Surface Water and Groundwater Relationships in the Mataura Catchment above Gore

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1 Executive Summary

Environment Southland monitors groundwater and surface water resources through a number of programmes, many of which have only been developed since 2001 in response to a significant increase in water demand and Environment Southland's Proposed Regional Water Plan. This report is intended to summarise the current state of knowledge of groundwater and surface water relationships in the Mataura catchment above Gore based primarily on data collected over the past seven years. This report will also supplement a groundwater modelling study currently being undertaken with Phreatos Limited to address management of stream depletion effects from groundwater abstraction.

Discharge from the Eyre Creek catchment and run-off from the Eyre Mountains make up the bulk of the flow measured in the Mataura River at Parawa during medium flows. In the Mataura catchment headwaters, Roberts Creek and the Mataura River above their confluence contribute approximately 20 percent each of the flow at Parawa. As flows in the catchment decrease during periods of low rainfall, the contribution of catchment run-off also diminishes until the Brightwater Spring and net groundwater drainage become the largest components of river base flow, contributing approximately 30 percent each of the flow at Parawa. The balance of the low flow is comprised of the return of lost surface water flow, principally from the Mataura River near Fairlight and other creeks such as Eyre Creek, which lose flow as they cross the alluvial floodplain. A small component of the overall water balance is also contributed by a number of small springs like Parawa Creek.

During dry periods base flow in the Waikaia River downstream of Mahers Beach is maintained by a combination of discharge from the upper reaches of the catchment and groundwater drainage. Approximately 70 percent of the flow in the Waikaia River at its confluence with the Mataura River is sourced from the Waikaia catchment above Mahers Beach while 25 percent comes from groundwater infiltration directly into the bed of the Waikaia River. Approximately half of the groundwater drainage occurs in the relatively short reach downstream of the Waipounamu Bridge Road and this is interpreted to represent groundwater drainage predominantly from the Waipounamu groundwater zone. The remaining flow is comprised of run-off and groundwater discharge into relatively small tributaries such as the Garvie Burn and Wendon Creek.

Downstream of Cattle Flat, the Mataura River loses and gains flow depending on the relative head difference between the water table and river stage height. Between Ardlussa and the Riversdale Bridge the Mataura River loses up to 30 percent of its flow predominantly southwards into the Riversdale groundwater zone. Downstream of the Riversdale Bridge, the Mataura River, slowly then more rapidly below Pyramid, gains flow through groundwater discharge.

The Riversdale groundwater zone is drained by a number of spring-fed streams that run in a southerly direction across the floodplain, gaining flow continuously along their reaches, the best known of which is the Meadow Burn. These springs discharge up to 700 l/sec of groundwater from the Riversdale groundwater zone into the Mataura River.

Numerous small springs also occur along the base of the Longridge terrace, the largest of which is the McKellar Stream, and flow in a south-easterly direction. These springs are perched above the water table upstream of Riversdale and are typically not gaining springs due to stream bed clogging.

Flow gains in the Mataura River downstream of Riversdale represent the return of lost surface water flow and groundwater discharge via springs and direct groundwater infiltration into the river bed. In total, groundwater discharge constitutes up to 40 percent of the flow measured at Gore during extended periods of flow recession.

The riparian aquifers surrounding the Mataura and Waikaia Rivers are important contributors to base flow acting as both a source of water and a receiving environment for surface water drainage. In addition, springs are a significant component of the water balance in the Mataura River during low flow periods. While the overall water balance in the Mataura catchment upstream of Gore has now been established, it is important Environment Southland continues to quantify groundwater and surface water exchanges in order to ensure resource development is managed in a way that ensures surface water values are protected.

2 Introduction

The Mataura River catchment is one of the 10 largest catchments in New Zealand and has long been recognised as one of New Zealand's top rivers for recreational fishing, particularly for brown trout. The river has also been an important source of water for industry downstream of Gore. Over 70 percent of the catchment has been developed for farming and between 1940 to 1980 there was widespread willow clearing, channel straightening and artificial drainage installed throughout the catchment (Poole, 1990) which significantly altered the catchment hydrology in many areas. In 1984, the Acclimatisation Societies applied for a National Water Conservation Order to preserve the stability and quality of the Mataura River and its tributaries, and ensure its outstanding biological and recreational features were protected (Riddell, 1984). In 1997, the Water Conservation (Mataura River) Order came into effect and established minimum water quality standards along with a maximum water allocation threshold of five percent of the naturalised flow in the Mataura and Waikaia Rivers.

At the time the Mataura Conservation Order (MCO) was introduced, groundwater abstraction in the catchment was limited to a small number of domestic and industrial takes and a few public supply wells located in close proximity to the Mataura River. This changed dramatically after 2001 when over a four year period demand for groundwater in Southland increased eight-fold. This was primarily driven by pasture irrigation development in northern Southland, over two-thirds of which is located in the Mataura catchment. This significant increase in demand for groundwater in Southland led to increasing concern over the potential effects groundwater abstraction could have on surface water flows, particularly with regard to the minimum flow criteria set out in the MCO. It became increasingly apparent that interaction between groundwater and surface water bodies within the catchment was relatively complex and needed to be better understood in order to ensure surface water flows were not adversely impacted by groundwater abstraction.

In 2001, Environment Southland established a gauging programme to investigate water balances within catchments. A spring discharge programme was also established to measure the temporal range of groundwater discharge. The primary objective of this report is to review, analyse and summarise data from these monitoring programmes in the Mataura catchment above Gore, and to provide some direction for future monitoring priorities.

This report will also form an important component to the numerical groundwater model currently being developed as a tool for managing stream depletion effects resulting from groundwater abstraction in the mid-Mataura catchment.

The Mataura River, its tributaries and key sites for the study area are shown in Figure 1.

Figure 1: Location map

In 2003, Southland was delineated into 17 surface water management zones and 27 groundwater management zones (Lincoln Environmental, 2003). The management zones were delineated on the basis of catchment boundaries and areas of similar geographical and geological features and form the basis of water resource management in Environment Southland's Proposed Regional Water Plan. The surface water zones generally have a long-term flow recorder site at the downstream end which represents the zone's overall discharge.

This report has been structured around the three surface water management zones in the study area, as shown in Figure 2. It is important to note that of the 10 groundwater zones within this area, this report only includes those groundwater zones that are hydraulically connected to the Mataura and Waikaia Rivers i.e. the Upper Mataura, Cattle Flat, Wendon, Wendonside, Riversdale, Waipounamu and Knapdale groundwater zones.

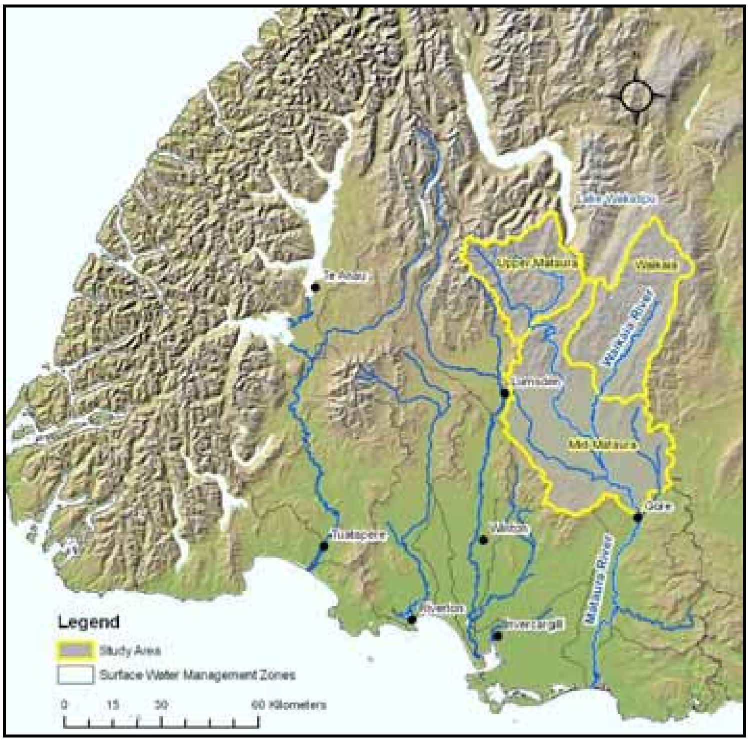

Figure 2: Water resource zones

The Upper Mataura surface water resource zone covers an area of 801 square kilometres and extends from the Eyre Mountains to the south and west of the southern arm of Lake Wakatipu to the western slopes of the Garvie Mountains and down to the Nokomai Gorge. A majority of the area is covered by alpine and high country tussock lands, however, dry stock farming and cropping occurs on the floodplain of the Mataura River.

The Waikaia surface water resource zone covers the Waikaia catchment downstream of Environment Southland's flow site at Mahers Beach (near Freshford). For the purposes of this report, the surface water resource zone has been extended down to the confluence of the Waikaia and Mataura Rivers, which covers an area of 1,830 square kilometres. The catchment is mostly covered by tall tussock grassland and indigenous forest north of Waikaia and pasture to the south. This report focuses on the portion of the Waikaia catchment below Freshford, where the Waikaia River moves across the alluvial floodplain towards its confluence with the Mataura River.

The mid-Mataura surface water resource zone extends downstream from Parawa to Gore and covers an area of approximately 950 square kilometres. The area extends from the hill country of the Mataura Ranges and the western slopes of the Garvie Mountains southwards to the Hokonui Hills. Agriculture is the predominate land use including intensive dairy, sheep and beef farming and cereal cropping.

3 Environmental Setting

3.1 *Upper Mataura Surface Water Resource Zone*

The headwaters of the Mataura River cover the area of the Eyre Mountains to the south and west of the southern arm of Lake Wakatipu and drains the western slopes of the Garvie Mountains which divide the Mataura and Waikaia catchments. The Mataura River upstream of Parawa has a total catchment area of 801 square kilometres, a majority of which is occupied by alpine and/or high country tussock lands. Jane Peak at 2,022 metres marks the highest point in the Mataura catchment and forms the north-western boundary of the Mataura catchment.

There is only one mapped groundwater zone in the upper Mataura catchment, also named Upper Mataura, as shown in Figure 3.

Figure 3: **Key topographical and hydrological features of the Upper Mataura surface water resource zone**

The boundary of the Upper Mataura groundwater zone is limited to the Quaternary outwash gravel terraces and recent alluvial fan deposits on the surrounding hills. These gravels infill an intermountain basin formed by Cenozoic fault movement. The Moonlight fault scissors across Lake Wakatipu and runs south through the

Eyre Mountains, while the Nevis-Cardrona fault runs along the eastern edge of Slate Range to Saddle Road about 3 km south of Garston. The effects of the faults are particularly evident at the southern end of the valley where the Mataura River is diverted through a narrow gorge at Parawa.

Although there are relatively few bore logs, available data indicates gravel deposits are over 30 metres thick and are comprised of a sequence of relatively coarse, poorly sorted, alluvial gravel and sand. The alluvial gravels have a relatively high permeability as illustrated by the significant interaction between surface and groundwater resources.

Groundwater within the upper Mataura groundwater zone discharges directly into the Mataura River via numerous springs like the Brightwater Spring and Parawa Creek. The aquifer is recharged from rainfall, run-off, surface water discharge and side slope infiltration from the surrounding hills and Trotters Plain to the north. Although regular groundwater level monitoring has only begun recently in this area (see Table 2), groundwater level fluctuations to date are typical of a riparian aquifer (see Section 4.3).

Major tributaries in the upper Mataura catchment include Roberts and Allen Creeks which drain the Eyre Mountains to the west of Kingston, Eyre and Quoich Creeks which flow into the Mataura River downstream of Athol, and Parawa Creek which flows into the Mataura River immediately above the Nokomai Gorge.

The major spring in the upper Mataura catchment is the Brightwater Spring located on the true right bank of the Mataura River, upstream of Garston. This spring originates along the base of an alluvial terrace and accounts for approximately half of the total discharge from the upper catchment during times of low flow.

3.2 *Waikaia Surface Water Resource Zone*

The headwaters of the Waikaia River drain the southern slopes of the Old Man Range to the north, the Garvie Mountains to the west and the Umbrella Mountains to the east. The Waikaia River has a total catchment area of 1,830 square kilometres, a majority of which is covered by tall tussock grassland and indigenous forest north of Waikaia and pasture to the south. This report focuses on the portion of the Waikaia catchment below Freshford, where the Waikaia River moves across the alluvial floodplain towards its confluence with the Mataura River.

There are two groundwater zones in the Waikaia surface water resource zone:

- the Wendon and Wendonside groundwater zone, and
- the Waipounamu groundwater zone, which is in both the Mid-Mataura and Waikaia surface water resource zones, as shown in Figure 4.

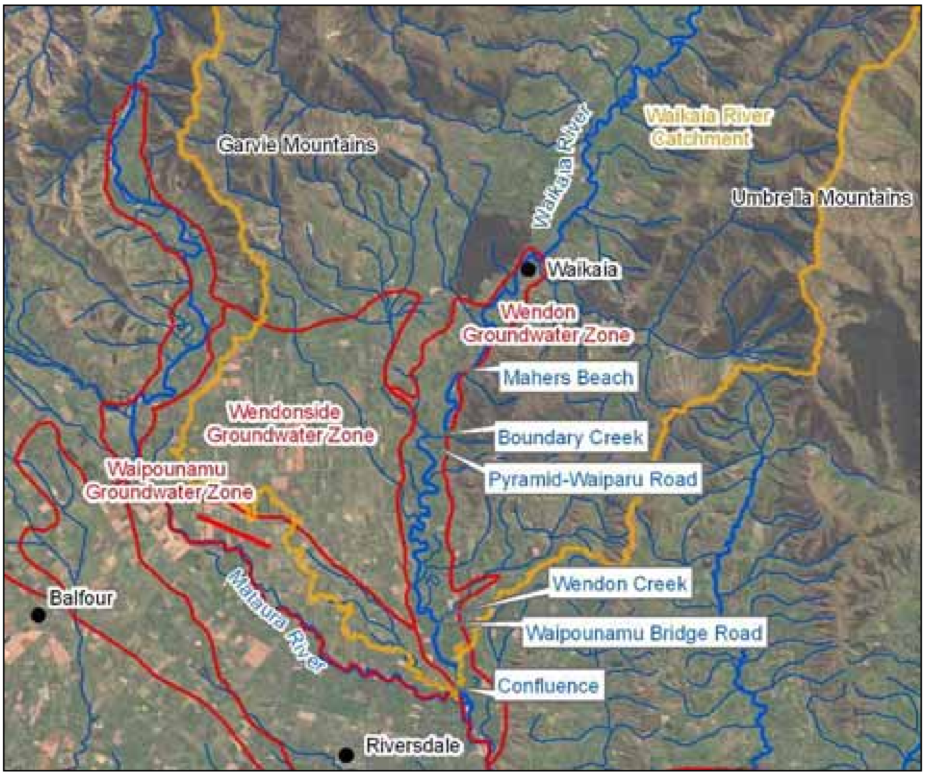

Figure 4: Key topographical and hydrological features of the lower Waikaia River catchment

The Wendon groundwater zone encompasses the floodplain terrace adjacent to the Waikaia River. The eastern boundary follows along the base of the Umbrella Range and includes the Wendon Stream and Pyramid Creek catchments. The western boundary follows the base of the large remnant Quaternary gravel terrace which forms the Wendonside groundwater zone. The Waipounamu groundwater zone extends from the southern edge of the Wendonside terrace to the Mataura River. These non-conforming gravel deposits of the groundwater zones overlie Tertiary sediments of the eastern Southland group.

Bore log and pumping test data show the three groundwater zones have distinct hydrogeology. The alluvial gravel deposits in the Waipounamu groundwater zone contain a relatively low percentage of clay and silt reflecting significant reworking of older Quaternary gravel deposits by the Mataura River. The extent and depth of reworked gravels appears to diminish with proximity to the Waikaia River. The sediment deposits of the Wendon groundwater zone are poorly sorted containing a much higher percentage of fine mud and silt in the gravel matrix.

In some locations, semi-confined aquifer conditions are exhibited due to the presence of laterally continuous clay-bound gravel layers. The significant difference in the character of the gravel deposits of the Wendon and Waipounamu groundwater zones may reflect the schistose geology of the Waikaia catchment compared to the greywacke dominated headwaters of the Mataura catchment.

The Wendonside groundwater zone is comprised of Quaternary gravels which have a much lower permeability than the Recent gravels in the Waipounamu groundwater zone. Anecdotal reports indicate the thickness of the gravel deposits in the Wendonside groundwater zone is highly variable which may indicate the presence of a paleochannel or highly channelised gravels running in a north-west/south-easterly direction. This pattern is also evident in the soil data. The Livingston fault runs parallel to the Hokonui Hills beneath the Mataura and Waikaia River's confluence. The effect of this fault on catchment geometry is unknown.

Through flow from the Wendonside terrace and discharge from the riparian aquifers in the Wendon and Waipounamu groundwater zones provides most of the discharge to the Waikaia River. Groundwater recharge is sourced from rainfall, side slope infiltration from the Umbrella and Garvie Mountain Ranges and surface water discharge where the streams emerge onto the floodplain and Wendonside terrace.

Major tributaries in the Waikaia catchment include the Dome Burn, Garvie Burn, Gow Burn, Steeple Creek, Argyle Burn, Steven Burn, Winding Creek, Wendon Stream and Welshman's Creek. All of these tributaries, except for Wendon Stream and Garvie Burn, enter the Waikaia River upstream of Mahers Beach and are therefore outside the area of interest for this report.

3.3 *Mid–Mataura Surface Water Resource Zone*

The Mid-Mataura water resource zone extends downstream from Nokomai to Gore and covers an area of approximately 2,000 square kilometres. The catchment covers the hill country of the Mataura Range and the western slopes of the Garvie Mountains and extends across the Waimea Plains to the Hokonui Hills.

There are six groundwater zones in the mid-Mataura surface water resource zone – Cattle Flat, Longridge, Waimea Plain, Riversdale, Knapdale and Chatton groundwater zones, as shown in Figure 5. The Waipounamu groundwater zone straddles both the mid-Mataura and Waikaia surface water resource zones and for the purposes of this report, is included in the Waikaia catchment summary.

