TECHNICAL REPORT Investigations and Monitoring Group

Hinds/Hekeao Plains Technical Overview – Subregional Plan Development Process

Report No. R14/79
Hinds/Hekeao Plains Technical Overview – Subregional Plan Development Process

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Executive summary

The protection and use of water and soil resources across the Canterbury Region in New Zealand is managed by the Canterbury Regional Council (Environment Canterbury). The Hinds/Hekeao Plains catchment is located in the Ashburton District on New Zealand’s Canterbury Plains.

Environment Canterbury has divided the region into ten different water management zones for the purposes of subregional planning. Environment Canterbury is facilitating regional plan reforms through the implementation of the Canterbury Water Management Strategy (CWMS) that seeks to achieve community-determined outcomes for ten target areas of water management. This report summarises the economic, ecological, cultural and social wellbeing analyses that formed part of this process.

Each water management zone is led by a Zone Committee, consisting of community members who are appointed to represent the varied interests and aspirations for current and future management of the water and soil resources. The Ashburton Zone Committee was set up in 2010 to represent the Ashburton Zone. This zone includes the Hinds/Hekeao Plains catchment, which is known to have two major problems: an insufficient and unreliable supply of water to meet the increasing demand for irrigation, and poor water quality resulting from nutrient leaching.

The Ashburton Zone Committee produced a Zone Implementation Programme (ZIP) in 2012, which prioritised 25 Desired Outcomes for the water in the Hinds/Hekeao Plains catchment. The ZIP supported the development process for the Hinds/Hekeao Plains Subregional Plan, which would include the final recommendations on the best way to achieve the water management targets.

This report provides a conceptual model of the Hinds/Hekeao Plains catchment that focuses primarily on groundwater, as the majority of the Ashburton Zone Committee’s 25 Desired Outcomes depend directly on the condition of the aquifer underneath the Hinds/Hekeao Plains.

Between January 2013 and March 2014, the Hinds/Hekeao Plains technical team generated comparison scenarios in support of this process for the Hinds/Hekeao Plains Subregional Plan. These scenarios were divided into two groups: Exploratory Scenarios, and Solution Scenarios. This report provides an overview of the technical information that was used to generate these comparison scenarios and establish the final recommendations for the water quantity and water quality targets and limits. This report also summarises the biophysical numerical modelling that was done as part of the scenario development process. Water quality modelling was based on a spreadsheet-based accounting tool that utilised on-farm modelling with Overseer® to calculate the nitrogen loading related to various land uses. The water quantity analysis used a combination of approaches based on two modelling platforms (the Regional Distribution Model (RDM) for simple mass balance calculations, and a MIKE SHE (DHI) surface-groundwater spatial model).

The three Exploratory Scenarios (baseline, development, and environmental) showed the contrast between different future outcomes resulting from different land and water usages in the catchment. The Baseline Exploratory Scenario (the current condition) was compared against the Development Exploratory Scenario (which prioritised economic targets) and the Environmental Exploratory Scenario (which prioritised water quality and water quantity targets).

The first Solution Scenario - the Potential Options Scenario - proposed a series of catchment-scale and local-scale mitigation strategies to achieve the 25 Desired Outcomes. These mitigation strategies were refined after further community consultation, leading to the second Solution Scenario - the Solutions Package. This was used by the Ashburton Zone Committee to create their final recommendations (ZIP Addendum) for the Hinds/Hekeao Plains Subregional Chapter (Variation 2) of the proposed Land and Water Regional Plan (pLWRP). In general, the Solutions Package is the final community-based set recommendations to improve the economic, cultural, environmental and social conditions that are related to water quality and water quantity in the catchment.

The Solutions Package for the Hinds/Hekeao Plains catchment identifies two primary catchment-scale mitigation strategies: Managed Aquifer Recharge (MAR), and on-farm nutrient management. These are supported by various local-scale mitigation strategies (such as riparian fencing, in-stream habitat
restoration, and the protection and restoration of wetlands) to help improve water quality, water quantity, biodiversity and habitat. The ability of the community to implement these local-scale mitigation strategies will also determine whether the cultural values of mahinga kai, wāhi tapu and wāhi taonga are protected.

To help address the issues with water quality, which are a major concern of the community, the Solutions Package sets a catchment load limit for nitrogen of 3400 tonnes N/yr. While an additional 30,000 ha of new irrigation is also included, farms converting to more intensive nutrient leaching activities are capped at 27 kgN/ha/yr. Water quality targets for nitrate-N concentrations are set at 6.9 mgN/L for the shallow groundwater system and most coastal spring-fed waterbodies, and 3.8 mgN/L for the lower Hinds/Hekeao River. All of these targets are seen as achievable by 2035 with the implementation of the Solutions Package. For the Upper Hinds/Hekeao Plains catchment, load limits of 114 tonnes N/yr (nitrogen) and 6.1 tonnes P/yr (phosphorus) are also included, based on Overseer® and ARCGIS spatial analysis work.

However, the national drinking water target was seen to be unachievable, even with the new limit of 6.9 mgN/L, so the ZIP Addendum includes recommendations that local and regional authorities continue to develop appropriate options to help protect water supplies.

Water quantity and reliability of supply are also addressed by the Solutions Package, which proposes the development of a Hinds Drains Working Party consisting of local stakeholder representatives. Their goal is to agree on a number of water quantity targets related to minimum flows and reliability, to enhance the effectiveness of in-stream habitat restoration strategies and flood protection in the coastal waterbodies.

Numerical modelling indicates that catchment-scale MAR can help to improve both the minimum flows and reliability of supply for the Hinds/Hekeao spring-fed waterbodies. A pilot MAR project is recommended to improve the communities' understanding of this tool, address various concerns about its use in the Hinds/Hekeao Plains catchment, and demonstrate its benefits.
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Glossary

**Allocation regime** means the provisions relating to the quantity or rate at which water may be abstracted while the waterway remains above its minimum flow. The allocation regime and the minimum flow together create the environmental flow regime.

**Augmentation** used generically in the document to refer to the artificial addition of water to help achieve a quantity target or outcome. Augmentation can be achieved by using Managed Aquifer Recharge (MAR), Targeted Stream Augmentation (TSA), or direct augmentation to waterbodies.

**Baseflow** represents the portion of flow in surface waterbodies that is provided by groundwater discharge. Spring-fed waterbodies maintain their low-flow season flows primarily from baseflow. These flows are different from minimum flows but can be related, as both represent the lowest flows.

**Environmental flow** is a comprehensive term that encompasses all components of a river’s flow regime. It is dynamic over time, providing for flow variability and addressing social, economic and environmental values.

Environmental flow regime means the provisions that manage and maintain the range of flows in a river. This can include the setting of minimum flows and/or sharing and/or a cap on water available to be abstracted. An environmental flow regime also incorporates a structure for the allocation of water above the minimum flow.

Determining the setting of a minimum flow for a river is only one part of the environmental flow regime review process.

The main reasons for establishing environmental flow regimes are to:

- protect instream values (by setting minimum flows)
- avoid ‘flat lining’ (artificially maintain flows at the minimum flow for prolonged periods)
- maintain flow variability above the minimum flow
- help maintain reliability of supply for abstractors (by capping allocation).

When it comes to determining environmental flow regimes, there is no ‘one size fits all’ solution. Each minimum flow must be set after considering the nature of the river, and the in-stream values and out-of-stream use that the river sustains.

**Ephemeral** (in terms of flow) means a stream or river which flows intermittently. For example, a stream that does not flow at all times, and flows for brief and often unpredictable periods after rainfall.

**Groundwater replenishment scheme (GRS)** – an aquifer recharge system using the tools of Managed Aquifer Recharge (MAR) with the goal to sustainably manage groundwater at a catchment-wide scale. GRS are often operated similar to other water management systems (e.g. irrigation schemes, municipal water supply and treatment systems, etc.) GRS framework would likely include mechanisms to create revenue, specific consenting structures that assist in the recharge activities, and specific recharge goals specific to a broader groundwater management purpose.

**Intermittent** means it is a flowing water body but has discrete periods where it ceases to flow (generally predictable).

**MALF(7d)** Mean Annual Low Flow (7d) is the average of each annual lowest average flow experienced over seven consecutive days. It should be based on >25 years of data to incorporate climatic variation. If these data are not directly available, existing data are extended by correlation with a long-term recorder site. Naturalised MALF(7d) (accounting for water abstractions and discharges) is a commonly-used statistic when dealing with minimum flows and allocation.

**Managed Aquifer Recharge (MAR)** – the set of physical and regulatory tools intended to assist in the artificial recharge of groundwater.

**Minimum flow** is the flow value below which consented abstractions from a waterway must cease. Minimum flows do not need to be constant throughout the year, and can vary by month or season. All surface water irrigation takes and groundwater takes considered to be ‘direct’ and ‘high’ stream depleters should have minimum flows specified for their source waterways.
**Irrigation efficiency** in this report is defined as the efficiency of water application and use. It is computed by dividing evapotranspiration of applied water by the total applied water and converting the result to a percentage. Efficiency can be computed at three levels: farm, district, or basin.

**Outcomes, Desired Outcomes** Ashburton Zone Committee community aspirations for current and future management of natural resources in the Hinds/Hekeao catchment. 25 total Outcomes were sourced from the Ashburton Zone Committee Zone Implementation Plan. These outcomes were used to guide the subregional process and develop the final Solution Package of recommendations to Environment Canterbury.

**Partial restriction** means that irrigation takes are permitted, but at a reduced rate. Partial restrictions prevent water being taken to below the minimum flow. For example: if the flow is 10 L/s above a minimum flow and the allocation is 20 L/s without partial restrictions, abstractors can take the full allocation and leave the watercourse at 10 L/s below the minimum flow, but with partial restrictions, abstractors can only take the amount of water above the minimum flow (in this example 10 L/s or 50% of the allocation).

**Perennial** (in terms of flow) means a permanent all-year-round flow.

**Reliability of supply** (in relation to irrigation) is the ability of the water supply to meet demand from one or more abstractors, when operating within the flow and allocation regime. It can be measured in terms of time and/or volume.

**Stream depleting take** (stream depleter) is generally a shallow groundwater take within 2 km of a surface waterbody that can be shown, using analytical modelling techniques, to have an effect on that surface waterbody. Environment Canterbury uses a classification ranking for stream depleting takes that ranges from direct, high and medium to low, depending on the modelled degree of influence on the surface waterbody. These rankings are used to manage any restrictions on the takes that may apply.

**Targeted Stream Augmentation** – is a term developed in the Selwyn Te Waihora CWMS process for augmentation with the goal of targeting spring flows in the lowland waterbodies. This term was not used during the Hinds/Hekeao process but is referred to indirectly as a means of Augmentation related to MAR.

**Targets** – refers to specific environmental numerical targets used to guide the modelling process. Were used in final recommendations as limits. For example, 6.9 mgN/L of nitrate-N was used as the environmental target for groundwater and spring-fed waterbody concentrations. Water quality modelling with the various mitigations (MAR and on-farm) were used to achieve this target. They are related to the desired Outcomes, as ‘Healthy Lowland Streams’ is measured (in Hinds/Hekeao context) as being 6.9 mgN/L.
1 About this report

1.1 Background to this report

The Hinds/Hekeao Plains catchment is located in the Ashburton District on New Zealand’s Canterbury Plains (Figure 1-1). This district is part of the Canterbury Region, the natural resources of which are managed by the Canterbury Regional Council (Environment Canterbury).

Figure 1-1: Boundary of the Hinds/Hekeao Plains catchment area
Environment Canterbury facilitates the implementation of the Canterbury Water Management Strategy (CWMS), the blueprint for the sustainable management of the region’s water resources that is based upon a collaborative and community-based approach to achieving ten target areas (Canterbury Water, 2009). The ten target areas are:

- environmental limits
- drinking water
- regional and national economies
- ecosystem health and biodiversity
- energy security and efficiency
- water use efficiency
- irrigated land area
- recreation
- natural character
- kaitiakitanga

The region is divided into 10 water management zones. Each of the zones develops recommendations based on a community-based engagement process. Each zone is led by a Zone Committee consisting of community members who are appointed to represent the varied interests and aspirations for current and future management of the resources. The Ashburton Zone Committee represents the Ashburton Zone, which includes the Hinds/Hekeao plains catchment area (Figure 1-1).

### 1.2 Report scope and process

The Ashburton Zone Committee has been responsible for the development of Subregional Plan recommendations for the Hinds/Hekeao Plains catchment. Development of these recommendations was guided by the Ashburton Zone Committee’s 2012 Zone Implementation Programme (ZIP), which prioritised catchment-specific future outcomes for the Hinds/Hekeao Plains catchment (Environment Canterbury, 2012).

Between January 2013 and March 2014, the Ashburton Zone Committee undertook a community-based collaborative process, using public meetings to present various land use and water management scenarios for the CWMS planning timeframe (2015 to 2040). The various scenarios were divided into two groups: Exploratory Scenarios, and Solution Scenarios.

The three Exploratory Scenarios provided a contrast between various potential future land and water use outcomes, and comparison of the different results from each scenario.

- The Exploratory Development Scenario looked primarily at continued intensification of land use (e.g. additional irrigation of 30,000 ha).
- The Exploratory Environmental Scenario, which held land use at current levels, looked primarily at achieving environmental targets for water quantity and water quality.
- The Exploratory Baseline Scenario represented an estimated ‘current condition’ for the Hinds/Hekeao Plains catchment.

The two Solution Scenarios were the Potential Options Scenario, and the “Solutions Package”. The development of the Potential Options Scenario began with the technical team presenting a set of potential mitigation options to the community for consideration. This scenario aimed to find a balance between 26 Hinds/Hekeao Plains outcomes for environmental, economic, cultural and social factors, in order to develop a final community-based plan and recommendations for land use and water management issues in the catchment. From June 2013 to March 2014, the Ashburton Zone Committee worked with stakeholders to develop a final set of mitigation options that sought to achieve the water quality and water quantity targets within a timeframe that was both reasonable and equitable for the various stakeholders.
The Solutions Package contains the final set of mitigation options, as described in the \textit{Ashburton ZIP Addendum – Hinds Plains Area} (Environment Canterbury, 2014). The Solutions Package aims to strike a balance between the 25 outcomes for the Hinds/Hekeao Plains catchment through both catchment-scale mitigation options (requiring system wide implementation) and local-scale mitigation options (which are site-specific).

This entire technical, planning and community collaboration process was technically complex and underwent constant change as the approach and analytical models were adapted based on community input, peer reviews and new or improved analysis tools becoming available.

Changes in one area within a scenario (e.g. on-farm mitigation options) often required changes to other related areas (e.g. water quality), which made documentation of this process particularly challenging. Consequently, technical documentation completed at the various earlier stages of this process was sometimes superseded later, to reflect the community’s final recommendations.

1.3 Purpose of this report

This purpose of this report is to:

- provide an overview of the technical information generated to support the Hinds/Hekeao Plains Subregional Plan development process, and summarise the land and water management scenarios developed for the community of the Hinds/Hekeao Plains catchment (Figure 1-1).
- outline the analysis methods and results of the three Exploratory Scenarios (baseline, development, and environmental), which were used by the technical team to help the community compare and consider a range of potential outcomes and environmental targets.
- give an overview of the various streams of technical work used in this process and the supporting economic, cultural, social, and environmental analyses. It follows the development of the scenarios, and provides the links to the peer-reviewed science that supports the findings.

1.4 Structure of this report

The report structure reflects the logical progression of the process used to develop the Hinds/Hekeao Plains Subregional Plan.

- **Hinds/Hekeao Plains limit setting process.** This section provides the background to the technical approach and the development of the outcomes and targets. It also covers the community consultation process that was undertaken by the technical team.
- **Conceptual understanding of the Hinds/Hekeao Plains catchment.** This section outlines the social, cultural, economic, physical, ecological and historical aspects of the area, and summarises the current conditions.
- **Biophysical modelling tools and assessments.** This section reviews the various modelling tools used during the development process and shows how the results fit together into a final conceptual understanding of the Solutions Package.
- **The Exploratory Scenarios.** This section explains the background and findings from the three different exploratory scenarios (baseline, development and environmental).
- **The Solution Scenarios.** This section explains the background of the mitigation options, analyses and findings in the Potential Options Package. It also summarises the supporting analyses and findings for the Ashburton Zone Committee’s final set of mitigation options and targets relative to the outcomes that are documented in the Solutions Package.
1.5 Technical information used for this report

This report is underpinned by various sources of technical information and supporting documents. These include information about the historical background and trends in the catchment, conceptual models and analysis frameworks, the scenario assessments and Solutions Package, and a summary of the technical consultation that was undertaken with the various community stakeholders.

Throughout the report, references are made to various sources of technical information, which comes in various forms ranging from published reports through to technical memos prepared specifically to meet a particular information need. Figure 1-2 outlines the overall structure of these various information sources and organises them into logical groupings.

![Figure 1-2: Schematic of the technical documents and other supporting information that underpin this report](image)

This Hinds/Hekeao Plains Technical Overview report presents the overall summary of the entire process, and has a particular focus on bringing together the logic and findings that support the Ashburton Zone Committee’s final Solutions Package.

The Solutions Package Technical Analysis Compendium (Environment Canterbury, 2014a) represents a collection of various reports, memos and draft community summary statements, all of which were pieces of work not captured in the other reports. It also includes references to draft memos provided during a series of community workshops. Although the information presented in these community summaries was often superseded by more up-to-date information, it is important to document them as part of the process.

The other three categories of technical information are the numerical modelling, assessments and mitigation options (both catchment-scale and local-scale).
• The numerical modelling information focuses on the water quality and water quantity modelling done to assess the various scenarios, and leads to the development of environmental targets and load allocations.

• The assessment information focuses on the cultural, economic, social, and environmental analyses used for the development process. These reports provide a range of information including the physical context, historical perspectives, and the supporting scientific basis behind the environmental targets. The assessments also generally provided a review of the Solutions Package relative to their perspective topic and evaluated any implications, costs or changes that might be expected from implementation of the subregional plan.

• The mitigation options information provides an analysis of the solutions developed for use in the Solutions Package, and includes an evaluation of current conditions.

The technical information generated for the Hinds/Hekeao Plains Subregional Plan development process was provided by Environment Canterbury’s technical staff, and subcontracted consultants. As part of Environment Canterbury’s standard method of peer review, all reports and technical memos deemed relevant to the final Hinds/Hekeao Plains Subregional Plan and the Ashburton Zone Committee’s proposed Solutions Package were peer-reviewed (both internally and externally).

Table 1-1 provides a summary of the reviews completed for the main reports, their relative technical area, and identifies the various experts who were contracted to provide an independent peer-review of the science. The reports varied in the information they provided to the various relevant scenarios (from Baseline to Solutions Package).
### Table 1-1: Hinds/Hekeao primary technical reports and reviewer information

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<td>Potential Options (PO)</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td>Solutions Package (SP)</td>
</tr>
<tr>
<td>Water Quality Background and Modelling</td>
<td>Scott (ECan)</td>
<td>ECan</td>
<td>Conceptual modelling approach – Vince Bidwell Final Report – Vince Bidwell</td>
<td>B, D, E, PO</td>
</tr>
<tr>
<td>Water Quantity Background and Modelling</td>
<td>Durney, P., Ritson, J (ECan)</td>
<td>ECan</td>
<td>Technical Analysis – Golder – Ian Lloyd Final Report – Golder – Ian Lloyd</td>
<td>B, D, E, PO</td>
</tr>
<tr>
<td>On Farm Mitigations and Economics</td>
<td>Everest et al. (MacFarlane Rural Business (MRB))</td>
<td>MRB&lt;sup&gt;1&lt;/sup&gt;</td>
<td>MRB Internal Review</td>
<td>PO, SP</td>
</tr>
<tr>
<td>Te Rūnanga o Arowhenua – Cultural Perspective</td>
<td>Tapa &amp; Associates</td>
<td>Tapa &amp; Associates</td>
<td>Te Rūnanga o Arowhenua</td>
<td>All</td>
</tr>
<tr>
<td>Economics: Local, Regional and National</td>
<td>AgResearch</td>
<td>Dr. Simon Lovatt, Stephen Sinclair</td>
<td>University of Waikato – Dr. Graeme Doole</td>
<td>B, D, SP</td>
</tr>
<tr>
<td>Ecology – Ecosystems, Environmental Targets</td>
<td>Meredith, A., Lessard J (ECan)</td>
<td>ECan</td>
<td>Golder – Richard Allibone</td>
<td>SP</td>
</tr>
<tr>
<td>Local Mitigation Options Assessment</td>
<td>Meredith, A., Lessard J (ECan)</td>
<td>ECan</td>
<td>Golder – Richard Allibone</td>
<td>PO, SP</td>
</tr>
<tr>
<td>Social Assessment – Summary Report</td>
<td>Taylor Baine Associates</td>
<td>Nick Taylor</td>
<td>Environmental &amp; Behavioural Consultants – Mark Fenton</td>
<td>All</td>
</tr>
<tr>
<td>MIKE SHE Modelling – Integrated Surface-Groundwater Modelling</td>
<td>Durney, P., Ritson, J (ECan)</td>
<td>ECan</td>
<td>DHI&lt;sup&gt;2&lt;/sup&gt;, EIM&lt;sup&gt;3&lt;/sup&gt; – Mark Gyopari</td>
<td>B, SP</td>
</tr>
<tr>
<td>Managed Aquifer Recharge – Solutions Package</td>
<td>Golder Associates (NZ) Limited (Golder)</td>
<td>Golder</td>
<td>Golder – Brett Sinclair</td>
<td>PO, SP</td>
</tr>
<tr>
<td>Solution Package Technical Compendium – Technical Memos</td>
<td>ECan</td>
<td>ECan</td>
<td>Golder – Nat Wilson&lt;sup&gt;4&lt;/sup&gt; MRB – Mark Everest&lt;sup&gt;5&lt;/sup&gt;</td>
<td>SP</td>
</tr>
<tr>
<td>Technical Overview – Hinds Plains Process and Technical Appendices</td>
<td>Bower, R (ECan)</td>
<td>ECan</td>
<td>David Painter Consulting Ltd – David Painter</td>
<td>All</td>
</tr>
</tbody>
</table>

Notes:  
1 – DairyNZ review including sensitivity analysis, 2013.  
2 – DHI internal review of MIKE SHE model construction and software usage.  
3 – Reviewed the MIKE SHE conceptualisation, calibration and groundwater results relative to their use.  
4 – Reviewed Environment Canterbury water quality memos and model (Scott).  
5 – Reviewed Overseer® model usage for upper catchment load modelling.
2 Limit setting for the Hinds/Hekeao Plains Catchment

2.1 Environment Canterbury’s preferred approach

The National Policy Statement for Freshwater Management (NPS-FM) became operative in July 2014. This document sets statutory directions for regional councils to adopt a staged approach to setting water quantity and quality limits by no later than 2025.

In areas where limits are exceeded and resources are over-allocated, regional councils are required to set appropriate targets and methods to reduce the over-allocation within a set time. Environment Canterbury has ultimate responsibility for setting the water quality and water quantity limits for the Hinds/Hekeao Plains catchment, and for ensuring that these limits are achievable. Environment Canterbury endorsed a method for managing the cumulative effects of land use on water quality and water quantity known as “Preferred Approach” (Environment Canterbury, 2012). This approach was used in the limit setting process for the Hinds/Hekeao Plains catchment.

The method is based on a case study used in the Hurunui-Waiau Catchment, but has since been revised because of the lessons learnt in the Selwyn-Waihora limit setting process which also used the Preferred Approach. The method was adapted for the particular circumstances of the Hinds/Hekeao Plains catchment.

The Preferred Approach is a process that can be adapted to suit the communities’ needs, and the challenges in an individual catchment. Essentially, it is a two-stage process. Firstly the process provides for the setting of limits for the catchment and, second, identifies the interventions needed to meet these catchment loads and targets (Figure 2-1).
The first stage, Setting the Limits, comprises a community-led collaborative process to establish the limits, which are then translated via a final set of recommendations into a statutory plan consistent with the Resource Management Act (RMA).

Under the auspices of the Canterbury Water Management Strategy (CWMS), the Ashburton Zone Committee was set up as a joint committee of Environment Canterbury and the Ashburton District Council in 2010. The Ashburton Zone Committee is made up of selected members to provide a balance of local expertise and perspectives across a range of stakeholder values and interests. A number of Zone Committee members are also appointed to represent local government (e.g. Ashburton District Council, Environmental Canterbury) and iwi (Arowhenua). Although the committee has a number of appointees, the operating philosophy requires that members represent the range of stakeholders’ interests in the area, and reach a decision by consensus. The committee was responsible for putting forward the final set of recommendations for the catchment.

Environment Canterbury developed the Preferred Approach process to facilitate this community-led limit setting process. From a technical perspective, the Preferred Approach was important because it helped to provide a set of guidelines by which the technical work (particularly the land use and water management solutions) could be developed. The Preferred Approach outlines ten key principles to consider, which are directly applicable to the technical process undertaken in the Hinds/Hekeao Plains Subregional Plan development process:
Focus on outcomes: Directed by the community input and Zone Committee decisions, the technical team ensured that the various proposed solutions continued to aim at achieving the Ashburton Zone Committee’s recommended outcomes from the Zone Implementation Plan (Environment Canterbury, 2012). The protection and management of groundwater was the focus of the mitigation options that were developed to manage this resource holistically. This approach helped to keep the solutions focused on the core purpose of the process.

Whole catchment approach: The mitigation strategies ranged from catchment-scale options (those needing widespread implementation) to local-scale options (those needing site-specific design and implementation), so this whole catchment approach was a critical component of the technical process. The primary resource of both the water quality and water quantity in the catchment is the underlying groundwater reservoir. Technical solutions to help restore and manage the groundwater resource at a catchment-scale were critical. The whole catchment approach was reaffirmed through outcomes such as the cultural outcome of ‘Water as a Wāhi Taonga’. This simply means that the Solutions Package provides an acceptable minimum level of water quality, in-stream and riparian (Environment Canterbury, 2014).

Collaborative management: The technical team engaged with the community, industry groups, local runanga, NGOs, and the Ashburton Zone Committee through a wide range of formats. Workshops, meetings, phone calls, print media, community forums and emails were used to share, discuss and re-evaluate information between the participants. The mitigation options and solutions that resulted from this process reflect the need for collaborative management of the groundwater into the future, through the Hinds Drains Working Party.

Quadruple-bottom line: The structure of the Preferred Approach ensured that the participants used a balance of the quadruple-bottom line parameters (economy, environmental, cultural and social) to direct the progress of technical analysis and modelling.

Adaptive management: The technical nature of this development process requires an assumption that new tools, additional information and changing physical conditions will result in proposed mitigations that are adaptive through the life of the plan. This assumption is critical to understanding the proposed Solutions Package.

Flexibility: The technical solutions in the Solutions Package focus on holistic, rather than prescriptive, solutions. This is evident in the catchment-scale solutions that aim to manage the aquifer’s water quality and water quantity issues for the benefit of the entire community and to meet their outcomes. The methods used by the Ashburton Zone Committee to implement these mitigation options is flexible, based on the local physical and logistical conditions.

Certainty: From the mitigation options developed on through to the modelling and data used, the Hinds/Hekeao process contained varied levels of certainty relative to the accuracy and validity of the predicted changes. The Hinds technical work recognises that an adaptive management approach during the implementation of the solutions package is critical to achieving the targets and outcomes.

Equity: The mitigation options developed by the technical team aimed to provide a balance between providing equity to existing water and land use activities while providing an opportunity for development opportunities. Although the mitigation options acknowledge existing practices, they require all parties to work towards achieving the outcomes established by the community.

Avoidance of irreversible and/or perverse outcomes: The technical team had a strong focus on providing the scientific information to the community as a suite of options to consider in balance. The key objective was to avoid presenting irreversible economic, social, cultural and/or environmental outcomes as part of the final Solutions Package.
2.2 Implementing the preferred approach

This section briefly outlines the sequence of steps taken by the Ashburton Zone Committee to support of the Hinds/Hekeao Plains Subregional Plan development process and lead to a suite of final recommendations.

1. **Establishing community values and outcomes**: The committee described their aspirations for the Hinds/Hekeao Plains catchment in the 25 outcomes and future directions (Figure 3-2) in the Ashburton Zone Committee’s 2012 Zone Implementation Programme (ZIP). This information was used to inform and guide the limit setting process. (January 2012)

2. **Establishing current conditions and agreed approach**: The committee agreed to proceed with the limit setting process, based on three Exploratory Scenarios. These scenarios would help to understand the consequences of different future land use and water management options in terms of the social, economic, cultural and environmental outcomes described in the ZIP. The committee presented this approach in the first community workshop along with a summary of the catchment’s current conditions relative to water quality, water quantity, and the ZIP outcomes. (January 2013)

3. **Exploratory Scenarios**: The technical team developed the three exploratory scenarios using biophysical models, and specialised technical expertise, to determine the relative changes in each of these exploratory scenarios. They presented this information to the Ashburton Zone Committee and the wider community through a series of workshops. The committee designed these workshops to facilitate and encourage community feedback about the development of the potential mitigation options and community guidance on how to balance the various outcomes and targets. The technical team presented the results in a way that aimed to provide the community with a relative sense of magnitude and uncertainty for achieving the ZIP outcomes. (February to May 2013)

4. **Developing collaborative solutions**: The technical team used the feedback gathered during the Exploratory Scenario workshops to form an extensive list of community ideas for mitigation options to address the various catchment issues. The Potential Options Scenario was the first of the two solution scenarios to be presented to the Ashburton Zone Committee and community (June 2013). The following eight months were spent in deliberating and revising these mitigation options through numerous committee, stakeholder and community workshops, meetings, phone calls and emails. The technical team revised the way it presented the information, focusing more strongly on providing a range of possible mitigation options relative to both the overall planning timeframe (2015 to 2040) and the degree to which they could be achieved. Much of the deliberation between the participants was more focused on the specific limits (e.g. Hinds/Hekeao catchment load limit of 3400 tonnes Nitrate-N/year by 2035) than on the suite of 25 outcomes during this stage. (June 2013 to February 2014.)

