AQUA INTEL AOTEAROA Insights and actions for sustainable water use

Southland water storage: options and opportunities assessment

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GNS SCIENCE TE PŪ AO

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EXECUTIVE SUMMARY

Investment in water storage can provide a significant means of increasing prosperity for many regions. The Government has set up a science platform – Aqua Intel Aotearoa – to explore regional water storage needs and opportunities and consider the potential for water storage to support a lift in sustainable regional production.

PDU-GNS platform: Regional Water Needs Assessments

Aqua Intel Aotearoa will identify how water availability constrains sustainable land development, explore means for overcoming these constraints and identify initial scientific investigations that could progress water storage for the region. The Government is particularly interested in investigating opportunities to support Māori land being brought into production. Aqua Intel Aotearoa is working with four regions within this programme – Northland, Gisborne, Otago and Southland.

Southland's Water and Land

Surface water in Southland is dominated by two large lakes (Lake Te Anau and Lake Manapōuri) and four large river systems (Waiau, Aparima, Ōreti and Matāura rivers). Water bodies in Southland are highly connected, flowing through the landscape as surface water and groundwater and eventually discharging at the coast. Unconfined aquifers occur over large areas of Southland, predominantly within valley and plains systems of the major rivers. Southland's waterbodies have been extensively modified, reducing the volume of seasonal water storage in many shallow unconfined aquifers and subsequent outflows to rivers and streams during summer and autumn.

While Southland experiences some of the highest rainfall across the country, annual (seasonal) rainfall is not always adequate for agriculture in localised areas north of the Hokonui Hills. Producers in the horticulture and floraculture industries have faced water shortages in the past. Demand for surface water and groundwater has been increasing in Southland and can be expected to increase further with population growth and any projects that increase land productivity. Water takes are already highly allocated, with limited or no further water available for land development in a number of Southland surface water and groundwater catchments.

Southland's economy is significantly rural with 87% of the developed land in agriculture and 16% of its GDP derived from the agriculture sector. Southland recognises the challenges that its agricultural economy places on its environment and is exploring options for reducing the impact of existing land use through diversification into tourism, aquaculture, sheep milk production, functional foods and horticultural crops. Water storage and water demand are part of a wider regional assessment of how to improve water quality and other environmental outcomes by moving to more sustainable land uses.

As with many regions, the three main water quality issues in Southland are sediment, nutrients and bacteria. These are often associated with the impact of land use on water.

Investing in Water Storage to Improve Southland's Land Productivity and Water Quality

Southland's primary sector largely involves dairy, sheep and beef farming. The region is currently considering how it uses water to address the impact of livestock on its environment. The impacts on land and water quality of nutrient discharge, winter grazing and pugging will need to be addressed through regulation by the regional council. The approach will be considered in partnership with Ngāi Tahu ki Murihiku as part of implementing Te Mana o te Wai. An opportunity exists to examine water storage and water demand alongside the need to support land-use change in Southland, which will arise as a result of limit setting in Southland.

This assessment considers diversification of farming into expansion of existing crops and/or growth of new crops such as:

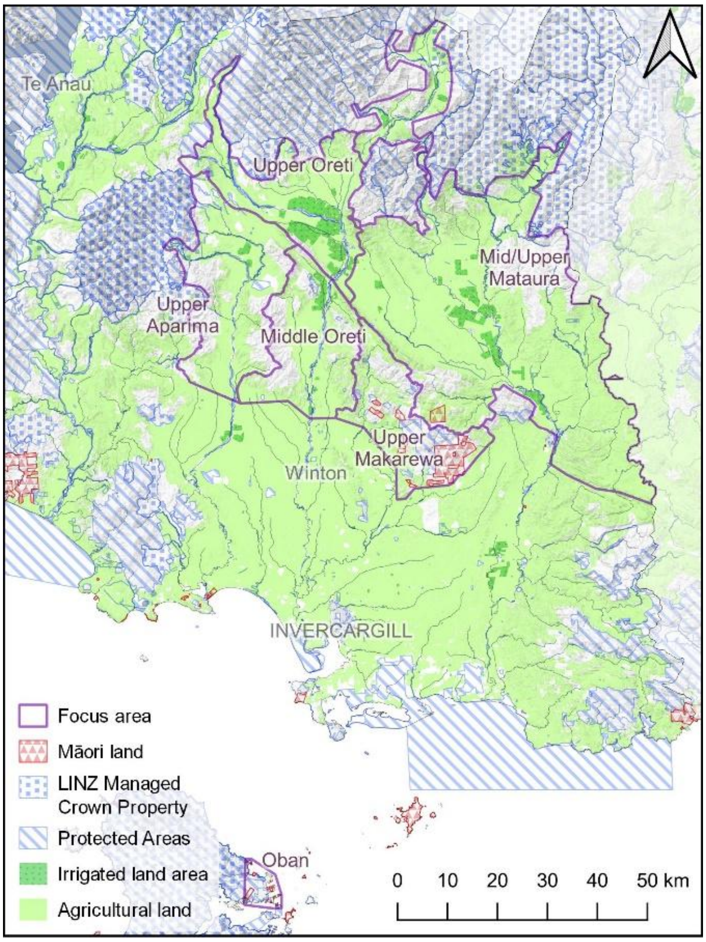
- arable (predominantly wheat, barley and oats)
- vegetables
- cut flowers and bulbs, and
- horticulture (hydroponic lettuce, blueberries).

The temperate climate and fertile soils result in high crop yields with low disease pressure compared to many other regions. The majority of future crop opportunities are only likely to materialise with access to reliable water, for both production and processing purposes. A reliable water source is required in most instances to provide confidence to invest in changing land use and to secure commercial offtake agreements.

This will ultimately drive the need for land-use change; however, it is important that environmental impacts of alternative land uses are also assessed, alongside a broad range of other considerations.

Water Storage Focus Areas and Water Storage Approaches

This work identified a number of focus areas within Southland where there is productive land that could be brought into higher value sustainable uses. Within these focus areas, water storage approaches were identified that could enable this land to be brought into horticulture.



Water storage options were identified from a variety of options that take water from surface water or groundwater including: dams for baseflow enhancement, (natural) groundwater storage, galleries (where groundwater is taken from shallow gravel-filled pits excavated below the water table), managed aquifer recharge, land subsoil recharge and dams (Appendix 1). A GIS method was used to assess storage options that are relevant to the Southland region. The method included assembly of GIS maps (national and regional) such as land use, soil properties, climate, geology and water flows (rivers and groundwater).

For each of the focus areas, an assessment (using the GIS maps and discussions with local water experts) has identified the top potential water storage options.

Focus Area	Potential Water Storage Methods
Matāura: Mid/Upper	Groundwater storage Water harvesting from ephemeral streams Wetland enhancement Augmentation of flow from Lake Wakatipu
Ōreti: Upper	Groundwater storage Water harvesting from ephemeral streams Wetland enhancement
Ōreti: Middle	Groundwater storage Water harvesting from ephemeral streams Wetland enhancement Riverine Galleries

Focus Area	Potential Water Storage Methods
Ōreti: Upper Makarewa	Water harvesting from ephemeral streams Wetland enhancement Baseflow enhancement dams Small dams Groundwater storage
Aparima: Upper	Groundwater storage Water harvesting from ephemeral streams Wetland enhancement Riverine Galleries
Fiordland and Islands: Oban	Groundwater storage

Investigations into Water Availability

Funding is available for a range of activities that will improve the understanding of the availability of water across Southland. These include:

- Undertaking aerial electromagnetic surveying (aquifer mapping) to identify the boundary between the Upper Ōreti and Mid/Upper Matāura (Mossburn-Lumsden-Riversdale). This would provide better information about the aquifer to the regional council and the community and give them greater confidence about how much water could be available to bring land into sustainable production.
- Capturing information on ephemeral streamflows in Mid/Upper Matāura, Upper Ōreti, Aparima, Upper Makarewa to explore the potential for harvesting and storing peak flows for use in dry periods, potentially for the augmentation of wetlands.
- Undertaking test drilling to explore the boundary between the Upper Ōreti and Mid/Upper Matāura (in the vicinity of Lumsden) in lieu of, or in addition to, aquifer mapping.
- Exploration into the viability of a diversion of water from Lake Wakatipu into the headwaters of the Matāura River main branch south of Kingston to increase security of supply for groundwater and surface water in the Matāura River catchment. Such a study would consider the hydrology and effects of increased water availability.

Aqua Intel Aotearoa will progress investigations of water storage options for the region in a manner that is consistent with the regulatory and cultural imperatives for the region, particularly in relation to enhancing water quality outcomes. Aerial electromagnetic surveying, the capturing of ephemeral streamflows and the enhancement of wetlands are projects that offer strong water storage potential while being consistent with the water quality priorities of the region.

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1.0 INTRODUCTION

This report is prepared through Aqua Intel Aotearoa – a collaboration between the Provincial Development Unit (PDU) and GNS Science (GNS) to assess regional water storage and opportunities. The Government has invested $10 m from the Provincial Growth Fund (PGF) for Aqua Intel Aotearoa to undertake regional needs assessments and mapping of water availability in four regions – Northland, Gisborne, Otago and Southland.

Water storage is one of the most significant investments that can be made to lift regional productivity. For most of the regions, the primary sector is a major element of the local economy. Land-based production is a comparative advantage of the regions relative to urban areas and has shown itself to be a critical part of the economy through COVID-19.

The key objectives for PGF wider investment in water storage are to:

- strengthen regional economies by shifting to higher-value sustainable land uses
- address disparities in Māori access to water for land development
- support micro- to medium-scale water storage projects that strengthen regional partnerships and provide wider public benefits, and
- support land use that does not increase (and ideally reverses) negative impacts on water quality and maintains and improves the health of waterways.

In meeting these objectives, PGF investments also consider how investments:

- contribute to a just transition to a low emissions economy and/or contribute to building community resilience to climate change, and
- provide an incentive to change land use that risks degrading the environment to high-value more sustainable uses.

All PGF water storage investments are guided by a set of investment principles in line with these objectives (Appendix 1). The PDU-GNS regional needs assessments are consistent with these objectives and investment principles.

Water storage and distribution infrastructure can enable regions to bring under-utilised land into production, where this is consistent with the National Policy Statement on Freshwater Management. It can also potentially enable them to improve the productivity of existing land by moving to higher-value land uses. Providing reliable access to water can be a pre-requisite for higher-value land uses. Reliable access to water can enable regions to diversify their land use and increase horticultural activities, to ensure the primary sector operates sustainably – minimising negative impacts on water quality and maintaining and improving the health of waterways.

The main focus of PGF funding for water storage is to increase land productivity from horticulture. There are a number of limitations on the purposes for which PGF water storage funding can be used. In general, PGF funds cannot be used for municipal water supply or Three Waters infrastructure, provision of maintenance funding for existing schemes or to support land use that leads to ruminant intensification.

Consideration is underway in other parts of government about the adequacy of water for other purposes, such as drinking water. With climate change, access to water may decline in some regions, leading to greater deprivation for some communities. Water storage can support community and incomes in this context.

In this report, the benefits of water storage and improved knowledge of aquifer distribution to Southland are summarised and resources relevant to water storage are outlined (Section 2). The report identifies nine focus areas where water storage could provide benefits to the productive sector and the environment (Section 3). Water storage options in nine selected areas are outlined, including surface water and groundwater sources (Appendix 2), with maps of preferred options in each area (Section 4); storage options in the other focus areas will be assessed in future work. In each of the nine focus areas, the report comments on potential benefits of water storage and potential initial investments in each area (Section 5).

1.1 Water Storage Development

The delivery of water storage infrastructure is a lengthy process that takes place over a number of years, with a number of phases leading to construction and operation (Figure 1.1 and Table 1.1).

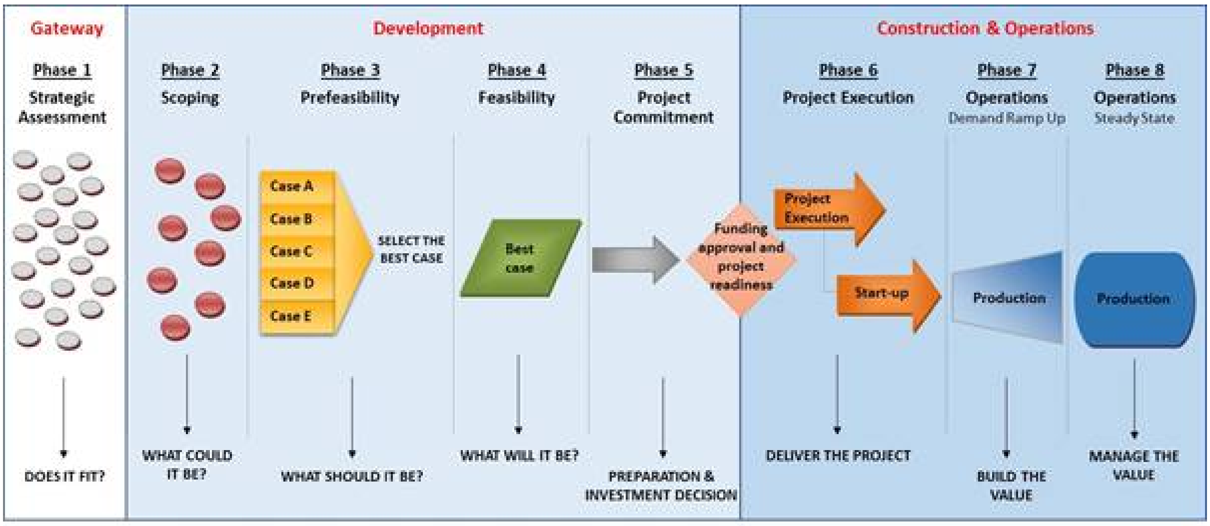

Figure 1.1 The water infrastructure development process.

Information about water availability and potential land use is necessary to effect water storage projects. The information developed through these regional water needs assessments inform Gateway: Phase 1 – the strategic assessment of whether water storage projects could be taken to the development phase.

Table 1.1 Development phases for water infrastructure.

Phases	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Water Availability (Water Supply)	Identify potential sources of water and water storage approaches. Monitor availability of water, e.g. low flows and harvestable flows of water in rivers, streams and groundwater. Determine whether sufficient sustainable water will be available to take water for productive purposes, including meeting regulatory requirements and community expectations.	Assess whether water supply will be sufficient to justify investment.	Identify potential water storage sites based on regional freshwater objectives and regulatory settings, technical feasibility and storage scale. Secure water resource consent(s).		Final site for water storage chosen.	Water storage infrastructure constructed and water becomes available to landowners.		
Land Use (Water Demand)	Identify areas for potential land-use change and what water is needed to support this (including considering land uses that require less water). Undertake preliminary discussions with landowners and potential business partners to assess potential interest in securing water.	Assess whether water demand is likely to be sufficient to meet construction costs.	Build demand from landowners, business partners and other potential owners of the infrastructure (e.g. municipal, industrial).	Secure land-based consents	Owners sign up to project.	Landowners invest funds through purchasing a share of the asset. They utilise water to increase the sustainable productivity of their land.		
Project Development	-	-	Develop a business case for infrastructure investment based on adequate supply and demand. Establish a vehicle to deliver the project.			Manage delivery of project.		

The regional water needs assessments being prepared by Aqua Intel Aotearoa relate to Phase 1, for example:

- considering the current status of land use and water availability in focus areas within the regions;
- considering the potential land use and water storage approaches that could generate an increase in sustainable land development; and
- identifying and funding activities that will progress work on water availability within the focus areas, where the assessment shows that a viable and sustainable water storage approach is achievable and land productivity can be sustainably increased in line with the PGF objectives above.

Funding available for investment through Aqua Intel Aotearoa will be prioritised toward activities that can progress the region through to later stages of water development (Figure 1.1; Table 1.1). For example, the project will fund gauging of surface water in areas that are known to experience water shortages. Decisions about where to undertake gauging will be informed by local expertise from regional councils and water specialists.

1.2 Southland Water Needs Assessment

Southland needs water to address land productivity whilst providing environmental benefits. The PGF investment considers land productivity alongside environmental benefits because of the impacts of existing land use on water quality in the region. The PGF investment can progress productivity and sustainability objectives in tandem but cannot invest for environmental outcomes alone. GIS mapping indicates sufficient quantities of water being available in some focus areas to provide productivity and environmental benefits. Therefore, local assessment of specific water challenges will be undertaken in Southland. The approach will ensure that recommendations for future investigations address existing water issues, e.g. water quality, water allocation limits and uncertainty about future water allocations.

This assessment of Southland water needs and opportunities considers potential water use and water availability within nine focus areas of the region (Section 4), with particular emphasis on northern Southland due to allocation and water availability constraints in these areas. Southland has a well-developed agricultural sector that relies on access to water (i.e. surface water from run-of-river schemes and groundwater from wells) to support productive farmland. Many of the water challenges faced in Southland arise in areas where freshwater systems have been degraded. Although regulatory limits for water quality have not yet been finalised, it is likely that considerable land areas will require water quality improvement, rather than maintenance, in the future. Regulatory limits for water quantity have been set within the proposed Southland Water and Land Plan (pSWLP; 2018). Water has been largely available from run-of-river and groundwater to date, therefore significant investment in water storage projects of scale has not occurred. Existing projects are often small-scale, providing 15–25 days of storage. Beyond that level, the costs outweigh the value of additional storage when water demand is not high every year. With water allocation limits being reached, this situation is changing and storage could offer access to a greater quantity of reliable water.

For Southland, the challenge will be to make additional water available for productive purposes in the focus areas while addressing environmental issues. There is an opportunity to progress water storage options in a way that contributes to changing land-use options. This may inform and support changes to regulatory limit setting, provided that the areas of greatest impact from a limit-setting perspective also align with the water focus areas of this project. In Southland, investment will relate more to the PGF’s environmental objectives than to productivity and Māori land objectives.

There is a low level of Māori-owned land in Southland (Table 1.2). The Māori land in the region is predominantly under native or exotic forestry and predominantly located on hill slopes. Access to water is unlikely to support this land being brought into production. While Aqua Intel Aotearoa prioritises Māori land development across the regions, given the nature of the Māori land in Southland, this issue is not considered further in this report.

Table 1.2 Land areas in the Southland focus areas.

Item	Total (ha)
High-producing exotic grassland	315,000
Māori land (all)	6609
Agricultural land and Māori land	670

1.3 Te Mana o te Wai

Since 2017, the National Policy Statement for Freshwater Management (NPS-FM) requires councils to consider and recognise ‘Te Mana o te Wai’ in policy development related to freshwater. Te Mana o te Wai is the integrated and holistic well-being of freshwater bodies, which supports the health and well-being of people and the environment. The NPS-FM 2020 requires that freshwater management “gives effect to” Te Mana o te Wai. This has increased the legal weighting from ‘consider and recognise’ and introduced a hierarchy of priorities that confirmed the health and wellbeing of waterbodies (including groundwater) as first priority. The economic wellbeing of people and communities are a lower priority.

A suite of draft freshwater objectives have been agreed for Murihiku Southland as a result of partnership between the regional council and Te Ao Marama (representing Ngāi Tahu ki Murihiku), subject to establishing limits, targets, methods, action plans and timeframes (Bartlett et al. 2020). These are based on a ki uta ki tai framework, and freshwater management is viewed through the lens of Te Mana o te Wai. The draft freshwater objectives have been formed through an enduring partnership between Te Ao Marama and Environment Southland and a commitment to using environmental science and mātauranga to benefit one another.

Ngāi Tahu ki Murihiku see Murihiku (Southland) as a region that faces significant challenges from legacies of past and present uses of lands and waters, which adversely impact on mana whenua association and uses. Ngāi Tahu ki Murihiku seek to see wetland extent, indigenous vegetation and tussocklands restored in the Waiau, Aparima, Ōreti, Matāura and Waituna freshwater management units (FMUs), equivalent to what has been lost since 2007 by 2030 and what has been lost since 1995 by 2035 (Te Ao Marama 2020). Ngāi Tahu ki Murihiku recognise that restoration of wetlands and indigenous land cover provides multiple co-benefits, including slowing water down, intercepting the movement of contaminants to waterways (e.g. via overland flow, ephemeral waterbodies), improving indigenous biodiversity and supporting mana whenua association and uses, as well as having the potential to improve natural-systems-based water storage within a catchment setting. In addition, Ngāi Tahu ki

Murihiku are seeking review of allocation and flow regimes on the Waiau, Aparima, Ōreti and Matāura rivers by 2025.

Ngai Tahu ki Murihiku considers the following factors in relation to draft freshwater objectives and mana whenua objectives:

- The Murihiku Southland economy incorporates Ngāi Tahu ki Murihiku economic activity, which includes customary practice (e.g. mahinga kai) that sustains whānau and households and is reliant upon both maintain and restoring te hauora o te wai.
- Disparity is associated with degradation of waterbodies and loss of mahinga kai, and review of flow and allocation regimes is about accessing water to support ahi kā, mahinga kai and kaitiakitanga rather than having a singular land development focus.
- Micro- and medium-scale projects are more likely to be helpful in contrast to larger-scale development projects.
- Land use must maintain and/or restore with reference to draft freshwater objectives.
- Just transition to a low-emissions economy and reducing the risks of degrading the environment are important objectives to mana whenua.

The NPS-FM 2020 provides a pathway for an increased role of mana whenua in water resources management. In particular, it provides the principle of mana whakahaere, which supports iwi having a partnership role in decision-making around freshwater management. Overall, decisions regarding water storage in Southland should be advanced with partnership and decision-making in the context of giving effect to Te Mana o te Wai.

2.0 SOUTHLAND REGIONAL SUMMARY

Southland (Murihiku) covers an area of more than 3.2 million hectares (12% of New Zealand). The Southland region is predominantly a mix of intensively farmed land (23%) and Department of Conservation (DOC) estate (53%) with other land uses such as urban areas (24%) (RPS 2017). The land and water in Southland located within public conservation estate is managed by DOC, predominantly within Fiordland and Rakiura National Parks (Nicol and Robertson 2018).

