Groundwater Provisions of the Proposed Southland Water and Land Plan

Technical background

June 2017

Prepared By:

For any information regarding this report please contact:

Brydon Hughes

Phone: 021 495 229 or 03 310 7420

Email: Brydon@landwaterpeople.co.nz

Land Water People Ltd
PO Box 70
Lyttelton 8092
New Zealand

LWP Client Report Number: LWP17063

Report Date: June 2017

LWP Project:

Quality Assurance Statement

Version	Reviewed By	
Version 1	Karen Wilson	

Document History

Version	Date	Status:	Description
Draft	30/6/2017	Draft	Draft for client review
Final	4/7/2017	Final	

Table of Contents

1 Background

1.1 Introduction

Water and Land 2020 & Beyond is an Environment Southland project to maintain and improve Southland's freshwater (including rivers, lakes, wetlands and groundwater). This project is in partnership with Ngai Tahu ki Murihiku and aims to maintain and improve Southland's water quality, ultimately helping the Southland community achieve its goals for our region's water.

The proposed Southland Water and Land Plan (pSWLP) is a new plan that is a combination of the existing *Regional Water Plan for Southland* (RWP) and *Regional Effluent Land Application Plan.* The pSWLP seeks to address update provisions of these existing plans to incorporate improved knowledge of the Region's water resources and specifically address activities that are known to have a significant effect on water quality.

The pSWLP was publically notified by Environment Southland in June 2016.

1.1.1 Report Scope

This report is intended to provide documentation of provisions of the pSWLP relating to the management of Southlands groundwater resources.

Section 2 of the report provides a brief background to the development of provisions relating to groundwater management in the Regional Water Plan (RWP). Section 3 documents specific changes (and accompanying rationale) to groundwater management provisions between the RWP and pSWLP.

2 Existing groundwater management framework

2.1 Regional Water Plan

Following circulation and compilation of community feedback in late 1999, Environment Southland notified a Proposed Regional Fresh Water Plan in October 2000. While the Regional Policy Statement (which became operative in December 1997) contained some general provisions relating to the management of freshwater resources, the draft Plan was the first planning document to outline a specific framework for the sustainable management of the quantity and quality of water resources across the Southland Region[1].

Overall, the provisions of the draft Fresh Water Plan established a basic framework for sustainable management of freshwater sources. However, many of the policies and rules (including those relating to groundwater) were relatively high level and provided limited guidance regarding specific resource management issues. In part, the limited specificity of provisions in the Proposed Freshwater Plan reflected the limited development of water resources in the Southland Region prior to 2000.

However, during the late 1990s, a gradual shift occurred across many parts of Southland. During the early 2000s, ongoing changes in land use saw the initial development of pastoral irrigation in drier (inland) parts of the region. During 2002-03, this resulted in a rapid increase in water (particularly groundwater) allocated for consumptive use, and an increasing recognition that management provisions contained in the draft Plan were not always adequate to address resource management issues associated with large-scale water resource development.

2.1.1 Southland Water Resources Study

The Southland Water Resources Study[2] was initiated in 2003 in response to changing land use and an overall increase in water allocation Southland Region since the late 1990s..

Although not a statutory document, outputs from the study (Morgan and Evans (2003)[3], SMM (2005)[4]) provided important technical background to facilitate the development of groundwater provisions later incorporated into the Regional Water Plan (RWP) via Variation 3 (Water Quantity). This study was the first detailed investigation of the Southland Regions groundwater and surface water resources. Output from this investigation included:

- Definition of water resource (management) zones;
- Identification of long-term demand for water in the Southland Region;
- Identification of water resources likely to come under the greatest pressure in the future;
- Recommendation for allocation of groundwater and surface water resources.

---

[1] Some existing statutes prior to this time, such as the Water Conservation Order (Mataura River) Order 1997, specified provisions for water management in specific parts of the region.

[2] http://www.venturesouthland.co.nz/Latest-Articles/articleType/ArticleView/articleId/172/Southland-Water-Resources-Study

[3] Morgan, M., Evans, C., 2002*; Southland Water Resources Study - Stages 1 to 3*. Report prepared for Venture Southland, September 2003.

[4] SKM, 2005; *Southland Water Resources Study Stage* 4. Report prepared for Venture Southland, August 2006

Reports documenting the findings of the study provide useful background to the development of Variation 3 to the Regional Freshwater Plan[5].

2.2 Variation 3

Variation 3 (Water Quantity) to the Regional Fresh Water Plan was notified in late 2004. The variation outlined a suite of provisions intended to provide a more detailed framework for the sustainable management of water quantity. Due to the incomplete knowledge of the Regions water resources available at the time, Variation 3 adopted a '*staged management approach*' to management and allocation of freshwater resources. This approach incorporated the concept of adaptive management whereby staged volumes of allocation were prescribed based on the level of risk of environmental effects. This approach[6] did not set fixed volumes of allocation, rather it specified increased information, assessment and monitoring requirements as the level of resource development increased.

In terms of groundwater management Variation 3 established 27 groundwater management zones as the spatial framework for monitoring, investigation and management of groundwater resources in the Southland Region. Individual groundwater zones were delineated using a range of criterion including:

- surface water catchments;
- known geology or aquifer extents;
- geomorphology;
- observed groundwater quality and/or groundwater level fluctuations; and,
- resource development.

The groundwater management zones were then classified into five basic aquifer "types". Which aggregated separate aquifer systems on the basis of observed similarities in geology, geomorphology, aquifer response and groundwater-surface water interaction. The aquifer types defined were:

- Riparian Aquifers
- Terrace Aquifers
- Lowland Aquifers
- Confined Aquifers
- Fractured Rock Aquifers

A staged groundwater allocation regime was proposed for each aquifer type based on the sensitivity of that particular hydrogeological setting to the various adverse effects that may potentially result from groundwater abstraction. This approach was considered an

[5] Provisions relating to management of surface water quantity (e.g. water allocation and minimum flows) were guided by recommendations provided in Jowett, I.G., Hayes, J.W., 2004; *Review of methods for setting water quantity conditions in the Environment Southland draft Regional Water Plan*. NIWA Client Report: HAM2004-018, June 2014.

[6] At least until the implementation of the National Policy Statement for Freshwater Management in 2014 which required Councils to establish fixed allocation limits.

appropriate means to deal with uncertainty associated with the limited knowledge of the groundwater resource by enabling a precautionary approach to allocation which required information from monitoring and investigations to be incorporated in the resource allocation decision-making process.

Variation 3 also contained specific provisions relating to the management of effect on the environment associated with groundwater abstraction, including well interference and stream depletion.

2.3 Variation 12

Variation 12 to the Regional Water Plan (RWP) was notified in late 2011. The Variation sought to address difficulties encountered with the practical application of the groundwater management framework established under Variation 3, particularly with regard to the practical management of allocation from confined and fractured rock aquifers. Major changes introduced into the RWP via Variation 12 included:

Confined Aquifers

- Management criteria to establish primary allocation volumes from confined aquifers was changed from effects of abstraction on potentiometric head to a set proportion of aquifer throughflow; and
- Specific provision for establishment of management controls (including minimum aquifer level cut-offs and seasonal recovery triggers)

Fractured Rock Aquifers

- Removal of Catlins and Hokonui groundwater zones (where the fractured rock aquifers were currently delineated and Chatton groundwater zone (where parts of the zone are fractured rock) from the classified groundwater management zones in the Water Plan.
- A methodology to establish activity status for groundwater takes outside designated groundwater management zones based on rainfall recharge over the relevant land area where the water is to be used; and

Other amendments introduced by Variation 12 include:

- Applications for resource consent to abstract water are to be supported by a conceptual hydrogeological model that is relevant to the level of resource development.
- Guidelines for minimum aquifer test specifications to be available from Environment Southland.
- Having minimum level cut-offs and seasonal recovery triggers as potential management tools to be backed up by policy framework.
- Having exceptions to the limits on drawdown for activities such as aquifer testing, construction dewatering and mining (only of short duration).

- Restrictions on the impact any take may have on a bore used for long-term monitoring of water levels.
- Introducing supplementary allocation of groundwater to enable the abstraction of excess water in an aquifer that may be available due to above average aquifer recharge.

3 Groundwater provisions of the Proposed Southland Water and Land Plan

3.1 Groundwater Abstraction

3.1.1 Permitted Activity

Rule 23(a) of the RWP establishes the threshold for abstraction of groundwater as a permitted activity at 20 m^3/landholding per day, provided the rate of abstraction does not exceed 2 L/s.

Rule 54(a) of the pSWLP proposes to change the threshold for permitted abstraction to a maximum of *86 cubic metres per landholding per day*, at a maximum rate of *less than 5 L/s*, with this allowance including domestic and stock drinking water supplies taken under Section 14(3)(b) of the Resource Management Act[7].

The proposed changes to the permitted activity thresholds are intended to better reflect the actual potential for localised and cumulative effects to result from small-scale groundwater abstraction. Experience (and improved knowledge of the hydrogeological environment) has shown the groundwater takes of less than 86 m^3/day (equivalent to an average abstraction rate of 1 L/s) are unlikely to result in more than minor effects on the environment in terms of:

- Well interference effects - groundwater takes with an average abstraction rate of less than 1 L/s result in minimal drawdown of groundwater levels across the range of hydrogeological environments present in the Southland Region. The only situation where such abstraction could potentially be an issue is where pumping bores are in close proximity (e.g. immediately adjacent across a property boundary) in areas where aquifer permeability is low. This issue is addressed by performance standards on the proposed rule that require a minimum separation distance of 50m metres between adjacent permitted groundwater takes;

- Effects on surface water – localised and cumulative effects on surface water from groundwater takes <2 L/s are treated as *de minimus* under the existing RWP and proposed (pSWLP) stream depletion effects policies;

- Effects on groundwater sustainability – although there are currently a large number of water permits (between 450 to 500) authorising small-scale groundwater abstraction in the Southland Region[8], the cumulative volume of groundwater abstraction by these takes represents a small portion of the aquifer water budget across all groundwater management zones[9].

Given the large numbers, consenting and compliance activities associated with small groundwater takes requires significant council resources for limited environmental benefit.

---

[7] So, in some circumstances, the proposed change may result in a reduction in the volume of water able to be taken as a permitted activity as it now includes water taken for 'reasonable' stock and domestic supplies under RMA s14(3)(b), which were previously excluded from the permitted activity volume under the RWP.

[8] i.e. between the existing RWP permitted activity threshold of 20 m^3/day and the proposed threshold of 86 m^3/day

[9] Wilson, K., 2011; *State of the Environment: Groundwater Quantity Technical Report*. Environment Southland Report, February 2011.

Virtually all such water permits are currently issued without the need for technical review as associated environmental effects are considered to be no more than minor.

Under the proposed permitted activity rule for groundwater abstraction (i.e. a set volume per landholding), water use accounting required under the NPS-FM can be achieved in the same manner as for existing permitted takes (i.e. existing takes permitted under RWP provisions as well as those operating under RMA S14(3)(b)). Certainly current recording and reporting of water use for small-scale takes (<86 m^3/day) has a high rate of non-compliance and the information collected suffers from a range of data quality and reliability issues. It is also noted that takes less than 5 L/s are excluded from requirements for measurement and reporting of water use under the Resource Management (Measurement and Reporting of Water Takes) Regulations 2010.

The proposed increase in the maximum rate for permitted groundwater abstraction (from 2 L/s to 5 L/s) reflects the moderating influence of groundwater storage which ultimately results in the longer-term volumetric pumping rate (in m^3/day) being the ultimate determinant of the magnitude of effects resulting from an individual groundwater take. For this reason, short periods of higher-rate groundwater abstraction (up to 5 L/s) are considered unlikely to result in adverse environmental effects provided the daily average pumping rate remains below 86 m^3/day (equivalent to a continuous pumping rate of 1 L/s).

The proposed permitted activity rule does however limit the cumulative volume of surface water and groundwater abstraction to a maximum of 86 m^3/day per landholding to reduce the potential for cumulative effects on the water resource in any given catchment.

3.1.2 Non-consumptive Use

The RWP does not make any distinction between consumptive and non-consumptive groundwater takes in terms of activity status or management of groundwater allocation.

Rule 54(b) the pSWLP provides for small to moderate-scale non-consumptive groundwater takes as a permitted activity, subject to restrictions on the rate *(<10 L/s*) and volume *(<750 m^3/day*) of abstraction. The proposed Rule also establishes performance standards for permitted, non-consumptive groundwater to ensure an equal volume is returned to the source waterbody to that taken and that the return of water occurs *without delay*.

The intent of the proposed Rule is to enable small-scale, non-consumptive groundwater takes (e.g. gravel washing, ground source heat pumps[10]) which do not result in any net reduction in an aquifer water budget to operate without requiring resource consent. Establishing this class of take as a permitted activity will formalise current practice of excluding such takes from cumulative allocation calculations[11].

3.1.3 Aquifer Testing

The RWP does not include any specific reference to aquifer testing, so a water permit is required for individual aquifer tests if the rates and volumes of abstraction exceed the permitted activity threshold.

[10] Management of the quality of water returned to the aquifer is dealt with under other provisions of the pSWLP (e.g. Policy 15, Policy 20)

[11] It is noted that larger, non-consumptive takes may also be excluded from cumulative allocation but will require resource consent.

Rule 54(c) of the pSWLP establishes aquifer testing as a permitted activity, provided the test is undertaken at a maximum instantaneous pumping rate of *less than 75 L/s* for a duration of less than *5 days*. The proposed Rule also establishes performance standards to ensure aquifer testing does not result in adverse effects on water quality in receiving waters or in terms of flooding on adjoining land and requires that test results be supplied to Environment Southland within one month of test completion.

The proposed Rule recognises that aquifer testing (within the nominated rate and duration) has limited potential to result in adverse effects on the environment and that any effects which do occur will be transitory in nature. The proposed permitted activity classification also recognises the valuable data the aquifer test provide to assist characterisation of the groundwater resource.

3.2 Groundwater Allocation

The RWP establishes the activity status for groundwater abstraction on the basis of a fixed percentage of land surface recharge[12] which varies between individual groundwater management zones (on the basis of aquifer type). Groundwater takes greater than 2 L/s are classified as a discretionary activity where cumulative allocation is less than the primary allocation volume. Where total allocation in individual groundwater management zones exceeds these thresholds, additional groundwater abstraction is classified as a non-complying activity. Table 1 summarises the criterion used to establish primary allocation in different aquifer types under the RWP.

The pSWLP adopts a similar overall approach to allocation to that utilised in the RWP, but proposes a primary allocation limit for each individual groundwater management zone on the basis of a fixed percentage of rainfall recharge. Groundwater allocation up to the nominated primary allocation limit is classified as a discretionary activity and as a non-complying activity in excess of the limit. Numerical allocation limits (and associated groundwater level triggers) are proposed for nominated confined aquifers, with a methodology (Appendix L.6) to enable determination of primary allocation for confined aquifers which are not specifically listed in the proposed Plan. Further explanation of the primary allocation volumes outlined in the pSWLP is provided in Section 2.2.2 below.

Due to existing levels of allocation for hydropower development, both the RWP and pSWLP classify any further or new water abstraction, damming, diversion and use from the Waiau River as a non-complying activity. These provisions also apply to groundwater abstraction, except those takes classified as having a low degree hydraulic connection under stream depletion policies outlined in the respective plans.

[12] The term *land surface recharge* used in the RWP is essentially equivalent to the term rainfall recharge used in the pSWLP.

Table 1. RWP criteria for establishing primary allocation limits in different aquifer types

Aquifer type	Activity Status for Groundwater Abstraction
Riparian	*Discretionary* - cumulative allocation less than or equal to 50% of land surface recharge *Non-complying* - cumulative allocation greater than 50% of land surface recharge
Lowland	*Discretionary* - cumulative allocation less than or equal to 50% of land surface recharge *Non-complying* - cumulative allocation greater than 50% of land surface recharge
Terrace	*Discretionary* - cumulative allocation less than or equal to 15% of land surface recharge *Non-complying* - cumulative allocation greater than 15% of land surface recharge
Confined	*Discretionary* - cumulative allocation less than or equal to 75% of groundwater throughflow *Non-complying* - cumulative allocation greater than 75% of groundwater throughflow
Outside defined groundwater management zones	*Discretionary* - less than or equal to 50 percent of rainfall recharge on an individual landholding *Non-Complying* - less than or equal to 50 percent of rainfall recharge on an individual landholding

3.2.1 Groundwater Management Zones

The basic premise of groundwater management zones as the fundamental geographical unit for managing groundwater allocation has been carried through from the RWP to the pSWLP. However, the number and spatial extent of individual management zones has been modified in the pSWLP to reflect improved understanding of regional hydrogeology and practical experience with managing water allocation through the resource consent process.

One of the main changes to the spatial extent of groundwater zone is the modification of zone boundaries to better reflect the extent of Quaternary alluvium defined by the QMap 1:250,000 geological coverage which was not available when the original zones were defined. Other changes include re-definition of zone boundaries to better reflect local hydrogeological settings including hydraulic boundaries and the interaction between groundwater and surface water resources.

The spatial extent the RWP and pSWLP groundwater management zones are illustrated in Figure 1. Major changes in spatial extent of individual groundwater management zones and associated rationale are summarised in Table 2. Specific details of amendments and additions to individual zones are detailed in Appendix 1.

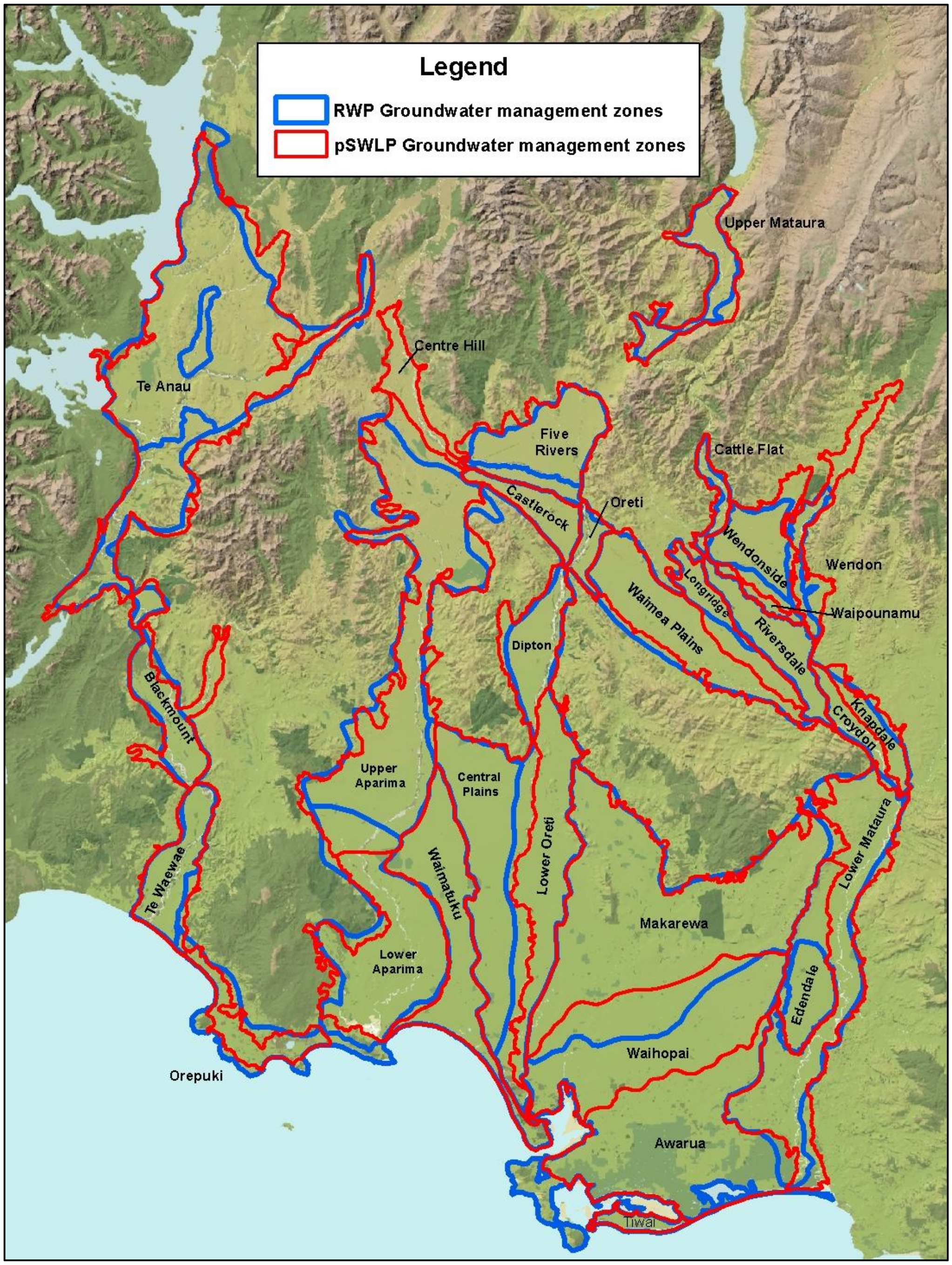


Figure 1. Comparison of the spatial extent of RWP and pSWLP groundwater management zones (labels denote pSWLP groundwater zones)

Table 2. Summary of major changes in groundwater management zones between the RWP and pSWLP

RWP groundwater management zones		pSWLP groundwater management zones		Comment
Zone Name	**Area (Ha)**	**Zone Name**	**Area (Ha)**	
		Awarua	44,048	Subdivision of the RWP Waihopai zone
		Blackmount	13,716	Subdivision of RWP Lower Waiau zone
Castlerock	6,800	Castlerock	6,558	Minor boundary refinement
Cattle Flat	2,638	Cattle Flat	3,045	Minor boundary refinement
Central Plains	26,257	Central Plains	35,878	Re-definition of eastern boundary along the Oreti River channel
		Centre Hill	5,975	New zone to include area of Oreti River catchment not included in RWP zones
		Croydon	4,585	Subdivision of the RWP Knapdale zone
		Dipton	11,655	Subdivision of the RWP Lower Oreti Zone
Edendale	7,529	Edendale	12,409	Boundary extended northward to incorporate whole Q4 Edendale Terrace
Five Rivers	13,795	Five Rivers	18,516	Incorporation of lower Q1 alluvial terrace on true right bank of Oreti River upstream of Lumsden
Knapdale	8,185	Knapdale	4,908	Transfer of area of recent alluvium to the proposed Croydon zone
Longridge	4,393	Longridge	8,269	Incorporation of the Sandstone Stream catchment
Lower Aparima	34,327	Lower Aparima	28,034	Boundary refinement to match QMap coverage
Lower Mataura	40,084	Lower Mataura	34,929	Transfer of northern portion of Q4 Edendale Terrace into the proposed Edendale zone
Lower Oreti	41,155	Lower Oreti	22,486	Subdivided into proposed Dipton zone and portion incorporated into proposed Central Plains zone
Lower Waiau	35,218			Subdivided into the proposed Blackmount, Te Anau and Te Waewae zones
Makarewa	78,924	Makarewa	65,908	Waikiwi catchment incorporated into proposed Waihopai zone
Orepuki	13,699	Orepuki	7,259	Refinement of boundary to geological coverage
Oreti	6,128	Oreti	3,295	Upstream portion included in proposed Five Rivers zone
Riversdale	10,342	Riversdale	10,969	Minor boundary refinement
Te Anau	56,478	Te Anau	78,534	Incorporation of RWP Whitestone groundwater zone, extension to cover all Te Anau Basin
		Te Waewae	11,899	Subdivision of RWP Lower Waiau zone
Tiwai	2,489	Tiwai	2,407	Minor boundary refinement

RWP groundwater management zones		pSWLP groundwater management zones		Comment
Zone Name	**Area (Ha)**	**Zone Name**	**Area (Ha)**	
Upper Aparima	49,290	Upper Aparima	56,053	Extension of northern boundary to margin of the Oreti River catchment
Upper Mataura	8,235	Upper Mataura	10,542	Boundary refinement to better match QMap coverage
Waihopai	73,965	Waihopai	41,797	Transfer of areas along the south coast to the proposed Awarua zone, incorporation of the Waikiwi Stream catchment
Waimatuku	26,889	Waimatuku	23,679	Boundary refinement
Waimea Plain	25,200	Waimea Plains	19,680	Transfer of the Sandstone Stream Catchment into the proposed Longridge zone
Waipounamu	3,213	Waipounamu	1,743	Significant proportion incorporated into proposed Wendonside zone
Wendon	4,066	Wendon	8,995	Boundary extended north to Piano Flat
Wendonside	8,769	Wendonside	12,968	Boundaries extended to include a portion of the RWP Waipounamu zone
Whitestone	2,277			Incorporated into the proposed Te Anau zone

While the groundwater management zones defined in the both RWP and pSWLP relate to unconfined or semi-confined (stratified) aquifers hosted in Quaternary alluvium, two confined aquifers are also delineated in the pSWLP. These aquifer systems (the North Range and Lumsden aquifers) are located in the Oreti Basin and exhibit a limited hydraulic connection to shallow groundwater and hydraulically connected surface water resources so require management as separate groundwater resources. The spatial extent of these aquifers is illustrated in Figure 2.

It is noted that the Garvie Aquifer which was managed as a confined aquifer under the RWP, has been incorporated into the proposed Wendonside groundwater management zone. Reclassification of this aquifer system is based on improved hydrogeological information that indicates that individual water-bearing layers in this area are hydraulically connected, so allocation is best managed in terms of a single primary allocation volume for all groundwater takes, regardless of depth.

It is noted that individual consent applications in some areas (e.g. Dipton, Eastern Southland) have identified water-bearing layers which appear to satisfy the technical definition for confined aquifers. However, at the current time, there is insufficient information to delineate specific management zones for these water resources so allocation is currently managed following the methodology established in Appendix L.6.