5. **Solutions Package**: The deliberation about the various mitigation options resulted in the completion of the Solutions Package, which provided freshwater objectives and limits (Table 2-1). The technical team presented a draft of the Solutions Package to stakeholders and the community through a series of workshops and meetings. Comments were received and incorporated into the final Solutions Package, (February 2014).

6. **Addendum of Recommendations**: The final Solutions Package is described in the Zone Committee’s Ashburton Zone Implementation Programme Addendum 2014 (ZIP Addendum), (Environment Canterbury, 2014).

7. **Adoption of recommendations**: The Solutions Package described in the ZIP Addendum was adopted by Environment Canterbury (March 2014) and by Ashburton District Council (April 2014).

8. **Subregional Plan – Variation 2**: The ZIP Addendum is being used to develop Variation 2. This variation will become a subregional chapter to the proposed Land and Water Regional Plan (pLWRP) (Environment Canterbury, 2013) specific to the Hinds/Hekeao Plains.
catchment. Variation 2 will include specific rules that are enforceable under the RMA, and it aims to facilitate implementation of the ZIP Addendum’s Solution Package, including setting the limits for nutrient loads, water quantity and water quality in the catchment. A completed Variation 2 will set the beginning of the ‘Managing to Limits’ portion of the Preferred Approach (Section 2.1). Environment Canterbury’s planning staffs have scheduled to notify the Variation as part of the RMA process toward the end of 2014.

2.3 Establishing the outcomes

The Canterbury Water Management Strategy (CWMS) outlines high-level regional outcomes across four target areas: economic, social, cultural and environmental. However, not all of the outcomes in the Ashburton ZIP were relevant to the Hinds/Hekeao Plains catchment or this specific limit-setting process. In addition, it is important to note that some of these outcomes were process-based (e.g. driving continuous improvements in science and mitigation options) or could not be evaluated by the biophysical modelling analyses (e.g. remnant indigenous vegetation areas do not decrease in size).

The Ashburton Zone Committee developed a set of outcomes for each of the four target areas for their zone. During the early community workshops 26 desired outcomes (outcomes) were listed which was refined to 25 to consolidate two outcomes relative to these outcomes are part of the overall solutions package and continue to be relevant to the committee’s aspirations. There are 25 outcomes in the four target areas (Table 2-1) for the Hinds/Hekeao Plains catchment area.

Table 2-1: The CWMS target areas and outcomes for the Hinds/Hekeao Plains catchment

<table>
<thead>
<tr>
<th>CWMS Target Areas</th>
<th>25 Ashburton Zone Committee Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environmental</td>
<td>Maintain flows in lowland streams to protect biodiversity values</td>
</tr>
<tr>
<td></td>
<td>Water quality in drains/streams is improved</td>
</tr>
<tr>
<td></td>
<td>Reduced nutrient inflow into lowland streams supports historical ecosystem health</td>
</tr>
<tr>
<td></td>
<td>Ecologically significant wetlands and peat swamp remnants are protected</td>
</tr>
<tr>
<td></td>
<td>Protect and enhance indigenous fish and habitats in lowland streams and foothills</td>
</tr>
<tr>
<td></td>
<td>Protect and enhance habitat for trout</td>
</tr>
<tr>
<td></td>
<td>Protect and enhance streams and sub-catchments with only indigenous fish species</td>
</tr>
<tr>
<td></td>
<td>Remnant indigenous vegetation areas do not diminish in size</td>
</tr>
<tr>
<td></td>
<td>Retain unique features and biodiversity of the dongas (Section 3.3.1)</td>
</tr>
<tr>
<td></td>
<td>Protect remaining dry land biodiversity</td>
</tr>
<tr>
<td>Cultural</td>
<td>Wāhi tapu and wāhi taonga are protected and access enhanced</td>
</tr>
<tr>
<td></td>
<td>Mahinga kai is protected and enhanced</td>
</tr>
<tr>
<td></td>
<td>Maintain flows in lowland streams to protect cultural values</td>
</tr>
<tr>
<td>Economic</td>
<td>Security and increased demand reliability (95%) for abstractive users</td>
</tr>
<tr>
<td></td>
<td>Increase irrigated area by 30,000 ha from current irrigated land</td>
</tr>
<tr>
<td></td>
<td>Ready access to reliable quality stock water</td>
</tr>
<tr>
<td></td>
<td>Protect current water availability, including for smaller landowners</td>
</tr>
<tr>
<td></td>
<td>Economic growth in Hinds and Mayfield communities</td>
</tr>
</tbody>
</table>

1 Two outcomes ‘drain flows provide for abstractive use’ and ‘drain flows provide for flood conveyance’ were merged by the Environment Canterbury team for clarification into ‘Drain flows provide for flood conveyance and current abstractive use’.
2.4 The framework for the technical assessment

The framework used for the technical assessment of the Hinds/Hekeao Plains catchment contained the following four key elements.

- **Conceptual understanding and modelling**: An assessment of the scope and boundaries of the Hinds/Hekeao Plains catchment, which included physical, regulatory (planning) and practical considerations.

- **Biophysical modelling and technical assessments**: Setting the limits, based on numerical modelling which helped to generate the scenarios for comparison. Technical assessments provided input data and analysis for the supporting models, as well as technical reviews of the consequences of the various scenarios.
  
  - **Modelling**:
    - Water quantity – groundwater and flow levels.
    - Water quality – load limits and relative targets.

  - **Assessments**:
    - Economic – Analysis with modelling of mitigations and regional impacts.
    - Social – evaluating relative social changes of scenarios.
    - Cultural – Documentation of Te Runanga o Arowhenua’s values and cultural indicators.
    - Ecological – Analysis of ecological trends and targets.

- **Development of catchment-scale and local-scale mitigation options**:
  
  - **Catchment-scale**:
    - On-farm mitigation options to reduce contaminant leaching to groundwater and transport to surface waterbodies, at different levels and economic costs.
    - Groundwater replenishment with Managed Aquifer Recharge (MAR) to increase the amount of high quality water being recharged to the groundwater system, providing improvements in both water quality (through dilution of contaminants) and water quantity (increased aquifer storage).

  - **Local-scale**:
    - Site-specific mitigation options targeted at improving habitat, waterway connectivity and waterbodies for ecological and drainage functions (e.g. riparian fencing and stock exclusion).
    - A suite of management, research, and regulatory tools which provide support in achieving the Outcomes (e.g. farm environment plans).

- **Assessment of the different scenarios**: This is a team process. It uses specialised expertise from different scientific disciplines to review the modelling results and mitigation
options, and scores the likelihood of achieving various community outcomes and the sense of the difference the changes will have toward effecting change.

Environment Canterbury used each of these four key elements as a basis to develop the technical assessment process. When new scientific and/or community information became available, these elements were revised to ensure that the direction and scope of the solutions package stayed in alignment with the community values and outcomes.

2.5 Managing uncertainty and creating a ‘fit for purpose’ assessment framework

Setting the outcomes and natural resource limits for a catchment, and deciding on the available capacity and limits for resource use involve more than technicalities. These decisions are value judgements that involve weighing up, trading off, and balancing conflicting outcomes and values. The role of the technical team is to support informed decisions, by clearly explaining the consequences, rather than making the decisions themselves.

This means that Environment Canterbury’s role is that of a ‘knowledge-broker’ rather than a knowledge ‘arbiter’, and explores the implications of different management options with the community. It also shifts the role of science away from trying to find the ‘right’ answer and defending that position in scientific terms, to a role that provides support and information (Robson, 2014).

The technical team needed to supply sufficient relevant and credible information that was legitimately gathered and analysed. This information needed to be presented to the community in a way that was helpful in understanding the physical connections and the likely consequences of any specific mitigation options. This was achieved during the development of the solution scenarios for the Hinds/Hekeao Plains catchment, through the creation of the decision tools for the Ashburton Zone Committee.

This approach also meant that an understanding of the inevitable uncertainty of the science or limited information is integral to the nature of the decisions being made, and is not used as a reason for not making them (Robson, 2014). Finding a balance between acknowledging these uncertainties while providing a level of fit-for-purpose model predictions that allowed the community to make decisions on specific load limits (e.g. catchment load limit of 3,400 tonnes/year of nitrate-N by 2035) was the crux of the Hinds/Hekeao Plains Subregional Plan development process.

As in many large-scale, multi-faceted catchment assessment processes there are many sources of potential uncertainty. Uncertainty manifests itself through the input sources of information, numeric models and assessment techniques that are used to make predictions. There is also a great deal of uncertainty in the future conditions that may or may not eventuate based on changing economics, changing climate, or the types of mitigation that may be developed to help manage the issues.

This uncertainty has generally been documented in the individual reports and memos. However, no quantitative assessment of overall uncertainty of the scenario predictions has been attempted. The technical team believes that the strength of this process has been in the comparative scenario of relative change, and not on the absolute numbers generated from the analysis. For this breadth of complicated physical, geochemical, hydrological, ecological and economical interactions that relate to various changes in the catchment, a monitoring and adaptive management approach is consistent with the certainty from which the predictions were made.

In order to help the Ashburton Zone Committee and wider community to make informed value judgements, the technical team aimed to:

- Describe the direction of change and likely magnitude of change under future scenarios
- Predict the likelihood of outcomes being achieved for each of the future scenarios

The technical team used the following methods to try to develop a credible, relevant and legitimate assessment framework:
o Assessments based on a logical framework
o Use of the best information available at the time of assessment
o Agreement by the technical team and stakeholders on a conceptual understanding of how the catchment works hydrologically
o Examine the outputs from each model component for sense and plausibility before passing on the information (including a review of relevant literature if applicable)
o Calibrate the individual biophysical model components where possible, based on the best available data, modelling tools and time permitted under scheduled subregional process.
o Use of independent advice and reviews through the initial modelling set up and creation of the assessment framework.

2.6 Capturing uncertainty in the scenarios

The technical team used a method for each of the three Exploratory Scenarios to describe the direction and likely magnitude of the perceived ability to achieve the outcomes during the consultation process. This method helped to provide consistency when translating the scenario results relative to the outcomes.

A similar method, developed for the Selwyn-Waihora Zone (Robson, 2014), was used during the comparative Exploratory Scenarios process (Baseline, Development And Environmental). This method used a scoring system, which was also used by the technical team to assess the likelihood of achieving any one Outcome from a scientific perspective. It is important to note that the outcomes themselves are a value judgement made by the community (e.g. healthy lowland waterbodies). The technical team implicitly weighted the relative importance of a range of individual indicators that would contribute to, or detract from, a Outcome. These scoring categories were constructed to help provide a sense of the scale of uncertainty, and colours are used to provide a visual cue to the results (Table 2-2).

<table>
<thead>
<tr>
<th>Likelihood of outcome being achieved</th>
<th>Almost certainly</th>
<th>Probably</th>
<th>Possibly</th>
<th>Unlikely</th>
<th>Highly Unlikely/No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indicative numeric likelihood out of 10</td>
<td>9, 10</td>
<td>7, 8</td>
<td>4, 5, 6</td>
<td>2, 3</td>
<td>0, 1</td>
</tr>
</tbody>
</table>

This scoring method was used only for the three Exploratory Scenarios (Baseline, Development And Environmental) for the Hinds/Hekeao Plains catchment. The community requested a different approach for the Solutions Scenarios moving forward. The technical team presented these scoring tables in both the workshop presentations and the draft community summaries for each of these three scenarios (Table 2-3).
Table 2-3: Example of the scoring table for a Outcome

Environmental Outcome 1
Aim: Maintain flows in lowland streams to protect biodiversity values

<table>
<thead>
<tr>
<th>Met</th>
<th>Very likely to be met</th>
<th>Likely to be met</th>
<th>Unlikely to be met</th>
<th>Very unlikely to be met</th>
<th>Not met</th>
</tr>
</thead>
</table>

After the Exploratory Environmental Scenario workshop, feedback from the community helped to change this approach towards presenting the information. The community and the Ashburton Zone Committee directed the technical team to present the information and let the community weigh up the uncertainties and magnitude of changes from their own consultations and discussions.

From this time onwards, much of the community discussion focused on key issues and targets and the associated outcomes. While all of the 25 outcomes remained a part of the dialogue, there was less focus on these and more focus on the science and issues related to the most difficult outcomes that the community had to explore.

A by-product of this change in approach was the committee’s interest in having a range of possible mitigation options to consider, particularly around nutrient load setting. Figure 2-2 was the decision tool (Vattala & Scott, 2013) developed to provide a range of possibilities for water quality targets relative to the mitigation options.

Figure 2-2: Hinds/Hekeao Plains catchment area nutrient decision tool

Long-term average nitrate-nitrogen concentrations (mg/L) in shallow groundwater and lowland waterways

9.3 mg/L N = 3400 T N

<6.9 mg/L N = 3400 T N + 27 kg/ha cap + M&AR

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Uncertainty around the increased irrigation, on-farm mitigation options and Managed Aquifer Recharge (MAR) required that all of these needed to be considered at different levels. Since the water quality targets were jointly and highly dependent on these three mitigation options, a tool was developed to provide choices to the community. This tool allowed a range of possible configurations of the mitigation options to be presented in direct relationship to the targets that would be achieved. While some level of uncertainty was still relevant (the likelihood of achieving a target), it provided a more hands-on approach to the options.

### 2.7 Consultation and collaboration process

#### 2.7.1 Consultation workshops

After adopting the scenario approach requested by the Ashburton Zone Committee, the important first step was to provide the community with a ‘state of the catchment’ summary. A workshop\(^2\) in January 2013 presented the current state of Hinds/Hekeao catchment, covering the history, society, environment, economy and culture, as well as historical trends for water quality and water quantity. Workshops were well attended with some of the later workshops having as many as 100 community members in attendance.

This introduced the community to the limit setting planning process and set the stage for further discussions and collaboration. This workshop (Workshop 1) helped to facilitate the development of a history of the Hinds/Hekeao Plains catchment from the people at the meeting and from follow-up discussions. The technical team also presented the community workshop approach and process timeline (Table 2-4).

<table>
<thead>
<tr>
<th>Methodology</th>
<th>Community workshop number</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introductory</td>
<td>#1 - Current Conditions</td>
<td>Tuesday 29 January 2013</td>
</tr>
<tr>
<td>Exploratory</td>
<td>#2 - Baseline Scenario</td>
<td>Tuesday 19 March 2013</td>
</tr>
<tr>
<td></td>
<td>#3 - Development Scenario</td>
<td>Tuesday 9 April 2013</td>
</tr>
<tr>
<td></td>
<td>#4 - Environmental Scenario</td>
<td>Tuesday 7 May 2013</td>
</tr>
<tr>
<td>Solutions</td>
<td>#5 - Potential Options</td>
<td>Thursday 27 June 2013</td>
</tr>
<tr>
<td></td>
<td>#6 solutions package</td>
<td>Tuesday 25 February 2014</td>
</tr>
</tbody>
</table>

The next step was the creation of the exploratory scenarios and solution scenarios so that the community could explore issues and opportunities in the Hinds/Hekeao Plains catchment. The first three (exploratory) scenarios were developed and assessed from January to May 2013 (Table 2-4). Modelling for each scenario used the best information available at the time of analysis. However, it should be noted that both the analysis methods and input data sets evolved over the course of this project, based on community feedback and improvements in the biophysical modelling tools.

After introducing these Exploratory Scenarios, the project focused on developing the mitigation options in the form of the two solution Scenarios (the Potential Options Scenario and the Solutions Package (Table 2-4). After Potential Options Scenario was presented to the community, the various mitigation options were revised based on numerous stakeholder workshops, meetings, and a considerable amount of formal and informal deliberations held by the Ashburton Zone Committee with the various stakeholders and interest groups. Stakeholder workshops usually had up to about twenty to twenty-five community members in attendance, depending on the particular topic or setting.

All of these discussions led to numerous versions and assessments of the Solutions Package. This culminated in a Solutions Package Scenario that was presented to the community at the Hinds

\(^2\) Workshop #1: Current state of catchment information can be found at: [http://www.ecan.govt.nz/hinds](http://www.ecan.govt.nz/hinds)
Community Centre in February 2014, which represented the basis on which the committee made its final recommendations to Environment Canterbury for the Hinds/Hekeao Plains Subregional Plan.

2.7.2 Stakeholder interactions

The technical team conducted a wide range of stakeholder interactions in the form of workshops, meetings, phone discussions, emails and site visits, in addition to the updates given to the Ashburton Zone Committee and Ashburton District Council. Ashburton District Council was updated three times at its Council workshops about how the limit setting process was progressing, and what the final recommendations were.

Arowhenua Rūnanga had a representative on the Zone Committee, who provided guidance to the Zone Committee on cultural matters, and made significant contributions to the public workshops. The Zone Committee and Environment Canterbury staff had two hui with Arowhenua Rūnanga in July 2013. The first hui was to discuss the current state of environment, and the second hui was to discuss the elements of the Solution Package. In February 2014, the Zone Committee and Environment Canterbury staff had a third hui with Arowhenua Rūnanga. The purpose of this hui was to obtain feedback on the near final recommendations.

During three of Zone Committee workshops where the recommendations were discussed, a representative of Te Rūnanga o Ngāi Tahu (TRoNT) attended. They provided support to the rūnanga members on the Zone Committee, and contributed to the Zone Committee discussions. The Zone Committee considered their views and where there was consensus, made changes to the recommendations as suggested by TRoNT.

A series of workshops hosted by the technical team with the local Hinds Plains Land and Water Partnership (HPLWP) are particular notable. These workshops covered all aspects of the technical information being used in the process, including the modelling done for water quality, water quantity, and economics. Environment Canterbury staff, members of the Zone Committee and HPLWP meet 13 times after the initial public scenario workshops until the Zone Committee finalised the recommendations (Hunt and Vattala, 2014). HPLWP reviewed draft versions of the ZIP addendum and suggested changes, many of which are included in the final version of the ZIP addendum.

Three meetings were held in Mayfield to get feedback and comments from the Upper Hinds/Hekeao Plains community. These meetings focused on cover aspects of the subregional plan development and water quality load setting modelling relevant to their current farming practices (Hunt and Vattala, 2014). Industry groups, such as DairyNZ and Federated Farmers, were also engaged extensively during the process, to provide peer review of the on-farm mitigation modelling and specific technical responses to questions from these groups. A number of hui with Te Rūnanga o Arowhenua were also held to cover the modelling and proposed mitigation options being presented in the Solutions Package.

Other meetings with the Department of Conservation, and Fish and Game, were organised to capture their particular interests and issues in the overall process. Specific meetings were also held with irrigation schemes (the Eiffelton, Mayfield-Hinds, and RDR irrigation schemes). The technical team also presented updates to the Environment Canterbury Commissioners in a series of briefings throughout the subregional plan development process. Additional consultations were held with the Canterbury District Health Board (drinking water and human health-related issues).

Public meetings were advertised in the local newspaper, on the local radio station, and via an email list of contacts Environment Canterbury had established through the development of the process (Hunt and Vattala, 2014).

This wide range of activities and considerable effort by the technical team aimed to ensure that the information being compiled was available in a transparent and open format.

2.7.3 Incorporating community and stakeholder information

The Preferred Approach to load setting outlines a process that allows both value judgements and anecdotal community information to be incorporated into a technical framework. The technical team
aimed only to provide information and technical predictions of the various social, economic, environmental and cultural outcomes, and not to make the decisions for the community. This new approach differs from the traditional method of resource management adopted in Canterbury.

The new approach also meant that ‘an understanding of the informed value of the inevitable uncertainty of science or limited information is integral to the nature of the decisions being made, and is not used as a reason for not making them’ (Robson, 2014).

In order to assist the Ashburton Zone Committee and the community to make improved value judgements and consider this uncertainty, the technical team intended to provide:

- a direction and magnitude of change under the exploratory scenarios and solution scenarios
- a sense of the likelihood of the outcomes being achieved, based on quantifiable measures.

The following processes were used to try to create a consistent and credible framework for the technical models:

- Utilise the most robust and readily available; analysis techniques, numerical modelling tools and data sources for support of the technical process
- Develop a conceptual physical understanding (across biophysical models) of how the catchment worked, and consistently apply that to the technical analysis
- Set up a logical assessment framework to provide relevant information related to the quadruple bottom line factors
- Provide a sequential methodology for the technical team to revise its information and updated the supporting documentation
- Calibrate individual components whenever possible
- Transition to more accurate analysis tools when these become available, or when found to not be ‘fit-for-purpose’ through peer review
- Use sensitivity analysis to help determine a sense of uncertainty (e.g. MAR quantities required for minimum flows)
- Constant dialogue with the Ashburton Zone Committee, stakeholders and the wider community to help refine the tools and predictions by incorporating local and land use knowledge
- Use various lines of evidence, both local and international
- Make all information publicly available in as timely a manner as is practicable, including answering specific community questions through a Question and Answer forum on the process webpage
- Make the technical information and analysis process as transparent and open as possible
- Keep a positive and open approach to questions and issues that arise, and work on behalf of the community to help develop the technical information needed to make informed decisions
- Use the Ashburton Zone Committee’s outcomes and targets as the guiding principle to develop and analyse the scenarios in all lowland waterbodies, not just a few.

As an example of incorporating stakeholder recommendations into the process, during the Potential Options Scenario workshop, the community was asked for ‘specific ideas on solutions’ that could be implemented for the Hinds/Hekeao Plains catchment area. A Deliberation Booklet was given to the participants, which summarised the outcomes relative to the scenario in the form of specific questions to consider (Table 2-5). The participants broke into smaller discussion groups and, with an Environment Canterbury facilitator, generated answers that were recorded by the facilitator. After the workshop, the answers were tabulated and then incorporated into the development of the mitigation options.
Groundwater Allocation

The Hinds Plains have two Groundwater Allocation Zones Valetta and Mayfield Hinds. The Valetta groundwater zone is over allocated and the Mayfield-Hinds groundwater is moving closer to the allocated limit. The existing groundwater usage coupled with the conversions to piped races and reductions in irrigated recharge (border dyke to spray) is leading to declines in groundwater levels and discharge to springs. The provision of surface water into new irrigated areas provides an opportunity for existing groundwater users to swap to scheme surface water. This will only happen if there is an economic incentive to do so either in terms of the financial benefits of improved reliability or lower costs of water. If these incentives become plausible then the groundwater allocation could be reduced, which overtime could lead to more sustainable level of groundwater allocations and improved flows in lowland streams.

Is reducing groundwater allocations acceptable to you?

If reducing groundwater allocations are not acceptable, what else do you suggest?

Table 2-5: Example of a Deliberation Handbook issue and questions format for the potential options workshop in June 2013

3 Conceptual understanding of Hinds/Hekeao Plains catchment

3.1 Physical aspects of the catchment

The project area is located on the Canterbury Plains south of Ashburton, between the Rangitata River and Ashburton/Hakatere River, bounded up-gradient by the Canterbury foothills and down-gradient by the Pacific Ocean (Figure 1-1 and Figure 3-1). These two alpine rivers are fed mainly by rain and snowmelt in the Southern Alps/Kā Tiritiri o te Moana. They provide the source water for an extensive system of irrigation and stockwater distribution races in the catchment.

The Rangitata Diversion Race (RDR) diverts water from the Rangitata River and pumps water from the Rakaia River. The RDR was designed to provide both hydropower and irrigation, feeding the two largest irrigation schemes in the catchment; Mayfield-Hinds, and Valetta. Hydropower is produced on the main RDR race at the Montalto (1.9 MW) and Highbank (28 MW) power stations operated by TrustPower (TrustPower³). Other irrigation schemes include the Eiffelton, which relies on spring-fed waterbodies and supplementary groundwater pumping, and the Lynnford, which relies solely on surface flows (Durney and Ritson, 2014). Ashburton District Council also maintains a network of stockwater races that divert water from the two alpine rivers to provide a water supply throughout the year.

The Hinds/Hekeao Plains zone (catchment) boundaries are based on a combination of the physical hydrologic catchment area and planning and jurisdictional boundaries. The alpine rivers fall under a different planning process. The Hinds/Hekeao project boundary has the same geographical scope as the Hinds/Hekeao Plains sub-regional section of the pLWRP. The project boundary represents only part of the overall Ashburton Canterbury Water Management Strategy Zone⁴, which is governed by the Ashburton District Council and regionally by Environment Canterbury.

Within the Hinds/Hekeao project boundary, the catchment is sub-divided into several distinctive sub-catchment areas ranging in elevation from 1153 metres amsl to sea level. The Upper Hinds River/Hekeao catchment includes the foothill-fed drainage areas of the north and south branches of the Hinds/Hekeao River (Figure 3-1).

We have divided the Lower Hinds/Hekeao Plains catchment into the Ruapuna Plains and Westfield Plains areas, the Middle Hinds/Hekeao River and Lower Hinds/Hekeao River, and the Lowland Waterways. From near the north and south branch forks until State Highway 1, the Middle Hinds/Hekeao River is generally considered to be ephemeral, losing flow naturally to groundwater recharge. The Lower Hinds/Hekeao River reach benefits from the subsequent natural returns of groundwater, making it perennial in the lower sections of the catchment. The coastal section of the Hinds/Hekeao River is also supplemented by flow from a number of spring-fed waterbodies. During

³ https://www.trustpower.co.nz/
⁴ As defined by the Ashburton Zone Implementation Programme (Ecan 2012): http://ecan.govt.nz/publications
episodic rain events, typically during winter, the Hinds/Hekeao River does run continuously from its headwaters to the ocean. The coastal Lowland Waterways catchment area has more than 30 spring-fed waterbodies that make up a natural stream and anthropogenic drainage network.

Average annual precipitation ranges from 614 mm at the coast (Durney and Ritson, 2014) to approximately 950 mm on the foothills at the top of the Plains (Figure 3-1). Snow only becomes a regular part of the hydrologic cycle in the upper sections of the catchment, above 500 m amsl.
3.2 Social and historical aspects of the catchment

The Hinds/Hekeao Plains catchment has a long and varied history, both culturally and socially. The Hinds/Hekeao Plains catchment is wholly within the takiwā (territory) of Te Rūnanga o Arowhenua.

Historically, Ngāi Tahu lived on the shores of lakes, wetlands, streams and lagoons across Canterbury. They developed use patterns, moving across designated whānau and hapū-managed territories. The area between the Rangitata and the Orari Rivers was traditionally barren while the Rangitata River was a large braided river with high velocity flows, which made it dangerous for many cultural uses. Whānau were often dependent on resources that could be gathered from the safer waters of the Hinds/Hekeao zone.

Hekeao and Tokara (the two branches of the Upper Hinds/Hekeao River) traditionally supported a number of Ngāi Tahu nohoanga (settlements). These settlements included Hekeao, Kakaho, Koroki, Te Mihi, Pakutahi, Karipo, Purakaunui, Rukuhia and Tokara (Tipa and Associates, 2013). This history of occupation means that a number of urupā are associated with the river. (Urupā are the resting places of Ngāi Tahu tupuna (ancestors) and the focus for whānau traditions. These places hold the memories, traditions, victories and defeats of Ngāi Tahu tupuna, and they are frequently protected by secret locations.)

The Hinds/Hekeao River was an important source of mahinga kai, particularly tuna (eel) and kanakana (lamprey). The tupuna had considerable knowledge of whakapapa, traditional trails and tauranga waka, places for gathering kai and other taonga, ways in which to use the resources of the river, the relationship of people with the river and their dependence on it, and tikanga for the proper and sustainable utilisation of resources (Tipa and associates, 2013). All of these values remain important to Ngāi Tahu today.

When European settlers arrived in the 1800s, considerable changes occurred in the lower catchment. A vast wetland existed whose outer perimeter ‘...extended from Coldstream to Lowcliffe, along the Isleworth Road to Boundary Road below Hinds settlement, then to Tinwald, Wheatston, Ashton, Waterton, Longbeach and above Lower Beach Road to Coldstream. The area of the inherently wet swamp land was 18,180 ha.’ (Mitchell, 1980). The potential use of this wetland was quickly identified by the European settlers in the 1850s and, by the turn of the century, drainage had been completed.

Some historic accounts report that the Hinds/Hekeao River had no permanent outlet to the sea and required an artificial channel to be excavated, to lead the water into a coastal ‘convenient coastal gully’, today called a donga (Mitchell, 1980). Flooding of farmland became an increasing problem due to the lack of maintenance on the early wetland drainage network. In 1939, a drainage district was formed for the spring-fed lowland waterbodies. The bulk of the scheme, which also included re-engineering of the lower Hinds/Hekeao River, was completed by 1950. At present, the Hinds/Hekeao River and drainage network is maintained by Environment Canterbury through the governance of local drainage boards.