Southland's economy is significantly rural with $890 million (16.4%) of its GDP derived from the agriculture sector (GDP from 2017). The percentage of Southland GDP from agriculture is second only to the West Coast (20%) and considerably greater percentage when compared to many other regions in New Zealand. Southland has the third largest dairy sector in New Zealand ($0.75 billion), behind Waikato ($1.4 billion) and Canterbury ($2.2 billion).

Table 2.1 Summary of agricultural and horticultural land-use area in Southland for the period 2002–2016 (Stats NZ 2016).

Farm Type	2016	%
Dairy (ha)	301,979	25
Sheep and beef (ha)	699,141	60
Other livestock (ha)	4,5439	4
Forestry (ha)	7,5183	6
Fruit and berry (ha)	-	-
Vegetable growing (ha)	736	-
Grain growing (ha)	51,802	4
Total (ha)	**1,174,280**	-

The Southland dairy sector brings significant economic benefits to the region, with the Dairy sector contributing to 14.8% of Southlands economy (Ballingall and Pambudi 2017). This sector has also led to a number of challenges to environmental outcomes with nutrient discharge, winter grazing and pugging impacting on land and water quality. Southland recognises the challenges that its agricultural economy places on its environment. Options for reducing the impact of existing land use are being explored, such as through diversification into tourism, aquaculture, sheep milk production and horticultural crops.

An opportunity exists to examine water storage and water demand alongside the need to support land-use change in Southland, which will arise as a result of the requirement to improve environmental outcomes. Limiting setting in Southland will inevitably result in the need to reduce and change some land-use activities, especially where water quality is deemed to be of poor quality. This will ultimately drive the need for land-use change; however, it is important that environmental impacts of alternative land uses are also assessed, alongside a broad range of other considerations. For example, customary uses of water and waterbodies continue wherever degradation has not reached a level that prevents safe use.

2.1 Water

Water is allocated for numerous purposes in Southland (Table 2.2). Meridian Energy has the largest allocation for the Manapōuri power scheme. Other important uses include industry, agriculture and human drinking water supply.

Table 2.2 Summary of consented water takes in Southland (Environment Southland 2020).

Consented Water Take Use	Annual Volume (M m^3/yr)	Percentage of Consumptive Takes
Industrial	51.9	32%
Irrigation	51.2	31%
Town supply	35.2	21%
Stock	25.9	16%
Other	0.1	<1%
Meridian Energy	34,122.5	-

Groundwater is an important resource in the Southland region. Although characterisation of groundwater quality and quantity has improved in the region, knowledge is comparatively poor compared to that held for surface water. Demand for surface water and groundwater has been increasing in Southland and can be expected to increase further with population growth and any projects that increase land productivity. Current constraints to development include fulfilment of allocation limits in some surface water and groundwater catchments. Consented groundwater allocation increased significantly over the last 20 years through increased irrigation demand in the Matāura and Ōreti catchments (Wilson 2011). In addition, further stress on groundwater resources is likely to be driven by long-term changes to regional climate, particularly documented changes in precipitation (Zammit et al. 2018; Ministry for the Environment 2018; Wilson 2011).

Southland's waterbodies have been extensively modified. Land drainage has diverted water so that it is more rapidly routed into rivers and streams. This has led to a reduction in the volume of seasonal water storage in many shallow unconfined aquifers and subsequent outflows to rivers and streams during summer and autumn. In addition, abstraction of groundwater for use (e.g. for irrigation, drinking water supply, industrial use) has also altered the natural equilibrium between aquifer recharge and discharge (and therefore the water balance).

Surface hydrology in Southland is dominated by two large lakes (Lake Te Anau and Lake Manapōuri) and four large river systems (Waiau, Aparima, Ōreti and Matāura rivers). Many smaller streams and rivers occur in the catchments of these features and there are numerous small inland and coastal lakes. There are two hydroelectric power stations in Southland–Manapōuri and Monowai (Section 2.5).

Water bodies in Southland are highly connected, flowing through the landscape as surface water and groundwater and eventually discharging at the coast. Estuaries in Southland are the natural 'sink' for catchment contaminant loads. As a result, these estuaries are often highly degraded and reflect the impacts of land use intensification, in particular mobilisation of sediment. Unconfined aquifers occur over large areas of Southland, predominantly within valley and plains systems of the major rivers. These unconfined aquifers are hosted in Quaternary alluvium deposits, which are often thin and very shallow. Groundwater provides an important source of baseflow to many streams. Deeper confined aquifers have been identified in the Ōreti Basin and throughout eastern and central Southland (Hughes 2017). Information on the spatial extent and hydraulic properties of confined aquifers in Southland is limited. Key aspects for groundwater management in Southland include groundwater–surface water interaction, impacts of land use on groundwater quality and abstraction of groundwater for industrial uses (e.g. Matāura). There are limited (if any) reports of seawater intrusion.

Water quality in Southland is highly variable and is predominantly influenced by land use, resulting in many catchment-specific water quality issues. The state of surface water and groundwater quality ranges from 'pristine' to highly degraded (LAWA 2020a; Snelder et al 2019). There are three main issues that affect surface water quality (Environment Southland 2020). Sediment (mud and silt) accumulates on the beds of rivers, lakes and estuaries, which can compromise the habitats of macroinvertebrates and fish and promote slime algae growth. Sediment in streams can be generated from heavy rainfall on vulnerable soils, disturbance of the riverbed or bank by heavy machinery and stock; or from direct discharges. Nutrients, particularly bioavailable forms of nitrogen (N) and phosphorus (P) cause problems with excess slime algae and aquatic plant growth. Bacteria (including *E. coli* and cryptosporidium) are produced with faecal material from animals and humans and transported to waterways.

A recent model of total oxidised nitrogen (TON) concentrations indicated contamination of shallow oxidised groundwater by human activities across much of the managed groundwater zones in Southland (Snelder et al. 2019). The results are consistent with increased NO_3-N inputs and losses associated with high-intensity land use, primarily agriculture, across the alluvial plains of northern and southern Southland. Results indicate highest concentrations are associated with intensive agriculture in areas with well drained soils (or soils susceptible to bypass flow) where groundwater is primarily recharged by soil moisture infiltration. Analysis of surface water datasets (2003–2013) indicated an increasing trend in surface water nitrate-nitrogen concentrations at 31 sites, no significant trend at 36 sites and a decreasing trend at two sites (Environment Southland 2015). Similarly, analysis of Dissolved Reactive Phosphorus (DRP) concentration in surface water indicated an increasing trend at nine sites, the majority of sites with no trend (42 sites) and a decreasing trend at 17 sites.

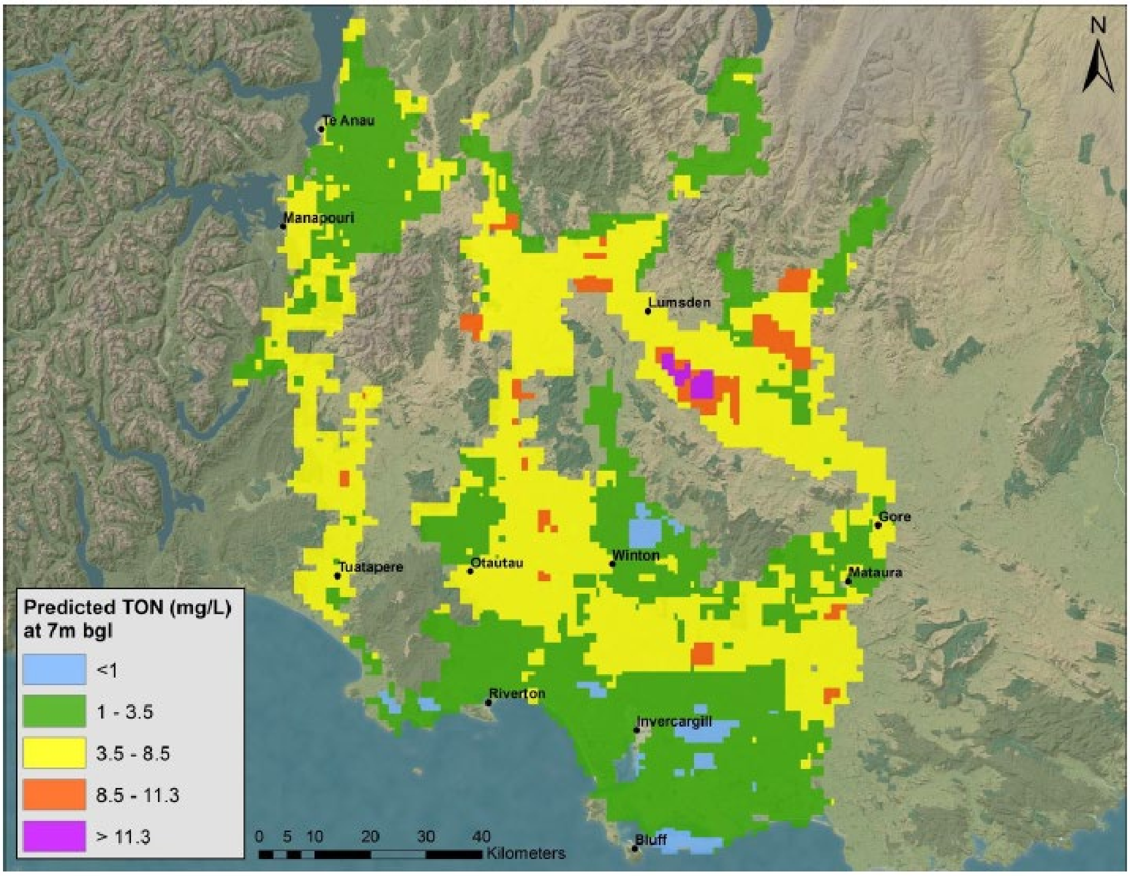

Figure 2.1 Predicted groundwater total oxidised nitrogen (TON) concentrations at a nominated depth of 7 m BGL (Snelder et al. 2019).

Consistent themes on the state of water quality in Southland's rivers and streams include:

- non-point source agricultural inputs (e.g. leaching, runoff) are the main pathways for nutrient contaminants in Southland’s rivers;
- elevated microbial contamination in lowland rivers and streams;
- macroinvertebrate community health standards are not met at c. 20% of monitoring sites; and
- nuisance growth of benthic periphyton in the lower Matāura, Aparima and Waiau Rivers and several lowland streams.

Given the time it takes for water and contaminants to ‘flow’ through a system some of the effects are legacies of past activities. Many areas of agricultural land in Southland have been subject to extensive modification, including installation of sub-surface drainage, surface drainage and channel modification to maintain soil productivity (Figure 2.2).

> *“Artificially drained soils have far less ability to remove nitrogen and other substances from water flowing through the soil than would otherwise be the case, as most of the water bypasses the soil zone.”* (Moran et al. 2019).

Flood-control structures are required in the Southland Plains to protect highly-productive land and urban settlements. These activities alter the physical landscape and have flow-on effects to surface water quality and values.

Surface water availability is close to allocation limits in several Southland catchments (i.e. surface water allocation is >70% of the limit) (Figure 2.3). Groundwater allocation is within 70% of the limit in several groundwater management zones in the mid-Matāura area (Figure 2.4).

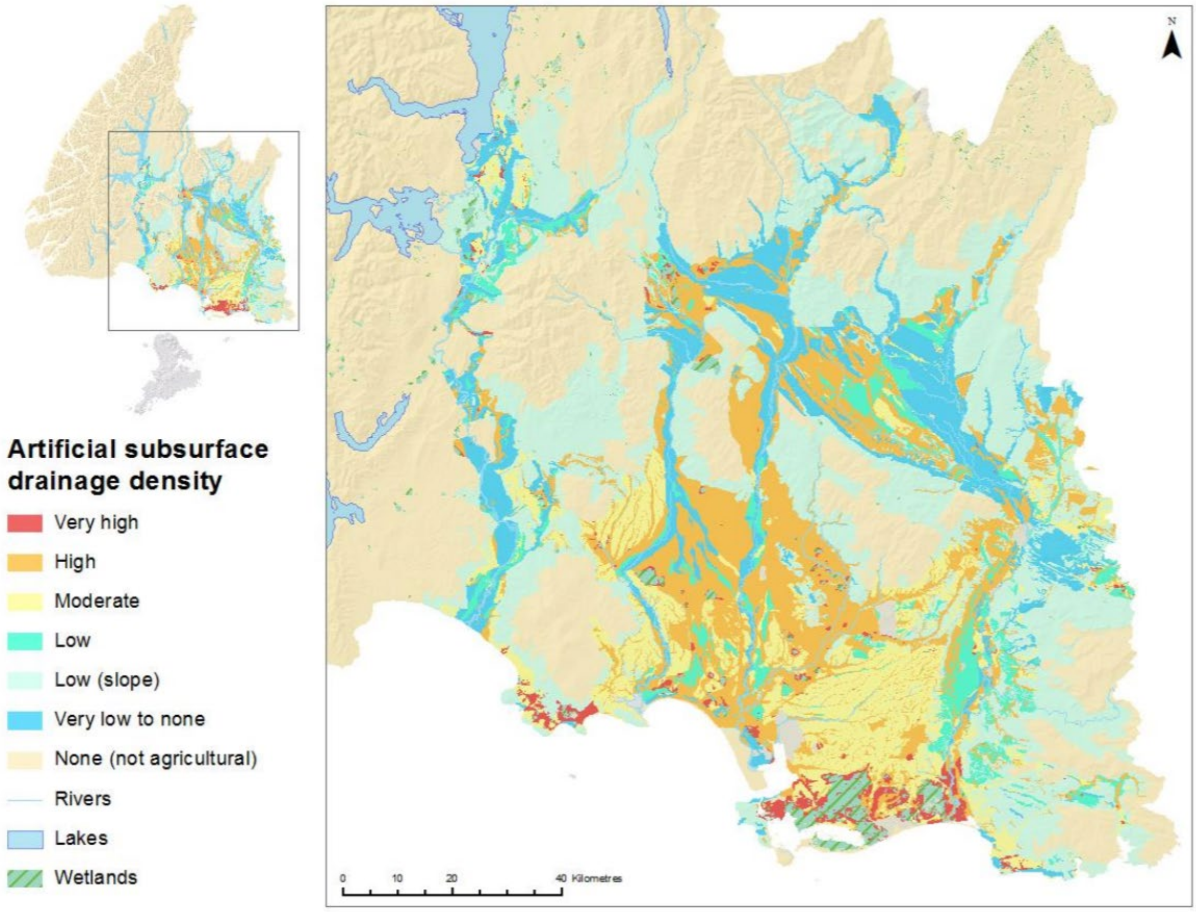

Figure 2.2 Estimated density of artificial drainage in Southland (Moran et al. 2019).

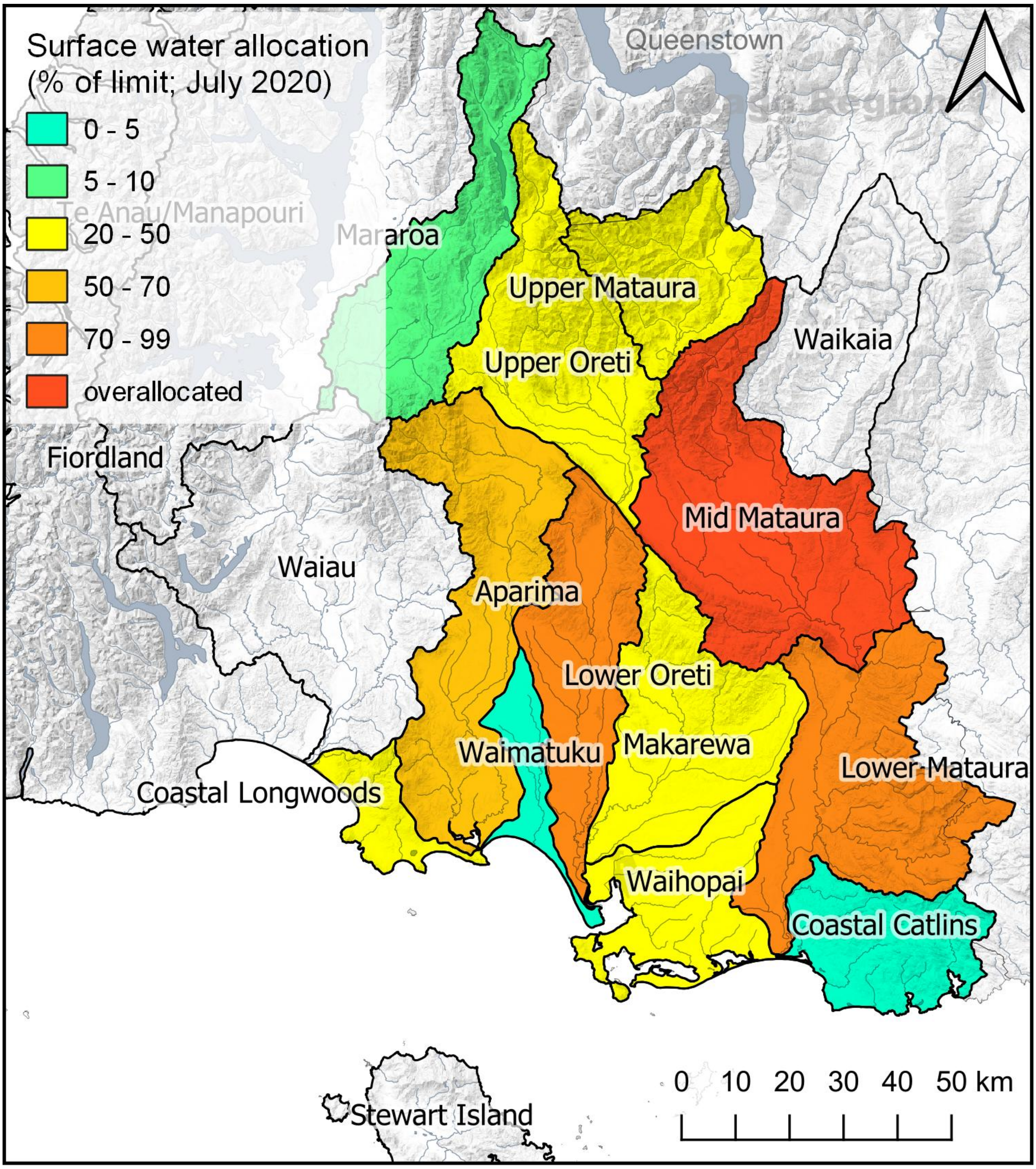

Figure 2.3 Overview of catchment allocation by surface major sub-catchment. Surface water allocation includes the surface water depletion component of groundwater takes (Kees 2020, pers. comm.).

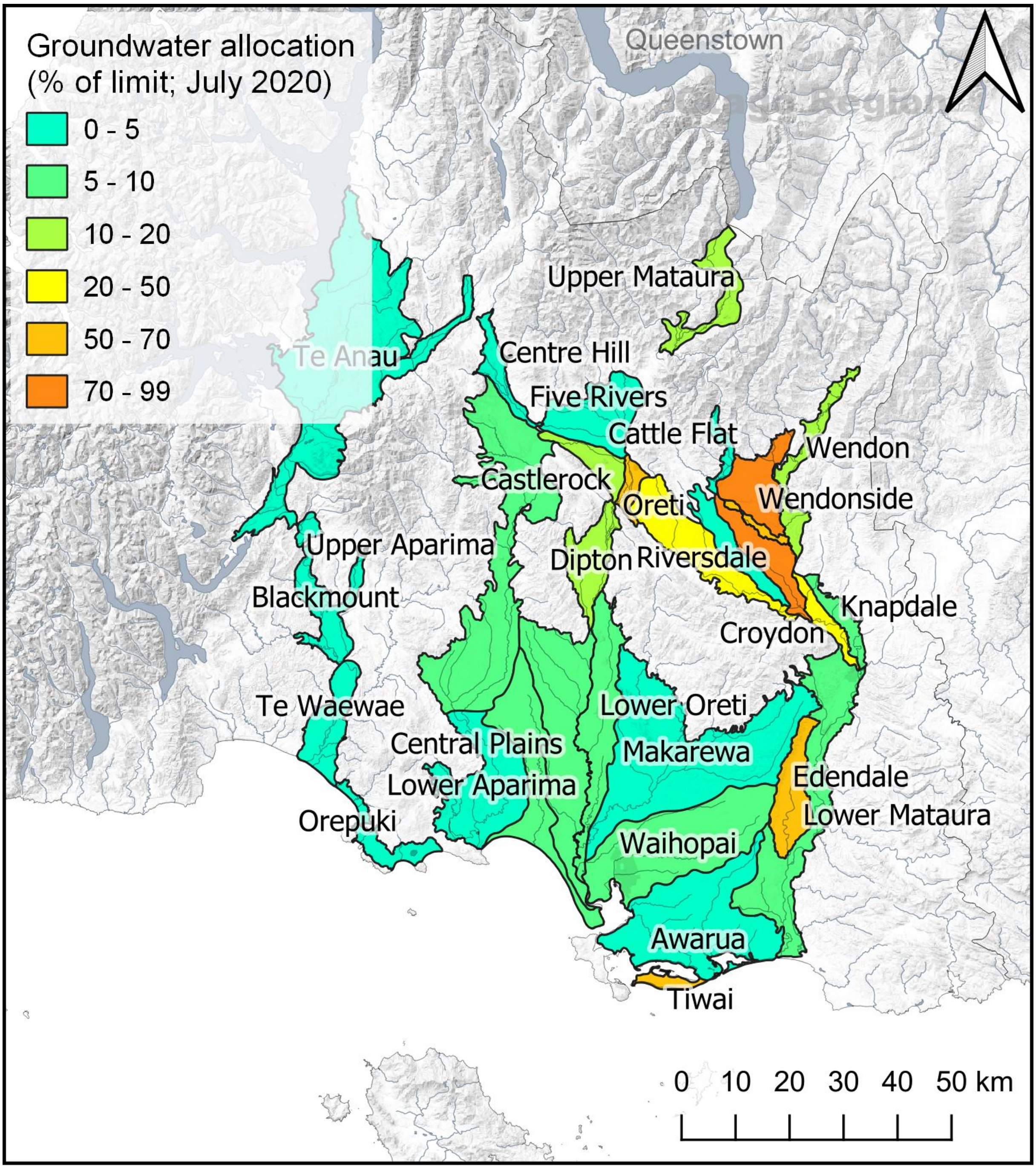

Figure 2.4 Overview of catchment allocation by groundwater management zone (Kees 2020, pers. comm.).