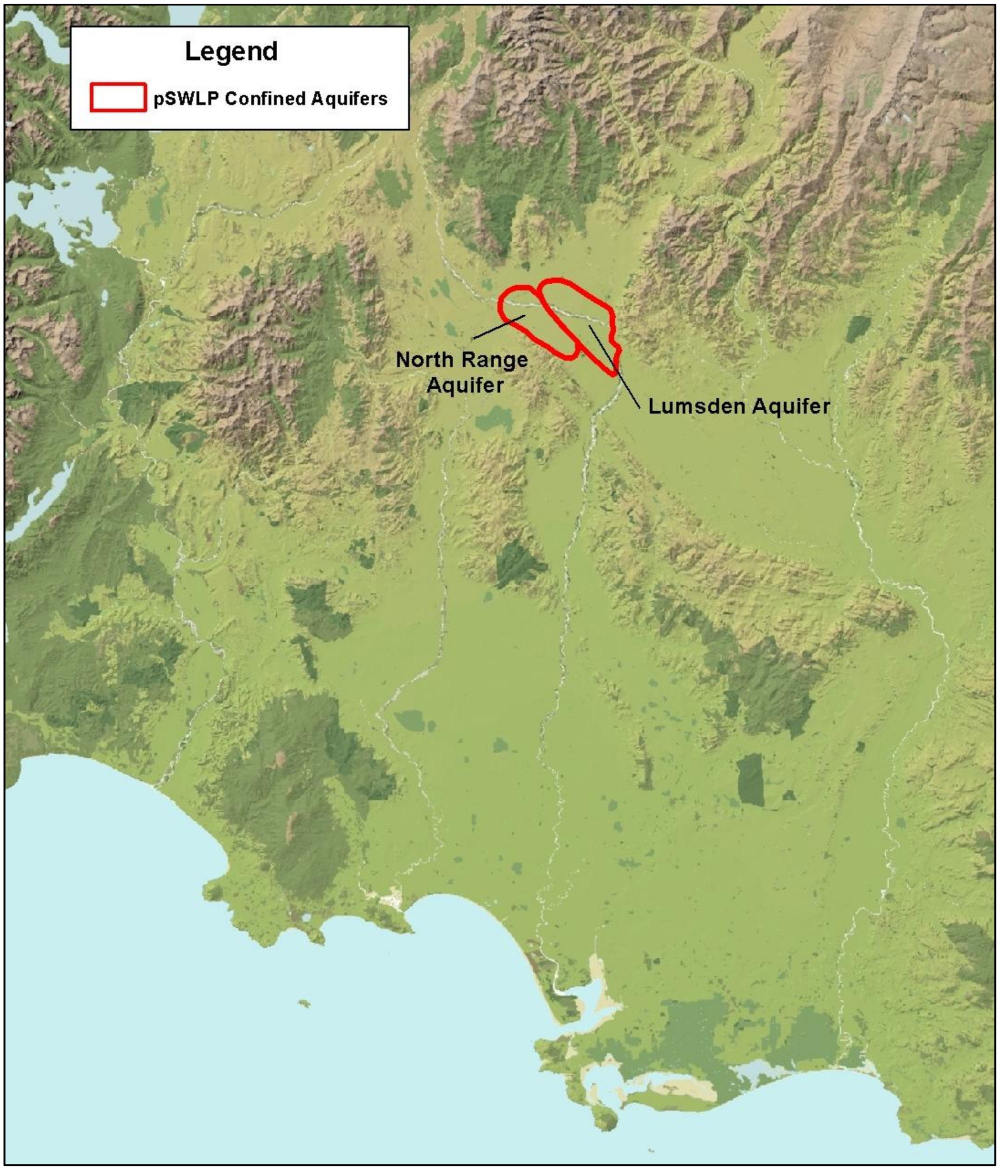


Figure 2. Confined aquifers defined in the pSWLP.

3.2.2 Allocable Volumes

3.2.2.1 Unconfined Aquifers

Allocation volumes for groundwater management zones defined in the RWP were derived from estimates of rainfall recharge calculated by Morgan and Evans (2002). The total volume of rainfall recharge was calculated for each management zone and with an allocable volume determined on the basis on the aquifer type classification, taking into account the potential sensitivity of that particular hydrogeological setting to adverse effects resulting from groundwater abstraction.

Primary allocation volumes for groundwater management zones defined in the pSWLP were calculated based on updated estimates[13] of rainfall recharge calculated using the methodology outlined by Chanut (2014)[14]. Although this methodology does not account for the effects of artificial drainage, it is considered to provide the best available estimate of rainfall recharge available at the time the pSWLP was drafted[15].

Figure 3 illustrates the spatial distribution of calculated mean annual rainfall recharge. These data indicate appreciable spatial variation in recharge from in excess of 400 mm/year in the Waiau River catchment to less than 150 mm/year on lighter soils on the Waimea Plain.

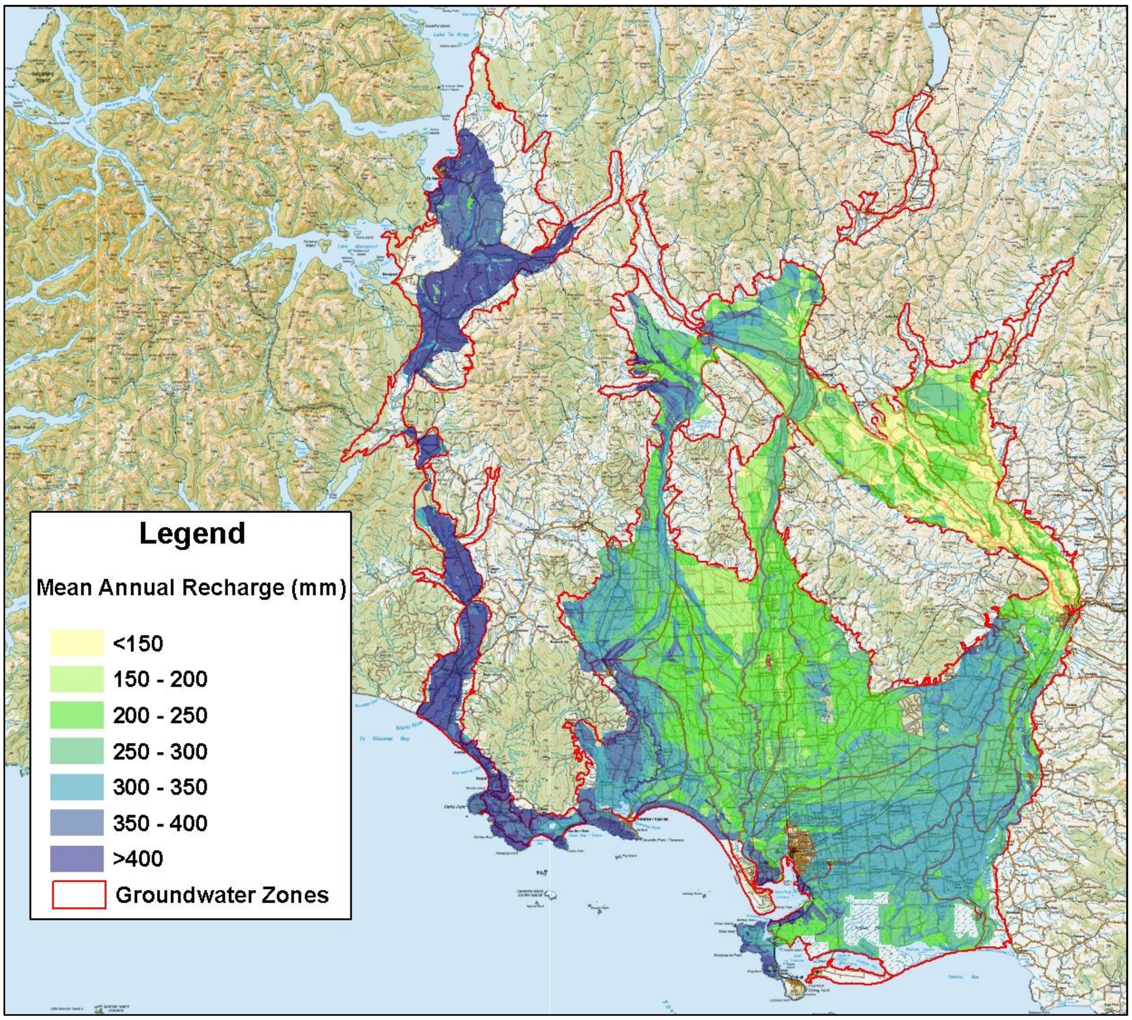


Figure 3. Mean annual rainfall recharge (mm)

---

[13] Rainfall recharge estimates were calculated using R code developed by Chanut (2014) as part of the Physiographics of Southland project (Hughes, B., Wilson, K., Rissmann, C Rodway, E., 2016; *Physiographics of Southland: Development and application of a classification system for managing land use effects on water quality in Southland*. Environment Southland Publication 2016/11, November 2016.)

[14] Chanut, P. 2014: *Seasonality of land surface recharge in Southland.* Report to Environment Southland, April 2014.

[15] It is noted mean annual recharge calculated using the Chanut (2014) methodology is typically 30 to 40 percent lower than equivalent estimates outlined in Morgan and Evans (2003)

Rainfall recharge has a strong seasonal pattern with most of the recharge occurring during late autumn and winter (May, June, July and August) and diminishing in September and October, while recharge rates throughout the region are typically low between November and April. Winter recharge typically comprises around 60% of average annual recharge in coastal areas but increases to over 80% of annual recharge in inland areas.

As illustrated in Figure 4, the mean annual rainfall recharge layer was intersected with the groundwater management zone spatial coverage and a weighted mean annual recharge value calculated for each zone. For zones where the mean annual recharge coverage did extend across the entire zone, the value calculated from the portion covered was assumed to be representative of the zone as a while. For groundwater management zones outside the mean annual recharge coverage (Centre Hill, Tiwai, Upper Mataura) conservative mean recharge values were adopted based on recharge volumes for equivalent soil types in adjacent zones.

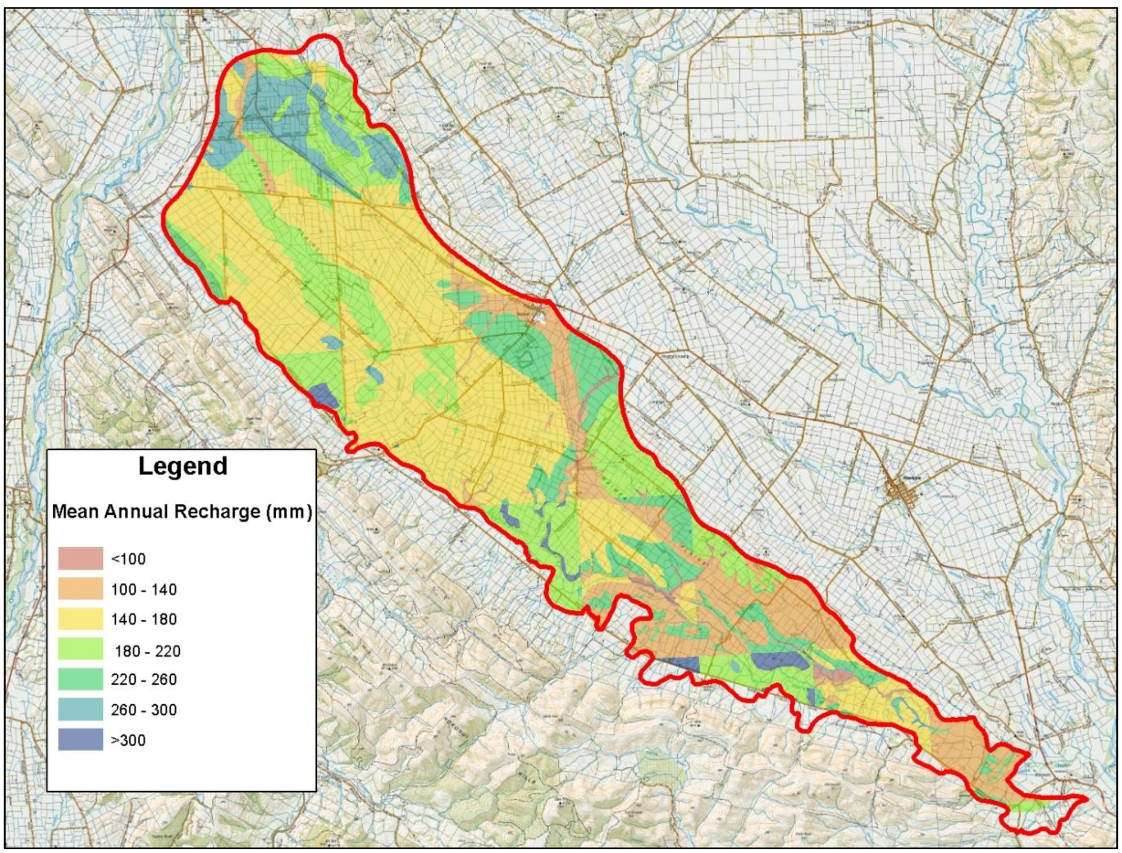


Figure 4. Estimated mean annual rainfall recharge (mm) in the Waimea Plains groundwater zone (weighted mean value = 180 mm/year)

Primary allocation volumes for each groundwater management zone were calculated as equal to 35 percent of mean annual rainfall recharge following the methodology outlined in the *Proposed National Environmental Standard for Environmental Flows and Water Levels*

(MfE, 2008)[16]. Table 3 lists the calculated area, mean annual rainfall recharge and primary allocation volumes for each groundwater management zone[17]. It is considered the proposed primary allocation represent an appropriately conservative percentage of recharge which can be allocated while avoiding significant hydrological alteration to the groundwater system (see Beca (2008))[18].

Table 3. Primary groundwater allocation volumes calculated for pSWLP groundwater management zones

Groundwater Zone	Area (Ha)	Mean Annual Rainfall Recharge (mm)	Annual Recharge (m^3/year)	Primary Allocation (m^3/year x 10^6)
Awarua	43,059	304	130,899,664	45.81
Blackmount	13,716	440	60,334,924	21.12
Castlerock	6,558	267	17,489,119	6.12
Cattle Flat	3,051	223	6,816,828	2.39
Central Plains	35,878	241	86,538,460	30.29
Centre Hill	5,978	250	14,945,500	5.23
Croydon	4,585	160	7,327,150	2.56
Dipton	11,655	233	27,191,815	9.52
Edendale	12,409	270	33,467,882	11.71
Five Rivers	17,528	278	48,709,756	17.05
Knapdale	4,908	159	7,823,511	2.74
Longridge	8,269	162	13,354,920	4.67
Lower Aparima	28,073	330	92,613,817	32.41
Lower Mataura	34,929	286	99,931,869	34.98
Lower Oreti	22,486	245	55,158,158	19.31
Makarewa	65,908	272	179,071,221	62.67
Orepuki	7,259	415	30,101,829	10.54
Oreti	3,295	237	7,792,439	2.73
Riversdale	10,969	170	18,646,620	6.53
Te Anau	78,554	430	337,860,324	118.25
Te Waewae	11,899	455	54,116,197	18.94
Tiwai	2,449	300	7,346,400	2.57
Upper Aparima	56,053	290	162,664,645	56.93
Upper Mataura	9,897	300	29,691,900	10.39

[16] MfE, 2008; *Proposed National Environmental Standard on Ecological Flows and Water Levels*. Ministry for the Environment Publication ME 28, Wellington, March 2008. 64p.

[17] It is noted the proposed primary allocation volumes are also within the 15% of average annual rainfall guideline for "first-order" allocation recommended by Aitchison-Earl, P., Scott, D., Sanders, R., 2004; *Groundwater Allocation Limits: Guidelines for the Canterbury Region*. Environment Canterbury Report No. U04/02.

[18] Beca, 2008; *Draft Guidelines for the Selection of Methods to Determine Ecological Flows and Water Levels*. Report prepared by Beca Infrastructure Ltd for MfE. Wellington: Ministry for the Environment.

Groundwater Zone	Area (Ha)	Mean Annual Rainfall Recharge (mm)	Annual Recharge (m^3/year)	Primary Allocation (m^3/year x 10^6)
Waihopai	41,797	304	127,145,257	44.5
Waimatuku	23,640	269	63,615,778	22.27
Waimea Plains	19,680	180	35,443,860	12.41
Waipounamu	1,743	190	3,314,615	1.16
Wendon	9,017	165	14,905,432	5.22
Wendonside	12,968	211	27,310,819	9.56

It is also noted the pSWLP does not retain the full 'aquifer type' classification adopted in the RWP. While this classification provided a useful method for grouping similar hydrogeological environments, the pSWLP only retains a general hydrogeological distinction between groundwater management zones (comprising unconfined and semi-confined aquifers) and confined aquifers. It is considered that these two classes better reflect the overall sensitivity of the different hydrogeological environments present in the Southland Region to environmental effects associated with groundwater abstraction.

Overall, while primary allocation limits (or the equivalent thereof in the RWP) for individual groundwater management zones vary between the RWP and pSWLP due to differences in spatial extent, both the calculated mean annual recharge and the percentage of total recharge available as primary allocation reduce (often substantially) under the pSWLP[19]. This change reflects both utilisation of updated assessment of aquifer recharge and improved understanding of aquifer response to groundwater abstraction. It also reflects a shift from the staged management philosophy outlined in the RWP[20] to the fixed allocation limits for individual waterbodies required under the National Policy Statement for Freshwater Management (2014).

3.2.2.2 Confined Aquifers

Extensive confined aquifers are present in the Tertiary lignite measure sediments underlying the Quaternary gravel deposits throughout eastern and central Southland. Confined aquifers are also present in deeper alluvial sediments infilling the Oreti Basin. Sustainable management of allocation from confined aquifers presents a particular resource management challenge when, in many cases, limited information is available to characterise the spatial extent and hydraulic properties of such waterbodies.

Following the '*staged management approach*' underlying Variation 3, the initial approach to management of confined aquifers was that, in situations where the degree of hydraulic connection between a deeper water-bearing layer and the overlying unconfined groundwater resource was uncertain, the default position was to manage the deeper aquifer as a

[19] Estimated mean annual recharge generally reduces by between 20 to 50 percent under the calculation (Chanut, 2014) utilised for the pSWLP compared to equivalent figures used in the RWP (Morgan and Evens, 2003). Primary allocation as a percentage of total recharge also reduces from 50percent to 35 percent for all groundwater zones with the exception of those classified as Lowland Aquifers under the RWP.

[20] i.e. where knowledge gained from monitoring and progressive development of the resource was incorporated into the resource allocation decision-making process

separate confined aquifer. Groundwater allocation in any groundwater resource classified as a confined aquifer was undertaken on the basis of limiting the maximum cumulative drawdown in piezometric levels.

Due to practical difficulties implementing the initial RWP management approach, Variation 12 amended management criteria for confined aquifers to establish primary allocation based on a conservative estimate of aquifer throughflow, following recommendations outlined in SKM (2008)[21] and Liquid Earth (2010)[22].

The pSWLP retains the current RWP allocation methodology for confined aquifers generally (Appendix L.6), but establishes specific management controls (in terms of primary allocation and minimum groundwater level cut-offs) for the North Range and Lumsden aquifers. These aquifer systems have a significant history of resource development, monitoring and water use. Allocation volumes and management tools (minimum level cut-offs and seasonal recovery triggers) developed through the resource consent process over the past 10 to 15 years for these aquifers have formally been adopted in the Appendix L.5 of the pSLWP.

In the case of deeper water-bearing layers for which limited information hydrogeological information exists, once the confined nature of the aquifer is established through aquifer testing[23], the general allocation methodology outlined in Appendix L.6 provides a methodology to enable a conservative primary allocation to be established (including, if appropriate, minimum groundwater level cut-offs and seasonal recovery triggers).

3.2.2.3 Secondary Allocation

As outlined in Liquid Earth (2010), the intent of secondary allocation is to enable flexibility in the management of groundwater allocation. Secondary groundwater allocation potentially enables allocation of groundwater in excess of the primary allocation limit on a *temporary or intermittent basis*, provided appropriate safeguards are in place to avoid adverse effects on the environment. Supplementary allocation of groundwater also provides a management option to help optimise allocative efficiency and avoid situations where a water permit to abstract groundwater for a short period can effectively 'tie up' allocation over an extended consent term.

Circumstances where secondary groundwater allocation could potentially occur include:

- Short-term abstraction (e.g. dewatering for construction purposes), including abstraction in excess of the primary allocation limit, that will not adversely impact on long-term aquifer storage;
- Situations where actual abstraction is consistently lower than primary allocation limit or where it can be demonstrated allocation in excess of the primary allocation limit on a temporary or intermittent basis will not result in adverse effects on the environment;
- Where recharge is enhanced by artificial means (e.g. Managed Aquifer Recharge).

---

[21] SKM, 2008; *Management of Confined Aquifers in the Southland Region*. Report prepared for Environment Southland, February 2008.

[22] Liquid Earth, 2010; *Fractured Rock and Confined Aquifers. Recommendations for Sustainable Management*. Report prepared for Environment Southland, October 2010.

[23] Following procedures outlined in Appendix L.1

Policy 30(d)(iii) of the RWP identifies that the Council will provide for supplementary allocation of groundwater for consented water use, but provides no specific guidance regarding how such allocation will be managed.

Rule 54 of the pSWLP enables secondary allocation of groundwater as a discretionary activity. In combination with Appendix L.6, the proposed Rule outlines criterion for managing secondary allocation including establishment of minimum groundwater level cut-offs and seasonal recovery triggers to ensure such abstraction avoids adverse effects on the environment, including the reliability of supply for existing groundwater users and long-term aquifer storage volumes.

3.2.3 Calculation of Seasonal Volumes

Appendix L.4 of the pSWLP provides guidance for establishing seasonal allocation volumes for groundwater takes for a variety of water uses. The peak daily and annual average water requirements for various stock types listed in Appendix L.4 are derived from the Lincoln University Farm Technical Manual (2003)[24] and similar reviews of stockwater requirements (e.g. Aquas Consultants and Aqualinc Research Ltd, 2007[25]). A simple methodology is also provided for establishing seasonal allocation for uses other than stock water and dairy use.

It is intended the figures will provide guidance for establishing seasonal volumes for new groundwater takes, and assist calculation of cumulative allocation by providing a methodology to enable calculation of a seasonal volume for existing water permits that do not have an equivalent figure specified in consent conditions.

3.3 Managing effects of groundwater abstraction

3.3.1 Stream Depletion Effects

The concept of hydraulic connectivity describes the degree of interconnection between groundwater and surface water resources in a given environmental setting. The degree of hydraulic connectivity determines the potential timing and magnitude of effects on surface water flows and levels resulting from groundwater abstraction.

Groundwater and surface waterbodies can be regarded as exhibiting a high degree of hydraulic connectivity if water can readily flow from a surface water body into, or out of, a hydraulically connected groundwater resource. In contrast, stream-aquifer systems may be characterised as exhibiting low (or poor) hydraulic connectivity if the movement of water between these systems is limited. Natural stream-aquifer systems may range from highly to poorly connected, depending on local topography, geology and climate conditions. As a result, the degree of connectivity between surface and groundwater may vary across a catchment reflecting local conditions.

Policy 29 of the RWP outlines a methodology for the classification, assessment and management of potential stream depletion effects. The methodology classifies groundwater takes into four categories of hydraulic connection (Direct, High, Moderate and Low), and

[24] Lincoln University, 2003; *Farm Technical Manual*. P Fleming (Ed) Farm Management Group, Lincoln University

[25] Aquas Consultants and Aqualinc Research Ltd, 2007; *Reasonable Stock Water Requirements. Guidelines for Resource Consent Applications*. Technical Report prepared for Horizons Regional Council, December 2007

defines different criteria for calculating the magnitude of stream depletion for each category. The Policy 29 methodology also establishes criteria for managing stream depletion effects in terms of calculation of surface and groundwater allocation and the application of minimum flow controls to mitigate effects.

Policy 23 and Appendix L.2 of the pSWLP essentially retain the RWP stream depletion effects methodology, with some minor alterations and additions. The most significant changes are:

- The addition of a Riparian hydraulic connection category. The proposed Riparian category effectively classifies any groundwater take within 5 metres of a surface waterbody as a surface water take, unless there is clear evidence that demonstrates that abstraction will not result in stream depletion effects (e.g. showing the stream is disconnected from the aquifer system). This classification does not include the 2l/s threshold for assessment of stream depletion effects utilised for the remaining hydraulic connection categories;
- Amendment of criteria for the classification and assessment of groundwater takes with a High or Moderate hydraulic connection. The RWP methodology specifies that assessment of the potential magnitude of stream depletion effects will be undertaken (in part) using the average rate of abstraction over a nominal 150 day period. Water use data now available in Southland indicate that a majority of groundwater takes for irrigation (which comprise a majority of total groundwater allocation) rarely operate for durations exceeding 100 days per year. To better reflect actual pumping, proposed assessment criteria for these categories are amended to include maximum pumping rate scenarios (i.e. continuous pumping at the maximum rate until the seasonal volume is utilised) and average pumping rate scenarios over a shorter assessment period (90 days);

Appendix L.2 of the pSWLP also outlines criteria to guide classification and assessment of stream depletion including:

- A requirement for stream depletion assessments to be supported by a conceptual model that describes the nature of local groundwater/surface water abstraction. This is intended to ensure that analysis methods used to calculate the potential magnitude of stream depletion are consistent with the actual hydrogeological setting.

  This criterion was previously included in *Information to be submitted with a resource consent application* listed appendix A of the RWP;
- The use of representative aquifer hydraulic properties for the calculation of potential stream depletion effects. This requirement is intended to reflect the fact that the timing and magnitude of stream depletion is a reflection of the 'bulk' aquifer properties between the point where groundwater abstraction occurs and adjacent hydraulically connected surface water bodies. Aquifer hydraulic properties derived from individual aquifer tests are not always representative of the hydraulic properties across the wider aquifer system.

  The RWP did not include a specific reference to aquifer hydraulic properties to be used for assessment of potential stream depletion effects;

- The exclusion of ephemeral streams from the assessment of stream depletion effects (i.e. stream depletion effects calculated for a stream that does not flow during low flow conditions are not be counted as part of cumulative surface water allocation). The criteria listed do however, identify that groundwater abstraction should not result in more than minor effects on the frequency, duration and extent of flow loss in such streams.

  Criteria related to the assessment of stream depletion effects in ephemeral streams were previously included in explanation to Policy 28 of the RWP.

- Specification of a methodology for dealing with situations where a groundwater take has the potential to result in stream depletion effects in two or more hydraulically connected surface waterbodies based on recommendations in ECan (2000)[26].

Overall, the criterion for assessment and management of stream depletion in the RWP and pSWLP are largely equivalent, with the minor changes being made to better reflect typical hydrogeological settings and water use in the Southland Region.

3.3.2 Well Interference Effects

Well interference effects occur where the cumulative drawdown from groundwater abstraction adversely affects the ability of an existing groundwater user to exercise their water permit (i.e. by reducing the yield available from an existing bore).

Policy 31 of the RWP establishes criteria for acceptable cumulative well interference effects resulting from groundwater abstraction as no more than 20 percent of the saturated thickness in an unconfined aquifer or 50 percent of the potentiometric head[27] in a confined aquifer. While providing a useful reference for assessing the potential magnitude of cumulative drawdown on existing groundwater users, practical problems are encountered in implementing this policy, due to difficulties in establishing the available drawdown in complex, stratified hydrogeological settings where it is difficult to accurately determine appropriate values for saturated thickness or potentiometric head.

Policy 22, Rule 54 and Appendix L.3 in the pSWLP adopt a similar overall methodology for assessing ‘acceptable’ well interference to that specified in the RWP. However, the proposed definition of ‘acceptable’ well interference effects for bores screened in unconfined aquifers has been changed from no more than 20% of saturated thickness, to no more than 20 percent of the available drawdown in bores which *adequately penetrate* the source aquifer. Under the proposed criteria, adequate penetration is defined as the top of the screened interval being positioned at a depth of greater than 3 times the average seasonal groundwater level variation below the mean groundwater level[28] (illustrated in Figure 5 below). Criteria for confined aquifers and long-term groundwater level monitoring sites remain the same as those specified in the RWP.

---

[26] ECan, 2000; *Guidelines for the Assessment of Groundwater Abstraction Effects on Stream Flow*. Environment Canterbury Publication R00/11, June 2000,=.

[27] By definition, confined aquifers are fully saturated, with a static head which rises above the lower surface of the overlying confining layer. Potentiometric head is a measure of difference in relative elevation between the static head and the base of the confining layer.

[28] i.e. where A (depth of penetration) > 3 x B (average seasonal groundwater level variation)

The overall intention of the modification to the assessment methodology for unconfined aquifers is to provide criteria that more readily workable for the consenting process and which better recognises different sensitivities to well interference (reflecting differing requirements for 'adequate penetration') in differing hydrogeological environments.