These waterbodies still provide a valuable source of mahinga kai, supply irrigation water, support a significant ecosystem and provide drainage of the lower Hinds/Hekeao Plains to allow productive commercial farming of the drained areas. The villages of Hinds, Mayfield and Tinwald (a suburb of Ashburton) are some of the small agricultural-based communities within this catchment. Farming is the primary source of employment and income for many people who live in the catchment. In recent years, a transition from pastoral agricultural activities (e.g. sheep, arable, and deer) to more intensive irrigated activities (e.g. dairy and dairy support) has transformed both farming operations and the local and regional economy. Economically, the Ashburton zone, which includes the Hinds/Hekeao catchment represents a significant portion of New Zealand’s National Gross Domestic Product (25% in 2010) and approximately 43% of the nation’s arable production (Taylor, 2014).

Recent intensification using irrigation, and the transition to dairy farming, has resulted in significant changes to the water quality and ecological health of the catchment. Agricultural-related contaminants in groundwater, rivers, and spring-fed waterbodies include nitrate-nitrogen (nitrate-N), phosphorus, sediments and faecal bacteria, and have shown increasing trends. A combination of over-allocation of water usage, changes to irrigation practices and dramatic increases in nutrient leaching to groundwater have led to degraded water quality, flows and habitat quality throughout the
Hinds/Hekeao Plains Technical Overview – Subregional Plan Development Process

Hinds/Hekeao catchment (Meredith and Lessard, 2014A). These water quality effects are most pronounced in the lower catchment where the degraded conditions have led to significant declines in the ecological and cultural values of the lower catchment waterways, including the Hinds/Hekeao River. In particular, nitrate-N concentrations exceed toxicity thresholds for sensitive species, and minimum flows are significantly below those needed for thriving in-stream ecological communities. However, it is important to note that even in the current degraded state, there are portions of the catchment where the waterways continue to support ecological and cultural values.

The Hinds/Hekeao River and associated lowland streams and drains are a local resource and used to be a considered a regional resource for recreational opportunities. Local people and fishers describe the river and some drains as having had significant local recreational value for both fishing and swimming in the past (the middle of the last century) and argue that this resource has declined significantly with longer periods of dry river bed and declining ecological conditions. The lower river retains low values as a trout fishery. The decline in recreational use of the river, streams and drains over recent years is very clear and cannot simply be attributed to fishers and other recreationists preferring other places, or to wider social changes such as changing attitudes to outdoor recreation.

The Hinds/Hekeao Plains catchment was the second catchment (under the pLWRP) to start a freshwater load and limit setting process due to the changes in water quality, habitat and quantity, combined with the start of the Canterbury Water Management Strategy (CWMS) process.
Figure 3-2: Current Land Uses (baseline) for Hinds/Hekeao Catchment (2011, 2011 data compiled by Macfarlane Rural Business, Landcare Research and Environment Canterbury)
3.3 Conceptual understanding of the biophysical modelling

The conceptual model of the Hinds/Hekeao Plains catchment, as it relates to setting the limits for modelling biophysical water quality and quantity, focuses primarily around the groundwater system.

Many of the Zone Committee’s quality and quantity outcomes (Figure 3-2) are directly dependent on the levels and condition of the Hinds/Hekeao groundwater system. Eighteen of the 25 outcomes are directly dependent on management of the aquifer’s water quality and quantity conditions (shown in blue), five are partly dependent (shown in green) and only two (shown in red) are independent of the groundwater.

It is important to note that the alpine-sourced water from the Rangitata and Ashburton Rivers plays a key role in both the current sources of alpine-sourced water for the catchment and likely will be part of an overall future management strategies (e.g. future storage). However, groundwater is the driving factor and remains at the centre of this conceptual model, relative to limit and load setting for each of the biophysical quantity and quality models.

Figure 3-3: The 25 Outcomes as they relate to the groundwater conceptual framework

Constructing the conceptual framework required a consistent definition of the groundwater balance and spatial and temporal interactions with surface activities such as land use and irrigation practices.
In the conceptual framework, the groundwater system is recharged by natural rainfall, river recharge (Rangitata, Ashburton and Hinds/Hekeao Rivers) and alpine-sourced irrigation waters (Figure 3-4). Discharges include evapotranspiration from crops and natural foliage, outflows from rivers and lowland waterbodies to the ocean and subsurface offshore groundwater discharges.

Irrigation activities, including both recharge (drainage) and discharge (bore pumping), represent a primary variable in understanding how much, where, and when water is available throughout the system. Groundwater storage (recorded as water levels) has a direct influence on the majority of the baseflows available in the Hinds/Hekeao River and coastal spring-fed waterbodies systems.

Rainfall events contribute to the recharge of most of the Middle Plains area of the catchment, and are closely related to overland flow and drainage issues in the coastal waterbodies. These coastal waterbodies consist of both natural streams and manmade drains and have a key role in providing drainage protection for farms and residences in the wetter area of the catchment. A key balance of the system occurs between drainage of storm events, groundwater levels and sufficient perennial baseflows to maintain irrigation, ecological and cultural values.

![Diagram of groundwater system](image)

**Figure 3-4:** Conceptual drawing of the Hinds/Hekeao Plains catchment to show the groundwater-dominated hydrologic system

Land use activities, as they relate to the leaching of agricultural-related groundwater contaminants (nitrogen primary focus) through the soil profile into the saturated zone of the groundwater system are the principal drivers of determining water quality (Figure 3-4). Changes to irrigation practices have reduced the amount of water recharging the aquifer (border dyke to spray) and more intensive land use activities have also led to higher concentrations of contaminants entering the shallower portion of the underlying aquifer. The spring-fed coastal waterbodies are driven by groundwater, so contamination of the aquifer has also had a direct effect on these groundwater-dependent ecosystems.
and irrigation supplies. A key assumption here is that keeping contaminants out of the aquifer (a reduction of nutrient leaching) is the first and best method to help reduce groundwater contamination within this catchment area.

The conceptual model of the Hinds/Hekeao aquifer system is considered to behave as a single aquifer for both the water quantity and water quality biophysical modelling (Durney et al., 2014). For water quantity, the principle of a water balance or budget, means that ‘…the one common factor for all groundwater systems is that the total amount of water entering, leaving, and being stored in the system must be conserved.’ (USGS 1999). Because any water that is used must come from somewhere, human activities affect the amount and rate of movement of water in the system, entering the system, and leaving the system. As human activities change the system, the components of the water budget (inflows, outflows, and changes in storage) also will change and must be accounted for in any management decision (USGS, 1999). With regards to the effects of withdrawing ground water, we can conclude that the source of water for pumpage must be supplied by (1) more water entering the ground-water system (increased recharge), (2) less water leaving the system (decreased discharge), (3) removal of water that was stored in the system, or some combination of these three.

In terms of the sustainable management of an aquifer the CWMS provides a management framework that looks decades (until 2040) into the future. In the past, short-term views of aquifer management prevailed, including the localised view of individual bores and their well interference effects on neighbours or the adjacent stream flows. This approach allowed the shorter-term bore-by-bore ‘borrowing’ from aquifer storage where the catchment-scale increases in river losses (to replace pumped water) or the decreased discharge to spring-fed waterbodies were not considered. By applying a single aquifer, catchment scale approach, the cumulative effects of the hundreds of bores over many years are taken into account. Environment Canterbury’s creation of the 2004 Groundwater Allocation Zones (GAZ) was a step in the direction of managing groundwater sustainably, and in keeping with the CWMS framework. The sustainable, catchment-scale approach to groundwater management also provides a better mechanism by which to manage the anticipated more severe, longer-term droughts and severe weather events associated with climate change. A sustainably managed groundwater supply that has ample water stored for human use during droughts or that will continue to provide good quality, environmental baseflows to streams and rivers is an asset to a community.

The issue of quantifying recharge is related to the changes that occur in irrigation practices and irrigation efficiencies. Although conservation and efficient management of water through piping and lining of races is beneficial for the farming community, this process has negative consequences for other parts of the catchment water system (reduced aquifer recharge). In the past, these kinds of activities and their effects on the catchment-scale water balance were not considered in the context of the overall outcomes. As the CWMS framework provides us with a strategy to include various stakeholders, it is important that the conceptual framework reflects the interconnected and long-term consequences of the various beneficial and detrimental actions, to help us devise solutions that account for these inevitable changes.

In the water quality conceptual framework, leached nutrients from the overlying soils tend to accumulate firstly in the shallower part of the aquifer system. However, over time, those contaminants move downwards (from deeper pumping and downward saturated gradient movement) so contamination of the shallower part of the aquifer system is relative to the overall aquifer condition. Therefore, although the ‘drill deeper to avoid contaminated water for drinking’ concept might provide a short-term fix, the CWMS approach means that mitigation strategies need to be managed for the longer-term sustainability of the resource.

Another important physical, catchment-level feature of our conceptual model that is relevant to water quality is the concept of a ‘lag effect’ (Scott, 2014c). This characteristic relates to the actual movement of nitrogen molecules through the soils into the aquifer system, commonly known scientifically as fate and transport of contaminants in natural environments. A surrogate measure of this effect is the age of the water in the aquifer, ranging on average from 10 to 20 years in the shallower portions. In

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5 Scientific principle that seeks to quantify a chemical’s initial release to the environment and its various chemical and physical movements through a medium and time to arrive at its ultimate destination.
principle, it means that although mitigation strategies can be implemented in the short-term, the actual response in terms of the overall water quality of the system is unlikely to be immediate.

3.3.1 Geology and hydrology

The geology of this aquifer system is dominated by Quaternary glacial outwash fans and plains formed by depositional fluvial river materials deposited on a basement of bedrock. The resulting sedimentary formation is variable and heterogeneous in structure.

The spring-fed waterbodies of the Hinds/Hekeao Plains consist of a series of highly modified drains that either connect to larger drains or discharge directly to the sea. These reaches are steeper than typical lowland streams in Canterbury and retain more natural meandering stream forms, especially in areas with higher coastal cliffs. The steep eroded stream channel areas are referred to as ‘dongas’ and contain ponded areas and coastal lagoons (hāpuas) behind the beach.

Most of the groundwater beneath the Hinds/Hekeao Plains comes from water that drains down through the soils on the plains (Durney and Ritson, 2014). This is often called Land Surface Recharge (LSR) and it includes net sum of the natural rainfall and irrigation water percolating through the soils as drainage minus the water lost to evapotranspiration from the soils and plants. Water in the shallower parts of the aquifer tends to flow through higher permeability zones into the spring-fed waterways near the coast.

Although pressure responses of increased recharge activities show downgradient responses over relatively short periods (months), the actual saturated movement of water molecules is measured in years to decades. As in many fluvial depositional groundwater systems, the deeper you move into the aquifer, the slower the velocities of the saturated groundwater flows.

Deep groundwater is represented by water that is aged in decades, which moves offshore as subsurface discharge. This area of the conceptual model is the least understood feature of the groundwater system; it is a speculative area and needs a better understanding. Although the higher porosity materials have varied features related to the fluvial depositional paleochannels, the water between these horizontal features is generally thought to be reasonably well-connected, both horizontally and vertically.

Relative to the water budget, losses from the Ashburton River/Hakatere are known to contribute some recharge to the aquifer at the upper end of the Valetta GAZ. Geochemical data and gaugings collected along the Rangitata River, which show gains/losses within the range of error for the measurements (±8%), suggest that losses from this river are minimal. Most of the alpine-sourced river water entering the Hinds/Hekeao aquifer comes from irrigation activities taken off the Rangitata Diversion Race (RDR) and associated irrigation schemes. Historically, border dyke irrigation was widespread (circa 1940 to the 2000s) and added more incidental recharge to the aquifer, increasing groundwater and related spring-fed flows. Historically, the Ashburton District Council (ADC) stockwater race system also contributed a considerable proportion of the incidental recharge to the aquifer through its vast network of leaky races (Figure 3-1).

A steady-state groundwater budget for the aquifer, which summarises the major inputs and outputs for the Hinds/Hekeao Plains, is shown in Table 3-1.
### Table 3-1: Analytical steady-state groundwater balance/budget (based on Durney and Ritson, 2014)

<table>
<thead>
<tr>
<th>Average inputs (m³/s)</th>
<th>Average outputs (m³/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land surface recharge</td>
<td>15.5</td>
</tr>
<tr>
<td>River recharge</td>
<td></td>
</tr>
<tr>
<td>- Ashburton</td>
<td>1</td>
</tr>
<tr>
<td>- Hinds/Hekeao River</td>
<td>0.3</td>
</tr>
<tr>
<td>- Rangitata River</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Water race losses</td>
<td>3.2</td>
</tr>
<tr>
<td>Total inputs</td>
<td>20</td>
</tr>
<tr>
<td>Coastal drains</td>
<td>3.0-7.0</td>
</tr>
<tr>
<td>Groundwater abstraction</td>
<td>3.0-7.5</td>
</tr>
<tr>
<td>Discharge to Rangitata River</td>
<td>0.3</td>
</tr>
<tr>
<td>Offshore groundwater flow</td>
<td>9.2-9.7</td>
</tr>
<tr>
<td>Total outputs</td>
<td>20</td>
</tr>
</tbody>
</table>

### 3.3.2 Contaminants and water quality

The conceptual model for the groundwater quality assumes that most of the recharge to the groundwater system drains down through the soils on the plains (Scott, 2013). Land surface recharge produces soil drainage, which leaches nitrate-N from the soils into the groundwater system (Figure 3-4). The nitrate-N in soils typically comes from diffuse sources such as fertiliser application, tilling and cultivation, livestock wastes, although it can also come from point sources such as leaking animal effluent storage ponds. The amount of nitrate, or leaching load, depends on the activities that take place on the soil and the volumes of water involved.

Recharge from large alpine and hill-fed rivers contains low to very little nitrate-N compared to land surface recharge. River recharge can dilute contaminants from land surface recharge. Irrigation races and stockwater races also carry water from the alpine rivers across the plains and may help to dilute the nitrates from land surface recharge.

Groundwater flows into the waterways (springs, rivers, drains and races) on the lower plains where the groundwater table is near the surface. These waterways intercept the shallowest groundwater, which has the highest nitrate-N concentrations. Slightly deeper groundwater that does not flow to the spring-fed waterways flows instead to the ocean, carrying its nitrate-N with it. We do not really know how this nitrate-N discharge affects the coastal ocean waters. The four key contaminants in the Hinds/Hekeao Plains catchment, similar to the rest of Canterbury, are:

- nitrate-nitrogen,
- phosphorus
- sediment
- faecal bacteria.

Nitrate-nitrogen (nitrate-N) is highly soluble, so it is easily carried by water and can be immediately taken up and used by plants. Leaching is the main pathway for nitrate-N loss. When drainage water leaves the root zone of plants, it can carry nitrate-N with it. The use of Overseer® is generally accepted as providing a reasonable estimate of nitrogen leaching for annual comparisons between farm operations, which could then be incorporated into mass balance models for estimating changes in groundwater quality.

Phosphorus, sediment and faecal bacteria are generally lost through overland flow or shallow interflow through artificial drainage, although phosphorus and bacteria leaching is also possible (Webb et al., 2010) and faecal bacteria can be found in aquifers, but are typically associated with ‘borrow pits’ or poor wellhead protection. Catchment models available at the time of this work were not as robust for adequately characterising phosphorus, sediment or faecal bacteria loss pathways to water for this

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⁶ LSR = (precipitation + irrigation – evapotranspiration)

⁷ Max possible abstraction is 7.5 m³/s averaged over a year, 2011/2012 consumption is approximately 40%.
catchment. It was assumed that other mitigations would be used (e.g. riparian fencing and buffers) to help address these overland flow contaminants. However, they are important in the assessment of impacts of scenarios on various receiving environments.

Nitrogen, therefore, was the only contaminant directly modelled in the water quality analyses conducted for this catchment (Scott 2013). Many forms of nitrogen exist, but for groundwater, streams and rivers, this report is mainly interested in the nitrate-N form.

Figure 3-5 provides a conceptual diagram of the Hinds/Hekeao catchment relative major ground recharge and discharge mechanisms and the irrigation source nutrient leaching into shallow aquifer and spring-fed waterbodies.

![Figure 3-5: Conceptual drawing of the catchment-scale recharge and discharge pathways for quality and quantity](image)

### 3.4 Current conditions and historical trends

#### 3.4.1 Water quantity: flow

The upper branches of the Hinds/Hekeao River are similar in size and flashier (storm event driven) in nature, typical of hill-fed catchments of the Canterbury Plains. The middle and lower parts of the Hinds/Hekeao River have been heavily modified for flood protection and drainage works and have out-of-stream abstractions (Durney and Ritson 2014). The middle reaches below Mayfield are intermittent and have suffered increased losses and long periods of drying in recent years. The lower reaches below SH1 show more consistent flows based on groundwater discharge.
The spring-fed lowland waterbodies have also seen declining baseflows in recent years, associated with decreasing groundwater levels in each Groundwater Allocation Zone (GAZ). In the Mayfield-Hinds zone, flows are generally still considered as perennial through the irrigation season, but some surface takes are starting to struggle with late season reliability (Per. Comms., Hinds Drains Working Party, 2014). Upgradient reductions in border dyke irrigation and increased groundwater usage are likely to have played a role in these changes. In the Valetta GAZ spring-fed baseflows declined significantly transitioning these waterbodies from historically perennial to intermittent. Drying of the channels in the irrigation season has increasingly occurred which landowners attribute to both less border dyke irrigation, increased piping of races, and more groundwater pumping (Per comms Hinds Drains Working party).

In both the Mayfield-Hinds GAZ and the Valletta GAZ, spring-fed baseflows consistently benefit from being close to the Hinds/Hekeao River. Water lost in the middle reaches of the Hinds/Hekeao River helps to support groundwater levels and subsequent spring flows in waterbodies adjacent to the river. This benefit tends to decline further away from the river where upgradient irrigation and rainfall tends to be the predominant source of groundwater inflows.

In the Valetta GAZ, the Eiffelton irrigation scheme supplements spring-fed flows with groundwater that is pumped and added to several of the spring-fed waterbodies. The addition of pumped groundwater to the springs helps to keep baseflows higher than the baseflows in catchment areas further north. As you move into the middle portion through the Ashburton River, baseflows have become intermittent during the irrigation season, and reliability of supply has become a critical issue. A considerable number of surface take holders have had to move to groundwater to provide the reliability of supply needed for their irrigation. Currently, these systems have allocations that generally exceed the actual water available. The changes to surface flow conditions are directly linked to changes in upgradient groundwater management which include decreasing incidental recharge (changes from border dyke to spray irrigation and piping of Valetta irrigation scheme) and increasing groundwater abstractions.

### 3.4.1 Water quantity: groundwater

Environment Canterbury manages Hind/Hekeao groundwater in two Groundwater Allocation Zones; the Mayfield-Hinds GAZ and the Valetta GAZ (Figure 1-1). Groundwater represents the majority of allocated water in the catchment, with 490 consents taking 249.7 million m³/yr (Table 3-2, and Table 3-3). Surface water consents, which are also significantly dependent during the irrigation season on groundwater spring flows, make up 132 consents, totalling 91.5 million m³/yr assuming continuous pumping for a 150-day irrigation season. The combined total allocated from groundwater is 341.2 million m³/yr.

**Table 3-2: Groundwater allocation status colour system**

<table>
<thead>
<tr>
<th>Colour</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>White</td>
<td>0 to 80 % of groundwater allocation limit assigned</td>
</tr>
<tr>
<td>Yellow</td>
<td>80 to 99 % of groundwater allocation limit assigned</td>
</tr>
<tr>
<td>Red</td>
<td>Full groundwater allocation limit assigned</td>
</tr>
</tbody>
</table>

---

Table 3-3: Groundwater allocation in the Mayfield–Hinds and Valetta groundwater zones (as at 1 May 2013)

<table>
<thead>
<tr>
<th>Groundwater Zone</th>
<th>Percentage allocated</th>
<th>Total volume allocated (m³)</th>
<th>Percentage allocated including consents in process</th>
<th>Total volume including consents in process (m³)</th>
<th>Allocation limit (m³/yr)</th>
<th>Number of consents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mayfield – Hinds</td>
<td>81.3</td>
<td>120,345,556</td>
<td>82.60%</td>
<td>122,240,973 (122.2 million m³/yr)</td>
<td>148 million m³/yr</td>
<td>265 with an additional 10 in process</td>
</tr>
<tr>
<td>Valetta</td>
<td>134</td>
<td>117,804,672 + 11,619,160²</td>
<td>137.20% including Valetta hearing decision wells</td>
<td>132,196,091 (132.2 million m³/yr)</td>
<td>96.6 million m³/yr</td>
<td>226 with an additional 47 in process</td>
</tr>
</tbody>
</table>

- At time of publication, ² These takes are essentially B permits, that only allow takes after groundwater availability is assessed each year.

Water usage includes both surface and groundwater takes. The RDR provides the Mayfield-Hinds scheme, which irrigates approximately 32,000 hectares on the south side of the Hinds/Hekeao River, with a maximum extraction rate of 16.5 m³/s (Figure 1-1). North of the Hinds River, the RDR supplies the Valetta scheme, which irrigates approximately 7000 hectares with a maximum extraction rate of 4.4 m³/s.

An additional scheme that depends on alpine-sourced flows is the Barrhill Chertsey (BCI) scheme, which is consented to irrigate approximately 4700 hectares in the upper catchment from the Ashburton River and Coleridge/Rakaia River systems with a current maximum rate of 2.5 m³/s. Two other schemes in the lower catchment that both depend solely on groundwater sources (spring-fed or bore supplemented) are the Eiffelton, which irrigates approximately 2700 hectares, and the Lynnford (Lower Hinds/Hekeao River), which irrigates approximately 120 hectares.

The technical team linked the allocated usage with actual usage through an analysis of groundwater metering⁹ information (Table 3-4). Since 2011, metering data from the Hinds/Hekeao Plains catchment has provided the actual amount of water used under current consented allocations (Table 3-3). The average usage of total per consented allocation ranges from 22 to 38% (Mayfield-Hinds) and from 35 to 58% (Valetta) (Durney and Ritson, 2014). For the Valetta GAZ, this information indicates that although nearly half of the consented allocation is not being used, there has been a downgradient effect on spring-flows and reliability.

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⁹ Surface water usage metering information is not considered sufficiently reliable to use for these kinds of comparisons (Pers. Comm. Durney, August 2014).
Table 3-4: Environment Canterbury groundwater metering information (2011 to 2013)

<table>
<thead>
<tr>
<th>Groundwater allocation zone</th>
<th>2011/12</th>
<th>2012/13</th>
<th>Comparison</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sum actual use for metered consents</td>
<td>Sum allocated volume for metered consents</td>
<td>Average use per consent</td>
</tr>
<tr>
<td>MH GAZ</td>
<td>8.6 million m³/yr</td>
<td>58.9 million m³/yr</td>
<td>22%</td>
</tr>
<tr>
<td>VA GAZ</td>
<td>27.8 million m³/yr</td>
<td>92.2 million m³/yr</td>
<td>35%</td>
</tr>
</tbody>
</table>

Trends in groundwater resource development are shown in Figure 3-6, using the number of bores allocated through time. The earliest recorded groundwater bores were drilled in the 1930s, but the majority were drilled from the early 1990s and peaked in 2004 when the Groundwater Allocation Zone limits came into effect. In 2004, groundwater allocation limits were set for both of the Groundwater Allocation Zones, with the Valetta GAZ already considered as over-allocated.

Figure 3-6: Trends in groundwater bore development in the Hinds/Hekeao Plains catchment (Golder, 2013)
3.4.2 Water quality: groundwater and surface flows

Nitrate-N concentrations are elevated and increasing in the groundwater and the spring-fed waterways (Figure 3-7). The Hinds/Hekeao Plains waterways have some of the highest nitrate-N concentrations for surface water in New Zealand (Ballantine et al., 2010). The maximum concentration of nitrate-N in groundwater exceeds the drinking-water standard, and the average concentration exceeds half the standard (Scott, 2013).

Some of the larger waterways sampled (e.g. Boundary, Blees, Deals drains) have average nitrate-N concentrations equal to that of the shallow groundwater (Scott 2014). The lower Hinds/Hekeao River has slightly lower nitrate-N concentrations, probably influenced by river recharge further up the catchment.

Deeper groundwater\(^{10}\) generally has lower concentrations of nitrate-N than the shallow groundwater, but these concentrations are still above the average for deep wells in Canterbury (Hanson, 2002). We do not know how much these concentrations are influenced by mixing alpine river water recharge with the deeper groundwater or by the lag times taken for higher nitrogen loads from more intensive land uses to reach the deeper groundwater.

Increasing trends in nitrate-N concentrations are seen in most of the shallow wells and waterways that have a high groundwater baseflow component. The increasing trends are not localised in any particular area of the Hinds/Hekeao Plains (Scott, 2014).

Environment Canterbury has not been sampling the deeper part of the groundwater system long enough to conduct the same statistical trend analysis that was done for the shallower groundwater system. However, the time series trends\(^{11}\) in Figure 3-7 suggest that increasing concentrations of nitrate-N are also starting to occur in the deeper groundwater. This deeper groundwater may not be as reliable a source of low-nitrate-N water when compared to the deeper groundwater in the coastal confined aquifer system of the Central Plains and Christchurch, where alpine river-sourced groundwater upwells and provides a reliable long-term source of low nitrate-N water.

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\(^{10}\) A 30 m well depth cut-off was used to classify shallow and deep groundwater.

\(^{11}\) Time series graphs (Figure 10 to Figure 13) were compiled from Environment Canterbury’s State of the Environment Monitoring Programme data using average annual concentrations for samples collected from monitoring wells or drains in the Hinds plains area for each hydrological year (one year period from July of one year to June of the following year).
E. coli bacteria concentrations (an indicator for pathogens) are high in the drains and detectable in the groundwater. Deep groundwater generally meets the drinking-water standard for E. coli, but each year between 10 and 20% of samples from shallow groundwater fail to meet the standard. Bacteria concentrations in shallow groundwater show an increasing trend. There do not appear to be any long-term trends in the drains, but this may be because concentrations are so high they are often at or near laboratory detection limits.

The time series graphs (Figure 3.1) were compiled from Environment Canterbury’s State of the Environment Monitoring data using annual average concentrations for each hydrological year (one year period from July of one year to June of the following year). Averages were calculated using data from 13 shallow wells, 9 deep wells and 7 surface water sites (4 drains and 3 sites on the lower Hinds River/Hekeao).
Phosphorus concentrations are elevated in the drains and have become highly variable year to year. No long-term trends in phosphorus evident for all the drains, but individual drains show both increasing and decreasing trends. Phosphorus is not routinely measured in groundwater because it tends to bind to soil and the main pathway for phosphorus is surface runoff.
Average measurements of suspended solids and turbidity for all the drains are also high and variable from year to year with no long-term trend. However, over the past 10 years the beds of many of the drains have become increasingly clogged with deposits of soils, silts and clays. Therefore, there appears to be an increasing load of organic and inorganic material deposited in the drains from the land.
3.4.3 Economic and social conditions

Drinking water in the Hinds/Hekeao Plains catchment is sourced mainly from shallow wells, with community schemes for the villages of Hinds and Mayfield. The Mayfield scheme is due for an upgrade as the quality is deemed poor. The trend towards a decline in drinking water quality of groundwater concerns the people in the catchment and the health services in the Ashburton District.

In a rural area such as the Hinds/Hekeao Plains catchment, the economy drives employment, which in turn influences the size and composition of the population, its growth, and the services and community life that sustain a high level of social and economic wellbeing for residents (Taylor, 2014). The Hinds/Hekeao Plains catchment experienced a strong population growth of 27.2% from 2001 to 2013, with only Mayfield not growing faster than the national average. The population growth was driven by growth in employment, particularly in agriculture and dairy farming. The population is becoming more ethnically diverse and, at the District level, is ageing.

In recent years of very slow economic growth nationally, the Ashburton District has performed comparatively well. Over 25% of the Gross Domestic Product of the Ashburton District in 2010 was generated by primary natural resource industries. The District’s agricultural production accounts for over 43% of the national arable production. Food processing and engineering are also key contributors to the District’s economy, and there are a large number of seed companies with cleaning, packing and distribution facilities including facilities in Hinds village. The main sources of employment in the District are meat processing, dairy farming, sheep, beef and grain farming and support services for agriculture, forestry and fishing.

Early agricultural development in the catchment depended, particularly in the lower reaches, on extensive drainage through a combination of open and tile drains. Crops in the early years included
large areas of grain production and a range of other cropping activities, plus stock. In recent years, growth in intensive \(^{13}\) dairy farming has been a feature of the District and the Hinds/Hekeao Plains catchment in particular. This move to more intensive farming practices has resulted in substantial changes to the catchment’s social settings, such as population growth and flow-on benefits to local schools and community life. At the same time, tension has arisen due to new farmers and workers entering the community. Tension is also evident around the deteriorating quality and availability of groundwater and surface water.