2.2 Land

In 2017, it was estimated that Southland had around 19,000 ha of land under irrigation (Ministry for the Environment 2020). Of the 192 irrigation consents, 139 were for groundwater abstraction and 53 were for surface water abstraction. Land under irrigation in Southland has continued to increase since 2017, in particular in the Upper Waimea Plains and Wreys Bush area on the Aparima Catchment (Kees 2021, pers. comm.). Irrigation is predominantly undertaken for dairy farming and pastoralism, followed by livestock other than dairy, arable and horticultural land uses (Stats NZ 2016). Areas of higher-intensity irrigation occur in the Five Rivers, Lumsden, Riversdale and Waimea Plains areas (Ministry for the Environment 2020). More recently, an increased reliability of supply has been achieved by converting surface water abstractions to groundwater abstractions from confined aquifers or unconfined aquifers with a low connection to surface water. This conversion is a result of surface water takes often being subject to low-flow cut-offs, often because low river flows coincide with the highest demand for irrigation.

Many areas of Southland have adequate soil moisture to sustain pasture growth throughout the year for current land use. However, in some areas (e.g. Hokonui Hills, Te Anau Basin, Five Rivers and Riversdale) extended dry periods can create periods of sustained soil moisture deficit. Meanwhile, it has been predicted that it is

> *"… likely that parts of the Southland region, particularly the central-northern part of the region, will experience more drought conditions in the future than at present"* (Environment Southland 2020).

Since annual (seasonal) rainfall is not always adequate for agriculture in localised areas north of the Hokonui Hills, there is the potential for irrigation to increase productivity (e.g. conversion from extensive pastoralism to dairy, horticulture, or arable) in the western Central Plains area. Producers in the horticulture and floraculture industries have faced water shortages in the past. In some instances, this has led to non-compliance (e.g. abstraction of water greater than consented volumes, or without a water permit to prevent crop destruction), loss of productivity and/or loss of yield. A reliable and flexible irrigation water supply would provide the horticulture and floraculture industry with greater reliability of supply.

As agriculture occupies 87% of the developed land in Southland (Moran et al. 2019), the region is focused on addressing the impact of this sector on the health of its waterbodies, particularly in light of the impact of modifications made to support agriculture of the Aparima and Ōreti catchments in Central Southland.

2.3 Climate

Climate conditions vary across Southland due its wide range of topography and exposure to weather systems moving onto the country from the west or from the south (Macara 2013). The region is in the latitudes of prevailing westerlies, and areas around Foveaux Strait frequently experience strong winds, which are lighter inland. Winter is typically the least windy time of year, as well as (for many, but not all, areas), the driest season. Rainfall differs significantly across the region, from a minimum of 800 mm in the eastern lowlands near Fiordland to over 8000 mm in the western ranges. Rainfall tends to be fairly evenly distributed throughout the year, except in Gore, Te Anau, Tuatapere and Waikaia, where maximum rainfall (e.g. 30% of annual rainfall) occurs in summer.

Temperatures in Southland are on average lower than over the rest of the country with frosts and snowfalls occurring relatively frequently each year. Summer temperatures in Southland reach between 18–22°C whereas overnight winter temperatures fall to 0–2°C (Macara 2013). Inland plains and valley areas of Southland typically record higher daily maximum temperatures in summer and lower daily minimum temperatures in winter compared to coastal areas. Lower temperatures occur throughout the year at higher elevations. Frosts are more frequent in the cooler months. On average, Southland receives less sunshine than the remainder of New Zealand. Southwestern areas of Southland are particularly cloudy, and these areas receive less than 1300 hours of bright sunshine annually. Most of the populated areas of Southland receive between 1600 hours and 1750 hours of bright sunshine annually. In Southland, dry spells occur more frequently in inland areas and are uncommon in coastal areas. Southland has experienced numerous extreme weather events, with significant damage and disruption caused by heavy rain, flooding and snow falls over the past 30 years (Macara 2013).

2.4 Climate Change

Southland temperatures are projected to increase, from the 1986–2005 'reference' climate, by 0.5–1.0°C (2031–2050; mid-century) and 0.7–3.0°C (2081–2100; late-century) (Zammit et al. 2018; Ministry for the Environment 2018). By 2090, Southland is projected to have 5–55 additional days per year where temperatures exceed 25°C, with around 10–20 fewer frosts per year. Winter rainfall is expected to increase, with largest increases in the north of the region, meanwhile there will be a likely 10% decrease in summer rainfall in western Southland. The Potential Evaporation Deficit is expected to increase by 40–80 mm/year for most of Southland, up to 100 mm per/year for the highest emission scenario by 2090. Storms are expected to become more frequent.

The potential effects in Southland as a result of predicted changes in climate include flooding; increased intensity and duration of droughts; coastal erosion and inundation; storminess; and sea level rise (Ministry for the Environment 2018). Overall, annual average discharge is likely to remain stable or decrease slightly by mid-century, whereas average annual flows are likely to increase (up to 50% in the Matāura and Ōreti catchments) by late century. Seasonally, spring flows are expected to increase and summer flows are expected to decrease. Warmer temperatures could increase the spread of pests and weeds but could also provide a longer growing season, opportunities for new crops and faster growth.

2.5 Infrastructure

Environment Southland operates regional flood protection infrastructure, which consists of 458 km of stop banks, seven dams and associated culverts and structures. Southland has an extensive land drainage system that consists of artificial drainage canals and community drains (Environment Southland 2020). Manapōuri hydropower station (800–850 MW) operates using the natural 178 m height difference between Lake Manapōuri and the sea at Deep Cove in Doubtful Sound, Fiordland. The Manapōuri hydropower system uses the Mararoa Weir feed water from the Mararoa River into Lake Manapōuri. The Monowai hydropower station (7.6 MW) is fed by Lake Monowai and the Monowai River in Fiordland National Park.

Southland District Council (SDC) operates 11 rural water supply schemes (e.g. Duncraigen, Five Rivers, Homestead, Eastern Bush – Otahu Flat, Kakapo, Lumsden-Balfour, Matuku, Mount York, Princhester, Ramparts and Takitimu), primarily for stock water supply. The majority of these schemes are not suitable for human drinking water, excluding Eastern Bush – Otahu Flat and Lumsden-Balfour, which are treated and can be used for human drinking water. Property owners are able to purchase water units from SDC for a daily allocation, which is controlled by a restrictor device at the tank.

Water for irrigation in Southland is sourced from surface water and increasingly from groundwater. The majority of irrigation and industrial takes are point takes, including abstraction from a river (or near-river) or from a well, rather than distributed systems (e.g. irrigation scheme intakes, ponds and channels). Water storage infrastructure in Southland is limited to small-scale on-farm and municipal supply storage, with no existing large-scale irrigation schemes.

Looking beyond the scope of PGF investments, Southland’s primary municipal water supplies include Invercargill City (ICC) and Gore City (GDC). These supplies are currently under pressure to provide a sufficient volume of water at the required quality. Although ICC has recently undertaken a 20-year-planned upgrade to the reticulation network, there is significant risk in the city municipal and industrial supply being solely reliant on a single source (i.e. the Ōreti River at Branxholme). In addition, SDC operates 11 smaller community water supply schemes and 18 wastewater schemes in small towns and settlements throughout Southland.

2.6 Provincial Growth Fund Investments in Southland Water Storage

The Government has invested $850k into the Ōreti Managed Aquifer Recharge Trial Project (Ōreti MAR) through the PGF. The primary aims of the project are to explore options to improve the management of groundwater storage and to improve supply reliability whilst ensuring that the environmental, cultural and social values of water are protected and enhanced. The project acknowledged that aquifers are also ecosystems unto themselves and will begin to explore subterranean habitats, collecting valuable information about the resident fauna and their influence on the aquatic habitat and natural biochemical processes. The project plans to hold a series of community workshops to discuss the MAR trial findings and how groundwater storage may provide both economic and environment benefits to the wider Southland region.

Ngāi Tahu ki Murihiku do not support use of managed aquifer recharge in the region because of the impact of existing land and water uses on groundwater quantity and quality within confined aquifers. They instead focus on te hauora o te wai and the restoration of degraded water systems and approaches that manage within natural limits. In 2020, the Ōreti MAR trial project went through a resource consent application phase and a hearing was held in early 2021. The outcome of the consent hearing was a decision to decline the application, which was not appealed by the applicant. This outcome indicates the necessity for partnership decision-making regarding water storage to be undertaken with Ngāi Tahu ki Murihiku.

2.7 Regional Council Consenting Considerations

Five Freshwater Management Units (FMUs) are defined in Southland (i.e. Aparima, Matāura, Ōreti, Waiau and Fiordland and Islands) in accordance with the NPS-FM (2014; amended in 2017 and 2020). Water allocation is based on primary allocation thresholds, which are intended to be precautionary, with fixed allocation limits to be developed over time in the pSWLP within the FMUs (Figure 2.5).

Figure 2.5 Southland FMUs and primary surface water features (Nicol and Robertson 2018).

Environment Southland allocate groundwater and surface water through the resource consent process. However, not all consented water is used and not all water use requires a consent. There is approximately 0.47 billion m^3 of groundwater available in Southland for allocation, with 0.05 billion m^3 currently allocated (equivalent to 11% of groundwater available) (LAWA 2020b). As at March 2015, less than 50% of the groundwater primary allocation thresholds had been allocated in the majority of the region (Environment Southland 2020). Some aquifers are fully allocated, or close to fully allocated, in terms of the primary allocation thresholds.

Water allocation to hydro-power (Manapōuri and Monowai power stations) equates to 99.5% of all the water allocated in Southland and 40% of all water used in New Zealand (Section 2.5). Excluding hydro-power, consumptive water allocation is dominated by industrial (32%) and irrigation (31%) uses, followed by town supply (21%) and stock supply (16%). The Waiau River catchment is fully allocated due to Manapōuri hydropower scheme that uses water from Waiau River catchments and from Fiordland. The Matāura Water Conservation Order (WCO) constrains water availability in the Matāura River catchment.

The primary groundwater allocation limits in unconfined aquifer management zones are calculated as a percentage of land surface recharge. Abstraction below this limit is classified as a discretionary activity; abstraction above this limit is (currently) a non-complying activity under the pSWLP (2018; Hughes 2017). The North Range and Lumsden confined aquifers have management controls. These aquifers are located in the Ōreti Basin and are connected with shallow groundwater and surface water, to varying degrees. A primary allocation limit has been set for these aquifers. Allocation of groundwater from aquifers is managed under the pSWLP (2018) that requires aquifer testing to produce reliable estimates of aquifer hydraulic properties and modelling to estimate stream depletion that is caused by pumping.

3.0 POTENTIAL BENEFITS FROM INVESTMENT IN WATER STORAGE

As a region, Southland has a diverse range of existing land uses, including:

- livestock (dairy, sheep, beef and deer)
- arable (predominantly wheat, barley and oats)
- vegetables
- cut flowers and bulbs, and
- horticulture (hydroponic lettuce, blueberries).

The region is currently considering how it uses water to address the impact of livestock on water quality. This assessment is likely to involve diversifying farming into growth of new crops.

The temperate climate and fertile soils result in high crop yields with low disease pressure compared to many other regions. However, the intensification of land use in Southland is coming under increasing pressure as a result of environmental regulation, with an estimated land-use change in Southland under the current NPS-FM (2020) of 9.6% required to achieve the NPS-FM standards (Cabinet Paper Action for Healthy Waterways, May 2020).

At present there is limited information to support decision making on alternative agricultural land-use opportunities in Southland, although there are a number of different work streams currently underway that may, in time, inform land-use change decisions. Some of the scientific research being undertaken via National Science Challenges (NSC) includes:

- climate change and its effect on our agricultural land;
- the Land-Use Suitability Analyser; and
- next-generation systems, e.g. speciality grains and pulses.

In addition to NSC undertakings, the Southland Regional Development Agency (Great South) have also undertaken some preliminary work to understand the opportunities in the agricultural landscape. In October 2019, Great South released TopoClimate Soils Information and Crop Data Sheets.

The Crop Data Sheets provide information on approximately 30 alternative crops that may have potential for commercial production in Southland (Table 3.1). The crops included those which have been grown for demonstration or research purposes at the New Crop Centre in Invercargill, as well as some species not presently available in New Zealand but which, based on soils and climate data, would be able to grow in Southland.

Table 3.1 Potential crops for commercial production in Southland (Crop data sheets 2019).

Berry Fruits	Arable and Bio Oil Crops
• Blueberry • Gooseberry • New Zealand Cranberry • Saskatoon Berry • Sea Buckthorn	• Grain Amaranth • Hemp • Meadowfoam
Flowers and Foliage	**Medicinal Herbs**
• Allium • Astilbe • Ballota • Bells of Ireland • Brachyglottis • Campanula • Carex • Chatham Island Forget-me-not • Daffodils • Delphinium	• Arnica • Borage • Echinacea • Evening Primrose • Ginseng • Goldenseal • Muńa-Muńa • Phacelia • Valerian • White Sage
Vegetables and Culinary Herbs	**Tree Crops**
• Asparagus • Azuki Bean • Burdock • Coriander • Daikon • Globe Artichoke • Horseradish • Saffron • Soramame Bean • Wasabi	• Chestnuts • Gevuina • Hazelnuts • Olives

Certain areas of Southland are already well known for growing arable crops, particularly within the northern Southland and the Mid/Upper Matāura and Upper Ōreti focus areas. A report prepared by Leftfield Innovation (2019) identifies six crops (i.e. soy, quinoa, hemp, chickpeas, oats and buckwheat) that could be grown successfully in existing arable Southland areas.

Great South have spent considerable time exploring options associated with the development of an oat milk industry in Southland. It is understood that significant capital investment would be required to establish processing capability in the region, and Great South are continuing to successfully raise capital to progress with an oat milk processing factory.

Hemp has a wide range of potential uses, including, pharmaceutical, nutraceuticals and natural fibres and building materials. A small area of hemp is already grown within the Balfour area of Southland, with the potential expansion. Typically, the areas that are best suited for arable crops are also the areas that have the greatest water demand. Hemp may also have value as a catch crop when used within a diversified farming system. The expansion of current niche operations in the sheep milking industry, which has been pioneered by Blue River Dairy, is another potential opportunity particularly if there is investment in processing facilities.

Southland grows vegetables and fruit for New Zealand. Potatoes, carrots and parsnips are the main vegetables grown commercially in the region at present. Up to 50% of parsnips sold domestically are grown in Southland (Southland 2017). Distance from markets is a significant commercial barrier for expansion both in the horticulture and vegetable space but could be overcome by a shift toward frozen goods processing, whereby both domestic and export markets could be accessed more easily.

Horticulture is currently estimated to be worth $50 million annually to Southland (Great South, 2019). At present there is one commercial blueberry growing operation in Southland and a small hydroponics lettuce growing operation. Horticulture and hydroponics have potential for expansion and require access to reliable water.

The majority of future crop opportunities are only likely to materialise with access to reliable water, for both production and processing purposes. A reliable water source is required in most instances to provide confidence to invest change of land use and secure commercial offtake agreements. A report prepared by AgFirst (Journeaux et al. 2017) identifies the key considerations for new crops are soil type, slope, climate and access to water. Once these factors are satisfied, then a range of other factors come into play. Perhaps the most significant of these could be loosely termed ‘economic’, with the relative profitability of the differing land uses being of paramount importance. Several researchers indicate that profitability is the key driver to change.

Often the land use capital cost of changing land use is significant, coupled with a delay in achieving a return on that investment, which can often act as a barrier to change and needs to be incorporated in any risk assessment around land-use change, including risks associated with access to reliable water. The opportunity in Southland lies around the capture and storage of water, as the region is not water short, but opportunities are enhanced where storage can drive land-use change reduce the ‘environmental footprint’ of farming activities. Therefore, access to reliable water supplies will play a role in supporting future land-use change. In this regard, Journeaux et al. (2017) noted that environmental externalities are starting to be recognised by regulatory change. As this process progresses, the economic cost of production will be impacted, which will see the market adjust accordingly providing incentives for land-use change.

4.0 FOCUS AREAS

4.1 Selection of Focus Areas

Focus areas in Southland were selected based on alignment with the PGF water storage objectives and consideration of the following factors:

- productive land that could be brought into higher value sustainable land use, and
- exclusion of conservation land and other crown land where water storage options would be difficult to proceed with (e.g. tenure review land) or would provide little regional economic development benefit.

In this assessment, productive land was identified using classifications within the Land Cover Database (LCDB; v5). The term 'Agricultural Land' was used to identify productive land in Southland by combining LCDB classifications of high-producing grasslands, croplands, orchards and vineyard and areas of known irrigation. There is potential that other areas, not identified as agricultural land in this assessment, may also become more productive over time. Where there is an expectation of short-term water demand in these areas, they have been included in the focus areas.

Within these target areas, water storage approaches are identified that meet the PGF objectives of:

- supporting micro- to medium-scale community water storage projects, and
- supporting land use that does not increase (and ideally reduces) the negative impacts of land use on water quality and maintains or improves the health of waterways.

Following engagement with the Southland region, the analysis concentrated on those focus areas where water storage could contribute to bringing land into production or diversification of land use, while addressing environmental concerns. These include focus areas of:

- Ōreti FMU (Upper Ōreti; Middle Ōreti; Upper Makarewa)
- Matāura FMU (Mid-Upper Matāura)
- Aparima FMU (Upper Aparima), and
- Fiordland and Islands FMU (Oban).

It was determined that in other parts of the region, there is either sufficient water throughout the year or insufficient opportunities for land development to justify investment in water storage, within the scope of this project. A full summary of datasets and methods applied to this project is provided in Appendix 1.

4.2 Summary of Focus Areas

Maps in this section show information from the LCDB, including Māori land, Crown land (managed by LINZ), protected areas and agricultural land (Figure 4.1). Areas of irrigation are also indicated, for which the type of irrigation can also be explored in GIS (Ministry for the Environment 2020). A total of six focus areas were selected for Southland, three of which are located within the Ōreti FMU (Upper Ōreti, Middle Ōreti and Upper Makarewa) and one each within the Matāura (Mid/Upper), Aparima (Upper) and Fiordland and Islands (Oban) FMUs; the Oban focus area was included as a minor focus area.

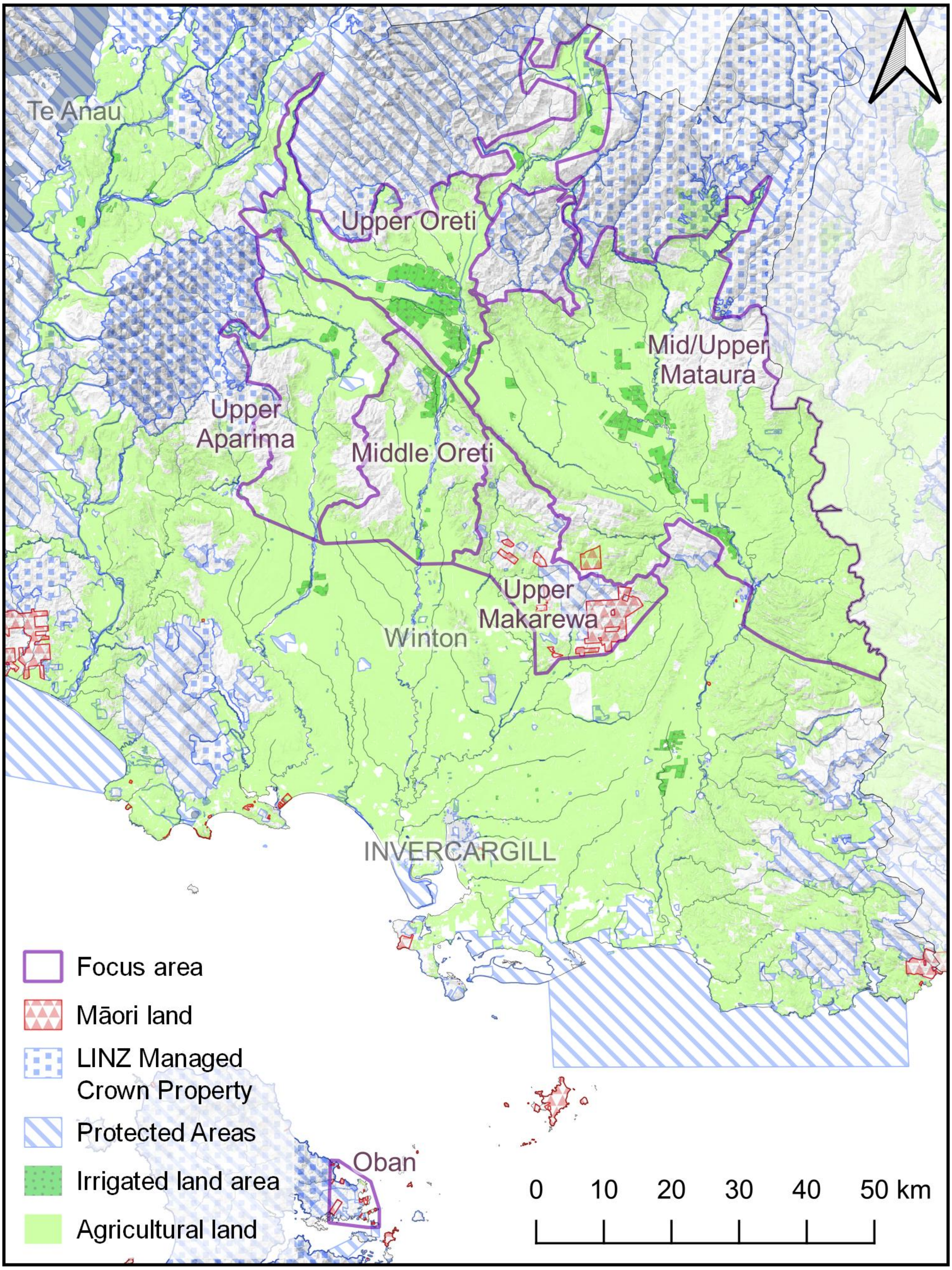

Figure 4.1 Location and extent of the six focus areas selected for assessment of water storage in Southland.