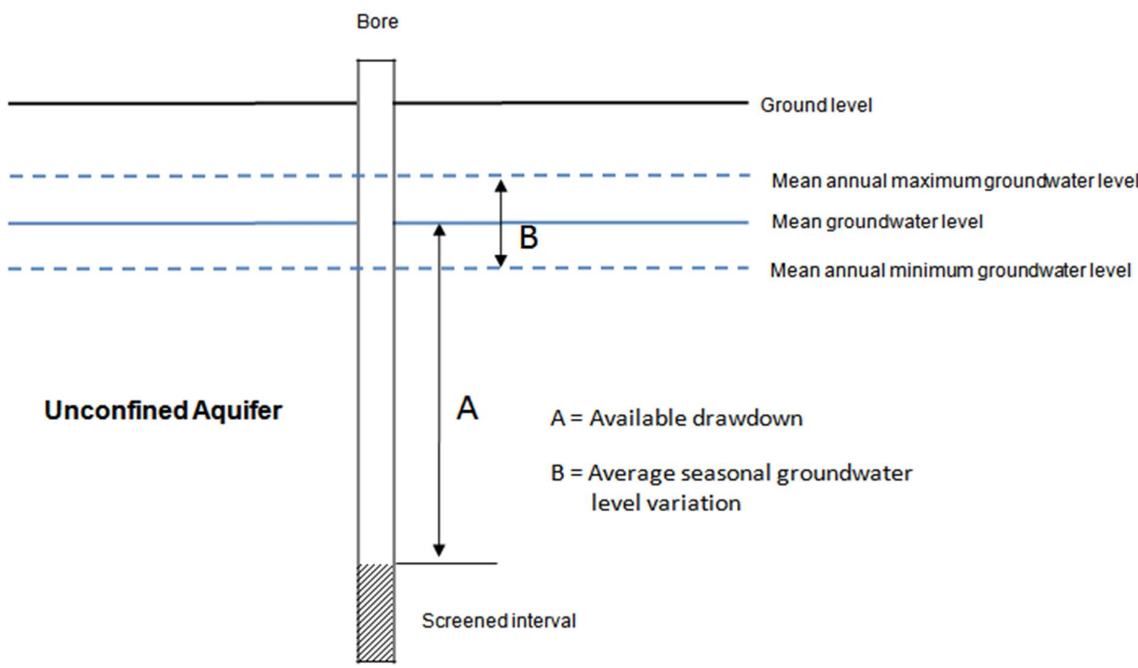


Figure 5. Criteria for determining adequate penetration for calculation of well interference effects in unconfined aquifers (reproduced from pSWLP Appendix L.3).

3.3.3 Reasonable and Efficient Use

Allocative efficiency[29] is achieved when the allocation available from a water resource is utilised in a manner that optimises the overall benefit resulting from use of the resource. In terms of overall resource management, allocative efficiency is an outcome of the manner in which access to the available water resource is assigned to individual resource users.

One of the primary factors contributing to sub-optimal allocative efficiency is a situation where the rate and/or volume of water allocated to an individual user exceeds that actually used. Where water is allocated on this basis, it may result in a significant proportion of available allocation being held by users who rarely (if ever) utilise their full allocation. This processes effectively 'ties up' water that could otherwise be accessed by other users, thereby reducing the overall productive benefit able to be derived from the available resource.

Aside from hydropower in the Waiau catchment, irrigation is the largest consumptive water use in the Southland Region. Figure 6 shows a plot of the percentage of water actually used

[29] For a definition of allocative efficiency see for example: Counsell, K., 2003; *Achieving Efficiency in Water Allocation: A Review of Domestic and International Practices*. New Zealand Institute for the Study of Competition and Regulation, October 2003.

by irrigation resource consents supplying water use data to Environment Southland between the 2002/03 and 2015/16 irrigation seasons. The data indicate that seasonal water usage for irrigation averages just under 40 percent of cumulative seasonal allocation, with maximum usage of 56 percent of cumulative allocation recorded during the 2007/08 season[30].

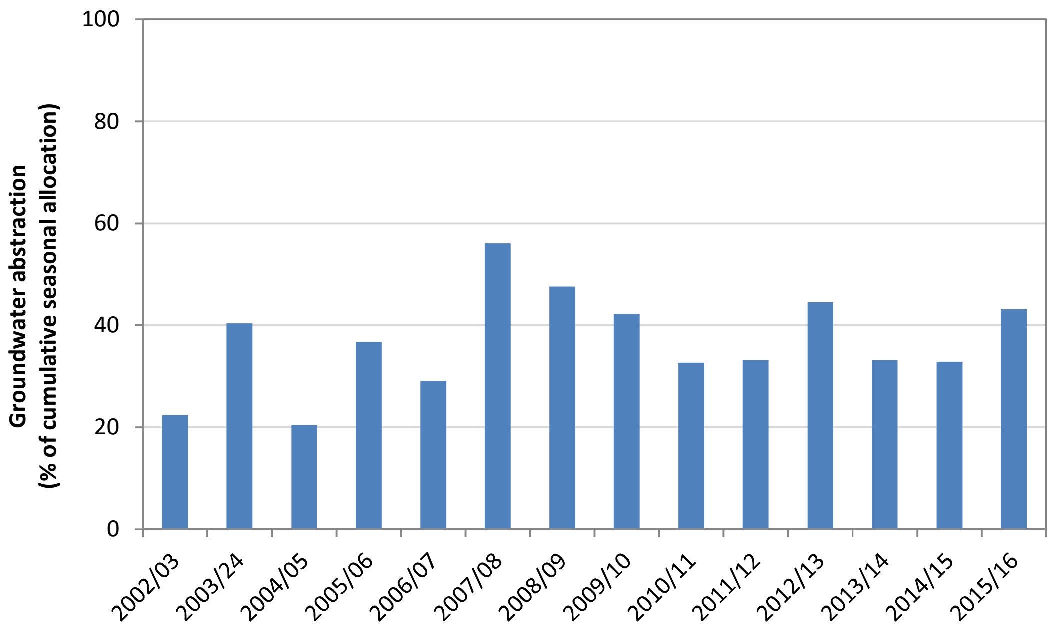


Figure 6. Recorded irrigation water usage for selected resource consents as a percentage of cumulative allocation, 2002/03 to 2015/16

These data indicate that a significant proportion of water allocated for irrigation in Southland is not actually used. Given constraints on water availability in many parts of the Southland Region, improving allocative efficiency is an important consideration to enable effective management of water resources.

Establishing seasonal allocation which aligns with a realistic estimate of actual usage is also important in terms of managing cumulative effects of water abstraction on the environment. In the case of stream depletion, groundwater takes classified as having a high or moderate hydraulic connection are assessed on the basis of pumping scenarios which are determined on the basis of seasonal allocation (both under the RWP and pSWLP). Where seasonal allocation is significantly higher than actual water use, calculated stream depletion effects may be significantly higher than those resulting from actual abstraction. Particularly where surface and hydraulically connected groundwater are managed on the basis of a proportional flow allocation (for example, under the Water Conservation (Mataura River) Order 1997), this can potentially result in a significant reduction in the reliability of supply for downstream water users and prevent other users from accessing the resource (due to low supply reliability).

[30] For those consents supplying water use data to Environment Southland

Policy 21 of the RWP requires that the Council ensure that the rate and volume of abstraction specified on water permits to take and use water are no more than reasonable for the intended end use. The intent of the policy is to help achieve allocative efficiency; however its practical implementation is limited by a lack of guidance regarding how efficiency of use is assessed.

Appendix O of the pSWLP provides specific criteria for establishing reasonable and efficient through the resource consent process. For irrigation takes, the proposed criteria require applications seeking a seasonal volume in excess of 3,000 m^3/year (equivalent to an application depth of 300 mm/year) to be supported by assessment using a field validated irrigation demand model. The nominal 300 mm/year annual application depth at which such modelling is required is based on a review of available irrigation water use data for the Southland Region dating back to 2003/04 which show few instances of irrigation at rates in excess of this figure, even during dry seasons such as 2007/08. The 300 mm/year annual application depth has also been used as an informal guideline used to assess reasonable use for replacement water permit applications in many areas of Southland.

Under the criterion outlined in pSWLP Appendix O, applications for replacement resource consent for irrigation are also required to utilise historical water use records to establish a seasonal allocation based on historical water use, taking into consideration any proposed changes to the set-up or operation of the irrigation system. Criterion outlined in Appendix O of the pSWLP also identify methods for group or community supplies and other water users to demonstrate proposed water use meets efficiency criteria.

Overall, the methods outlined in Appendix O of the pSWLP are intended to help the Council ensure water is allocated in an efficient manner whereby rates and volumes of allocation, to the degree practicable, are consistent with actual water use so utilisation of the available allocation is optimised (i.e. allocation available to additional users is not unduly restricted), rather than being held by water permits which are not fully utilised.

3.3.4 Effects on Water Quality

The pSWLP contains a suite of Policies and Rules which address effects of land use on water quality (including groundwater quality) developed from the Physiographics of Southland Project. Technical background to these provisions to these provisions is provided in a number of technical reports including Rissmann et al. (2016)[31], Hughes, et al. (2016) and Monaghan (2016)[32].

Other than specific Physiographic Zone Policies and Rules, provisions of the pSWLP related to man agement of groundwater quality are broadly similar to those in the RWP and seek to

[31] Rissmann, C., Rodway, E., Beyor, M., Hodgetts, J., Snelder, T., Pearson, L., Killick, M., Marapara, T.R., Akbaripasand, A., Hodson, R., Dawe, J., Millar, R., Ellis, T., Lawton, M., Ward, N., Hughes, B., Wilson, K., Horton, T., Mat, D., Kees, L., 2016; *Physiographics of Southland Part 1: Delineation of key drivers of regional hydrochemistry and water quality*. Environment Southland Publication No. 2016/3, June 2016.

[32] Monaghan, R.M., 2016; *Management practices and mitigation options for reducing contaminant losses from land to water*. Report prepared for Environment Southland by AgResearch, June 2016.

avoid point source or non-point source discharges, or use and development of surface or groundwater resources that may adversely affect the quality of groundwater resources.

4 Summary

The pSWLP was notified in June 2016 and provides an updated framework for the sustainable management of the Regions freshwater resources which incorporates and builds on provisions of the existing *Regional Water Plan for Southland* and *Regional Effluent Land Application Plan.* This report documents provisions of the pSWLP related to management of groundwater resources.

The major change between groundwater management between the RWP and pSWLP relates to the spatial framework for management of groundwater allocation which has been updated to incorporate improved understanding of the regional hydrogeological setting. Volumetric allocation for consumptive use in each individual groundwater management unit has been updated to incorporate improved estimates of aquifer recharge and a shift from the staged management approach of the RWP to fixed primary allocation volumes consistent with the NPS-FM.

Other significant changes to groundwater management provisions include:

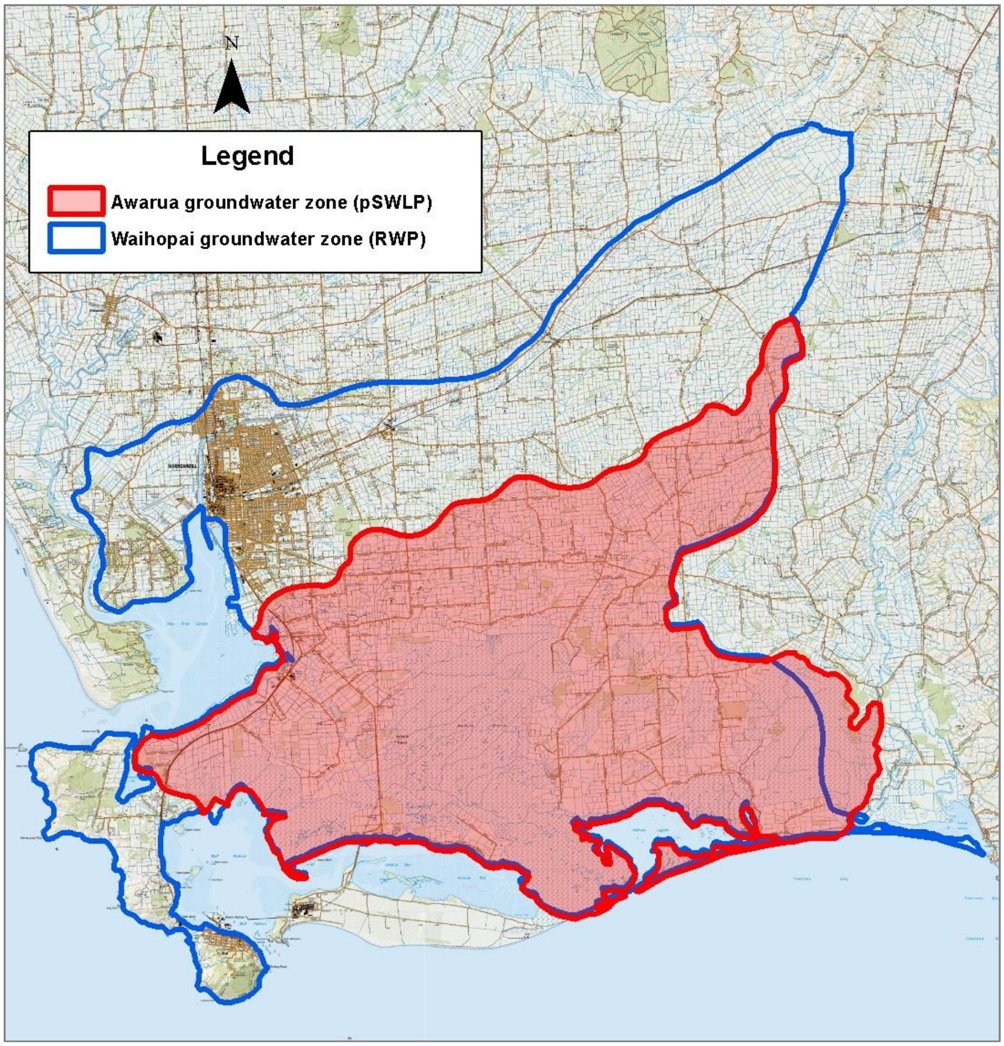
- Changes to rules relating to abstraction of groundwater including non-consumptive takes and aquifer tests;
- Establishment of primary allocation volumes and associated management provisions (e.g. minimum groundwater level cut-offs and seasonal recovery triggers) for nominated confined aquifers
- Amendments to the methodology for assessing stream depletion effects to better reflect actual water use;
- Changes to criterion for the assessment of well interference effects; and
- Improved guidance to improve allocative efficiency.

Appendix A Proposed groundwater management zones

Awarua groundwater zone

Status: New (pSWLP)

Area: 44,048 Ha



Overview: The proposed Awarua groundwater zone is a subdivision of the existing (RWP) Waihopai groundwater zone to reflect the flow divide between the Waihopai River catchment and catchments draining to the south coast. The proposed zone represents a single management unit for groundwater flow systems draining to Awarua Bay, and Waituna Lagoon (and a small area of the New

River estuary). Background references include Rissmann, *et al.,* 2012 [33] (primarily focussed on groundwater in the Waituna catchment but applicable to the entire proposed zone).

Rainfall recharge is the primary recharge source to the Awarua groundwater zone, with discharge occurring to lower order streams and the artificial drainage network. Some minor groundwater discharge may also occur directly to coastal waterbodies (Awarua Bay, Waituna Lagoon)

Boundary Definition:

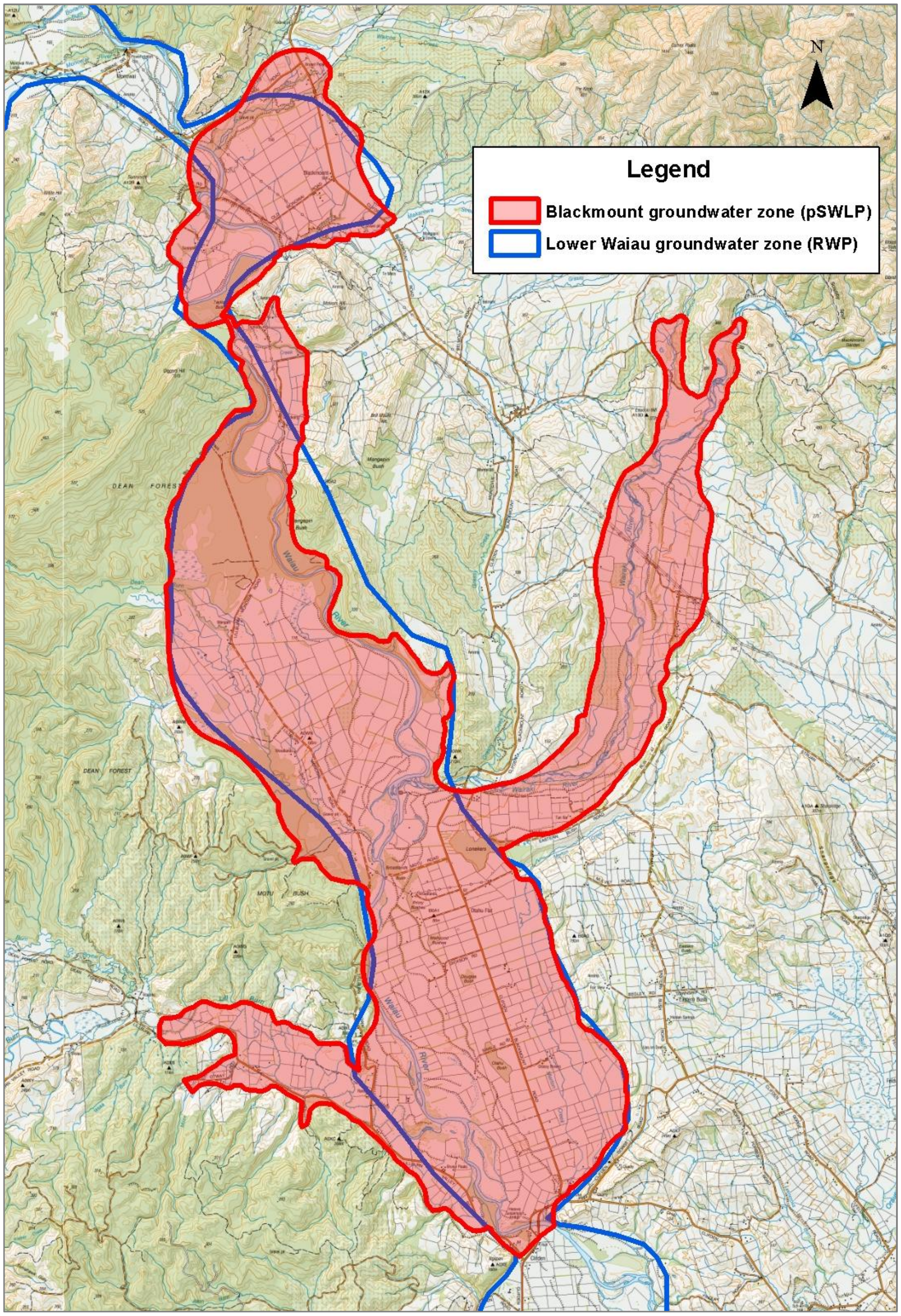
- The northern boundary follows the approximate flow divide between of 4th and 5th order (REC) streams draining to the Waihopai River (including Otepuni Creek and Kingswell Creek) and the South Coast (e.g. Duck Creek, Waituna Creek);
- The eastern boundary follows the existing boundary between the (RWP) Waihopai and Lower Mataura groundwater zones except for an extension to include all of the (Topo 50) Waituna Wetland extent;
- The western and southern boundaries follow the approximate coastal margin.

[33] Rissmann, C., Wilson, K., Hughes, B., 2012; *Waituna Catchment Groundwater Resource*. Environment Southland Publication No 2012-04, May 2012.

Blackmount groundwater zone

Status: New (pSWLP)

Area: 13,716 Ha



Overview: The proposed Blackmount groundwater zone is a subdivision of the existing (RWP) Lower Waiaui groundwater zone to reflect the hydrological divide created by limestone escarpments at Sunnyside (upstream) and Clifden (downstream) which effectively form a closed basin (i.e., all water enters/exits the mid-Waiau catchment via these points).

Groundwater occurs under a series of alluvial terraces along the margins of the Waiau River. Static groundwater levels are generally above river level with recharge primarily derived from rainfall and infiltration of runoff from the surrounding hills. The Waiau River is generally gaining, but temporally variable groundwater/surface water interaction may occur along the riparian margin of larger tributaries (e.g. Wairaki River)

Boundary Definition:

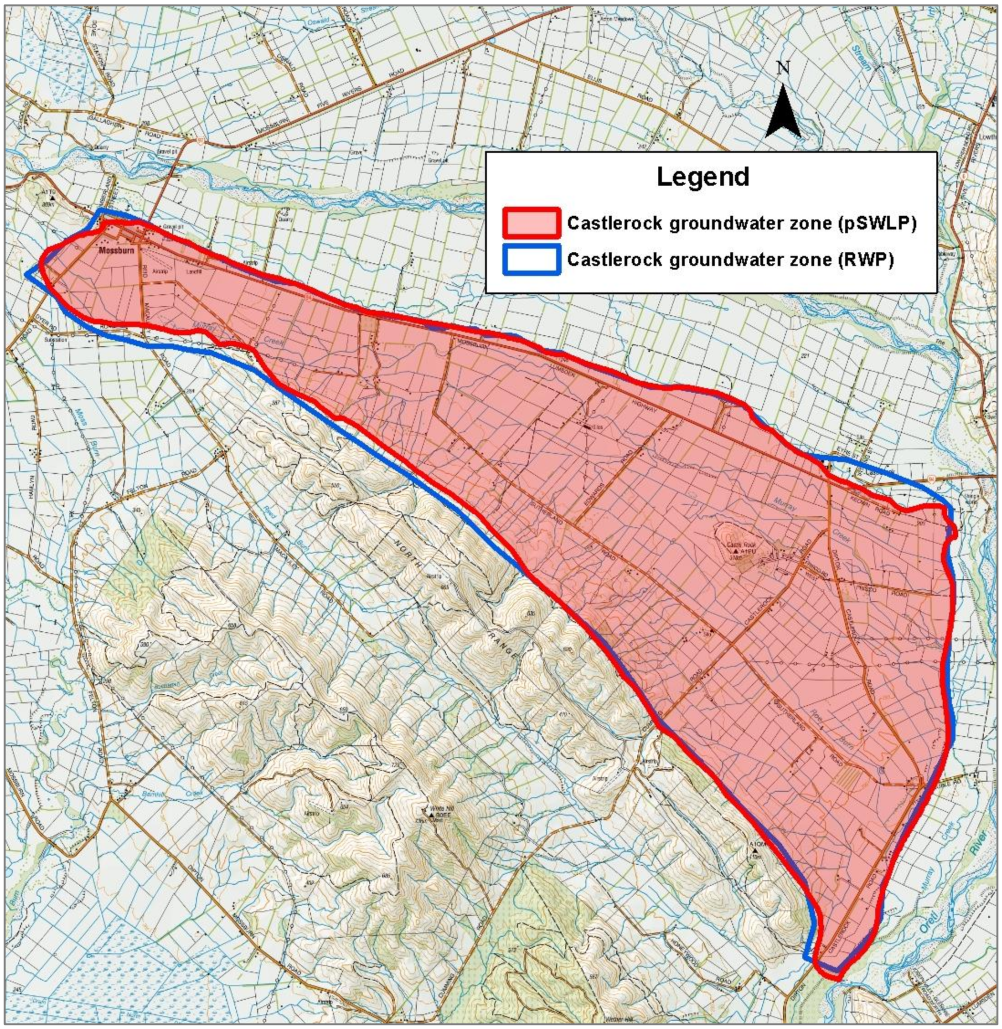
- The northern boundary is defined at the narrow gorge through exposure of the Blackmount Formation at Sunnyside;
- The southern extent of the zone at Clifden reflects exposure of Lower Clifden Subgroup limestone in the Waiau River;
- Compared to (RWP) Lower Waiau zone, the proposed Blackmount zone boundary is extended significantly to include additional areas of alluvial sediments adjacent to the mid to lower reaches of the Lil Burn and Wairakei River;
- Lateral boundaries of the Blackmount zone generally follow the QMap boundary between basement rock and Quaternary alluvium

Castlerock groundwater zone

Status: Existing (RWP)

Area: 6,800 Ha (RWP)

6,558 Ha (pSWLP)



Overview: The Castlerock groundwater zone defines the shallow unconfined aquifer system underlying the Q2 alluvial deposits and associated alluvial fans extending along the footslopes of the North Range between Ram Hill and Mossburn.

The Castlerock groundwater zone overlies portions of both the North Range and Lumsden aquifers. These confined aquifers are separated from the shallow unconfined aquifer in the Castlerock groundwater zone by a thick layer of tightly claybound gravel. The relative difference in static water levels varies the confined and unconfined aquifers varies across the Castlerock groundwater zone, from a downward gradient of several metres, to positive (artesian) head in the North Range aquifer east of Sutherland Road.

Boundary Definition:

The proposed (pSWLP) Castlerock zone is only slightly modified from the existing (RWP) zone.

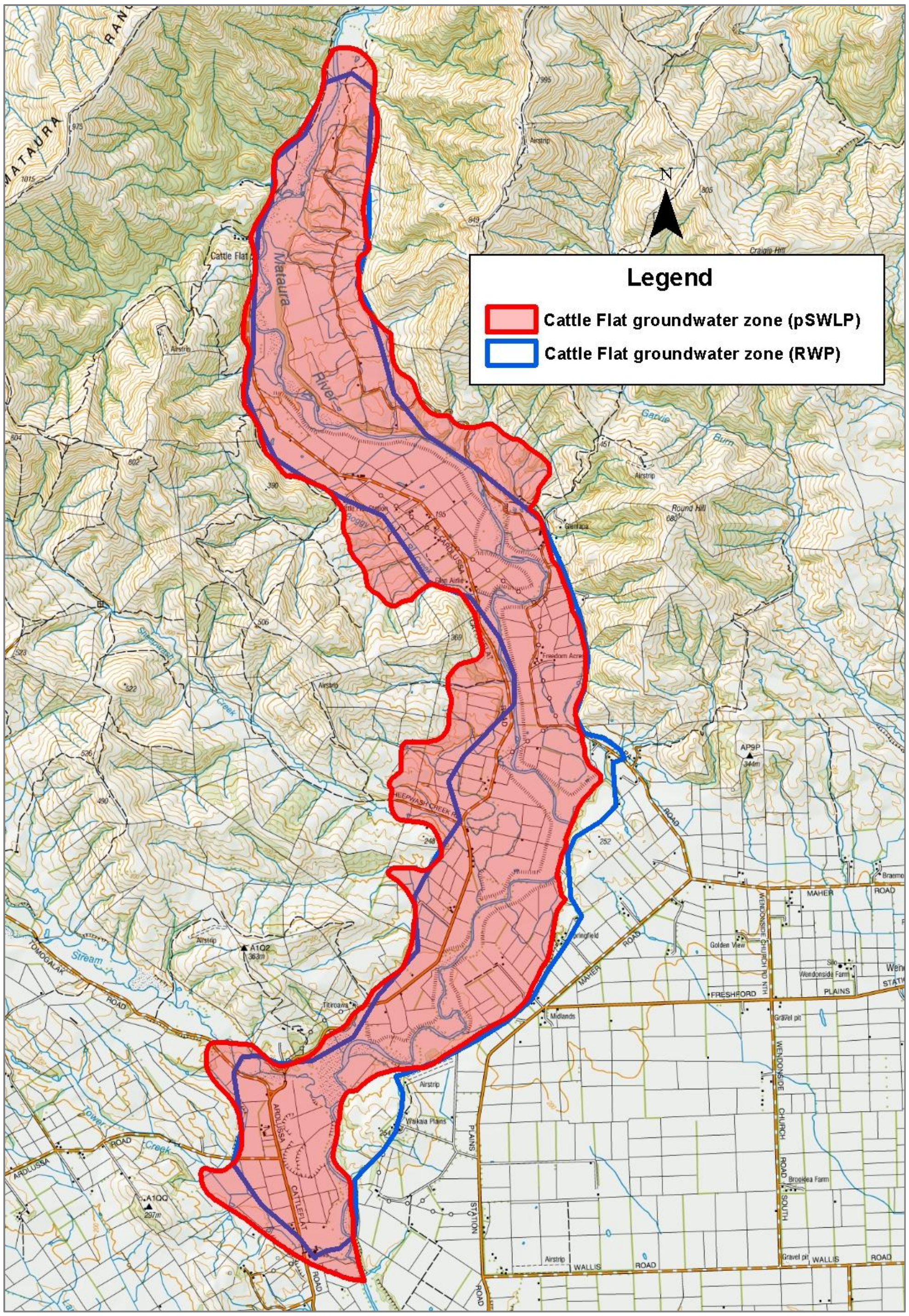
- The southern boundary generally follows the QMap boundary denoting exposure of Murihiku basement (North Range Group). Although QMap defines local areas Matai Group basement north of this boundary, these units have been included in the Castlerock zone to reflect the geometry and likely contribution of runoff/infiltration from higher alluvial fans to recharge (both to the Castlerock zone as well as the underlying North Range Aquifer);
- The northern boundary follows the terrace denoting the boundary between the Q2 alluvium of the Castlerock Terrace and Q1 alluvium of the Oreti River floodplain (which exhibits a significant degree of hydraulic connection to the Oreti River);
- The eastern boundary departs from the QMap boundaries and follows approximate terrace margin immediately east of the Dipton-Castlerock Road. This alignment reflects both the potential for a significantly greater hydraulic connection to the Oreti River on the lower terrace, as well as the occurrence of several large springs (and significant flow gain in Murray Creek) along the base of the terrace riser (i.e. these features essentially form a constant head boundary to the groundwater flow system underlying the Castlerock Terrace);
- The western extent of the Castlerock zone is relatively indistinct (in terms of surface or groundwater flow divides) so is mapped along the QMap boundary between older (Q4-Q8) alluvium to the west and the Q2 alluvium of the Castlerock terrace.