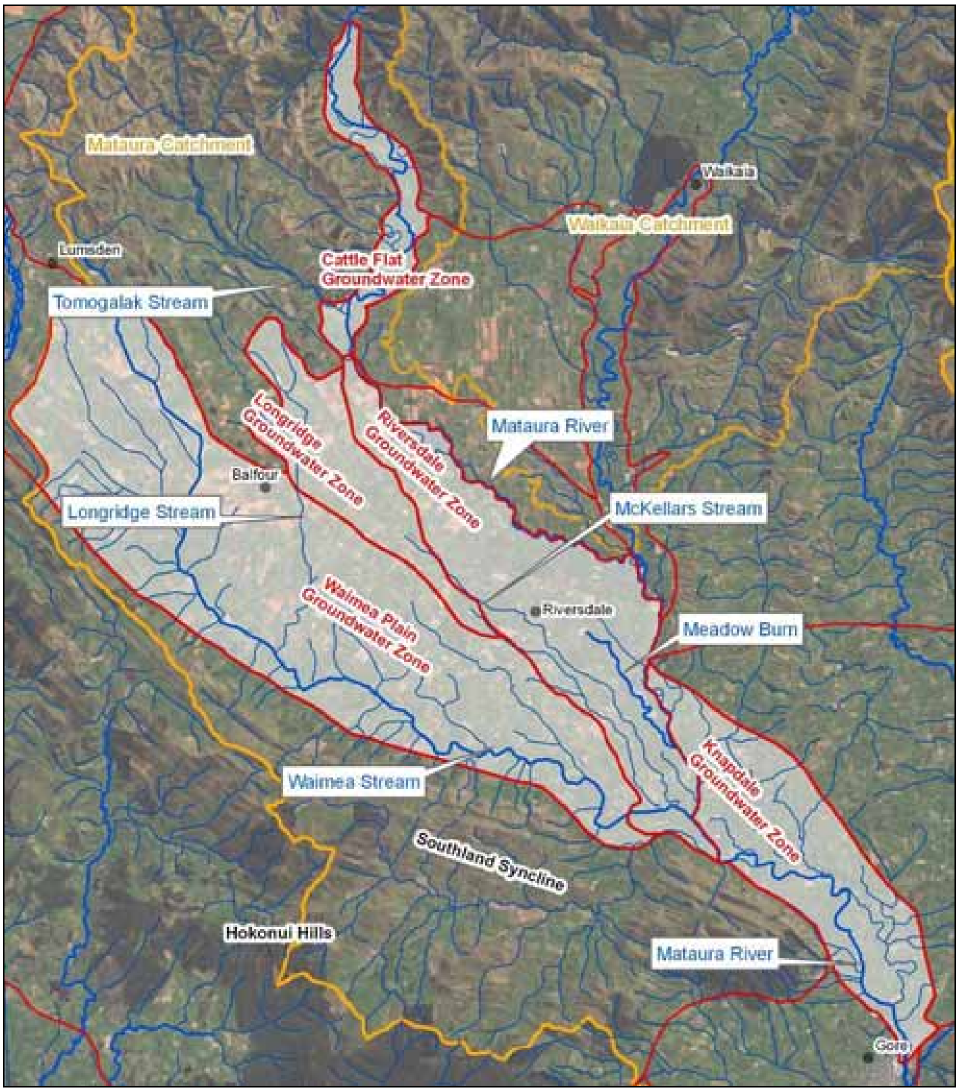

Figure 5: Key topographical and hydrological features of the Mid-Mataura surface water resource zone

The Cattle Flat groundwater zone encompasses the narrow, confined valley upstream of Ardlussa to the Nokomai Gorge. There are few bore logs available for the area and even fewer pumping test data so aquifer yields and lithology are largely uncertain. What information exists shows a sequence of sandy gravel overlying claybound gravels which is common in the alluvial aquifers within the Mataura catchment. While there is likely to be a significant degree of interaction between the Mataura River and adjacent riparian aquifer, through flow to the Riversdale and Waipounamu groundwater zones is probably limited due to the channelling of the river between two basement outcrops immediately upstream of Ardlussa.

The Riversdale groundwater zone encompasses the Recent floodplain terrace on the true right bank of the Mataura River between Ardlussa and the Otamita Bridge. The northern boundary follows the main channel of the Mataura River while the southern boundary follows the prominent alluvial terrace which marks the outer boundary of the Mataura floodplain.

The thickness of the moderate to poorly sorted claybound gravels ranges from 30 metres west of Riversdale to less than 10 metres near Mandeville. The gravels have a significant through flow as evident by the large scale irrigation in the area, although there is a high degree of variability with hydraulic conductivity generally reducing away from the river. This is assumed to reflect depositional processes with greater reworking and fine sediment removal in the area adjacent to the current river channel.

Piezometric survey results shown in Figure 6 show flow is lost from the Mataura River to the Riversdale groundwater zone south of Ardlussa, while downstream of Pyramid the relative gradient is reversed with contours indicating groundwater discharge to the river. The piezometric contours also indicate drainage of groundwater from the Longridge groundwater zone to the Riversdale groundwater zone. This through flow is assumed to constitute a relatively minor part of the overall water balance as the older Quaternary gravels in the Longridge groundwater zone have much lower hydraulic conductivity.

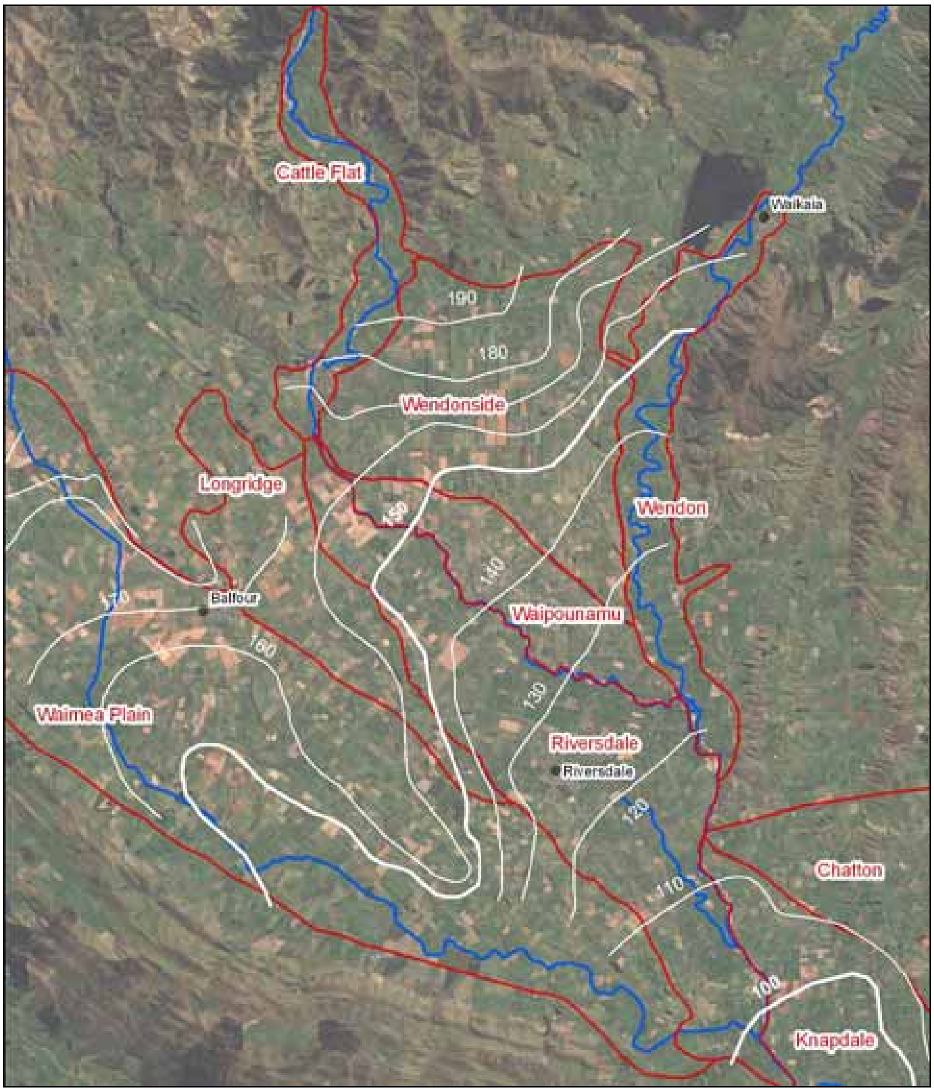

Figure 6: Groundwater piezometric contours from 2004 surveying

In the vicinity of Otamita, basement rock (assumed to be Murihiku) occurs within 3-4 metres of the surface and effectively separates the Knapdale groundwater zone from the upstream Riversdale groundwater zone. The Knapdale groundwater zone encompasses the floodplain on the eastern side of the Mataura River between Pyramid and Gore. The northern boundary follows the large terrace that marks the older Quaternary gravel terrace remnants along the southern margin of the Chatton groundwater zone. The Quaternary gravels within the Knapdale groundwater zone are comprised of relatively thin deposits of recent river gravels overlying older weathered Quaternary gravels which have previously been prospected and dredged in places for gold. The permeability of the gravels varies with the more recently deposited and reworked gravels having higher permeability thus creating preferential flow paths. Aquifer thickness is also variable, ranging from approximately 10-40 metres, with the thicker gravels tending to occur toward the northern margin. This may reflect a paleochannel developed on the upper surface of the Tertiary sediments during historical river entrenchment.

The main tributaries in the mid-Mataura catchment include the Waimea and Waikaka Streams along with a large number of smaller tributaries such as the Otama, Tomogalak, Otamita and Pukerau Streams. There are a number of smaller springs which start along the base of the Longridge terrace like the McKellar Stream, and numerous contact springs which originate in the Riversdale groundwater zone, the best known of which is the Meadow Burn. The springs drain into the Mataura River towards Mandeville.

The downstream extent of the Mid-Mataura surface water resource zone occurs at Gore where the river is confined to a narrow channel cut into the basement rock of the Murihiku terrace which comprises the Hokonui Hills.

4 Overview of Catchment Hydrology

Environment Southland has a network of automatic monitoring stations which have recorded rainfall and river stage since the 1950s. These sites were installed for floodwarning purposes so were generally located catchment headwaters or near major townships. In the 1970s, many of these sites were rated so that real-time river flows could be recorded. In the 1980s, the network was significantly expanded for floodwarning and water resource monitoring purposes. Today the automatic monitoring network includes climate, soil moisture and temperature, groundwater level and surface water quality monitoring in addition to rainfall, river stage and flow. It is data from this network which forms the basis of the following summary on catchment hydrology.

4.1 *Rainfall*

Southland is renowned for its reliable and consistent rainfall which is important to the region's agricultural production. Environment Southland has rain gauge recorders at a number of sites in the headwaters of the Mataura River catchment, shown in Table 1. The rainfall network consists of seven automatic gauges which record rainfall totals at 15 minute intervals, and four daily rainfall sites which have a lower accuracy than the automatic sites and are generally only suitable for use in monthly statistics. All Environment Southland rainfall monitoring sites within the study area are shown in Figure 7. The Cainard Station, Eyre Creek, Glenlapa, Hyde Rock, Piano Flat and Mandeville rain gauges were installed for floodwarning purposes while the Riversdale rain gauge was installed more recently to help quantify rainfall recharge to the Riversdale aquifer.

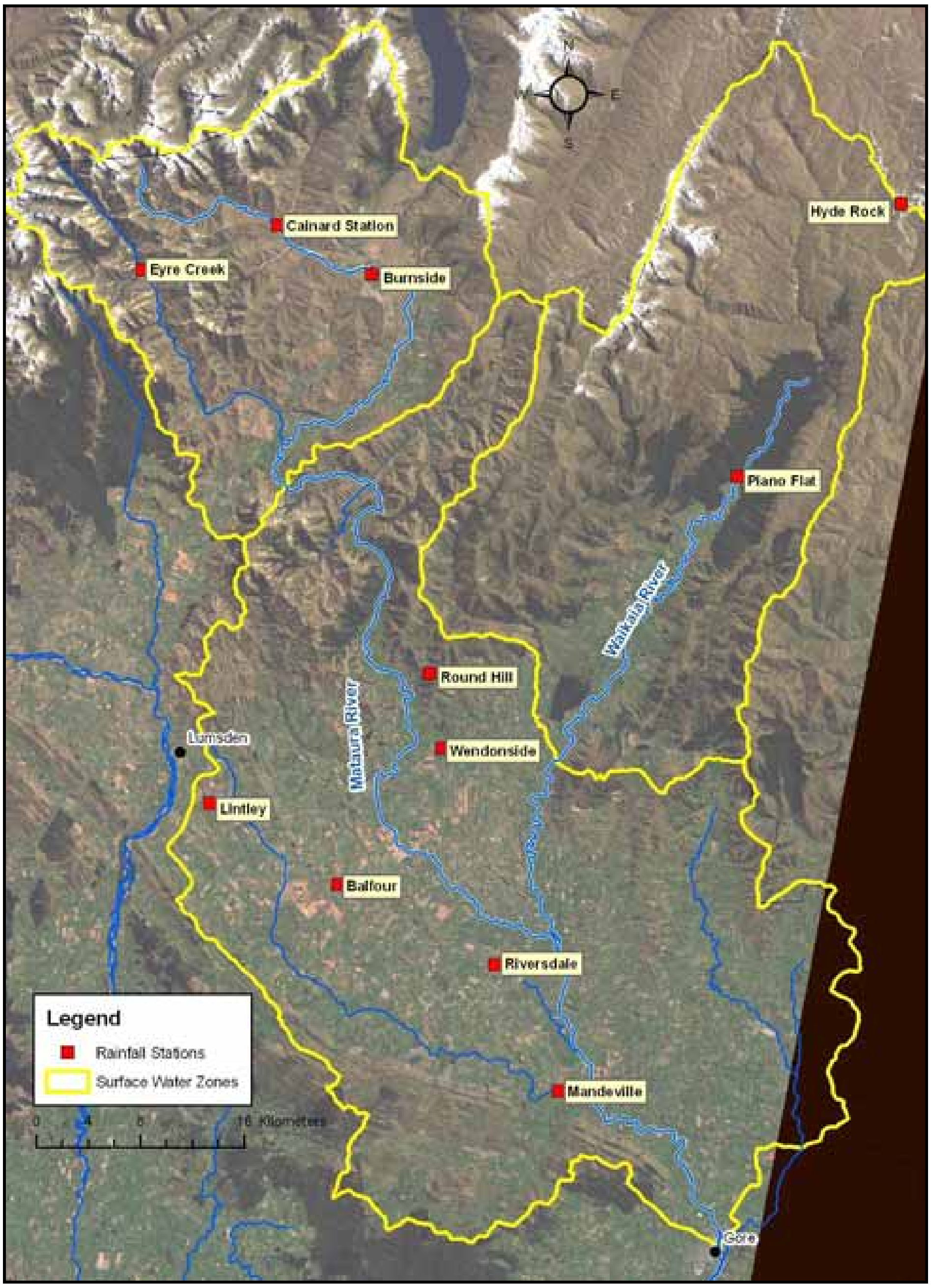

Figure 7: Map of Environment Southland's rainfall stations within the study area

The mean annual rainfall total for the Mataura catchment above Gore is generally around 900 mm, however, as Table 1 (next page) shows there is considerable variability depending the altitude and aspect of the rain gauge. The Waimea Plains generally receives less rainfall than the areas surrounding it due to the hot, dry winds of the north-westerly weather systems which occur during summer. These winds increase evapotranspiration, and when prolonged or severe, may result in significant soil moisture deficits.

Table 1: Environment Southland Rain Gauge Sites Summary Statistics

Site	Elevation (metres* *)	Record Start Date	Mean Annual Rainfall (mm)	Mean Summer* Rainfall (mm)	Lowest Summer Rainfall (mm)	Date of Lowest Rainfall
Upper Mataura Surface Water Resource Zone						
Fairlight at Cainard Station	411	09-Sep-77	913	202	106	1980/81
Mataura River at Burnside	320	01-Feb-80	897	247	65	1980/81
Eyre Creek at Shepherd Creek Hut	485	30-Aug-89	1,215	319	162	1998/99
Waikaia Surface Water Resource Zone						
Upper Waikaia at Hyde Rock	1,652	16-Nov-05	Record to short for meaningful statistics			
Waikaia River at Piano Flat	240	28-Aug-77	955	278	187	1998/99
Wendonside at Mahers Road	200	01-Jan-85	1,018	302	184	1998/99
Mid-Mataura Surface Water Resource Zone						
Glenlapa at Round Hill	584	25-Aug-05	Record to short for meaningful statistics			
Lintley at Lintley District Road	189	01-Jan-77	987	289	118	1980/81
Balfour at Balfour Ardlussa Road	170	01-Mar-86	890	256	154	1998/99
Riversdale Aquifer at Liverpool St	128	03-Dec-02	812	255	164	2006/07
Waimea Stream at Mandeville	104	26-Feb-88	851	241	147	2006/07

*"Summer" is defined as the months of December to February, inclusive
* *metres above mean sea level using Bluff 1949 datum

The seasonal pattern is relatively consistent across the entire catchment with highest rainfall totals occurring during summer, and the lowest during winter. There is generally one-third less rainfall in the driest month (July) compared to the wettest month (December). Figure 8 shows the mean monthly rainfall distribution from a monitoring site within each of the surface water management zones.

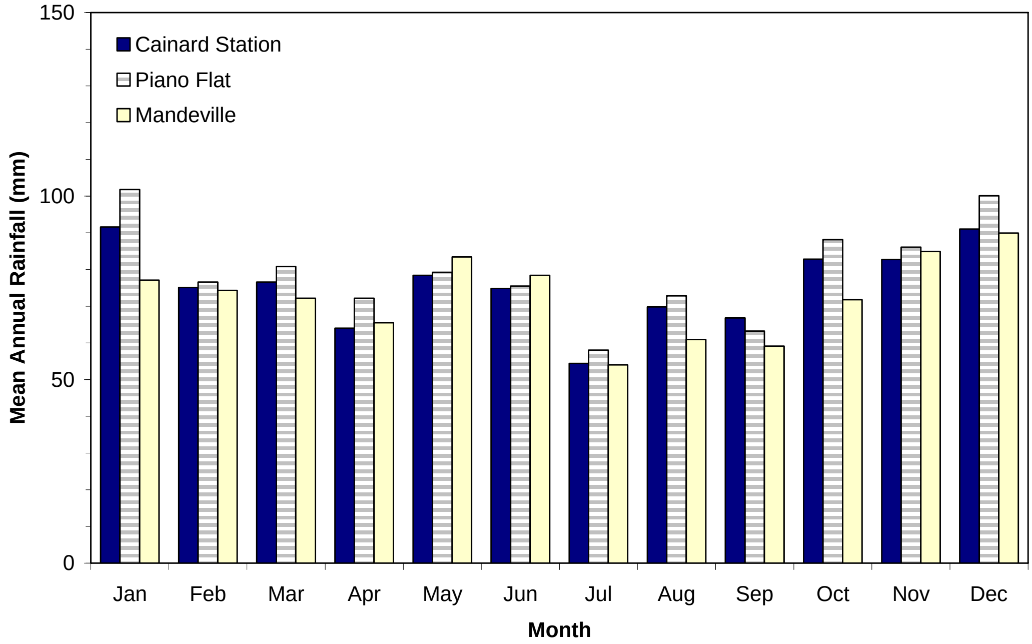

Figure 8: Temporal distribution of mean monthly rainfall

Cumulative rainfall departure plots for rainfall sites within the area show also show a reasonably consistent pattern. The late 1980s to early 1990s were a relatively dry period, as indicated by a downward trend in the residual rainfall mass line in Figure 8. However, since 2002, rainfall totals have tended to be wetter than normal shown by the upward trending residual rainfall mass line in Figure 9. The apparent cyclical pattern in long-term rainfall variability has been recognised in rainfall records from elsewhere in Southland (McKerchar and Henderson, 2003). The wet/dry periods appear to come in 2-3 year cycles which may be related to global circulation patterns.

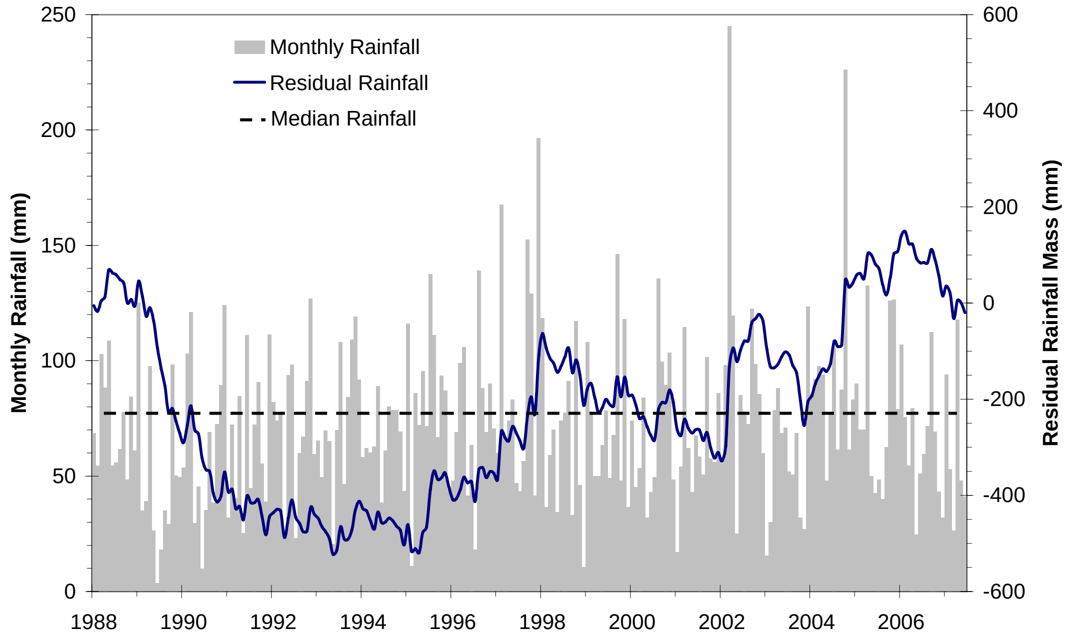

Figure 9: Cumulative rainfall departure from the mean annual rainfall at Mandeville

4.2 *Soil Moisture*

Environment Southland has one soil moisture monitoring site within the study area, shown in Figure 10. It is located on the northern boundary of the Riversdale township and was installed to enable determination of rainfall and riparian recharge into the Riversdale groundwater zone. The data are also used for irrigation efficiency compliance monitoring by ensuring effluent and water irrigation only occurs when soil moisture is below field capacity. Estimates by Lincoln Environmental (2003) indicate soil moisture infiltration is approximately 35 percent of the mean annual rainfall at Riversdale. This is much lower than other parts of Southland where up to 50 percent of the rainfall is estimated to recharge the underlying aquifer. The difference is caused by regional variations in evapotranspiration rates and soil water holding capacities.

