Edendale Groundwater Management Zone

Technical Report

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1. Executive Summary

Groundwater is one of the Southland region's most important natural resources and is used for a variety of purposes including domestic, stock, irrigation and community supply, as well as playing a crucial role in sustaining stream flows, particularly during droughts and other low-flow periods. This report summarises the current state of knowledge about groundwater resources in the Edendale groundwater management zone and assesses where future monitoring and investigation should be focused to best address emerging issues or information gaps.

The Edendale aquifer is hosted in the Quaternary alluvial gravel deposits, which underlie the southern section of the Edendale terrace in the Lower Mataura Valley. The aquifer system contains an extensive groundwater resource, which is utilised for municipal, industrial, irrigation, farm and domestic water supplies, as well as a receiving environment for discharges associated with agricultural land use and wastewater disposal from the Edendale dairy factory. Current allocation for consumptive use totals a maximum of approximately 50,000 m^3/day.

The aquifer system is primarily recharge from infiltration of local rainfall. Groundwater level monitoring shows a regular seasonal fluctuation reflecting recharge during the winter and spring. Temporal trends in groundwater levels appear to follow both annual and long-term trends in rainfall with little, if any, evidence of changes in aquifer storage due to current levels of groundwater abstraction.

Piezometric contours (and water quality monitoring data) indicate groundwater generally flows in a southerly direction through the aquifer system following the natural topographic gradient before being discharged via a series of spring-fed streams in the Seaward Downs area, which flow into the lower Mataura River. The total volume of aquifer discharge via these springs is estimated to be in excess of 30 million m^3/year (~1 m^3/sec).

Groundwater quality monitoring results illustrate the vulnerability of the aquifer system to contaminants introduced by overlying land use activities. In particular, elevated nitrate concentrations primarily associated with historical wastewater disposal activities are observed in the central portion of the aquifer system. Due to the complicated nature of nitrate leaching from the soil profile, legacy effects of wastewater historical wastewater discharge activities combined with existing land use present a relatively complex pattern of spatial and temporal variation in groundwater nitrate concentrations. In particular, elevated nitrate concentrations associated with wastewater discharge appear to be superimposed on an underlying trend of increasing nitrate concentrations, possibly associated with more general intensification of land use across the wider Edendale groundwater zone.

2. Introduction

Groundwater is one of the Southland region's most important natural resources. It is estimated groundwater is the main source of drinking water to more than one-third of Southland's total population (Environment Southland and Te Ao Marama Inc, 2010) and is used for domestic purposes by more than 60 percent of rural properties (Hamill, 1998). In some areas, groundwater is the only reliable source of water suitable to meet domestic, stock, irrigation and community needs. Groundwater also plays a crucial role in sustaining stream flows, particularly during droughts and other low-flow periods.

In response to increasing pressure on groundwater resources, Environment Southland formally began a State of the Environment (SOE) groundwater monitoring programme in 2000. The purpose of the programme was to provide a regional perspective to:

- quantify the current state of the groundwater resources;
- identify trends in the ambient condition of groundwater resources;
- determine the cumulative effect of pressures, including those from human activities;
- provide a basis for assessing environmental effects;
- identify resource management issues; and
- assist in monitoring the effectiveness of regional plans.

In addition to the long-term SOE monitoring programme, Environment Southland also developed a groundwater investigations programme, designed to improve definition of the hydrogeological characteristics of the region's aquifer systems to enable the effective and sustainable management of quantity and quality of the groundwater resource. Applications of this work include the establishment of sustainable allocation limits, improved understanding of the inter-relationship between groundwater and surface water resources, and characterisation of potential linkages between land use change and impacts on groundwater quality.

As a result of these programmes, knowledge and understanding of Southland's groundwater resources has increased considerably over the past 10 years, particularly in those areas that have experienced higher levels of resource development.

In order to assist resource management of the region's groundwater resources, Southland was divided into 29 groundwater management zones in 2003. These zones were an integral part of a groundwater variation to the Proposed Regional Freshwater Plan (as it was then called) in 2004. Due to the limited information available at the time to describe the nature and extent of various aquifer systems, especially those in tertiary period and basement deposits, the groundwater management zones were delineated on the basis of topographic gradient, known geology of aquifer extents, geomorphology, observed groundwater quality, groundwater level fluctuations and resource development (Hughes, 2003a). As a result, they are generally only relevant for unconfined aquifer systems. The groundwater zones were then further classified according to aquifer type based on the hydraulic properties and recharge/discharge characteristics and this formed the basis of the groundwater allocation framework, which is used in the Regional Water Plan for Southland, 2010 (RWP).