Cattle Flat groundwater zone

Status: Existing (RWP)

Area: 2,638 Ha (RWP)

3,044 Ha (pSWLP)



Overview: The Cattle Flat groundwater zone comprises the shallow unconfined groundwater resource hosted in recent alluvium and associated alluvial fans along the margin of the Mataura River upstream of Ardlussa.

Boundary Definition:

The proposed (pSWLP) Cattle Flat groundwater zone is only slightly modified from the existing (RWP) zone.

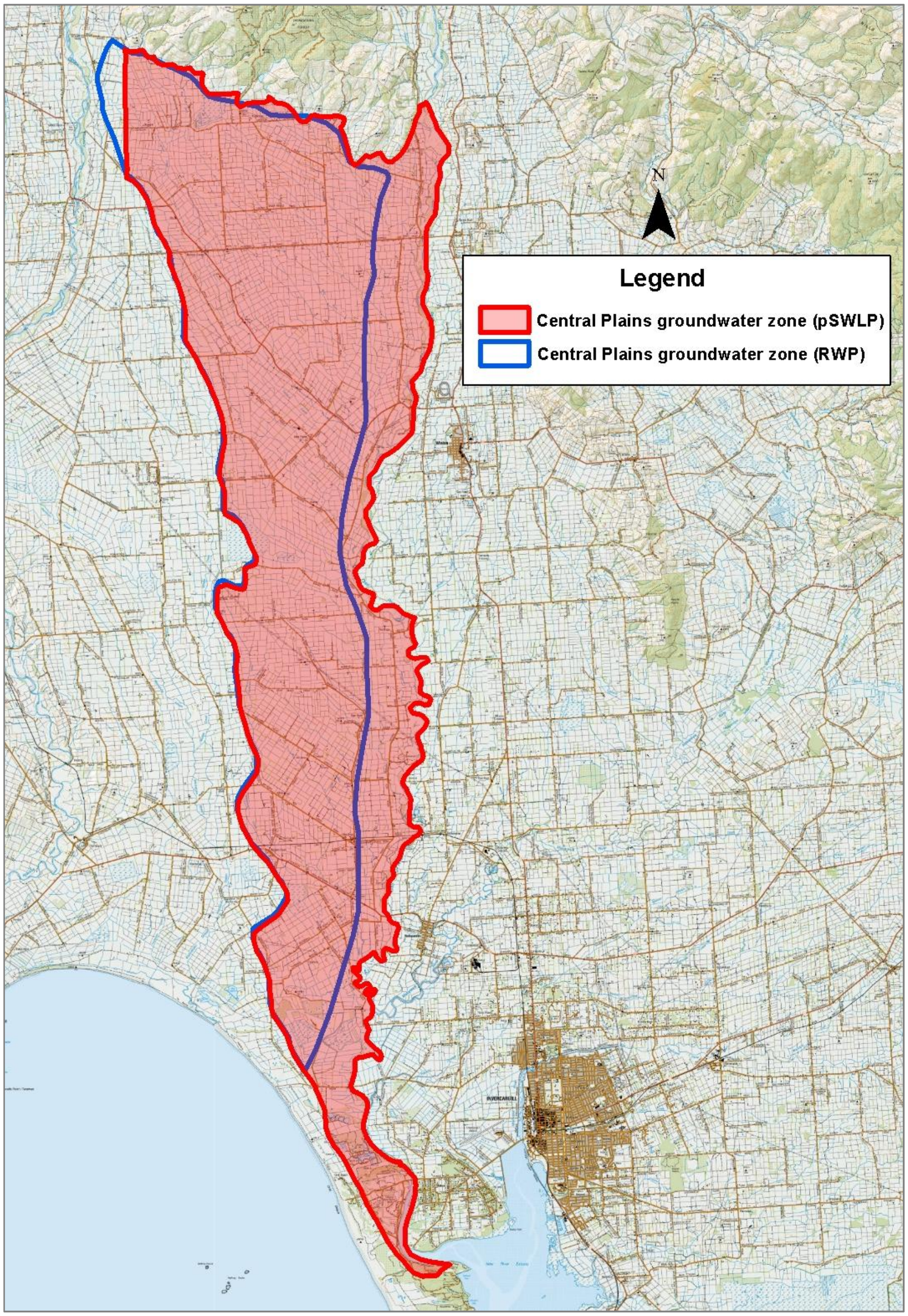
- Lateral boundaries of the proposed Cattle Flat zone have been adjusted to better reflect the spatial extent of Q2, Q4 and Q6 alluvial deposits along the margins of the Mataura River valley;
- Towards the southern end of the zone the boundary now excludes the basement exposure at Wairakei Plains and approximates the break in slope break between alluvial flats and hill country around Tower Creek and Tomogalak Stream;
- Along the north-western margin of the Wendonside Terrace the boundary has been adjusted to better reflect basement exposure and the terrace riser separating Q4 and Q6 alluvial deposits;
- The northern extent is defined along an arbitrary boundary where the narrow gorge through to Parawa widens out;
- The southern extent approximates the narrow gorge through bedrock immediately upstream of Parawa

Central Plains groundwater zone

Status: Existing (RWP)

Area: 26,257 Ha (RWP)

35,878 Ha (pSWLP)



Overview: The Central Plains groundwater zone comprises the shallow unconfined groundwater resource hosted in Quaternary alluvial deposits underlying an older (Q6-Q8), slightly elevated, alluvial terrace extending between the Waimatuku catchment and the Oreti River.

The aquifer system is recharged by local rainfall and infiltration of runoff from the Taringatura foothills to the north and is drained by numerous, partially incised second and third order streams of the

Boundary Definition:

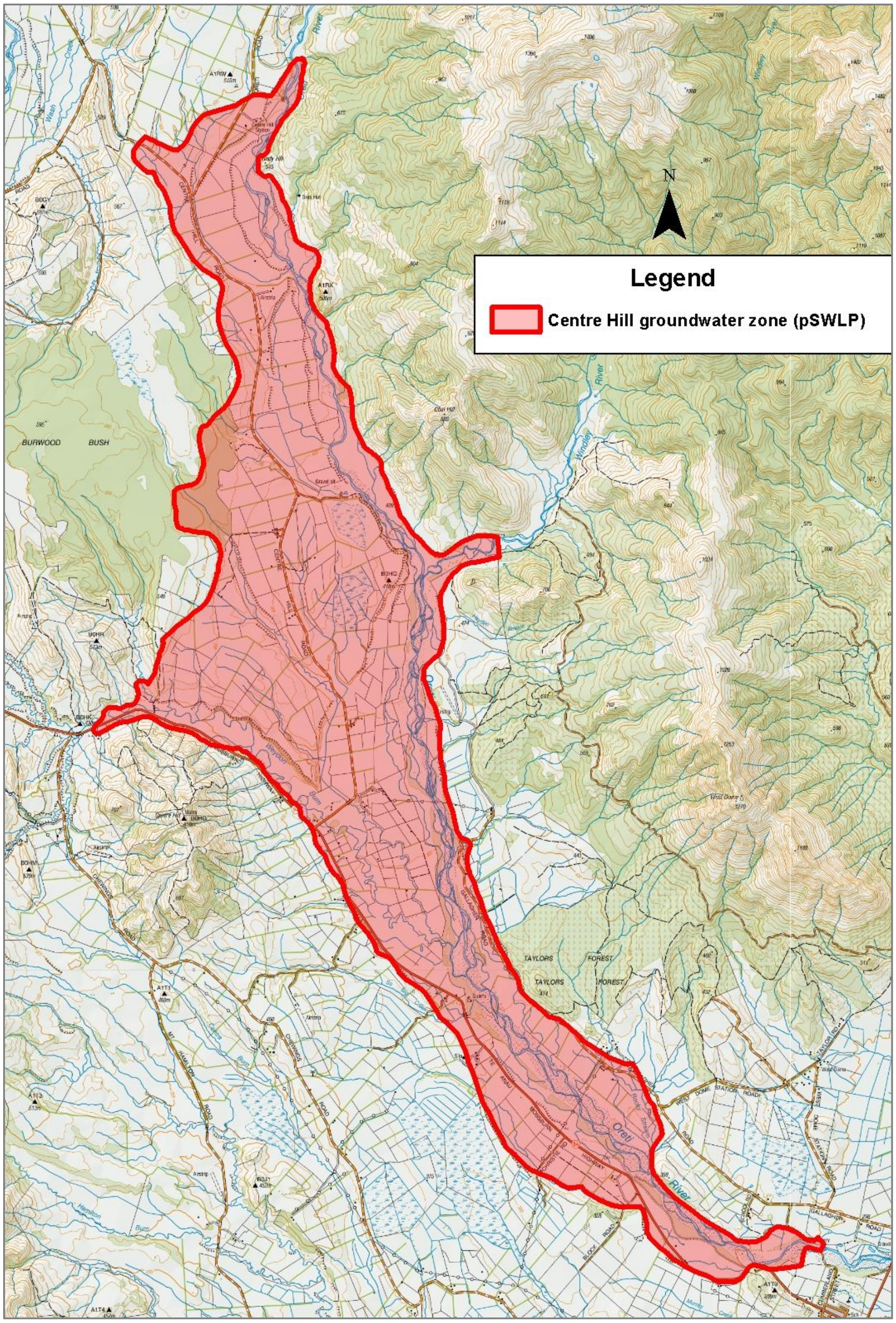
The proposed (pSWLP) Central Plains groundwater zone represents a slight modification to the existing (RWP) zone.

- The western boundary is largely unchanged from the existing (RWP) and follows the approximate flow divide between the Waimatuku and Oreti catchments;
- The north-western margin is truncated along a line which represents a northward extension of the boundary of the proposed (pSWLP) Waimatuku groundwater zone toward the western margin of the Taringatura Hills to the north;
- The eastern boundary has been shifted from the eastern margin of the older Q8 alluvial deposits to follow the approximate alignment of the Oreti River. This change reflects the significant drainage of groundwater and surface water across this area toward the river, and the limited hydraulic connection observed along the riparian margin of the Oreti River;
- The northern boundary follows the QMap boundary between alluvial deposits and Murihiku basement of the Taringatura Hills

Centre Hill groundwater zone

Status: New (pSWLP)

Area: 5,975 Ha (pSWLP)



Overview: The Centre Hill groundwater zone is a new zone which comprises the shallow unconfined groundwater resource hosted in Quaternary alluvial deposits along the margins of the Oreti River upstream of Rocky Point. This area is not included in any existing (RWP) groundwater management zone.

The aquifer system in this area is recharged by a combination of local rainfall and infiltration of runoff from the surrounding hills. Significant interaction may occur between surface water and groundwater underlying recent alluvial deposits (Q1) on the active floodplain of the river channel.

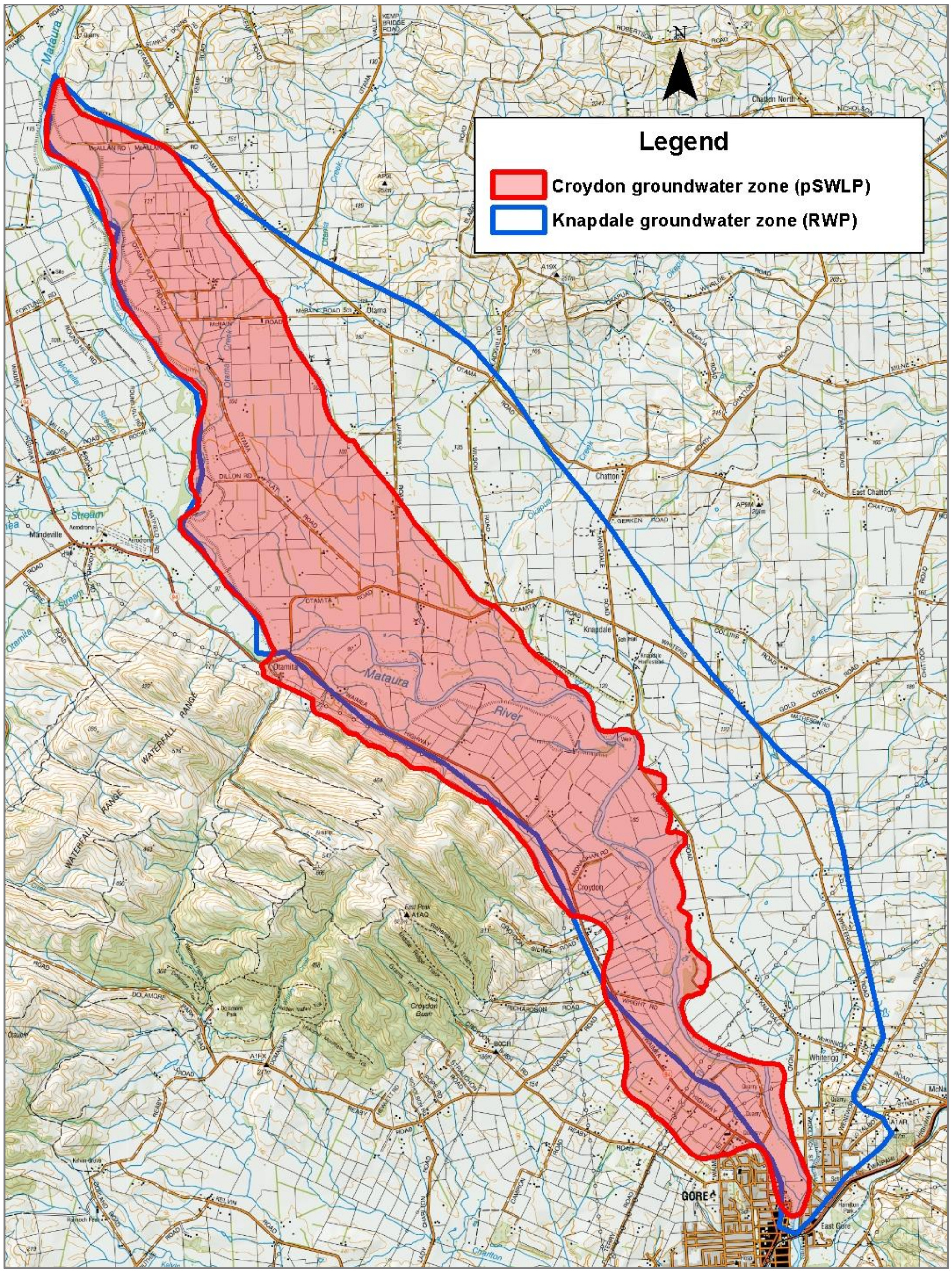
Boundary Definition:

- Lateral boundaries of the Centre Hill groundwater zone generally follow the QMap contact between alluvial deposits (Q1 to Q8) and basement rocks.
- Zone boundaries are truncated at arbitrary locations in the lower reaches of tributary streams such as the Weydon Burn and Windley River (generally where the gorges widen out toward the Oreti valley);
- The northern extent of the zone is arbitrarily defined at a point where the lower alluvial terraces widens across the Oreti valley, across downstream of Three Kings;
- The southern extent is defined at an arbitrary boundary where Murihiku basement is exposed in the Oreti River at Rocky Point;
- Upstream of Rocky Point, the southern margin follows the prominent terrace riser marking the boundary between reworked (Q1) alluvium associated with the Oreti River and older (Q8) alluvial terraces along the northern extent of the Aparima catchment (which represent alluvial deposits associated along a former channel of the Oreti River (Turnbull *et al*., 2004).

Croydon groundwater zone

Status: New (pSWLP)

Area: 4,585 Ha



Overview: The proposed Croydon groundwater zone represents a subdivision of the existing (RWP) Knapdale groundwater zone. The subdivision separates lower-lying alluvial terraces along the riparian margin of the Mataura River from older

(>Q4), higher elevation terrace remnants along the northern margin of the Mataura Valley. Delineation of the Croydon zone follows recommendations in Liquid Earth (2012)[34] to separate areas of the Knapdale groundwater zone hydraulically connected to the Mataura River from those with little or no hydraulic connection.

Boundary Definition:

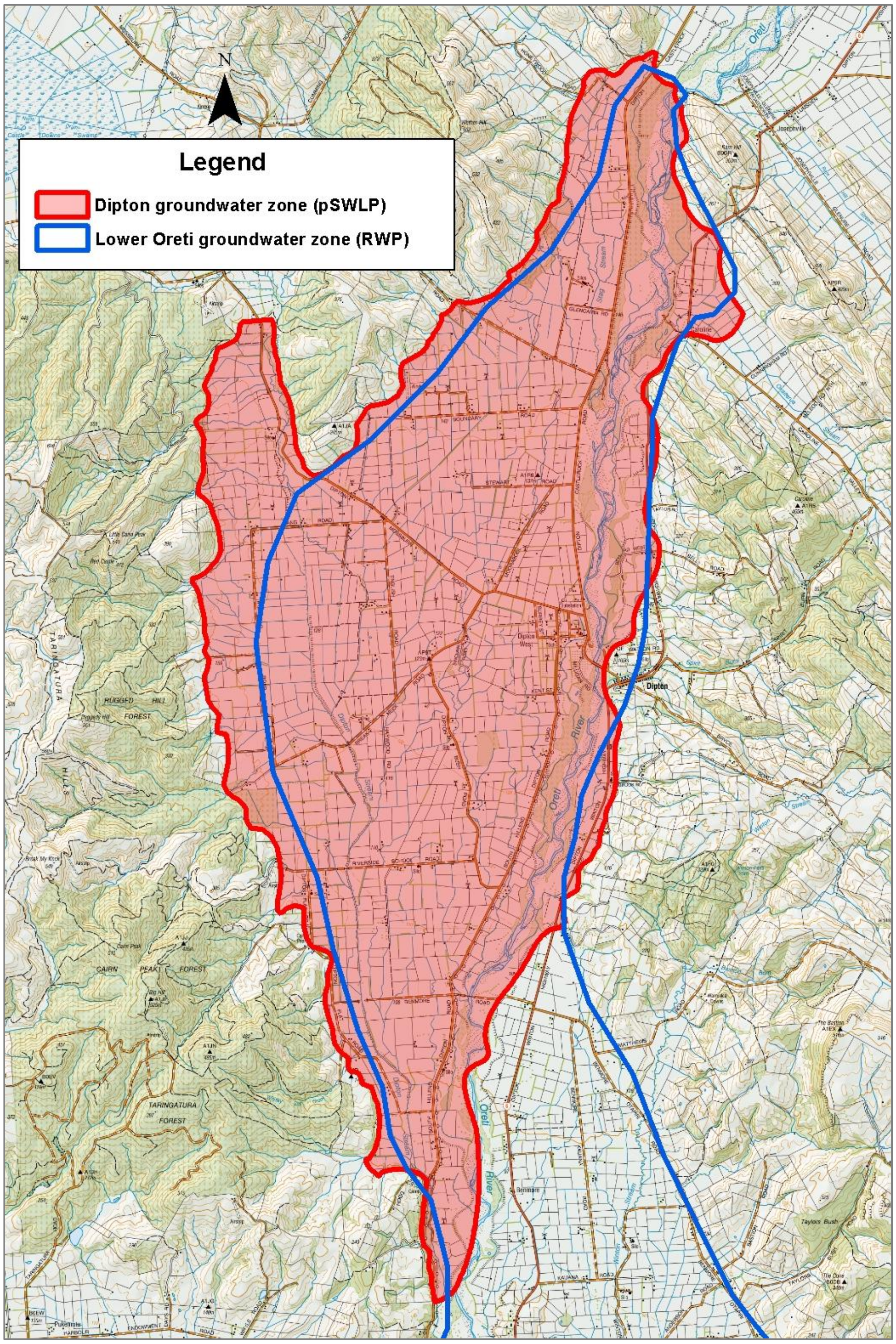
- The southern boundary of the proposed Croydon zone follows the QMap boundary between alluvial sediments and Murihiku basement along the foot of the Murihiku escarpment to the east of Otamita and the approximate alignment of the Mataura River to the west.
- West of Knapdale Road the northern boundary follows QMap boundaries between flatter-lying Q2 alluvium on the Mataura River floodplain and higher, rolling alluvial terraces to the north;
- East of Knapdale Road the northern boundary follows the approximate QMap boundary between Q1 and Q2 alluvium (reflecting the low degree of hydraulic connection between the Q2 alluvium and the Mataura River observed in the vicinity of GDC Coopers Wells)
- The southern extent of the Croydon zone follows an approximate boundary near the SH1 bridge where Murihiku basement is exposed in the Mataura River (i.e. effectively defining the downstream extent of the mid-Mataura basin)
- The upstream (northern) extent is of the proposed zone limited to the floodplain on the true left (northern) bank of the Mataura River downstream of Pyramid.

[34] Liquid Earth, 2012; *Knapdale Groundwater Zone Technical Report*. Report for Environment Southland, June 2012.

Dipton groundwater zone

Status: New (pSWLP)

Area: 11,655 Ha



Overview: The proposed Dipton groundwater zone represents a subdivision of the existing (RWP) Lower Oreti groundwater zone. This subdivision reflects differences in geology and hydrogeology between the Dipton Basin and the Southland Plains. In particular, relatively thick semi-confined (alluvial) and deeper confined (limestone) aquifers present in the Dipton groundwater zone are not observed south of the Hokonui Hills where geology typically comprises a relatively thin layer of Quaternary alluvium overlying lignite measure sediments (generally dominated by thick mudstone).

The groundwater resource in the Dipton Basin is recharged by local rainfall and infiltration of runoff from the surrounding hills. Significant interaction between groundwater and surface water occurs in younger (Q1 alluvium) along the riparian margin of the Oreti River and major tributaries (e.g. Stag Stream).

Boundary Definition:

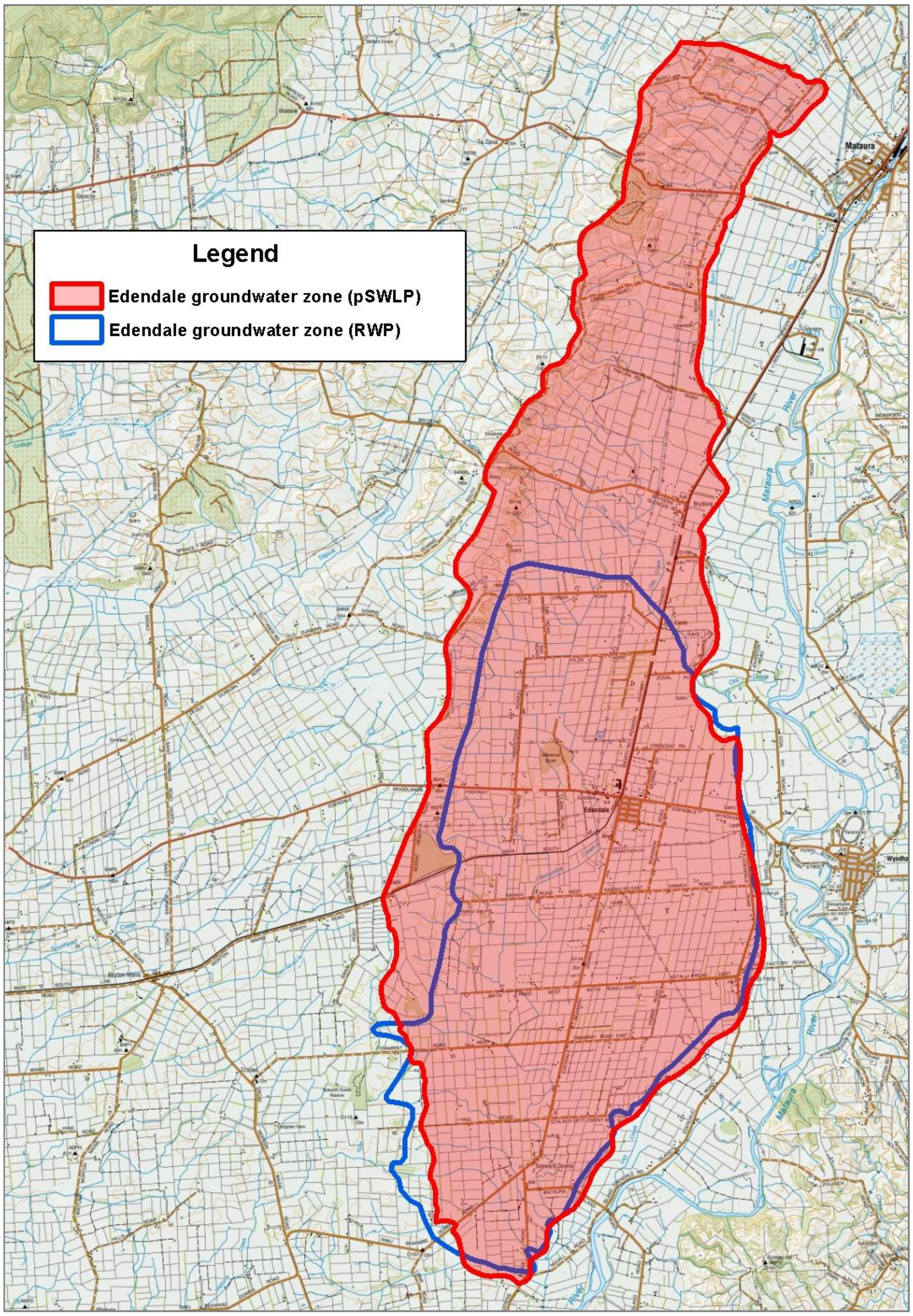
- The upstream boundary of the proposed Dipton zone is defined at an arbitrary point across the Oreti River at Ram Hill. This point represents the hydrological division between the Oreti Basin to the north and the Dipton Basin to the south. All discharge from the Oreti Basin effectively occurs via the Oreti River at this point (excluding and minor component of groundwater throughflow in deeper alluvium underlying the Waimea Plain);
- The eastern and western margins of the Dipton zone generally follow the QMap boundary between alluvial sediments and the Murihiku basement of the Hokonui and Taringatura Hills;
- The zone boundary is arbitrarily truncated in the Caroline Valley as it is assumed alluvial deposits are very thin or absent in this area (bore logs in the valley typically show little or no alluvium overlying Murihiku bedrock);
- North of Benmore the eastern boundary follows the general alignment of the Oreti River (which is assumed to form a hydraulic boundary between the proposed Dipton and Lower Oreti zones). The downstream (southern) margin of the Dipton zone is truncated at an arbitrary position on the true right (western) bank of the Oreti River where the Taringatura Hills are at their closest point to the river.

