. Well yields are also poor in the deeper part of the aquifer in some parts of the Waimakariri zone.

Table 3-11 Reduction in MAV exceedance risks from deepening domestic supply wells

Simulation	Current well depths		Deepened wells	
	Mean MAV exceedance risk	No of wells >= MAV	Mean MAV exceedance risk	No of wells >= MAV
Current measured	3%	100	N/A	N/A
Current (after lag)	19%	610	8%	270
GMP	15%	500	7%	220
GMP + PC5 PA	25%	820	14%	470
GMP with New Irrigation	18%	590	8%	280

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Appendix 1 Community Water Supply Well Results

Results show risk that either treatment will be required or an alternative water supply source developed in order to meet the nitrate MAV.

Communities	Well no	Current measured	Current (after lag)	GMP	GMP + PC5 PA	GMP + New Irrigation
Cust	M35/11544	No data	5% to 18%	4% to 17%	8% to 23%	6% to 20%
Fernside	M35/2914	0% to 4%	5% to 18%	3% to 16%	24% to 44%	10% to 25%
Kaiapoi	M35/0834	0% to 0%	29% to 50%	20% to 39%	31% to 54%	25% to 45%
Kaiapoi	M35/0847	0% to 0%	29% to 50%	20% to 39%	31% to 54%	25% to 45%
Kaiapoi	M35/3529	0% to 0%	29% to 50%	20% to 39%	31% to 54%	25% to 45%
Kaiapoi	M35/5875	0% to 0%	29% to 50%	20% to 39%	31% to 54%	25% to 45%
Kaiapoi	M35/8211	0% to 0%	29% to 50%	20% to 39%	31% to 54%	25% to 45%
Kaiapoi	M35/8212	0% to 0%	29% to 50%	20% to 39%	31% to 54%	25% to 45%
Mandeville	M38/18638	0% to 4%	24% to 43%	14% to 30%	26% to 47%	20% to 38%
Ohoka	BW24/0262	No data	24% to 43%	14% to 30%	26% to 47%	20% to 38%
Oxford Urban	L35/0850	0% to 0%	5% to 19%	3% to 17%	30% to 52%	10% to 25%
Oxford Urban (not yet online)	BW22/0049	0% to 0%	5% to 19%	3% to 17%	30% to 52%	10% to 25%
Pegasus	M35/10908	0% to 0%	0% to 0%	0% to 0%	0% to 0%	0% to 0%
Pegasus	M35/18017	0% to 0%	0% to 0%	0% to 0%	0% to 0%	0% to 0%
Pegasus	M35/18018	0% to 0%	0% to 0%	0% to 0%	0% to 0%	0% to 0%
Pines Kairaiiki	M35/0833	0% to 0%	15% to 32%	14% to 30%	22% to 41%	16% to 33%
Pines Kairaiiki	M35/6662	0% to 0%	15% to 32%	14% to 30%	22% to 41%	16% to 33%
Poyntzs Rd	M35/0181	5% to 18%	12% to 28%	9% to 23%	11% to 27%	10% to 26%
Rangiora	M35/11199	0% to 0%	12% to 28%	9% to 23%	11% to 27%	10% to 26%
Rangiora	M35/11908	0% to 0%	12% to 28%	9% to 23%	11% to 27%	10% to 26%
Rangiora	M35/11910	0% to 0%	12% to 28%	9% to 23%	11% to 27%	10% to 26%
Summerhill/West Eyreton	M35/9566	No data	5% to 19%	3% to 17%	30% to 52%	10% to 25%
Waikuku Beach	M35/9594	0% to 0%	0% to 0%	0% to 0%	0% to 0%	0% to 0%

Communities	Well no	Current measured	Current (after lag)	GMP	GMP + PC5 PA	GMP + New Irrigation
Waikuku Beach	M35/0474	0% to 0%	0% to 0%	0% to 0%	0% to 0%	0% to 0%
Woodend	M35/11693	0% to 0%	0% to 0%	0% to 0%	0% to 0%	0% to 0%
Woodend	M35/7542	0% to 0%	0% to 0%	0% to 0%	0% to 0%	0% to 0%

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1 **Appendix 2 Flow comparison**

Plan	Water course	Minimum flow site location	7MALF (L/s)	WRRP minimum flow (L/s)	Ecological minimum flow proposal (L/s)	% difference from WRRP	Whanau minimum flow preference (L/s)	% difference from WRRP
WRRP	North Brook	Marsh Road	622 ¹	530	530	0%	590	11%
	Middle Brook	Marsh Road	31 ¹	60	30	-50%	50	-17%
	Greigs Drain	Greigs Drain Road	60 ²	150	230	53%	230	53%
	No. 7 Drain	Main Drain Road Culvert	67 ¹	60	60	0%	60	0%
	Ohoka Stream	Kaiapoi River confluence	505 ²	300	365	22%	420	40%
	Cam River	Youngs Road (Cultural site – Cam River at Bramleys Rd – has minimal gauging data so following discussion with ECan personnel Cam River at Youngs Rd was chosen as most appropriate)	1,010	1000	890	-11%	1200	20%
	South Brook	Marsh Road	171 ¹	140	120-140	-14%	170	21%
	Kaiapoi River / Silverstream	Neeves Road	1,350 ²	600	1000	67%	1200	100%
	Cust River	Rangiora-Oxford Road	300	20	120	500%	-	-
	Cust Main Drain	Threlkelds Road	492	230	230	0%	400	74%
	Courtenay Stream	Main North Road	332 ¹	260	350	35%	400	54%

2

Plan	Water course	Minimum flow site location	7MALF (L/s)	Consent minimum flow (L/s)	Ecological minimum flow proposal (L/s)	% difference from consent	Whanau minimum flow preference (L/s)	% difference from consent
Non Plan	Okuku River	Fox Creek	446	543	-	-	650	20 %
	Garry River	Birch Hill Road Bridge	102	-	-	-	100	-
	Leggats Creek	-	-	-	-	-	At least 90% of 7dMALF	-

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Plan	Water course	Minimum flow site location	7MALF (L/s)	LWRP minimum flow (L/s)	Ecological minimum flow proposal (L/s)	% difference from LWRP	Whanau minimum flow preference (L/s)	% difference from LWRP
LWRP	Little Ashley Creek	Ashley River/Rakahuri at SH1	-	50 L/s 30 L/s for 4 days each month	-	-	50	0% 67%
	Waikuku Stream	Waikuku Stream, Waikuku Beach Road	355	100 L/s Mon-Fri 150 L/s Sat-Sun	-	-	600	500% 300%
	Saltwater Creek	Saltwater Creek, Toppings Rd	0.1 ^{3,4}	100	-	-	-	-
	Taranaki Creek (Preeces)	Taranaki Creek, Kaipohia monument	174 ²	120	-	-	120	0 %
	Kaiapoi River / Silverstream	Skewbridge Road	1350	-	-	-	600	-
	Ashley River/ Rakahuri Gorge	Ashley at Gorge	2040	2500 Jan-Jul 4000 Aug-Nov 3000 Dec	-	-	5000 (with variability)	100 % 25 % 67 %
	Ashley River/ Rakahuri SH1	-	102	-	-	-	Visible connected flow (with variability)	-

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