Figure 10: Riversdale Aquifer at Liverpool Street Monitoring Station

4.3 *Groundwater Levels*

Groundwater level monitoring is a relatively recent addition to Environment Southland's monitoring network, and has developed largely in response to increasing resource demand. Between 2000 and 2005, groundwater demand in Southland increased eight-fold, primarily driven by the development of pasture irrigation in northern Southland. In response to this, Environment Southland has developed a groundwater monitoring network which currently has 14 automatic monitoring sites and approximately 90 monthly dipping sites. Figure 11 shows the location of the key monitoring bores in the study area. Table 2 (next page) provides an overview of site information.

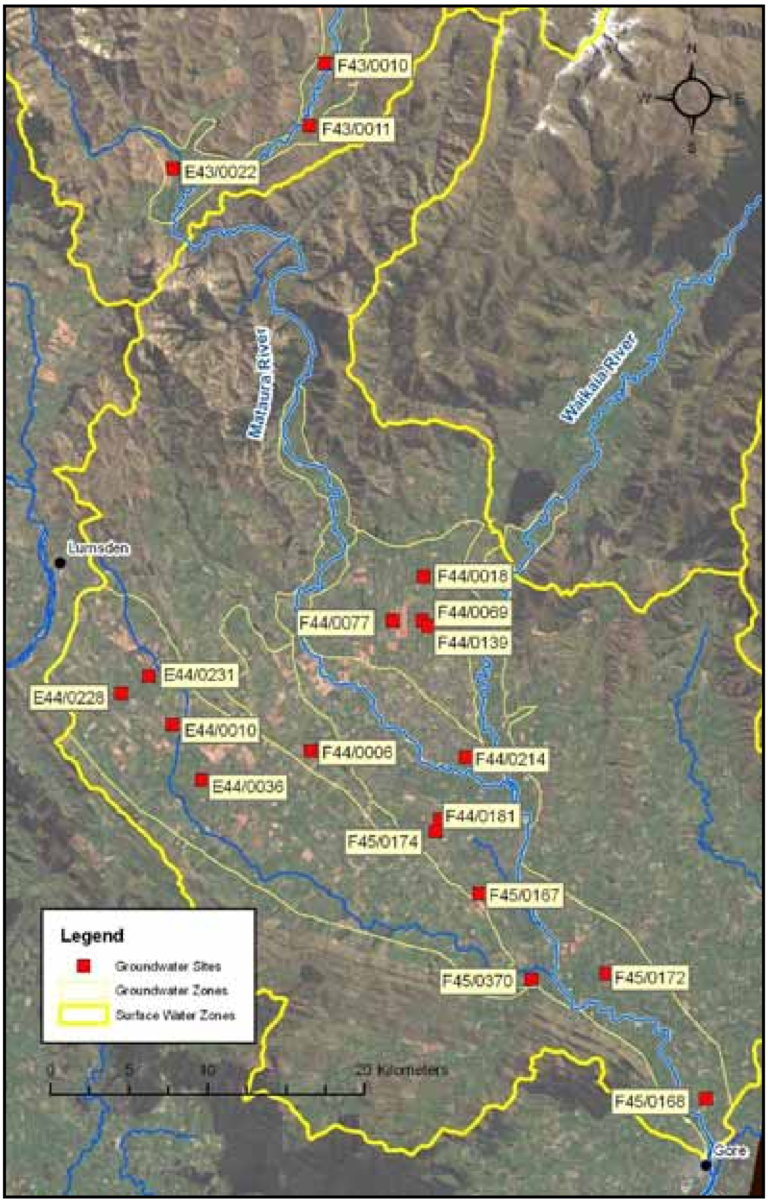

Figure 11: Key groundwater monitoring bores

Under natural conditions the volume of water in an aquifer reflects a balance between the recharge from rainfall and river flow, and discharge to other water bodies including rivers, streams and lakes. The storage of water within an aquifer provides a buffer between the highly variable climate driven recharge processes and the relatively constant outflow to rivers, streams and lakes. Groundwater levels vary throughout the year reflecting changes in aquifer storage.

Rainfall recharge occurs when soil moisture water holding capacity is exceeded and gravity drainage occurs within the soil profile. This generally occurs during winter when evapotranspiration rates are low or following heavy rainfall events. As a result, groundwater levels show a distinct seasonal pattern that corresponds to surrounding soil moisture levels. In general, groundwater levels drop through the summer and autumn, and increase during winter and spring, as shown in Figures 12,13 and 15.

Table 2: Key groundwater level monitoring sites summary information

Well Number	Grid Reference	Record Start Date	Monitoring Interval	Aquifer Type
Upper Mataura Groundwater Resource Zone				
F43/0010	F43:723-186	26-Oct-06	Monthly	Unconfined
F43/0011	F43:713-149	26-Oct-06	Monthly	Unconfined
E43/0022	E43:626-119	12-Apr-05	Monthly	Unconfined
Wendonside Groundwater Resource Zone				
F44/0018	F44:785-859	17-May-01	Monthly	Unconfined (perched)
F44/0069	F44:784-831	30-Sep-02	Monthly	Confined
F44/0139	F44:788-828	25-Mar-03	Monthly	Unconfined
F44/0077	F44:766-831	17-Jun-03	30 minutes	Semi-confined
Waipounamu Groundwater Resource Zone				
F44/0214	F44:812-744	06-Dec-04	30 minutes	Unconfined
Waimea Plain Groundwater Resource Zone				
E44/0036	E44:644-729	15-Mar-01	Monthly	Unconfined
E44/0010	E44:625-764	14-Sep-00	Monthly	Unconfined
E44/0288	E44:593-785	20-Jan-05	Monthly	Unconfined
E44/0231	E44:610-796	08-Dec-03	30 minutes	Unconfined
Longridge Groundwater Resource Zone				
F44/0006	F44:714-748	17-Mar-00	Monthly	Unconfined

Table 2 contd

Well Number	Grid Reference	Record Start Date	Monitoring Interval	Aquifer Type
Riversdale Groundwater Resource Zone				
F45/0167	F45:821-657	14-Sep-00	Monthly	Unconfined
F45/0181	F45:986-575	03-Dec-02	30 minutes	Unconfined
F45/0174	F45:793-697	14-Sep-00	Monthly	Unconfined
F45/0370	F45:854-602	12-Feb-04	Monthly	Unconfined
Knapdale Groundwater Resource Zone				
F45/0172	F45:902-606	14-Sep-00	Monthly	Unconfined
F45/0168	F45:966-526	14-Sep-00	Monthly	Unconfined

The riparian aquifers (upper Mataura, Cattle Flat, Waipounamu, Wendon and Riversdale groundwater zones) are by definition hydraulically connected to surface water and maintain base flow or drain rivers depending on the relative head difference between river stage height and surrounding groundwater level. This relationship acts to modulate groundwater levels so that the groundwater levels fluctuate within a relatively narrow range of 1-2 metres, as shown in Figure 12.

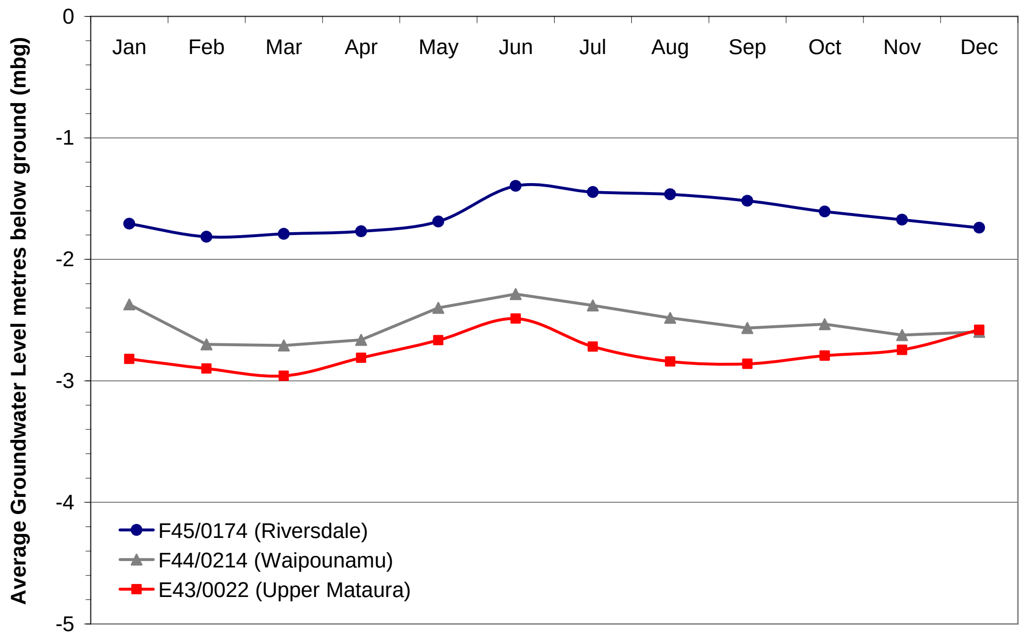

Figure 12: Temporal groundwater level variability for riparian aquifers

Terrace aquifers (Longridge and Wendonside groundwater zones) are not in direct hydraulic connection with surface waterways but are important in maintaining surface water flows through springs formed at the base of the terrace where the water table intersects the land surface. These aquifers are recharged solely by rainfall so groundwater levels mirror rainfall and soil moisture patterns. The magnitude of seasonal groundwater level fluctuations observed in terrace aquifers ranges from 2-5 metres depending on rainfall variability and spatial location of the monitoring bore within the aquifer system (Figure 13). Variability tends to decrease towards the terrace margins due to the constant head provided by spring discharge.

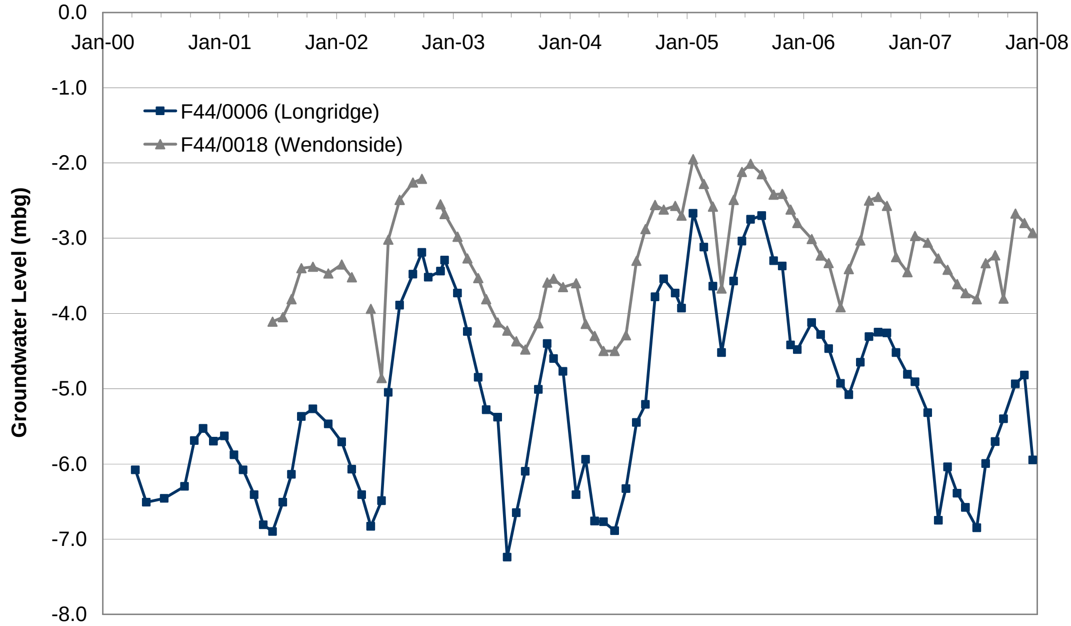

Figure 13: Temporal groundwater level variability for terrace aquifers

Groundwater level monitoring from the deeper, semi-confined aquifer under the Wendonside terrace suggests groundwater levels follow a similar pattern to the long-term catchment water balance (rainfall residual mass), with a time lag of approximately eight months. However, since 2006, groundwater levels in this aquifer have been steadily declining despite relatively average rainfall conditions, as shown in Figure 14. This aquifer is relatively unused and there is currently insufficient data to infer trends or causes for this anomaly. However, in addition to this clearly highlighting the importance of having long-term monitoring data, it also illustrates the importance of monitoring groundwater levels in aquifers which provide through flow to other groundwater zones.

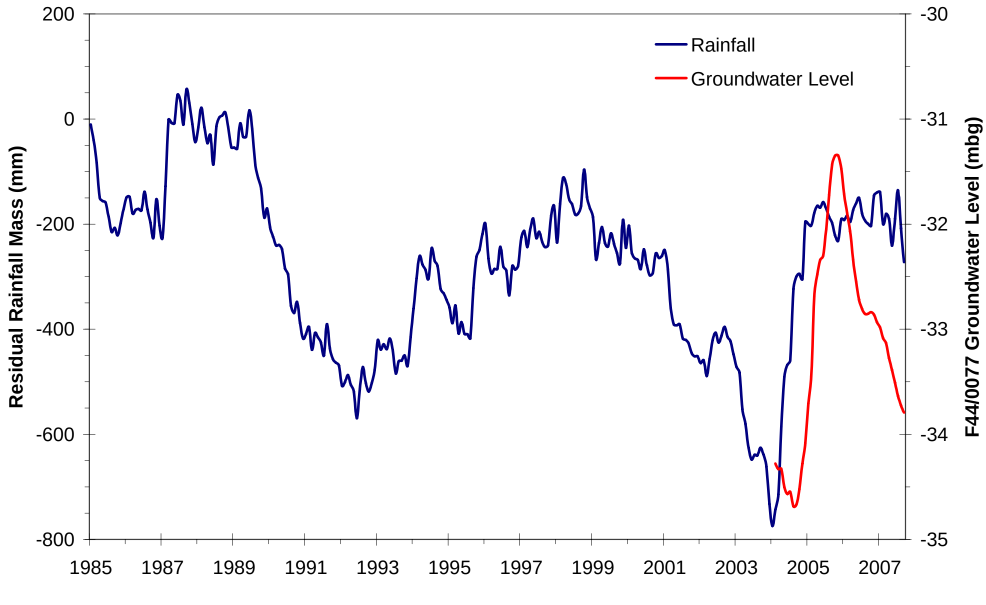

Figure 14: Cumulative mean monthly rainfall departure and groundwater levels on the Wendonside Terrace

Lowland aquifers (Knapdale and Waimea Plain groundwater zones) have a more complex relationship to surface water with partially incised first and second order streams draining shallow groundwater. There is a deeper circulation of groundwater underneath this system which follows the overall catchment drainage. Groundwater levels in lowland aquifers typically show a "saw-tooth" pattern, with a rapid rise in groundwater levels during May to June when soils are at field capacity, then receding in an almost linear fashion until recharge is initiated again (Figure 15).

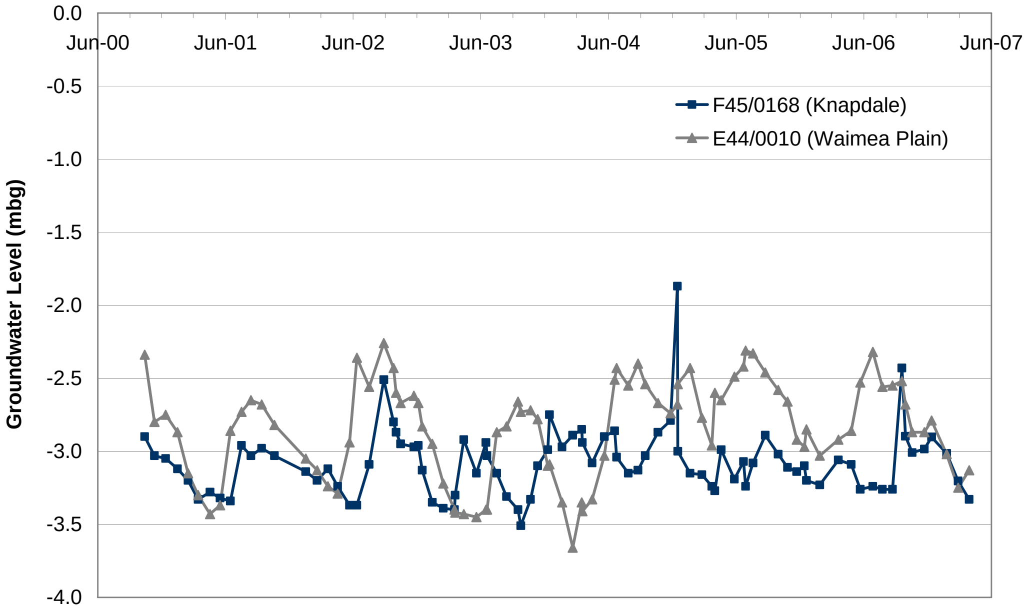

Figure 15: Temporal groundwater level variability for lowland aquifers

4.4 *River Flow*

Environment Southland has established continuous flow recorders at a number of sites in the upper and middle reaches of the Mataura River catchment, shown in Figure 16 (next page). These sites were initially installed for floodwarning purposes and due to the resolution of the chart recorder and problems with the reliability and frequency of measurements at low stages, some of the data collected prior to 1978 is of lower reliability. In Table 3 (next page), where the lowest recorded flow is dated earlier than the record start date, the flow data has been calculated from gauging data and correlations (*pers comms* C Jenkins, 2007).