Edendale groundwater zone

Status: Existing (RWP)

Area: 7,529 Ha (RWP)

12,409 Ha (pSWLP)



Overview: The proposed (pSWLP) Edendale groundwater zone describes the groundwater resource underlying an extensive Q4 alluvial terrace (the 'Edendale Terrace') which extends along the western margin of the Mataura River valley between Mataura and Seaward Downs.

The extent of the proposed zone differs from that of the existing RWP zone boundary in that it extends across the entire Q4 terrace, rather than being restricted to the portion south of Ota Creek Road (differences in postulated extent of the Edendale are discussed in Wilson (2010)[35]). While recognising there is uncertainty regarding the nature of the hydraulic connection either side of observed anomalies in the piezometric surface (inferred as possibly associated with a fault structure) in the vicinity of Ota Creek Road, the larger zone boundary is preferred in the absence of conclusive evidence of a flow divide in this area.

Boundary Definition:

- The western boundary of the proposed Edendale groundwater zone follows the Qmap boundary between Q4 alluvium and exposure of lignite measure sediments along the terrace riser along the western margin of the Mataura River valley, in places extending to the break in slope at the top of the terrace (i.e. the most likely position of a hydraulic divide);
- The eastern boundary follows the eastern margin of the Edendale Terrace (i.e the boundary between Q2-Q4 and Q4 alluvium which is marked by a prominent terrace riser for a majority of its extent);
- The northern boundary occurs along an arbitrary divide along the southern extent of the Waimumu Stream catchment;
- The south-western margin follows the QMap contact between Q4 alluvium and lignite measure sediments exposed in the terrace riser separating the Edendale Terrace from the older Kamahi Terrace surface (Q8-Q10) to the west.

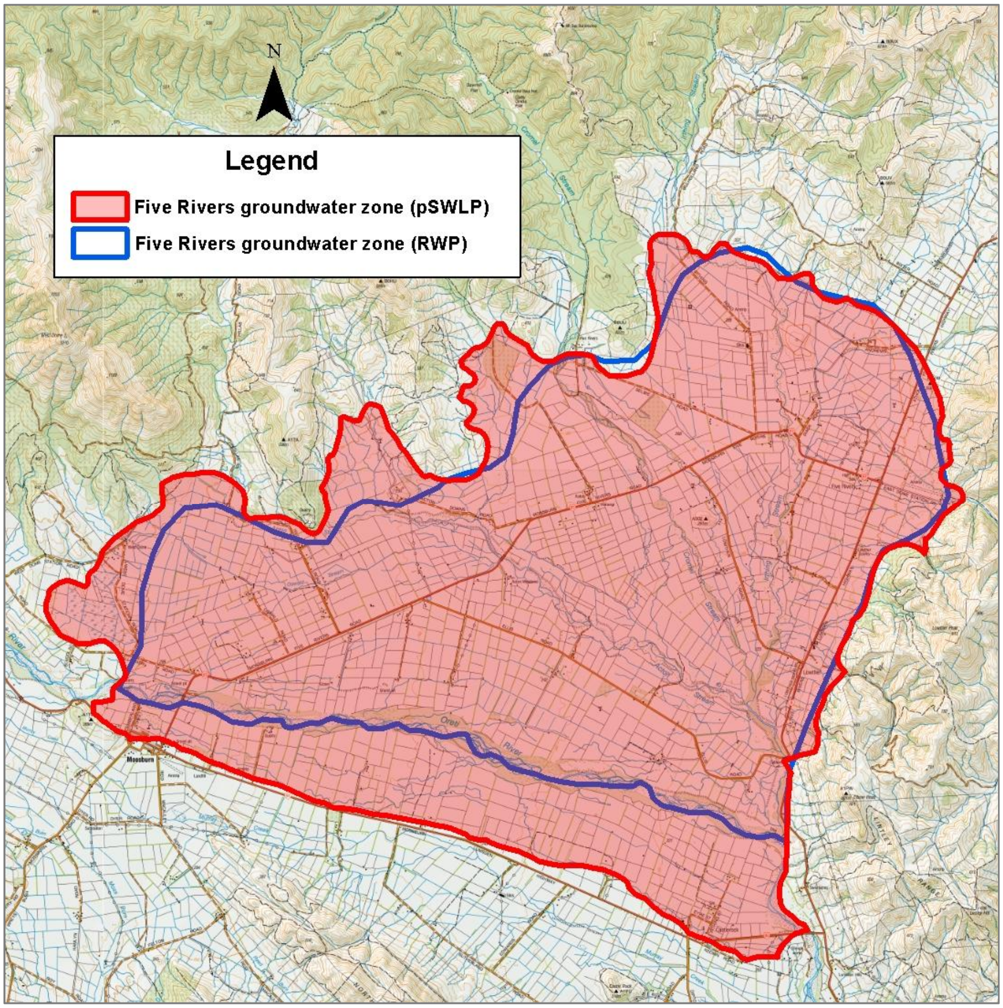
[35] Wilson, K., 2010; Edendale *Groundwater Management Zone Technical Report*. Report prepared for Environment Southland, October 2010

Five Rivers groundwater zone

Status: Existing (RWP)

Area: 13,795 Ha (RWP)

18,516 Ha (pSWLP)



Overview: The proposed (pSWLP) Five Rivers describes the shallow unconfined, hydraulically connected groundwater system which extends across central and northern areas of the Oreti Basin. This area is characterised by significant groundwater/surface water interaction, with significant losses and gains to surface waterways observed in all major streams crossing the area.

The southern portion of the Five Rivers groundwater zone is underlain by the confined Lumsden Aquifer. The Lumsden Aquifer is separated from the shallow unconfined aquifer by a thick sequence of tightly claybound alluvium. The difference in static head between these water-bearing layers varies from over of 20 metres toward the western end of Ellis Road, to 1-2 metres in the vicinity of Castlerock.

Boundary Definition:

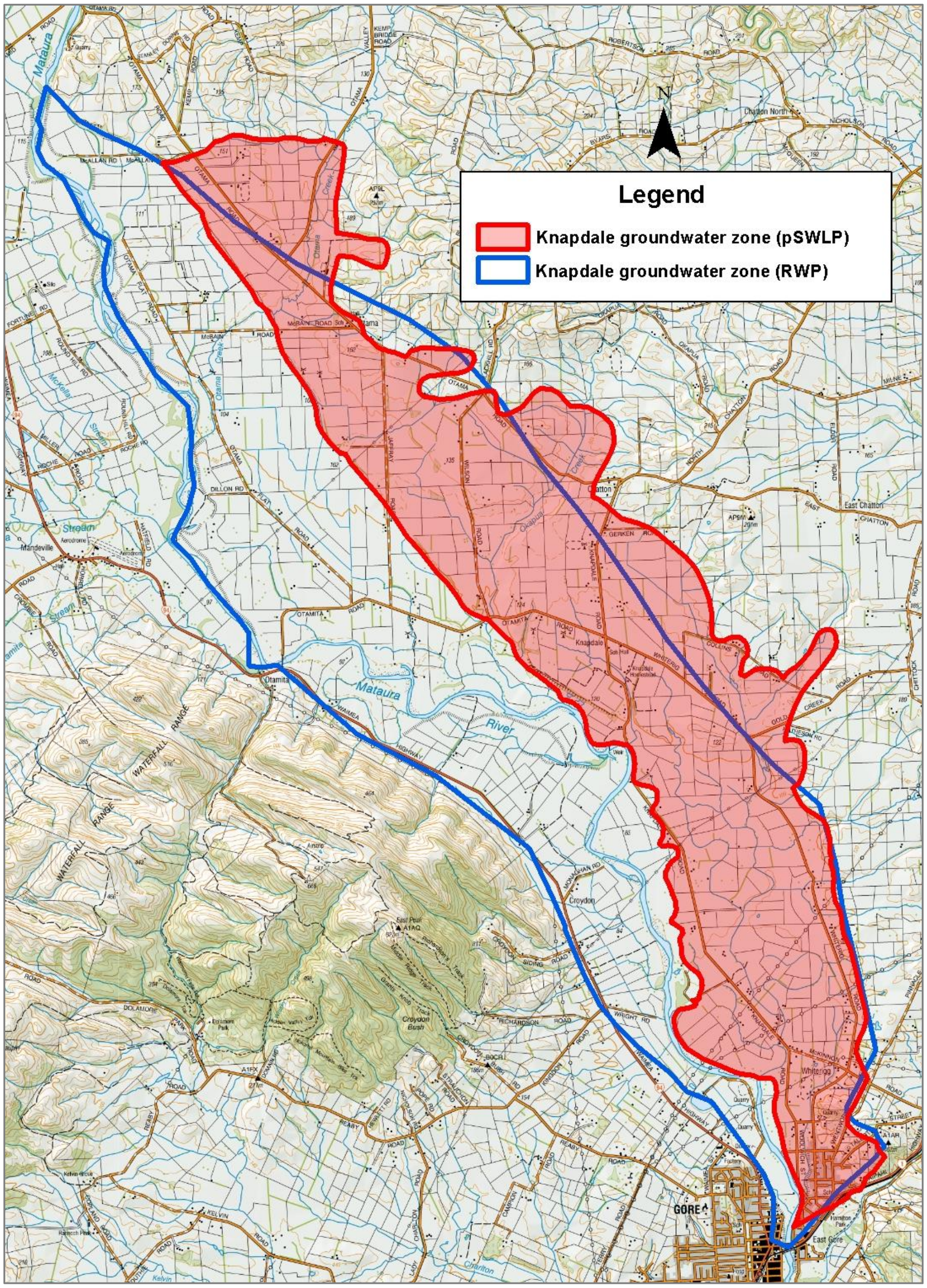
- The western and eastern boundaries of the proposed Five Rivers zone follow the QMap boundary between Quaternary alluvium and basement rocks of the Eyre Mountains and the Mataura Range;
- The southern margin of the existing (RWP) Five Rivers zone extends south along the alignment of the Oreti River along the terrace riser marking the boundary between Q1 and Q1 alluvium along the northern margin of the Castlerock Terrace. The proposed redefinition of the southern boundary groups areas of hydraulically connected groundwater in the Oreti Basin (upstream of the SH94 bridge) into a single management unit, given the relatively similar hydrogeological setting and nature of groundwater/surface water interaction.

Knapdale groundwater zone

Status: Existing (RWP)

Area: 8,185 Ha (RWP)

4,908 Ha (pSWLP)



Overview: The existing (RWP) Knapdale groundwater has been subdivided into two parts, the proposed Croydon zone representing riparian aquifers hydraulically connected to the Mataura River with the balance remaining in the Knapdale groundwater zone. The proposed Knapdale zone includes the groundwater resource hosted in alluvial deposits underlying older and more elevated terrace deposits along the northern margin of the Mataura Valley between Pyramid and Gore.

The aquifer system is primarily recharged by local rainfall, with some limited groundwater/surface water interaction occurring along the larger tributary streams (e.g. Gold Creek, Okapuka Creek).

Boundary Definition:

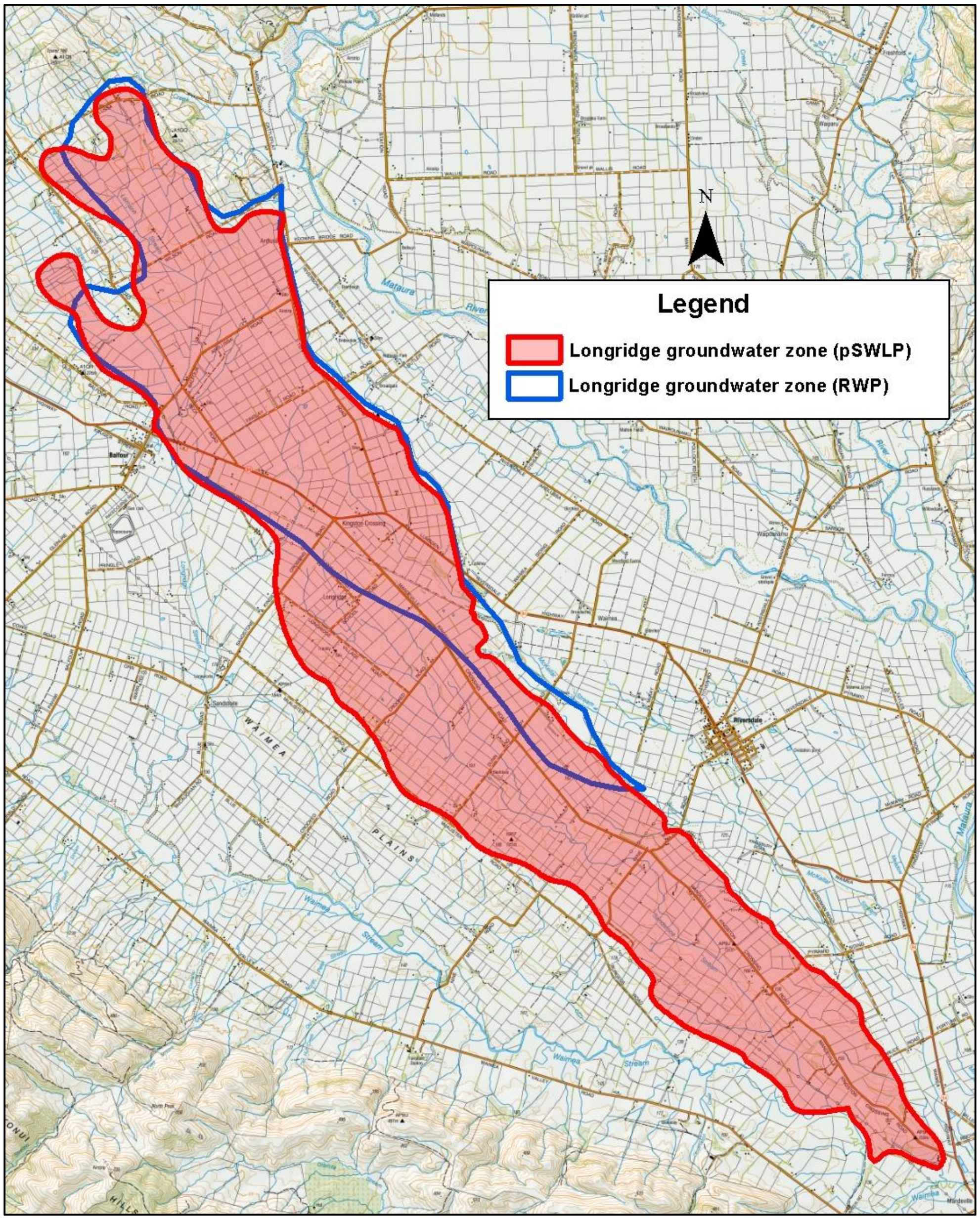
- The southern boundary of the modified (pSWLP) Kapdale zone follows the northern boundary of the proposed Croydon zone. West of Knapdale Road the this follows QMap boundaries between flatter-lying Q2 alluvium on the Mataura River floodplain and higher, rolling alluvial terraces to the north. East of Knapdale Road the boundary follows the approximate QMap boundary between Q1 and Q2 alluvium (reflecting the low degree of hydraulic connection between the Q2 alluvium and the Mataura River observed in the vicinity of GDC Coopers Wells)
- The northern boundary has been modified to follow the approximate contact between Quaternary alluvium (generally Q4-Q6) and Gore Lignite Measure sediments and older Gore Piedmont Gravels exposed to the north
- The revised groundwater zone boundary includes significant areas around Otama Creek, Okapuka Creek and Gold Creek that were originally included in the Chatton groundwater zone (which was removed from the RWP as part of Variation 12).

Longridge groundwater zone

Status: Existing (RWP)

Area: 4,392 Ha (RWP)

8,269 Ha (pSWLP)



Overview: The existing (RWP) Longridge groundwater zone represents the portion of the Waimea Plain north-east of the groundwater flow divide between the Waimea Stream and Mataura River catchments (reflected in local variation of piezometric contours south-east of Balfour). This flow divide is interpreted to reflect the presence of a basement ridge (Matai basement and overlying Tertiary sediments) which follows a northwest-southeast alignment across the eastern margin of the Waimea Plain. Alluvial sediments in the Longridge zone are typically older (Q8/Q10) than those in the Waimea Stream catchment (<Q6) to the west and south, and on the Mataura River floodplain (<Q2) to the east.

Groundwater in this zone is primarily recharged by local rainfall with discharge occurring via throughflow and spring discharge (e.g. McKellars Stream) to the Riversdale groundwater zone to the east, rather than the Waimea Stream catchment to the south. This potentially means groundwater flow in the Balfour area does not correspond to drainage in the Longridge Stream catchment (which is perched above the water table and cuts through the basement ridge to the west of Sandstone Kingston Crossing Road).

Boundary Definition:

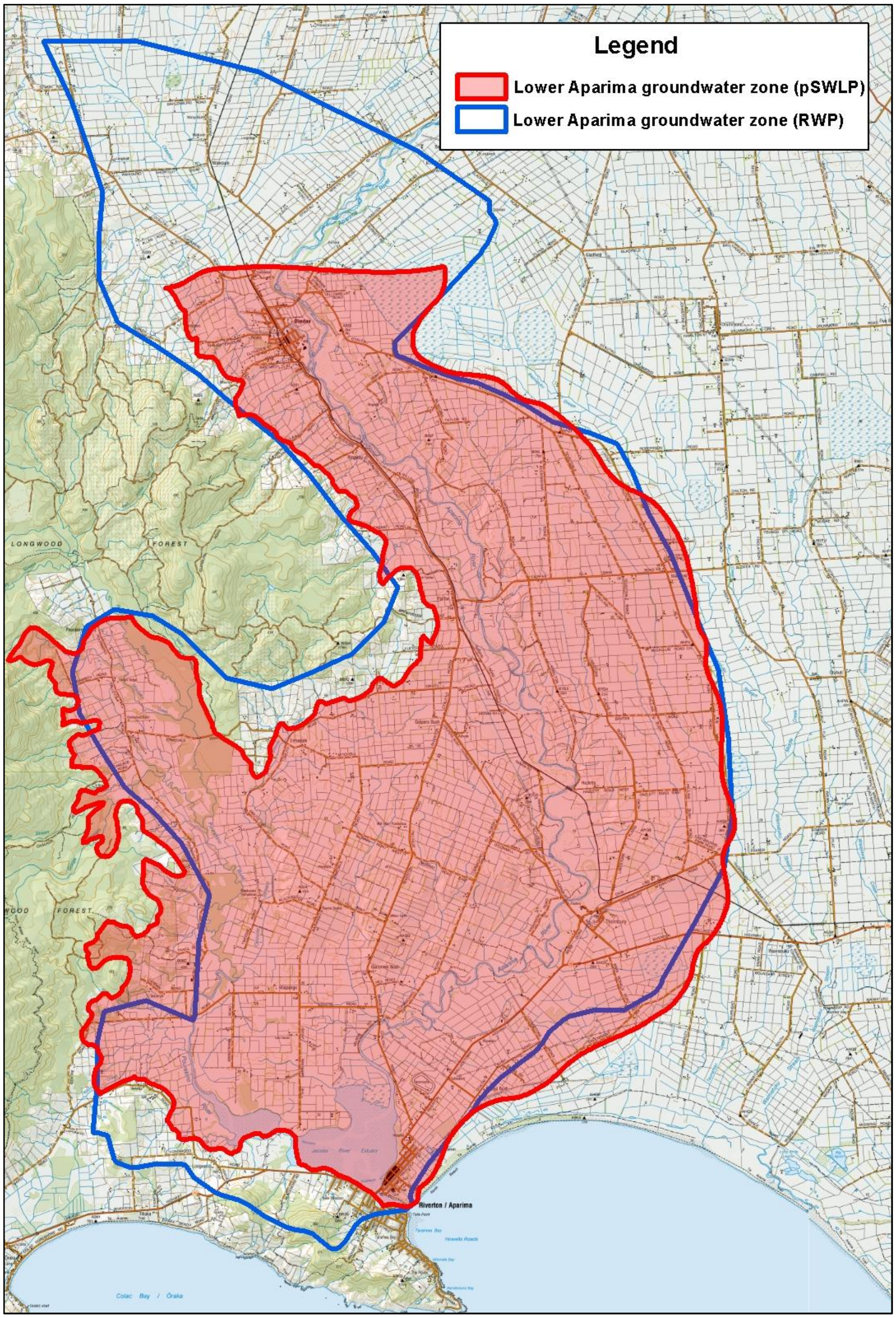
- The proposed (pSWLP) Longridge groundwater zone is expanded to include the Sandstone Stream catchment which is effectively separated from the Waimea Stream catchment by surface and near-surface exposure of Matai Group basement rocks and Tertiary sediments (Forest Hill Formation, East Southland Group) adjacent to Longridge Stream and near the bottom of the Sandstone Stream catchment.
- The northern boundary follows the terrace riser that marks the boundary between Q2 alluvium of the Mataura River floodplain and older (Q8/Q10) terrace remnants (underlain by shallow basement) of the Longridge/Sandstone Terrace.
- The southern boundary follows the approximate axis of the basement ridge (essentially the extent of 2nd and 3rd order REC catchments draining to Sandstone Stream and Waimea Stream.

Lower Aparima groundwater zone

Status: Existing (RWP)

Area: 34,327 Ha (RWP)

28,733 Ha (pSWLP)



Overview: The existing (RWP) Lower Aparima groundwater zone encompasses the groundwater resource in the lower reaches of the Aparima River catchment hosted in Quaternary alluvium and limestone deposits in the Isla Bank and Gummies Bush areas.

The aquifer system is primarily recharged by local rainfall recharge with some infiltration of runoff along the foothills of the Coastal Longwoods. In places (e.g. Islan Bank), the Quaternary alluvium is very thin and underlying deposits of sandy/fractured limestone host a majority of the groundwater resource. Available aquifer test data indicate the limestone deposits are semi-confined (large temporal variation in groundwater levels in the Isla Bank area reflect the limited secondary porosity in fractured limestone).

Boundary Definition:

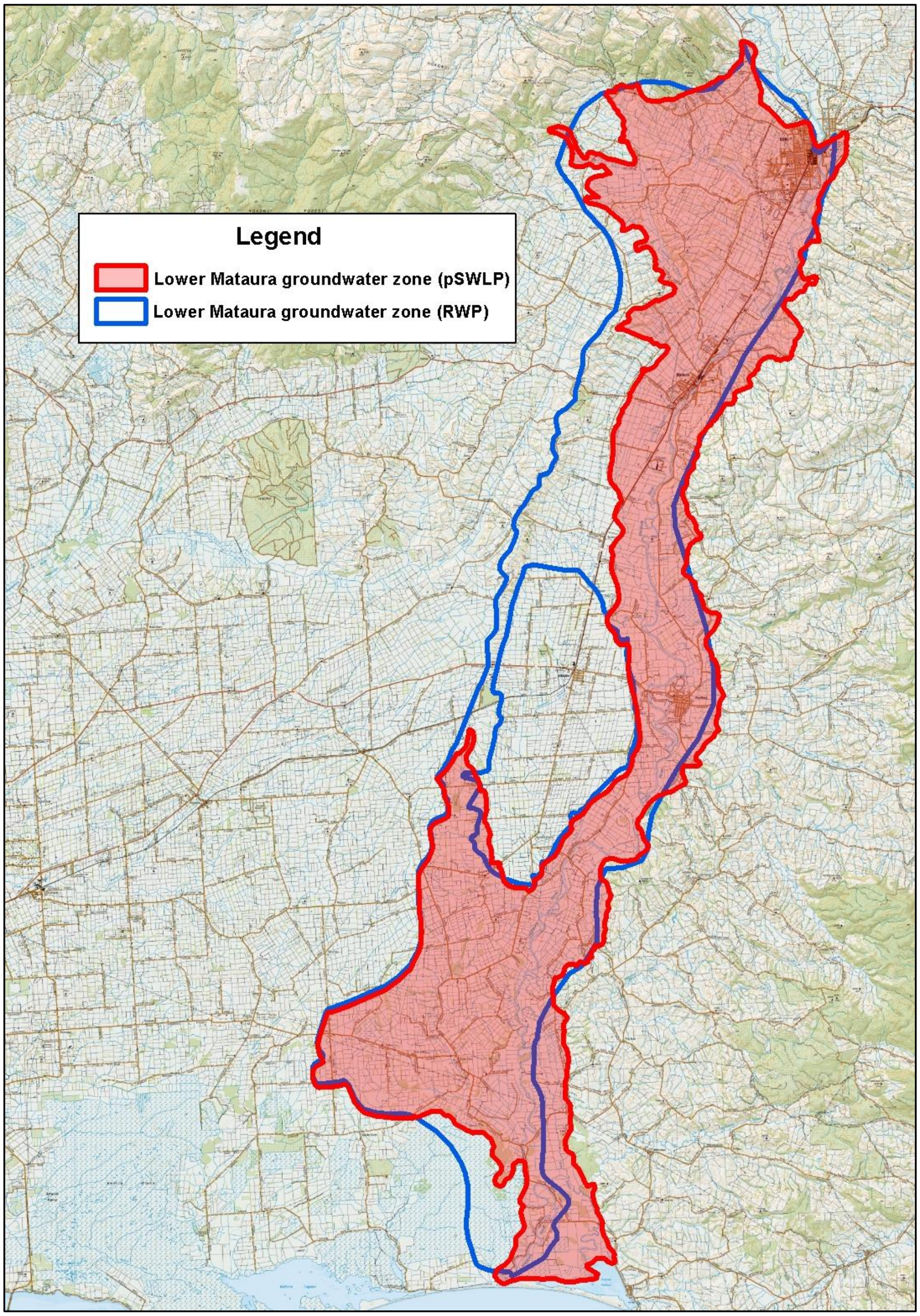
- The western boundary of the proposed (pSWLP) Lower Aparima groundwater zone follows the approximate QMap boundary between Quaternary alluvium and Brooks Street basement rocks of the Longwood Hills;
- The eastern boundary approximates the margin of the Q8 terrace which defines the lateral extent of the Waimatuku Stream catchment running onto the eastern margin of the marine terrace nearer the coast south of Thornbury;
- The southern margin follows the basement contact around the margin of Jacobs River estuary and is extended to reflect the extent of alluvial sediments in the Pourakino River catchment;
- The northern extent of the zone follows an arbitrary boundary across the Aparima River upstream of Otautau near the position where the Aparima River channel swings from a south-westerly to south-easterly alignment around the western margin of the limestone ridge at Yellowbluffs.