Agricultural in the catchment has been dominated by sheep, beef, deer and arable farming, with some dairying. However, land use has been changing over the past 10-15 years. As the availability of irrigation water became scarce, the understanding of efficient water use grew (Everest, 2013). The more advanced irrigation systems and conversions to more intensive dairying operations led to increased debt, but also the benefits of higher value products and improved cash flow. Where arable farmers had traditionally grown wheat, barley, ryegrass seed and clover seed as their staple crops, more reliable production systems brought higher value crops into their rotations. Sheep, beef and deer farmers (pasture farmers) have, with new irrigation technologies, looked to achieve more profitable land use such as finishing stock, more cropping and conversions to dairy farming.

The significant increase in land converted to dairy farming over the past 10-15 years from arable and sheep, beef and deer has seen an increase in the number of non-finishing stock (dairy replacements) to be grazed both during the summer and winter, creating a whole new farming system and dairy support industry (Everest, 2014a).

The Upper Hinds/Hekeao Plains catchment has traditionally been too climatically challenging to run dairy stock, and farmers have typically managed sheep, beef and deer farm operations. The foothill properties operating using a combination of irrigated and dry land systems, which depend on rainfall, climate and integration with other farm systems (any remaining breeding operation).

With improved irrigation efficiency and control over input resources, more reliable crops and pastures have been grown. Farmers have been given the confidence to alter their practices and systems to adopt some higher value (but higher risk and higher cost) cropping and grazing options and employ more staff.

In recent years, both farmers and industry have put significant resources into gaining a better understanding of farm systems, plant and animal requirements and environmental interactions. They have invested significant capital in infrastructure and science to minimise losses and improve the efficient use of resources to make farming systems more environmentally and financially sustainable (Everest, 2013).

One key social outcome for the Hinds was Drinking water wells and domestic supplies now and in the future at least meet national drinking water standards for E. coli\(^{14}\) and nitrate. The National Drinking water standard for nitrate-N is 11.3 mgN/L. An average concentration of 5.7 mg/L in shallow groundwater is considered to ensure that not more than 10% of samples exceed the Maximum Acceptable Value (MAV) for drinking-water in a given year. This is based on statistical relationships developed from Canterbury monitoring data (Hanson, 2012). Scott (2013) reports that there are no large community water supply schemes in the Hinds catchment. Most of the population source their drinking water from wells.

### 3.4.4 Ecological conditions

Although the Hinds/Hekeao Plains catchment is one continuous watershed, the technical team soon recognised that there were important differences in the primary objectives and challenges between the upper and lower catchment areas as well as between irrigation zones (that is, between the northern and southern areas of the lower catchment) (Meredith and Lessard, 2014a). Because of this, the

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\(^{13}\) Intensive dairy farming is defined as moving to large capital investment operations with large herd sizes (e.g. 1000 head).

\(^{14}\) Pathogen concentrations (represented by E. coli indicator bacteria) have not been modelled for the Hinds Plains.
technical team developed an ecological analysis that was organised and presented to highlight trends related to:

- land use and water management changes
- current conditions
- the impacts of recent changes on the values of waterways within these sub-catchments (Figure 3-1).

Meredith and Lessard (2014a) provides a detailed analysis and discussion of all the sub-catchments in the Hinds/Hekeao Plains catchment. Although all of these sub-catchments are important for the ecological health of the catchment, the spring-fed waterbodies in the Upper Hinds/Hekeao and coastal areas (Lower Hinds/Hekeao River, Valetta GAZ and Mayfield-Hinds GAZ) were critical areas of focus during the subregional planning process (Figure 3-11 and Figure 3-13).

Upper Catchment

The two river branches in the upper catchment (North Branch and South Branch of the Hinds/Hekeao River) are in relatively good ecological condition with a range of important in-stream values (Meredith, and Lessard, 2014a). These values include Canterbury galaxias, sport fish populations (brook char in particular), areas of good in-stream habitat, widespread populations of freshwater mussels (kakahi), and an absence of regular nuisance algal growth issues.

However, there are reports of areas with increasing sedimentation on the streambeds, stream bank erosion and tributaries with visibly reduced water quality. Stream surveys were used to support biodiversity projects and assist funding for fencing-off stream margins and wetland areas, to maintain and enhance waterway conditions and values in the upper catchment (Meredith and Lessard, 2014b).

An assessment of water quality in the upper catchment showed that the ecology of the upper Hinds /Hekeao South Branch is currently at risk, due to elevated nutrient concentrations from land use in the upper catchment. The relationship between nutrients and stream condition is acknowledged and reflected in the water quality guidelines within the pLWRP for both nitrogen and phosphorus (e.g. DIN guideline = 0.47 mg/L and DRP guideline = 0.010 mg/L). In the South Branch, recent measurements show the DRP exceeds this pLWRP value (Figure 3-12). In addition, faecal bacteria (E.coli) in the South Branch were elevated to levels that make this waterway unsuitable for contact recreation (Meredith and Lessard, 2014a).

The ecological analysis provided the zone committee with the information on which helped to inform their recommendation that to maintain the relative water quality and quantity conditions in the upper catchment, no additional nitrate-N load allocation or irrigation expansion would be permitted. However, additional biodiversity and riparian management is needed to improve conditions and reduce issues with sediment and bacteria (Meredith and Lessard, 2014b).

Lower coastal sub-catchments

The sub-catchment areas in the lower coastal Hinds/Hekeao Plains include the Lower Hinds/Hekeao River and the two zones of spring-fed waterbodies in their respective Groundwater Allocation Zones (Mayfield-Hinds GAZ and Valetta GAZ, Figure 3-13).

The lowland waterways that drain to the coast are all highly modified in both their construction and maintenance but maintain natural water flows of spring-fed groundwater. The Mayfield-Hinds GAZ is not yet over-allocated15 and the waterways within this area maintain higher baseflows.

Historically, the lower Hinds/Hekeao River supported a locally important trout fishery, a small opportunistic whitebait fishery, and native fisheries for eel and lamprey. Some values have been lost within both GAZs due to water quality changes and problems with erosion and fish barriers, but the flow issues that intensify these problems occur mainly within the Valetta GAZ. The majority of the lowland waterways in both GAZs still support native fish populations, plant communities and invertebrates of ecological and cultural value.

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15 Mayfield-Hinds GAZ considered not fully allocated as related to consenting, but declines in baseflows and groundwater levels from changes to irrigation practices and groundwater pumping indicate that continued allocation of groundwater will lead to similar situation as in the Valetta GAZ.
Figure 3-11: Map of the Upper Hinds/Hekeao Plains catchment relative to ecological assessment

Figure 3-12: DRP median nutrient concentrations - Upper Hinds/Hekeao Plains catchment

Dissolved reactive phosphorus (DRP) concentrations (Ecan, 2012/2013)

- North Branch
- South Branch

DRP Guideline Value (LWRP)
The spring-fed waterbodies of the Hinds/Hekeao Plains consist of a series of highly modified drains that either connect to larger drains or discharge directly to the sea. They represent most of the remaining aquatic ecological resources of the lower catchment. The steep eroded stream channel areas (dongas) contain a diversity of in-stream habitats including ponded areas and coastal lagoons (hāpuas) behind the beach.

Between 2000 and 2002, the lowland waterways of the Hinds/Hekeao Plains were considered the healthiest lowland stream communities in Canterbury (Meredith, 2006). These spring-fed waterways provided high quality habitats that supported abundant and diverse macroinvertebrate communities. They also provided important habitats for rare and endangered species such as Canterbury mudfish (kowaro, Neochanna burrowsius), torrent fish (Cheimarrichthys fosteri), bluegill bullies (Gobiomorphus hubbsi) and longfin eels (Anguilla dieffenbachii), and a wide range of other resident and migratory native fish species such as upland bullies (Gobiomorphus breviceps), Canterbury galaxids (Galaxias vulgaris), shortfin eels (Anguilla australis), lamprey (Geotria australis) and exotic brown trout (Salmo trutta). Many of these waterways supported abundant, but stunted, brown trout populations that were harvested regularly by Central South Island Fish and Game until the 1990s to stock inland Ashburton lake trout fisheries.

Since the mid-2000s flows, water quality and habitat conditions have deteriorated in the lowland waterways and ecological values have become degraded. The health of the macroinvertebrate community is one measure that can help understand the condition and health of a waterbody habitat. This measure is known as the Quantitative Macroinvertebrate Community Index (QMCI), and QMCI values are used widely by regional councils in New Zealand to monitor stream health. QMCI scores collected between 2001 and 2012 across the Lower Hinds/Hekeao Plains sub-catchments document the degradation of this habitat (Figure 3-14).
A Department of Conservation (DoC) literature survey and summary of the communities and habitats within the lower catchment showed that of the 20 fish species recorded in the catchment, 15 were native and eight were ranked as threatened (Benn, 2013; Goodman et al., 2014). Populations of Canterbury mudfish (kowaro, Neochanna burrowsius), which are ranked as nationally critical (Goodman et al., 2014) are found in several wetland habitats in the lower catchment (O’Brien, 2005). Seven threatened bird species have been recorded in the catchment, including black stilts (kaki, Himantopus novaezelandiae), ranked as nationally critical (Robertson et al., 2013). Two nationally endangered aquatic or riparian plants, Canterbury pink broom (Carmichaelia torulosa) and pygmy clubrush (Isolepis basilaris) have also been identified in the catchment (de Lange et al., 2013).

Lower Hinds/Hekeao River/Hekeao in-stream values appear to be limited by a combination of low to drying summer flows, poor habitat diversity, and poor water quality conditions. Although nitrate-N became the focus of much of the Hinds/Hekeao subregional plan development, other water quality factors are critical to many of the ecological community outcomes.

Sediment coming from runoff from agricultural activities adjacent to waterbodies carries a range of pollutants that affect ecological, cultural and social outcomes. Sediment can be measured by both turbidity and total suspended solids (TSS). Sediment can also carry faecal bacteria (E.coli) and nutrients (DRP), particularly during rainfall events (Table 3-5). High levels of faecal bacteria in the water column makes the collection of mahinga kai less attractive and potentially dangerous to public health. High levels of bacteria also make the water dangerous for contact recreation. High levels of nutrients, including phosphorus (DRP), are also related to nuisance algal growths. Ecosystem impacts associated with elevated nutrient levels not only affect the appearance of a river (due to nuisance periphyton), but also include a loss of biodiversity from degraded macroinvertebrate communities and reduced fishery values (Biggs, 2000; Death, 2013; Matheson et al., 2012; Quinn et al., 1997).
Table 3-5: Water quality indicators in the Hinds/Hekeao Plains coastal catchment areas (Environment Canterbury, 2011 to 2013)

<table>
<thead>
<tr>
<th>Lower Catchment Area</th>
<th>Total Suspended Solids – TSS (mg/L)</th>
<th>E.coli. – faecal bacteria (MPN/100 ml)</th>
<th>Dissolved Reactive Phosphorus – DRP (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Median</td>
<td>Range: (min – max)</td>
<td>Median</td>
</tr>
<tr>
<td>Lower Hinds River</td>
<td>1.7</td>
<td>0.25 – 89.0</td>
<td>210</td>
</tr>
<tr>
<td>Valetta spring-fed waterbodies</td>
<td>2.9</td>
<td>0.8 – 48.0</td>
<td>210</td>
</tr>
<tr>
<td>Mayfield-Hinds spring-fed waterbodies</td>
<td>1.8</td>
<td>0.7 – 72.0</td>
<td>520</td>
</tr>
</tbody>
</table>

3.4.1 Cultural conditions

The cultural history of the Hinds/Hekeao Plains catchment is outlined in Section 3.2. Despite the development of farming following the arrival of European settlers, many Ngāi Tahu continued to rely on their traditional resources for their existence.

Changing land uses over the last century, in particular the intensification of farming activity, resulted in losses of mahinga kai. Despite these changes, the cultural values and traditional mahinga kai behaviours have survived. Mahinga kai remains a cornerstone of the Ngāi Tahu culture and identity. Whānau from Arowhenua still travel and fish the Hinds/Hekeao waterways, which today include the lowland drains that are easily accessed from the roads.

Recently, sustainable practices have been applied to ensure that no area is over-harvested, meaning that gathering is spread across a range of sites over a large area. This practice has been described as being similar to rotational grazing. The Hinds/Hekeao area is within this itinerant or rotational pattern of use.

The key factor for Te Rūnanga o Arowhenua is the continuing significance of the Hinds/Hekeao Plains catchment, despite the extent of modification. The striking feature in recent decades is the significance of the drains and races in conveying the natural waters of the catchment, as these have become substitute sources of mahinga kai. Links to ecological indicators such as stream channel depth and E.coli are directly relevant as metrics for the safe collection and sustainable management of mahinga kai for Te Rūnanga o Arowhenua (Table 3-5).

4 Biophysical modelling tools and assessments

4.1 Background

The technical strategy for supporting the limit setting process was to develop numerical models for both water quality and water quantity. These numerical models could use various mitigation strategies as inputs to determine if the environmental targets (e.g. 6.9 mgN/L of nitrate-N in spring-fed waterbodies) could be achieved. A number of assessments that analysed the social, cultural, environmental and economic components of the project (Figure 1-2) provided the inputs and surrounding context for these numerical models. Finally, a series of additional reports provided information specific to the mitigation strategies.

The water quality modelling was based on an existing technique used in the Selwyn Te Waihora process (Hanson, 2013). Scott (2013) provides an explanation of the spreadsheet-based accounting tool that utilised on-farm modelling with Overseer® done by MacFarlane Rural Business to calculate the nitrogen loading related to various land uses (Everest, 2014).
A combination of two modelling platforms (Durney et al., 2014, Durney and Ritson, 2014) guided the development and calibration of two models used for water quantity in the Hinds/Hekeao Plains catchment. The first, Environment Canterbury’s Regional Distribution Model (RDM), is a regional water distribution model that allowed some simple mass balance calculations to be used for the Exploratory and Potential Options Scenarios. During the Hinds/Hekeao Plains catchment CWMS process, Environment Canterbury was also developing a MIKE SHE (DHI software)™️ surface-groundwater spatial model. This spatial model became ready for scenario use during the development of the Solutions Package that was used in the final development of the Addendum of recommendations and plan development. Economic models were also used and reported in both AgResearch (Paragahawewa, 2014a, and 2014b) and MRB (Everest 2013 and 2014) reports.

When using multiple models for both water quality and water quantity, it was critical to ensure that the conceptual model logic was consistent across the platforms. Throughout the process, various inputs were refined using both updated and more accurate information, as well as stakeholder and peer review discussions. The technical team focused on utilising the best available information to develop these tools, which meant that outputs changed as refinement occurred. Communicating these model changes and subsequent outputs to the community was fundamental in order to maintain the community’s confidence.

An important assumption inconsistency between the separate water quantity and quality modelling approaches was accounting for the economic outcome of ‘up to 30,000 ha of new irrigation’. Based on the Landcare and Environment Canterbury GIS Analysis, the quality modelling added approximately 28,500 ha of new irrigated land inside the irrigation scheme command areas. The quantity modelling used the consented irrigated areas for RDR and BCI schemes which was only 27,500 ha. The technical team assumes that these are similar enough for comparison purposes. Both fall short of the actual 30,000 ha outcome, which from GIS mapping appears to be difficult to achieve with remaining dryland areas. The difference between both the modelled areas and the outcomes are assumed to be within the range of the modelling uncertainty.

Supporting assessments included the MRB on-farm Overseer® modelling of management practices and farm level economics (Everest, 2013). Golder (2014) provided the other catchment-scale mitigation assessment on the use of groundwater replenishment using the Managed Aquifer Recharge (MAR) tools.

Taylor (2014) provided an assessment of the social trends and potential changes relative to each of the scenarios being produced. Tipa (2013) provided an assessment of the Arowhenua Te Rūnanga cultural history and cultural indicators to be used for assessment of effects. Further work was prepared by Meredith and Lessard (2014a) on the ecological trends and targets. Meredith (2014b) also presented local-scale mitigations to round out the supporting information.

4.2 Biophysical modelling and assessment methods/data sources

4.2.1 Water quantity modelling

For the Exploratory Scenarios process, the technical team used Environment Canterbury’s Regional Distribution Model (RDM) to provide analysis of likely changes in groundwater levels and surface water flows under the different land use scenarios. At this stage, our goal was to provide the community with a sense of relative change between the different scenarios on which to base their subregional planning recommendation.

The RDM is a system dynamics computer model (Brown and Lowry, 2012), which currently includes the water systems between the Eyre River (north of the Waimakariri River) and the Oirari River. The model operates on a monthly time-step and outputs include groundwater status per zone and the reliability of supply/demand for consented water takes. The model is, in effect, a simple mass balance model that provides the product of inputs minus outputs.

The first four scenarios (Baseline to Potential Options), were developed and assessed using the RDM from January to June 2013. The results for each scenario, presented at community meetings, used the

More information on MIKE SHE intergraded model platform is here.
best information available at the time. Limitations of the RDM approach meant that while the scenario
modelling could help to quantify groundwater flux, it is not the appropriate tool for translating this
information into changes in baseflows. The RDM model did however, continue to provide adequate
estimates of LSR rates and catchment water balances that were used to help develop and calibrate
the MIKE SHE model.

This decision to move away from the RDM Model was based on a comparison with Aqualinc’s
Regional Canterbury Groundwater Model (CGM). The CGM is a Regional FEMWATER, finite-element
model (Weir, 2007) which provides that the spatial and temporal accuracy that RDM could not, being a
simple balance model. The comparison pointed out some key issues in the RDM modelling results. In
particular, it recognised that RDM modelled spring-flows that increased with rising groundwater levels
(from changes in abstraction and addition of MAR) were higher than could actually be achieved, given
the physical drainage capacity of the existing network of drains.

At the time of this comparison, the development of Environment Canterbury’s MIKE SHE model was
nearing completion and allowed the technical team to transition away from the water balance (RDM)
and regional groundwater (CGM) models to the more integrated option provided through MIKE SHE
(Durney, et al., 2014).

At this time, Environment Canterbury’s MIKE SHE model was nearly complete and in preparation for
use. This model was particularly suitable for the Hinds/Hekeao Plains catchment planning
development process because (unlike the other models) it was not regional in scope and was a true
surface-groundwater interaction platform by design. It was built specifically for the Ashburton zone. As
the development process for the Hinds/Hekeao Plains catchment plan is primarily based on the links
between groundwater and surface water flows, the MIKE SHE model was used in the Solutions
Package Scenario. It is a fully integrated model that includes climate, land use, land surface recharge,
unsaturated zone and groundwater, and the calibration focused specifically on the shallow aquifer and
spring-fed lowland waterbodies. This was a critical factor in its use in the development process for the
Hinds/Hekeao Plains catchment plan.

The technical team used the MIKE SHE model specifically to support the development process for the
Hinds/Hekeao Catchment plan, in order to simulate the relative change between scenarios for:

- flow in the Hinds/Hekeao River in the lowland spring-fed waterbodies
- irrigation demand in the Mayfield-Hinds and Valetta irrigation scheme areas
- groundwater levels in a range of deep and shallow wells across the catchment
- irrigation application and efficiencies from variable surface water and groundwater sources
- simulating response of the system to groundwater recharge (MAR).

The limitations for all of these models are based on a limited amount of information about surface flow
for the lowland waterbodies. Therefore, the strength of the MIKE SHE model here is as a relative
change comparison tool, and not for developing specific numerical targets or goals for the
Hinds/Hekeao Plains catchment area.

4.2.2 Water quality modelling

The technical team used a spreadsheet-based accounting tool that combines mapped land use and
modelled leaching and drainage, which was then aggregated over the catchment to calculate a
catchment-scale nitrogen leaching load and total soil drainage volume. The approach was based on
the Culverden Basin Nitrate-N Account model developed for the Land Use and Water Quality Pilot
Project in the Hurunui catchment (Lilburne et al., 2011) and the water quality modelling for the Selwyn-
Waihora limit setting process (Hanson, 2014).

An important issue with this method is that, similar to the MIKE SHE method for water quantity, the
water quality model does not provide quantitative spatial or temporal predictions of water quality for
the Hinds/Hekeao catchment. Instead, the comparison of modelled scenarios provides the community
with a long-term picture of the relative state of water quality if different actions are taken. Several
assumptions and uncertainties are involved in this simple modelling approach. However, more
complex mathematical models would not necessarily give a better result because these also require
many assumptions and estimates due to the lack of quantified data.
All the results were presented as long-term annual averages at steady-state, assuming that land use does not change, no significant nitrate-N removal processes occur, and whatever lag there is in the groundwater system has passed.

The modelled leaching and drainage input came from Everest et al. (2013), who generated nitrogen leaching rates and soil drainage volumes from land use using the Overseer® agricultural management model and data from farm systems they considered representative of the Hinds/Hekeao Plains. The technical team considered this approach to be better than using the more generic look-up table values for Canterbury (Lilburne et al., 2010), because Overseer® is the tool that Environment Canterbury has chosen to manage farming practices into the future.

Farm management experts derived estimates of nitrogen leaching rates and drainage rates for different farm systems and soil classes. The technical team used a combination of land use classifications and soil maps to weight the leaching and drainage, then aggregated them for the whole catchment. From these estimates of annual leaching load and drainage volumes, further estimates were derived of the long-term, steady-state average nitrate-N concentration draining from the base of the soils under selected patterns of land use. The technical team compared these values with the Zone Committee’s targeted nitrate-N concentrations for maintaining drinking-water quality and ecological functioning in the spring-fed waterways (Scott, 2013).

4.3 Assessment methods/data sources

4.3.1 Social impact assessment

Any form of environmental or economic change in an area will have implications for the people who live and work there, and for people who use it for recreation. Some of these changes are tangible and some are not. The Social Impact Assessment (SIA) identified the potential positive and negative social effects for people associated with predicted changes.

The two main objectives of the SIA were to:

- develop a baseline of the current socio-economic context
- undertake an impact assessment of each of the scenarios and predict the consequences of the change on the social indicators.

The scenario assessments used comparative case data from other irrigation areas in Canterbury, including the Hurunui, Waitaki and Opuha irrigation areas. These comparison cases were used only as indicators of social change; local conditions were taken into account when predicting the impacts of each scenario. The Baseline profile was developed from a wide range of data sources in relation to the technical indicators, comprising of:

- published information
- official statistics including the census
- other documentary sources including local histories and manuscripts
- interviews and discussions conducted in the assessment area
- discussions at public meetings in Hinds and Mayfield, and at four Community Workshops in Hinds.

The social assessment used information from the biophysical, economic (on-farm and regional) and cultural scenario assessments. Outcomes selected by the Zone Committee for the Hinds/Hekeao Plains catchment were considered from a social viewpoint for this analysis. The technical team identified technical indicators for each outcome based on their experience with social analyses of other catchments, including Hurunui and Selwyn Waihora, and comparative case material (Taylor et al., 2014).
4.3.2 Economic assessment

The economic assessment considered the recommendations from the Zone Committee (AZC, 2014) when assessing the potential farm, catchment, and regional-scale economic impacts of implementing the proposed activities in the Hinds/Hekeao Plains area to achieve water quality and water quantity targets.

This assessment also tried to incorporate the costs and benefits of the environmental impacts of the proposed measures wherever possible. The assessment focused on the following outcomes, identified by the Zone Committee, and briefly discussed the policy implications of the proposed measures:

- security and increased supply reliability (95%) of water for abstractive users
- impacts of the increase in irrigated area by 30,000 ha from current irrigated land area
- economic growth in the Hinds and Mayfield communities
- sustainable, diverse, and productive land use.

Agresearch (Paragahawewa 2014a, and 2014b) based their economic assessment primarily on information provided by MacFarlane Rural Business (MRB). MRB provided Earnings Before Interest and Tax (EBIT) and Cash Farm Surplus (CFS) figures for current farm operations, as well as farm operations under various mitigation practices. They utilised two Farmax models for their farm system economic analysis: Farmax Pro (a sheep, beef, deer, crop, dairy support model) and Farmax Dairy (a dairy, crop and dairy support model). Farmax is a biophysical, agronomic software model used to record farm performance, predict performance and production, and assess the financial profitability of different scenarios. MRB based their economic models on the 2012 annual monitoring reports from the Ministry for Primary Industries and adjusted them to represent the Hinds/Hekeao Plains catchment.

MRB (Everest 2013 and 2014) used the Farmax data to estimate the catchment level financial performance by considering the area under various land use types in the catchment. It was not always possible to fully separate the Hinds/Hekeao Plains catchment area from the wider Ashburton District so much of the available data are at the District level. This analysis attempted to predict the future economic situation if the Solutions package in the ZIP Addendum (AZC, 2014) were adopted at catchment level (Paragahawewa, 2014a and 2014b).

4.3.3 Cultural assessment

An assessment of Ngāi Tahu cultural values was undertaken by Tipa and Associates (Tipa, 2014). The assessment included identification of values and interests of tangata whenua within the boundaries of the Hinds/Hekeao Plains catchment plan area. Mandated representatives of Te Rūnanga o Arowhenua undertook the cultural assessments in the Hinds/Hekeao Plains catchment using the Cultural Health Index process. These primary and secondary sources informed participants about the current situation in the catchment. The results of the assessment were summarised into themes detailing the cultural values sought in the catchment and perceived water management issues that are influencing the cultural values (Section 6.10).

4.3.4 Ecological assessment

The ecological assessment included a review of available information about the hydrology, water quality and ecology for the surface waterbodies in the catchment. The Zone Committee used this information to set objectives for flow and waterway habitat management for both cultural and ecological values. This analysis included protection of the upper catchment, minimum in-stream flow values in the spring-fed waterbodies, migratory access requirements, existing fish passage issues, and riparian and in-stream habitat management options. The technical team used this information to make recommendations relating to environmental and cultural values.

Unlike the other assessments (such as the social assessment and water quality assessment), the ecological assessment did not involve a formal assessment of each scenario. Water quality of nitrate-N modelling conducted before the ecological assessment (Scott 2013; Durney et al., 2014) revealed

17 http://www.farmax.co.nz/
that current land use (Baseline Scenario) is likely to cause a further decline in water quality (nitrate-N) in the long-term. Even if there are no more farm conversions, modelling showed that on-farm nutrient management alone would not be sufficient to reverse the declining water quality and associated ecological degradation of the lower catchment. Therefore, the ecological assessment focused on describing the existing ecological and cultural values for use with the development of targeted stream mitigations.

5 The Exploratory Scenarios

5.1 Overview

The scenarios used in the Subregional Plan development process are divided into two groups: exploratory and solutions (Table 5-1). The initial Exploratory Scenarios are derived from the aspirations of the Hinds/Hekeao Plains catchment ZIP (AZC, 2014) for further irrigation expansion and delivery of environmental goals. The Zone Committee agreed to the content of each scenario, and the content was discussed in a wider public forum. A number of assumptions and rules were used to model the surface water flow and water quality under each scenario. The community relied upon the water quantity and water quality technical reports and memoranda developed for each scenario for the assessment of environmental and cultural outcomes, and upon local knowledge from stakeholders.

When the initial Exploratory Scenarios phase was finished, the technical team developed the catchment and local-scale mitigation options as part of the process to provide the community with potential tools to help achieve the community outcomes. These potential mitigation options were assembled and then assessed in the potential options scenario and the subsequent final Solutions Package Scenario. The Zone Committee, Ngāi Tahu, community and other stakeholders reviewed these solutions scenarios, then the technical team modified the mitigation options (e.g. timing, quantities, etc.) based on the feedback.

The Zone Committee formally adopted the amended Solutions Package in the Addendum, which was accepted by both the Environment Canterbury Commissioners and Ashburton District Council (AZC, 2014).

Table 5-1: Scenarios investigated for the Hinds/Hekeao Plains catchment limit setting process

<table>
<thead>
<tr>
<th>Methodology</th>
<th>Scenario</th>
<th>Assumptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exploratory</td>
<td>Baseline</td>
<td>Land use and irrigation (as at 2011) continues into the future (<em>status quo</em>)</td>
</tr>
<tr>
<td></td>
<td>Development</td>
<td>Focus on achieving only the economic and social outcomes set by the Zone Committee (up to an additional 30,000 ha of irrigated land)</td>
</tr>
<tr>
<td></td>
<td>Environmental</td>
<td>Focus on achieving only the Zone Committee’s environmental outcomes (no irrigation expansion, flow augmentation or on-farm mitigations added)</td>
</tr>
<tr>
<td>Solutions</td>
<td>Potential Options</td>
<td>Focus on developing mitigation options that achieve all of the Zone Committee’s outcomes (up to an additional 30,000 ha of new irrigation conversions, flow augmentation and on-farm mitigation added)</td>
</tr>
<tr>
<td></td>
<td>Solutions Package</td>
<td>Revised Potential Options Scenario with mitigation options that are acceptable to the community and achieve all of the Zone Committee’s outcomes (up to an additional 30,000 ha of new irrigation conversions, flow augmentation, on-farm mitigations, and local scale mitigations)</td>
</tr>
</tbody>
</table>
5.2 Exploratory Baseline Scenario

5.2.1 Overview
The technical team presented the Exploratory Baseline Scenario to the community in March 2013 to show the long-term, steady-state effects of current land use activities. This Exploratory Baseline Scenario was then used for comparison against the Exploratory Development Scenario and the Exploratory Environmental Scenario. The two numerical modelling approaches for water quantity and water quality provided the community with a starting point for the limit setting process.