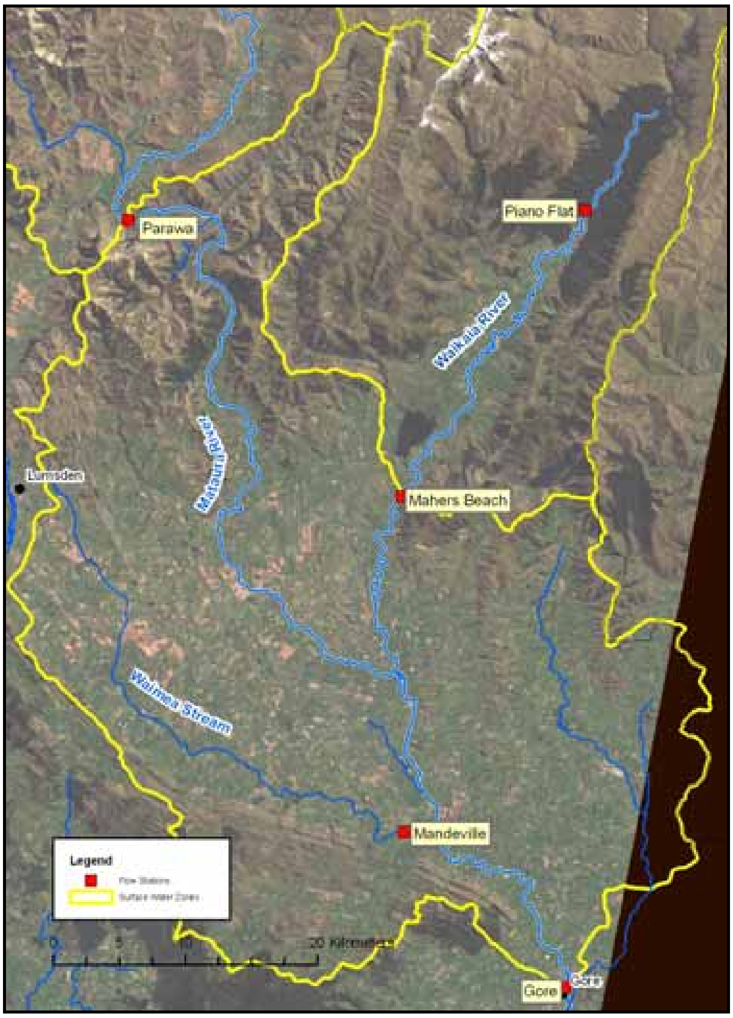

Figure 16: Map of Environment Southland flow stations

Table 3: Flow sites summary statistics

Site	Map Reference	Low Flow Record Starts	7-Day Mean Annual Low Flow (L/s)	Lowest Measured or Estimated Flow (L/s)	Date of Lowest Flow
Upper Mataura Surface Water Resource Zone					
Mataura River at Parawa	E43:635-073	21-Jun-77	5,996	3,151	23-Feb-71
Waikaia Surface Water Resource Zone					
Waikaia River at Piano Flat	F43:983-079	17-Jul-79	3,108	1,589	22-Feb-99
Waikaia River at Mahers Beach	F44:842-862	16-Mar-84	5,794	2,443	21-Feb-99
Mid - Mataura Surface Water Resource Zone					
Mataura River at Gore	F45:967- 489	18-May-77	17,724	7,185	23-Feb-71
Waimea Stream at Mandeville	F45:846-607	20-Sep-83	374	107	23-Feb-71

The Mataura River at Parawa and Gore has the same temporal variability in mean monthly flow as shown in Figure 17. In general, the lowest flows occur between February and April and steadily increase throughout the year to reach a maximum in October. This pattern does not match the pattern of rainfall in the catchment which is relatively consistent throughout the year with the lowest totals generally occurring in June. Instead, flow patterns reflect the influence of snow accumulation and melt in spring in an alpine catchment. Flows are also influenced by the prevailing climatic conditions as in most years soil moisture is at field capacity and evapotranspiration rates lowest in June, so although rainfall totals are low in winter, the net result is increased run-off generation following rainfall events.

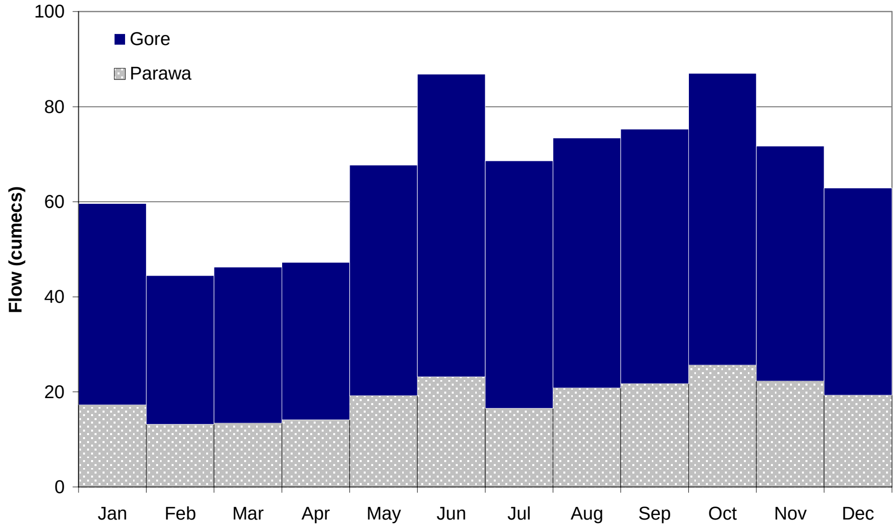

Figure 17: Temporal variability in mean monthly flow of the Mataura River at Parawa and Gore

The Waikaia River at Piano Flat and Mahers Beach sites have a similar pattern to the Parawa and Gore sites, as these sites are also in an alpine catchment. Figure 18 shows flows are generally lowest between February and March and increase to a pronounced peak in October reflecting the significant proportion of run-off generation from snowmelt in spring.

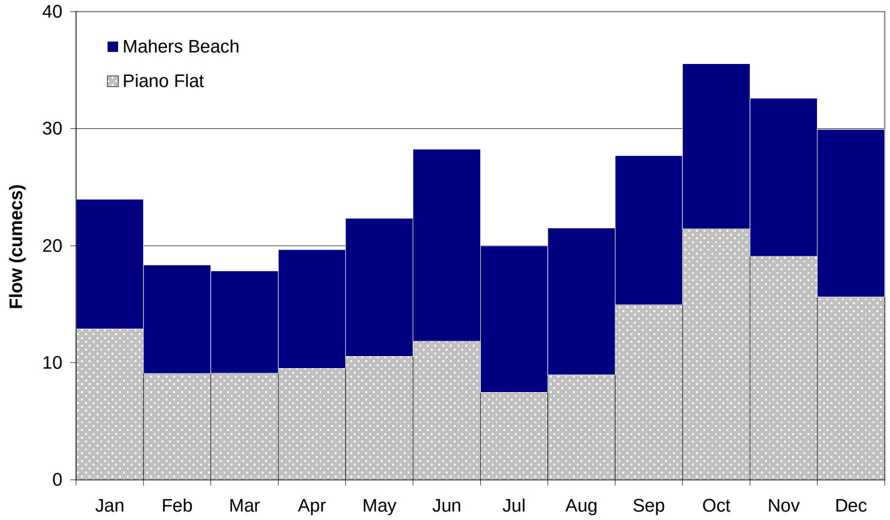

Figure 18: Temporal variability in mean monthly flow of the Waikaia River at Piano Flat and Mahers Beach

The Waimea Stream is a tributary of the Mataura River and shows a markedly different temporal pattern. Flows increase from a minimum in February to a peak between June and August reflecting the generation of rainfall run-off from a low elevation catchment. During winter, soil moisture in the catchment is near field capacity and a significant percentage of rainfall is lost to surface run-off to drains and streams. In addition, groundwater levels and consequently stream base flow is higher. In summer, soil moisture levels are lower reducing surface run-off generation and groundwater levels decline reducing stream base flow. Figure 19 shows groundwater levels and stream flows follow the same temporal pattern.

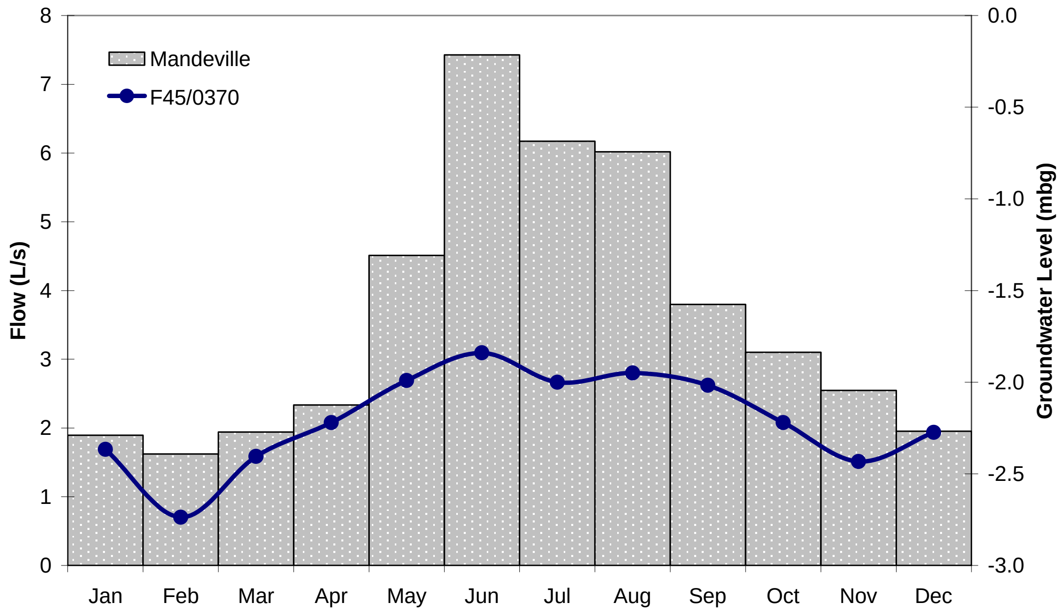

Figure 19: Temporal variation in mean monthly flow of Waimea Stream at Mandeville and groundwater level of F45/0370 (bore in Mandeville township)

5 Upper Mataura Catchment

5.1 *Catchment Water Balance*

In 2003, the first of a series of concurrent gaugings were undertaken in the Mataura catchment to identify and quantify significant gain and losses in stream flows.

The first of the concurrent gaugings were done upstream of Parawa and found significant flow loss from the Mataura River upstream of Fairlight, probably into the surrounding highly permeable alluvial gravel aquifer. The Mataura River at Fairlight, shown in Figure 20, is often dry once the Mataura River is below its seven day mean annual low flow (MALF). A net gain of water was returned to the Mataura River at Garston indicating drainage of the aquifer into the river.

The combined discharge of the Mataura River and Roberts Creek is more than 700 l/sec during dry periods and much or all of this flow is lost over the 8 km reach downstream to Fairlight during low flows.

Figure 20: Looking upstream the Mataura River at Fairlight. This reach dries up during low flows

Flows measured in the Mataura River and Roberts Creek at the base of the Eyre Mountains do not have any noticeable groundwater contribution indicating stream flow is derived from alpine rainfall, snow melt and run-off. Flow measurements show run-off out of the Eyre Mountains can contribute approximately 40 percent of flow at Parawa during times of medium to low flow, although the percentage decreases as the catchment gets drier. Figure 21 shows that run-off from the Eyre Mountains constitutes approximately 25 percent of the total flow when the Mataura River at Parawa is at its seven day MALF.

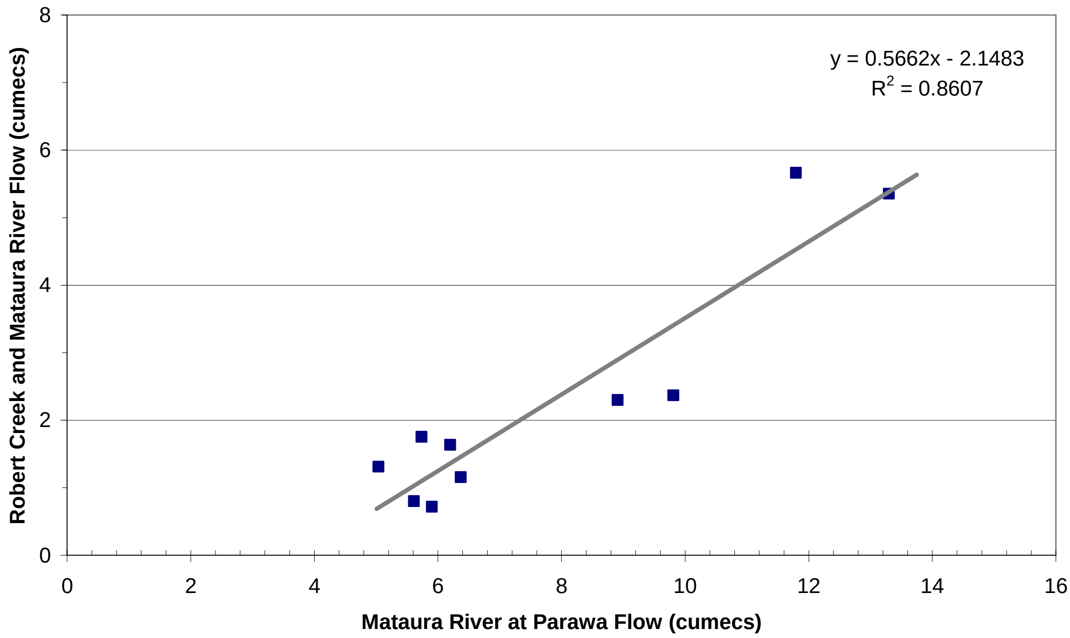

Figure 21: Linear regression between the Mataura River at Parawa and the combined flow of Roberts Creek and the upper Mataura River

Between Fairlight and Garston the Mataura River gains considerably more flow than can be accounted for by tributary inputs. Flows measured at Garston also show a strong correlation to groundwater levels which are not matched further up the catchment, as shown in Figure 22.

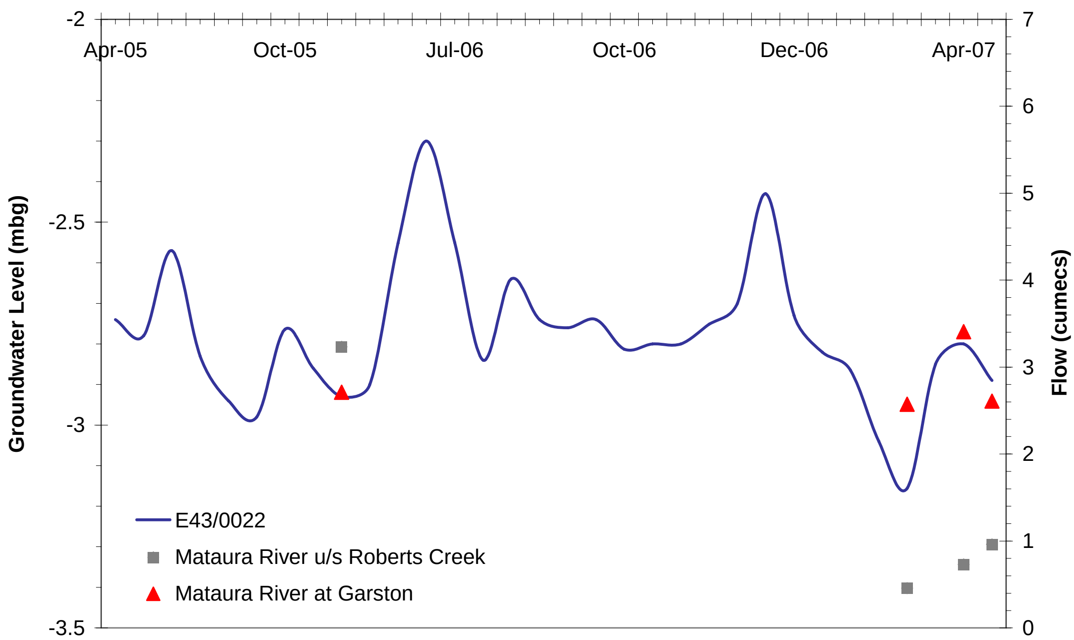

Figure 22: Groundwater levels and flows in the upper Mataura River

The gain in flow at Garston is interpreted to represent the return of flow lost to groundwater in the upstream reach, as well as drainage from the surrounding alluvial gravel aquifer and a significant contribution from Brightwater Spring. The Brightwater Spring maintains a consistent minimum flow of approximately 1,500 l/sec and contributes up to 60 percent of the flow measured at Garston during low flow periods.

Between Garston and Athol there is a net increase in flow of approximately 65 l/sec/km length of river while between Athol and Parawa there is an increase of approximately 90 l/sec/km. This indicates groundwater discharge to the Mataura River increases progressively downstream and illustrates the significant contribution of groundwater discharge to baseflow in the upper Mataura River.

Numerous springs and seeps are known to occur in the Athol area and may reflect further drainage of groundwater from the surrounding hills to the Mataura River. Eyre and Quoich Creeks lose flow where they emerge onto the Mataura floodplain and frequently dry up in the lower reaches near Athol. It is therefore likely that a portion of the flow gained downstream of Athol reflects the return of flow lost from Eyre and Quoich Creeks.

There has only been one set of concurrent gaugings conducted on Eyre Creek. Measurements taken on 14 February 1975 recorded 924 l/sec downstream of the Jail Creek confluence and 5 l/sec at Athol. Based on these data, it is assumed approximately 900 l/sec is lost from Eyre Creek into the surrounding aquifer although further gaugings are required to improve the estimate of riparian recharge from Eyre Creek into the underlying aquifer.

Eyre Creek provides approximately 25 percent of flow in the Mataura River at Parawa, however, the relative contribution of Eyre Creek declines markedly as the flow at Parawa diminishes, as shown in Figure 23. When Parawa reaches a flow of approximately 5,000 l/sec, Eyre Creek at Athol will be dry. Parawa will get down to 5,000 l/sec on average every other year for a total of nine days. In 1999, Parawa was below 5,000 l/sec for a total of 36 days, the longest low flow duration since the beginning of records in 1977.

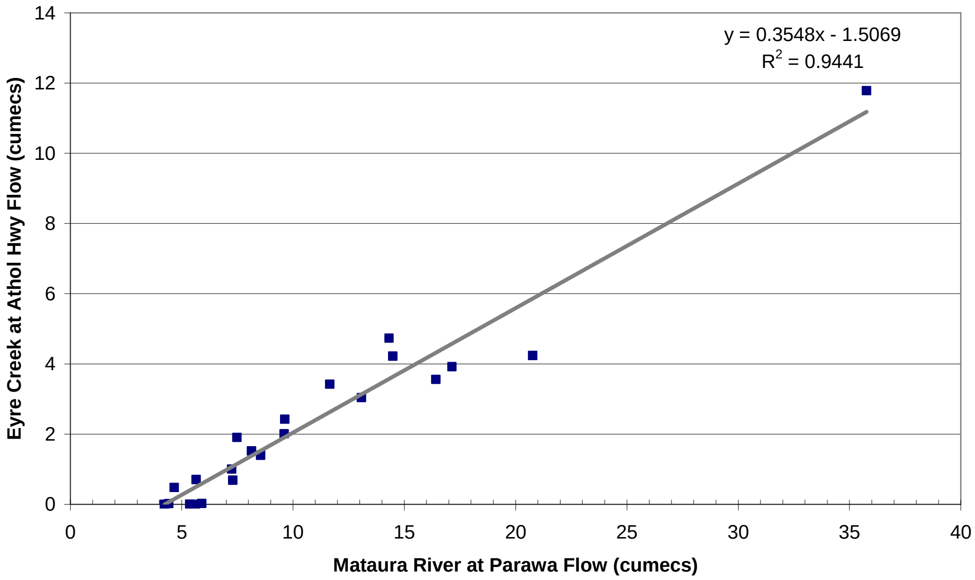

Figure 23: Linear regression between Eyre Creek and the Matura River at Parawa flows

As can be seen in Figure 24, the Mataura River is entrenched in a deep gorge (the Nokomai Gorge) downstream of Parawa. As a result, the alluvial gravel layer is very thin and it was assumed the flow measured at Parawa would remain relatively unchanged throughout the length of the Nokomai Gorge. However, two sets of concurrent gaugings in 2007 show between 5-10 percent of the Mataura River flow is lost between Parawa and the Nokomai Creek confluence, with the percentage decreasing as flows decrease. It is possible the difference in measured flow is a function of gauging error as the difference lies within the 8 percent error margin, however, it is recommended further investigations are required to eliminate gauging error and to determine what is going on.

Figure 24: Looking downstream at the Mataura River at Parawa (monitoring site at bridge)

5.2 *Major Springs*

Although few historical gaugings exist in the upper Mataura catchment, particularly on the tributaries, regular flow gaugings have been undertaken recently on two of the larger spring-fed streams i.e. the Brightwater Spring and Parawa Creek. Regular gaugings of these streams commenced in February 2002 and are monitored monthly during summer low flows periods and at less regular intervals during winter and spring.

5.2.1 Brightwater Spring

The Brightwater Spring is one of the largest springs in Southland, as illustrated in Figure 25 (next page), and is the largest tributary to the Mataura River above Parawa during low flow periods contributing up to 60 percent of the flow at Garston. While its importance in maintaining base flow is relatively well understood, the source of the Brightwater Spring is less certain.