Lower Mataura groundwater zone

Status: Existing (RWP)

Area: 40,084 Ha (RWP)

34,929 Ha (pSWLP)



Overview: The proposed (pSWLP) Lower Mataura groundwater describes the shallow unconfined aquifer system(s) hosted in Quaternary alluvium in the Mataura River catchment south of Gore, with the exception of the groundwater resource underlying the Q4 Edendale terrace (which is defined as a separate management zone).

The aquifer system is primarily recharged by rainfall and infiltration of runoff from the Catlins hills. Groundwater/surface water interaction is generally limited to the immediate riparian margin of the Mataura River and larger tributaries.

Boundary Definition:

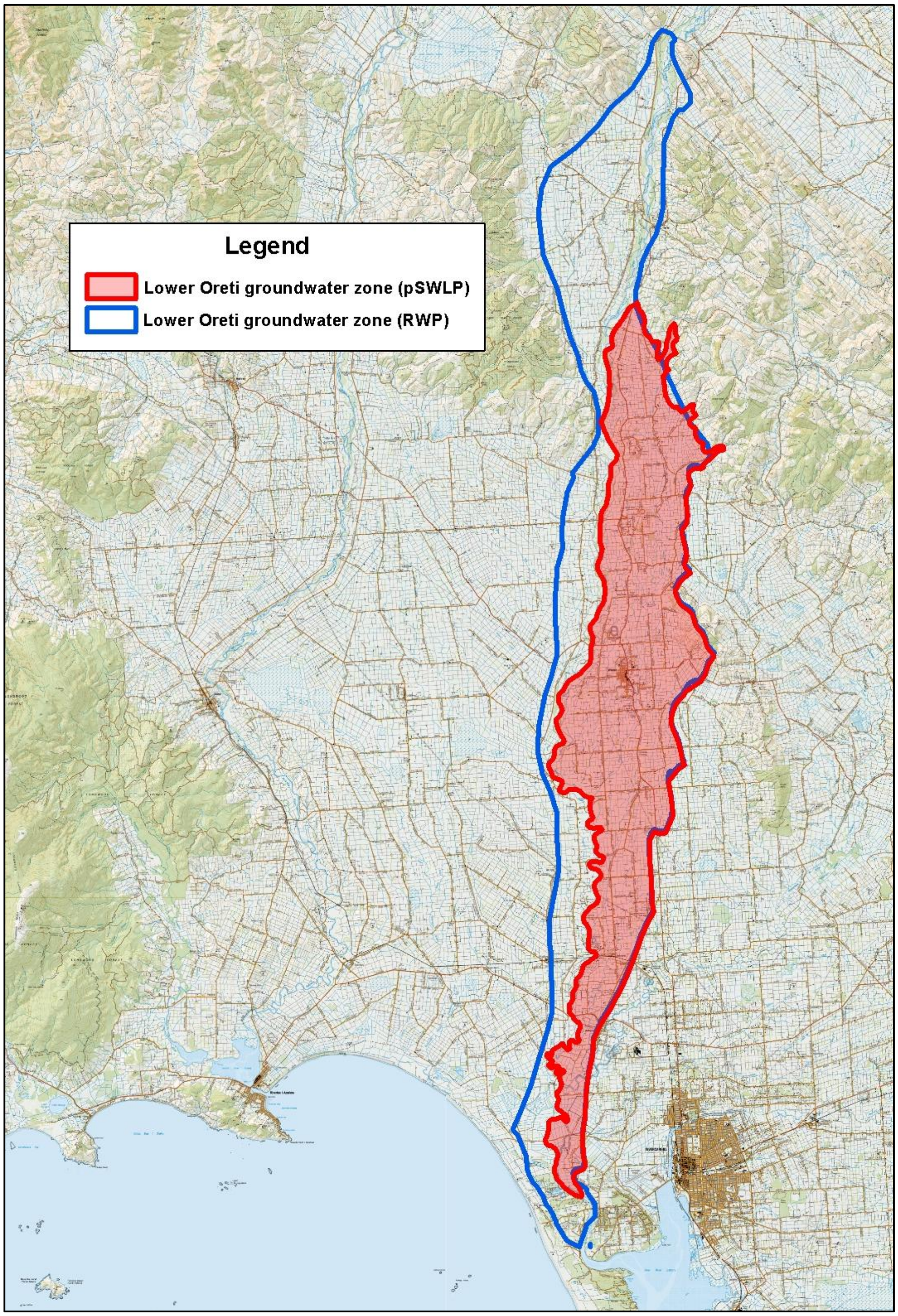
- The eastern boundary follows the approximate QMap boundary between Quaternary alluvium and greywacke basement of the Murihiku Terrane and Tertiary cover of the East Southland Group (mainly Gore Lignite Measures).
- The northern boundary west of Gore follows the boundary between Q4 and Q6 alluvial terraces. Near Gore township it follows the approximate location of the bedrock outcrop in the Mataura River which forms the southern extent of the mid-Mataura Basin;
- The western boundary follows the approximate QMap boundary between Gore Lignite Measure sediments (Croydon) and Kamahi Formation alluvium in the Waimumu Stream and Charleton Stream catchments;
- The western boundary south of Mataura follows the approximate boundary between Q2-Q4 and Q4-Q6 alluvium which becomes more clearly defined along the Edendale Terrace margin south of the Glencoe Highway;
- Along the southern margin of the Edendale Terrace the boundary follows the approximate contact between Q4 alluvium and surface exposure of Gore Lignite Measure sediments (essentially the break in slope to the west);
- Between Tramway Road and Waituna Gorge Road the boundary follows the hydrological divide between the Waituna Lagoon catchment and the Mataura River catchment. South of Waituna Gorge Road the boundary follows the eastern margin of the Waituna wetland.

Lower Oreti groundwater zone

Status: Existing (RWP)

Area: 40,084 Ha (RWP)

34,929 Ha (pSWLP)



Overview: The existing (RWP) Lower Oreti groundwater includes shallow unconfined aquifers along the riparian margin of the Oreti River, south of the Hokonui Hills.

The major changes in the extent of the proposed (pSWLP) Lower Oreti zone include the exclusion of the Dipton Basin (to form the proposed Dipton groundwater zone based on observed differences in geology and hydrogeology compared to areas south of the Hokonui Hills) and the transfer of areas along the true right (western) bank of the Oreti River to the revised Central Plains zone (to reflect significant throughflow from the Central Plains area and limited hydraulic connection to the Oreti River).

Boundary Definition:

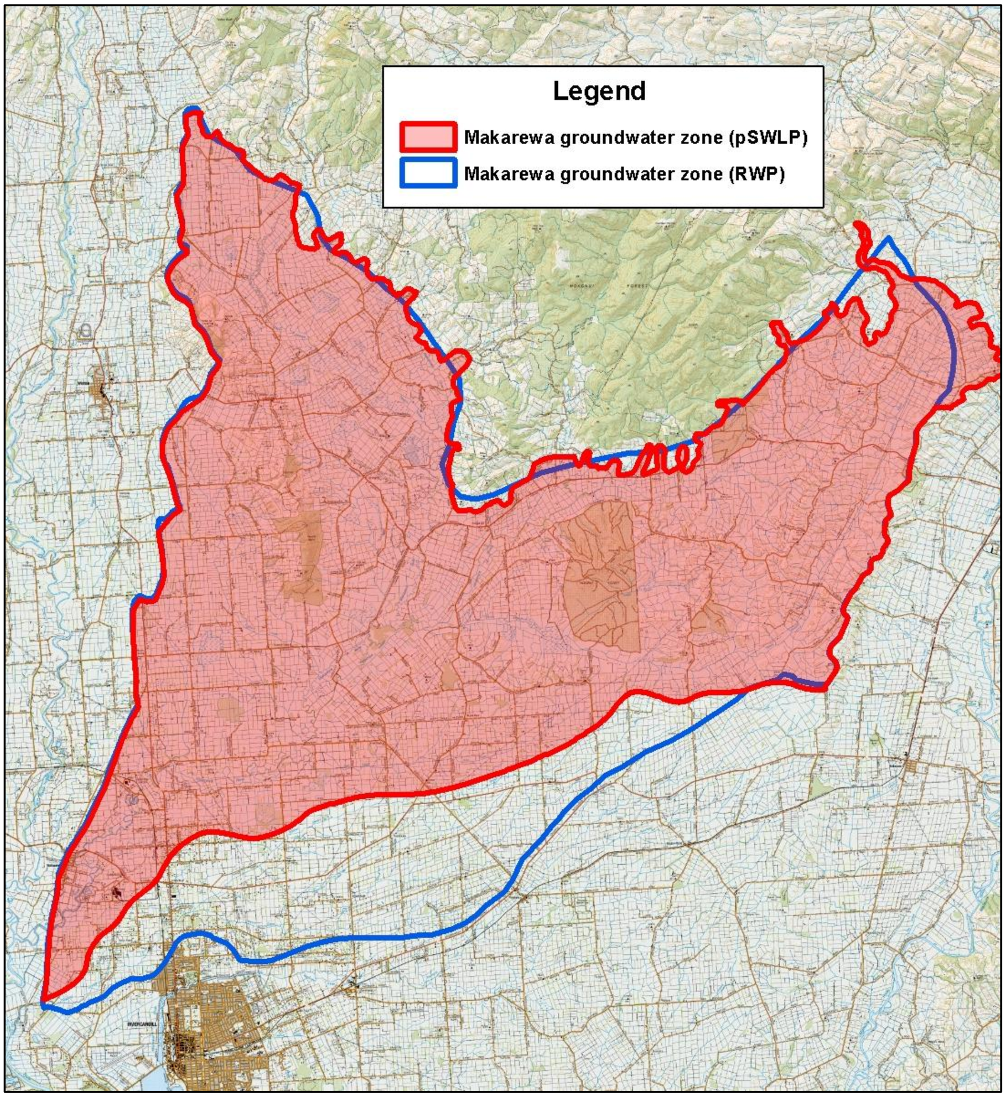
- The northern boundary follows the approximate QMap boundary between Quaternary alluvium and Murihiku basement along the Hokonui Hills;
- The western boundary follows the approximate alignment of the Oreti River channel
- The eastern boundary approximates the boundary between the Oreti River and Makarewa River catchments.

Makarewa groundwater zone

Status: Existing (RWP)

Area: 78,924 Ha (RWP)

65,908 Ha (pSWLP)



Overview: The existing Makarewa Groundwater zone encompasses the shallow unconfined groundwater resource present in the Makarewa River catchment. The major change between the existing (RWP) and proposed (pSWLP) zone boundaries is the exclusion of the Waikiwi Stream catchment.

The groundwater system is primarily recharged by rainfall and infiltration of runoff from the Hokonui Hills to the north. In many areas (e.g Kauana, Hedgehope) the groundwater resource is limited in extent comprising a thin sequence of low permeability claybound alluvium overlying Tertiary sediments (generally mudstone of the East Southland Group).

Boundary Definition:

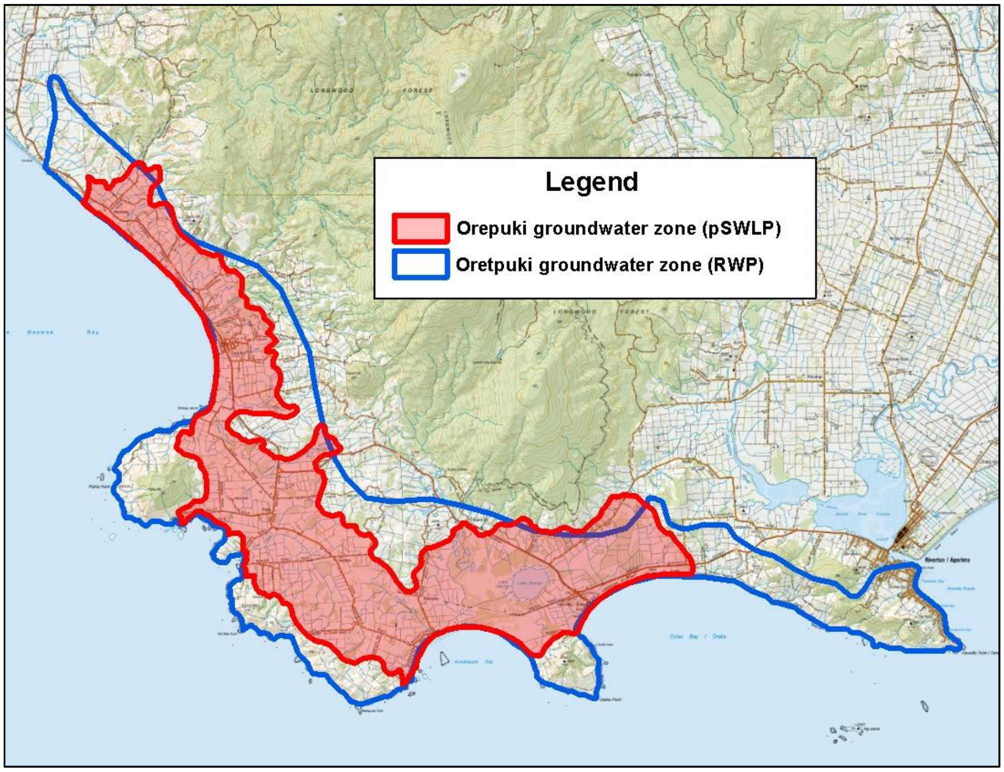
- The western boundary follows the approximate catchment boundary between the Oreti and Makarewa River catchments;
- The southern boundary has been modified to exclude the Waikiwi Stream catchments (included in the proposed Waihopai zone) due to greater similarity in hydrology and hydrogeological setting with the proposed Waihopai zone to the south);
- The eastern boundary is unchanged between Downs Road and McGill Road but extends further east in the Waimumu Stream catchment to follow the eastern margin of the Kamahi Terrace;
- The northern boundary largely follows the QMap contact between alluvial deposits and Murihiku basement/Tertiary sediments.

Orepuki groundwater zone

Status: Existing (RWP)

Area: 13,698 Ha (RWP)

7,259 Ha (pSWLP)



Overview: The proposed (pSWLP) Orepuki groundwater zone includes the groundwater resource hosted in Quaternary alluvium, tailings and marine terrace deposits along the southern margin of the Longwood Range which overlie Brooks Street basement and Tertiary cover rocks.

The main change to the existing (RWP) zone boundary is the use of QMap to better define the contact between alluvium and bedrock.

Boundary Definition:

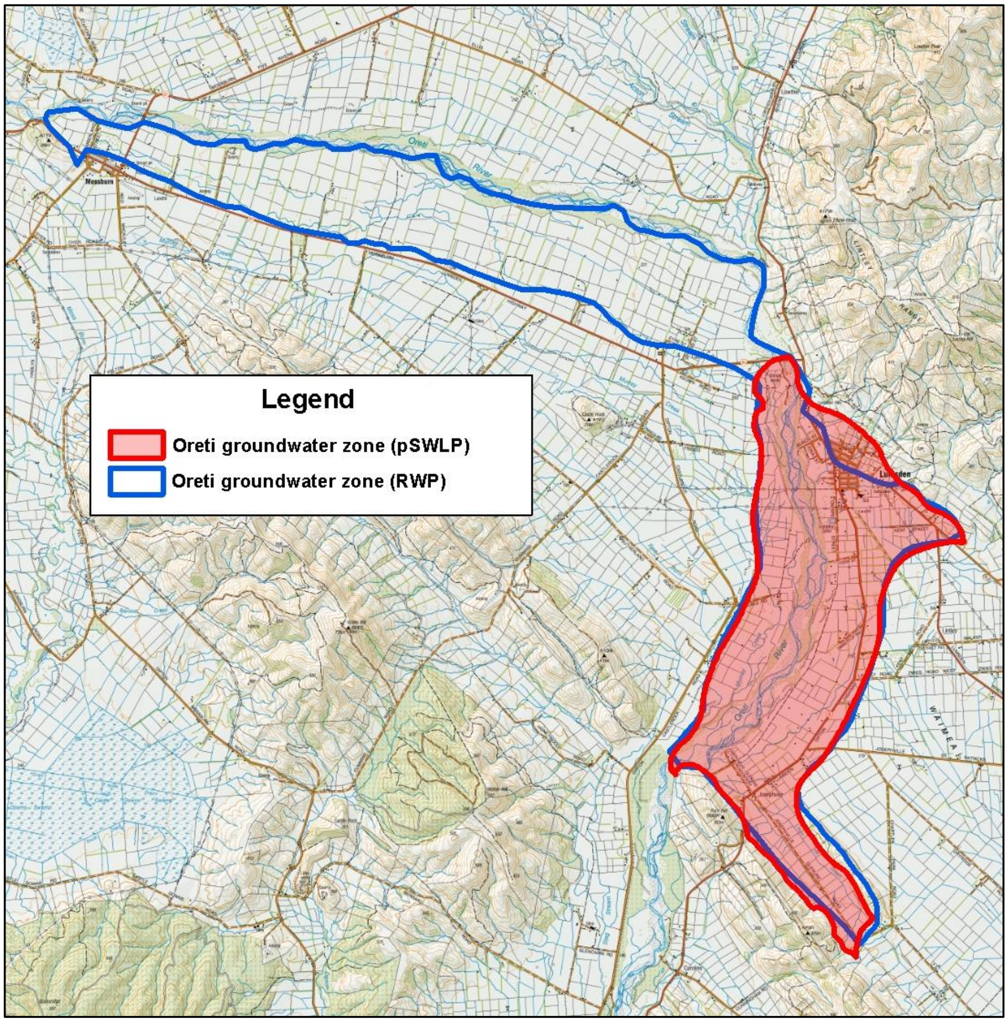
- Boundaries around the proposed zone generally follow the QMap extent of Quaternary alluvium and marine terrace deposits. The few wells recorded outside the proposed zone boundary show the presence of low-yielding Tertiary sediments;
- The western boundary of the zone is truncated slightly to better match the lateral extent of alluvial deposits associated with the Waiau River.

Oreti groundwater zone

Status: Existing (RWP)

Area: 6,128 Ha (RWP)

3,295 Ha (pSWLP)



Overview: The existing (RWP) Oreti groundwater zone includes shallow unconfined alluvial aquifers along the true right (southern) bank of the Oreti River between Mossburn and Lumsden, and on both sides of the river between Lumsden and Ram Hill.

The main change to the existing (RWP) zone boundary is the inclusion of the area upstream of Lumsden in the into the proposed Five Rivers zone (due to similarity with riparian aquifers across the wider Five Rivers area). The remaining area in the proposed (pSWLP) Oreti zone comprises the floodplain of the Oreti River between the eastern margin of the Castlerock Terrace and the catchment divide between the Oreti River and Waimea Stream from Lumsden township to Ram Hill.

The proposed Oreti zone represents the groundwater system along a complex (but indistinct) geological/hydrogeological boundary.

Concurrent gaugings undertaken in the Oreti River downstream of Lumsden indicate the area receives appreciable throughflow from the Castlerock Terrace (a portion of which discharges via Murray Creek and other spring-fed streams along the eastern margin of the Castlerock Terrace) and possibly leakage from the eastern (down gradient) extent of the Lumsden Aquifer.

The zone is also underlain on the eastern side of the Oreti River by a semi-confined water-bearing layer (previously referred to as the Lintley Aquifer) which extends down the Waimea Plain toward St Patricks. The western boundary of this layer appears to extend toward the Oreti River so potentially does not match the hydrological divide between the Oreti River and Waimea Stream in the overlying unconfined aquifer. However, the specific discharge of the Waimea Stream does not suggest a significant input of groundwater from outside its defined catchment area suggesting throughflow from the Oreti catchment via this deeper water-bearing layer is minor.

A significant difference in static water levels between the Lumsden Aquifer to the west and the “Lintley Aquifer” to the east suggests these water-bearing layers are (at least in part, if not wholly) separated by a hydraulic boundary which runs close to the alignment of the Oreti River. This boundary has been associated with the presence of a fault (the “Lumsden Fault”) extending from the western margin of the Mataura Range to Ram Hill (Blakemore, 2002).

Boundary Definition:

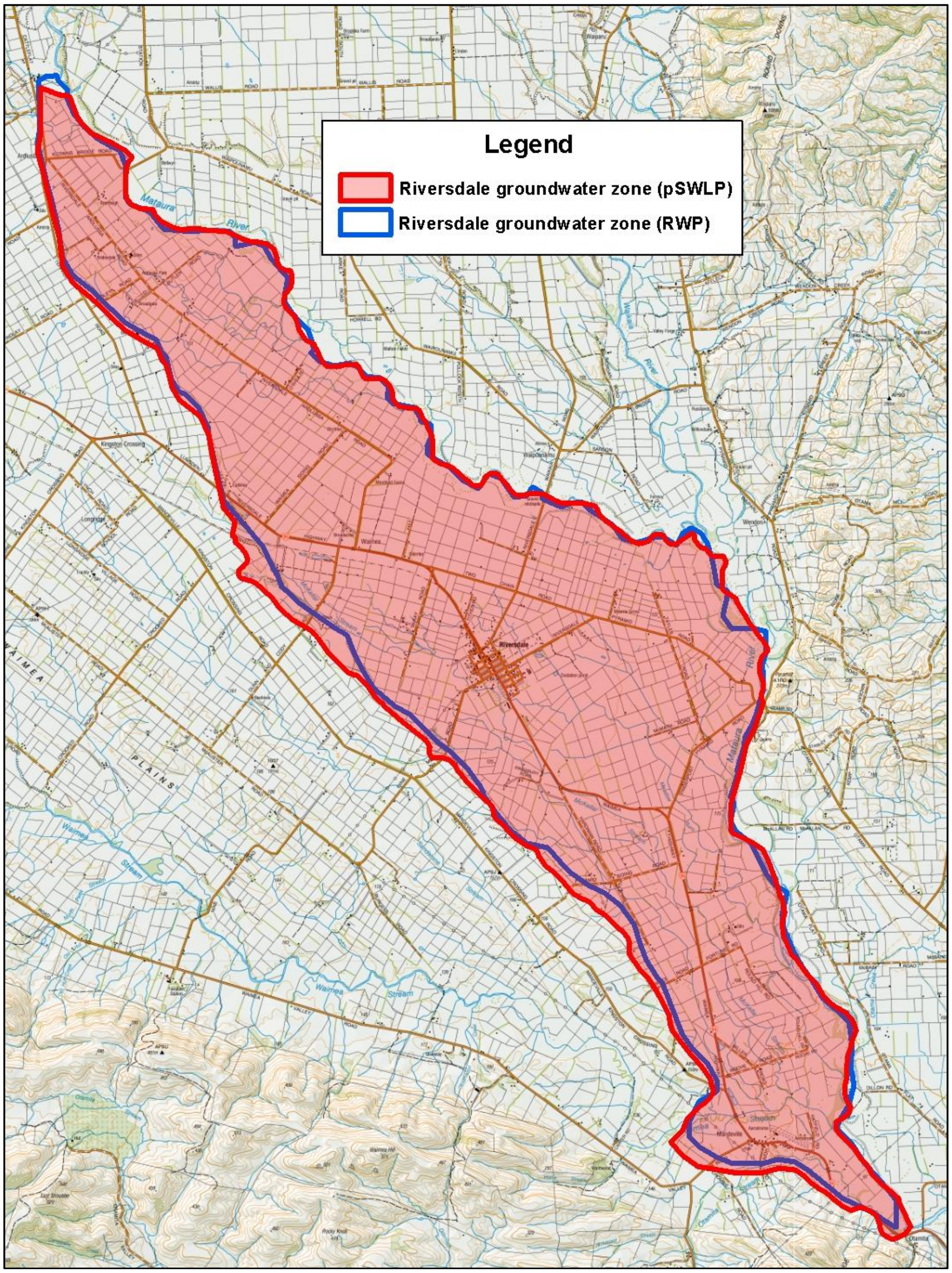
- The northern boundary follows the approximate contact between alluvial sediments and basement along the base of the Mataura Range.
- The southern extent of the Oreti zone terminates at Ram Hill which forms a geological control on discharge from the Oreti Basin (effectively forming a closed basin)
- The western boundary follows the approximate alignment of the eastern margin of the Castlerock Terrace (not particularly distinct in the vicinity of Ram Hill);
- The eastern boundary follows the approximate alignment of the Oreti River/Waimea Stream catchment divide (and the extent of older gravel units along the western margin of the Waimea Plain);
- The irregular extent of the zone boundary near Ram Hill represents alluvial sediments infilling a valley within the Murihiku Escarpment that drains to the Oreti River (via Ram Hill Stream) rather than the Waimea Stream catchment.

Riversdale groundwater zone

Status: Existing (RWP)

Area: 10,342 Ha (RWP)

10,969 Ha (pSWLP)



Overview: The proposed (pSWLP) Riversdale groundwater defines the groundwater resource hosted in Quaternary alluvium (Q1 and Q2) along the true right bank of the Mataura River between Ardlussa and Otamita. Wilson (2010)[36] describes the hydrogeology of this zone.

Boundary Definition:

- Boundaries of the proposed Riversdale zone are only altered slightly from the existing (RWP) zone.
- The western margin follows the QMap contact between basement/Tertiary/Q8-Q10 sediments on the elevated Longridge Terrace and Q2 alluvium of the Mataura River floodplain;
- The eastern boundary follows the approximate alignment of the Mataura River

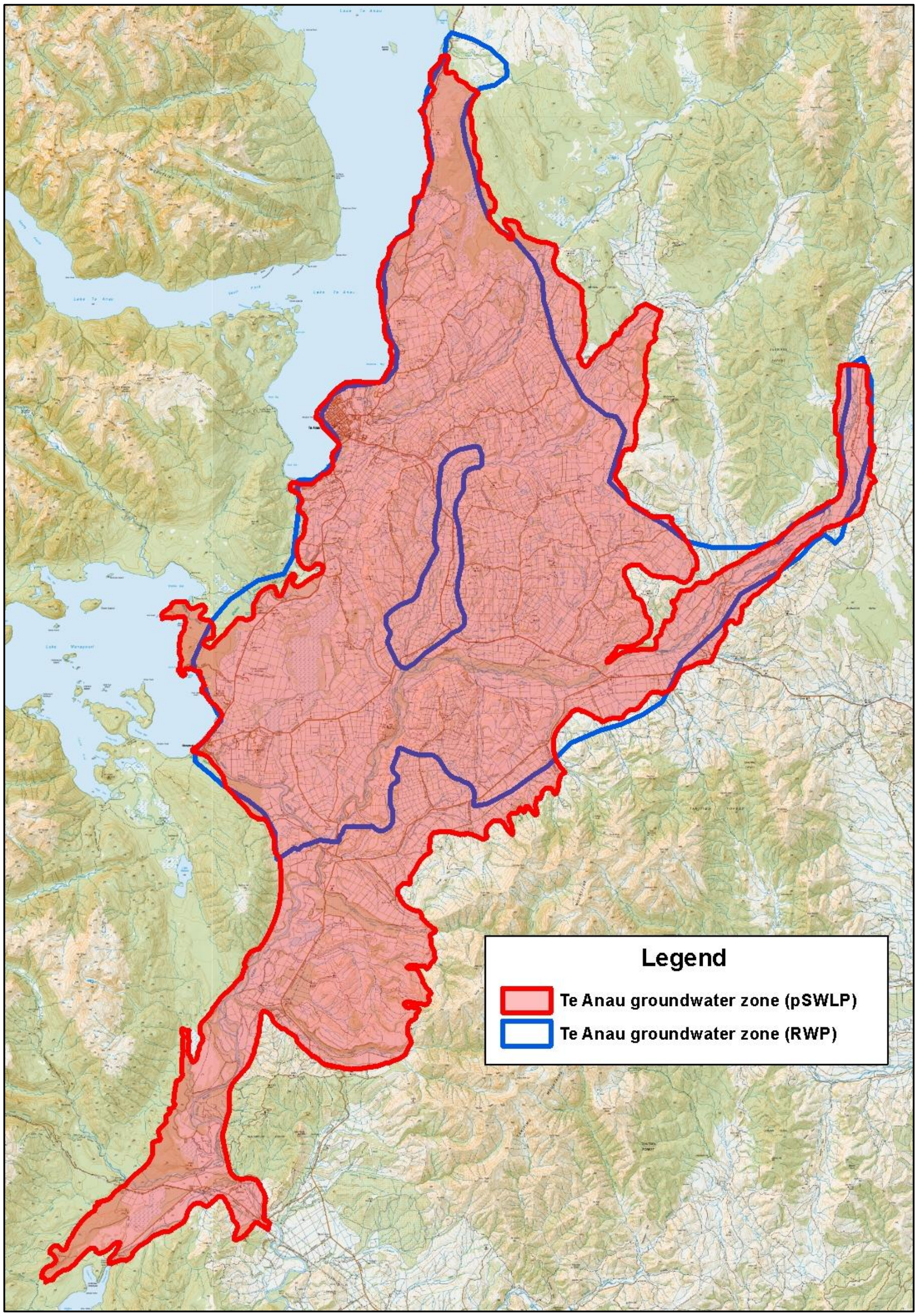
[36] Wilson, K., 2011; *Riversdale Groundwater Zone Technical Report*. Report prepared for Environment Southland, October 2011.