5.2.2 Water quantity modelling
The technical team ran a number of precursor model scenarios using Environment Canterbury's Regional Distribution Model (RDM) modelling platform. The scenarios looked firstly at historical irrigation practices (before 2000) then, secondly, with no irrigation applied and minimal stockwater losses. We did this to determine any potential background trends in the results, and to make calibration adjustments to the model (Durney and Ritson, 2014). The calibration exercise for this Exploratory Baseline Scenario highlighted several important conclusions about the measured changes in groundwater levels:

- Groundwater storage is significantly lower under modelled dry land conditions than under the border dyke irrigation simulation.
- Groundwater storage levels will be lower under the Exploratory Baseline Scenario than under the border dyke irrigation scenario, but on average, will be higher than under a scenario where no-irrigation is included in the modelling (dryland). This result is driven primarily by Land Surface Recharge (LSR) and groundwater abstraction.
- Seasonal groundwater storage fluctuations under the Exploratory Baseline Scenario conditions will be greater than under the a scenario that included historical levels of border dyke irrigation.
- Major causes of the overall groundwater storage level decline include the shift from border dyke irrigation to spray irrigation (LSR), the piping of races, and increases in groundwater abstractions.

Outputs from the model were presented to the community in the form of model calibration, and trends in both groundwater and flow levels in the lowland waterbodies.

5.2.3 Water quality modelling
This Exploratory Baseline Scenario represents the trends in water quality that might be expected in the future, assuming current farm types continue to exist, are farmed to Good Management Practice (GMP), and there is no further intensification in the catchment (Table 5-2).
Table 5-2: Exploratory Baseline Scenario estimates of steady-state recharge, nitrogen load and groundwater nitrate-N concentrations for the Hinds/Hekeao Plains catchment

<table>
<thead>
<tr>
<th>Model assumptions</th>
<th>Nitrogen load</th>
</tr>
</thead>
<tbody>
<tr>
<td>Additional irrigated area (ha)</td>
<td>0</td>
</tr>
<tr>
<td>Catchment nitrogen load (tonnes/yr)</td>
<td>4600</td>
</tr>
<tr>
<td>Additional recharge by MAR (m³/s)</td>
<td>0</td>
</tr>
<tr>
<td>Average leaching rate (kg N/ha/yr)</td>
<td>36</td>
</tr>
<tr>
<td>Soil drainage</td>
<td></td>
</tr>
<tr>
<td>Annual recharge (10⁶ m³/yr)</td>
<td>365</td>
</tr>
<tr>
<td>Shallow groundwater and waterways</td>
<td>13</td>
</tr>
<tr>
<td>Average soil drainage (mm/yr)</td>
<td>290</td>
</tr>
<tr>
<td>Lower Hinds/Hekeao River</td>
<td>8</td>
</tr>
</tbody>
</table>

Assessment against zone Outcomes

- Likely to meet drinking-water quality outcomes without treatment? No
- Likely to meet ecological outcomes for spring-fed waterways? No

The technical team expect the average concentration of nitrate-N will be higher at steady-state than at present. This is because there is an unmitigated lag time of several years before the full effects of current land uses are fully realised in the shallow groundwater (Scott, 2013a). Most of the shallow monitoring wells have shown increasing trends in nitrate-N concentrations from land use intensification in the catchment over the past decade, and the technical team expect these trends to continue for some time, even with no further intensification.

However, there are uncertainties in the modelling, which make it impossible for the model to accurately predict accurately the steady-state concentrations. Some of these uncertainties relate to the assumption that all farms are managed to GMP, and that the Overseer® modelling can predict the amount of nitrogen leaching under GMP. Information is not available to determine the average level of farm management at catchment-scale. There are also uncertainties in the drainage estimates, which do not account for any alpine river recharge, seepage from water races or the Hinds/Hekeao River in the Exploratory Baseline Scenario.

5.2.4 Assessment of outcomes

An important assumption for this Exploratory Baseline Scenario is that no change or intensification from 2011 land use occurs. Work completed with the community later in the Subregional Plan development process indicated that further intensification probably occurred from 2011 to 2013/14 (Scott, 2014b).

The information from the technical assessments of this scenario was grouped under each outcome grouping (social, environmental, cultural and economic), to make it easier for the community to use. The technical team evaluated the relevant Outcomes for each assessment area (social, cultural, economic and environmental) and determined the likelihood of that outcome being met under the Exploratory Baseline Scenario (Table 5-3).
Table 5-3: Summary of the Outcome assessments outcomes for the Exploratory Baseline Scenario

<table>
<thead>
<tr>
<th>Desired Outcomes</th>
<th>Aim</th>
<th>Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Social Outcomes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Drinking water wells and domestic supplies now and in the future at least meet national drinking water standard for <em>E. coli</em> and nitrate.</td>
<td>Not met</td>
</tr>
<tr>
<td>2</td>
<td>Enhanced recreational opportunities on waterways (e.g. fishing, picnicking, tourism).</td>
<td>Not met</td>
</tr>
<tr>
<td>3</td>
<td>Enhanced social wellbeing of rural communities.</td>
<td>Likely to be met</td>
</tr>
<tr>
<td>4</td>
<td>Maintain existing flood control to protect small communities and farmland.</td>
<td>Likely to be met</td>
</tr>
<tr>
<td>Cultural Outcomes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Wāhi tapu and wāhi taonga are protected and access enhanced.</td>
<td>Very unlikely to be met</td>
</tr>
<tr>
<td>2</td>
<td>Mahinga kai is protected and enhanced.</td>
<td>Very unlikely to be met</td>
</tr>
<tr>
<td>3</td>
<td>Maintain flows in lowland streams to protect cultural values.</td>
<td>Very unlikely to be met</td>
</tr>
<tr>
<td>Economic Outcomes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Security and increased demand reliability (95%) for abstractive users is achieved.</td>
<td>Very unlikely to be met</td>
</tr>
<tr>
<td>2</td>
<td>Increase in irrigated area by 30,000 ha from current irrigated land.</td>
<td>Not met</td>
</tr>
<tr>
<td>3</td>
<td>Ready access to reliable, quality stockwater.</td>
<td>Likely to be met</td>
</tr>
<tr>
<td>4</td>
<td>Protect current water availability, including for smaller landowners.</td>
<td>Very unlikely to be met</td>
</tr>
<tr>
<td>5</td>
<td>Economic growth in Hinds and Mayfield communities.</td>
<td>Very likely to be met</td>
</tr>
<tr>
<td>6</td>
<td>Drain flows provide for abstractive use.</td>
<td>Very unlikely to be met</td>
</tr>
<tr>
<td>7</td>
<td>Drain flows provide for flood conveyance.</td>
<td>Likely to be met</td>
</tr>
<tr>
<td>8</td>
<td>Sustainable diverse and productive land use.</td>
<td>Unlikely to be met</td>
</tr>
<tr>
<td>Environmental Outcomes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Maintain flows in lowland streams to protect biodiversity values.</td>
<td>Unlikely to be met</td>
</tr>
<tr>
<td>2</td>
<td>Water quality in drains/streams is improved.</td>
<td>Not met</td>
</tr>
<tr>
<td>3</td>
<td>Reduced nutrient inflow into lowland streams to support historical ecosystem health.</td>
<td>Not met</td>
</tr>
<tr>
<td>4</td>
<td>Ecological values of stockwater races are retained or offset.</td>
<td>Very likely to be met</td>
</tr>
<tr>
<td>5</td>
<td>Ecologically significant wetlands and peat swamp remnants are protected.</td>
<td>Unlikely to be met</td>
</tr>
<tr>
<td>6</td>
<td>Protect and enhance indigenous fish and habitats in lowland streams and foothills.</td>
<td>Very unlikely to be met</td>
</tr>
<tr>
<td>7</td>
<td>Protect and enhance habitat for trout.</td>
<td>Very unlikely to be met</td>
</tr>
<tr>
<td>8</td>
<td>Protect and enhance streams and sub-catchments with only indigenous fish species.</td>
<td>Likely to be met</td>
</tr>
<tr>
<td>9</td>
<td>Remnant indigenous vegetation areas do not decrease in size.</td>
<td>Very likely to be met</td>
</tr>
<tr>
<td>10</td>
<td>Retain unique features and biodiversity of the dongas.</td>
<td>Unlikely to be met</td>
</tr>
<tr>
<td>11</td>
<td>Protect remaining dryland biodiversity.</td>
<td>Very likely to be met</td>
</tr>
</tbody>
</table>
5.2.5 Summary of the outcomes from the Exploratory Baseline Scenario

The Exploratory Baseline Scenario does not appear to meet any of the outcomes fully, and the majority (17 of the 26) are, at least, unlikely to be met. This applies equally to the environmental, economic, cultural and social outcome groups (Figure 5-1).

![Outcome Summary Diagram](image)

Figure 5-1: Summary of the outcomes from the exploratory baseline scenario

5.3 Exploratory Development Scenario

5.3.1 Overview

The Exploratory Development Scenario is intended to show the long-term steady-state effects on the catchment if land use intensification continues. It includes the outcome to add up to 30,000 ha of new irrigation with no mitigations relative to achieving any modelled water quality and water quantity targets. The technical team presented the Exploratory Development Scenario to the community in April 2014 and included comparisons of water quantity and quality against the Exploratory Baseline Scenario.

5.3.1 Water quantity modelling

The technical team used the RDM modelling platform to assess the Exploratory Development Scenario for modelled water quantity with 27,500 ha\(^{18}\) of new irrigation. The modelling was achieved by specific scheme increases as follows:

- Mayfield-Hinds expands from 32,000 to 45,000 ha, and is all spray-irrigated
- Valetta expands from 7000 to 13,500 ha, and is all spray-irrigated
- BCIL expands from 4700 to 12,700 ha, and is all spray-irrigated.

Water management changes included:
- Surface-water takes from streams and rivers below SH1 are surrendered and replaced with deep groundwater to avoid local stream-depleting effects.

\(^{18}\) Differences in modelling platforms (quantity versus quality) and GIS analysis of land use lead to small differences between cumulative values for new irrigation. For quantity the value was 27,500 ha for quantity the value was approximately 28,500.
• Groundwater takes above SH1 are surrendered and replaced by the surface-water schemes.
• Groundwater usage in each allocation zone is reduced and limited to coastal areas below SH1.

Results indicated that groundwater levels would be lower, on average, than under the Exploratory Baseline Scenario conditions. The decreased groundwater storage levels would result in slightly lower flows in the lowland streams, and the reliability of supply for the lowland waterways would not meet the community outcome of 95%.

5.3.1 Water quality modelling

This Exploratory Development Scenario assumes an additional 28,500 hectares of both dry land and partially irrigated land uses are converted, in order to irrigate dairy and dairy support relative to the community outcome of up to an additional 30,000 ha of new irrigation.

Under this Exploratory Development Scenario, the nutrient load and nitrate-N concentrations reaching the groundwater and spring-fed waterways will increase (Scott, 2013). The catchment load calculations suggest that the nitrogen load may increase by about 30% compared to the Exploratory Baseline Scenario. However, there will also be more drainage due to the increased irrigation, so the nitrate-N concentrations in soil drainage may increase by about 15%. The average nitrate-N concentration exceeds the water quality target of 6.9 mgN/L in the shallow groundwater. Ecological and drinking water outcomes are unlikely to be met, and if land use intensification continues in the Hinds/Hekeao Plains catchment, it is very likely that there will be further deterioration of the water quality.

Table 5-4: Exploratory Development Scenario estimates of steady-state recharge, nitrogen load and groundwater nitrate-N concentrations for the Hinds/Hekeao Plains catchment

<table>
<thead>
<tr>
<th>Model assumptions</th>
<th>Nitrogen load</th>
</tr>
</thead>
<tbody>
<tr>
<td>Additional irrigated area (ha)</td>
<td>28,500</td>
</tr>
<tr>
<td>Catchment nitrogen load (tonnes/yr)</td>
<td>5900</td>
</tr>
<tr>
<td>Additional recharge by MAR (m³/s)</td>
<td>0</td>
</tr>
<tr>
<td>Average leaching rate (kg N/ha/yr)</td>
<td>46</td>
</tr>
<tr>
<td>Soil drainage</td>
<td></td>
</tr>
<tr>
<td>Annual recharge (10⁶ m³/yr)</td>
<td>405</td>
</tr>
<tr>
<td>Shallow groundwater and waterways</td>
<td>14</td>
</tr>
<tr>
<td>Average soil drainage (mm/yr)</td>
<td>320</td>
</tr>
<tr>
<td>Lower Hinds/Hekeao River</td>
<td>9</td>
</tr>
<tr>
<td>Assessment against zone Outcomes</td>
<td></td>
</tr>
<tr>
<td>Likely to meet drinking-water quality outcomes without treatment?</td>
<td>No</td>
</tr>
<tr>
<td>Likely to meet ecological outcomes for spring-fed waterways?</td>
<td>No</td>
</tr>
</tbody>
</table>

5.3.1 Assessment of outcomes

The information from the technical assessments of this scenario was grouped under each outcome, to make it easier for the community to use. Under each assessment area (social, cultural, economic and environmental), the technical team evaluated the relevant outcomes and determined the likelihood of that outcome being met under the Exploratory Development Scenario (Table 5-5).

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19 Represents a rounded value based on the GIS analysis done on land parcels, calculated value is 28,718 ha.
<table>
<thead>
<tr>
<th>Outcomes</th>
<th>Aim</th>
<th>Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Social Outcomes</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Drinking water wells and domestic supplies now and in the future at least meet national drinking water standard for <em>E.coli</em> and nitrate.</td>
<td>Not met</td>
</tr>
<tr>
<td>2</td>
<td>Enhanced recreational opportunities on waterways (e.g. fishing, picnicking, tourism).</td>
<td>Not met</td>
</tr>
<tr>
<td>3</td>
<td>Enhanced social wellbeing of rural communities.</td>
<td>Very likely to be met</td>
</tr>
<tr>
<td>4</td>
<td>Maintain existing flood control to protect small communities and farmland.</td>
<td>Likely to be met</td>
</tr>
<tr>
<td><strong>Cultural Outcomes</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Wāhi tapu and wāhi taonga are protected and access enhanced.</td>
<td>Very unlikely to be met</td>
</tr>
<tr>
<td>2</td>
<td>Mahinga kai is protected and enhanced.</td>
<td>Very unlikely to be met</td>
</tr>
<tr>
<td>3</td>
<td>Maintain flows in lowland streams to protect cultural values.</td>
<td>Very unlikely to be met</td>
</tr>
<tr>
<td><strong>Economic Outcomes</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Security and increased demand reliability (95%) for abstractive users is achieved.</td>
<td>Met</td>
</tr>
<tr>
<td>2</td>
<td>Increase in irrigated area by 30,000 ha from current irrigated land.</td>
<td>Met</td>
</tr>
<tr>
<td>3</td>
<td>Ready access to reliable, quality stockwater.</td>
<td>Met</td>
</tr>
<tr>
<td>4</td>
<td>Protect current water availability, including for smaller landowners.</td>
<td>Likely to be met</td>
</tr>
<tr>
<td>5</td>
<td>Economic growth in Hinds and Mayfield communities.</td>
<td>Met</td>
</tr>
<tr>
<td>6</td>
<td>Drain flows provide for abstractive use.</td>
<td>N/A</td>
</tr>
<tr>
<td>7</td>
<td>Drain flows provide for flood conveyance.</td>
<td>Likely to be met</td>
</tr>
<tr>
<td>8</td>
<td>Sustainable diverse and productive land use.</td>
<td>Unlikely to be met</td>
</tr>
<tr>
<td><strong>Environmental Outcomes</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Maintain flows in lowland streams to protect biodiversity values.</td>
<td>Unlikely to be met</td>
</tr>
<tr>
<td>2</td>
<td>Water quality in drains/streams is improved.</td>
<td>Not met</td>
</tr>
<tr>
<td>3</td>
<td>Reduced nutrient inflow into lowland streams to support historical ecosystem health.</td>
<td>Not met</td>
</tr>
<tr>
<td>4</td>
<td>Ecological values of stockwater races are retained or offset.</td>
<td>Not met</td>
</tr>
<tr>
<td>5</td>
<td>Ecologically significant wetlands and peat swamp remnants are protected.</td>
<td>Likely to be met</td>
</tr>
<tr>
<td>6</td>
<td>Protect and enhance indigenous fish and habitats in lowland streams and foothills</td>
<td>Unlikely to be met</td>
</tr>
<tr>
<td>7</td>
<td>Protect and enhance habitat for trout</td>
<td>Very unlikely to be met</td>
</tr>
<tr>
<td>8</td>
<td>Protect and enhance streams and sub-catchments with only indigenous fish species.</td>
<td>Likely to be met</td>
</tr>
<tr>
<td>9</td>
<td>Remnant indigenous vegetation areas do not decrease in size.</td>
<td>Unlikely to be met</td>
</tr>
<tr>
<td>10</td>
<td>Retain unique features and biodiversity of the dongas.</td>
<td>Unlikely to be met</td>
</tr>
<tr>
<td>11</td>
<td>Protect remaining dryland biodiversity.</td>
<td>Very unlikely to be met</td>
</tr>
</tbody>
</table>
5.3.2 Summary of the outcomes from the Exploratory Development Scenario
The Exploratory Development Scenario appears to meet only four of the eight economic outcomes, and one of the social outcomes. The other 22 outcomes for the catchment are unlikely or very unlikely to, or do not, meet the aims (Table 5-5). This result is to be expected from a scenario that focused specifically on further development of irrigation. When compared to the Exploratory Baseline Scenario, the Exploratory Development Scenario provides a number of benefits apart from additional irrigated land. These benefits include improved reliability of supply (from scheme water) to irrigated areas, and increases in the local and regional economies and jobs.

Challenges posed by this Exploratory Development Scenario include further increases in catchment load and in-stream concentrations of nitrogen, further degradation of environmental and cultural values, and increased risks for drinking water supplies. Projected recreation opportunities that are related to water show further declines. The modelled lower groundwater level has a direct influence on further declines in river and lowland waterbodies minimum flows and reliability of supply.

Figure 5-2 summarises the outcomes and clearly demonstrates the factors discussed here, with more economic outcomes being met and an increased number of outcomes moving to the left. At the same time, the majority of the environmental and cultural outcomes remain to the right of centre, meaning they are unlikely to be, or not, met.

![Outcome Summary](image)

Figure 5-2: Summary of the outcomes from the Exploratory Development Scenario

5.4 Exploratory Environmental Scenario

5.4.1 Overview
The Exploratory Environmental Scenario examined the implications of delivering the environmental outcomes and some social outcomes, while maintaining the levels of economic development shown in the Exploratory Baseline Scenario. This exploratory environmental scenario focused on two objectives: increased flows, and improved water quality. This twin focus meant that this scenario also moved towards achieving some of the cultural and social outcomes. In order to meet these assumptions, the Exploratory Environmental Scenario included:
• land use values from the Exploratory Baseline Scenario
• Piping of schemes and stockwater races
• 5.0 m$^3$/s of MAR with high quality, alpine-sourced water recharged to groundwater to help achieve targets for both water quality and water quantity
• 1 m$^3$/s of 5 m$^3$/s MAR targeted on the Hinds/Hekeao River for specific flow and quality enhancements.

The augmentation of MAR was added to the Exploratory Environmental Scenario because it seemed to be the only practical way to achieve the environmental outcomes (Golder, 2014). Other mitigations that included were land use change, significant reductions to water allocations, and on-farm mitigations, which were shown to be not as economically feasible. MAR was used for dilution (quality) and increased recharge (quantity – offsetting piping and stabilise and restore declining groundwater and flow levels).

5.4.2 Water quantity modelling
Using the RDM modelling platform, the Exploratory Environmental Scenario was assessed for water quantity by modelling with an additional 5.0 m$^3$/s of groundwater recharge. Multiple modelling iterations were run (ranging from 1 to 8 m$^3$/s of MAR) to determine if, and at what level of recharge, the outcomes could be met. The assumptions made by this modelling scenario included:

- baseline levels of water (surface and groundwater) and land usage
- groundwater takes remain the same as the Exploratory Baseline Scenario
- Stockwater and irrigation schemes are piped
- MAR water is available from alpine sources and/or storage.

Under this Exploratory Environmental Scenario, the technical team expect groundwater storage levels in the Hinds/Hekeao Plains catchment to be higher than the levels in both the exploratory baseline scenario and the Exploratory Development Scenario. This is due to additional recharge from the managed aquifer recharge inputs. Increases in recharge means that there would be higher flows and increased reliability in the lowland waterbodies.

5.4.3 Water quality modelling
Water quality modelling for the Exploratory Environmental Scenario used a combination of augmentation by 5.0 m$^3$/s of MAR and on-farm mitigations to improve water quality. These assumptions were modelled by adjusting the nitrogen load, land use and soil drainage values modelled in the Exploratory Baseline Scenario (Table 5-6).
Table 5-6: Exploratory Environmental Scenario estimates of steady-state recharge, nitrogen load and groundwater nitrate-N concentrations for the Hinds/Hekeao Plains catchment

<table>
<thead>
<tr>
<th>Model assumptions</th>
<th>Nitrogen load</th>
</tr>
</thead>
<tbody>
<tr>
<td>Additional irrigated area (ha)</td>
<td>0</td>
</tr>
<tr>
<td>Additional recharge by MAR (m³/s)</td>
<td>5.0</td>
</tr>
<tr>
<td>Soil drainage</td>
<td></td>
</tr>
<tr>
<td>Annual recharge (10⁶ m³/yr)</td>
<td>525</td>
</tr>
<tr>
<td>Average soil drainage (mm/yr)</td>
<td>410</td>
</tr>
<tr>
<td>Assessment against zone Outcomes</td>
<td></td>
</tr>
<tr>
<td>Likely to meet drinking-water quality outcomes without treatment?</td>
<td>No</td>
</tr>
<tr>
<td>Likely to meet ecological outcomes for spring-fed waterways?</td>
<td></td>
</tr>
</tbody>
</table>

The water quality modelling of MAR probably over-estimates the dilution effects, by assuming that the recharged water mixes primarily with the shallow groundwater. In practise, some of this water would also move deeper over time as would the surface-sourced nitrate-N. The distribution of MAR becomes a critical factor, to target areas of high leaching potential and where monitoring information shows ‘hot spots’.

The modelling results show that average nitrate-N concentration could ‘possibly’ meet the ecological target of 6.9 mgN/L. Targeted MAR augmentation for the Upper Hinds/Hekeao River would also possibly help to decrease nitrate-N concentrations in the Lower Hinds/Hekeao River to below 3.8 mg/L. The drinking-water targets of 5.7 mgN/L (1/2 MAV of National Drinking Water Standard) would still not be met without treatment.

5.4.1 Assessment of outcomes

An important assumption for this Exploratory Environmental Scenario is that the modelled values for increasing recharge to groundwater (using MAR) are reasonable and achievable. For this Exploratory Environmental Scenario, a recharge of 5.0 m³/s from an alpine source (high quality) was selected for both the water quality and water quantity targets. The availability and economic cost of this water (e.g. conveyance and/or storage costs) had not been fully developed at this stage.

The effectiveness of augmentation was another key assumption, with water quality and water quantity both requiring slightly different modelling methods, and spatial–temporal considerations relative to implementation (Golder, 2014). The information from the technical assessments of this scenario was grouped under each outcome, to make it easier for the community to use. Under each assessment area (social, cultural, economic and environmental), the technical team evaluated the relevant outcomes and determined the likelihood of that outcome being met under the Exploratory Environmental Scenario (Table 5-7).

---

20 Exploratory Baseline Scenario value of 4600 tonnes/yr reduced by 30% by advanced on-farm mitigation.

21 Exploratory Baseline Scenario value of 365 x 10⁶ m³/yr increased by 5 m³/s due to MAR.
### Table 5-7: Summary of the outcome assessments for the Environmental Scenario

<table>
<thead>
<tr>
<th>Outcomes</th>
<th>Aim</th>
<th>Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Social Outcomes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Drinking water wells and domestic supplies now and in the future at least meet national drinking water standard for <em>E. coli</em> and nitrate.</td>
<td>Unlikely to be met</td>
</tr>
<tr>
<td>2</td>
<td>Enhanced recreational opportunities on waterways (e.g. fishing, picnicking, tourism).</td>
<td>Likely to be met</td>
</tr>
<tr>
<td>3</td>
<td>Enhanced social wellbeing of rural communities.</td>
<td>Unlikely to be met</td>
</tr>
<tr>
<td>4</td>
<td>Maintain existing flood control to protect small communities and farmland.</td>
<td>Very likely to be met</td>
</tr>
<tr>
<td>Cultural Outcomes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Wāhi tapu and wāhi taonga are protected and access enhanced.</td>
<td>Likely to be met</td>
</tr>
<tr>
<td>2</td>
<td>Mahinga kai is protected and enhanced.</td>
<td>Likely to be met</td>
</tr>
<tr>
<td>3</td>
<td>Maintain flows in lowland streams to protect cultural values.</td>
<td>Likely to be met</td>
</tr>
<tr>
<td>Economic Outcomes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Security and increased demand reliability (95%) for abstractive users is achieved.</td>
<td>Met</td>
</tr>
<tr>
<td>2</td>
<td>Increase irrigated area by 30,000 ha from current irrigated land.</td>
<td>Not met</td>
</tr>
<tr>
<td>3</td>
<td>Ready access to reliable, quality stockwater.</td>
<td>Met</td>
</tr>
<tr>
<td>4</td>
<td>Protect current water availability, including for smaller landowners.</td>
<td>Very likely to be met</td>
</tr>
<tr>
<td>5</td>
<td>Economic growth in Hinds and Mayfield communities.</td>
<td>Very unlikely to be met</td>
</tr>
<tr>
<td>6</td>
<td>Drain flows provide for abstractive use.</td>
<td>Likely to be met</td>
</tr>
<tr>
<td>7</td>
<td>Drain flows provide for flood conveyance.</td>
<td>Very likely to be met</td>
</tr>
<tr>
<td>8</td>
<td>Sustainable diverse and productive land use.</td>
<td>Very unlikely to be met</td>
</tr>
<tr>
<td>Environmental Outcomes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Maintain flows in lowland streams to protect biodiversity values.</td>
<td>Very likely to be met</td>
</tr>
<tr>
<td>2</td>
<td>Water quality in drains/streams is improved.</td>
<td>Very likely to be met</td>
</tr>
<tr>
<td>3</td>
<td>Reduced nutrient inflow into lowland streams to support historical ecosystem health.</td>
<td>Likely to be met</td>
</tr>
<tr>
<td>4</td>
<td>Ecological values of stockwater races are retained or offset.</td>
<td>Not met</td>
</tr>
<tr>
<td>5</td>
<td>Ecologically significant wetlands and peat swamp remnants are protected.</td>
<td>Very likely to be met</td>
</tr>
<tr>
<td>6</td>
<td>Protect and enhance indigenous fish and habitats in lowland streams and foothills.</td>
<td>Likely to be met</td>
</tr>
<tr>
<td>7</td>
<td>Protect and enhance habitat for trout.</td>
<td>Likely to be met</td>
</tr>
<tr>
<td>8</td>
<td>Protect and enhance streams and subcatchments with only indigenous fish species.</td>
<td>Likely to be met</td>
</tr>
<tr>
<td>9</td>
<td>Remnant indigenous vegetation areas do not decrease in size.</td>
<td>Very likely to be met</td>
</tr>
<tr>
<td>10</td>
<td>Retain unique features and biodiversity of the dongas.</td>
<td>Very likely to be met</td>
</tr>
<tr>
<td>11</td>
<td>Protect remaining dryland biodiversity.</td>
<td>Likely to be met</td>
</tr>
</tbody>
</table>
5.4.2 Summary of the outcomes from the Exploratory Environmental Scenario

The Exploratory Environmental Scenario does not meet one of the eleven environmental outcomes, but the rest are all likely, or very likely, to be met. All of the cultural outcomes are likely to be met and half (two of four) of the social outcomes are also likely to be met. Only two outcomes are met, and both of these are economic.

This distribution of effects is expected from a scenario that was focused specifically on improvements to water quality and water quantity (Figure 5-3).

![Outcome Summary](image)

Figure 5-3: Summary of outcomes from the exploratory environmental scenario

The Exploratory Environmental Scenario provides a number of additional benefits when compared to the Exploratory Baseline Scenario. There are higher groundwater and stream flow levels, reductions in nitrogen concentrations, improvements in ecological protection, and improvements in cultural and recreational outcomes. The challenges are limitations on economic growth and employment, reductions in overall social wellbeing, and an increased risk of some unsustainable farm enterprises.

5.5 Comparison of the three exploratory scenarios

Both the discussions and the modelling showed that none of the three exploratory scenarios could meet all of the outcomes for the Hinds/Hekeao Plains catchment (Figure 5-4). The Exploratory Environmental Scenario was most likely to meet many more outcomes when compared to the other two scenarios, but potentially at significant social and economic costs.
General feedback from the community helped to change the technical team’s approach between that used for these exploratory scenarios, and the approach used for the two Solution Scenarios. The community wanted more public discussions about some of the key targets and outcomes, and were less interested than the technical team in ranking each scenario using the assessment system for the outcomes. The community also was not comfortable with this presentation style, as it appeared to give equal weighing to all of the outcomes, rather than highlight the ones they thought were most important. As a result, the technical team did not use the assessment system for the next part of the Subregional Plan development process, which investigated the Solution Scenarios.