Figure 25: Looking upstream the Brightwater Spring to the Eyre Mountains

Oxygen isotope samples can be used to distinguish rainfall from different altitudes which makes it useful as a natural tracer in identifying groundwater recharge sources. Results of the δ18O samples collected from the upper Mataura catchment are shown in Table 4. These results show significant differences in δ18O values between Lake Wakatipu and Brightwater Spring, even allowing for seasonal variation.

The δ18O values from the Mataura River are of a similar magnitude to those observed in Brightwater Spring, but are comparatively lower. This suggests that the Mataura River and Brightwater Spring are sourced from rainfall from a similar altitude. The slightly higher δ18O values from Brightwater Spring may reflect the contribution of run-off generated at altitude on the surrounding hills to recharge of the unconfined aquifer underlying the Mataura River floodplain and ultimately to Brightwater Spring discharge.

Table 4: Oxygen-18 isotope measurements from the upper Mataura catchment

Site	δ18O
Lake Wakatipu at Kingston	-9.23
Mataura River at Fairlight	-9.79
Mataura River at Pyramid Bridge	-9.87
Brightwater Spring	-10.11

It has been suggested that the Brightwater Spring is sourced from Lake Wakatipu but this is not supported by observations of catchment yield, flow loss or hydrochemical sampling.

It has also been suggested that the observed flow loss above Fairlight provides a possible recharge source for Brightwater Spring. Discharge from the Brightwater Spring does not correlate well with flows measured anywhere in the upper Mataura surface water zone, which reflects the relatively constant base flow of the Brightwater Spring compared with the more variable nature of discharge in response to rainfall and run-off from the catchment as a whole.

Based on observed flow losses from the upstream reach of the Mataura River, catchment yield and the hydrochemical sampling results, the source of Brightwater Spring discharge is interpreted to be predominantly groundwater. Specifically, the unconfined aquifer underlying the Mataura River floodplain combined with some minor mixing of lost Mataura River water and run-off from the surrounding hills.

The location of the source of Brightwater Spring may be related to the formation of a depression spring along the base of the alluvial terrace that runs obliquely across the Mataura floodplain approximately 500 metres west of the current river channel. Alternatively, the location of the spring discharge may reflect the structural features located on the upper surface of the underlying basement rock, possibly associated with faulting.

Flows measured in the Brightwater Spring show a fairly constant discharge ranging between 1,335 l/sec (April 2003) to 1,896 l/sec (August 2003), as illustrated in Figure 26. This demonstrates the negligible influence of run-off on flow in the Brightwater Spring, which is unsurprising given its very small run-off catchment area of 4 km^2. Parawa Creek has a much wider discharge range with measured flows ranging from 270 l/sec (March 2004) to 2,214 l/sec (June 2006) which reflects the greater contribution of surface run-off in the Parawa Creek catchment. Brightwater Spring and Parawa Creek discharge are poorly correlated (R^2=0.28) which reflects the greater run-off contribution to Parawa Creek.

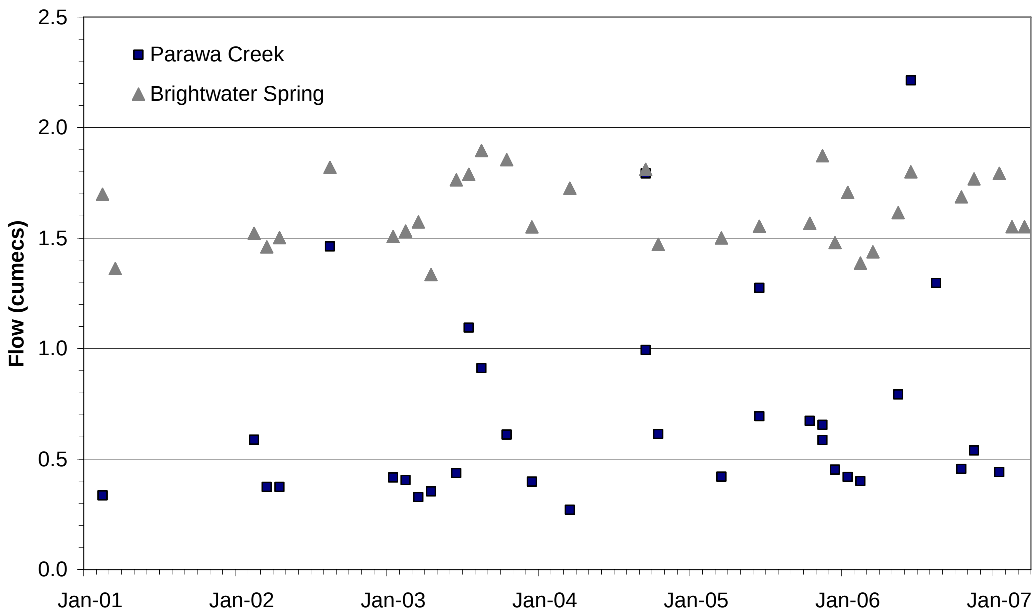

Figure 26: Flows measured in Brightwater Spring and Parawa Creek

5.2.2 Parawa Creek

Parawa Creek is fed by several small springs which originate on the floodplain approximately 2 km south-west of Athol. Parawa Creek flows in a predominantly southerly direction across the floodplain before entering the Mataura River approximately 3 km upstream of the Mataura River at Parawa hydrology station.

The hydrology of Parawa Creek is more similar to the Mataura River than the Brightwater Spring due to the higher portion of flow derived from localised catchment run-off. While smaller in size, Quoich Creek shows similar flow patterns to Parawa Creek, shown in Figure 26.

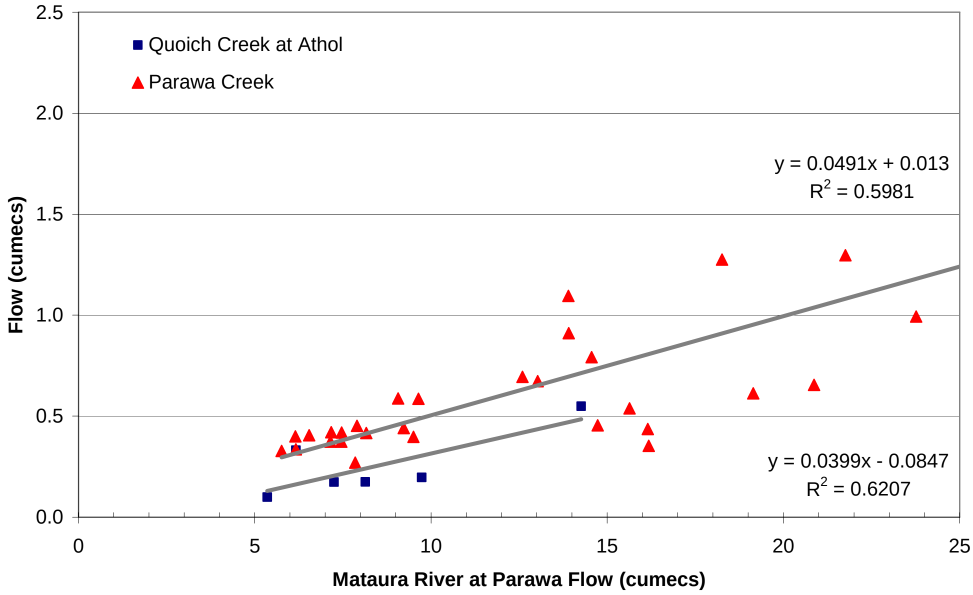

Figure 27: Linear regression between Parawa and Quoich Creeks and the Mataura River Parawa flows

CASE STUDY

5.3 *Hydrology Myth: Lake Wakatipu and the upper Mataura catchment*

During the last glaciation, the Mataura River drained the Lake Wakatipu catchment and many people believe it continues to do so either via an aquifer between Fairlight and Kingston or directly into the Brightwater Spring.

The information outlined in Section 5.2.1 indicates the Brightwater Spring is not sourced from Lake Wakatipu while an analysis of catchment yield in the upper Mataura catchment suggests that a hydraulic connection to anywhere in the upper Mataura catchment is unlikely. Due to the surrounding geology and the confined nature of the entrance to the Nokomai Gorge, all drainage from the upper Mataura catchment should be present within the river channel at Parawa. This means any additional input into the Mataura catchment, such as possible leakage from Lake Wakatipu, will result in an increased flow at Parawa above that which would be expected solely based on the topographical catchment area.

Table A: Headwater catchment yields in the Southland region

Site	1-day MALF (m^3/sec)	Catchment Area (km^2)	Catchment Yield (l/sec/km^2)
Mataura River at Parawa	5.776	801	7.21
Waikaia River at Piano Flat	2.787	493	5.65
Oreti River at Three Kings	2.398	271	8.85
Aparima River at Dunrobin	1.473	216	6.82

Table A compares yields from various alpine catchments in Southland using one day mean annual low flow (MALF). The numbers show a similar catchment yield of between 5.7-8.9 litres/sec/km^2 for the headwaters of the Mataura, Aparima, Oreti and Waikaia catchments. The consistency between catchments indicates it is unlikely that there is any significant transfer of water into the upper Mataura catchment from an external source such as leakage from Lake Wakatipu.

This interpretation is supported by analysis of hydrochemical results in the upper Mataura catchment. There are significant differences in isotope (δ18O) results from samples collected from the upper Mataura catchment. The δ18O values in Lake Wakatipu are lower than that measured in the Mataura River and Brightwater Spring, even allowing for seasonal differences, as discussed further in Section 5.1.1.

There is no empirical evidence supporting the “legend” that Lake Wakatipu provides a source of water to the upper Mataura catchment.

6 Waikaia Catchment

6.1 *Catchment Water Balance*

There have been only three sets of concurrent gaugings done on the Waikaia River, and these were done recently between 2005 and 2007. Similarly, relatively few gaugings exist on the major tributaries although gauging records do date back to 1975 for some creeks. Despite the limited amount of gauging data, the results consistently show a significant flow gain along the reach from Mahers Beach to the Mataura River confluence even accounting for inputs from tributaries.

There is also a strong correlation between gaugings at different points on the Waikaia River and the flow record at Mahers Beach (see Figure 28), with $R^2 \geq 0.97$. This is in part due to the low number of gaugings but also indicates run-off and tributary inputs constitute relatively minor components of base flow. Groundwater drainage appears to dominate, however, more gaugings are required to substantiate this.

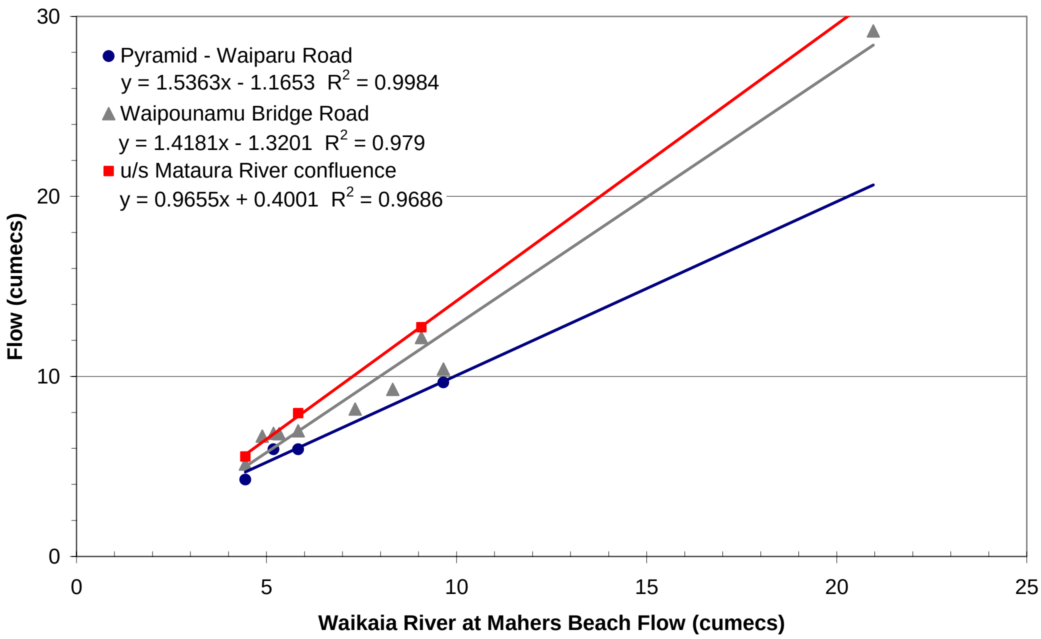

Figure 28: Linear regression between Waikaia River gauging sites

Results from concurrent gaugings show the Waikaia River gains flow between Mahers Beach and the confluence with the Mataura River. Groundwater infiltration directly into the bed of the Waikaia River is approximately 2,000 l/sec when Mahers Beach is at its seven day MALF, however, during prolonged dry periods this is reduced to 1,200 l/sec. Figure 29 (next page) shows the highly permeable bed material.

Figure 29: Looking upstream the Waikaia River at the Waipounamu bridge

Figure 30 shows gaugings in the Waikaia River at Mahers Beach and Waipounamu Bridge Road graphed against groundwater levels in the Waipounamu groundwater zone. Flows at the Waipounamu Bridge Road site appear to have a very good correlation to groundwater levels ($R^2 = 0.977$) although it should be noted this is based on a small number of measurements. Flow measurements from Mahers Beach also correlate reasonably well to groundwater levels in the Waipounamu groundwater zone except during spring when run-off and snowmelt elevate flow.

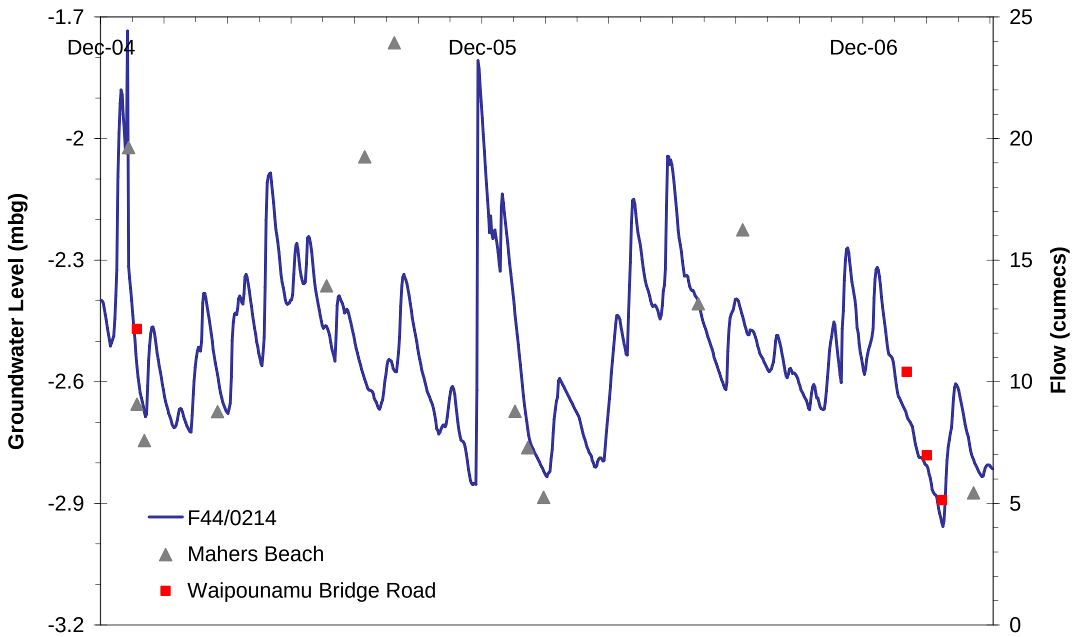

Figure 30: Groundwater levels in the Waipounamu groundwater zone with Waikaia River gaugings

Although the Wendon groundwater management zone is hydraulically connected to the Waikaia River, available aquifer test data shows transmissivity values are at least one order of magnitude lower than those in the Waipounamu groundwater zone. This means groundwater discharge from the Wendon groundwater zone contributes a relatively minor portion of the baseflow in the Waikaia River as illustrated in Figure 31 where Wendon groundwater levels lag behind flow in the Waikaia River, which may reflect bank storage. Groundwater levels in the Waipounamu groundwater zone mirrors base flow in the Waikaia River at Mahers Beach (Figure 32).

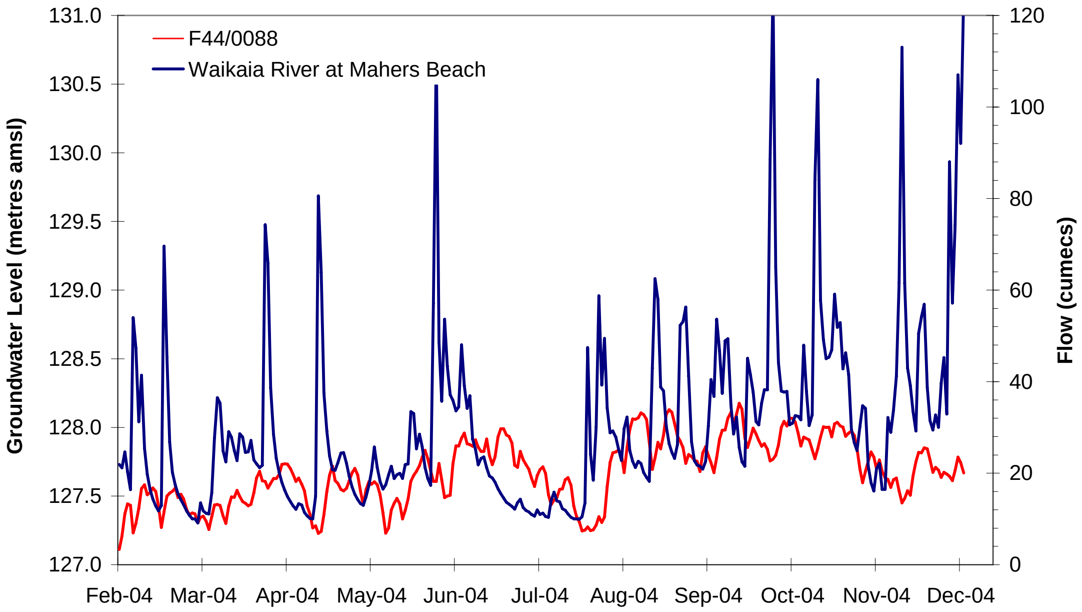

Figure 31: Groundwater levels in the Wendon Groundwater Zone and flow in the Waikaia River

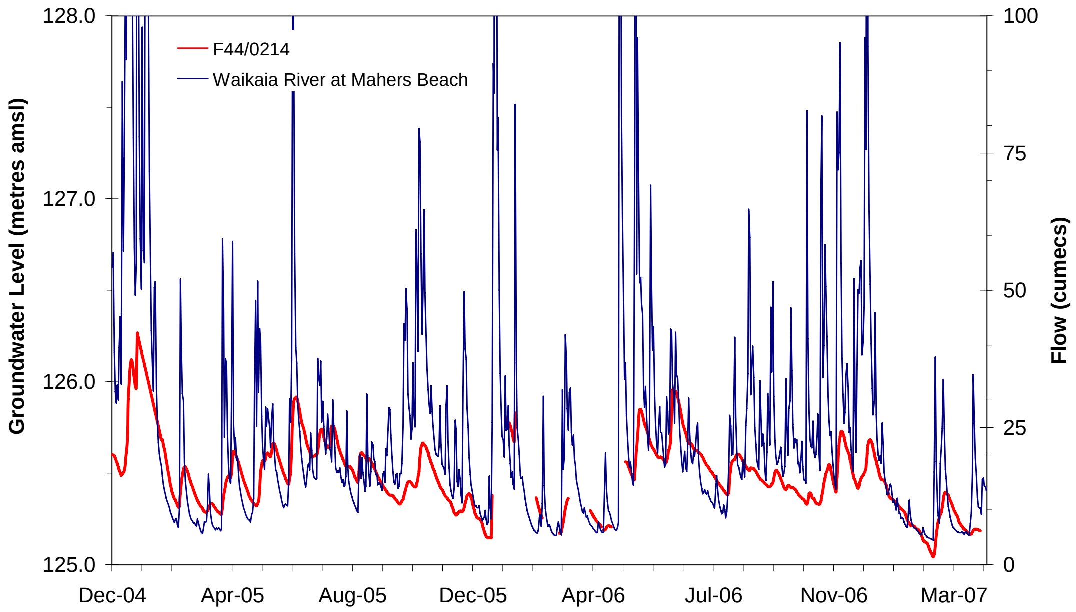

Figure 32: Groundwater levels in the Waipounamu Groundwater Zone with Waikaia River flow

Table 5 shows that groundwater drainage increases significantly downstream of the Waipounamu Road Bridge. This is interpreted to reflect groundwater drainage from the Waipounamu groundwater zone. Coarse water balance calculations (see Section 8) also indicate the Waipounamu groundwater is discharging into the Waikaia River in its lower reaches.