The basic premise of the management framework was the concept of adaptive management whereby the level of information and assessment required to support an individual resource consent application to take groundwater escalates as the level of allocation increases. As a consequence, the allocation framework does not establish definitive allocation limits, rather it recognises that the establishment of limits to consumptive groundwater use will, in a practical sense, only be determined through an iterative process involving further investigations, monitoring and resource development.

The overall philosophy establishes a management framework, which enables information derived from progressive resource development to inform the resource consent decision-making process as a groundwater resource is progressively developed.

2.1 Objectives

The purpose of this report is to document the current state of knowledge of the groundwater resource in the Edendale groundwater management zone and to assess where future monitoring and investigation should be focused to best address emerging issues or information gaps.

It is intended that, over time, similar technical reports will be produced for all of Southland's groundwater management zones and that these reports will be updated periodically as understanding of groundwater resources grows. It is intended that the information contained within these reports will provide a point of reference to assist the effective and sustainable management of groundwater resources in Southland.

2.2 Geology

The geology of the Southland plains has been described in detail in many previous reports (e.g. Isaac and Lindqvist, 1990; White and Barrell, 1996 and Durie, 2001). The following provides a summary of current understanding of the regional geological setting. The spatial distribution of the geological units described is illustrated in Figure 1.

The bedrock underlying the southern part of the South Island is comprised of at least six geological units (termed "terranes"), which represent rocks that have distinctly different origins. The oldest rocks in the Southland region were deposited on the ocean floor over 400 million years ago and were subsequently buried to significant depths then uplifted to form part of the Fiordland mountains. Most of the other geological terranes found in Southland represent an assemblage of geological materials formed along the margin of Gondwana over a period of tens of millions of years. These rocks include both igneous and metamorphic rocks, which range in age from 280 to 170 million years old. About 160 million years ago, Gondwana began breaking up and at about 85 million years ago, New Zealand separated from Australia (Reay, 2003).

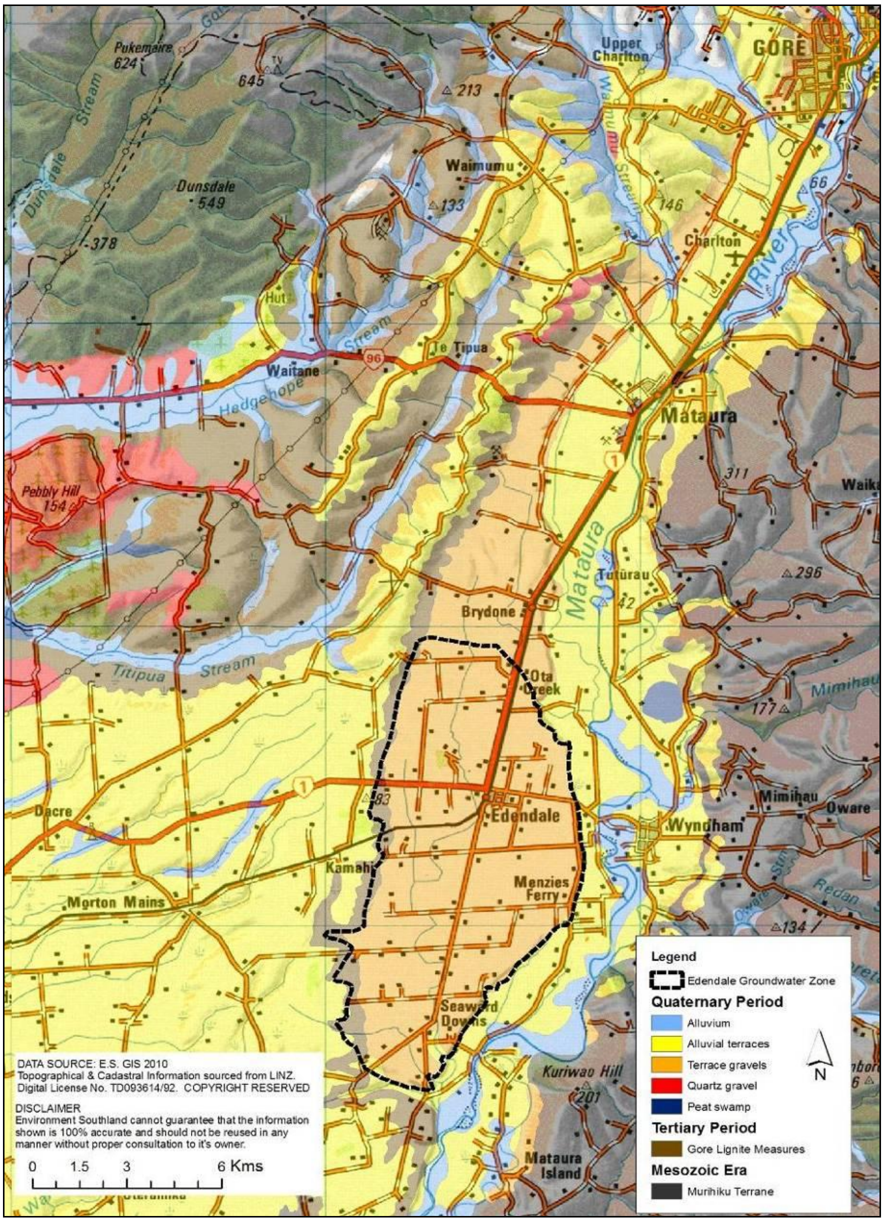

Figure 1: Map of the surface geology of the Edendale area (sourced Turnbull and Alibone, 2003)