4.2.1 Matāura FMU

Within the Matāura FMU, the Cattle Flat groundwater management zone has the best quality groundwater of any monitored zone in the FMU, and Waikaia River monitoring shows numeric results closest to draft freshwater objectives (compared with down catchment waterbodies). In comparison, the Waimea Plains is a culturally significant, highly modified mahinga kai area with settlement nohoanga present that requires significant restoration to achieve draft freshwater objectives. Significant wetland losses have occurred on the lower plains within the Matāura FMU. The Waimea Plains is a location where drainage schemes are present, and there has been significant loss of wetlands since pre-human times and some since 2007.

The Matāura River Catchment is fully allocated (Figure 2.2, Figure 2.3) largely because the WCO limits the availability and security of surface water and groundwater in the catchment. Ngāi Tahu ki Murihiku are seeking review of allocation and flow regimes on the Matāura River by 2025. Due to existing allocation limits and the WCO, reliable surface water resources are less available in the Matāura FMU than other parts of the region. Improved knowledge of the aquifer structure and groundwater flows, and possibly river augmentation, is required before making additional ground and surface water available for allocation. Gaining a better understanding of groundwater resources is particularly important for giving the community and the council confidence about how much water can be accessed from surface and groundwater while protecting the aquifer from unsustainable abstraction. Such extraction would risk environmental impacts on streams, rivers, wetlands and other water bodies in the FMU.

Land-use opportunities within the Matāura focus area are likely to be most diverse given climate and soil characteristics, particularly when considering the potential for increased arable and horticultural land uses within Southland. Access to water is already a barrier to the development of alternative crops within this focus area.

4.2.1.1 Mid/Upper Matāura Focus Area

The Mid/Upper Matāura focus area is a focus of mana whenua for protection, restoration and enhancement, as there are springs in this area that are of significant value to mana whenua. A key knowledge gap in the Mid-Upper Matāura focus area is characterisation of the hydraulic connection between the Upper Waimea and Upper Ōreti aquifer systems. At present the modelled water balance has a deficit, meaning that there is the potential 'loss' of water from the Ōreti catchment, such as via cross-boundary groundwater flow. Mapping of the aquifers in the Upper Ōreti in combination with test drilling could be undertaken to improve hydrogeological understanding in the area and determine whether there is scope to increase allocation in the focus area.

An option for enhanced water supply and storage in the Mid/Upper Matāura focus area includes potential augmentation of the Matāura River from Lake Wakatipu (Figure 4.4). Lake Wakatipu was previously the original source of the Matāura River (until c. 7000 years ago) (Thomson 2021). Distances between Wakatipu and headwaters of the Matāura Catchment are relatively short (3 km). Augmentation of the Matāura River low flows could address the challenges that led to the Matāura River WCO. Groundwater storage potential is highest in the Waimea Plains, Waipounamu and Riversdale. Precedence for inter-regional water transfer schemes includes use of water from the Waikato River (Waikato Region) for Watercare Services (Auckland Region) and use of water from the Waitaki River (Canterbury Region) for the North Otago Irrigated Company Ltd (Otago Region) (NOIC 2020; Watercare 2021). Consultation with affected parties, in particular Ngai Tahu, should be undertaken prior to any feasibility investigation for augmentation of the Matāura River from

Lake Wakatipu. Consideration of cultural effects, including the mixing or transfer of water from different catchments, should be addressed as potential effects.

In addition, options for off-channel water storage (e.g. routing of high surface water flows into small, off-channel dams/ponds) or small-scale embankment dams in ephemeral streams was identified through the consultation process. Opportunities include the mostly-ephemeral streams in the hills of east of Gore and in upper reaches of streams that feed the Waimea Plains. The standard method criteria for ‘small dams’ was altered to allow for storing and harvesting of higher winter and spring peak flows. Local topography is favourable to the siting of in-channel or off-channel storage of ephemeral flow with construction methods determined by other factors, including geology. Stored water could be useful to augment summer and autumn flows to sustain baseflow and to support diversification of land use. These methods could also assist in supporting water quality objectives through ensuring overland flow is intercepted by indigenous land cover, wetlands or engineered structures before entering connected waterbodies. A combination of indigenous land cover, wetlands and small dams may support mana whenua objectives, draft freshwater objectives and water storage improvements for the region. Water supply from small community-scale dams would potentially benefit other industry (e.g. such as slink skin processing that already operates in the headwaters) and other crops such as tulips. Processing of slink skin requires a reliable water supply and an isolated rural location is suitable due to public perception of the industry (see Section 3). In addition, streams within the vicinity of the Waikaka Catchment could be utilised to fill small off-channel ponds to sustain the existing land use and allow for development of land use within the valley.

There is currently limited surface water allocation available in the catchment. There is around 7000 ha of irrigated land in the focus area. An additional 165,000 ha of land is available for potential development, if sufficient reliable water was available after addressing water quality issues for land-use development. Water demand over the typical irrigation season is 35 mm/week. There is currently demand for a reliable water supply in Gore, to sustain industry (e.g. oat processing at an old dairy factory). Waikaka Stream north of Gore is excluded from Matāura River WCO and presents an opportunity for water storage. A feasibility study of ephemeral streams would be required to determine the approximate storage volume, potential water use and locations of off-channel and/or instream structures.

Ngāi Tahu ki Murihiku favour the use of connected natural water storage systems, such as unconfined aquifers and wetlands, over highly engineered interventions that involve altering natural systems or mixing waters that are separated by natural geology (e.g. flow augmentation). The construction of small out-of-stream dams could potentially align with mana whenua objectives and draft freshwater objectives for the region. Groundwater storage may be supported by wetland enhancement at the interface of surface water and groundwater and where the health of springs is likely to be a relevant consideration for mana whenua objectives and draft freshwater objectives for the region. In addition, many areas within the focus area have been subject to significant loss of wetlands. Wetland enhancement could align with mana whenua objectives and draft freshwater objectives for the region as these pertain to the Waimea Plains area.

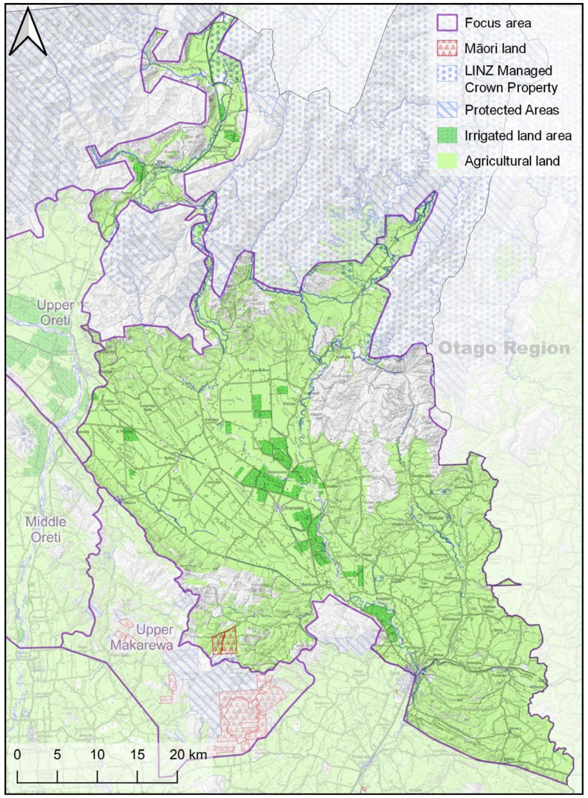

Figure 4.2 Mid/Upper Matāura focus area summary.

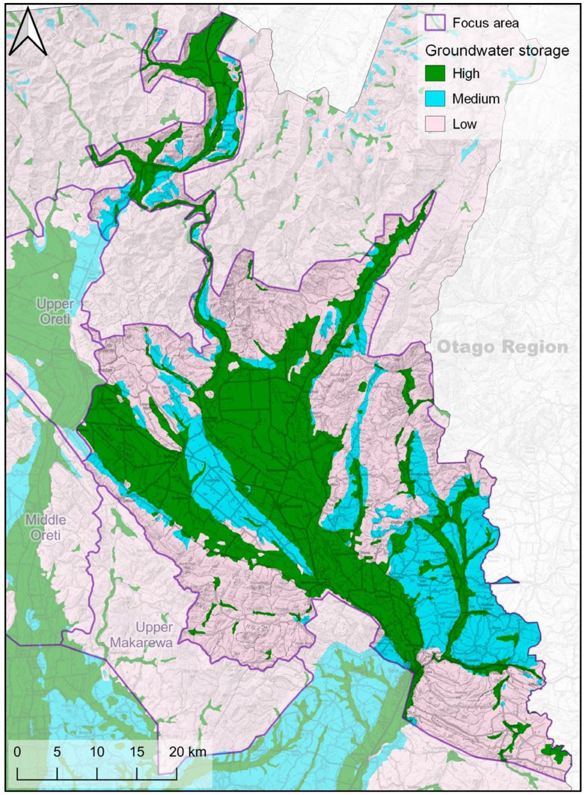

Figure 4.3 Mid/Upper Matāura options for groundwater storage.

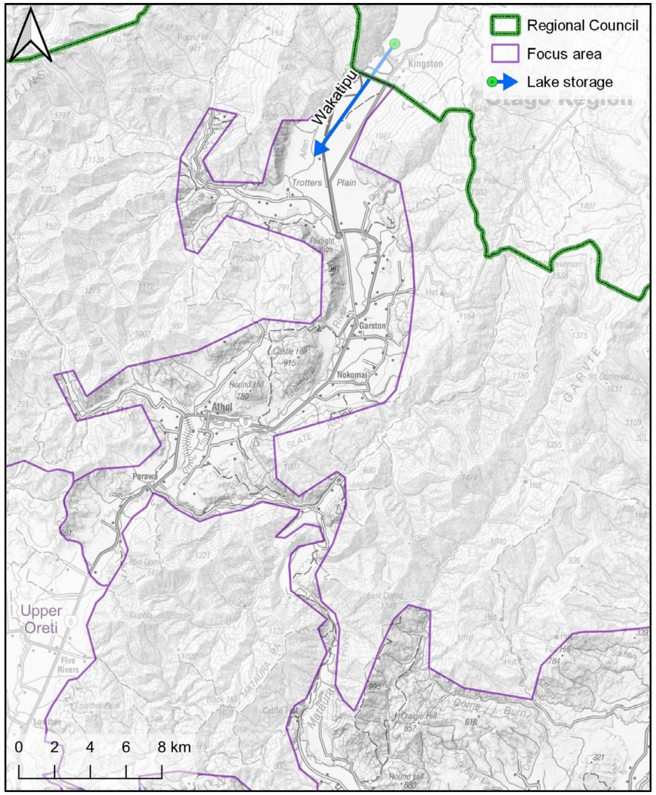

Figure 4.4 Mid/Upper Matāura options for augmented supply from Lake Wakatipu.

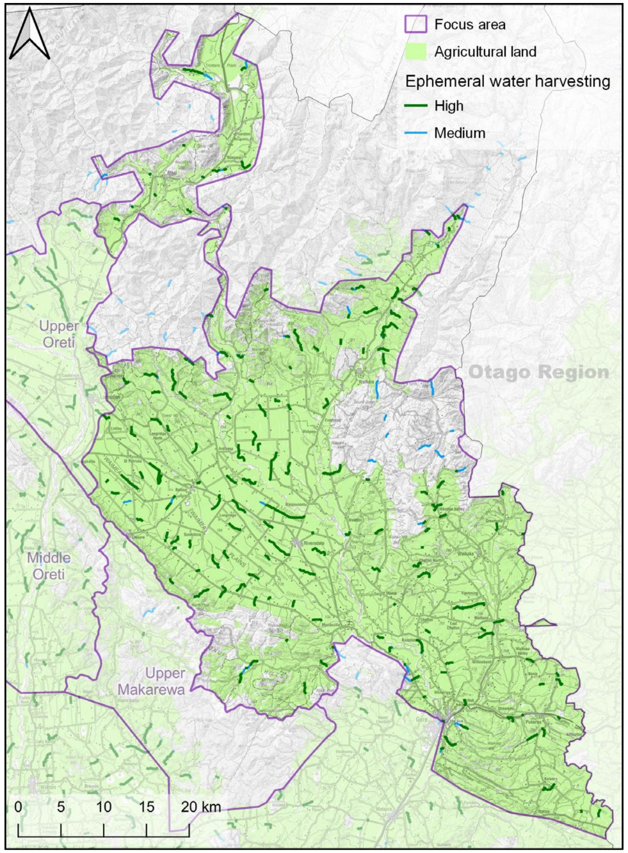

Figure 4.5 Mid/Upper Matāura options for ephemeral water harvesting.

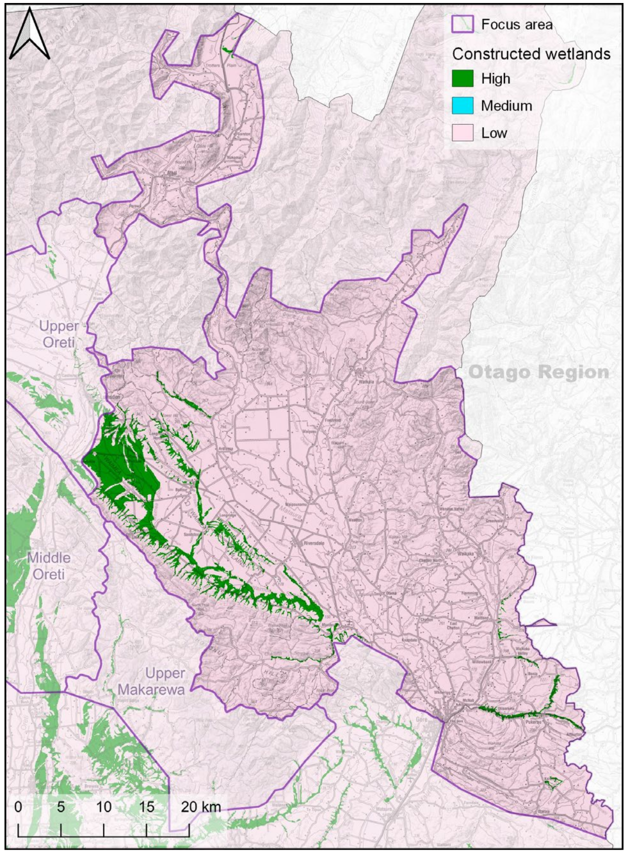

Figure 4.6 Mid/Upper Matāura options for wetland enhancement.

4.2.2 Ōreti FMU

The Ōreti FMU covers an area of more than 4200 km^2, spanning all three Southland territorial authorities. The FMU contains public conservation land and part of the RAMSAR Waituna-Awarua Wetland of International Importance. Approximately 3330 km^2 (78.5%) the land is developed. Of the developed land, predominant uses are sheep and beef farming (46%) and dairy farming (30%) (Nicol and Robertson 2018).

4.2.2.1 Upper Ōreti Focus Area

Groundwater and surface water allocation is currently available in the Upper Ōreti Catchment (930 L/s). Recently, some water users have explored abstraction from the deeper groundwater supply to enhance the reliability of supply. This is because surface water takes are subject to low-flow conditions, which usually coincide with the greatest water requirements (e.g. for irrigation). Approximately 20 days of on-farm storage is needed to carry farmers through the dry periods, which can be sourced during higher flow periods.

Existing irrigation covers approximately 7500 ha, predominantly around the Mossburn, Five Rivers and Lumsden areas. There is further potential for irrigation of up to 45,000 ha of high-producing grassland to support the transition to alternative land use or crops, largely in the north and north west of the focus area. Water demand over the typical irrigation season is 35 mm/week. Climate in these areas may provide a considerable opportunity for diversification of land use, including cropping and mixed-use farming models.

The Upper Ōreti focus area has significant potential for a diverse array of land uses, including horticulture and arable farming. Water, and specifically reliable water, will be a limiting factor for land-use change in this focus area, however. Another core consideration, alongside water availability, will be ensuring that alternative land uses result in less environmental impacts compared to current land uses.

The Upper Ōreti focus area contains the only settlement nohoanga in the FMU and is a focus of mana whenua for protection, restoration and enhancement. These considerations should be included in any assessment of alternative land uses in the focus area. Surface water monitoring shows numeric results closest to draft freshwater objectives (compared with down catchment waterbodies), while significant groundwater degradation is present, requiring restoration in the two monitored groundwater zones. Wetland losses have occurred since pre-human times, and some since 2007, within the focus area.

The preferred method for water storage in this focus area is groundwater storage. A cross-hydrogeological boundary issue is associated with the Ōreti River in the vicinity of Lumsden. A water budget of the area shows a water deficit, which could be explained by the groundwater and surface water boundaries in this area not being co-incident and groundwater at depth flowing across surface water catchment boundaries (i.e. an unknown proportion of groundwater flows eastwards from the Ōreti River possibly into the Waimea Plains in the vicinity of Lumsden). Improved hydrogeological knowledge of the area will contribute significantly to the understanding of this issue. Mana whenua support improved hydrogeological knowledge of the relationship between the Ōreti and Matāura FMUs. Groundwater storage could potentially be supported by wetland enhancement at the interface of surface water and groundwater and where the health of springs is likely to be a relevant consideration for mana whenua objectives and draft freshwater objectives for the region.

Mana whenua has opposed the managed aquifer recharge project that has been proposed within a confined aquifer in the Upper Ōreti focus area. The impact of existing land and water uses, including the declining groundwater quantity and quality within confined aquifers, remains a significant concern for mana whenua. In addition, baseflow enhancement options in the area were considered, with the Cromel Stream being regarded as the most effective stream for flow augmentation. It is understood that Cromel Stream loses water to the aquifer system as it exits the hills onto the alluvial plains and Acton Stream is thought to gain what flow is lost from Cromel Stream.

Options for off-channel water storage or small-scale embankment dams in ephemeral streams were identified (Figure 4.9). These opportunities could support water quality objectives through ensuring overland flow is intercepted by indigenous land cover and wetlands before entering connected waterbodies. This area has been subject to loss of wetlands. A combination of indigenous land cover, wetland enhancement and small dams may support mana whenua objectives and draft freshwater objectives as these pertain to upper Ōreti waterbodies and the related settlement nohoanga site.

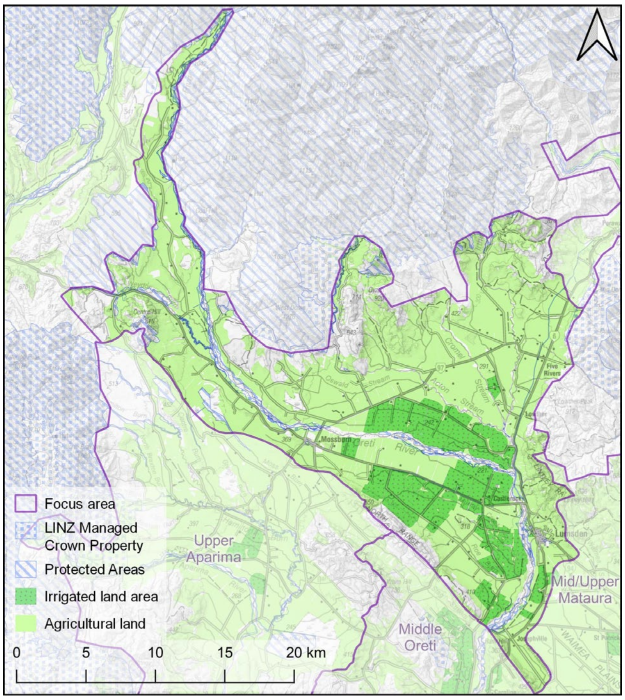

Figure 4.7 Upper Ōreti focus area summary.

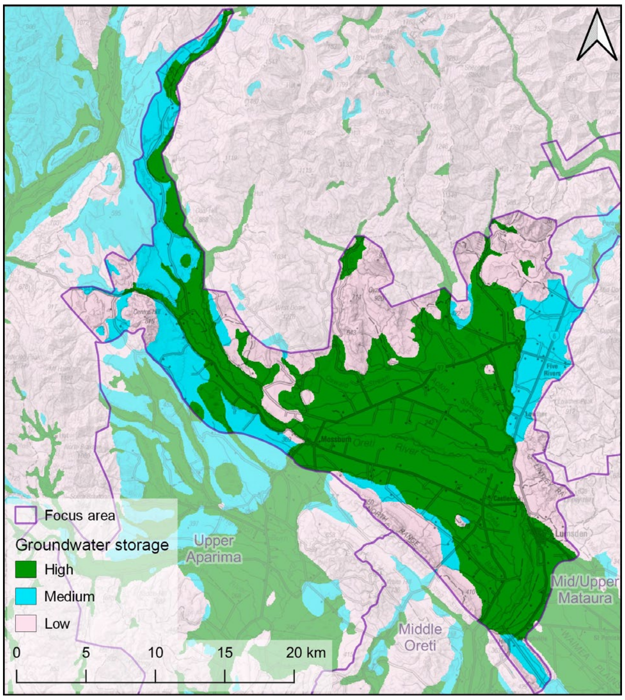

Figure 4.8 Upper Ōreti options for groundwater storage.