Table 5: Groundwater drainage in the Waikaia River *(based on 20 February 2007 gaugings when Mahers Beach was at 5.78 cumecs)*

Waikaia River Reach	**Length** (km)	**Net Flow Gain** (l/sec)	**Groundwater Drainage** (l/sec/km)
Mahers Beach to Pyramid – Waiparu Road	4.3	32	7
Pyramid – Waiparu Road to Waipounamu Bridge Road	13.1	967	74
Waipounamu Bridge Road to Mataura River confluence	3.5	982	284

It is interesting that in the same geographical location the Mataura River is losing flow while the Waikaia River is gaining flow. It is unclear why two rivers so close in proximity should behave so differently. Unfortunately, there is little bore log data available in this area so catchment geometry is largely unknown. Anecdotal reports from landowners and local drillers indicate the depth to mudstone (the start of the Gore Lignite Measures sequence) is highly variable. A single log for an irrigation bore (F44/0217) located between the Waikaia and Mataura Rivers 1.3 km above the confluence intercepted "blue mudstone" 10 metres below the surface. This could indicate elevated basement geology east of the Mataura River either through faulting or through relatively less degradation by the Waikaia River. The thinner alluvial gravel thickness in the Waikaia catchment may result in water being forced upwards into the Waikaia River, as proposed in Figure 33. The thicker gravel thickness west of the Mataura River is able to receive drainage from the Mataura River.

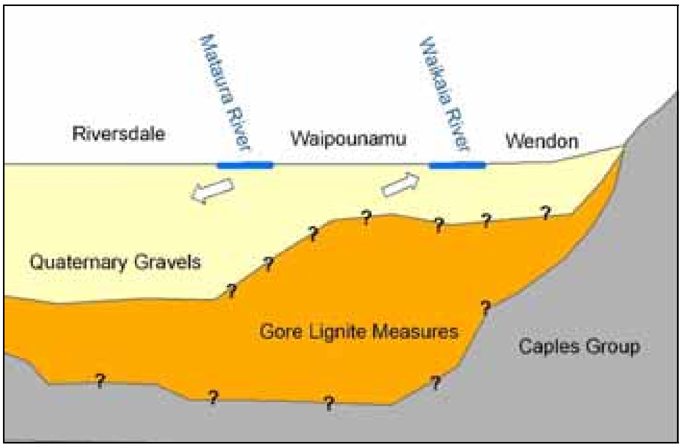

Figure 33: Hypothetical schematic cross-section of the southern end of the Waipounamu groundwater zone

The relationship between groundwater and surface water resources in the area around the confluence of the Mataura and Waikaia Rivers is not well understood due to the potentially complex geology and the absence of hydrogeological data. Given the catchment geometry is likely to have an important influence on hydrology, it is recommended further drilling occur to basement or surface geophysical surveying is conducted in order to determine the geological geometry of the area.

6.2 *Major springs and tributaries*

The Waikaia catchment includes the Wendonside terrace on which numerous streams drain the southern slopes of the Garvie Mountains. These streams dry up almost immediately upon emerging onto the Wendonside terrace, presumably into the underlying aquifer. No gaugings have been done to assess the volume of surface water recharge to the Wendonside groundwater zone.

6.2.1 Garvie Burn

The Garvie Burn headwaters are located in the Garvie Mountains and it is the largest tributary to the Waikaia River downstream of Mahers Beach. Available gaugings indicate a summer flow in the order of 100-200 l/sec near the confluence with the Waikaia River. A single set of concurrent gaugings done on the Garvie Burn during February 2007 show it is a gaining stream with 76 l/sec measured at Hurley Road near the base of the mountains which increased to 248 l/sec near the Waikaia River confluence. The Garvie Burn is partially spring-fed through seepage along the base of the Wendonside terrace and is also fed by the Rob Roy and Washpool Creeks. The Garvie Burn has a relatively poor correlation with the Waikaia River shown in Figure 34, particularly at mid to high flows where there is considerable variation in catchment run-off.

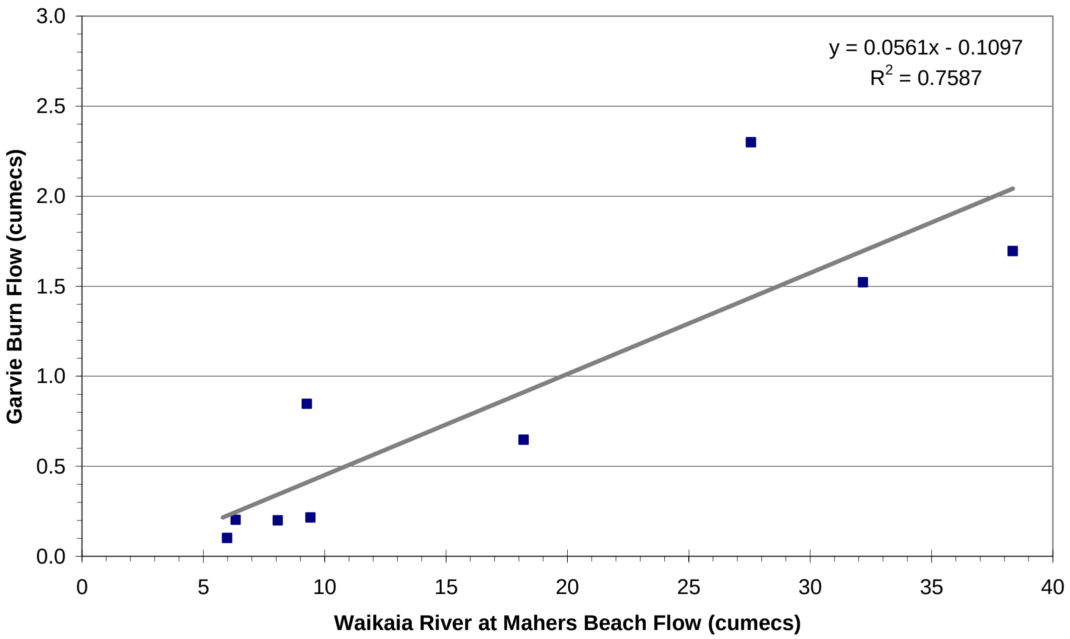

Figure 34: Linear regression between the Garvie Burn and Waikaia River

6.2.2 Wendon Creek

There are several small creeks and springs which are have their headwaters in the Round Downs Ranges and cross the narrow floodplain to drain into the Waikaia River. Many of these creeks dry up during summer as flow is derived from surficial run-off. Wendon Creek has the largest catchment area of these creeks and although Environment Southland's gauging register has no records of Wendon Creek drying up, groundwater input is assumed to be minor as flows decline rapidly during summer to approximately 55 l/sec near the Waikaia River confluence, as shown in Figure 35.

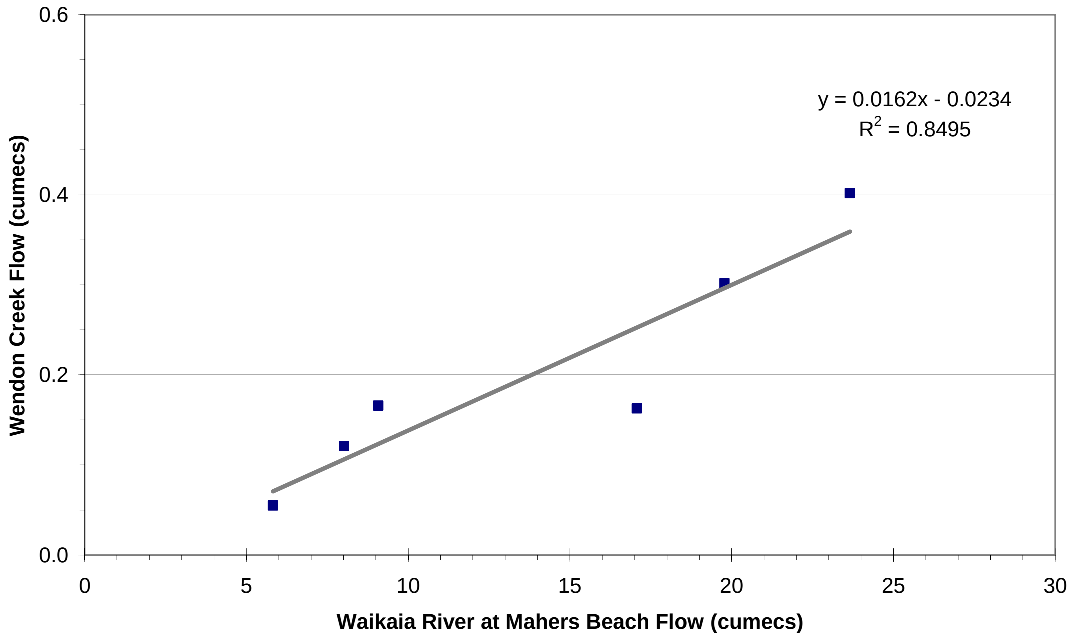

Figure 35: Linear regression between the Wendon Creek and Waikaia River

7 Mid-Mataura Catchment

7.1 *Catchment Water Balance*

The first set of concurrent gaugings for the mid-Mataura catchment were undertaken in 2003 and focused on the potential for river recharge to the Riversdale groundwater zone upstream of the Riversdale Bridge. Based on the results of these gaugings, the coverage was expanded downstream to the Otamita Stream confluence in order to gain an understanding of the water balance over this entire reach. Subsequent concurrent gaugings runs have been extended even further and on 20 February 2007 a four-team gauging party undertook 30 gaugings covering the entire Mataura River catchment above Gore, including the Waikaia River and other major tributaries.

The concurrent gauging data show there is limited flow loss from the Mataura River between Cattle Flat and Ardlussa when tributary inputs are accounted for. Flow loss is probably restricted by basement geometry as the Mataura River is confined within a relatively narrow valley bounded to the south and west by the foothills of the Mataura Range and to the east by the bedrock remnant which forms the prominent hill on Plains Station Road.

Downstream of Ardlussa, the rate of flow loss increases significantly as the Mataura River moves across the floodplain. Up to 30 percent of the flow in the Mataura River at Ardlussa is lost by the time the river reaches the Riversdale Bridge. Surveying results show an overall piezometric head gradient in a south-westerly direction which indicates flow loss from the Mataura River is predominantly through the true right bank into the Riversdale groundwater zone. As flow loss between Ardlussa and Riversdale Bridge is a major component of the water balance for the Riversdale groundwater zone, further gaugings are required to quantify riparian recharge over a range of flows and groundwater levels. Figure 36 shows the Mataura River recharges the Riversdale groundwater zone when groundwater levels at F44/0181 are below 126.5 metres above mean sea level or to put it another way, the Mataura River is recharging the Riversdale groundwater zone 75 percent of the time (exceedance percentile for 126.5 m amsl equals 25 percent).

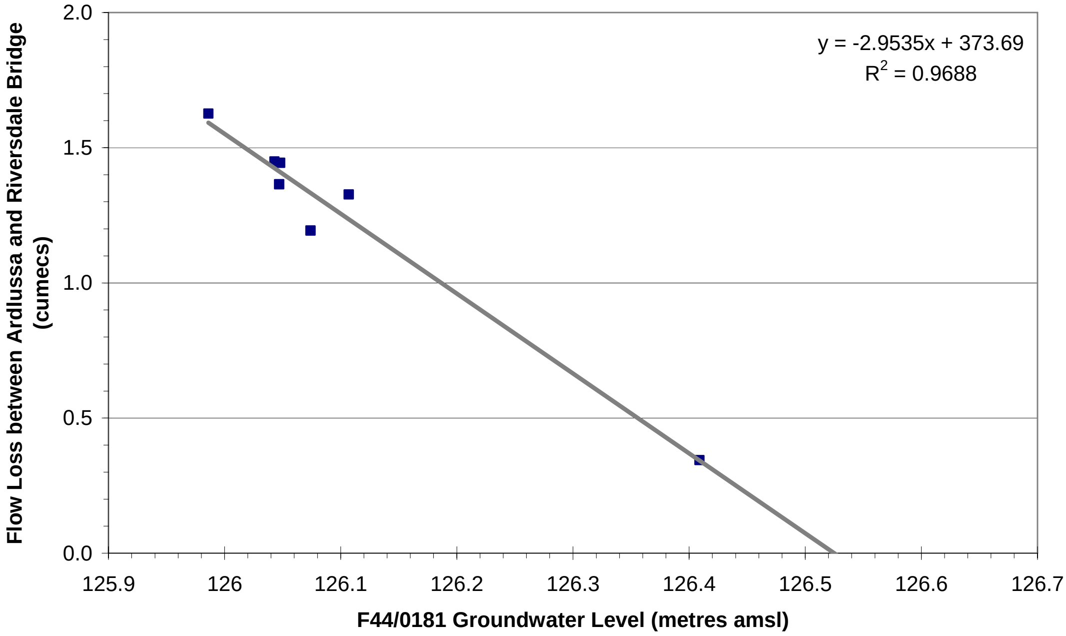

Figure 36: Riparian recharge from the Mataura River into the Riversdale aquifer

In order to determine the full extent of flow loss in the Mataura River, gaugings were conducted at a number of places between Ardlussa and the Waikaia River confluence during the comprehensive concurrent gauging run in February 2007. The lowest flow in the Mataura River between Gore and Cattle Flat was measured at the Riversdale Bridge.

Downstream of the Riversdale Bridge, the Mataura River starts to gain flow although the rate of flow gain is highly variable. Between the Riversdale Bridge and Otama Flat Road the amount of groundwater discharge which occurs via direct infiltration from the unconfined aquifer into the bed of the Mataura River flow is comparatively low at 55 l/sec/km length of river. Downstream of Otama Flat Road the volume of groundwater discharge increases to 84 l/sec/km between Otama Flat Road and the Otamita Bridge, then increases again to 154 l/sec/km between the Otamita Bridge and Gore, as shown in Table 6 (next page). In total, up to 3,300 l/sec of groundwater is discharged through direct infiltration into the bed of the Mataura River.

Groundwater is also discharged via numerous springs and spring-fed creeks. Approximately 420 l/sec of groundwater is discharged through several springs which originate south of the Riversdale township including the Meadow Burn and several smaller unnamed springs. Up to 350 l/sec of groundwater is discharged via springs which originate along the Longridge terrace margins and enter the Mataura River near Mandeville.

Up to 50 percent of the total groundwater discharge constitutes returned surface water flow lost from the Mataura River upstream of the Riversdale Bridge. Overall, the net volume of groundwater discharge to surface water bodies in the mid-Mataura surface water zone increases as river flow decreases, and is typically between 1,000–2,000 l/sec.

Table 6: Groundwater discharge to the Mataura River *(based on 6 March 2007 gaugings when Gore was at 13.510 cumecs)*

Mataura River Reach	Length (km)	Net Flow Gain/Loss (l/sec)	Groundwater Discharge (l/sec/km)
Cattle Flat - Ardlussa	22.3	-520	-23
Ardlussa – Riversdale Bridge	14.4	-1,626	-113
Riversdale Bridge – Waikaia River confluence	4.4	290	66
Waikaia River confluence – Otama Flat Road	8.9	432	48
Otama Flat Road – Dillon Road	5.3	660	125
Dillon Road – Otamita Bridge	3.4	68	20
Otamita Bridge - Gore	11.6	1,788	154
Groundwater discharge into the Mataura River:			**3,235 l/sec**

The Knapdale groundwater zone discharges into the Mataura River and numerous streams downstream of the Otamita Bridge. There is evidence to suggest there is limited hydraulic connection to the Mataura River on the western side of the Mataura River due to the non-conforming thin alluvial gravels overlying the greywacke basement ridges presumed to be part of the Murihiku Group, as illustrated in Figure 37. Groundwater discharge into numerous spring-fed streams like Otama Stream, Gold Creek at Okapua Creek is assumed to constitute a major component of the aquifer water balance with anecdotal information suggesting flow in these streams increases as they move toward their confluence with the Mataura River.

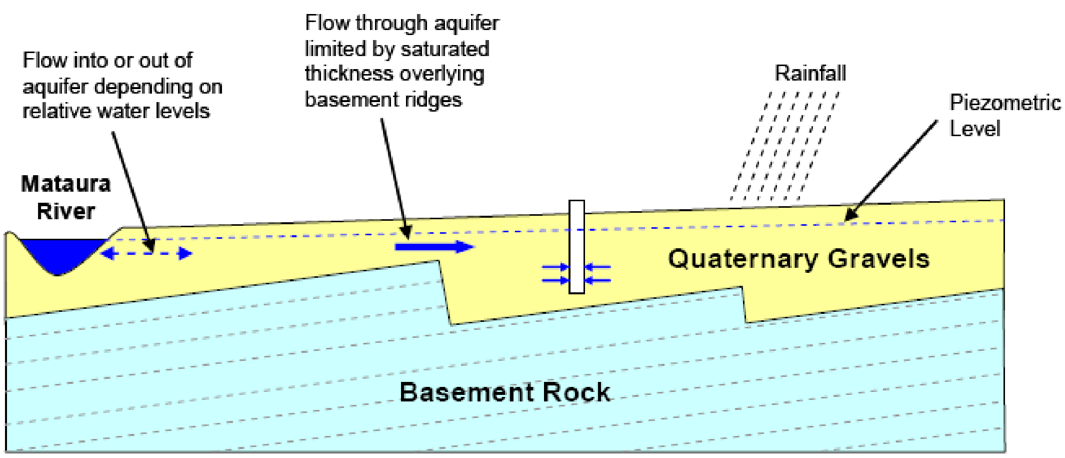

Figure 37: Conceptual hydrogeological model of the unconfined aquifer near Croydon *(Source: SKM, 2007)*

Since the 1970s, the Mataura River has degraded to basement level at Gore and has been scoured out through gravel extraction near Croydon. The overall lowering of the Mataura River bed has resulted in an increase to river yield along the reach from Otamita Bridge to Gore as shown in Figure 38.

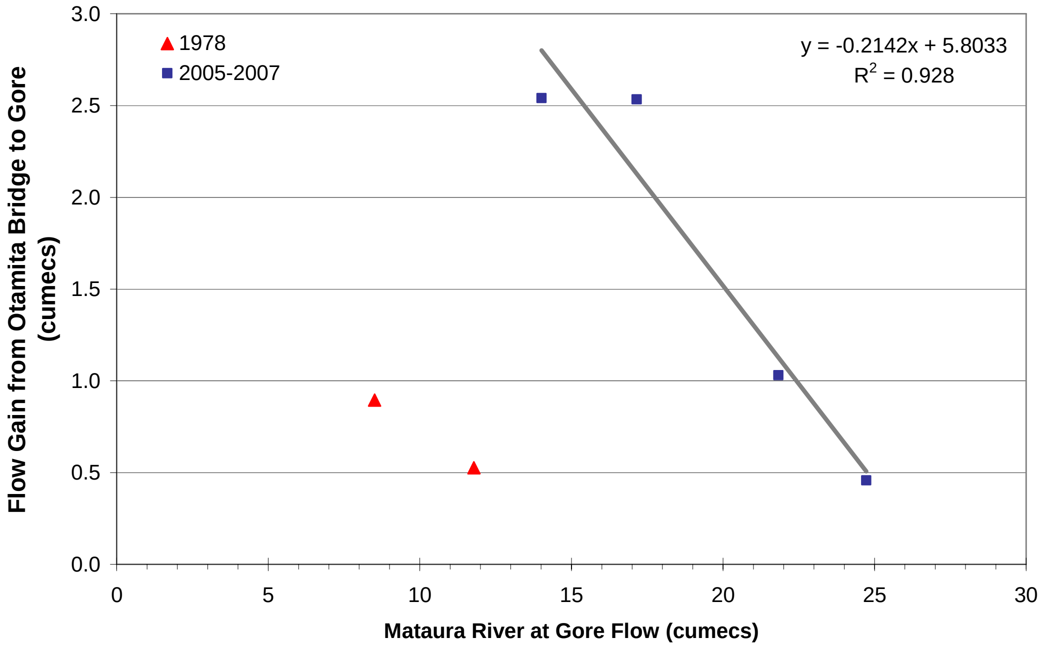

Figure 38: Effects of river degradation on flow in the Mataura River downstream of the Otamita Bridge

7.2 *Major Springs*

A number of spring-fed tributaries flow into the middle reaches of the Mataura River between Riversdale and Knapdale. Regular flow gaugings have been undertaken on five spring-fed streams in the Riversdale groundwater zone since 2001.