Te Anau groundwater zone

Status: Existing (RWP)

Area: 56,478 Ha (RWP)

78,534 Ha (pSWLP)



Overview: The proposed (pSWLP) Te Anau groundwater zone includes the groundwater resource hosted in alluvial deposits (glacial moraine and Quaternary alluvium) infilling the Te Anau Basin.

The proposed Te Anau zone incorporates the existing (RWP) Whitestone groundwater zone. The rationale for this change is to form a single zone which defines the larger groundwater system of the Te Anau Basin. Given the Whitestone groundwater zone is little different to other areas of Q1 alluvium along the Mararoa River (in terms of hydrogeological setting) and current and proposed allocation in the Waiau catchment (see relevant rules/policies in the RWP and pSWLP) the is little benefit in subdividing the basin into smaller management units. The proposed Te Anau zone therefore includes all major water-bearing alluvial deposits upstream of the hydrological divide at Sunnyside (rather than the Mararoa weir).

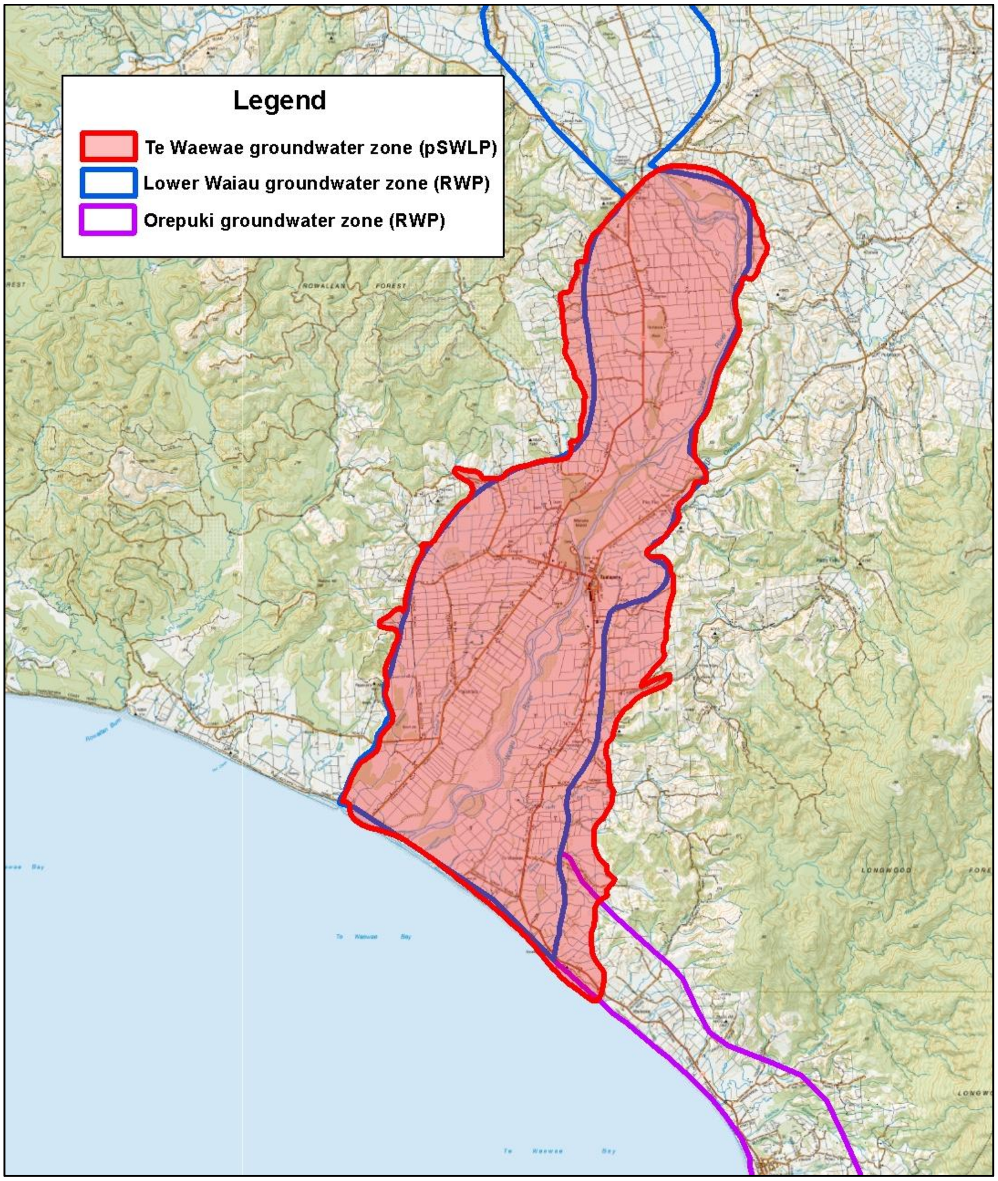
Boundary Definition:

- The eastern boundary in the Te Anau Downs area has been adjusted to better reflect a majority of the QMap boundary between alluvium and basement. In some catchments (e.g. Whitestone River) the boundary is truncated arbitrarily within areas of narrow valley fill alluvium rather than extending into upper catchment areas.
- Boundaries in the Mararoa catchment again generally follow the QMap basement/alluvium contact, although it does not incorporate numerous, small valley-fill alluvial deposits;
- The southern extent of the zone is truncated at Sunnyside which represents the downstream extent of a closed (hydrological) basin. In this area the boundary again generally follows the QMap alluvium/bedrock contact but many areas of valley-fill alluvium peripheral to the Waiau River valley are excluded (e.g. the Lake Rakutu area);
- Between Lake Te Anau and Lake Manapouri the boundary follows the Waiau River channel (i.e. excluding alluvial deposits on the western side of the river. For simplicity, the boundary did not exclude small basement outcrops (e.g. Mt York, Freestone Hill, View Hill);
- Along the Lake Te Anau foreshore the boundary effectively follows the Topo 50 lake margin.

Te Waewae groundwater zone

Status: New (pSWLP)

Area: 11,899 Ha (pSWLP)



Overview: The proposed (pSWLP) Te Waeawe groundwater includes the main water-bearing alluvial deposits present in the Waiau River valley downstream of Clifden. The proposed zone is a subdivision of the existing (RWP) Lower Waiau groundwater zone.

Boundary Definition:

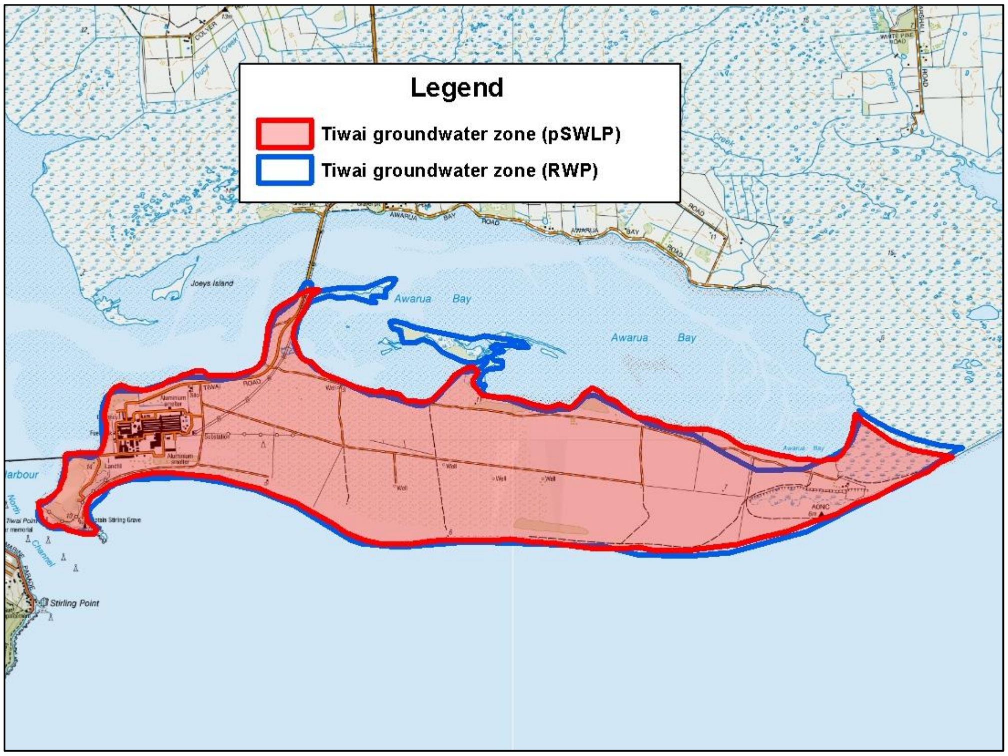
- The upstream boundary crosses the Waiau River at Clifden where limestone of the Lower Clifden subgroup crop out in the bed of the Waiau River effectively forming a hydraulic divide between the mid and lower Waiau catchment;
- Lateral boundaries of the zone follow the approximate QMap contact between Quaternary alluvium and basement/Tertiary sediments
- Zone boundaries are arbitrarily truncated in valley-fill alluvial deposits along major tributaries (e.g. Grove Burn, Camp Creek);
- The southern boundary follows the approximate Topo 50 shoreline along the south coast;
- The boundary between the proposed Te Waewae and Orepuki zones reflects the approximate lateral extent of alluvial deposits associated with the Waiau River.

Tiwai groundwater zone

Status: Existing (RWP)

Area: 2,448 Ha (RWP)

2,407 Ha (pSWLP)



Overview: The Tiwai groundwater zone includes the shallow unconfined groundwater system hosted in barrier beach deposits forming the Tiwai Peninsula.

The aquifer system comprises a thin sequence of barrier beach sand and gravel deposits that overlie lignite measure at shallow depths. The aquifer system is recharged by local rainfall and effectively forms a freshwater lens underlying the peninsula. See Hunt (1977)[37] for a description of the resource (from investigations undertaken for the Tiwai smelter).

Boundary Definition:

- The boundaries of the proposed zone are only adjusted slightly from the existing (RWP) zone to better match the Topo 50 shoreline and exclude small areas extending out into Awarua Bay.

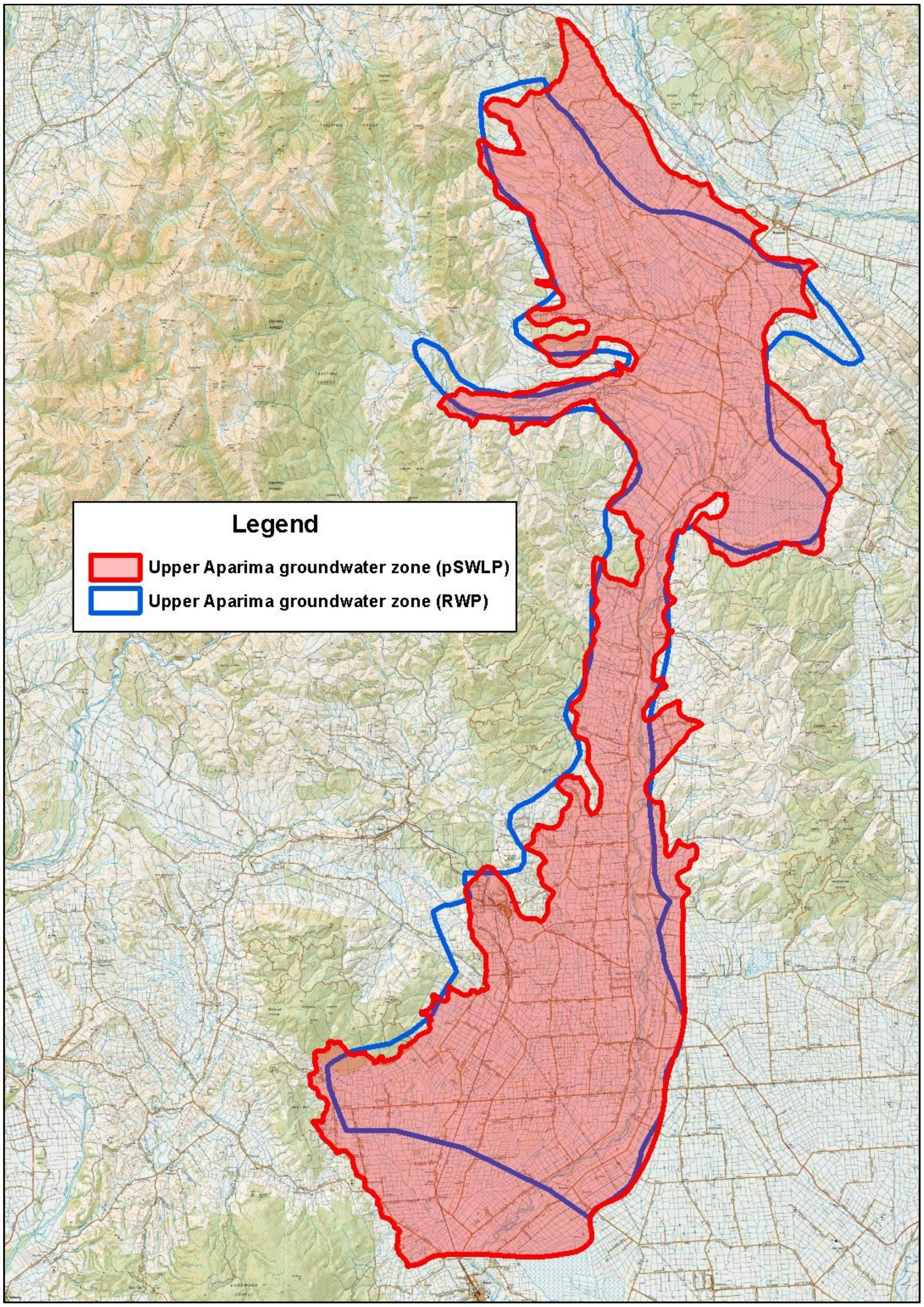
[37] Hunt, B., 1977; Tiwai Peninsula: A groundwater resource analysis. New Zealand Engineering Volume 34, Issue 7 (July 1979)

Upper Aparima groundwater zone

Status: Existing (RWP)

Area: 56,053 Ha (RWP)

49,290 Ha (pSWLP)



Overview: The proposed (pSWLP) Upper Aparima groundwater zone includes the groundwater resource hosted in Quaternary alluvium in the upper reaches of the Aparima River catchment. The groundwater system is recharged by rainfall and infiltration of runoff from surrounding hills. Some limited groundwater/surface water interaction occurs along the tiparian margin of the Aparima River.

Proposed amendments to the existing (RWP) Upper Aparima zone boundary mainly related to improved definition of the extent of alluvial deposits (from QMap) and amendment to the southern extent to better reflect the geological and hydrological transition to the lower catchment.

Boundary Definition:

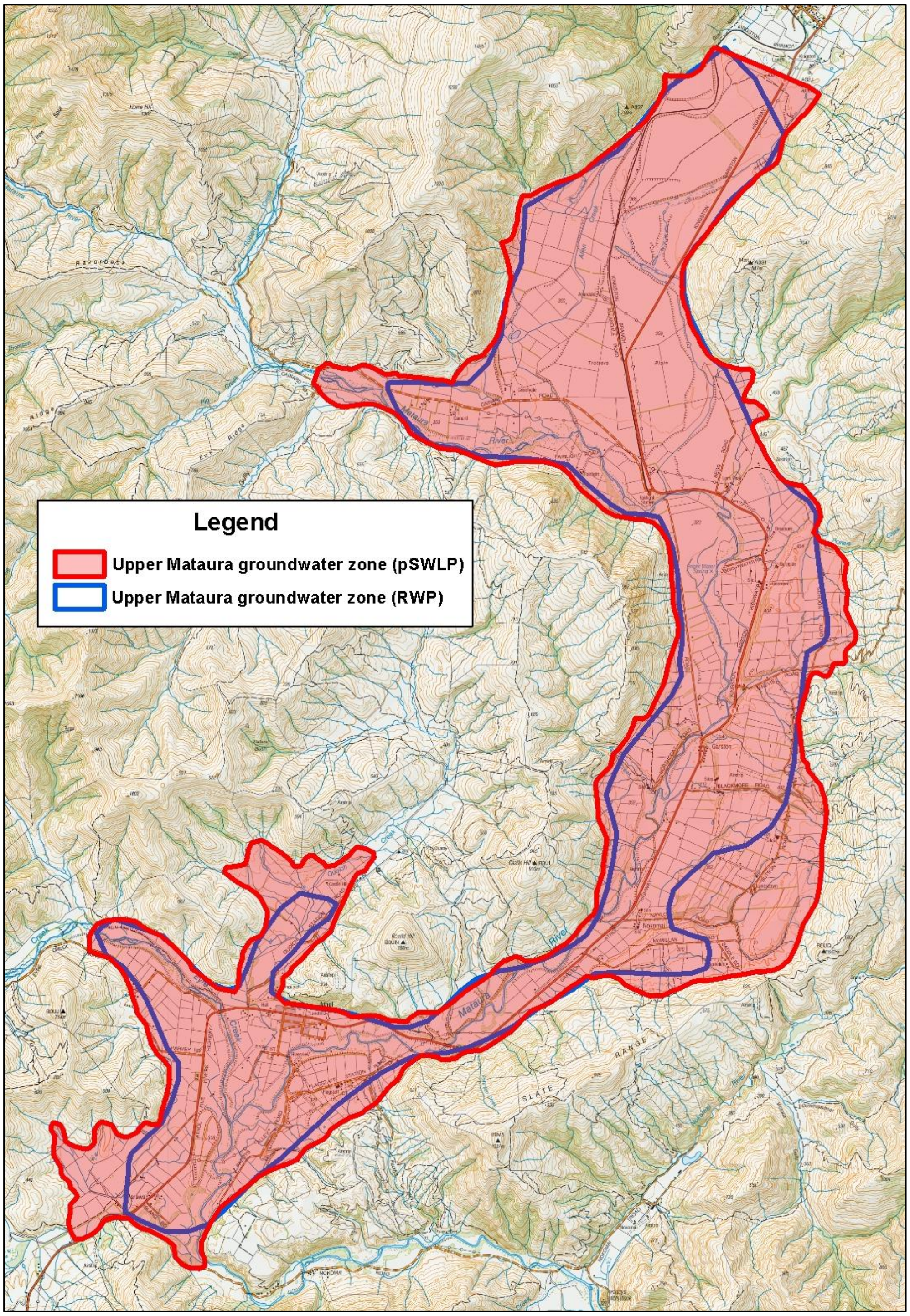
- The northern boundary of the proposed (pSWLP) Upper Aparima groundwater zone is extended north to follow the Q8 terrace edge along the southern margin of the Oreti River valley west of Mossburn;
- The western margin follows the approximate QMap boundary between Quaternary alluvium and Murihuku basement/Tertiary sediments;
- The downstream extent of the proposed zone has been shifted south to an arbitrary boundary across the Aparima River at Yellowbluffs. This boundary approximates the change in geology between the upper (Quaternary alluvium) and lower (alluvium and limestone) catchment areas;
- The eastern margin approximates the catchment divide between the Aparima River and Waimatuku Stream catchments;
- The proposed boundary is extended to include alluvial fans draining into the Castle Downs swamp;
- South of Mossburn it is difficult to determine the location of the flow divide between the Oreti and Aparima catchments at the western end of the Castlerock Terrace. The final boundary follows Qmap (Q2/Q8) boundary rather than the approximate extent of the Murray Creek catchment (recognising there may be some divergence in groundwater flow and surface runoff in this area).

Upper Mataura groundwater zone

Status: Existing (RWP)

Area: 8,235 Ha (RWP)

10,541 Ha (pSWLP)



Overview: The proposed (pSWLP) Upper Aparima groundwater zone includes the groundwater resource hosted in Quaternary alluvium infilling the Upper Mataura Basin.

The Upper Mataura groundwater zone is recharged by a combination of rainfall and infiltration of runoff from the surrounding hills. Significant interaction is observed between surface water and groundwater along the Mataura River and larger tributaries (particularly Eyre Creek). The Upper Mataura zone also includes the largest freshwater spring in the Southland Region (Brightwater Spring) as well as several other streams (e.g. Parawa Creek) which exhibit a high degree of hydraulic connection with the surrounding groundwater resource.

Boundary Definition:

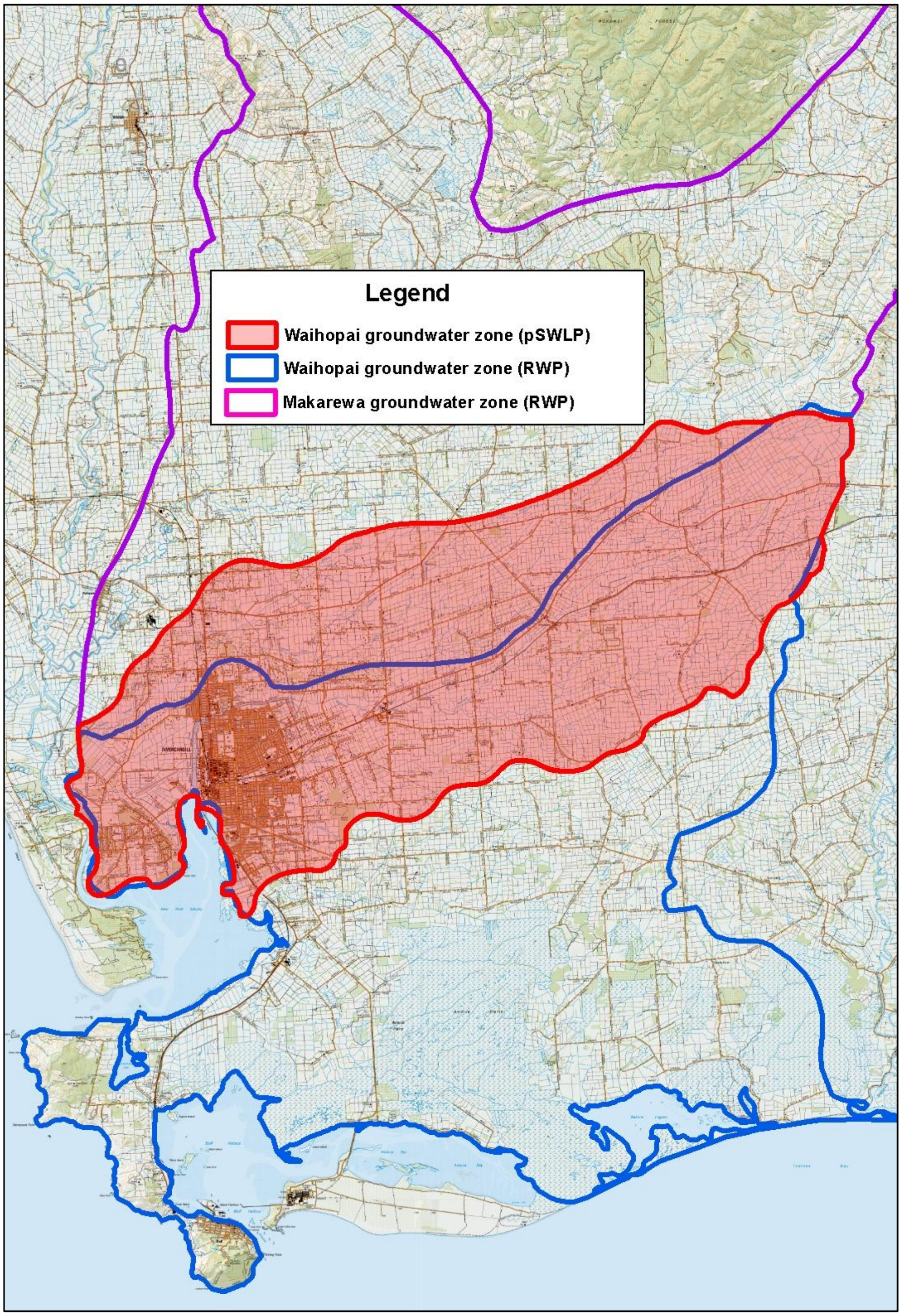
- Proposed amendments to the zone boundary are mainly related to improved definition of the extent of alluvial deposits (from QMap).
- The northern boundary on Trotters Plain is truncated along the Southland Region boundary. Limited throughflow from Lake Wakatipu is inferred to occur through the extensive moraine deposit at Kingston.
- The southern basin is truncated at an arbitrary location across the Mataura River where the alluvial deposits thin through a narrow valley upstream of Parawa (i.e. effectively the downstream hydraulic boundary of a closed basin).

Waihopai groundwater zone

Status: Existing (RWP)

Area: 73,965 Ha (RWP)

41,797 Ha (pSWLP)



Overview: The proposed (pSWLP) Waihopai groundwater zone represents a fundamental re-definition of the existing (RWP) Waihopai zone.

Whereas the existing (RWP) Waihopai zone includes all groundwater resources between the northern boundary of the Waihopai catchment and the south coast, the proposed zone is re-defined to include the groundwater resource hosted in Quaternary alluvium within the Waikiwi Stream and Waihopai River catchments (grouped to reflect similarity in topography, hydrology and hydrogeology). The proposed zone boundary includes part of the existing (RWP) Makarewa zone, but excludes groundwater resources south of the Waihopai catchment (which are included in the proposed Awarua zone).

Groundwater resources in the proposed Waihopai zone are recharged exclusively from local rainfall, with groundwater discharge mainly occurring via baseflow to the surface drainage network (including artificial drains).