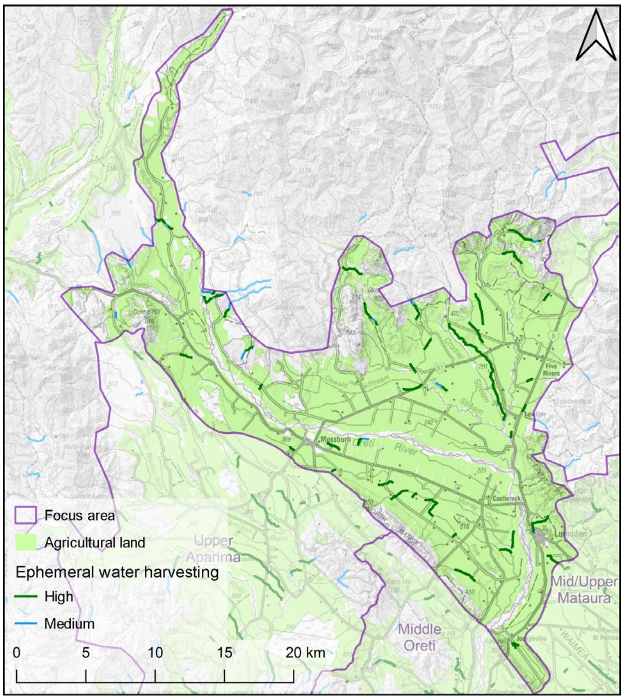

Figure 4.9 Upper Ōreti options for ephemeral water harvesting.

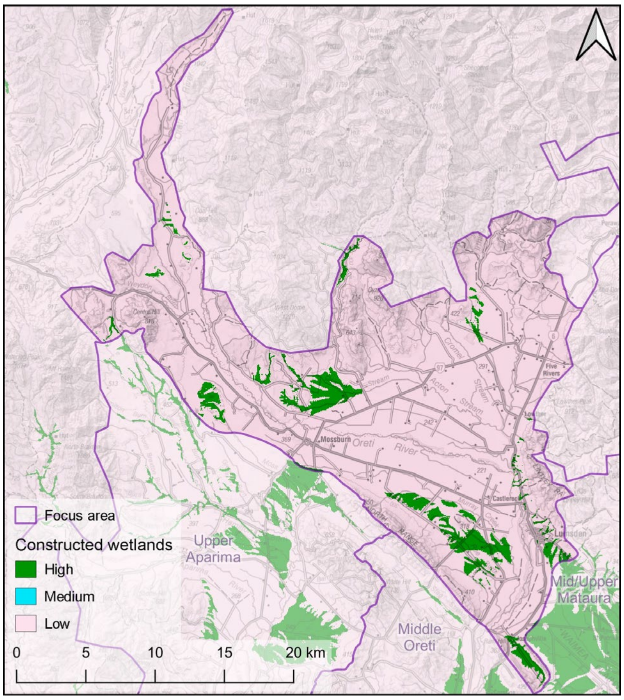

Figure 4.10 Upper Ōreti options for wetland enhancement.

4.2.2.2 Middle Ōreti Focus Area

The preferred method for water storage in this area is groundwater storage and galleries. Groundwater and surface water allocation is currently available in this focus area. Existing irrigation covers an area of around 1400 ha largely on land adjacent to the Ōreti River north of Dipton. There is potential for additional land to be brought into production through irrigation on land on both sides of the Ōreti River, such as existing farmland between Dipton to Centre Bush. One of the limitations will be topography in relation to the water availability, as the land is on hillslopes. Water demand over the typical irrigation season is an estimated 35 mm/week.

Groundwater storage may be supported by wetland enhancement at the interface of surface water and groundwater and where the health of springs is likely to be a relevant consideration for mana whenua objectives and draft freshwater objectives for the region. Riverine galleries and connected groundwater will need to be factored into the review sought by mana whenua of the Ōreti flow and allocation regime by 2025, with a view to prioritising the needs of the river.

In addition, consideration of small dams for water storage and/or baseflow enhancement options in the area may be worthwhile. Water quality objectives could be supported through ensuring that overland flow is intercepted by indigenous land cover, wetlands, etc. before entering connected waterbodies. A combination of indigenous land cover, wetlands and small dams may support mana whenua objectives, draft freshwater objectives and water storage improvements for the region.

The middle Ōreti focus area includes the Dipton groundwater management zone, which is one of only two monitored zones in the region that shows good quality water consistent with draft numeric freshwater objectives. The Dipton groundwater management zone is therefore a mana whenua priority for protection. Monitoring of surface waterbodies in this area shows that restoration is required to meet draft freshwater objectives. There have been significant wetland losses since pre-human times and some wetland loss since 2007, with drainage schemes present.

Greater water availability has the potential to provide for diversification of primary production, including cropping (grass seed), although some limitations are imposed by exclusion distances to aim to prevent cross-contamination of cultivars. Plant material that remains following the harvest of crops such as grass seed are often used for balage and as feed supplements, which may reduce the potential nutrient input into the catchment. This would need to take into account the objectives of mana whenua to protect, restore and enhance water quality in the Middle Ōreti focus area.

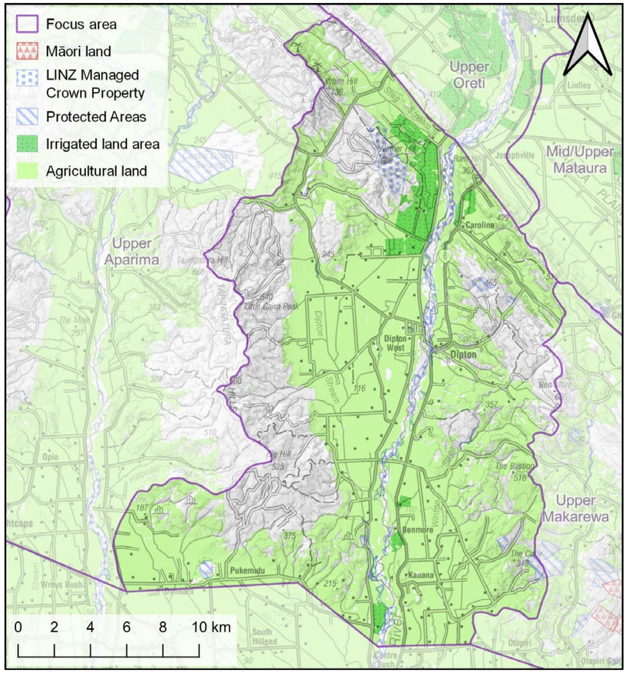

Figure 4.11 Middle Ōreti focus area summary.

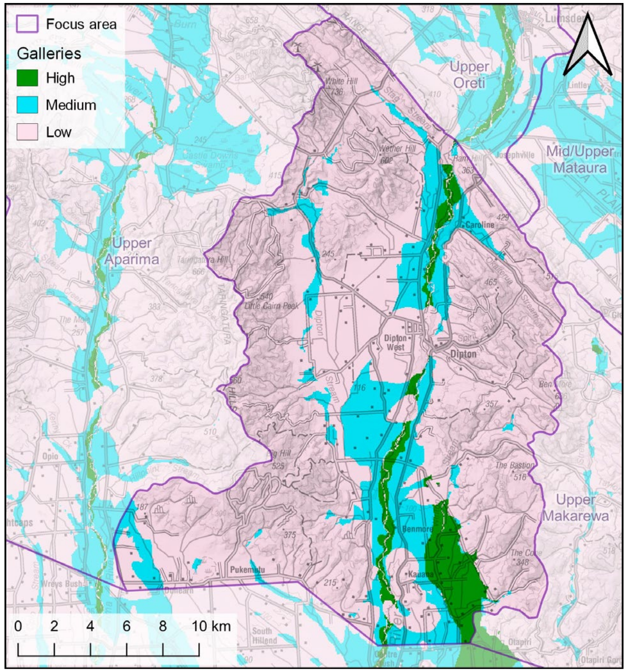

Figure 4.12 Middle Ōreti options for galleries.

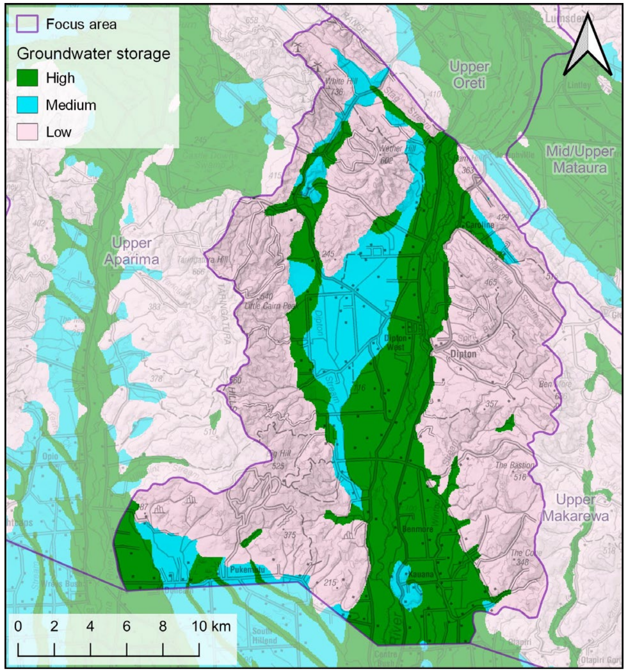

Figure 4.13 Middle Ōreti options for groundwater storage.

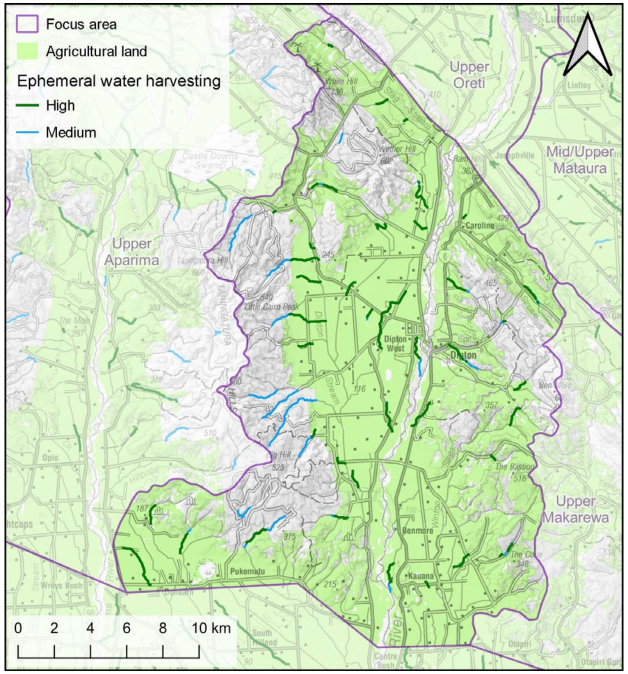

Figure 4.14 Middle Ōreti options for ephemeral water harvesting.

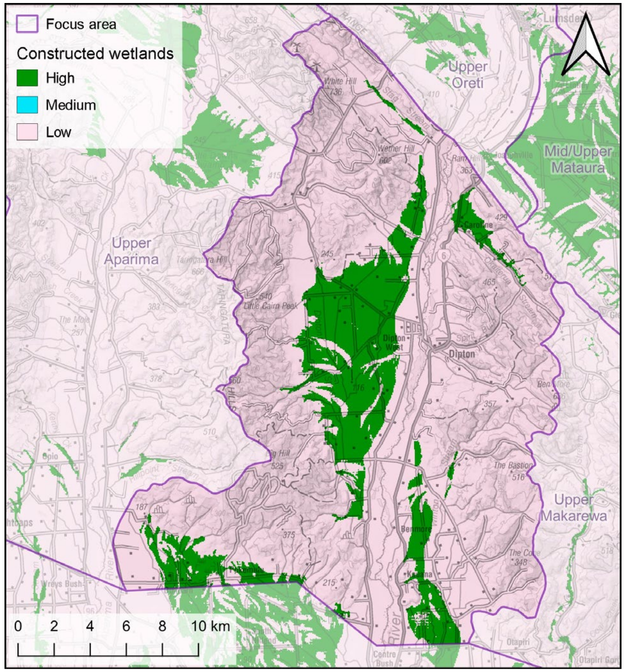

Figure 4.15 Middle Ōreti options for wetland enhancement.

4.2.2.3 Upper Makarewa Focus Area

Preferred water storage methods in this focus area include small baseflow enhancement dams and groundwater. Surface water allocation is currently available in Upper Makarewa area. Irrigation does not currently exist in the Makarewa area, due to a combination of climate (more reliable rainfall), land use (e.g. forestry) and topography (e.g. hill country). There is approximately 141,000 ha of high-producing grassland within this focus area, some of which has the potential to be brought into production through irrigation. Alternatively, a greater reliability of water supply to the Winton area may provide additional opportunities for high-value manufacturing, processing and industries, such as wood processing. Further, there is potential for the establishment of processing facilities in Winton if horticultural land use is established at scale, for example, blueberries (which are currently grown near Otautau). This would need to take into account the objectives of mana whenua to protect, restore and enhance water quality. Increasing land use in this area may threaten what mana whenua are seeking to protect, restore and enhance in the upper Makarewa.

The Upper Makarewa focus area is associated with culturally significant waterbodies flowing from the Hokonui Hills. A number of native reserve lands are present in this area. The Upper Makarewa River, Dunsdale Stream and upper Hedgehope Stream are a focus of mana whenua for protection, restoration and enhancement. Wetland losses, both historic and recent, are associated with this area.

The preferred water storage methods in this focus area include small baseflow enhancement such as in the Otapiri and Dunsdale streams (Figure 4.17). Local knowledge indicated that the landscape would be suitable for small off-channel dams, which were not identified by the initial current criteria. Dunsdale Stream is a mana whenua priority for protection, restoration and enhancement. Small out-of-stream dams have potential to support mana whenua objectives and draft freshwater objectives. Water quality objectives could be supported through ensuring that overland flow is intercepted by indigenous land cover and wetlands before entering connected waterbodies.

Another option of available water storage is existing groundwater currently stored in Quaternary gravel aquifers adjacent to streams (e.g. Otapiri and Dunsdale streams) and in the headwaters of the Makarewa River. Stream depletion effects would likely need to be considered in this instance. Groundwater storage may also be supported by wetland enhancement at the interface of surface water and groundwater and where the health of springs is likely to be a relevant consideration for mana whenua objectives and draft freshwater objectives for the region.

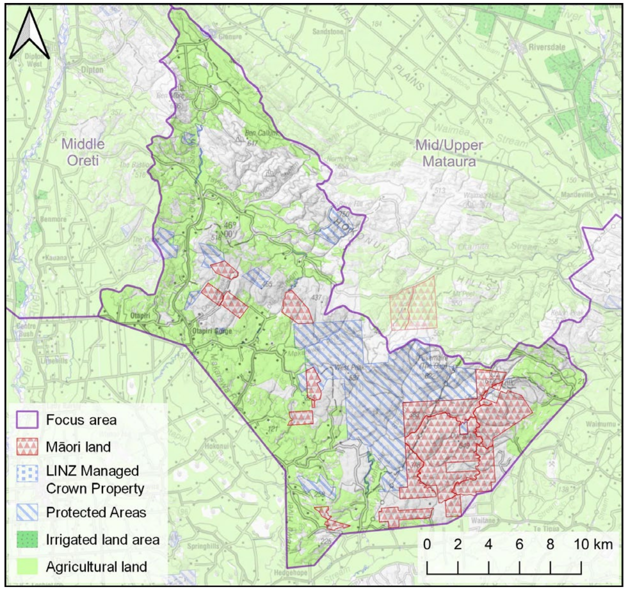

Figure 4.16 Upper Makarewa case study area.

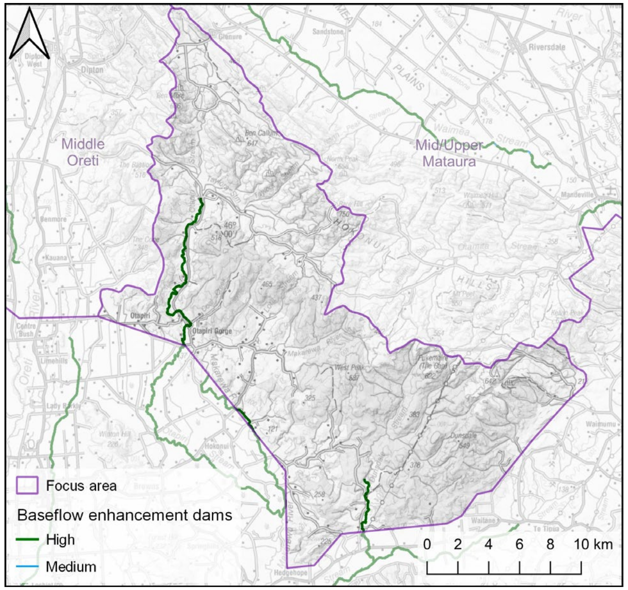

Figure 4.17 Upper Makarewa options for baseflow enhancement dams.

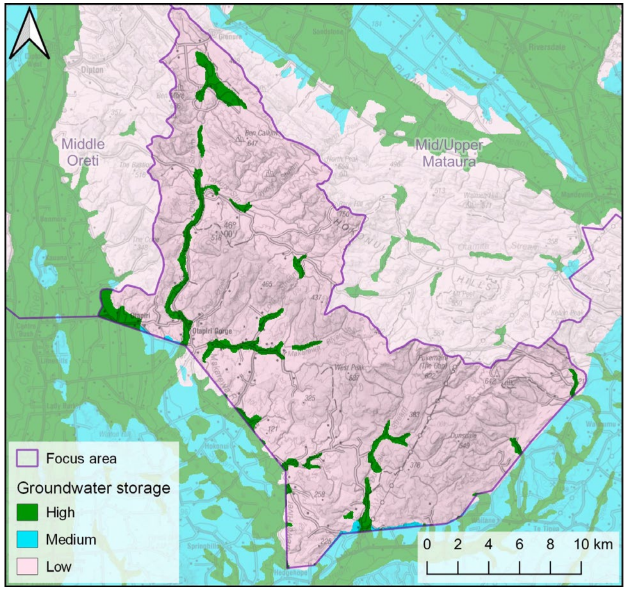

Figure 4.18 Upper Makarewa options for groundwater storage.

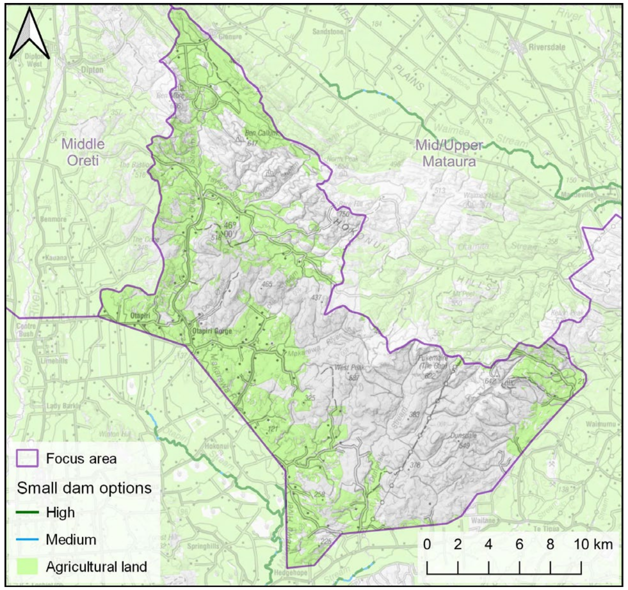

Figure 4.19 Upper Makarewa options for small dams.

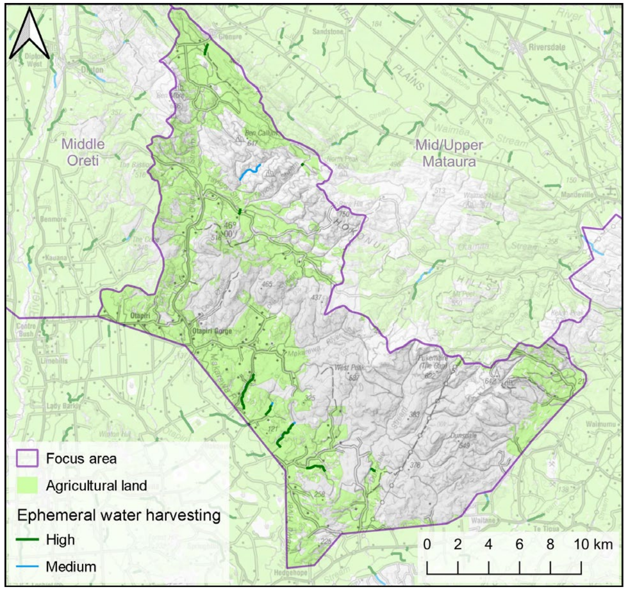

Figure 4.20 Upper Makarewa options for ephemeral water harvesting.

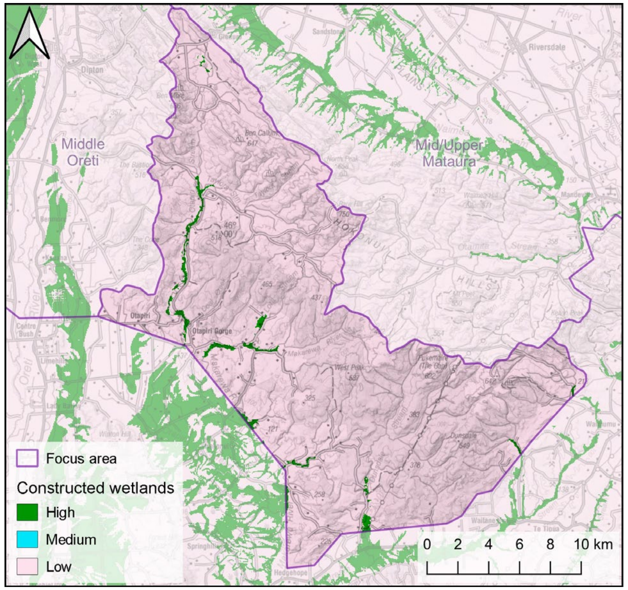

Figure 4.21 Upper Makarewa options for wetland enhancement.