Measured discharge from the spring-fed streams in the Riversdale area ranges from 21 l/sec in an unnamed spring on the Mandeville-Riversdale Highway to 467 l/sec in the Meadow Burn at Round Hill Road. The total discharge from spring-fed creeks in the Riversdale groundwater zone has been measured on one occasion at 716 l/sec on 17 January 2003.

Many of the spring-fed streams may gain significant flow downstream of the current gauging locations as illustrated by the Meadow Burn. Numerous consecutive gaugings on the Meadow Burn show flow increases by 60 percent between Fingerpost-Pyramid Road and the confluence with the Mataura River. It is likely other spring-fed streams will show a similar magnitude of flow gain over the lower reaches.

7.2.1 Meadow Burn

The Meadow Burn, shown in Figure 39, is the largest of the spring-fed creeks in the Mid-Mataura surface water resource zone and originates to the north of Riversdale township. It flows east-southeast across the Mataura River floodplain before entering the Mataura River approximately 6.5 km downstream of the Pyramid bridge. The Meadow Burn is considered to be an important fisheries refuge because it has a relatively stable stage regime and cooler water temperatures make it an attractive habitat to fish when the Mataura River is experiencing high and low flows.

Figure 39: Looking upstream the Meadow Burn at Round Hill Road

Figure 40 (next page) shows the Meadow Burn, which is approximately 11 km in length, is a gaining stream that increases in flow as it moves across the floodplain draining the surrounding aquifer across much of its reach. The gauging site at York Road is very close to the start of the Meadow Burn (within 250 metres) and is near the Riversdale groundwater zone reference monitoring bore F44/0181 (within 400 metres). The high correlation between groundwater level and flow at York Road shows the Meadow Burn is sourced from the highly permeable, unconfined alluvial aquifer running along the western margin of the Mataura River.

Gaugings show that as groundwater levels drop the Meadow Burn maintains a fairly constant discharge of 25 l/sec near its origin. At the downstream sites, run-off and possibly bank storage influence discharge resulting in increased scatter at higher flows shown in Figure 40. The Meadow Burn at Round Hill Road may also be influenced by high levels in the Mataura River which can inhibit discharge to the Mataura River.

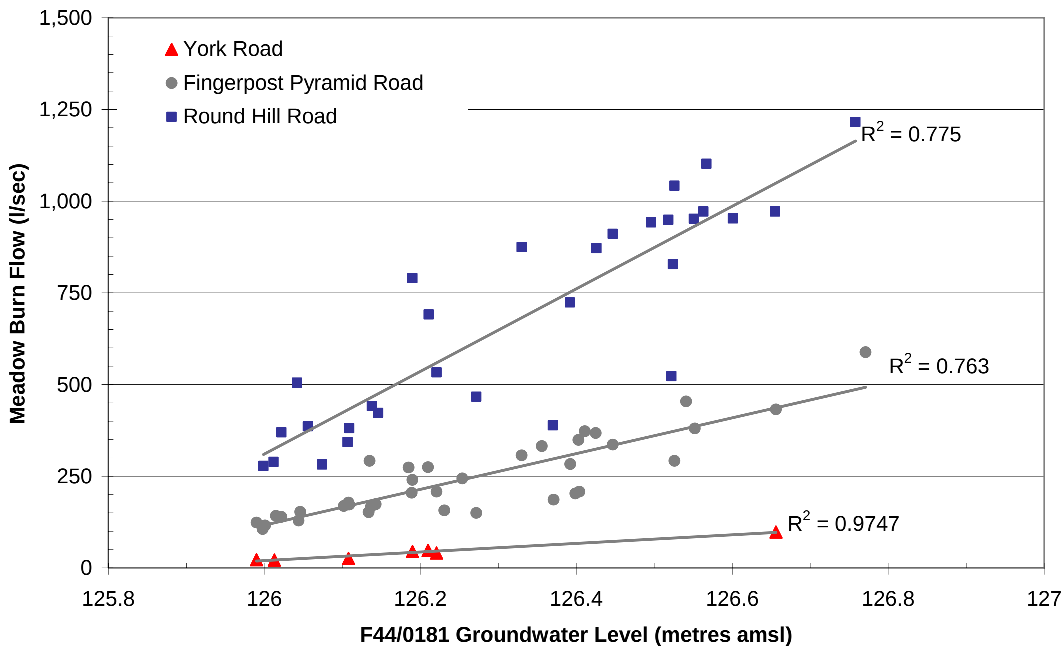

Figure 40: Linear regression of Meadow Burn discharge and groundwater levels in the Riversdale groundwater zone

Figure 41 shows that unsurprisingly, the total volume of groundwater discharge into the Meadow Burn increases as groundwater levels rise. Although the reach between York Road to Fingerpost Pyramid Road is similar in length to Fingerpost Pyramid Road to Round Hill Road, there is almost double the amount of groundwater discharge in the lower reach.

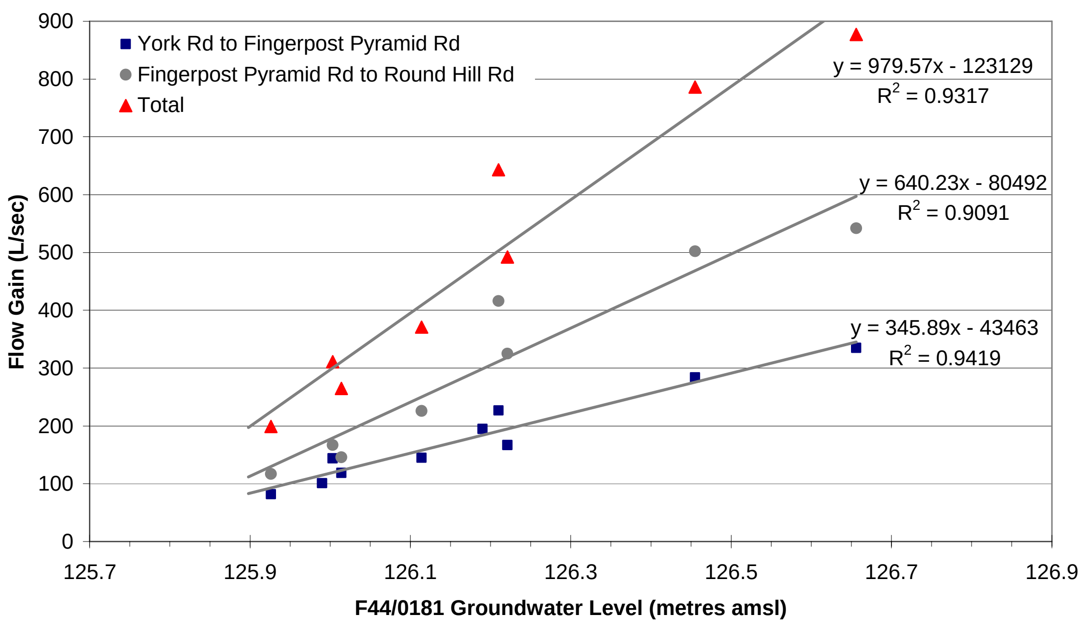

Figure 41: Groundwater discharge into the Meadow Burn

7.2.2 McKellar Stream

The McKellar Stream is sourced from a series of springs at the base of the Longridge terrace west of Dunn and Cody Road and flows across the Riversdale groundwater zone before discharging to the Mataura River near Mandeville.

Field measurements undertaken between Dunn and Cody Road and Nine Mile Road show the McKellar Stream is not hydraulically connected to the unconfined aquifer over this reach. Measurements of relative stream stage and groundwater level show the stream is perched above the aquifer, illustrated in Figure 42.

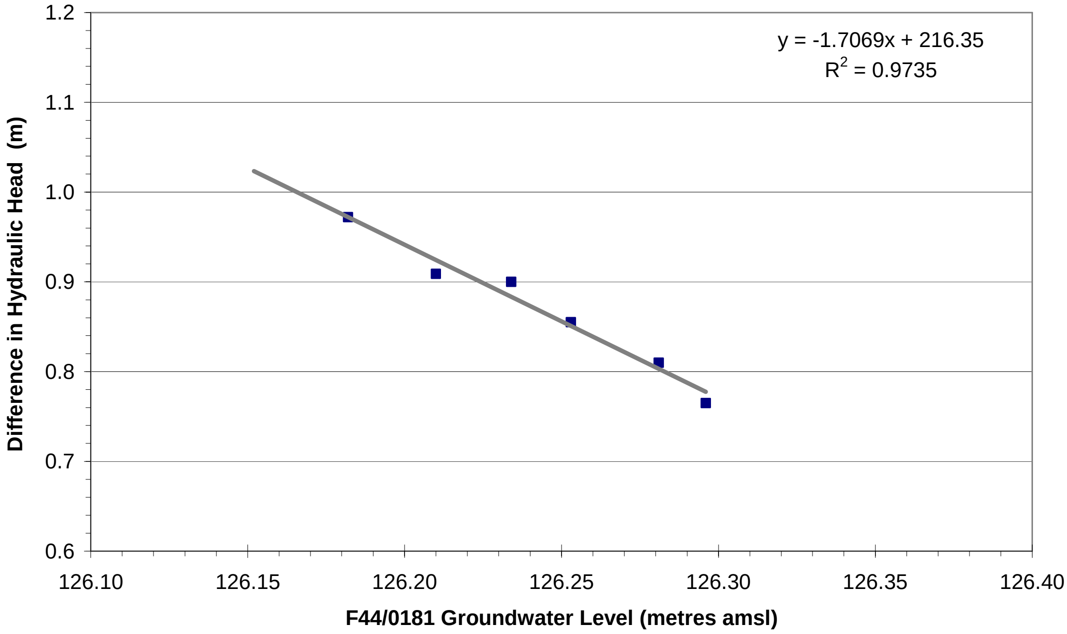

Figure 42: Hydraulic gradient between the water table and McKellar Stream at Dunn and Cody Road

Gauging data from the McKellar Stream indicate stream discharge upstream of Nine Mile Road is unaffected by variations in underlying groundwater level. During dry periods the reach between Dunn and Cody Road and Nine Mile Road loses flow as a result of the stream being perched above the aquifer. However, during wet periods soil through flow and run-off have a greater influence resulting in an increase in flow. Figure 43 (next page) shows that the rate of loss is independent of groundwater fluctuations in the underlying Riversdale aquifer.

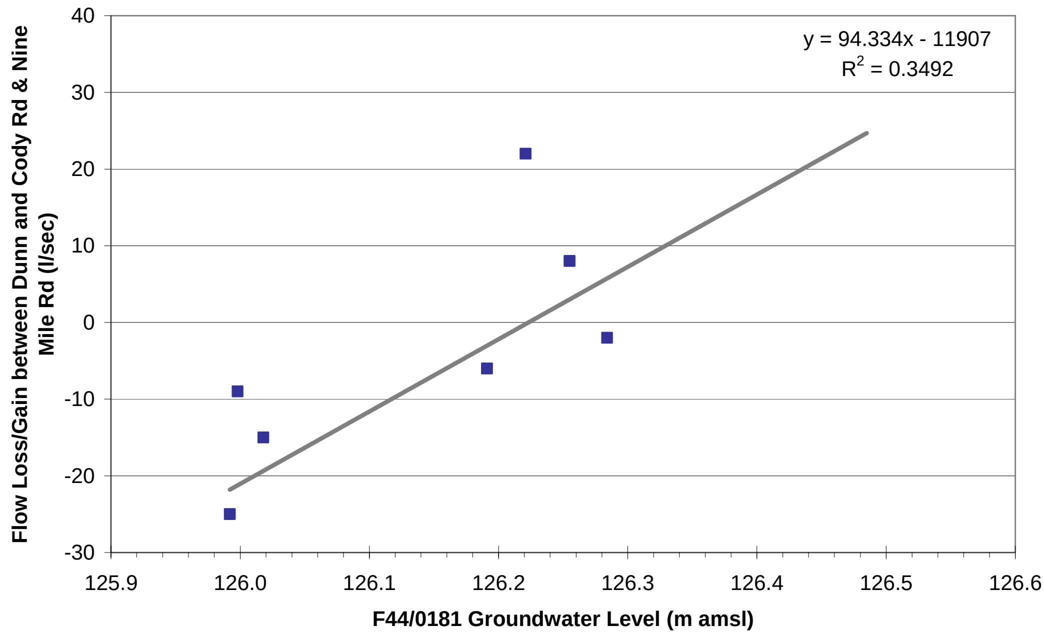

Figure 43: Riversdale groundwater level and flow gain/loss in the upper reaches of the McKellar Stream

Downstream of Nine Mile Road, the McKellar Stream exhibits a very low degree of hydraulic connection with the surrounding aquifer, as illustrate in Figure 44, although the stream is no longer perched. Gaugings during low flows show the flow in the McKellar Stream remains virtually constant between Nine Mile Road and Fortune Road regardless of the groundwater level suggesting the stream is effectively sealed from the aquifer due to streambed clogging.

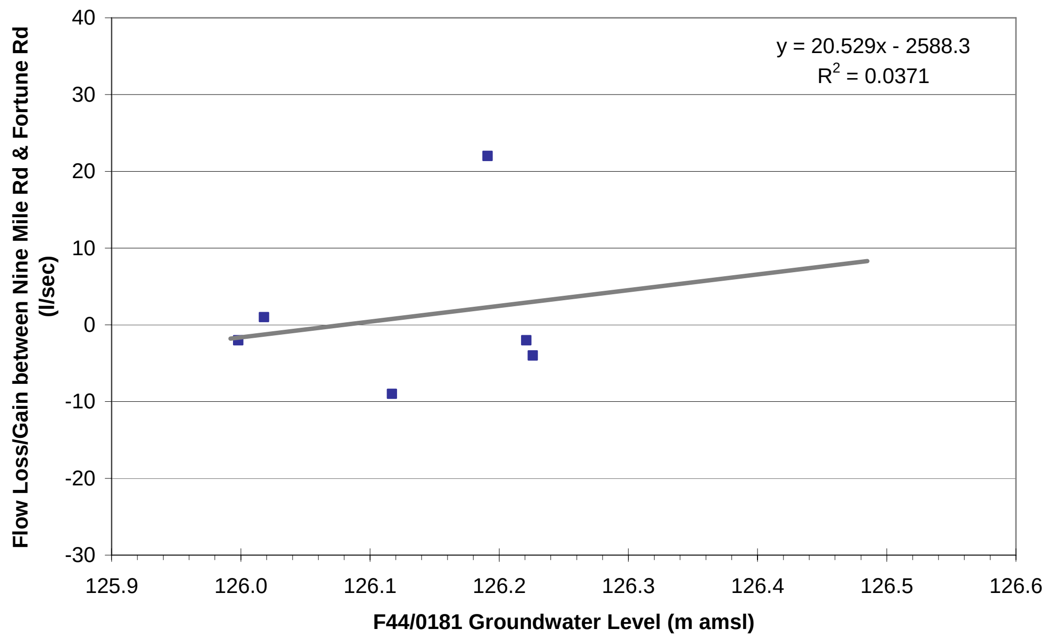

Figure 44: Riversdale groundwater level and flow gain/loss in the lower reaches of the McKellar Stream

7.2.3 Unnamed Springs

There are a number of smaller unnamed springs which originate south of Riversdale and cross the floodplain in a south-easterly direction to drain into the Mataura River between Pyramid and Mandeville. Two of these springs which cross Fingerpost Pyramid Road have been gauged regularly since 2001 and the results are shown in Figure 45. These springs are similar to the Meadow Burn in that they are gaining springs which drain groundwater from the Riversdale groundwater zone. Combined with the Meadow Burn, these three springs drain an average of 900 l/sec of groundwater.

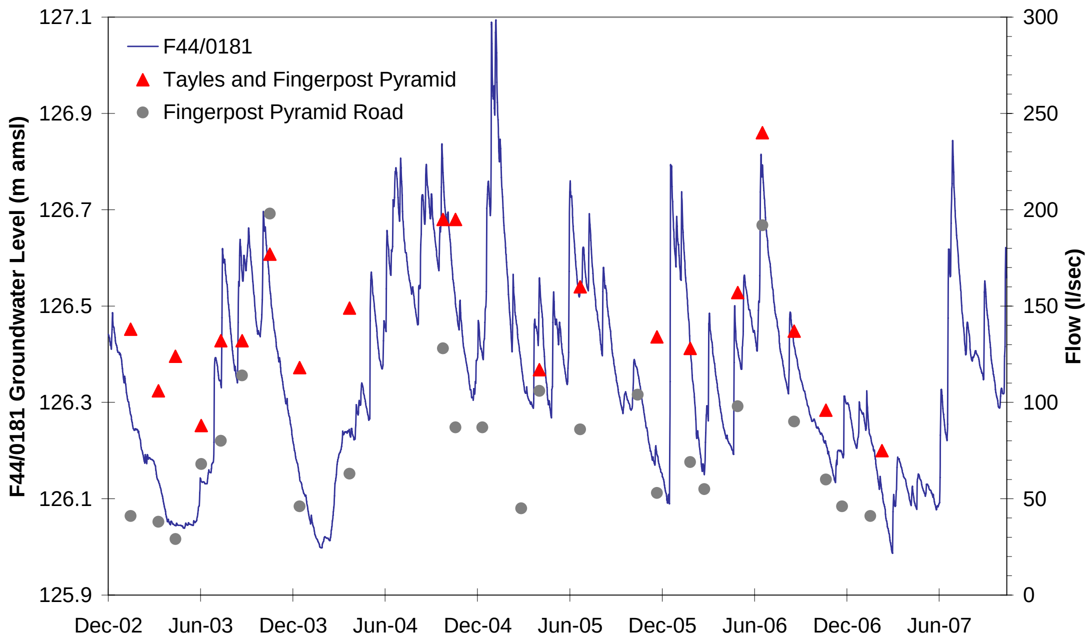

Figure 45: Riversdale groundwater level and flows in un-named springs at Fingerpost – Pyramid Road

Towards Mandeville there are several smaller springs which originate at the southern tip of the Longridge terrace and drain into the Waimea Stream near its confluence with McKellar Stream. Two of these springs have been gauged regularly since 2001. The unnamed spring which crosses the Kingston Crossing – Mandeville Road starts along the base of the southern tip of the Longridge terrace and has a fairly constant discharge indicating it is almost entirely sourced from drainage from the Longridge terrace. The second un-named spring which crosses the Mandeville–Riversdale Highway originates further north towards Pyramid–Siding Road. This spring probably sources its flow from a combination of discharge from the Longridge terrace and groundwater drainage from the Riversdale groundwater zone as it crosses the floodplain towards Mandeville. This is reflected in a much stronger correlation to groundwater levels from the Riversdale groundwater zone as shown in Figure 46. The combined discharge of these two un-named springs averages 200 l/sec.