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22 Outcome ‘Drain flows provide for abstractive use’ was not assessed during this workshop.
6 The Solution Scenarios

6.1 Overview

The next stage of this Subregional Plan development process required the development of mitigation options that could, potentially, address as many of the outcomes that were physically, economically, and technically feasible.

The technical team used a two-phase process. The first phase was the development of a potential options scenario, which was a suite of mitigation options that technically appeared feasible. The second phase took place over the following eight months, and involved community consultation, workshops, meetings and informal discussions. The aim was to refine and finally transform this set of mitigation options into a Solutions Package (AZC, 2014). The resulting solutions package was then shared and discussed with the community in an all-day workshop, to incorporate final feedback and ideas.

During the earlier exploratory scenario phase, it had already become obvious that any mitigation options for the Hinds/Hekeao Plains catchment area were not going to be resolved at an individual farm or stakeholder level. Instead, wholesale changes would be needed to reduce water contamination and increase water availability, because most of the outcomes were dependent on the condition of the groundwater system.

Therefore, the Solutions Package was divided into catchment-scale mitigation options (that require system-wide implementation and community-wide adoption), and local-scale mitigation options (that are site-specific and need individual management).

6.2 Hinds/Hekeao Plains catchment targets and goals

In order to determine if community outcomes were met, Hinds/Hekeao Plains catchment targets were presented to the community. These targets were based on scientifically documented environmental thresholds, as well as culturally identified values (Table 6-1). The links between community outcomes (e.g. healthy lowland streams) and specific numerical values (e.g. 6.9 mgN/L of nitrate-N) were determined through deliberations and modelling runs to define a final set of limits.

Another set of targets were not given as absolute values but ranges, because of the nature of the technical information available. For example, the quantity of MAR required started as 5.0 m³/s but through the modelling process it became clear that spatial variably, sources of water, and other factors including between biophysical models made it difficult to provide a definitive value. Many of these ranges started as targets at the beginning of the scenario development process. These goals would then, through community consultation, be further refined through an adaptive management approach for example including the Hinds Drains working party and/or MAR pilot project.
Table 6-1: Targets and goals for the two solution scenarios

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Mechanism</th>
<th>Numerical target/goal</th>
<th>Potential Option Scenario</th>
<th>Solutions Package</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improve water quality in the lower catchment</td>
<td>On-farm mitigation options: Load Limit and concentration targets for Nitrate-Nitrogen</td>
<td>Concentration target (mg/L) in groundwater and spring-fed waterbodies, catchment load of total N (tonnes)</td>
<td>3100 tonnes of nitrate-N, includes reductions from outside Overseer® farm mitigations</td>
<td>On-farm nutrient management transitions from Good Management Practices (GMP) to levels of advanced mitigation options, based on farm type to reduce leaching from baseline conditions (2009-2013)</td>
</tr>
<tr>
<td>Improve water quality in the lower catchment</td>
<td>Dilution of groundwater concentrations using MAR tools</td>
<td>Concentration target (mg/L) in groundwater and spring-fed waterbodies, catchment load of total N (tonnes)</td>
<td>6.9 mg/L nitrate-N, approximately 5.0 m³/s of MAR needed for water quality</td>
<td>MAR pilot testing, develop tool to maximise dilution capabilities relative to costs and water availability, at least 3.8 m³/s of MAR estimated as needed for water quality targets</td>
</tr>
<tr>
<td>Improve water quantity in the lower catchment</td>
<td>Increase aquifer storage levels and spring-fed waterbodies using MAR tools</td>
<td>Increase reliability for groundwater and surface takes, increase minimum flows levels for cultural and ecological values</td>
<td>Approximately 5.0 m³/s of MAR, 300 to 400 mm minimum channel depth in spring-fed waterbodies</td>
<td>Achieve 2020 goals by 2035 through development of MAR and augmentation tools, at least 2.8 m³/s of MAR estimated to be needed for quality targets</td>
</tr>
<tr>
<td>Maintain water quality in the upper catchment</td>
<td>Cap current water usage</td>
<td>Current allocated usage</td>
<td>Current allocated usage</td>
<td>Current Allocated usage ---</td>
</tr>
<tr>
<td>Maintain water quality in the upper catchment (catchment-scale)</td>
<td>On-farm nutrient management</td>
<td>Maintain current estimated catchment loads of 6.1 tonnes P/yr and 114 tonnes N/yr, GMP or better</td>
<td>6.1 tonnes P/yr and 114 tonnes N/yr, GMP or better based on Exploratory Baseline Scenario conditions</td>
<td>All land users to be at GMP or better, establish Overseer® baseline (2009-13)</td>
</tr>
<tr>
<td>Local-scale options</td>
<td>Implement a range of mitigation options relative to site conditions</td>
<td>Restoration; sufficient to achieve the environmental, cultural and social Community Outcomes</td>
<td>100% of waterbodies by 2035</td>
<td>Achieve targets by 2035</td>
</tr>
<tr>
<td>Local-scale options</td>
<td>Implement a range of mitigation options relative to site conditions</td>
<td>Restoration; sufficient to achieve the environmental, cultural and social Community Outcomes</td>
<td>100% of waterbodies by 2035</td>
<td>Achieve targets by 2035</td>
</tr>
<tr>
<td>Economic development</td>
<td>New irrigation</td>
<td>Up to 30,000 ha of new irrigation supporting more intensive nutrient loading activities</td>
<td>Up to 30,000 ha of new irrigation by 2035</td>
<td>30,000 ha Allowed to occur by 2035</td>
</tr>
</tbody>
</table>

23 Groundwater quality modelling defined MAR as ‘new water’, (See Figure 6-3).
24 Groundwater quantity modelling defined MAR as ‘new water’, (See Figure 6-3).
6.3 Catchment-scale mitigations

The primary challenge in setting up the Potential Options Scenario centred on the following question:

‘How to increase the area of intensive irrigated farm land whilst improving the water quality and water quantity in the underlying groundwater?’

This question summarises many of the opportunities and challenges in the Hinds/Hekeao Plains catchment. As mentioned in Section 6.1, groundwater plays the central role in most of the 25 outcomes, so finding the correct solutions to manage the aquifer in order to meet the water quality and water quantity targets is essential.

As aquifers are catchment-scale features, two primary tools were available:

1) Managed Aquifer Recharge to replenish groundwater with volumes of clean water for dilution and increased sub-surface storage.
2) On-farm nutrient management to reduce contaminants leaching to groundwater and lowland waterbodies.

Two additional items that were complementary to these primary tools were also included in the community discussions: surface water storage, and a regulatory approach to reducing groundwater allocations. Surface storage was included mainly as a measure to support the implementation of MAR, because the source of additional water for recharge was unclear. It also provided source water for additional irrigation beyond that gained through efficiencies such as piping of races.

Starting with the mitigation options to manage groundwater quantity, the reduction of groundwater allocations has two related issues. Firstly, consented (paper water) usage does not align with actual (metered) usage (Section 3.4.1). When considering the future management of groundwater, it is critical that consented allocation is reduced to better match actual usage and available groundwater supplies, because current consents represent a legal ability to use considerably more water from the aquifer (Table 3-3). This is also true of the spring-fed waterbodies, where consented allocations are considerably higher than the water currently available in the spring-fed waterbodies, due to declining baseflows. Therefore, if groundwater levels and spring-fed flows were increased as a result of MAR, the existing consented allocations could easily use the additional water, making it difficult to restore habitat and cultural values.

Secondly, declines in aquifer levels and spring-fed minimum flows are already occurring under the current actual usage. Therefore, simply reducing the consented allocations will not be enough to remedy the groundwater situation. The options that remain are to increase the amount of recharge to stabilise and restore the groundwater water balance, and/or provide new sources of water to be captured for recharge and/or additional irrigation activities (storage).

Figure 6-1 shows a conceptual comparison of current conditions and proposed options (the Exploratory Baseline Scenario compared to the potential options scenario), using allocation reductions coupled with MAR. For demonstration purposes, it depicts a simple water balance for the Hinds/Hekeao Plains aquifer, where various recharge mechanisms are balanced with discharge mechanisms.

Under the Exploratory Baseline Scenario conditions, some of the allocation (usage) is offset by current irrigation-related incidental recharge, but the recharge is not sufficient to compensate for over-abstraction. An aquifer system where total discharge exceeds recharge is considered to be in decline. This imbalance means that groundwater levels (and spring flows) continue to decrease over time, which is a prominent feature of the spring-fed waterbodies on the Valetta GAZ side of the catchment (Pers. Comm., Hinds Drains Working Party, 2014).

Declining groundwater levels means that hydraulic gradients begin to change between the aquifer and the surrounding rivers. These steepened gradients create an increased potential for channel bed losses, which reduces the alpine river baseflows. In the groundwater balance the increased abstraction is therefore partly offset by decreased river base flows. Irrigation and rainfall provide
episodic recharge, which is dependent on both climate patterns and farm water management. These in turn are both subject to long-term changes in weather patterns in response to climate change. The Rangitata and Ashburton River systems, in contrast to the rainfall and irrigation, represent a perennial potential source of recharge that is continually connected to the groundwater system (Golder, 2014).

In the Solutions Package Scenario, additional recharge (MAR) helps to balance groundwater storage in two ways. Firstly, it offsets the decreasing recharge which results from the piping of racings and from conversions to more efficient irrigation systems (border dyke to spray) (Figure 6-1). Secondly, the additional recharge increases the amount of water entering the aquifer to the point where it equals the amount being abstracted, and provides enough storage to support perennial baseflows to the lowland waterbodies.

The result is a managed and sustainable balance for the groundwater and lowland waterbodies, which could be implemented through an adaptive monitoring and groundwater replenishment scheme (Golder, 2014). A key issue, however, is that the lowland waterbodies also provide a drainage function, and this would need to be carefully managed through the scheme’s design and operation.

Figure 6-1: Groundwater balance: the current baseline compared with a potential solution (MAR)

Groundwater quality was the other target that the Potential Options Scenario was designed to address, and the catchment-scale mitigation option for water quality had two objectives. Firstly, to limit the amount of nitrogen entering the aquifer through the soil profile at the contaminant source (farm level leaching).

Secondly, to replenish the aquifer with additional high-quality water to help reduce contaminant concentrations. MRB (Everest 2013) used the nutrient budget model Overseer® to develop four on-farm mitigation levels (GMP, AM1, AM2 and AM325) that represented increased reductions in leaching for a series of representative farms in the catchment (Figure 6-2).

25 GMP (Good Management Practices), AM1 (Advanced Mitigations Level 1, 2 and 3) (Everest, 2013; Scott, 2013).
Through the development of the Potential Options Scenario, it appeared that GMP was sufficient for most farm systems, but dairy systems (dairy and dairy support) would require a combination of AM1 and AM2. However, these on-farm mitigations were insufficient to achieve the target nitrate-N concentration of 6.9 mgN/L in the aquifer (Scott, 2013), but the target concentration was achievable with the addition of MAR as a mechanism for dilution (see Section 6.6 for more information).

As the sources of nitrogen are spatially distributed, and the Zone Committee wanted to protect the quality of drinking water, MAR dilution (in the form of infiltration sites) was conceptually targeted to be located at or near high-leaching farm sources (Golder, 2014).

The technical team designed the targeted recharge to avoid portions of the aquifer becoming increasingly contaminated over time with nitrate-N, and to try to ensure that all of the spring-fed waterbodies had an equal opportunity to meet the target concentration of 6.9 mgN/L for nitrate-N (Figure 6-2). This is equally relevant to the groundwater storage being increased to ensure that minimum flows and reliability in the spring-fed waterbodies are enhanced with MAR. Targeting the replenishment of clean water at or near the sources of contamination and/or the areas where high nitrates are being recorded would reduce the time taken to achieve the target concentrations in the aquifer and spring-fed waterbodies.

Figure 6-2: Conceptual drawing of the catchment-scale groundwater replenishment scheme targeting a dilution nitrate-N and increased groundwater levels to support minimum flows in spring-fed waterbodies

Arowhenua strongly reinforced this whole aquifer approach during community consultations based on their principle of water as a wāhi taonga (Table 2-1). This cultural outcome requires that the water itself, the resources living in it, and the wider environment are sustained, and that the condition of the

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water is not affected by any modification that may have occurred. In practice, this means that allowing portions of the groundwater system and spring-fed waterbodies to become increasingly polluted is inconsistent with Arowhenua culture.

This whole aquifer approach is also relevant to providing consistent quality across the drinking water supplies for the catchment. Allowing some areas to have poor quality drinking water while other areas have higher quality drinking water, is considered socially inequitable. It is also inconsistent with the Canterbury Water Management Strategy (CWMS).

As part of the Potential Options Scenario, both the on-farm mitigations and MAR were implemented over the lifetime of the plan (2015 to 2040), as part of a staged approach. For the on-farm mitigation options, this gave farm managers the time to implement changes to their current nutrient and water management practices, as advanced mitigation options required additional expenditure. It also provided the agricultural industry with additional time to develop more advanced methods (such as nitrogen inhibitors) to reduce nutrient leaching.

The use of MAR also represented a new concept for the community. There were uncertainties around its effectiveness in helping to reduce contaminants in the aquifer, the costs and availability of source water, and the effect on lowland drainage. This meant that the implementation of MAR would start with a demonstration pilot before moving towards developing a catchment-scale replenishment scheme. It is also important to note that the lag effect plays a role in the Solutions Package Scenario timeline, in relation to the quality and concentration targets (Table 6-1).

Similarly, the water balance concept of dynamic equilibrium acknowledges that catchment-scale aquifers can take a considerable period of time to recover following major disturbances to the balance, such as long return period droughts or the instigation of a major MAR system. Large progressive changes in recharge, such as the shift away from border dyke irrigation or discharge in the form of increasing abstraction lead to extended periods of aquifer rebalancing. In effect, the groundwater system is continuously rebalancing in response to events and changes that occurred during the previous few years (Golder, 2014).

6.4 Local-scale mitigation options

The local-scale mitigation options in the Potential Options Scenario are intended to deliver smaller-scale improvements at point source, farm and stream-reach levels (Meredith and Lessard, 2014b). These mitigation options consist of both physical measures such as riparian fencing, and regulatory measures such as increasing minimum flows. Both types of measure aim to achieve the community outcomes and environmental targets.

These mitigation options provide variable benefits that will be more difficult to quantify, as they will be highly dependent on site-specific conditions and designs, and would vary across the sub-catchment areas (Figure 3-1). For example, the lowland waterbodies could benefit from some in-stream structural enhancements to improve habitat, but this has to be weighed against any significant reduction in the drainage functions. However, in the Upper Hinds/Hekeao Plains catchment there is an opportunity to focus more specifically on the goal of habitat restoration.

These mitigation options were presented to the community in the Potential Options Scenario, and are summarised in Table 6-2. At the time of this workshop, the estimated needs (e.g., how much riparian fencing was needed) and costs for these various mitigation options had not yet been estimated (they are further discussed in Section 7).
### Table 6-2: Local-scale potential mitigation options

<table>
<thead>
<tr>
<th>Local-scale mitigation</th>
<th>Benefit</th>
<th>Desired Outcomes</th>
<th>Hinds/Hekeao sub-catchment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wellhead protection</td>
<td>Reduces contaminants’ pathways through poorly protected bore casings</td>
<td>Drinking water, cultural, environmental</td>
<td>All</td>
</tr>
<tr>
<td>Riparian management</td>
<td>Reduces surface movement of contaminants to waterbodies, enhances habitat and biodiversity</td>
<td>Environmental, cultural, social</td>
<td>All</td>
</tr>
<tr>
<td>Improved drainage</td>
<td>Decreases drainage issues while enhancing ecological values by less invasive methods of maintenance</td>
<td>Environmental, cultural, drainage functions, water quality, water quantity</td>
<td>Coastal waterbodies</td>
</tr>
<tr>
<td>management</td>
<td>(e.g. macrophyte removal)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Targeted sediment</td>
<td>Removes legacy sediments in specific catchment locations</td>
<td>Environmental, cultural</td>
<td>Some Coastal waterbodies</td>
</tr>
<tr>
<td>removal</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>In-stream habitat</td>
<td>Restores in-stream channel morphology (e.g. depth, width, and complexity) for habitat</td>
<td>Environmental, cultural, social, water quality, water quantity</td>
<td>Upper, Hinds/Hekeao River, Coastal waterbodies</td>
</tr>
<tr>
<td>restoration</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>River mouth openings</td>
<td>Periodic openings for fish migration</td>
<td>Environmental, cultural</td>
<td>Lower Hinds/Hekeao River</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Removal or installation of passage barriers for fish</td>
<td>Promotes native and non-native fish species</td>
<td>Environmental, cultural, social (recreational)</td>
<td>Tributaries to Lower Hinds/Hekeao River, Coastal waterbodies</td>
</tr>
<tr>
<td>Constructed and natural wetlands</td>
<td>Protects spring-heads for quality and habitat, enhances opportunities to sustain and access mahinga kai</td>
<td>Environmental, cultural, water quality</td>
<td>Upper, Hinds/Hekeao River and coastal waterbodies</td>
</tr>
<tr>
<td>Minimum flows and allocation</td>
<td>Increases irrigation season flows through limit setting and allocation reductions</td>
<td>Environmental, cultural, water quality, water quantity</td>
<td>Lower Hinds/Hekeao River and coastal waterbodies</td>
</tr>
<tr>
<td>Point source discharges</td>
<td>Manages current and future point sources of contamination</td>
<td>Environmental, cultural, drinking water, water quality</td>
<td>All</td>
</tr>
<tr>
<td>Development of farm-level Farm Environmental Plans (FEP)</td>
<td>Builds specific management strategies for nutrient management</td>
<td>Environmental, cultural, water quality, water quantity</td>
<td>All</td>
</tr>
<tr>
<td>Targeted Flow Augmentation</td>
<td>Directs clean, small rates of water to key spring-head areas</td>
<td>Environmental, cultural, water quality, water quantity</td>
<td>Specific sites in coastal waterbodies</td>
</tr>
</tbody>
</table>

### 6.5 Water quantity modelling

The Potential Options Scenario was first presented in the community workshop using estimates from the RDM model, but in the following consultation period (June 2013 to March 2014), the MIKE SHE modelling platform was used and developed. Additionally, community discussions around the volumes and costs of MAR needed (e.g. 5.0 m$^3$/s, year round) made it more difficult to determine a specific number for MAR.

Another key challenge around the water quantity modelling was providing the community with clearer, more concise understanding of what the amount (measured in m$^3$/s) of MAR actually represented in each scenario. Total MAR needed consisted on a compilation of both replacement water (for offsetting historical and planned losses of incidental recharge) and new water (additional recharge that helped stabilise and restore groundwater and flow levels relative to overall declining trends (Figure 6-3). As irrigation efficiencies play a major role in the wise management of water volume and nutrient leaching, it is important to encourage their implementation. However, it is also important to consider that decreasing levels of incidental recharge, represents a loss of recharge to the aquifer system, making both the water quality and water quantity goals much harder to achieve.

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26 Achievement of universal minimum flows is linked to catchment-scale increases in groundwater levels restored from MAR.

27 Targeted Flow Augmentation (a potential tool of MAR) - use of targeted recharge near or at the spring-heads to help increase flows and reduce the in-stream concentrations of nitrogen. Under the COMAR (Tipa, 2014) the direct (water into water) mixing of waters was not culturally acceptable, making direct augmentation a topic that requires further consultation. The use of wetlands constructed to recharge groundwater near springs could also be considered to find compromised solution for targeted augmentation.
Using the RDM model, the technical team modelled the Potential Options Scenario to show the effects that the mitigation options would have had on changes in groundwater levels. A range of 3 to 7 m³/s (which includes both replacement and new water) of MAR recharge was modelled. The modelling did not spatially differentiate MAR rates between the Mayfield-Hinds GAZ and the Valetta GAZ. A final value of 5.0 m³/s was used for the community presentation. This value was consistent with the amount of dilution being estimated in the water quality biophysical model (Scott, 2013).

The technical team carried out correlations between increased minimum flows, to estimate increases in flow relative to the desired cultural (300 mm) and environmental (400 mm) depths of water in streams (Durney, 2014a). These flow projections were based on data from across the lowland waterbodies to develop a table of estimated minimum flows, and allocation recommendations. The technical team presented the results to the Zone Committee and the community through a series of meetings and workshops. There was considerable concern around the calculations, and the uncertainty around the ability of MAR to increase groundwater levels significantly and safely (without affecting drainage) to achieve these targets.

The result of those discussions was the Addendum recommendation of the Hinds Drains Working Party, proposing to work through a consultation process to develop a better understanding of these issues and make recommendations by December 2015.

As the Hinds/Hekeao community consultation process progressed, Environment Canterbury’s MIKE SHE model was finalised and made available, to better predicting the potential of the mitigation options in helping to improve groundwater levels and stream flows. The MIKE SHE model provided a truly integrated surface/groundwater catchment-scale model that was a more suitable modelling platform.

![Breakdown of MAR rates to show both new and replacement recharge needs](image)

Figure 6-3: Breakdown of MAR rates to show both new and replacement recharge needs

In order to determine the relative changes between the Exploratory Scenarios and the Solution Scenarios groupings, the MIKE SHE model was calibrated for a baseline, a dry land and several Solutions Package Scenarios. The three scenarios analysed using MIKE SHE were:

- **Baseline Scenario.** Used for calibration using the climate period 1981 to 2012, and estimated land use for 2011/12 irrigation season.
• **Dry Land Scenario.** Similar land use to baseline, but no irrigation, no stockwater races, and no RDR or distribution race losses including no groundwater pumping. Considered 'quasi-natural' as existing drainage infrastructure prevents groundwater levels from recovering to their original state. Modelled to determine the overall effects of incidental recharge from irrigation activities relative to the baseline.

• **Solutions Package Scenarios.** Two iterations of the Solutions Package Scenario for additional recharge with MAR:  
  - **Iteration 1.** A combined MAR rate of 5.38 m$^3$/s divided between the two Groundwater Allocation Zones for Mayfield-Hinds (2.87 m$^3$/s) and Valetta (2.51 m$^3$/s). Relative to replacement versus new water, this scenario meant a net loss for the Mayfield-Hinds GAZ where scheme piping was assumed, and a net gain of 1.3 m$^3$/s new water in the Valetta GAZ.  
  - **Iteration 2.** A combined MAR rate of 7.47 m$^3$/s divided between the two Groundwater Allocation Zones for Mayfield-Hinds (4.12 m$^3$/s) and Valetta (3.35 m$^3$/s). Relative to replacement versus new water, this scenario meant a net gain for the Mayfield-Hinds GAZ of 0.55 m$^3$/s and a net increase of 2.23 m$^3$/s of new water in the Valetta GAZ.

More specifically, the technical team assessed the effect on each scenario by running the scenario model for each land use scenario. This approach:

- allowed the resulting changes in groundwater levels and stream flows to be reviewed
- effectively assessed the relative change between the calibrated baseline model and each scenario under the same known climatic conditions
- eliminated the effects associated with the uncertainty of future forecasting
- focused only on the changes caused by the proposed land use.

The results of the scenarios show that if irrigation efficiency is increased (further conversions from border dyke to spray) in the Mayfield-Hinds GAZ, groundwater levels will decline even with a one-for-one swap of MAR for distribution losses in the Mayfield-Hinds GAZ (Durney, *et al.*, 2014). This modelling indicates that to maintain baseline flows in the Mayfield-Hinds GAZ, approximately 1 m$^3$/s of additional new water will be required.

In the Valetta GAZ, the model results show that, aside from scheme piping, groundwater pumping is a key factor in the current low stream flows. Additional MAR beyond a direct replacement for the lost incidental recharge from stockwater and scheme piping will be required to improve flows. Approximately 1 m$^3$/s of new water will maintain flows in the Valetta GAZ, similar to the Exploratory Baseline Scenario, while approximately 3 m$^3$/s of new water is needed to improve groundwater storage and surface water flows.

An example of Valetta GAZ area model results from Solution Package Scenario – Iteration 2 demonstrate that recharge of 2.3 m$^3$/s of new water will increase water levels and groundwater storage in the Upper and Middle Hinds/Hekeao Plains (Figure 6-4 and Figure 6-5). Bore K37/0589 model results are representative of overall MIKE SHE modelling results for the Valetta GAZ.

In comparison to the Exploratory Baseline Scenario, there is clearly increasing trend in groundwater levels, which indicates an overall increase in groundwater storage (levels) (Figure 6-6). This dampened groundwater level improvement in coastal areas is the intended goal of the Solutions Package (MAR), as it attempts to provide enough baseflow for reliable ecological, cultural and irrigation outcomes, but avoids raising groundwater to a level that results in soil saturation and field ponding.

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28 For modelling purposes, MAR was distributed evenly through the same network of injection bores used to model race losses in the Baseline scenario (Durney, *et al.* 2014).
Figure 6-4: Solutions Package Scenario Iteration 2 (for Valetta GAZ in Upper Hinds/Hekeao Plains) showing a comparison of increasing groundwater storage and water levels (m amsl)

Figure 6-5: Solutions Package Scenario Iteration 2 (for Valetta GAZ in Middle Hinds/Hekeao Plains) showing a comparison of increasing groundwater storage and water levels (m amsl)

Figure 6-6: Solutions Package Scenario (Iteration 2 for Valetta GAZ in Lower Hinds/Hekeao Plains) showing a comparison of improved groundwater storage and water levels (m amsl)

MIKE SHE modelling results for flows show that these improved groundwater levels represent improvements in the Hinds/Hekeao River (Figure 6-7).
When compared relative to the Exploratory Baseline Scenario, Iteration 1 and Iteration 2 show improved flows in the lower Hinds/Hekeao River of, on average, between 26 L/s to 58 L/s, which is a 10 to 21% range in improvement.

Similarly, improvements in spring-fed waterbodies’ flows are also evident, as shown in the Valetta GAZ on Flemington Drain (Figure 6-8). The Flemington Drain is particularly relevant as the historical trend of both decreasing reliability and minimum flow levels is reported to be most evident starting at this drain and moving north away from the Hinds/Hekeao River (Per. Comms., Hinds Drains Working Party 2014). This drying trend is evident in Environment Canterbury’s data for spring-fed waterbodies in this area, which show the frequency of drying increasing during the irrigation season (Durney et al., 2014).
Overall average improvements in average Mean Annual Low Flows (MALF) calculated for the spring-fed waterbodies in each of the solutions package iterations are shown in Table 6-3. While percentage increases could be relatively high, the actual flow improvements were in the order of tens of L/s. The level of overall improvements was not determined by the community process, so the target for minimum flows will be determined through the Hinds Drains Working Party process (AZC, 2014).

**Table 6-3: Solutions Package modelling results for average 7-day MALF flow increases in spring-fed waterbodies**

<table>
<thead>
<tr>
<th>Spring-fed Waterbodies</th>
<th>Model Area</th>
<th>Iteration 1 (L/s)</th>
<th>Iteration 1 (%)</th>
<th>Iteration 2 (L/s)</th>
<th>Iteration 2 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valetta GAZ</td>
<td></td>
<td>9 to 28 L/s</td>
<td>34 to &gt;1,000%</td>
<td>9 to 53 L/s</td>
<td>34 to &gt;1,000%</td>
</tr>
<tr>
<td>Mayfield–Hinds GAZ</td>
<td></td>
<td>1 to 33 L/s</td>
<td>5 to 47%</td>
<td>1 to 50 L/s</td>
<td>6 to 56%</td>
</tr>
</tbody>
</table>

Related to the community’s outcome to achieve 95% reliability in water supplies, the relative improvements (as a percentage) for each of the solutions package scenarios relative to baseline show that most of the 17 waterbodies could achieve the 95% reliability target under Iteration 2, and all showed overall improvements based on higher minimum flows. As modelled, the Hinds/Hekeao River did not achieve 95% reliability, but the use of more targeted recharge (Golder, 2012) could be used to bring up the reliability. Cultural issues around the mixing of waters would need to be further discussed.
The Solutions Package modelling using MIKE SHE revealed the following key points about the water quantity situation in the Hinds/Hekeao catchment:

**Groundwater:**
- Declines in groundwater levels were linked to groundwater pumping and changes in irrigation efficiencies (e.g. piping, border dyke to sprinkler conversions).
- If additional pumping and irrigation efficiencies occur in the Mayfield-Hinds GAZ, similar declines in groundwater levels will be experienced.
- Modelled mitigation options in the Solutions Package resulted in improved groundwater levels.

**Surface Water:**
- Lowest flows are specifically affected by irrigation season shallow groundwater pumping
- Modelled mitigation options in the Solutions Package improved both baseflows and reliability of supply

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29 Zone committee moved the minimum flow site was moved from Boundary Road to Poplar Road, and changed from 700 to 770 L/s (AZC, 2014). However, model outputs are for Boundary road. Flow reliability would be increased significantly at Poplar based on its location further downstream.