4.2.3 Aparima FMU

The Aparima FMU covers an area of approximately 2,067 km^2. Approximately 168,000 ha (81%) of the land is developed, largely for dry stock farming (41%) and dairy farming (34%) (Nicol and Robertson 2018). There is currently a lack of knowledge of hydrogeological boundaries in some areas of the Aparima River catchment, which has potentially impacted on effective water resources management in the FMU. In the Wreys Bush area, the catchment is bound by ranges through to the Takitimu Mountains. Uncertainty in the groundwater delineation is associated with the south-east of the Tarinatura Ranges in the headwaters of Bog Burn and Terrace Creek. This focus areas would benefit from an improved understanding of water resources. In particular, there are currently information gaps around the volume and location of groundwater resources that, if reduced, will enable greater confidence in security-of-supply for existing and future water users and provide the basis for sustainable economic growth in the area.

The Upper Aparima focus area is associated with culturally significant waterbodies flowing off Takitimu. These include the upper Aparima River and Hamilton Burn, which are a focus for mana whenua protection, restoration and enhancement. Significant wetland losses, both historic and recent, are associated with this area. An improved understanding of groundwater and hydrogeology in the Aparima FMU would be helpful for improved water resources management.

4.2.3.1 Upper Aparima Focus Area

Preferred storage options are galleries and groundwater storage. Approximately 50% of groundwater in the entire catchment has been allocated (primary allocation) and surface water is not yet fully allocated. However, surface water above Otautau Stream is nearing full allocation.

Currently, a small area of land is irrigated (c. 530 ha) in the north of the focus area, adjacent to the Aparima River. It is likely that this irrigation is partitioned between surface water and groundwater sources, depending on stream depletion effects. Approximately 100,000 ha of high-producing grassland is located in the focus area, some of which has the potential for development through irrigation, although some of this potential may be limited by topography. There is potential for diversification of land use in this focus area, especially in higher-value arable crops and horticulture. Water demand over the typical irrigation season is 35 mm/week. Consideration of any modification to wetlands would require assessment under the policy (e.g. pSWLP 2018; NPS-FM 2020). Increasing land use in this area would need to take into account mana whenua's objectives to protect, restore and enhance in the upper Aparima, including waters flowing from Takitimu.

The location of galleries and groundwater storage would predominantly be in Quaternary gravels adjacent to the Aparima River and tributaries (e.g. Hamilton Burn). Use of riverine galleries could be included in any reviews of the Aparima flow and allocation regime, as proposed by mana whenua. Groundwater storage may be supported by wetland enhancement at the interface of surface water and groundwater and where the health of springs is likely to be a relevant consideration for mana whenua. The potential for harvesting of ephemeral streamflow (e.g. streams from the Taringatura Ranges) and enhancement of wetlands is to be investigated (e.g. Castle Downs). Significant loss of wetlands has occurred. Water quality objectives could be supported through ensuring that overland flow is intercepted by indigenous land cover and wetlands before entering connected waterbodies. A combination of indigenous land cover, wetlands and small dams may support mana whenua objectives, draft freshwater objectives and water storage improvements for the upper Aparima and waters flowing from Takitimu.

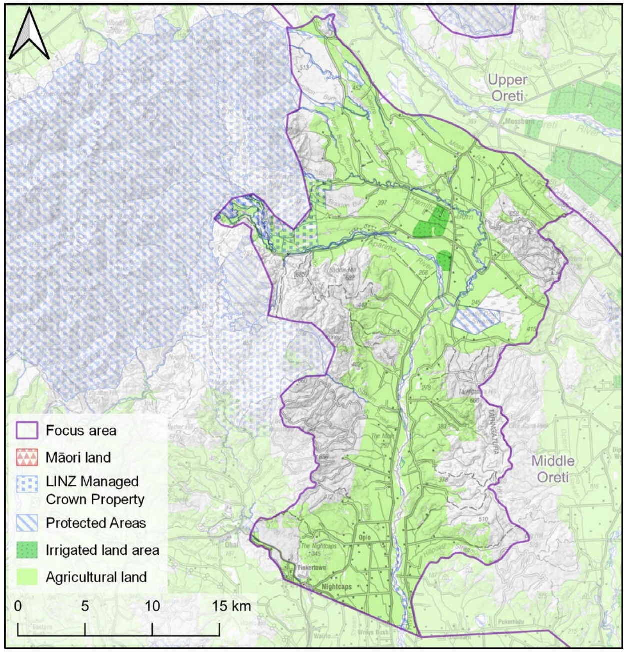

Figure 4.22 Upper Aparima focus area summary.

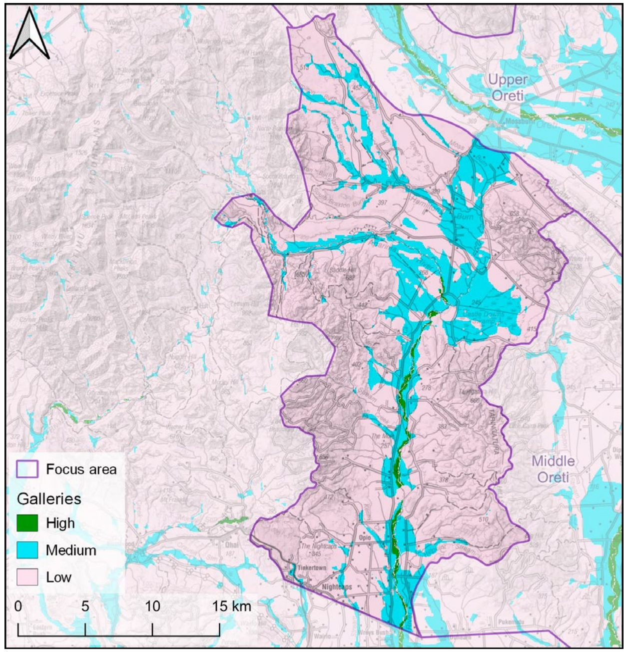

Figure 4.23 Upper Aparima options for galleries.

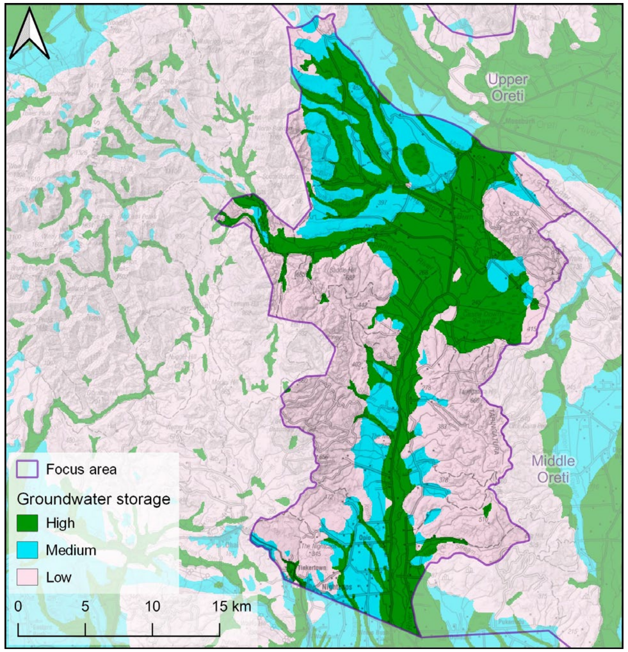

Figure 4.24 Upper Aparima options for groundwater storage.

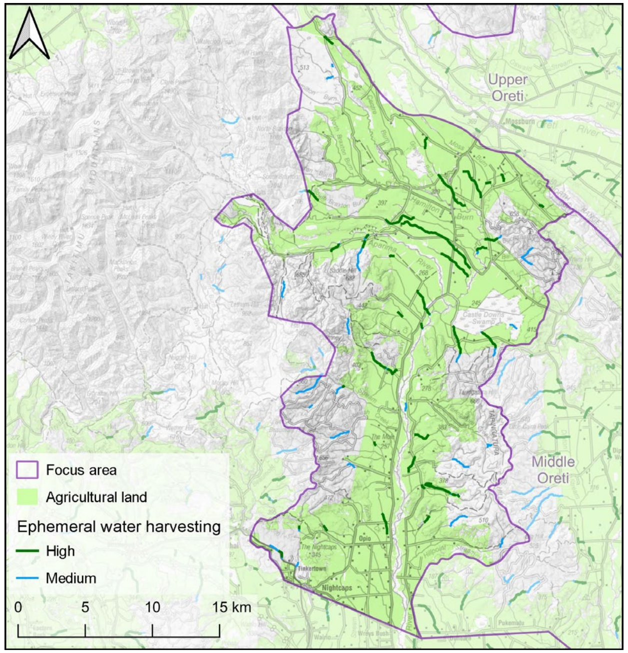

Figure 4.25 Upper Aparima options for ephemeral water harvesting.

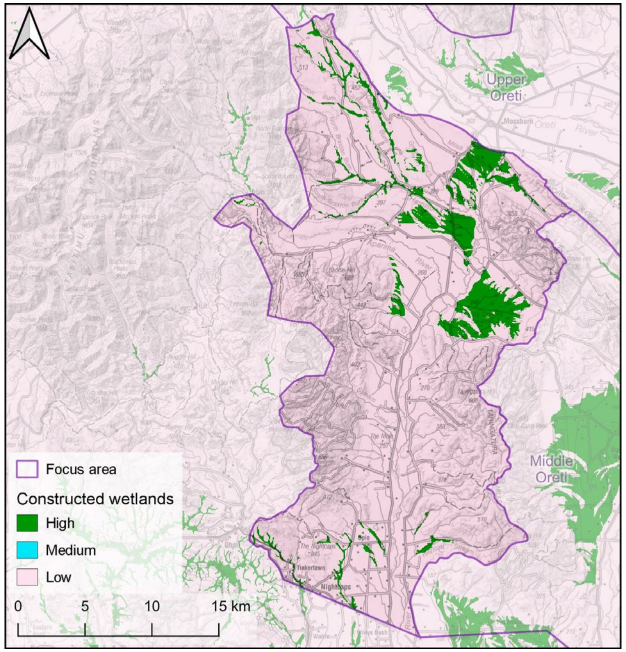

Figure 4.26 Upper Aparima options for wetland enhancement.

4.2.4 Fiordland and Islands FMU

Investigating water storage in Oban may provide for diversification of the economy and providing a reliability of supply that may encourage more industry (e.g. aquaculture processing). Economic growth in Oban is considerably restricted due to the cost of electricity generation and distribution, which is at least five times the cost on mainland New Zealand and 100% diesel generated. In 2019, $3.16 million of PGF was allocated to investigation of potential for wind energy development. Unfortunately, the project was discontinued in early 2021 due to unavailability of land for the development. Previously, high-level assessments of hydroelectric solar and ocean current options have been explored for alternative energy supply on Stewart Island. A key barrier to land-use development is the small area of land that has been cleared of indigenous vegetation that is suitable for agriculture and horticulture. A key barrier to other economic development (e.g. industry, food processing) is the cost of electricity and lack of sufficient water supply. The majority of Stewart Island land is in protected areas such as National Park.

There is a lack of knowledge on surface water and groundwater resources within the focus area, where the majority of Stewart Island's freehold land is located. There is an oil seep onshore at Stewart Island. An exploration well (Horseshoe-1) was drilled in 2012 from onshore Stewart Island out into the Great South Basin. Drilling results of this well remain unreported and therefore do not provide any further information on groundwater resources (NZPAM 2021). Currently there is no reticulated water supply in Oban although a community wastewater treatment network is in operation. Historically, surface flow, taken from Mill Creek, was transferred via a gravity fed piping network to several large properties. Consents have been granted for two shallow groundwater takes from the coastal sand aquifer in Halfmoon Bay (South Seas Hotel, Stewart Island Backpackers) and natural springs are understood to sustain several other properties. The majority of businesses and residents rely on individual rainwater harvesting infrastructure for water supply. A more reliable water supply would potentially support the aquaculture (and perhaps other) industry, to enable economic diversification.

4.2.4.1 Oban, Stewart Island Focus Area

There is currently no irrigation occurring in this focus area. Groundwater quality is generally poor with significant iron precipitate often fouling pumping equipment. Due to proximity to Halfmoon Bay, the groundwater resource is also impacted by tidal phases and subject to the effects of sea level rise. Preferred storage methods are associated with groundwater resources, in part because surface water flow rates and surface water quality are highly variable. Groundwater abstraction from wells would be most practical. Groundwater allocation would be determined by the primarily allocation (e.g. rainfall recharge) and is readily available for allocation as current groundwater takes are <25% of the allocation limit.

Mana whenua acknowledge the potential to improve water access and enhance water uses within the developed areas of Stewart Island / Rakiura. While this report does not propose to advance any options specific to the islands, it is noted that Ngāi Tahu ki Murihiku would expect this to be done in partnership with them.

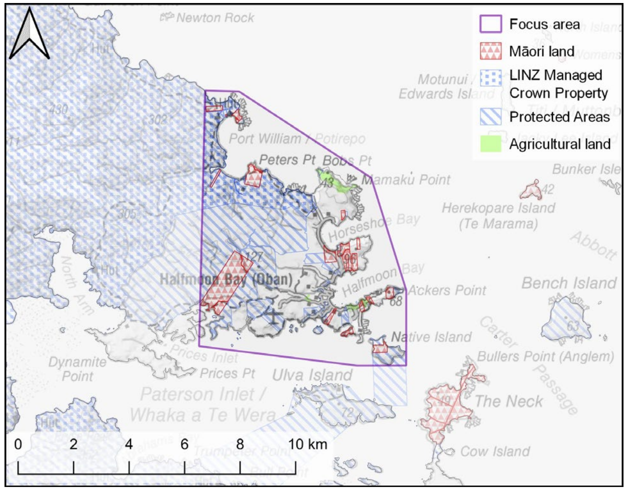

Figure 4.27 Oban focus area summary.

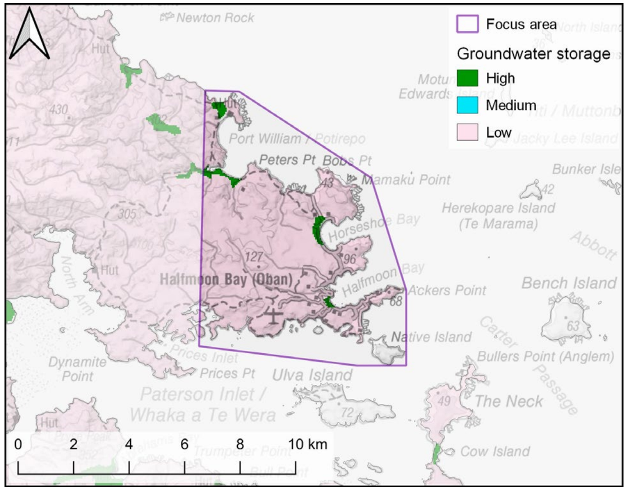

Figure 4.28 Oban options for groundwater storage.

4.3 Summary of Focus Areas

Potential water storage methods for each of the six focus areas in Southland are summarised and ranked from higher to lower priority following technical workshops and engagement with stakeholders (Table 4.1). The GIS processing datasets and methods identification of water storage methods are provided in Appendix 1. The term ‘groundwater storage’ in this report refers to water naturally stored within an aquifer and is distinguished from alternative groundwater such as ‘managed aquifer recharge’. Further, the ‘water harvesting from ephemeral streams’ will have associated groundwater storage infrastructure.

The general preference of Ngāi Tahu ki Murihiku is for ‘out-of-stream channel’ (rather than in-stream) diversions and infrastructure to be explored. It is important to note that Ngāi Tahu ki Murihiku have reservations about the augmentation of the Matāura River from the Wakatipu Catchment. Ngāi Tahu ki Murihiku indicated that, in particular, this option should not be explored further unless it is undertaken on a partnership basis with the support of mana whenua.

Table 4.1 A list of Southland focus areas and potential water storage methods. The methods have been ranked from higer to lower priority for each focus area.

Focus Area	Potential Water Storage Methods
Matāura: Mid/Upper	Groundwater storage Water harvesting from ephemeral streams Wetland enhancement Augmentation of flow from Lake Wakatipu
Ōreti: Upper	Groundwater storage Water harvesting from ephemeral streams Wetland enhancement
Ōreti: Middle	Groundwater storage Water harvesting from ephemeral streams Wetland enhancement Riverine Galleries
Ōreti: Upper Makarewa	Water harvesting from ephemeral streams Wetland enhancement Baseflow enhancement dams Small dams Groundwater storage
Aparima: Upper	Groundwater storage Water harvesting from ephemeral streams Wetland enhancement Riverine Galleries
Fiordland and Islands: Oban	Groundwater

5.0 INVESTIGATIONS INTO WATER AVAILABILITY ACROSS SOUTHLAND

The PDU has funding available for investment in water availability investigations in Southland. This funding will be applied to a range of activities that will improve the understanding of water needs and opportunities in the region, in relation to bringing about opportunities for land-use diversification to support a sustainable primary sector. This report identified the locations of interest, the potential benefits of water storage and the most beneficial forms of water storage infrastructure for these locations.

Further investigations could be undertaken toward determining the particular water storage investments required in the focus areas. These investigations will consider environmental benefits from investment in water availability as well as increases in land productivity for Southland. Addressing water quality and making more water available in areas that are already productive is the priority for the region. This would enable land-use change to take place that will support the region to meet environmental regulatory requirements. Investigations under this project fall into four categories for identification of priority areas:

- aerial electromagnetic surveying (aquifer mapping)
- a desktop assessment and flow gauging for community-scale storage (small dams or off-channel storage) on ephemeral streams
- drilling to explore groundwater properties, and
- cross-catchment augmentation.

These investigations will improve our understanding of what water is available on a sustainable basis and will inform which water storage solutions are most appropriate within each location for water quality and water availability purposes.

5.1 Aerial Electromagnetic Surveying (Aquifer Mapping)

Given the right geological conditions, aerial electromagnetic surveying can provide a community with greater certainty about the quantum of water that is present in an aquifer. This can give the regional council and the community confidence about how much water can be used to bring land into sustainable production. Priority areas identified by Environment Southland for aquifer mapping are in the vicinity of: Five Rivers–Mossburn–Lumsden–Riversdale between the Ōreti and Matāura FMU's; Fairlight; and Wreys Bush (Figure 5.1). Of these areas, Environment Southland would prioritise the Northern Plains area for field investigation. A short exercise working with Southland stakeholders could be undertaken to determine opinions on the priority area/s for aerial electromagnetic surveying.

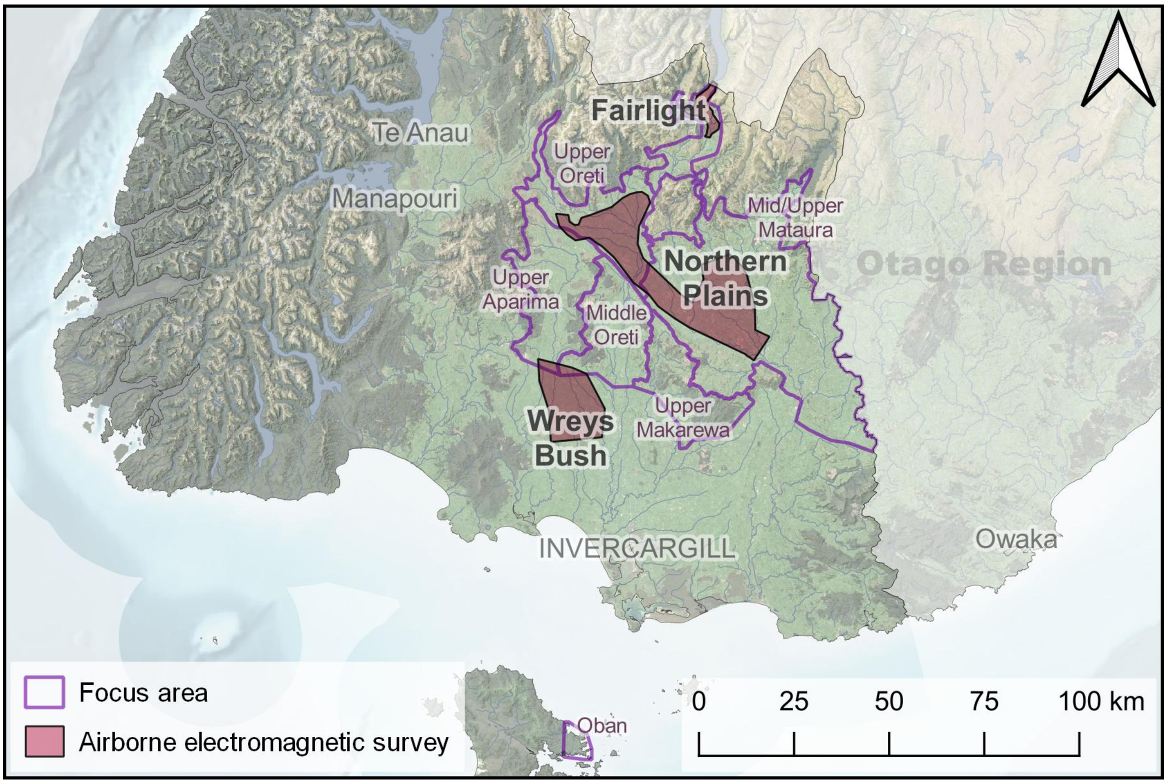

Figure 5.1 Priority areas of interest for potential aquifer mapping in the Southland Region, provided by Environment Southland. From north to south, Fairlight; Northern Plains (Five Rivers–Mossburn–Lumsden–Riversdale), and Wreys Bush.

Once the area of interest has been determined, aerial aquifer mapping involves three primary stages of work:

- pre-mapping investigations
- mapping and data collection, and
- application of data into modelling.

During the first stage of aquifer mapping, it will be determined whether the geological environment is conducive to aquifer mapping. It may be that the aerial mapping would not be able to sufficiently distinguish the base of the aquifer, and aquifer properties, depending on rock type. If aquifer mapping is not possible, then test drilling will be utilised. Some early drilling will be undertaken to inform the mapping process.

5.2 Capturing Ephemeral Streamflow and Enhancing Wetlands

A desktop study of useful community-scale water storage from ephemeral streams could be progressed for the Mid/Upper Matāura, Upper Ōreti, Aparima and Upper Makarewa focus areas (in order of priority). Potential for off-stream storage sites (in-stream dams where necessary) and potential to augment natural wetlands should be considered. Approximately 1000 ha of irrigated land would require storage greater than 3 million m^3 of water. Therefore, water storage volumes that would allow a group of landholders to share the benefits should be addressed, rather than single property-scale storage.