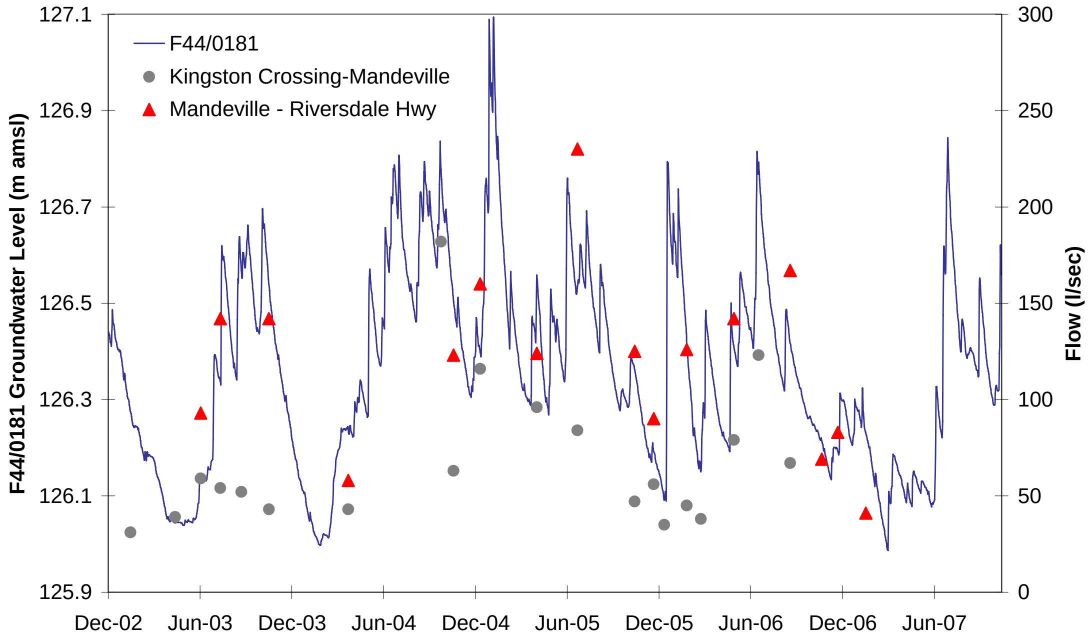

Figure 46: Riversdale groundwater level and unnamed spring flows on the Waimea highway

8 Summary

8.1 *Surface Water Balance*

At times of medium to low flows, groundwater is an important hydrological driver of flows in the Waikaia River and the Mataura River upstream of Gore. Different reaches of the Mataura River gain or lose flow depending on the relative head difference between stage height and groundwater level. It is important to understand where water is exchanged and by what volume so that water resources can be managed in accordance with governing policies like Environment Southland's Proposed Regional Water Plan and the MCO.

Figure 46 summarises gains and losses in the Mataura and Waikaia Rivers, accounting for the inputs of major tributaries and springs. Within the study area there are two natural control points where drainage is contained at the surface by basement geology. These control points have Environment Southland flow recorders installed at them and are located on the Mataura River at Parawa and Gore.

The gaugings indicate groundwater infiltration into the Mataura River is approximately 2,200 l/sec upstream of Parawa and 3,300 l/sec between Cattle Flat and Gore, as shown in Figure 47. However, within these areas significant flow loss occurs with up to 100 percent of the flow in the Mataura River lost between the Roberts Creek confluence and Fairlight and up to 30 percent of flow lost between Ardlussa and the Riversdale Bridge. Some of the net gain in flow therefore represents the return of lost surface water flow however overall there is a net gain in flow of 2,900 l/sec, which is interpreted to represent discharge from aquifer storage.

The Waikaia River downstream of Mahers Beach is a gaining river which reflects the influence of groundwater discharge. During low flow periods, approximately 70 percent of the flow in the Waikaia River at its confluence with the Mataura River is sourced from run-off in the catchment above Mahers Beach while 25 percent is sourced from groundwater infiltration directly into the bed of the river. Approximately half of the groundwater drainage occurs in the relatively short reach downstream of the Waipounamu Bridge Road which is interpreted to reflect a change in discharge from the Wendon groundwater zone to the much higher yielding Waipounamu groundwater zone. The remaining 5 percent of flow can be attributed to relatively small tributaries like the Garvie Burn and Wendon Creek.

Springs and spring-fed creeks are important contributors to baseflow in some sections of the Mataura River. The Brightwater Spring can account for up to 60 percent of the flow measured in the Mataura River at Garston during times of low flow, while the combined spring discharge can contribute up to 40 percentage of the flow measured in the Mataura River at Parawa. The Riversdale groundwater zone also contains a large number of springs, some of which originate along the base of the Longridge terrace (e.g. the McKellar Stream) or are contact springs which originate near the Riversdale township (e.g. the Meadow Burn). The combined discharge from springs in the Riversdale groundwater zone has been measured on one occasion at 700 l/sec.

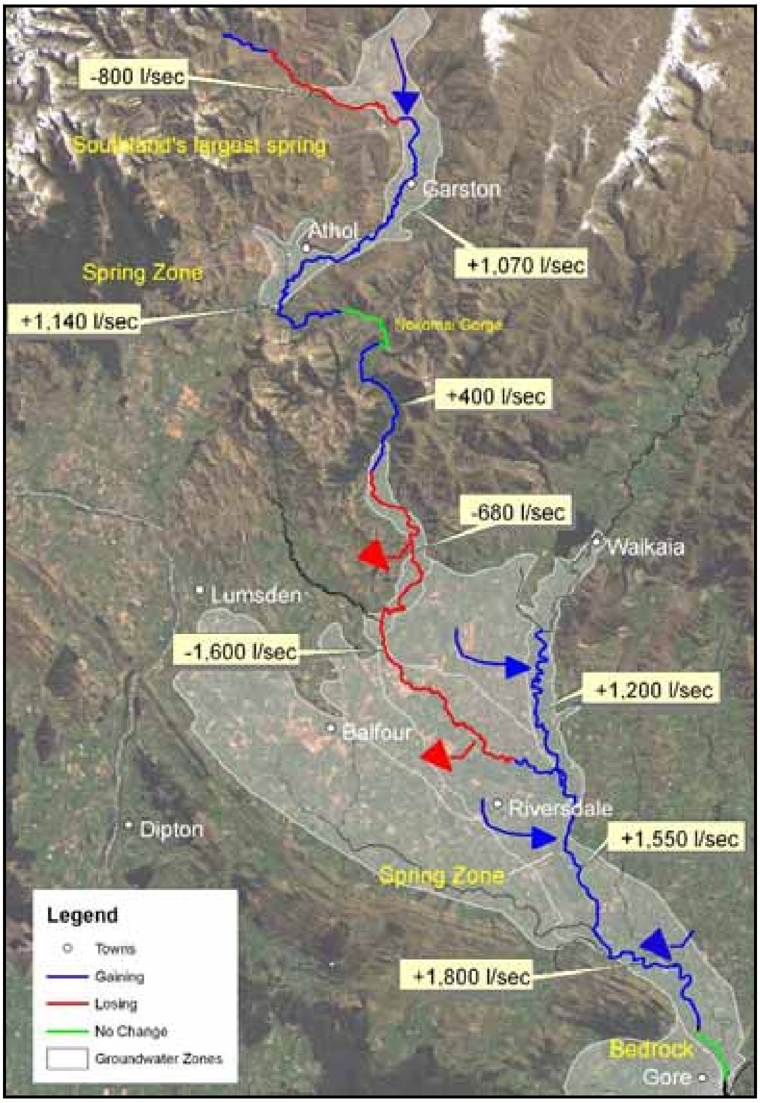

Figure 47: Net flow gains and losses in the Mataura and Waikaia Rivers (with major tributary inputs accounted for) when the flow at Gore is 13.5 cumecs

8.2 *Groundwater Water Balance*

Coarse water balance calculations of groundwater recharge and discharge indicate there is very little throughflow from the Longridge and Waimea Plains groundwater zones into the Riversdale groundwater zone. Groundwater within these zones presumably drains towards the Waimea Stream. There are several small springs which originate along the base of the Riversdale side of the Longridge terrace however their total discharge is less than 30 l/sec so they constitute a negligible part of the water balance.

Table 7 shows that the equivalent of approximately 80 percent of the land surface recharge to the Wendonside and Waipounamu groundwater zones discharges into the Waikaia River. The remaining 20 percent presumably drains into the Mataura River and flows through into the Riversdale groundwater zone.

Table 7: Water balance of groundwater zones

Groundwater Zone	Mean Annual Land Surface Recharge* (l/sec)	Net Flow Gain to the Mataura & Waikaia Rivers when Gore is at 14 cumecs (l/sec)
Upper Mataura	1,076	
Mataura River at Parawa:	**1,076**	**1,050**
Wendon	241	
Wendonside	868	Discharges to Wendon, Waipounamu and Riversdale groundwater zones
Waipounamu	428	Also drains into the Mataura River
Waikaia River at Confluence:	**1,537**	**1,268**
Cattle Flat	301	
Riversdale	880	
Knapdale	428	
Mataura River at Gore:	**1,608**	**1,640**

* Source: LVL & MWH, 2003

Table 8 summarises the contribution of groundwater discharge to baseflow in the Mataura River at Gore. As can be seen, during times of low flow most groundwater discharge is via stream bed infiltration directly into the Mataura and Waikaia Rivers and accounts for up to 60 percent of the flow measured at Gore. In the Upper Mataura and Mid-Mataura water resource zones, springs and spring-fed streams are important components of the water balance with spring discharge accounting for approximately 20 percent of the flow measured at Gore.

Table 8: Groundwater discharge as a proportion of the flow at Gore *(in l/sec)*

Water Resource Zone	Discharge via springs		Discharge via riparian infiltration		Total groundwater discharge		Lost surface water (riparian recharge)		Discharge from aquifer storage	
	20-Feb-07	6-Mar-07	20-Feb-07	6-Mar-07	20-Feb-07	6-Mar-07	20-Feb-07	6-Mar-07	20-Feb-07	6-Mar-07
Upper Mataura	2,152	2,098	4,120	2,841	6,272	4,939	2,247	1,434	4,025	3,505
Waikaia	<10	<10	1,981	1,268	1,981	1,268	0	0	1,981	1,268
Mid-Mataura	~750	~700	3,728	3,344	4,478	4,044	3,074	2,000	1,404	2,044
TOTAL	**2,902**	**2,798**	**9,829**	**7,453**	**12,731**	**10,251**	**5,321**	**3,601**	**7,410**	**6,817**
Percentage of Gore flow*	17%	21%	59%	55%	76%	76%	32%	27%	44%	50%

* Based on a Gore flow of 16,691 l/sec and 13,510 l/sec on 20 February and 6 March 2007 respectively

9 Recommendations

Many of the relationships described in this report are based on a relatively small set of gaugings and short groundwater monitoring history. It is important that the concurrent and spring gauging programmes continue to further test and quantify the relationships described in this report, particularly over a wider range of flows. The following recommendations are intended to help prioritise and target future water resource investigation work in the Mataura catchment above Gore.

9.1 *Upper Mataura catchment*

- **Further concurrent gaugings runs along the Mataura River to improve quantification of groundwater and surface water interaction** - further concurrent gauging runs will improve the accuracy of groundwater and surface water interaction and improve understanding of the spatial and temporal relationships within the catchment.

- **Conduct some concurrent gaugings along Eyre Creek in order to measure the flow loss rate** - to date, there is one set of concurrent gaugings for Eyre Creek from 1975 which showed approximately 900 l/sec was lost from Eyre Creek into the underlying aquifer. This suggests Eyre Creek provides a significant volume of riparian recharge to the aquifer in terms of the overall water balance and should therefore be quantified.

- **Include the Mataura River at the Nokomai Gorge site in future concurrent gaugings to establish whether there is flow loss through this reach** - two sets of concurrent gauging runs during 2007 showed the Mataura River was losing between 5 to 10 percent of its flow as it flowed through the Nokomai Gorge. Further concurrent gaugings runs should include sites downstream of Parawa in order to determine if the observed flow loss is a real phenomenon and if it is, to quantify the surface water balance in this reach.

- **Install an automatic groundwater level monitoring site in the riparian aquifer to improve understanding of the dynamic behaviour of the aquifer system, particularly in relation to rainfall and surface water flows** - currently, groundwater levels in the upper Mataura catchment are monitored on a monthly basis which is adequate for assessing long-term trends, however, does not provide understanding of the dynamic behaviour of the aquifer system. Given the dominance of groundwater discharge on surface hydrology during times of medium to low flows, real-time groundwater level monitoring data would improve understanding of both groundwater and surface water resources within the catchment. This could become increasingly important should utilisation of water resources for pasture and crop irrigation increase.

9.2 *Waikaia catchment*

- **Further concurrent gauging runs along the Waikaia River and tributaries** - to date, there have only been three sets of concurrent gauging runs along the Waikaia River, and similarly relatively few gaugings exist on the major tributaries. Further concurrent gauging runs should be conducted in order to substantiate the tentative relationships described in this report, particularly downstream of the Waipounamu Bridge Road where considerable groundwater discharge has been observed. It would also be interesting to extend the concurrent gauging runs upstream towards Piano Flat in order to determine the influence of groundwater discharge above Mahers Beach.

- **Establish a groundwater level monitoring site within the Wendon groundwater zone** - as can be observed in Table 2, there are currently no groundwater level monitoring sites within the Wendon groundwater zone. Results from a temporary recorder installed during 2004 show groundwater levels within the Wendon groundwater are markedly different from those in the surrounding aquifers, as illustrated in Figures 31 and 32. This may reflect the difference in the character of the gravel deposits and climate. Given the relatively unique behaviour of groundwater levels within the Wendon groundwater zone and its importance as a receiving environment for throughflow from the Wendonside groundwater zone and losing streams (such as Pyramid Creek), it is recommended that at least one monitoring site be established within the Wendon groundwater zone.

- **Quantify riparian recharge to the Wendonside groundwater zone** - the Wendonside groundwater zone is recharged through a combination of rainfall, sideslope infiltration and surface water discharge where streams emerge onto the Wendonside terrace. Gaugings of Boundary Creek and other streams at the foot of the Garvie Mountains will help quantify run-off and surface water recharge into the northern boundary of the Wendonside groundwater zone. This is particularly important given the unexplained decline in groundwater levels underneath the Wendonside terrace, as shown in Figure 14.

- **Amend the Waipounamu groundwater zone boundary so it is adjacent to the Waikaia River** - the information provided in previous chapters indicates the Waipounamu groundwater is discharging into the Waikaia River downstream of the Waipounamu Road Bridge. The groundwater zone boundary should reflect this by being modified at the southern tip to extend to the Waikaia River as shown in Figure 48. This will require the preliminary allocation limits in Appendix H in the Proposed Regional Water Plan to be adjusted accordingly.

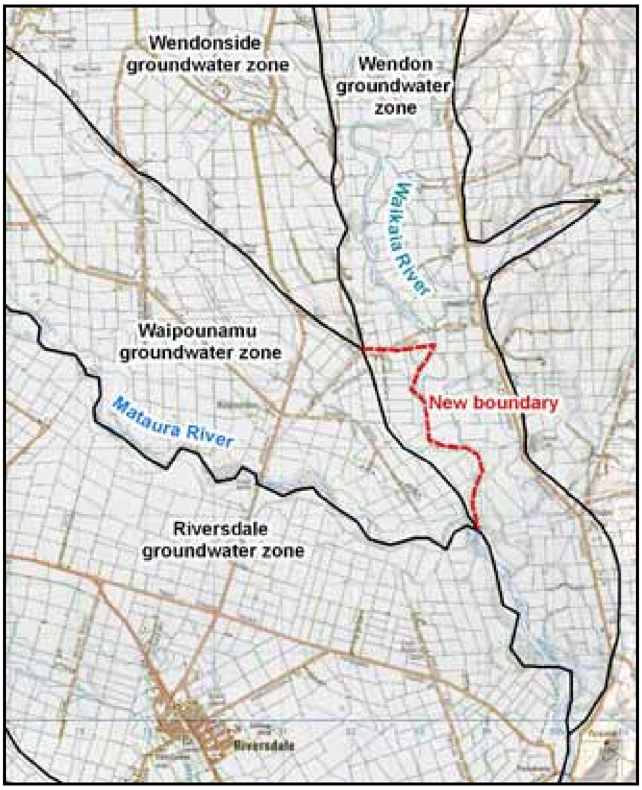

Figure 48: Proposed Waipounamu groundwater zone boundary change

9.3 *Mid-Mataura catchment*

- **Further concurrent gauging runs along the Mataura River to improve quantification of groundwater interaction at very low flows** – there have been no concurrent gauging runs undertaken on the Mataura River during times of very low flow (e.g. when the flow at Gore is less than 13 m^3/sec) which is when aquatic habitats are most reliant on groundwater discharge to maintain baseflow. In addition to conducting concurrent gaugings during periods of very low flows, it is also recommended that at least one set of concurrent gaugings be undertaken annually in order to determine the impact river degradation/aggradation has on baseflow.

- **Conduct geophysical surveying to determine aquifer geometry** – geophysical surveying undertaken near the confluence of the Waikaia and Mataura Rivers would help to determine the structure and depth of the basement geology which appears to control groundwater drainage and flow direction in this area. Geophysical surveying would also be useful to identify the basement depth within the Riversdale groundwater zone and could be used to determine whether there are channelised gravels which feed the springs near Riversdale, including the Meadow Burn.

- **Complete concurrent gauging runs along major tributaries to determine if there is any groundwater and surface water interaction** – there are a number of large tributaries with little or no flow information e.g. the Tomogalak and Nokomai Streams. These should be gauged in order to determine whether they are hydraulically connected to underlying groundwater resources and to what extent.

- **Continue regular gaugings of spring-fed streams to ensure groundwater abstraction does not adversely impact on flows** – groundwater discharge into springs constitutes a significant component of the Mataura catchment water balance as illustrated in Table 8. Regular gaugings of springs should be continued, particularly in those which originate in the Riversdale area where groundwater abstraction is most intensive. Attempts have been made to establish a rated flow site at several points within the Meadow Burn however this has proved unfeasible due to the prolific macrophyton growth characteristic of springs and the influence of the Mataura River. Regular gaugings are therefore the most practical means for monitoring stream depletion effects.

10 References

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Glossary

Alluvial
Sediments deposited by a river or other running water.

Above mean sea level (amsl)
The elevation of any object relative to the average sea level datum. In this report the New Zealand Bluff 1949 datum has been used.

Aquifer
A saturated rock or soil material capable of transmitting and yielding water in sufficient quantities for abstraction.

Base flow
Stream discharge level during long periods when no precipitation has occurred.

Cenozoic
An era of geologic time spanning between 66 million years ago to the present. The Cenozoic contains the Tertiary (66 – 2 million years ago) and the Quaternary (2 million years ago to present) periods.

Confined aquifer
An aquifer which is overlain by a low permeability or impermeable layer where water in the aquifer is under pressure.

Fault
A fracture along which the blocks of crust on either side have moved relative to one another parallel to the fracture.

Floodplain
The flat or nearly flat land along a river or stream or in a tidal area that is covered by water during a flood.

Gauging
The physical measurement of stream flow.

Lowland
Any broad expanse of land with a general low level and a relatively flat slope.

Mean Annual Low Flow (MALF)
Mean annual low flow, in the context of this report, is the natural seven-day mean annual low flow. The natural seven-day mean annual low flow is defined as the average of the minimum flow over a continuous seven day period each year.

Metres below ground (mbg)
Distance unit from the ground surface to the top of the water table.

Piezometric head
The level to which groundwater will rise in a bore or well penetrating an unconfined aquifer.

Riparian

Pertaining to anything connected with or immediately adjacent to a river or stream.

Spring

A point where the aquifer surface meets the ground surface and groundwater flows out of the ground.

Stream flow

The volume of water to pass a given point on a river or stream bank per unit of time, usually expressed in cubic metres of water per second (m^3/sec) or litres per second (l/sec).

Terrace

A level plain lying above and running parallel to a stream bed. A stream terrace is formed when a river's bed erodes to a substantially lower level, leaving its floodplain high above it.

Tertiary

The first period of the Cenozoic era extending from 66 to 2 million years ago.

Quaternary

The youngest of the geological periods, extending from 2 million years ago up to the present.