30 Direct takes from the drains were modelled as shallow groundwater.
6.6 Water quality modelling

During the development of the Solution Scenarios, numerous consultations with the community and industry experts (including DairyNZ and MRB) led to agreed changes in our approach to water quality modelling. Originally, MRB used Overseer® modelling and added some nutrient reduction mitigations, which are not currently widely accepted in the industry as ‘scientifically proven’ as they are still being field trialled. MRB did this to try and project scientific advancements that ‘could’ be available in the next 25 years of modern agricultural advancements. Since the implementation of the Subregional Plan revolved around the use of Overseer® for the consenting and accountability of the load limits, the additional nutrient reduction mitigations were removed from the overall Solutions Package. This meant that the overall catchment loads increased, so the water quality and economics modelling had to be recalculated to account for the changes.

The key ‘outside Overseer®’ additional mitigations excluded in the water quality (nitrate-N) modelling from the original MRB (Everest, 2013) information (Scott, 2014a):

- The use of mixed pasture sward.
- Short rotation ryegrass.
- Nitrification Inhibitors (e.g. dicyandiamide, DCD) on forage crops all used to reduce leaching.

The net effect of the exclusions was that it increased the catchment load calculations up by approximately 10%. Note that MRB (Everest, 2013) original work did include DCD use on pasture inside the Overseer® modelling. This mitigation measure was kept as the zone committee made the assumption that there was a strong chance of some form of nitrification inhibitor being developed over the next 25 years. Therefore this ‘inside Overseer®’ use of DCD remained in the final modelling results. All DCD was removed from GMP farming practices when the Baseline Scenario (current conditions) was remodelled for comparison.

During the community consultation process, many iterations of the water quality model were performed that included work done to populate the nutrient decision tool (Figure 2-2), comparisons to updated local information (e.g. HPLWP land use estimates) and other changes. As the Scott (2013) report only documented the modelling work through the potential options scenario, additional technical memos were prepared. These documented in Scott, 2013a, Scott, 2013b, Scott, 2013c, Scott, 2014a, 2014b, 2014c, and 2014d. These technical memos were prepared, so that these other changes could be documented.

Following the revisions to the MRB work, the final estimates for each of the MRB farm systems, soil groupings and mitigation levels could be calculated with current leaching rates ranging from 5 to 71 kg N/ha/yr (Table 6-5). There are a large number of technical revisions, assumptions and limitations to this the information presented in this table, which are detailed in Scott, 2014a.

Table 6-5: Solutions Package final nitrogen leaching estimates (kg N/ha/yr) based on farm systems, typical soil types and mitigation levels (Scott, 2014a)

<table>
<thead>
<tr>
<th>Farm system*</th>
<th>Soil</th>
<th>Current</th>
<th>GMP</th>
<th>AM1</th>
<th>AM2</th>
<th>AM3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arable 1</td>
<td>MH</td>
<td>18</td>
<td>18</td>
<td>9</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Arable 2</td>
<td>L</td>
<td>27</td>
<td>27</td>
<td>18</td>
<td>14</td>
<td>13</td>
</tr>
<tr>
<td>Arable 3</td>
<td>MH</td>
<td>16</td>
<td>16</td>
<td>12</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>Arable 4</td>
<td>DPD</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Dairy 1</td>
<td>VL</td>
<td>64</td>
<td>64</td>
<td>26</td>
<td>24</td>
<td>10</td>
</tr>
<tr>
<td>Dairy 2</td>
<td>VL</td>
<td>71</td>
<td>71</td>
<td>36</td>
<td>23</td>
<td>11</td>
</tr>
<tr>
<td>Dairy Support 1</td>
<td>VL</td>
<td>69</td>
<td>67</td>
<td>33</td>
<td>22</td>
<td>11</td>
</tr>
<tr>
<td>Dairy Support 2</td>
<td>L</td>
<td>43</td>
<td>41</td>
<td>22</td>
<td>16</td>
<td>9</td>
</tr>
<tr>
<td>Sheep, beef, deer 1</td>
<td>MH</td>
<td>10</td>
<td>10</td>
<td>7</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Sheep, beef, deer 2</td>
<td>L</td>
<td>19</td>
<td>19</td>
<td>12</td>
<td>9</td>
<td>8</td>
</tr>
</tbody>
</table>

* Excluded from this table - small farm systems that included lifestyle and other, making up <3% of lower catchment total area.
From this point onwards, the process focused on developing the community recommendations for the Solutions Package. Three primary issues drove the technical iterations for the water quality modelling and consultation process, as follows:

- On-farm mitigations: the costs (GMP $ to AM3 $$$), the community’s confidence in the effectiveness of these mitigation, and the time required for farmers to transition to more advanced/costly mitigation options.
- MAR has been shown internationally to be a useful water management tool, but its application in the Hinds/Hekeao Catchment Subregional Plan development process was still considered as an unknown.
- The ability of the community to allow both new irrigation whilst trying to reduce the overall nitrate-N load in the catchment was of considerable concern.

Following the revisions to the MRB input information, the current catchment load was calculated at 4500 t N/yr. Through the continued development of additional intensive dairying activities, the catchment load could increase to more than 5900 t N/yr. This would equate to a nitrate-N concentration in shallow groundwater of 14 mg N/L or more, well over the national bottom-line value of 6.9 mg/L nitrate-N in lowland streams.

It is important to note that, early in the discussion about the overall water quality modelling process, the technical team decided to round the values output from the water quality model to the nearest hundred tonnes. This was due to the uncertainty surrounding all of the combined model inputs, data accuracy, and to avoid projecting a false sense of accuracy around the water quality modelling. (e.g. an output value of 4524 t N/yr for the current catchment load was presented as 4500 t N/yr). The goal of the two catchment-scale mitigation options (on-farm mitigation, and MAR) was to achieve nitrate-N concentrations in lowland waterbodies that were below 6.9 mg N/L.

If all farming operations implement the maximum advanced mitigation options that are available (Advanced Mitigation Level 3 – AM3), the catchment load calculations show that 6.9 mg N/L could be achieved without MAR (Figure 2-2). However, given the very high infrastructure costs of AM3, the Zone Committee did not see this as a viable option. Economic assessments done by Agresearch (2014, Paragahawewa, 2014) also showed that a groundwater replenishment scheme that targeted high quality water using MAR throughout the catchment was more cost-effective than the AM3 mitigation levels for dairy and dairy support (Section 6.8.1).

The final catchment load target of 3400 t N/yr (3,446 t N/yr) derived for the Solutions Package Scenario was calculated to give a concentration of 9.9 mg/L nitrate-N in shallow groundwater and spring-fed waterbodies, with the application of on-farm mitigation options (Scott, 2014a). Modelling showed that application of the on-farm mitigation options alone is insufficient to meet the water quality targets, and MAR is required to dilute the 9.9 mg N/L to 6.9 mg N/L that was calculated to be greater than 4.8 m³/s of MAR (new water). Through the consultation process, to help meet the outcome of increasing economic activity by 30,000 ha of new irrigation, a leaching cap of 27 kgN/ha/yr for farms wanting to convert to higher leaching land uses (Table 6-6). When the Solutions Package was modelled to include the cap, the total nitrogen load reduced to 3200 tN/yr (3241 tN/yr) and nitrate-N concentrations leaching losses reduced to 9.3 mgN/L. This resulted in only 3.8 m3/s of MAR being required to dilute groundwater concentrations to the target of 6.9 mgN/L by 2035.
Table 6-6: Nitrogen loads and nitrate-N concentrations from the Hinds/Hekeao Plains water quality model (assuming 28,500 ha new irrigation) in the Solutions Package Scenario

<table>
<thead>
<tr>
<th>Scenario</th>
<th>No cap</th>
<th>Capped at 27 kgN/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>RECHARGE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land surface recharge volume (million m$^3$/yr)</td>
<td>349</td>
<td>349</td>
</tr>
<tr>
<td>Average soil drainage (mm/yr)</td>
<td>275</td>
<td>275</td>
</tr>
<tr>
<td>NITROGEN LOADS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leaching losses by land use (tN/yr)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arable – irrigated (GMP)</td>
<td>503</td>
<td>503</td>
</tr>
<tr>
<td>Arable – dry land (GMP)</td>
<td>0.9</td>
<td>0.9</td>
</tr>
<tr>
<td>Dairy (AM1/AM2 with DCD)</td>
<td>1637</td>
<td>1552</td>
</tr>
<tr>
<td>Dairy support (AM1 with DCD)</td>
<td>1128</td>
<td>1008</td>
</tr>
<tr>
<td>Sheep, beef and deer</td>
<td>140</td>
<td>140</td>
</tr>
<tr>
<td>Other</td>
<td>34</td>
<td>34</td>
</tr>
<tr>
<td>Forest</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Catchment total nitrogen load (tN/yr)</td>
<td>3446</td>
<td>3241</td>
</tr>
<tr>
<td>Average nitrogen leaching rate (kgN/ha/yr)</td>
<td>27</td>
<td>25.5</td>
</tr>
<tr>
<td>NITRATE-NITROGEN CONCENTRATIONS</td>
<td>9.9</td>
<td>9.3</td>
</tr>
<tr>
<td>Average in shallow groundwater and springs without managed aquifer recharge</td>
<td>9.9</td>
<td>9.3</td>
</tr>
<tr>
<td>MANAGED AQUIFER RECHARGE</td>
<td>Volume of MAR (new water) needed to dilute nitrate-nitrogen concentrations to the 6.9 mgN/L target (m$^3$/s)</td>
<td>4.8</td>
</tr>
</tbody>
</table>

This leaching cap value of 27 kgN/ha/yr was calculated from two different aspects of the information available. Firstly, 27 kgN/ha/yr it is the average nitrogen leaching rate for entire catchment load (3,400 t/yr) divided by total catchment ha (approximately 127,028 ha). Secondly, using the MRB (Everest, 2013) information, 27 kgN/ha/yr appears technically feasible around the AM2 mitigation level. MRB also reported that the AM2 level of mitigation was also economically feasible for farms in the Hinds/Hekeao catchment. When this leaching cap was modelled as part of the final Solutions Package, it reduced the overall catchment load to 3200 t N/yr (3241 t N/yr). As the Zone Committee recommendation was for a catchment load of 3,400 t N/yr (3446 t N/yr), this unallocated 200 t N/yr can provide additional flexibility to existing farm systems to select mitigations practices from either AM1 and AM2, or may help to reduce the amount of MAR needed for further dilution.

This difference also provided some room for the difference between the community outcomes of 30,000 ha of new irrigation and the actual modelled values of 28,500 ha. The amount of dilution required from MAR in this final scenario was between 3.8 m$^3$/s and 4.8 m$^3$/s to achieve the target of 6.9 mgN/L.

To achieve these targets, the community requested that a percentage reduction be included in the final Solutions Package recommendation for the existing higher leaching farm systems (Figure 6-7). In this model, all farm system would achieve GMP by 2017, with only existing dairy and dairy support systems needing further reductions to achieve the load of 3400 by 2035.
Table 6-7: Solutions Package percentage reductions for nitrogen leaching (Scott, 2014g)

<table>
<thead>
<tr>
<th>Land use</th>
<th>2017</th>
<th>2020</th>
<th>2025</th>
<th>2030</th>
<th>2035</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dairy farm</td>
<td>GMP</td>
<td>15%</td>
<td>25%</td>
<td>35%</td>
<td>45%</td>
</tr>
<tr>
<td>Dairy support</td>
<td>GMP</td>
<td>10%</td>
<td>15%</td>
<td>20%</td>
<td>25%</td>
</tr>
<tr>
<td>All others</td>
<td>GMP</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
</tbody>
</table>

### 6.7 Additional water quality assessment and modelling

#### 6.7.1 Median versus average for target concentrations

Throughout the Hinds/Hekeao Plains Subregional Plan development process, the technical team’s calculated average concentrations of nitrogen, which was assumed to all be present as nitrate-N, for comparison with the targets in groundwater and lowland streams (Scott, 2013c).

In July 2014, the Ministry for the Environment (MfE, 2014) finalised the National Policy Statement for Freshwater Management, which sets national bottom lines for firewater quality. The policy proposed both an annual median and annual 95th percentile criteria. The MfE (2013) defined an annual median value of 6.9 mgN/L as the national bottom line for nitrate-N in lakes and rivers.

The technical team looked at the seasonality of nitrate-N concentrations in the Hinds/Hekeao Plains and determined that due to the high year round concentrations, the median criteria were most relevant effects criteria for the Hinds waterways. The 95th percentile toxicity criteria also need to be adhered too, but will be less restrictive than median criteria. MfE (2013) defined a median value of 6.9 mgN/L as the ‘national bottom line’ for nitrate-N in lakes and rivers. However, throughout the assessment process, the water quality models for the Hinds/Hekeao catchment produced average nitrogen values. The technical team compared the calculated median and average values for the Hinds/Hekeao catchment monitoring data and determined that they were similar so that the modelled average values were acceptable for comparison with a median target concentration in these waterways.

#### 6.7.2 Lag effects of potential response to changes in land use management

A key issue in developing the solutions package was gaining an understanding of how long it would take the catchment’s groundwater system to change relative to proposed mitigation options was (Scott, 2013a: Technical Compendium). To achieve the nitrate-N concentration targets by the planned goal of 2035, it was necessary to look at potential lag effects for the fate and transport of nitrate-N through the groundwater system.

The technical team looked firstly at groundwater age tracers as a way of determining the time of saturated groundwater movement through the system, with age for shallow groundwater ranging around 10 to 20 years. The technical team also looked at indirect relationships with time series trends in concentration in groundwater relative to land use changes. That information seemed to suggest a relatively quick response (in order of a few years) to increased nitrogen leaching activities. Finally, the technical team also considered that the targeted dilution of groundwater (Golder, 2014) could help reduce the lag effect.

The solutions package ended up moving the implementation of dilution (MAR) to the first ten-years of the plan (2015 to 2025), and on-farm advanced mitigation options to 2035. Modelling indicates that the 6.9 mgN/L groundwater target could be achieved by 2035, with targeted dilution and on-farm reductions.

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31 80% species protection level: Starts impacting regularly on the 20% most sensitive species (12% reduction in growth). Hinds/Hekeao spring-fed waterbodies are currently rated as beyond the most polluted, classification (D-class) streams with values > 9.8 mg/L Nitrate-N.

32 80% species protection level: Starts impacting regularly on the 20% most sensitive species (reduction in growth). Hinds/Hekeao spring-fed waterbodies are currently rated as beyond the most polluted classification (D-class) streams with values > 9.8 mg/L nitrate-N.
6.7.3 Comparison with land use areas from HPLWP information

During the consultation process, the technical team worked with the Hinds Plains Land and Water Partnership (HPLWP) (Section 2.7). During this process, one of the HPLWP members (George Lumsden) did an assessment of 2014 land use activities in the catchment (Scott, 2014b), as the HPLWP was concerned that land use information underestimated the current area of intensive land use. The information was provided to the technical team, who used it to ask fundamental questions about the load setting work:

a) How does the HPLWP estimate compare to the MRB/Environment Canterbury information?  
b) What would the lower catchment nitrogen load be, if the HPLWP data were used?

When comparing the land use information, it appears that the overall distribution of the HPLWP and MRB/Environment Canterbury land uses are very similar. There are relatively small differences around some excluded upper catchment areas (HPLWP) and classification (e.g. HPLWP’s Mixed class). Considering only the dairy areas, the HPLWP data indicated that approximately 5,000 additional ha of new dairy farm systems were present in 2014 compared to 2011 (Environment Canterbury/MRB Baseline). For the planning process, this meant that approximately 17% (5,000 of 30,000 ha) of the new irrigation had already occurred. Using the MRB/Environment Canterbury modelling and adjusting for these additional 5,000 ha, the loads were compared and found to be very similar. This HPLWP information was very useful in providing independent verification of the land use information being used by the Hinds/Hekeao water quality modelling process.

Other water quality technical memos covered topics such as comparisons with other water quality targets being set in Canterbury through the subregional planning process (Scott, 2014f), and documentation of the various on-farm mitigation options and MAR dilution staging modelled in support of the Zone Committee’s consultation process (Scott, 2014g).

6.7.4 Total nitrogen load estimations for the Hinds/Hekeao Plains catchment

Throughout the Hinds/Hekeao Plains Subregional Plan development process, a lot of the consultations and modelling was on the lower catchment and the agricultural sources. There are two main reasons for this (Scott, 2014d).

Firstly, farm-related nitrate-N sources make up 99% of estimated total current and solutions package load for the catchment (Table 6-8). The other 1% is from sources that include point source on-site septic systems, lifestyle blocks or leaking dairy effluent ponds, and natural (non-farmed) background sources of nitrogen such as forests, native vegetation, roadways and urban runoff (Scott, 2014c; Loe, 2012). Secondly, of all the sources of nitrogen in the overall catchment, only the lower Hinds/Hekeao plains area is being required to reduce leaching through on-farm reductions and dilution (MAR). The Upper Hinds/Hekeao catchment is being managed to maintain current levels of nutrient leaching.

Table 6-8: Total contributions to the nitrogen load for the Hinds/Hekeao catchment

<table>
<thead>
<tr>
<th>Activity</th>
<th>Source</th>
<th>Area (ha)</th>
<th>Nitrogen load (tonnes) 2017 GMP^</th>
<th>Nitrogen load (tonnes) 2035 Solutions Package</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farmed</td>
<td>Upper catchment</td>
<td>11,000</td>
<td>114 (2 %)</td>
<td>114 (3 %)</td>
</tr>
<tr>
<td></td>
<td>Lower catchment</td>
<td>123,300</td>
<td>4524c (97 %)</td>
<td>3446b (96 %)</td>
</tr>
<tr>
<td></td>
<td><strong>Total farming</strong></td>
<td><strong>134,300</strong></td>
<td><strong>4614 (99 %)</strong></td>
<td><strong>3514 (99 %)</strong></td>
</tr>
<tr>
<td>Point source discharges to land</td>
<td>On-site septic systems and leaking dairy effluent ponds</td>
<td>-</td>
<td>27</td>
<td>27</td>
</tr>
<tr>
<td>Non-farmed</td>
<td>Urban/roads/river beds/forest</td>
<td>3700</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td><strong>Total non-farming</strong></td>
<td><strong>3700</strong></td>
<td><strong>30 (1 %)</strong></td>
<td><strong>30 (1 %)</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Total all sources</strong></td>
<td><strong>138,000</strong></td>
<td><strong>4668</strong></td>
<td><strong>3590</strong></td>
</tr>
</tbody>
</table>

^ Modelled loads from Hinds/Hekeao Plains technical work (Scott, 2014A, Bower et al., 2014), b (Scott, 2014e), c – rounded to 4,500, d – rounded to 3,400 for load setting estimates.
From the modelling work, estimates of the load distribution in the lower catchment between each of the Groundwater Allocation Zones showed the Mayfield-Hinds GAZ with approximately 60% of the total load and the Valetta GAZ with the remaining 40% of the load. However, monitoring data of groundwater concentrations in both zones are similar, so the technical team continued modelling at catchment-scale.

Unlike the water quantity modelling, the water quality model did not have the capacity to consider changes in the recharge to groundwater from irrigation race losses (e.g. as a result of current piping of the Valetta Irrigation Scheme or possible future piping in the Mayfield-Hinds scheme). These could have a measurable impact on the distribution of nitrate-N concentrations in the shallow groundwater and lowland streams, which cannot be accounted for in the catchment scale modelling.

6.7.5 Upper Hinds/Hekeao catchment nutrient loading modelling

Because the Upper Hinds/Hekeao Plains catchment is hydrologically different, has unique cultural and ecological values and currently has a ‘good’ state of surface water quality, it was analysed differently from the Lower Hinds/Hekeao Plains area (Bower et al., 2014). The objective of the load analysis was to help to determine an estimate of current nutrient loads for phosphorus and nitrogen in the upper catchment. This was done using a combined approach similar to the lower catchment where Overseer® model of representative farms was combined with an ARC GIS spatial analysis of soils, topography and an understanding of current farm operations. The results indicated that the average estimated concentration of 10.4 kg N/ha/yr and 0.55 kg P/ha/yr, which translated into an upper catchment load of 114 tonnes kg N/yr nitrate-N and 6.0 tonnes kg P/yr of DRP.

Due to the hydrologic conditions of this upper catchment, which is prone to flash floods, it was estimated that the majority of this load would move into the Hinds/Hekeao River through the south and north branches of the river during higher flow events. There are insufficient data to determine the fate of these nutrients as they leave the upper catchment and move into the plains. Storm driven flows could help to carry nutrients through the lower catchment to the ocean, but no specific data are available support this concept. These nutrients could contribute to the groundwater loads in the lower catchment, but are relatively minimal when compared to current land use activities in the Lower Hinds/Hekeao Plains catchment.

6.7.6 Comparison of technical assessments (water quality and quantity) relative to Hinds/Hekeao Subregional and pLWRP planning boundaries

The Hinds/Hekeao Plains was originally identified as being a sub-regional planning area under the CWMS development process. The boundaries were established through a combination of the primary quality and quantity issues as well as regional jurisdictions (e.g. management of regional rivers falling under the Regional Committee and not zone committees).

Relative to the issue of water quality on the Lower Hinds/Hekeao Plains, the pLWRP defined nutrient allocation zones that were defined based on regional level knowledge. The pLWRP regional generic zones were defined as: Green - meets water quality outcomes; Orange – water quality outcomes at risk; and Red – water Quality outcomes not met. The pLWRP zones never were supposed to provide an accurate picture. They were a high level holding position until sub-regional planning could improve on them. These generic, regional boundaries were altered during the Hinds/Hekeao process based on catchment-specific information.

Catchment-specific monitoring indicated that the water quality outcomes for the aquifer and lowland water bodies were not being met across the whole of the Lower Hinds/Hekeao Plains area. As an example, Figure 6-9 shows overlaid information from pLWRP nutrient allocation zones and Hinds/Hekeao-specific monitoring information (Figure 6-10). The well numbers K37/0493 (red dot in the current green zone) and K37/0147 (green dot in the current orange zone) are located within the provisional green and orange zones, respectively, but show similar nitrate-N concentrations and trends to the monitoring wells in the provisional red zone. Figure 6-10 shows ten-year trends in nitrate-N concentrations in these two wells. Shallow groundwater has already exceeded the 6.9 mg NO₃-N/L target and is likely to do so more often in future, given the increasing trend. This information and
monitoring data from the lowland waterways provide evidence that the whole Lower Hinds/Hekeao Plains is an area where water quality outcomes are not being met and should be considered a red nutrient allocation zone for sub-regional planning purposes.

For the Upper Hinds/Hekeao catchment, a number of physical (e.g. topography, soils, etc.) and land use parameters were used to define this sub-catchment areas (Bower et al., 2014). Generally, it was defined to encompass a majority of the South and North branches of the Hinds/Hekeao River while staying in the area where the unique hydrogeology (lack of substantial groundwater resources), the run-off dominant hydrology, and relatively good quality of water, habitat, biodiversity and cultural values.
Figure 6-9: Overlaid information from pLWRP nutrient zones and Hinds/Hekeao Plains planning boundary and monitoring sites
6.8 Economic aspects of the solutions package

The economics for the Hinds/Hekeao Plains Subregional Plan process was covered in a number of
the separate technical analysis reports. For on-farm costs relative to the various mitigation levels,
MRB (Everest, 2013) completed economic modelling for each farm system. This modelling included
assessments of farm Earnings Before Interest and Tax (EBIT) and Cash Farm Surplus\(^{33}\) (CFS) for the
different mitigation options. Due to the exclusions of the “outside Overseer®” mitigations that were not
used by Environment Canterbury in the Solutions Package (Section 4.2.1), MRB did some additional
economic modelling to exclude the benefits of these other mitigations (Everest, 2014).

Cost estimates for both the Groundwater Replenishment Scheme (Golder, 2014) and the local-scale
mitigation options (Meredith and Lessard, 2014b) also contributed to the overall economic assessment
information. The original assessment by AgResearch (Paragahawewa, 2014a) and a follow-up
amended analysis (Paragahawewa, 2014) were also based on MRB (Everest, 2014) changes to EBIT
and Net Profit After Tax (NPAT) and represented the overall economic assessment for the on-farm
nutrient mitigations (Figure 6-11).

The other critical inputs for the solutions package were costings for the Groundwater Replenishment
scheme (MAR) (Golder, 2014) and the costs of local-scale mitigation options (e.g. riparian fencing,
Farm Environmental Plans, etc.) that were part of the final Addendum.

\(^{33}\) AgResearch used MRB CFS values (from a draft version) during their analysis. MRB revised their values to
The work by AgResearch provided an assessment of the local to regional economies as they related to the solutions package. An economic comparison between the Exploratory Baseline Scenario, Exploratory Development Scenario, and the Solutions Package looked at a variety of catchment-level mitigation options relative to gains in catchment-level incomes including MAR, local-scale options and the value of reliability of supply for irrigation water (Paragahawewa, 2014a).

Agresearch (Paragahawewa, 2014a) also discussed the potential policy measures related to the Hinds/Hekeao process. The report indicates that the potential net public benefit of the Solutions Package will be considerable compared to the baseline and the development scenarios. This assessment based on the relative magnitude of the net private and public benefits of proposed land use changes shows that incentives and technological innovation will be crucial in successful implementation of the solutions package. Agresearch (Paragahawewa, 2014a) also emphasised the importance of adaptive rules, regulations, and social norms to cope with the potential risk and uncertainties of the outcome of the proposed mitigations.

The AgResearch findings also show that the proposed on-farm mitigation practices, local-level mitigation practices, additional irrigation area, and managed aquifer recharge will have mixed impacts on the catchment. The biggest impact will be the reduced Cash Farm Surplus (CSF) for farmers operating in the catchment due to the proposed farm mitigation practices. However, the overall Solutions Package shows a net 10% increase in catchment-level CFS compared to the current land use practices, mainly related to the increase in 30,000 ha of new irrigation. Furthermore, the present value of farm-level costs for implementing the local-scale mitigations within the Solutions Package were estimated to be NZ$4.70/ha. This cost was not originally considered in the CFS values given by MRB (Everest, 2014) so if these are passed solely onto the farmers, there will be further reductions in farm earnings.

The public net benefits of the Solutions Package, however, will be greater than the public net benefits of the Exploratory Development Scenario if the intended outcomes such as protecting remaining wetland areas and associated biodiversity, and improving water quality in the streams, are achieved. Some values derived for these environmental assets indicate that the value of remaining wetland area in the Hinds/Hekeao Plains catchment could range from NZ$360,000 to $12.6 million.
The value of clean drinking water was estimated to vary from NZ$380,000 to $1.42 million (assuming that the most sensitive members of the catchment's population - breast-feeding and pregnant women - have to purchase and use bottled water). The costs of measures such as water treatment, and deeper drilling to obtain clean water in the catchment to protect the whole community from water pollution, will cost around NZ$1.2 million to $11.2 million.

The economic value of improvements to rivers and streams in Ashburton District could vary from NZ$13 million to $29 million in 2013 currency. The average estimated costs of local-scale mitigation options (NZ$4.70/ha), average costs of MAR at farm level (NZ$22/ha), and farm-level mitigation costs to conserve these environmental assets can be justified from a sustainable development perspective for the Hinds/Hekeao Plains catchment.

The following sections discuss some of the specifics of the AgResearch analysis directly relative the Hinds/Hekeao Technical team work.

6.8.1 Value of MAR

Golder (2014) provided cost estimates for the development of a Groundwater Replenishment Scheme (GRS) using the tools of MAR for development in a ten-year window, from 2015 through 2025. This estimate included capital costs (e.g. large infiltration basins and smaller galleries and basins) for both the development of a pilot project (final recommendation) through to the full development of a GRS. Operation costs included a conceptual partnership with local irrigation schemes to manage operations and personnel, a surface and groundwater monitoring network and the cost of land acquisitions for the MAR sites.

The total cost for the programme for the entire period (2015 through 2040) was NZ$5.5 million, of which $4.8 million was establishment costs, with approximately $700,000 for completion of operations post-scheme (2025 through 2040). All the cost figures involved in establishment and operation of MAR are given in Agresearch (2014), and Golder (2014).

The technical team used these data to estimate the Present Value Cost (PVC) of MAR using standard project analysis techniques. This assessment was carried out for different price ranges given for water by Environment Canterbury. The price of water was determined from a range of potential water sources from free ($0/m$^3$) to $0.14/m^3$ (Golder, 2014). This price range was developed from a combination of potential sources including purchasing water from winter generation supplies (e.g. RDR at $0.03/m^3$) and from irrigation scheme storage at Lake Coleridge (e.g. BCI Ltd at $0.14/m^3$). An average water price of $0.09/m^3$ was also used for the source-water estimations with an 8% discount rate to reflect the cost as a private investment.

Using these estimates, AgResearch (Paragahawewa, 2014a, and 2014b) estimated the potential benefit of MAR considering the reliability gain at catchment level due to the MAR, and the potential costs of using the most advanced mitigation practices on-farm to achieve the catchment-level nutrient reduction. While the AM3 mitigations appeared non-viable economically (MRB, 2014a), it was also important to compare them against MAR, as the alternative option.