Ephemeral streams, which only contain flowing water following rainfall events or extended periods of above average rainfall, are considered as suitable sources of water for storage. In addition, dams on such streams generally have fewer ecological impacts than dams on perennial streams. The desktop study should identify a range of sites the size of storage that can be reliably filled and current land ownership. For an embankment dam, good storage sites are those yielding a storage ratio of greater than four (water capacity: earth embankment volume). A community-based approach to water storage can identify and construct dams that are more economic to build than smaller dams on individual farms. Off-channel storages require less construction cost for diversions during construction and spillway provision, and often reduced regulatory hurdles, but may not offer the best storage ratios. They do offer less impact on the normal catchment processes and if debris or sediment loads are significant an off-channel storage may be preferred. Lined storage ponds may be preferable in areas of alluvial sediments.

5.3 Test Drilling for Groundwater Availability

The drilling of test sites for groundwater provides more localised knowledge of groundwater availability at a lower cost than aquifer mapping. This could be utilised in areas where groundwater is still the priority source of water but where insufficient funds are available from the project to undertake aquifer mapping. The priority areas for this approach in Southland include the Lumsden area (in lieu of, or in addition to, aquifer mapping) and the Brightwater area south of Kingston.

Land ownership can become a constraint on being able to use land for water storage and for some sites it would be prudent to ensure that land status change does not prevent future development of suitable water storage. This may require identifying and purchasing land upfront for community water storage development at some future time to keep options for such development viable. Surface water gauging to better understand the flows in ephemeral streams should be undertaken using traditional and/or novel methods. This would allow for identification of catchments where the flows could be sustainably harvested.

5.4 Cross-Catchment Augmentation

Diversion of water from Lake Wakatipu into the headwaters of the Matāura River main branch south of Kingston is an option that provides for increased security of supply to groundwater and surface water users in the Matāura River catchment.

A desktop study to improve our understanding of the hydrology and effects of increased water availability could be progressed. Initially, this study would involve collation of existing hydrological information and development of water budgets. From this, options for the rate of augmentation (e.g. in the range 1–5 m^3/s as a baseflow augmentation, possibly on a seasonal basis) will be identified and the sustainability of each option discussed within the context of annual and seasonal climate.

An investigation into the possible benefits and constraints of proposed flow augmentation options could be undertaken. This would include consideration of:

- increased security of supply that would reduce the occurrence of water-use restrictions due to low flows in the Matāura River and produce increased economic benefits to primary production
- increased land productivity due to opportunities for diversification brought about by a more reliable water supply
- improved water quality in the Matāura River, and
- identification of any risks or constraints to the proposed augmentation (e.g. cross-boundary and physical mixing of waters).

5.5 Te Ao Marama Perspective

Options for water availability investigations in Southland were discussed with Te Ao Marama (as representatives of Ngāi Tahu ki Murihiku) to gain a deeper insight into their perspective.

Knowledge gaps exist in relation to the natural characteristics of confined aquifers and the location of tile drains that can affect the ability to manage these waterbodies and systems. Aquifer mapping investigations are supported as useful to improve understanding of groundwater systems in the upper Ōreti and upper Matāura. Mapping sub-surface tile drains both within and outside of the focus areas would assist freshwater management in the region, and, if possible, should be incorporated into any geophysical research. Mana whenua have a preference to better understand connected unconfined aquifer systems with shorter groundwater residence times (rather than confined aquifer systems) in order to support restoration and maintenance of te hauora o te wai (with reference to draft freshwater objectives).

Use of storage dams situated out of waterbodies is preferred over in-stream dams when engineered or structural solutions are considered. Investigation of ephemeral streamflows would have a co-benefit of assisting to understand overland flow paths of contaminants to waterways and where introduction of wetlands or indigenous vegetation could support te hauora o te wai by slowing and filtering water. In addition, water storage benefits of wetland enhancement associated with ephemeral waterbodies should be considered. Connected natural water storage systems, such as unconfined aquifers and wetlands, are favoured over engineered interventions that involve altering natural systems or mixing waters that are separated by natural geology (e.g. flow augmentation). Consideration should be given to the potential relationship between ephemeral streams, indigenous land cover and wetland enhancement. Small out-of-stream storage and supporting flow and allocation regimes that provide for te hauora o te wai is supported. Augmentation is not a favoured option where alternatives exist.

5.6 Next Steps

Aqua Intel Aotearoa will progress investigations in relation to a number of the water storage approaches outlined in the report. The priority projects will be those that progress water storage options for the region in a manner that is consistent with the regulatory and cultural imperatives for the region, particularly in relation to enhancing water quality outcomes. These options will be explored with mana whenua. Aerial electromagnetic surveying and capturing of ephemeral streamflows and enhancing of wetlands are projects that offer strong water storage potential while being consistent with the water quality priorities of the region.

Aerial electromagnetic surveying will be considered in focus areas where greater certainty about the aquifer's characteristics can provide the most useful input to the regulatory limit setting process and thereby the greatest support to sustainable land use in the region. This would identify the boundary between the Upper Ōreti and Mid/Upper Matāura (Mossburn-Lumsden-Riversdale). In undertaking aerial electromagnetic surveying, some drilling will also be undertaken, which will enhance existing information on the aquifer's characteristics.

A case study for utilising stored water for wetland enhancement will be undertaken in a priority location for the region. This will look at harvesting water from ephemeral streams for storage and deployment into the wetland, with benefits anticipated for downstream water bodies.

Aqua Intel Aotearoa will work with Environment Southland, Te Ao Marama and local experts as it progresses this work programme.

Undertaking aerial electromagnetic surveying (aquifer mapping) to identify the boundary between the Upper Ōreti and Mid/Upper Matāura (Mossburn-Lumsden-Riversdale) would provide better information about the aquifer to the regional council and the community and give greater confidence about how much water could be available to bring land into sustainable production.

In addition, there are a number of completed and current projects directed by Environment Southland that are relevant in regards to supporting the potential water storage investigations (Kees 2021, pers. comm.). Environment Southland may be able to contribute in-kind resources to support potential further investigations. A summary of these projects include:

- Hydrochemistry and age dating of groundwater in the vicinity of Waimea plains, Upper Ōreti, and Brightwater Spring (existing, aligned future project);
- Concurrent gauging data and time series monitoring data relating to the focus areas (existing, aligned future project);
- Update of regional geological model for long term display/conceptualisation of SkyTEM data in relation to broader geological setting (existing, aligned future project);
- Mid-Matāura Groundwater Flow Model (ModFlow) (existing);
- Calibrate and validate Mid-Matāura groundwater boundary and run allocation demand scenarios (aligned future project);
- Regional hydro-geochemical study (to assist SkyTEM interpretation) (existing); and
- Surface water modelling of focus catchments to inform ephemeral stream predictions (NIWA TopNET) (existing, aligned future project).

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7.0 REFERENCES

Action for healthy waterways – decisions on national direction and regulations for freshwater management [Cabinet paper]. 2020. [Wellington] (NZ): Ministry for the Environment; [accessed 2021 Mar]. https://www.mfe.govt.nz/sites/default/files/media/Fresh%20water/cab-paper-action-for-healthy-waterways-decisions-on-national-direction-and-regulations-for-freshwater-management.pdf

Ballingall J, Pambudi D. 2017. Dairy trade's economic contribution to New Zealand. Wellington (NZ): New Zealand Institute of Economic Research; [accessed 2021 Mar]. https://www.dcanz.com/UserFiles/DCANZ/File/Dairy%20economic%20contribution%20update%20FINAL%2021%20February%202017.pdf. Prepared for DCANZ.

Bartlett M, Kitson J, Norton N, Wilson K. 2020. Draft Murihiku Southland Freshwater Objectives: providing for hauora, the health and well-being of waterbodies in Murihiku Southland. Invercargill (NZ): Environment Southland Regional Council. 143 p. Technical Report 2020-06.

Beacon. [date unknown]. Invercargill (NZ): Environment Southland; [accessed 2021 Mar]. https://maps.es.govt.nz/

Booker DJ. 2015. Hydrological indices for national environmental reporting. Christchurch (NZ): National Institute of Water & Atmospheric Research. 39 p. Report CHC2015-015. Prepared for Ministry for the Environment.

Columbus J, Sirguey P, Tenzer R. 2011. A free fully assessed 15 metre digital elevation model for New Zealand. *Survey Quarterly.* 66:16–19.

Crop data sheets. 2019. Invercargill (NZ): Great South; [accessed 2021 Mar]. https://greatsouth.nz/resources/crop-data-sheets

GDP from manufacturing in New Zealand. 2017. Wellington (NZ): Ministry of Business, Innovation & Employment; [accessed 2021 Mar]. http://webrear.mbie.govt.nz/theme/gdp-by-industry/map/barchart/2017/southland/agriculture?accessedvia=southland&right-transform=absolute

Hughes B. 2017. Groundwater provisions of the proposed Southland Water and Land Plan: technical background. Lyttelton (NZ): Land Water People Ltd. 88 p. Report LWP 17063. Prepared for Environment Southland.

Journeaux P, van Reenen E, Manjala T, Pike S, Hanmore I, Millar S. 2017. Analysis of drivers and barriers to land use change. Hamilton (NZ): AgFirst; [accessed 2021 Mar]. https://www.mpi.govt.nz/dmsdocument/23056/direct. Prepared for the Ministry for Primary Industries.

Kees L. 2020. Personal communication. Senior Scientist – Water Resources, Environment Southland. Invercargill (NZ). lawrence.kees@es.govt.nz

Kees L. 2021. Personal communication. Senior Scientist – Water Resources, Environment Southland. Invercargill (NZ). lawrence.kees@es.govt.nz

Land Air Water Aotearoa. [2020]a. [place unknown]: Land Air Water Aotearoa. Southland region; [accessed 2021 Mar].. https://www.lawa.org.nz/explore-data/southland-region/

Land Air Water Aotearoa. [2020]b. [place unknown]: Land Air Water Aotearoa. Southland region: water quantity; [accessed 2021 Mar]. https://www.lawa.org.nz/explore-data/southland-region/water-quantity/

Leftfield Innovation Ltd. 2019. Specialty grains & pulses report. Christchurch (NZ): Leftfield Innovation Ltd; [accessed 2021 Mar]. https://ourlandandwater.nz/wp-content/uploads/2020/05/NGS_190628-LFI-Specialty-Grains-and-Pulses-Report-3.pdf

LINZ Data Service. 2019. Wellington (NZ): Land Information New Zealand. NZ building outlines; [updated 2020 Aug 24; accessed 2020 May 19]; [dataset]. https://data.linz.govt.nz/layer/101290-nz-building-outlines/

LRIS Portal. 2000. Lincoln (NZ): Landcare Research New Zealand. FSL Profile Available Water; [accessed 2020 May 19]; [map]. https://lris.scinfo.org.nz/layer/48100-fsl-profile-available-water/

LRIS Portal. 2020. Lincoln (NZ): Landcare Research New Zealand. LCDB v5.0 – Land Cover Database version 5.0, mainland New Zealand. [updated 2020 Jan 29; accessed 2020 May 19]; [map]. https://lris.scinfo.org.nz/layer/104400-lcdb-v50-land-cover-database-version-50-mainland-new-zealand/.

Macara GR. 2013. The climate and weather of Southland. 2nd ed. Auckland (NZ): National Institute of Water & Atmospheric Research. 40 p. (NIWA Science and Technology series; 63).

Ministry for the Environment. 2018. Wellington (NZ): Ministry for the Environment. Climate change projections for the Southland region; [accessed 2020 Oct 28]. https://www.mfe.govt.nz/climate-change/likely-impacts-of-climate-change/how-could-climate-change-affect-my-region/southland

Ministry for the Environment. 2020. Wellington (NZ): Ministry for the Environment. Freshwater guidance and guidelines: irrigated land in New Zealand; [accessed 2020 June 5]. https://www.mfe.govt.nz/fresh-water/freshwater-guidance-and-guidelines/irrigated-land-new-zealand

Moran E, Pearson L, Couldrey M, Eyre. 2019. The Southland Economic Project: agriculture and forestry. Invercargill (NZ): Environment Southland. 322 p. (Technical report; 2019-04).

Moreau M, White PA, Mourot F, Rawlinson Z, Tschritter C, Cameron SG, Westerhoff RS. 2019. Classification of New Zealand hydrogeological systems. Lower Hutt (NZ): GNS Science. 28 p. (GNS Science report; 2018/35).

Nicol S, Robertson R, 2018. The Regional forum: Southland context. Invercargill (NZ) Southern Land & Water Planning Ltd. 92 p. Prepared for Environment Southland.

North Otago Irrigation Company. [2020]. Oamaru (NZ): North Otago Irrigation Company. Infrastructure; [accessed 2020 Aug 21]. https://www.noic.co.nz/infrastructure.

[NZPAM] New Zealand Petroleum & Minerals. c2021. Wellington (NZ): Ministry of Business, Innovation & Employment; [accessed 2021 Mar]. https://www.nzpam.govt.nz/

Snelder T, Beyer M, Hughes B, Rodway E. 2019. Spatial model of groundwater total oxidised nitrogen concentration for the Southland region. Lyttleton (NZ): Land, Water, People.

Southland … horticulture's sleeping giant. 2017. *NZ Grower.* 72(10): 39–44. https://www.pressreader.com/new-zealand/nz-grower/20171101/281857233817078

[Stats NZ] Stats NZ Tatauranga Aotearoa. 2016. http://infoshare.stats.govt.nz/browse_for_stats/environment/environmental-reporting-series/environmental-indicators/Home/Land/land-use.aspx

[Stats NZ] Stats NZ Tatauranga Aotearoa. 2020. Wellington (NZ): Stats NZ. Regional Council 2020 (generalised). [updated 2020 Jan 30; accessed 2020 May 19]; [dataset]. https://datafinder.stats.govt.nz/layer/104254-regional-council-2020-generalised/

Tait A, Henderson R, Turner R, Zheng X. 2006. Thin plate smoothing spline interpolation of daily rainfall for New Zealand using a climatological rainfall surface. *International Journal of Climatology*. 26(14):2097–2115. doi:10.1002/joc.1350.

Te Ao Marama. 2020. Ngāi Tahu ki Murihiku freshwater objectives. Invercargill (NZ): Te Ao Marama. 119 p. Prepared for the Southland Regional Forum.

Thomson.R, 2021. Geology: geological rock and roll at Glenorchy. Glenorchy (NZ): Glenorchy Community; [accessed 2021 May]. https://www.glenorchycommunity.nz/glenorchy/geology/

Thompson S, Grüner I, Gapare N. 2003. New Zealand Land Cover Database Version 2: illustrated guide to target classes. Wellington (NZ): Ministry for the Environment. 126 p.

Todd DK, Mays LW. 2005. Groundwater hydrology. 3rd ed. Hoboken (NJ): Wiley. 636 p.

Watercare. 2021. Auckland (NZ): Watercare. Waikato River consents; [accessed 2021 Feb 21]. https://www.watercare.co.nz/Water-and-wastewater/Where-your-water-comes-from/Rivers/Waikato-River-consents.

Westerhoff RS, Tschritter C, Rawlinson ZJ. 2019. New Zealand Groundwater Atlas: depth to hydrogeological basement. Wairakei (NZ): GNS Science. 20 p. Consultancy Report 2019/140. Prepared for the Ministry for the Environment.

Westerhoff R, White P, Miguez-Macho G. 2018. Application of an improved global-scale groundwater model for water table estimation across New Zealand. *Hydrology and Earth System Sciences*. 22(12):6449–6472. doi:10.5194/hess-22-6449-2018.

White PA, Moreau M, Mourot F, Rawlinson ZJ. 2019. New Zealand Groundwater Atlas: hydrogeological-unit map of New Zealand. Wairakei (NZ): GNS Science. 89 p. Consultancy Report 2019/144. Prepared for Ministry for the Environment.

Wilson K, 2011.State of the Environment: Groundwater Quantity Technical Report. Environment Southland Report.

Woods R, Hendrikx J, Henderson R, Tait A. 2006. Estimating mean flow of New Zealand rivers. *Journal of Hydrology (New Zealand)*. 45(2):95–110.

Zammit C, Pearce P, Mullan B, Sood A, Collins D, Stephens S, Woolley JM, Bell R, Wadhwa S. 2018. Southland climate change impact assessment. Christchurch (NZ): National Institute of Water & Atmospheric Research. 138 p. Client Report 2018120CH. Prepared for Environment Southland, Invercargill City Council, Southland District Council and Gore District Council.

APPENDICES

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APPENDIX 1 WATER STORAGE METHODOLOGIES

Environment Southland / GNS Science workshops were held in September and November 2020 (Appendix 2) following virtual meetings between these organisations and the PDU. The primary aim of the workshops was to enable further discussion between GNS Science and Environment Southland technical staff. The workshops were hosted by Environment Southland under direction of Elaine Moriaty (Environment Southland).

Two video workshops were held to initiate collaborative work between Environment Southland, Ngai Tahu / Te Ao Marama Incorporated (TAMI) and GNS Science staff members in relation to water storage opportunities for the Southland region. The project team (groundwater, planning and policy expertise) presented the scope of the project and the initial storage options identified to Environment Southland specialists from the science, policy, strategy and natural hazards teams. Related discussions, focused in particular on local knowledge, iwi engagement, constraints, on-going projects and strategic approach, were also held to inform the next steps of the project development.

During the course of the workshop, a practical policy exercise was undertaken. Attendees were asked to identify values or systems within the region that may present significant policy, or other, limitations to the exploration of water storage options. Wetland enhancement projects were identified as the more limiting factors for the use of different water storage options. Other limiting factors included minimum flow allocation, baseflow levels, the mixing of different waters and water conservation orders.

A1.1 Storage Methods

A1.1.1 Groundwater Storage

The groundwater storage method was developed by combining the HS and HUM stacked datasets (Moreau et al. 2019; White et al. 2019).

Firstly, the HUM units were subdivided using hydrological systems boundaries. Then the stacked polygons were collapsed to a 2D dataset to identify confinement status. The confinement status qualifies the way groundwater is stored within a host formation (or a group of formation), which in turn influences the ability for this groundwater to flow and therefore be retrieved. Subsequently, fixed storage coefficient values were assigned to sub-HUM units based on the HUM_type (Aquifer/Aquitard/Aquiclude and Basement) and the aquifer confinement status (e.g. unconfined or confined). The assigned values were checked against published values (Kees, 2021). As part of developing the groundwater storage method, layer thicknesses were estimated using the depth to basement and equilibrium water table datasets (Westerhoff et al. 2018, 2019). Finally, the High/Medium/Low assessment was assigned based on groundwater storage coefficient values.

A1.1.2 Riverine Galleries

This method was developed by combining the HUM outcrop, Equilibrium Water Table, FSL profile available water, river flow and LCBD datasets (LRIS Portal 2000; Booker 2015; White et al. 2019; LRIS Portal 2020). The High/Medium/Low assessment was assigned based on outcropping lithologies (sand/silt/gravel or else), depth to the water table, proximity to a stream, river flow data, median PAW value and land cover. In addition, areas with unsuitable land cover (e.g. built-up areas, transportation infrastructure or permanent snow and ice) are classified as ‘Low’.

A1.1.3 Modified Wetlands

This method combines the regional council's boundaries, the LCDB, mean annual precipitation and mean annual evapotranspiration datasets (Tait et al. 2006; Woods et al. 2006; Stats NZ 2020; LRIS Portal 2020). LCDB v5.0 was used to identify freshwater wetlands in the Southland Region.

The wetlands polygons were used as an input layer for further processing to select wetlands that could potentially be modified for water storage purposes. Wetlands are usually complex systems consisting of several land cover classes, e.g. open water classed as lakes and ponds, areas of herbaceous freshwater or saline vegetation, flaxland and scrub classes (Thompson et al. 2003). The saline vegetation classes of wetlands (i.e. herbaceous saline vegetation and mangrove) were excluded, as estuarine and coastal wetlands would not allow freshwater storage due to saline 'contamination'.

The potential supply of water to the selected 'freshwater wetlands' was then calculated based on the difference between the long-term mean annual precipitation (P) and the long-term mean AET on the wetland area. Adjacent wetlands (i.e. located within 50 m) were considered as part of the same wetland for this exercise. The freshwater wetlands allowing a water supply greater or equal to 50 L/s were then characterised as presenting a 'High' potential for water storage, the remaining freshwater wetlands as 'Medium' potential and the other land covers as 'Low' potential.

A1.1.4 Dams for Baseflow Enhancement

This method was developed using the HS, HUM outcrop and river flow datasets (Booker 2015; Moreau et al. 2019; White et al. 2019). The storage potential was assessed based on proximity and mean flow rates of perennial streams, outcropping lithologies and hydrogeological system type. In addition, areas with unsuitable land cover (e.g. built-up areas, transportation infrastructure or permanent snow and ice) are classified as 'Low.'

A1.1.5 Land Subsoil Recharge

This method was developed using the HS, HUM outcrop and FSL datasets (LRIS Portal 2000; Moreau et al. 2019; White et al. 2019), combined with ground slopes calculated from the Digital Elevation Model.

A1.1.6 Galleries

This method was developed by combining the HUM outcrop, Equilibrium Water Table FSL and LCBD datasets (LRIS Portal 2000; Westerhoff et al. 2018; White et al. 2019; LRIS Portal 2020). The water storage potential was assessed based on outcropping lithologies (sand/silt/gravel or else), depth to the water table, median PAW value and land cover. In addition, areas with unsuitable land cover (e.g. built-up areas, transportation and infrastructure or permanent snow and ice) are classified as 'Low'.

A1.1.7 Managed Aquifer Recharge

This method was developed using the HS, HUM outcrop and FSL datasets (LRIS Portal 2000; Moreau et al. 2019; White et al. 2019), combined with ground slopes calculated from the Digital Elevation Model.