Boundary Definition:

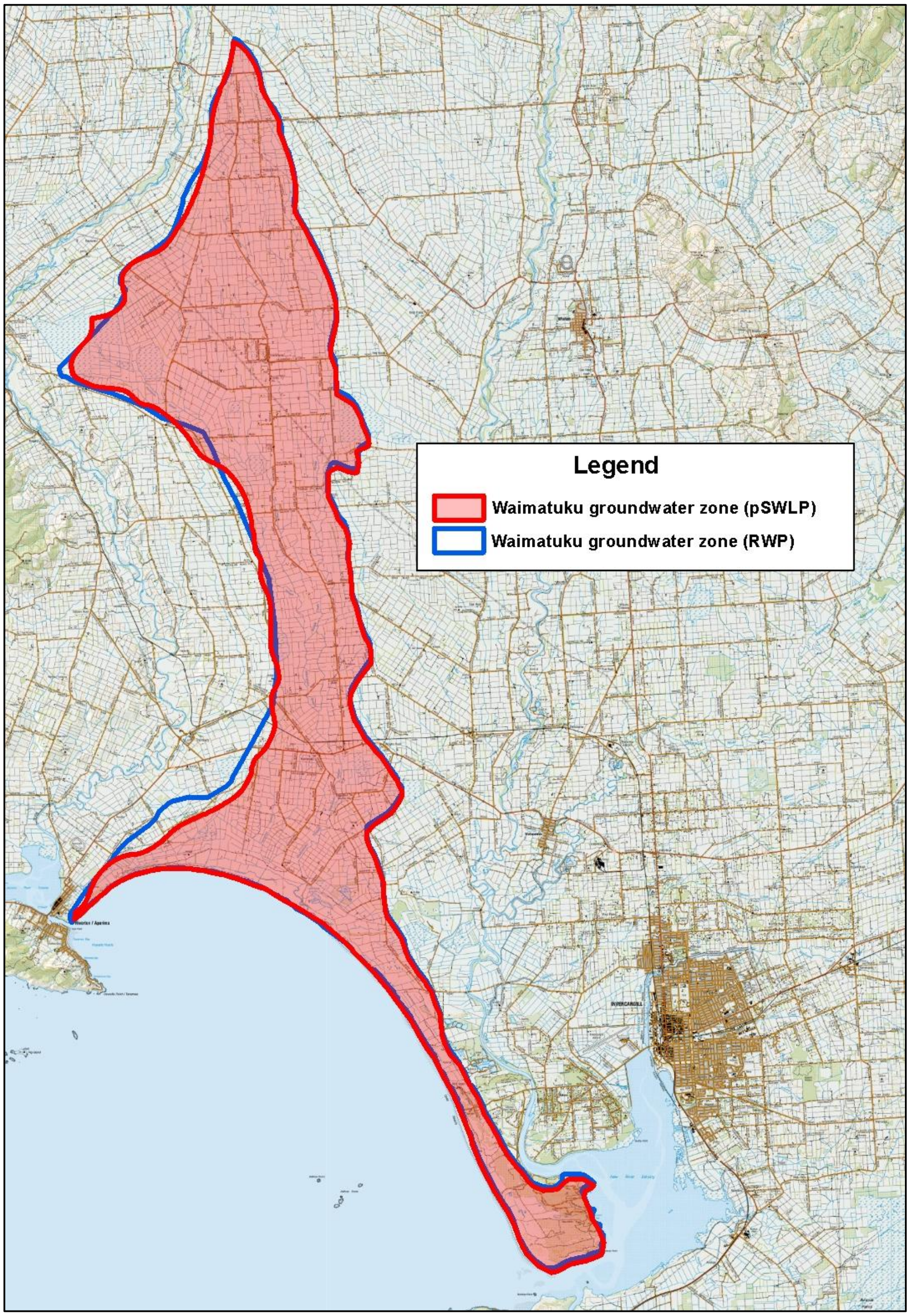
- The northern boundary of the proposed (pSWLP) Waihopai groundwater zone generally follows the northern boundary of 3rd order REC catchments associated with the Waikiwi Stream;
- The southern boundary generally follows the southern boundary of 3rd order REC catchments associated with the Waihopai River;
- The western boundary follows the general alignment of the Oreti River/ Waihopai/Waikiwi catchment boundary;
- The eastern boundary follows the general alignment of the Waihopai/Mataura catchment boundary.

Waimatuku groundwater zone

Status: Existing (RWP)

Area: 26,889 Ha (RWP)

23,678 Ha (pSWLP)



Overview: The proposed (pSWLP) Waimatuku groundwater zone includes the groundwater resource hosted in Quaternary alluvium within the Waimatuku Stream catchment.

The Waimatuku zone occupies a historic channel of the Aparima River when it flow southward from Wreys Bush during the last interglacial (130,000 to 70,000 years BP) before being subsequently diverted westward to its current alignment (Turnbull, *et al*., 2004). The aquifer system comprises a relatively thin layer of reworked alluvium overlying older, stratified gravel deposits in excess of 80 metres thick in the Drummond area. The aquifer system is recharged by local rainfall, with little, if any recharge occurring from the Aparima River. Groundwater discharge occurs via baseflow to the surface drainage network in the Waimatuku catchment.

Boundary Definition:

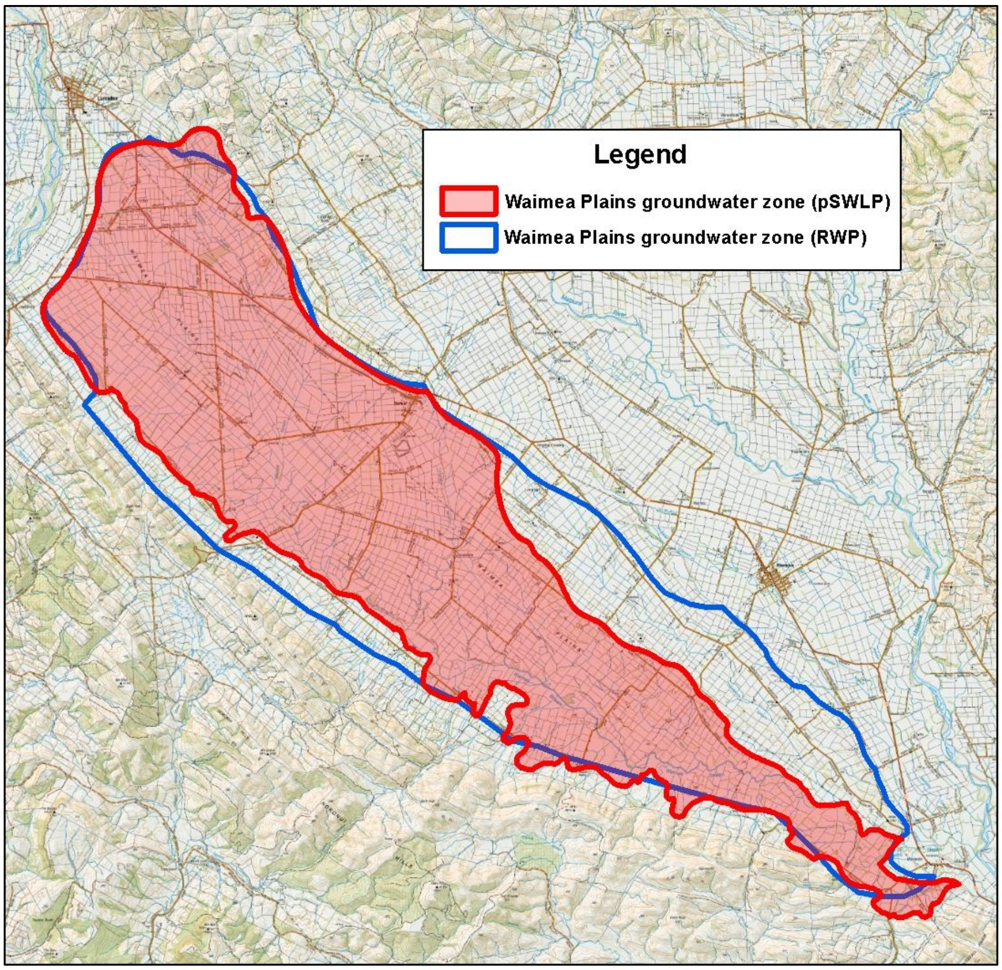
- The boundaries of the proposed Waimatuku groundwater zone are largely consistent with the spatial extent of the existing (RWP) zone and follow the general alignment of QMap boundaries between Q2 alluvium of the Waimatuku floodplain and older (Q6-Q8) forming elevated terraces to the east and west;
- The western boundary follows the general alignment of the Waikiwi Terrace which comprises a thin veneer of Q8 alluvium overlying Forest Hill Formation limestone. Some springs occur along this margin suggesting possible throughflow of groundwater from the limestone deposits into the Waimatuku catchment along this area;
- The southern margin extends in a south-east direction along the coastal margin following the Waikmatuku Stream catchment boundary. This area comprises Q1 sand deposits that are likely to be hydraulically connected to wetlands and lakes (e.g. Lake Murihiku) in the Oreti catchment with discharge occurring through the surface water catchment boundary to the south coast.

Waimea Plains groundwater zone

Status: Existing (RWP)

Area: 25,200 Ha (RWP)

19,680 Ha (pSWLP)



Overview: The proposed (pSWLP) Waimea Plains groundwater zone extends across the Waimea Plain from the Oreti River to Mandeville (covering a majority of the Waimea Stream catchment).

East of Sandstone, the zone narrows reflecting the presence of a basement ridge which obliquely crosses the eastern end of the Waimea Plain following a north-west/south-east alignment. This structure forms a flow divide between older (Q8/Q10) alluvial terraces in the Longridge/Sandstone area and the Q2-Q6 alluvium of the Waimea Plain to the south, and effectively diverts groundwater flowing down the Waimea Plain southwards toward the Waimea Stream.

West of St Patricks the aquifer system comprises a thin, unconfined aquifer and a deeper, semi-confined water-bearing layer (previously referred to as the Lintley Aquifer).

The groundwater system is primarily recharged by local rainfall and infiltration of runoff from the surrounding hills. The specific yield of the Waimea Stream catchment does not indicate any appreciable throughflow from the Oreti catchment. Groundwater discharge occurs via baseflow to the Waimea Stream.

Boundary Definition:

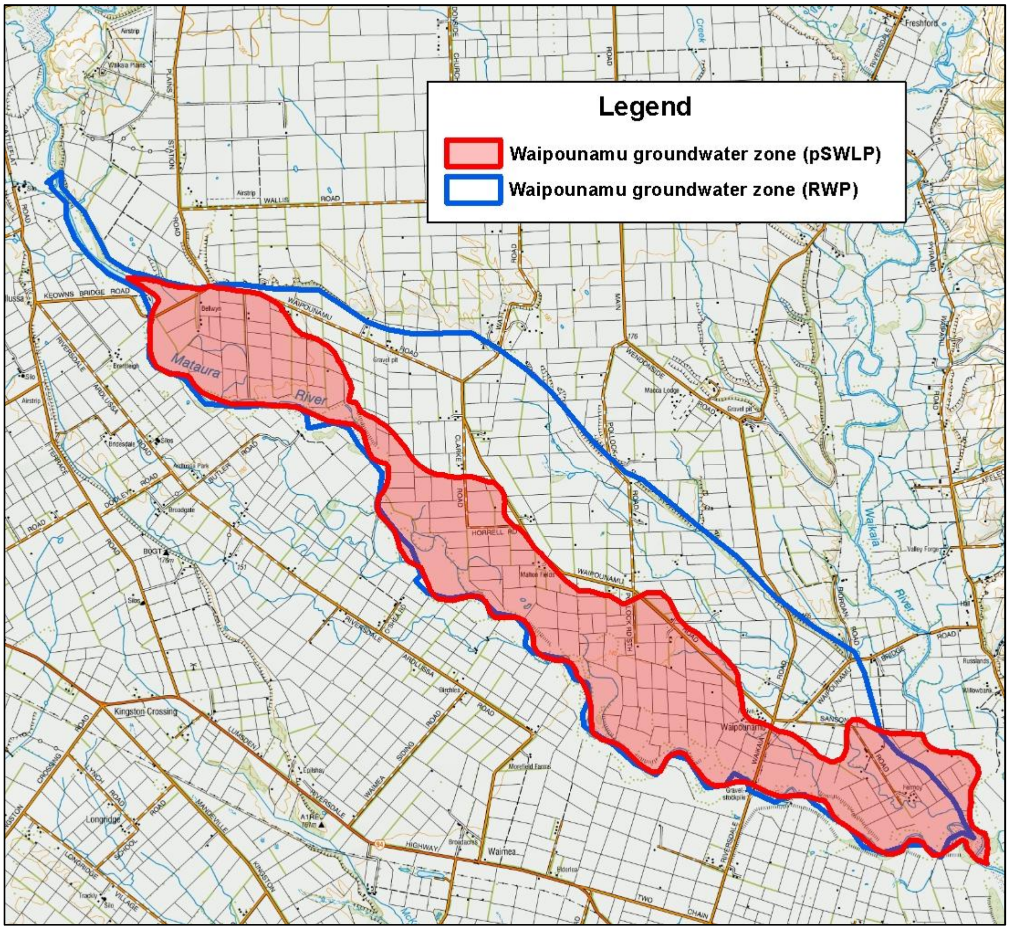
- The main changes to the boundary of the proposed (pSWLP) Waimea Plains groundwater zone reflect use of the Qmap geological coverage to improve definition of the spatial extent of Quaternary alluvium and the exclusion of the Sandstone Stream catchment (noew included in the proposed Longridge groundwater zone);
- The southern boundary follows the approximate QMap contact between alluvial fan deposits and Murihiku basement along the foot of the Hokonui Hills;
- The western boundary approximates the hydrological boundary between the Oreti River and Waimea Stream catchments and which is assumed to approximate the groundwater flow divide in the shallow unconfined aquifer. However, the deeper water-bearing layer is observed in bores located in the area between SH6 and the Oreti River. This may reflect the influence of the Lumsden Fault hydrogeology and sediment accumulation during the Late Quaternary (see Blakemore (2002)) and suggests that the flow divide between the Waimea Stream and Oreti River catchments is relatively complex and may occur at different locations in shallow and deep water-bearing layers;
- West of Balfour, the northern boundary approximates the QMap alluvium/basement contact. East of Balfour the boundary is modified to follow the approximate axis of the bedrock ridge which crosses the valley forming a flow divide between the Waimea Stream to the south and older alluvial terraces (which drain to the Mataura River catchment) to the north.

Waipounamu groundwater zone

Status: Existing (RWP)

Area: 3,213 Ha (RWP)

1,743 Ha (pSWLP)



Overview: The proposed (pSWLP) Waipounamu groundwater zone encompasses the riparian (i.e. hydraulically connected) aquifer on the true left (northern) bank of the Mataura River between Ardlussa and the Waiakai River confluence.

The existing (RWP) Waipounamu zone encompasses the entire width of the lower Q2 alluvial terrace adjacent to the Mataura River. However, the northern portion of this area has been transferred into the proposed Wendonside zone to the north. Recent drilling investigations have shown that highly permeable water-bearing layers underlying the Wendonside Terrace (formerly referred to as the Garvie Aquifer) in places extend south of the southern margin of the Wendonside Terrace (but not as far as the Mataura River). Along the northern margin of lower Q2 terrace, aquifer testing shows the deeper water-bearing layers are hydraulically connected to the overlying unconfined aquifer (possibly due to the removal of some of the overlying aquitard materials during late Quaternary entrenchment of the Mataura River).

The modified boundary of the Waipounamu groundwater zone separates the Q2 terrace into two areas. The northern section (included in the proposed Wendonside zone) exhibits limited hydraulic connection to the Mataura River (as illustrated by the hydrograph from the Waipounamu Aquifer at Waipounamu Road groundwater monitoring site) and has the potential to be influenced by abstraction from the deeper water-bearing layers. Closer to the Mataura River, groundwater exhibits a higher degree of hydraulic connection to the river (illustrated by the hydrograph from the Waipounamu Aquifer at Sanson Road monitoring site), and deeper water bearing layers (i.e. those underlying the Wendonside Terrace) appear to be absent.

Boundary Definition:

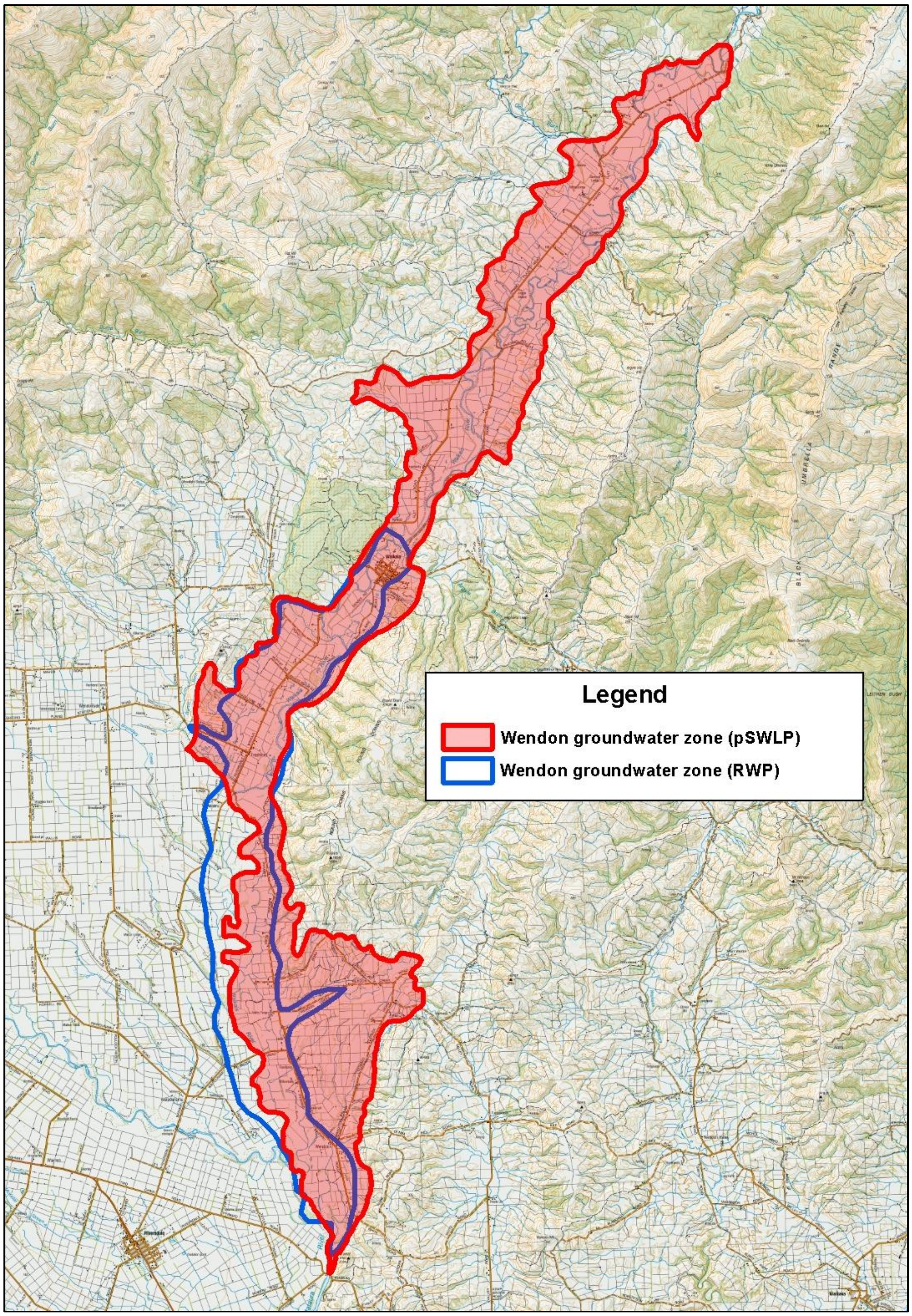
- The southern boundary of the proposed (pSWLP) Waipounamu zone follows the approximate alignment of the Mataura River;
- The northern boundary is somewhat arbitrary given the uncertain extent of the deeper water-bearing layers so follows the boundary between Mataura and Riversdale soils (reflecting more recent fluvial influence) and Gore soils to the north.

Wendon groundwater zone

Status: Existing (RWP)

Area: 4,066 Ha (RWP)

8,995 Ha (pSWLP)



Overview: The proposed (pSWLP) Wendon groundwater zone encompasses the groundwater system hosted in Q1 Q2, and Q2-Q4 alluvial deposits underlying a majority of the floodplain of the Waikaia River between Piano Flat and the Mataura River confluence.

The alluvial deposits of the Waikaia Valley typically exhibit different hydraulic characteristics (lower permeability) compared to equivalent deposits in the Mataura catchment (possibly due to a higher fines content reflecting proximal origin in schist terrain of the Garvie Mountains and Old Man Range). As a result, the hydraulic connection between the Waikaia River and adjacent groundwater is significantly lower than that observed in the mid-Mataura catchment.

The groundwater resource is inferred to be primarily recharge by rainfall and infiltration of runoff from the surrounding hill country, with the Waikaia River exerting a limited influence on the shallow unconfined aquifer (apart from during high stage flow events).

Boundary Definition:

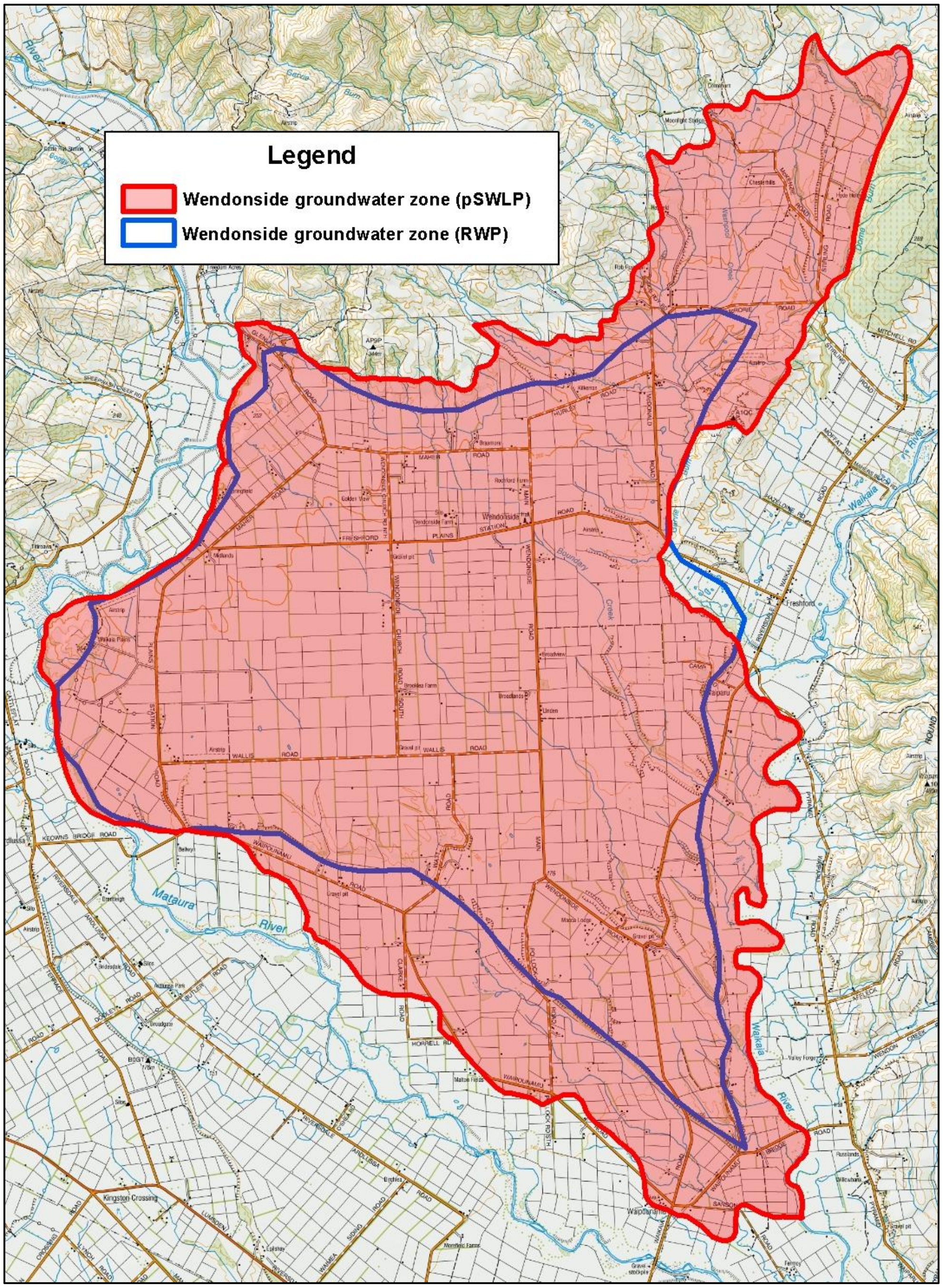
- The main modifications to the boundary of the proposed (pSWLP) Wendonside zone boundary are the extension of the zone to include alluvial deposits in the Waikaia Valley at far north as Piano Flat and re-definition of the western boundary south of Freshford.
- South of Freshford the zone boundary has been redefined to follow the approximate alignment of the Waikaia River channel. Areas on the true right (western) bank of the Waikaia River are now included in the proposed Wendonside groundwater zone to reflect the potential for significant throughflow of groundwater from the Wendonside Groundwater zone into the lower reaches of the Waikaia River;
- Elsewhere the zone boundary has been adjusted to follow the approximate QMap contact between alluvial deposits and Caples Group basement/cover rocks. This change has resulted in a significant increase in the groundwater zone area in the Wendon Creek and Garvie Creek catchments.

Wendonside groundwater zone

Status: Existing (RWP)

Area: 8,769 Ha (RWP)

12,968 Ha (pSWLP)



Overview: The proposed (pSWLP) Wendonside groundwater zone includes the area underlain by water-bearing sediments associated with the Wendonside Terrace.

The Wendonside groundwater zone forms a complex geological and hydrogeological setting which reflects:

- a basement ridge along the eastern margin of the Wendonside Terrace
- large alluvial fans extending out from the Garvie Mountain foothills to the north
- the presence of Tertiary lignite measure sediments at relatively shallow depths under north-eastern and south-western area of the Wendonside Terrace
- multiple, highly permeable water-bearing layers under the southern portion of the terrace extending under the northern margin of the Mataura River floodplain (possibly infilling a paleochannel-type structure);

To better reflect this environmental setting, the existing (RWP) Wendonside zone boundary has been modified to reflect:

- the spatial extent of water-bearing alluvium in the Washpool Creek/Dome Burn catchments;
- extension of deeper, highly permeable water-bearing layers underlying the south-western quadrant of the Wendonside Terrace onto the northern margin of the Q2 alluvial terrace to the south; and
- the limited (ephemeral) surface runoff from the Wendonside Terrace surface and the potential for significant throughflow from the Wendonside groundwater zone into the lower reaches of the Waikaia River.

Boundary Definition:

- The southern boundary of the proposed (pSWLP) zone has been modified to reflect the presence of deeper, hydraulically connected water-bearing layers along the northern terrace margin and the extent of riparian influence along the Margin of the Mataura River. In the absence of more definitive criteria soil types have been used to identify the most likely extent of riparian influence;
- The eastern margin south of Freshford has been re-defined to follow the approximate alignment of the Waikaia River to reflect the potential contribution of throughflow from the Wendonside zone to baseflow in the lower reaches of the Waikaia River. North of Freshford the western boundary follows the approximate extent of Caples Group basement outcrops;
- The northern boundary floows the approximate QMap alluvium/basement contact along the Garvie foothills;

- The western margin follows the terrace riser demoting the boundary between Q2 alluvium of the Mataura valley and Q6-Q8 alluvium of the Wendonside Terrace.