The MAR PVC were calculated for a range of costs of potential source water, from free to storage rates from BCI Ltd. These water prices were then used to estimate the cost per hectare, and showed that PVC varies from $8 to $34/ha/year averaging around $22/ha/year (Table 6-9).
### Table 6-9: Present value (cost/ha) of MAR scheme relative to a range of potential water costs (NZ$/ha/yr at 8% discounted rate)

<table>
<thead>
<tr>
<th>MAR implementation timeline</th>
<th>Available water (Cost = free) - (NZ$/ha/yr)</th>
<th>Water price</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>RDR rate (Cost = $0.03/m³)</td>
</tr>
<tr>
<td>2015 to 2015 (10 years)</td>
<td>0.83</td>
<td>8.0</td>
</tr>
</tbody>
</table>

This translates into an estimated Net Present Value (NPV) of MAR of $401 million (at a water price of $0.14/m³). The average benefit:cost ratio was estimated to be at least 4:1, indicating high returns to MAR (Table 6-10).

### Table 6-10: Estimated benefits of MAR scheme at catchment-level

<table>
<thead>
<tr>
<th>MAR benefit and costs (NZ$ million at 8% discounted rate)</th>
<th>Water price</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Free (Cost = NZ$0.03/m³)</td>
</tr>
<tr>
<td>Present value of benefits</td>
<td>536.4</td>
</tr>
<tr>
<td>Present value of costs</td>
<td>3.3</td>
</tr>
<tr>
<td>Net present value</td>
<td>533.1</td>
</tr>
<tr>
<td>Benefits:costs ratio</td>
<td>164:1</td>
</tr>
</tbody>
</table>

### 6.8.2 Value of the solutions package mitigation options

The final solutions package was assessed for the present value of catchment-level farm EBIT, which was 21% higher than under the Exploratory Baseline Scenario (Table 6-11). Overall benefits for the solutions package over the entire life of the plan was $3,370 million (Paragahawewa, 2014a and 2014b). An assessment of the regional economic benefits show a net gain of $102.8 million/year in EBIT and employment benefits in the order of 229 FTE/year during the life of the plan, under the solutions package.

### Table 6-11: Estimated benefits of proposed mitigations at catchment scale (8% discounted rate)

<table>
<thead>
<tr>
<th>Land use scenario</th>
<th>PV-EBIT ($ million)</th>
<th>PV-CFS ($ million)</th>
<th>PV-EBIT/year ($ million)</th>
<th>PV-CFS/year ($ million)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>2764</td>
<td>629</td>
<td>92</td>
<td>21</td>
</tr>
<tr>
<td>Solutions Package</td>
<td>3370</td>
<td>710</td>
<td>112.3</td>
<td>24</td>
</tr>
</tbody>
</table>

### 6.8.3 Value of local-scale mitigation options

The Solutions Package consisted of a number of local-scale mitigation options (Table 6-2) for the Hinds/Hekeao Plains catchment, to help deliver all of the community’s outcomes. The technical team developed cost estimates (Meredith and Lessard, 2014b) for each mitigation option (e.g. fencing per km), and the potential costs of each mitigation option that may be needed in the catchment (Appendix A-1, A-2). These costs were then distributed over the life (2015 to 2040) of the plan as shown in Table 6-12.
Table 6-12: Local-scale mitigations high-level costing estimates

<table>
<thead>
<tr>
<th>Solutions Package</th>
<th>2015</th>
<th>2017</th>
<th>2025</th>
<th>2030</th>
<th>2035</th>
<th>2040</th>
<th>Total Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local Scale Options</td>
<td>$196</td>
<td>$3,359</td>
<td>$11,443</td>
<td>$8,265</td>
<td>$8,265</td>
<td>$8,260</td>
<td>$39,788</td>
</tr>
<tr>
<td>Actions/Plans</td>
<td>$463</td>
<td>$769</td>
<td>$722</td>
<td>$672</td>
<td>$672</td>
<td>$602</td>
<td>$3,900</td>
</tr>
<tr>
<td>Assessments/ Monitoring</td>
<td>$194</td>
<td>$375</td>
<td>$1,225</td>
<td>$875</td>
<td>$875</td>
<td>$875</td>
<td>$4,419</td>
</tr>
<tr>
<td>Totals</td>
<td>$853</td>
<td>$4,503</td>
<td>$13,390</td>
<td>$9,812</td>
<td>$9,812</td>
<td>$9,737</td>
<td>$48,107</td>
</tr>
</tbody>
</table>

The objective was to capture some of the mitigation costs of the solutions package, relative to the overall economic benefits. Where assumptions were required about the extent of each mitigation option (e.g., riparian fencing of spring-fed waterbodies), the technical team used the most conservative value (e.g., all streams, both sides). These costs therefore represent the ‘worst case’ cost for many of these mitigation options. In addition to the local-scale mitigations, the costs of the other recommendations shown in the Addendum (which included plans and assessments) covered:

- Farm Environmental Plans
- farm extension programs and workshops
- An Inventory Assessment Project by the Hinds Drains Working Group
- biodiversity inventory and outreach
- a modelling study of stream-depleters to reduce costs of implementation
- a river mouth opening study and annual openings (costed)

Although the actual costs of both the local-scale mitigation options and these Addendum recommendations may not be carried at farm level (e.g., through support from Environment Canterbury funding, industry workshops, etc.), the technical team considered that it was important to capture these costs and offset them against the benefits. These costs include materials and labour to install the mitigations, landowner’s lost revenue if the mitigation removes previously productive land from use, and on-going maintenance of the mitigation options.

The most recent economic analysis conducted within Canterbury, which summarized the costs of stream mitigation options, is the economic technical report written as part of the Selwyn-Waihora subregional planning process (Harris 2014). The assumptions about implementation costs for stream mitigation options were used to calculate the costs of the same mitigation options in the Hinds/Hekeao Plains catchment, unless catchment-specific or other updated information was available. The total costs of these mitigation options (discounted at 8%) were $15,536,000 (local-scale) and $3,795,000 (plans and assessments) for a total of $19,331,000, with a cost per hectare of $5.60 if funded solely from farm income.

The most important and overarching recommendation in the solutions package was the establishment of the Hinds Drains Working Party, whose primary task outside setting flow allocations will be to use landowners’ and stakeholders’ local knowledge to develop a more robust assessment of actions that are needed.

6.8.4 Value of increased reliability of water supply

AgResearch (Paragahawewa, 2014a) used baseline estimates of current reliability of supply and potential pasture production data from MRB (Everest 2013; Paragahawewa, 2014) to provide an estimate for value under the solutions package. This analysis indicated that there is a range in farm-level gains at catchment-level for increased reliability of supply. If the benefit was split
between dairy farm systems, the gain ranged from $1.2 million (dairy support) to $6.6 million (dairy). AgResearch modelling for regional GDP under the solutions package showed gains from $6.4 million/year (dairy support) to $33 million/year (dairy), while the employment gain varies from 11 FTE/year (dairy support) to 79 FTE/year (dairy).

6.9 Social aspects of the Solutions Package

The assessment of the Solutions Package from a social perspective found that, as with the scenarios, it is difficult to meet all of the objectives (Taylor, 2014). Further irrigation will bring economic benefits from employment, both on-farm and off-farm, which drive further benefits from additional income and increased population that flow into community wellbeing. However, these benefits to social wellbeing are potentially offset by further declines in the standard of drinking water in groundwater supplies, which brings stress, risks and costs to households, particularly those with babies and young children.

On its own, the additional irrigation of 30,000 ha could lead to a decline in water quality and steam ecological outcomes, and further degrade the local recreational resource. However, a move to advanced farm mitigation options in the solutions package, in conjunction with the additional irrigation economic benefits and MAR, has evident benefits for the ecology of the river, streams and drains and these will be enhanced further by selective local initiatives (such as stream restoration). These ecological benefits, along with additional flows, will enhance recreational use and this is an important beneficial social outcome of the Solutions Package.

Therefore, the social assessment concluded that the full solutions package (Addendum) should bring net positive outcomes to both social and economic wellbeing. With the addition of a change management approach designed to minimise negative social effects and enhance positive ones, the Solutions Package should make a substantial contribution to enhancing the social and economic wellbeing of the people of the Hinds/Hekeao River catchment and Ashburton District (Taylor, 2014).

6.10 Cultural aspects of the Solutions Package

The cultural assessments that were undertaken in the Hinds/Hekeao Plains catchment used the Cultural Health Index process (Tipa & Teirney 2003; 2006). Te Rūnanga o Arowhenua assisted in the preparation of the Cultural Opportunity Mapping, Assessment and Responses (COMAR) report for the Hinds/Hekeao Plains catchment area (Tipa and Associates, 2013).

This report identified preferred flows for cultural values and specifications for other management actions necessary to provide for cultural interests. Two meetings were held with the mataaitai committee of Te Rūnanga o Arowhenua to discuss existing information and the aspirations of the rūnanga.

The Arowhenua COMAR report required ‘average’ water depths of at least 30 cm to maintain cultural values. This is based on their experience that this water depth provides for healthy populations of tuna (eel), as well as safe and effective cultural opportunities for a range of healthy mahinga kai species/communities and other cultural values. The key cultural themes across the Hinds/Hekeao Plains catchment include:

- Redefining a new system of waterways. As many of the natural watercourses have been modified, there is a need to re-examine the role of drains and races in providing linkages (ki uta ki tai). Natural waters, which are highly valued by whānau, are being conveyed in waterways that have varying degrees of modification. The waters remain a taonga regardless of the means of conveyance.
- Restoration of mahinga kai. Mahinga kai is the ultimate test of a river’s health. Maintaining flows and water quality standards to support the enhancement of the eel fishery is a priority. Watercress is taken from drains and streams, but because it absorbs contaminants in the streams, whānau want to see the input of contaminants to the waterway minimised. Drainage, drain management, spraying and gravel extraction all have the potential to adversely impact both mahinga kai and the attempts by Te Rūnanga o Arowhenua to enhance mahinga kai.
Protection of spring heads. Reliable flows, good water quality, water depth, water temperature and clarity are important characteristics that are sustained by springs.

Clean water is a key factor that will decide the future of the Hinds/Hekeao River for cultural use. Whānau recognize that land in the catchment is used intensively, and know that a substantial improvement in water quality in the lower catchment is needed. Intensified land use cannot be undertaken at the expense of cultural use.

Fish passage is also a priority, to enable fish to have unimpeded passage through the system consistent with historic ranges. Whānau believe that migrant eels, once at the coast, will be able to cross the shingle barrier and leave the system. However, connectivity is needed to provide the eels with a passage to the coast. The extent of connectivity through streams and drains needs to be investigated. It is likely that the dongas will need to be open to the sea at times of migration to allow passage into the system.

A team of four people undertook a field visit in April 2013. Eleven sites with easy access were visited and assessed, using the modified CHI methodology (Tipa and Associates, 2013). The team identified a number of management priorities, and the key recommendations from this cultural assessment were:

- Protection of the remaining good stuff (wetlands, springs, remnants of native vegetation). It is important that no further losses occur before starting to identify opportunities to restore or reconstruct habitats in such a modified catchment area.
- Regulation to ensure more appropriate in-stream management. Whanau want the spraying of in-stream vegetation to be prohibited.
- Regulation to improve drain management. In some districts of Canterbury, whānau have been involved developing a drain management protocol. Te Rūnanga o Arowhenua want to see many of their recommendations included in the policy framework of the catchment plan, rather than just encouraging more sensitive drain management.
- Strategies implemented to ensure compliance with standards. It is unclear how many of the best practice models can be implemented if a farmer does not have the financial resources to adopt them.
- Commitment to prescribe the topics to be covered in farm plans (e.g. drain management for biodiversity gains). Environment Canterbury should require farm plans for the Hinds/Hekeao Plains catchment area to include strategies for achieving biodiversity gains at an individual farm level by improving drain management. This includes managing drains for their biodiversity values to deliver cultural outcomes.
- Commitment by Environment Canterbury to prioritise indigenous biodiversity above introduced species. Whānau are concerned that projects proposed by Fish and Game that focus on introduced species may be prioritized over projects with native species.
- Uncertainty about Managed Aquifer Recharge (MAR). In theory, MAR could enhance flows in the waterways of the catchment, but Tangata whenua have a low level of confidence that this method will deliver them with tangible outcomes.
- Liaison with Te Rūnanga o Arowhenua about land tenure issues for riverbeds, drains, wetlands etc. Whānau need to know where ad medium filum aquae rights (to the middle line of the water) apply in the Hinds/Hekeao catchment. Maps are needed to illustrate how these rights impact the many waterways in the zone. This information is required before any decisions about MAR, inter-catchment transfer or storage can be considered.
7 Zone committee addendum: technical aspects of the Solutions Package

7.1 Summary

During the development of the Exploratory Scenarios, the technical team used a scoring method to help provide the community with a sense of the uncertainty and magnitude of change relative to each of the 25 desired outcomes (Table 2-2 and Table 2-3). Although this approach was not carried through to the development of the solutions package, it is important to summarise the final technical results against the outcomes (Table 2-1).

Many of the analyses and assessments indicate that, under the solutions package, improvements are expected for water quality, water quantity and across the quadruple bottom-line (economics, environment, social and cultural). However, not all of the outcomes were achieved under the solutions package. Under the social outcomes, the drinking water target (defined as: Drinking water wells and domestic supplies now and in the future at least meet national drinking water standard for E.coli and nitrate-N Table 2-1) was considered as 'not met'. A statistically determined average value of 5.6 mg/L of Nitrate-N (% the MAV of 11.3 mgN/L) was required to achieve this Outcome. The community decided that the average 6.9 mgN/L for the aquifer was achievable using the suite of mitigations under the Solutions Package. E.coli values were not specifically modelled for the catchment but current values, measured throughout the groundwater and surface waterbodies, indicate that the drinking water Outcome will not be achieved. The costs to the community of unsafe drinking water supplies are estimated to be as high as NZ$11 million to drill bores deeper and/or provide treatment for the numerous private domestic supply bores in the catchment (Paragahawewa, 2014a).

A number of the Solutions Package recommendations included the Hinds Drains Working Party, which convened in May 2014 (Table 7-1). The Hinds Drains Working Party was assigned a number of critical tasks including setting minimum flow targets for the spring-fed waterbodies in the lower catchment. Relative to the original outcomes, most of the environmental and cultural outcomes rely upon the Hinds Drains Working Party being able to establish a consensus on these values.

The local-scale mitigation options, coupled with the evaluation of the MAR pilot project, will determine whether the cultural values of mahinga kai, wāhi tapu and wāhi taonga are protected and whether access is enhanced. Riparian buffers, stock exclusions, and the protection and restoration of wetlands will help greatly in reducing current high levels of faecal bacteria, which have an adverse impact on mahinga kai gathering. The final progress made by Hinds Drains Working Party will determine how many of these related outcomes will be achieved.

Table 7-1: Management goals and key issues for the Hinds Drains Working Party

<table>
<thead>
<tr>
<th>Stream-by-stream management plans</th>
<th>Deliver cultural values including opportunities to gather mahinga kai (e.g. by, but not limited to, the minimum depth calculated from COMAR (Tipa, 2013))</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Improve ecosystem health, including the habitat of trout</td>
</tr>
<tr>
<td></td>
<td>Safeguard reliability for existing water users</td>
</tr>
<tr>
<td>Key issues</td>
<td>Minimum flows</td>
</tr>
<tr>
<td></td>
<td>Minimum flow measuring sites</td>
</tr>
<tr>
<td></td>
<td>The application of partial restrictions to protect stream dewatering</td>
</tr>
<tr>
<td></td>
<td>Consented versus actual takes as they relate to ‘reasonable usage’</td>
</tr>
<tr>
<td></td>
<td>Equity between those with minimum flows and those without</td>
</tr>
<tr>
<td></td>
<td>Switching takes from surface water to deep groundwater</td>
</tr>
<tr>
<td></td>
<td>The effectiveness of the MAR pilot programme</td>
</tr>
<tr>
<td></td>
<td>In-stream and habitat restoration, including fish passage</td>
</tr>
<tr>
<td></td>
<td>Drain management</td>
</tr>
<tr>
<td></td>
<td>Differences in characteristics (and therefore the optimum solutions) for different drains or groups of drains</td>
</tr>
<tr>
<td></td>
<td>Any negative effects resulting from the key issues (actions)</td>
</tr>
</tbody>
</table>
The economic outcomes are largely met with the 30,000 ha of new irrigation being part of the Solutions Package. Changing global markets, changing commodity prices and the ability of farmers to reduce nitrate-N leaching through new technologies and innovations will dictate how much actual additional farming is feasible. However, questions around the effectiveness of MAR in helping to raise groundwater storage without exacerbating drainage issues in the coastal portion of the Hinds/Hekeao Plains catchment mean this option contains a degree of uncertainty. More variable future weather predictions, relative to a changing climate, suggest that storm events will make drainage issues a more challenging problem over the plan period.

Although the use of MAR for dilution is logical and appears feasible, dilution is only likely to work if on—farm mitigations can first reduce the amount of nutrients entering the aquifer. As downgradient drainage represents a limit on the amount of MAR that can occur, the on-farm advanced mitigations on high-leaching farm systems will have to drive much of the improvement in water quality for nitrate-N. High nitrate-N concentrations in water entering the ocean, either as surface or groundwater flows, also raise the risk of hypoxic coastal waters, which has been linked internationally to dead zones with low oxygen levels and adverse effects on marine life. A MAR pilot project was started in May 2014, with plans for the trial to begin monitoring and operations in the end of 2014, early 2015. Many of the catchment-scale water quantity and quality outcomes depend on the results and future implementation of this tool.

The Zone Committee made changes to the groundwater allocation limits (e.g. capping allocation from the Mayfield-Hinds GAZ) that are intended to help avoid causing similar flow reliability and environmental and cultural issues that occurred in the Valetta GAZ. However, if plans for piping of the Mayfield-Hinds Irrigation Scheme proceed (in the next 25 years), some kind of augmentation is also likely to be required.

A number of the recommendations encourage innovation and improvements in technical assessment tools, increased monitoring, education, and development of the community’s ongoing understanding of the catchment’s land use and natural resources. The technical team see these areas as critical to the success of the Hinds/Hekeao Plains Subregional Plan implementation.

34 http://en.wikipedia.org/wiki/Dead_zone_(ecology)
8 References for Hinds Plains Technical Reports


## Appendix 1: Hinds local scale costings

<table>
<thead>
<tr>
<th>On-the-ground mitigations</th>
<th>Subitem</th>
<th>Description</th>
<th>Quantity (assumed maximum)</th>
<th>Units</th>
<th>Cost/unit</th>
<th>Capitol cost</th>
<th>Total Cost</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fencing</td>
<td></td>
<td>25.7</td>
<td>km</td>
<td>$9,000</td>
<td>$231,300</td>
<td>$1,463,790</td>
<td>Jen Ritson GIS data and calculations; S-W Economics report (Allows for 7 wire fence, but no gates, corners etc.)</td>
</tr>
<tr>
<td></td>
<td>Planting</td>
<td>Fencing and restoration all 409 spring head areas to protect stream flow at the source. 10 m radial buffer assumed</td>
<td>12.65</td>
<td>ha</td>
<td>$47,430</td>
<td>$599,990</td>
<td>$1,463,790</td>
<td>Jen Ritson GIS data and calculations; S-W Economics report (4500 plants/ha at 6.54/plant plus $4/plant for maintenance over 2 years.)</td>
</tr>
<tr>
<td></td>
<td>Maintenance</td>
<td></td>
<td>12.65</td>
<td>ha</td>
<td>$101</td>
<td>$1,277.65</td>
<td>$1,288</td>
<td>Jen Ritson GIS data and calculations; S-W Economics report. Weed and pest, repairs and maintenance, and vehicle costs from a Canterbury sheep farm budget per ha costs</td>
</tr>
<tr>
<td></td>
<td>Land</td>
<td></td>
<td>12.65</td>
<td>ha</td>
<td>$50,000</td>
<td>$632,500</td>
<td>$632,500</td>
<td>Values from Hinds Working party (40-60k)</td>
</tr>
<tr>
<td></td>
<td>Fencing</td>
<td></td>
<td>6.9</td>
<td>km</td>
<td>$9,000</td>
<td>$62,100</td>
<td>$62,100</td>
<td>Area and length calculations based on goal of 20 sites at 20 m radius in Upper Hinds, 50@10m in MH and 20@10m in LH. DoC WERI xlsx sheet indicates total existing wetlands are 72 ha. Costing based on S-W $$: Allows for 7 wire fence, but no gates, corners etc.; Weed and pest, repairs and maintenance, and</td>
</tr>
<tr>
<td></td>
<td>Planting</td>
<td></td>
<td>4.7</td>
<td>ha</td>
<td>$47,430</td>
<td>$222,921</td>
<td>$222,921</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Maintenance</td>
<td>Naturally bogggy areas where groundwater and surface water is drained toward that require fencing for further protection.</td>
<td>4.7</td>
<td>ha</td>
<td>$101</td>
<td>$475</td>
<td>$475</td>
<td></td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th>Line Item Description</th>
<th>Location</th>
<th>Area (ha)</th>
<th>Cost Basis</th>
<th>Cost (S$)</th>
<th>Cost (MRB)</th>
<th>Cost (MRB covered)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Predator Control</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vehicle costs from a Canterbury sheep farm</td>
<td></td>
<td>4.7</td>
<td>$20</td>
<td>$94</td>
<td></td>
<td></td>
</tr>
<tr>
<td>budget per ha costs.</td>
<td>From Landcare presentation for multi-species control</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Land</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>4.7</td>
<td>$50,000</td>
<td>$235,000</td>
<td>$235,000</td>
<td></td>
</tr>
<tr>
<td><strong>Hinds River Hapua Enhancement</strong></td>
<td>Line item for targeted enhancement of the Hinds/Deals Drain Hapua</td>
<td>1</td>
<td>$100,000</td>
<td>$100,000</td>
<td>$100,000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Values from Hinds Working party (40-60k)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Donga Protection and Enhancement</strong></td>
<td>Line item for targeted enhancement of the Dongas along Lower Beach Rd including vegetation and in-stream protection and enhancement</td>
<td>10</td>
<td>per donga</td>
<td>$10,000</td>
<td>$100,000</td>
<td>$100,000</td>
</tr>
<tr>
<td></td>
<td>Line item ID from mitigations mtg</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Riparian Restoration (Drains + Hinds River)</strong></td>
<td>Exclusion of livestock from water bodies</td>
<td>654</td>
<td>km</td>
<td>$9,000</td>
<td>$5,886,000</td>
<td>MRB covered</td>
</tr>
<tr>
<td></td>
<td>Jen Ritson GIS data and calculations; S-W Economics report (Allows for 7 wire fence, but no gates, corners etc.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Riparian planting</td>
<td>Site specific riparian restoration includes planting along fenced (costed separately) riparian areas. Width is assumed 3m along drains, 20 m along the Hinds mainstem and branches, 5 m along Limestone Creek and 3m along Surrey Hills Stream</td>
<td>451</td>
<td>ha</td>
<td>$47,430</td>
<td>$21,390,930</td>
<td>$43,940,930</td>
</tr>
<tr>
<td></td>
<td>Jen Ritson GIS data and calculations; S-W Economics report (4500 plants/ha at 6.54/plant plus $4/plant for maintenance over 2 years.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maintenance</td>
<td>Vegetation Maintenance</td>
<td>451</td>
<td>ha</td>
<td>$101</td>
<td>$45,551</td>
<td>$54,571</td>
</tr>
<tr>
<td></td>
<td>Jen Ritson GIS data and calculations; S-W Economics report (Weed and pest, repairs and maintenance, and vehicle costs from a Canterbury sheep farm budget per ha costs)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Predator Control</td>
<td>Control of invasive terrestrial predators that may thrive in catchment due to additional vegetation</td>
<td>451</td>
<td>ha</td>
<td>$20</td>
<td>$9,020</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Estimate based on Landcare presentation for multi-species control</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project Area</td>
<td>Activity Description</td>
<td>Land</td>
<td>ha</td>
<td>$50,000</td>
<td>$22,550,000</td>
<td></td>
</tr>
<tr>
<td>------------------------------------</td>
<td>--------------------------------------------------------------------------------------</td>
<td>-------</td>
<td>-----</td>
<td>---------</td>
<td>-------------</td>
<td></td>
</tr>
<tr>
<td>Dryland Vegetation Protection</td>
<td>Exclusion of livestock from areas of dryland habitat</td>
<td>451</td>
<td>ha</td>
<td>$9,000</td>
<td>$22,500</td>
<td></td>
</tr>
<tr>
<td>Enhanced drain network management</td>
<td>Includes costs for all drain mgmt activities undertaken by Ecan in the Hinds Catchment</td>
<td>364</td>
<td>km</td>
<td>$418</td>
<td>$152,152</td>
<td></td>
</tr>
<tr>
<td>Passage barriers</td>
<td>Installing built barriers for protection of non-migratory galaxiids from invasives</td>
<td>6</td>
<td>1</td>
<td>$10,000</td>
<td>$60,000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Culvert retrofit</td>
<td>5</td>
<td>1</td>
<td>$2,500</td>
<td>$12,500</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fish passage friendly erosion protection/control retrofits</td>
<td>72</td>
<td>1</td>
<td>$2,500</td>
<td>$180,000</td>
<td></td>
</tr>
<tr>
<td>Instream habitat restoration</td>
<td>Drains in stream habitat improvements including adding in cobbles or boulders and wood</td>
<td>468</td>
<td>1</td>
<td>$1,000</td>
<td>$468,000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hinds</td>
<td>15</td>
<td>1</td>
<td>$2,500</td>
<td>$37,500</td>
<td></td>
</tr>
<tr>
<td>Sea connectivity</td>
<td>Mechanical mouth openings on Hinds river to improve life cycle requirements for such as trout, eels and whitebait. Improved flows in should help connectivity in lowland streams.</td>
<td>3</td>
<td>1</td>
<td>$5,000</td>
<td>$15000</td>
<td></td>
</tr>
<tr>
<td>Legacy sediment removal</td>
<td>Proactively removing sediment from select streams mechanically for habitat and flood protection needs.</td>
<td>2</td>
<td>km</td>
<td>$10,000</td>
<td>$20,000</td>
<td></td>
</tr>
</tbody>
</table>

Values from Hinds Working party (40-60k)

- Dryland Vegetation Protection: 20 sites with 20m radius. Allows for 7 wire fence, but no gates, corners etc.
- Enhanced drain network management: From Drain mgmt team
- Passage barriers: estimate from DoC, big range, optimistic estimate
- Fish passage friendly erosion protection/control retrofits: DoC estimate from ARC of average cost (wide range)
- Instream habitat restoration: Indicative estimate from mitigation mtg.
- Sea connectivity: Indicative estimate from mitigation mtg.
- Legacy sediment removal: Indicative estimate of length from mitigation mtg. $10/m which allows for 150/hour (3 labour units plus additional equipment and disposal costs estimated) doing 15m/hour. Assumes that removed sediment can be dumped on adjacent land.
# Appendix 2: Hinds Zone Committee recommendation costings

<table>
<thead>
<tr>
<th>Ashburton ZC Recommended Actions</th>
<th>Subitem</th>
<th>Description:</th>
<th>Quantity (assumed maximum)</th>
<th>Units</th>
<th>Cost/unit</th>
<th>Capitol cost</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farm Environmental Plans</td>
<td>Plan Set-up</td>
<td>Assumed 65% of landowners will need a farm plan</td>
<td>344</td>
<td></td>
<td>$2,000</td>
<td>$687,700</td>
<td>G. Lumsen est. ~529 indiv. Decision makers</td>
</tr>
<tr>
<td></td>
<td>Plan Turnover</td>
<td>Assumes 15% of farms turnover or change farm systems annually</td>
<td>52</td>
<td></td>
<td>$2,000</td>
<td>$103,155</td>
<td>S-W economics report</td>
</tr>
<tr>
<td></td>
<td>Plan Auditing</td>
<td>Assumes 100% of farms with plans audited</td>
<td>344</td>
<td></td>
<td>$600</td>
<td>$206,310</td>
<td>S-W economics report; L. Brown 2012 pers com quotes $600/audit</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>FEP total yearly costs (post plan development) = (103,155 every (25 years / 6 years = 4 x 103,155), audits 206,310/4. $24,757</td>
</tr>
<tr>
<td>Farm Extension Programs and Workshops</td>
<td>Workshops/Field Days</td>
<td></td>
<td>26</td>
<td></td>
<td>$1,500</td>
<td>$39,000</td>
<td>S-W economics report; Assumes 20 farmers per workshop and 529 potential participants, 1 workshop each</td>
</tr>
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<td></td>
<td>Farm Trials</td>
<td></td>
<td>10</td>
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<td>$20,000</td>
<td>$200,000</td>
<td>S-W economics report; AgResearch</td>
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<tr>
<td>Hinds Drains Working group - Inventory Assessment Project</td>
<td>Assessment of all springs, wetlands, and surface water resources in the Hinds Plains Catchment</td>
<td>1</td>
<td></td>
<td>$103,340</td>
<td>$103,340</td>
<td>Study design outlined by B. Bower</td>
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<tr>
<td>Biodiversity Inventory and Outreach</td>
<td>Investigation of terrestrial biodiversity within the Catchment</td>
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<td>$22,540</td>
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<td>Study design outlined by B. Bower</td>
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<tr>
<td>Stream depleters modelling study</td>
<td>Investigation of stream depletion effects modelling</td>
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<td>$47,740</td>
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<td>River Mouth Opening Study</td>
<td>Investigation of the Hinds River mouth hydrology, sea connectivity and impacts on fish populations</td>
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<td>$40,300</td>
<td>$40,300</td>
<td>Study design outlined by B. Bower</td>
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