Areas of interest for MAR were identified as areas underlain by unconsolidated sediment with a low-gradient slope and a low median PAW value. Any areas that fulfilled all of the previously mentioned conditions and also intersected with catchments or aquifers that had any allocation/take of surface water or groundwater, respectively, were categorised as having a 'High' potential to augment groundwater resources and stream baseflow. Any areas that fulfilled the first three conditions but did not have any allocation/take of surface water or groundwater, respectively, were categorised as having a 'Medium' potential. All areas that did not fall into either the 'High' or the 'Medium' category, or areas with unsuitable land cover (e.g. built-up areas, transportation infrastructure or permanent snow and ice), were categorised as having a 'Low' potential for MAR.

A1.1.8 Water Tanks

Water tanks provide opportunities for storage throughout Southland. Rooftop rainfall is calculated from GIS datasets that map 114,885 buildings in Southland (except Stewart Island), with a combined rooftop area of 20.25 km^2; these buildings collect an estimated rainfall of approximately 1050.5 mm/year.

A1.2 GIS Processing

A1.2.1 Datasets

A combination of national- and regional-scale datasets was used to assess water storage potential in Southland (Table A1.1); these datasets are briefly described the sections below.

Table A1.1 New Zealand datasets and associated references.

Coverage	Dataset	References
National	Digital Elevation Model	Columbus et al. 2011
National	Depth to basement	Westerhoff RS, Tschritter C, Rawlinson ZJ. 2019. New Zealand Groundwater Atlas: depth to hydrogeological basement. Wairakei (NZ): GNS Science. 20 p. Consultancy Report 2019/140. Prepared for: Ministry for the Environment.
National	Equilibrium water table	Westerhoff R, White P, Miguez-Macho G. 2018. Application of an improved global-scale groundwater model for water table estimation across New Zealand. *Hydrology and Earth System Sciences*. 22(12):6449–6472. doi:10.5194/hess-22-6449-2018.
National	Fundamental Soil Layer Profile Available Water	LRIS Portal. 2000. Lincoln (NZ): Landcare Research New Zealand. FSL Profile Available Water; [released 2000 Jan 1; accessed 2020 May 19]; [map]. https://lris.scinfo.org.nz/layer/48100-fsl-profile-available-water/
National	Hydrogeological Systems	Moreau M, White PA, Mourot F, Rawlinson Z, Tschritter C, Cameron SG, Westerhoff RS. 2019. Classification of New Zealand hydrogeological systems. Lower Hutt (NZ): GNS Science. 28 p. (GNS Science report; 2018/35).
National	Hydrogeological-Unit Map	White PA, Moreau M, Mourot F, Rawlinson ZJ. 2019. New Zealand Groundwater Atlas: hydrogeological-unit map of New Zealand. Wairakei (NZ): GNS Science. 89 p. Consultancy Report 2019/144. Prepared for Ministry for the Environment.

Coverage	Dataset	References
National	Land Cover Database	LRIS Portal. 2020. Lincoln (NZ): Landcare Research New Zealand. LCDB v5.0 – Land Cover Database version 5.0, mainland New Zealand. [updated 2020 Jan 29; accessed 2020 May 19]; [map]. https://lris.scinfo.org.nz/layer/104400-lcdb-v50-land-cover-database-version-50-mainland-new-zealand/
National	Mean annual actual evapotranspiration	Woods R, Hendrikx J, Henderson R, Tait A. 2006. Estimating mean flow of New Zealand rivers. *Journal of Hydrology (New Zealand)*. 45(2):95–110.
National	Mean annual rainfall	Tait A, Henderson R, Turner R, Zheng X. 2006. Thin plate smoothing spline interpolation of daily rainfall for New Zealand using a climatological rainfall surface. *International Journal of Climatology*. 26(14):2097–2115. doi:10.1002/joc.1350.
National	National building outlines	LINZ Data Service. 2019. Wellington (NZ): Land Information New Zealand. NZ building outlines; [updated 2020 Aug 24; accessed 2020 May 19]; [dataset]. https://data.linz.govt.nz/layer/101290-nz-building-outlines/
National	Regional Council boundaries	Stats NZ. 2020. Regional Council 2020 (generalised). [updated 2020 Jan 30; accessed 2020 May 19]; [dataset]. https://datafinder.stats.govt.nz/layer/104254-regional-council-2020-generalised/
National	River flow data	Booker DJ. 2015. Hydrological indices for national environmental reporting. Christchurch (NZ): National Institute of Water & Atmospheric Research. 39 p. Report CHC2015-015. Prepared for: Ministry for the Environment. https://data.mfe.govt.nz/layer/53309-river-flows/
Regional	Groundwater Management Zones	Environment Southland 2020; personal communication from Lawrence Kees.
Regional	Surface water Management Zones	Environment Southland 2020; personal communication from Lawrence Kees.

A1.2.2 Digital Elevation Model

The New Zealand School of Surveying Digital Elevation Model (NZSoSDEM v1.0) is a free Digital Elevation Model (DEM) covering the country at a spatial resolution of 15 m, created by the School of Surveying by interpolating the LINZ topographic vector data. This DEM was created as a series of 30 maps, whose extents correspond exactly with the LINZ Topo250 topographic map series (Columbus et al. 2011).

A1.2.3 Depth to Basement

This dataset provides an update of New Zealand's depth to hydrogeological basement map. Depth to hydrogeological basement can be loosely defined as the 'base of aquifers', or, more strictly, as:

> *"the depth to where primary porosity and permeability of geological material is low enough such that flued volumes and flow rates can be considered negligible"* (Westerhoff et al. 2019).

A1.2.4 Equilibrium Water Table

The equilibrium water table dataset consists of a raster file, where the values represent modelled depth to the water tables from the ground surface. The underlying model is a global-scale groundwater flow model that received national input data relevant to terrain, geology and recharge (Westerhoff et al. 2018).

A1.2.5 Fundamental Soil Layer Profile Available Water

The publicly available New Zealand Fundamental Soil Layer (FSL) information combines soil physical, chemical and mineralogical characteristics from the National Soils Database with physical land resource information from the New Zealand Land Resource Inventory. This dataset contains the best available estimate of Profile Available Water (PAW) data, which estimates total available water for the soil profile to a depth of 0.9 m, or to the potential rooting depth (whichever is the lesser). Values are weighted averages over the specified profile section (0–0.9 m) and are expressed in units of mm of water (LRIS Portal 2000).

A1.2.6 Hydrogeological-Unit Map

The publicly available Hydrological-Unit Map (HUM) dataset consists of two GIS files: a stacked map and an outcropping unit map. This is because differently aged HUM units occur within the same area and therefore are 'stacked' vertically within a given land area. The HUM datasets comprise a classification of geological units in terms of their importance for groundwater flow and storage in an ArcGIS seamless digital map. HUM units are classed into four broad types of hydrogeological unit: aquifer, aquiclude, aquitard and basement, defined as follows:

- Aquifer: a hydrogeological unit type defined as: "a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs … unconsolidated sands and gravels are a typical example" (Todd and Mays 2005).
- Aquitard: a hydrogeological unit type defined as a saturated but poorly permeable stratum that impedes groundwater movement and does not yield water freely to wells that may transmit appreciable water to or from adjacent aquifers and, where sufficiently thick, may constitute an important groundwater storage zone; sandy clay is an example (Todd and Mays 2005).
- Aquiclude: a hydrogeological unit type defined as a saturated but relatively impermeable material that does not yield appreciable quantities of water to wells; clay is an example (Todd and Mays 2005).
- Basement: a hydrogeological unit type defined as a geologic layer, or group of layers, of Cretaceous age and older; in Northland and East Coast, Tertiary age allochthons were included as Basement.

However, the definition of an aquifer includes an assessment of ‘significant quantities of water’, which is a regionally variable property. In the nationally consistent HUM dataset, the classification assesses what is considered ‘significant quantities of water’ at the national level in New Zealand (i.e. what is defined as an aquifer versus an aquitard) (White et al. 2019).

A1.2.7 Hydrogeological Systems

The Hydrological Systems (HS) digital map (1:250,000 scale), consists of two publicly-available GIS files: a set of polygons defining hydrogeological systems and relevant attributes and a set of polylines defining the system boundaries and relevant attributes. Hydrogeological systems were defined as geographical areas with broadly consistent hydrogeological properties and similar resource pressures and management issues. Individual systems were mapped using geological, topographical, surface drainage and, where available, groundwater divides data (Moreau et al. 2019).

A1.2.8 Land Cover Database

The New Zealand Land Cover Database (LCDB) is a publicly available, multi-temporal, thematic classification of New Zealand’s land cover. It identifies 33 mainland land cover classes (35 classes, once the offshore Chatham Islands are included). Land cover features are described by a land cover code and name per polygons at multiple time steps (summer 1996/97, summer 2001/02, summer 2008/09, summer 2012/13 and summer 2018/19). The dataset is designed to complement New Zealand’s 1:50,000 topographic database in theme, scale and accuracy and is suitable for infrastructure planning (LRIS Portal 2000).

A1.2.9 Mean Annual Precipitation

Average annual rainfall was based on a NIWA dataset based on the rainfall measurements at individual rainfall stations interpolated throughout New Zealand by NIWA and averaged for the period 1960–2006 (Tait et al. 2006).

A1.2.10 Mean Annual Actual Evapotranspiration

Annual actual evapotranspiration (AET) was estimated by GIS as actual evapotranspiration from the land surface, derived from a national-scale map developed by NIWA for the period 1960–2006 without specific consideration of land use, land cover, soil type or groundwater recharge (Woods et al. 2006; Henderson 2019).

A1.2.11 National Building Outlines

The publicly available ‘national building outlines’ GIS dataset provides building outlines within mainland New Zealand, extracted from multiple years of aerial imagery. It is a 2D representation of the roof outline of a building, which has been classified from LINZ aerial imagery using a combination of automated and manual processes to extract and refine a building roof outline (LINZ 2020).

A1.2.12 River Flow Data

The publicly available ‘River flow’ datasets consist of river flow statistics attributed to specific river reaches, which can be used to assess how much water is available for irrigation, drinking water, hydro-electric power generation and recreational activities such as fishing and boating. River flows are also very important for maintaining the health and form of a waterway. This dataset was created to support environmental reporting (Booker 2015).

A1.2.13 Regional Council Datasets

Nationally consistent regional boundaries were obtained from Statistics NZ (Stats NZ 2020). The following Environment Southland GIS datasets were used in this project:

- Groundwater_Management_Zones (Environment Southland 2020).
- Surface_water_Management_Zones (Environment Southland 2020).

A1.2.14 GIS Engine Implementation

Source spatial datasets were provided either as vector (e.g. shapefile) or raster (e.g. GeoTIFF), with different extents and resolutions. To overlay the spatial information together, each dataset was rasterised or re-gridded to the same projection, extent and grid resolution for the region. This allows each layer to be processed in an array-processing environment. Results were then stored as GeoTIFF rasters, with codes corresponding to low, medium and high assessments. The assessments were made with a set of rules for process the GIS data (Table A1.2).

An illustrative example of the spatial overlay method is shown in Figure A1.1 for infiltration galleries:

- (a) shows Quaternary-aged aquifers consisting of gravel, sand and/or silt; other units are excluded using the HUM dataset (White et al. 2019).
- (b) shows median PAW from the FSL dataset (LRIS Portal 2000), with values greater than 80 mm hashed to indicate that they are a poorer soil type for infiltration galleries.
- (c) shows water table depth (WTD), estimated using the equilibrium water table dataset (Westerhoff et al. 2018), where depths greater than 2 m are too deep for infiltration galleries.
- (d) shows land cover (LRIS Portal 2020), which excludes infiltration galleries in built-up areas and standing water (among several other conditions that apply outside the figure).

The resulting map (e) was produced by assigning assessment values following a consistent method that combines the datasets. Assessments are depicted using a three-colour or ‘traffic light’ scheme suitable for a colour-blind audience.

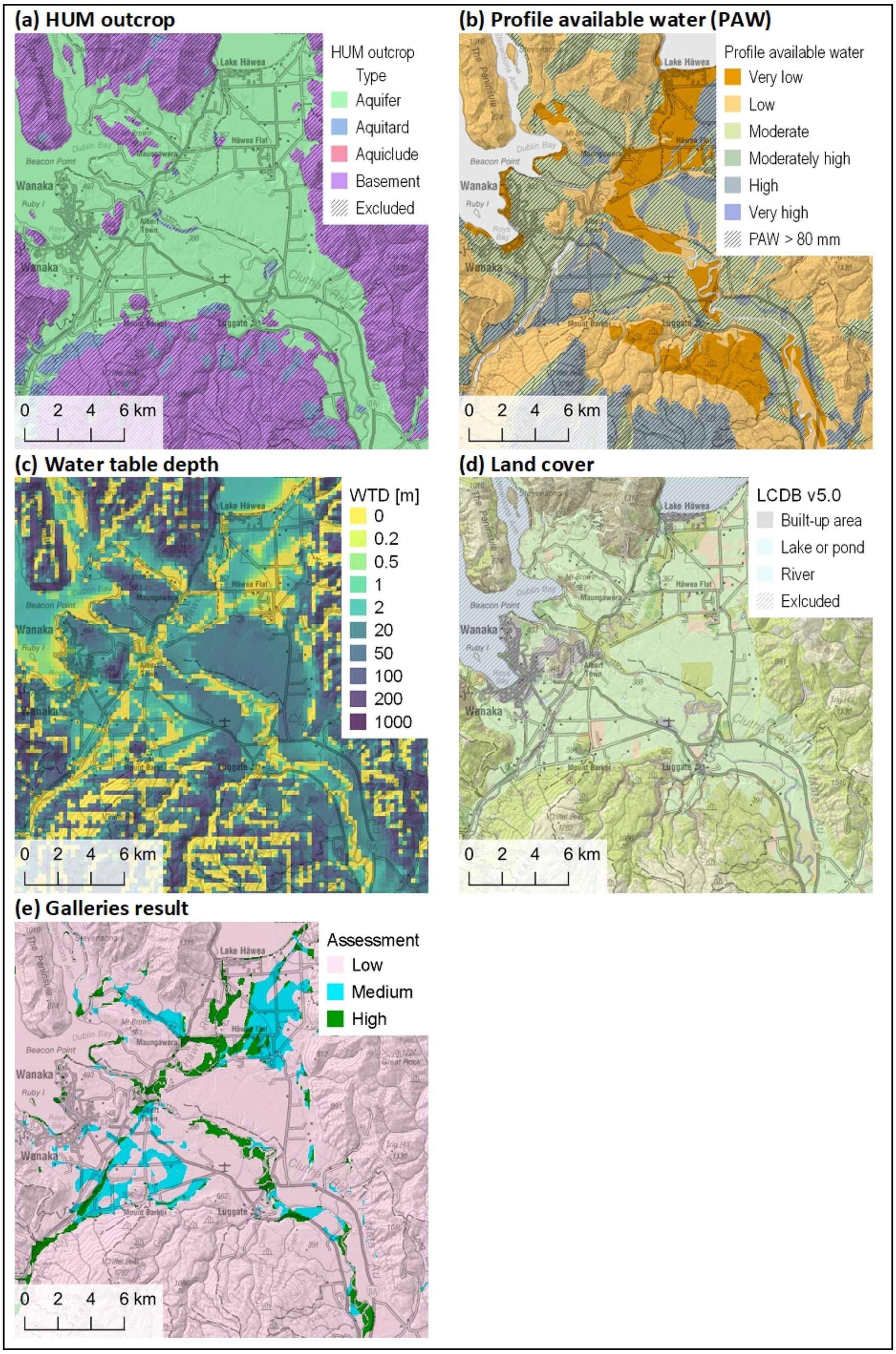

Figure A1.1 Example of a GIS overlay assessment for galleries. Acronyms used in the figure are as follows: Hydrogeological-Unit map (HUM), water table depth (WTD), Land Cover Database (LCDB).

Table A1.2 Description of assessment methods and associated datasets.

Method	Assessment			Source Datasets
	High	**Medium**	**Low**	
Groundwater storage	Sedimentary aquifers not fully enclosed within the Basement Hydrogeological System.	Volcanic aquifers and sedimentary aquifers fully enclosed within the Basement Hydrogeological System; aquitards.	Aquicludes and Basement.	Hydrogeological-Unit Map Hydrogeological Systems
Riverine galleries	Sediments at surface; water table less than 2 m deep; location within 100 m of stream; low flow greater than 0.1 m^3/s; PAW* less than, or equal to, 80 mm.	Sediments at surface, water table less than 2 m deep, location within 100 m of stream, low flow greater than 0.1 m^3/s, PAW* greater than 80 mm.	No sediments at the ground surface and/or water table deeper than 2 m and/or unsuitable land-cover type (built-up area, etc.).	Hydrogeological-Unit Map Hydrogeological Systems Equilibrium Water Table FSL Profile Available Water River flow data
Modified wetlands*	Wetlands receiving more than 50 L/s supply of water (calculated by subtracting actual evapotranspiration from rainfall over a wetland area*).	Wetland receiving less than 50 L/s supply of water.	Area not covered by any wetlands currently or wetland with saline inputs.	Land Cover Database Mean annual precipitation Mean annual evapotranspiration Regional Council boundaries
Wetland enhancement (Southland)	TWI >10 and soil drainage classified as very poorly drained / poorly drained,	-	All other areas.	Topographic Wetness Index (TWI) Digital elevation model (DEM) FSL Soil Drainage Class Land Cover Database
Dams for baseflow enhancement	Areas outside of townships with perennial streams that have a low flow in the range 0.2–0.8 m^3/s and Q1 and Q2 sediments in the Hydrogeological system polygon.	Areas outside of townships with perennial streams that have a low flow in the range 0.2–0.8 m^3/s.	All other areas not covered by the 'High' and 'Medium' category.	Hydrogeological-Unit Map River flow data Land Cover Database
Land subsoil recharge	Areas in the HUM outcrop file in the rock types 'GravelSandSilt' and 'Sand' categories that are outside town areas and have a slope less than, or equal to,	Areas in the HUM outcrop file in the rock types 'GravelSandSilt' and 'Sand' categories that are outside town areas and have a slope less than, or equal to, 2%	All other areas not covered by the 'High' and 'Medium' category and/or unsuitable land-cover type (built-up area, etc.).	Hydrogeological-Unit Map Land Cover Database Fundamental Soil Layer Profile Available Water Digital Elevation Model

Method	Assessment			Source Datasets
	High	Medium	Low	
	2% and a median PAW less or equal 80 mm.			
Galleries	Sediments at surface; water table less than 2 m deep; PAW less than, or equal to, 80 mm.	Sediments at surface; water table less than 2 m deep; PAW greater than 80 mm.	No sediments at the ground surface and/or unsuitable land-cover type (built-up area, etc.).	Equilibrium Water Table Land Cover Database Hydrogeological-Unit Map Fundamental Soil Layer Profile Available Water
Managed aquifer recharge	Sediments at surface; sediments silt, sand, or gravel; slope less than, or equal to, **1**5%; PAW less than, or equal to, 80 mm; drainage class 4 or 5; water allocation in the catchment; excluding built up areas.	Sediments at surface; sediments **silt,** sand, or gravel; slope less than, or equal to, **1**5%; PAW greater than 80 mm; drainage class 2 or 3; water allocation in the catchment; excluding built-up areas.	No sediments at the ground surface and/or unsuitable land-cover type (built-up area, etc.).	Hydrogeological-Unit Map Hydrogeological Systems Fundamental Soil Layer Profile Available Water Allocation maps (groundwater and surface water) Digital Elevation Model
Hydro-lake storage	Water from hydro-storage can be moved, mostly under gravity.	Water from hydro-storage can be moved, mostly with pumped systems.	All other areas not covered by the 'High' and 'Medium' category.	Land Cover Database Digital Elevation Model
Small Dams	MALF between 0.4–1 m^3/s located within high-producing grassland.	MALF 0.4–1 m^3/s in any other location	All other areas not covered by the 'High' and 'Medium' category.	River flow data Land Cover Database
Ephemeral water harvesting (Southland)	MALF 0–0.01, upstream catchment area of >300 ha and in high-producing grassland or exotic grassland	MALF 0–0.01, upstream catchment area of >300 ha and in any other location	All other areas not covered by the 'High' and 'Medium' category.	Land Cover Database River flow data Digital Elevation model
Water tanks	Average annual rooftop rainfall.	Not applicable.	Not applicable.	National Building Outlines

APPENDIX 2 PROVINCIAL GROWTH FUND WATER STORAGE INVESTMENT PRINCIPLES

Economic

- Water storage will strengthen regional economies by shifting land use to higher value, sustainable uses, while avoiding increases in livestock intensification.
- Water storage will help address disparities in Māori access to water for land development.

Community

- Small-scale community level projects will be supported rather than mega irrigation schemes.
- There must be public benefit from government funding of a project.
- Projects will involve stronger partnerships at the local level, including with regional councils.
- The Crown Irrigation Investments Limited (CIIL)'s programme of work will not be progressed, although communities that were involved in CIIL initiatives cab submit PGF proposals that align with PGF objectives.

Environment

- Water storage proposals should demonstrate that they will support land use that does not increase – and ideally reverses – negative impacts on water quality.
- Proposals should maintain the health of waterways.
- Water storage will not be used to increase the intensity of ruminant agriculture or other land uses in a catchment where this puts greater cumulative pressure on water and risks compromising water quality.
- Water storage proposals should incorporate activities that improve water quality, e.g. activities that improve *E. coli* levels and ecological health, restoration and protection projects such as improvements in wetlands, fish and wildlife habitats, riverbanks, biodiversity activities, soil health and sediment control.

Climate Change

- Where practical, proposals should contribute positively to the target of reducing greenhouse gases and demonstrate how they will contribute to mitigating or adapting to climate change effects and a just transition to a low emissions economy.
- Proposals should consider the potential to contribute to community resilience to climate change. Strengthening municipal water supply is not an objective of PGF funding. However, the PGF will work with councils to include municipal supply as a component of wider water initiatives, if it enables councils to contribute more to regional water management.