Most of the eastern Southland plains are underlain by the Murihiku Terrane, which comprises of marine sediments accumulated between 250 to 170 million years ago. The depositional environment in which these sediments formed is interpreted to be a collision zone between an oceanic plate and a continent, similar in nature to the present day geological setting found along the west coast of South America (Reay, 2003). The greywacke, hard sandstone and mudstone rocks that make up the Murihiku Terrane have undergone extensive faulting and folding, which is most apparent in the Southland Syncline that forms a dominant feature of the Southland landscape along the Hokonui Hills and the Catlins ranges.

In the Edendale area, greywacke rocks of the Murihiku Terrane lie approximately 300 metres below the ground surface. However, bore log data from lignite exploration drilling in the 1970s and 1980s indicates the presence of significant paleotopograhpy on the upper surface of the Murihiku Terrane. The overall structure of the basement rocks is interpreted to represent a series of relatively flat-lying basins interspersed between uplifted basement ridges (termed basement highs) which exhibit considerable relief. To the north of Edendale, at least three major basement highs have been identified in the Charlton, Te Tipua and Brydone areas. The Charlton High is relatively small with 50 metres of relief while the Te Tipua High and Brydone Highs rise approximately 100 metres and 150 metres respectively above the surrounding geological basement. The sediment patterns of the tertiary rocks (65 to 2 million years old) which overlie the Murihiku Terrane indicate the basement "highs" were major paleotopographic features during the Late Oligocene to Early Miocene (or 28 to 16 million years ago).

The rocks of the Murihiku Terrane are unconformably overlain by the tertiary aged marine and terrestrial sediments of the East Southland Group. These rocks comprise of two distinct sub-units in the Edendale area - the deeper Chatton formation and the near surface Gore lignite measures. The Chatton formation comprises a thick (up to 200 metre) sequence of marine sandy limestone and sandstone while the Gore lignite measures comprise an alternating sequence of sandstone, mudstone lignite and occasional gravel layers deposited in lower coastal, delta, marginal marine and alluvial plain environments. The Gore lignite measures are approximately 100 metres thick (based on limited lignite exploration bore log data from the Edendale terrace) and dip at a low angle to the south west.

The Gore lignite measures are in turn unconformably overlain by a thin veneer (less than 30 metres thick) of Quaternary period (last 2 million years) alluvial gravels. The Quaternary gravel deposits were formed on the extensive floodplains of the major braided rivers and streams of the region transporting glacial outwash from further north in what is today the headwaters of the Mataura catchment. During successive interglacial and post-glacial periods, the ancestral Mataura River eroded and reworked existing sediments to form a broad valley extending up to 11 km in width in the Edendale area. Within the river valley, a succession of alluvial terraces formed reflecting the progressive entrenchment of the river whereby the highest terraces contain the oldest gravels while the lowest terraces and present day floodplains contain the youngest gravel material.

The Quaternary gravel deposits in the Edendale area consist of poorly sorted quartz and greywacke gravel with accessory lenses of silt and clay. The gravel deposits are overlain by loess (windblown) deposits which range in thickness from 2 to 5 metres and accumulated during pleistocene (2 million to 11 thousand years ago) glaciations. These low permeability deposits underlie the modern soil profile and limit infiltration rates in some areas, creating surface drainage problems.

2.3 Aquifer Extent

The Edendale groundwater zone encompasses the saturated gravels underlying the Edendale terrace adjacent to the Mataura River. The aquifer is bounded to the west and south by the tertiary Gore lignite measures (see Figure 1), which mark the extent of the Mataura Valley. The eastern boundary of the aquifer follows the erosional contact between the Edendale terrace and the lower elevation Wyndham terrace, which flanks the current course of the Mataura River. Delineation of the northern aquifer boundary is less clear-cut. Some reports suggest it extends as far north as Mataura (e.g. White and Barrell, 1996; Dumbleton, 2002) while others have postulated there is a groundwater divide close to Ota Creek (Rekker, 1995). The differences in the interpolated boundaries of the Edendale aquifer are shown in Figure 2.

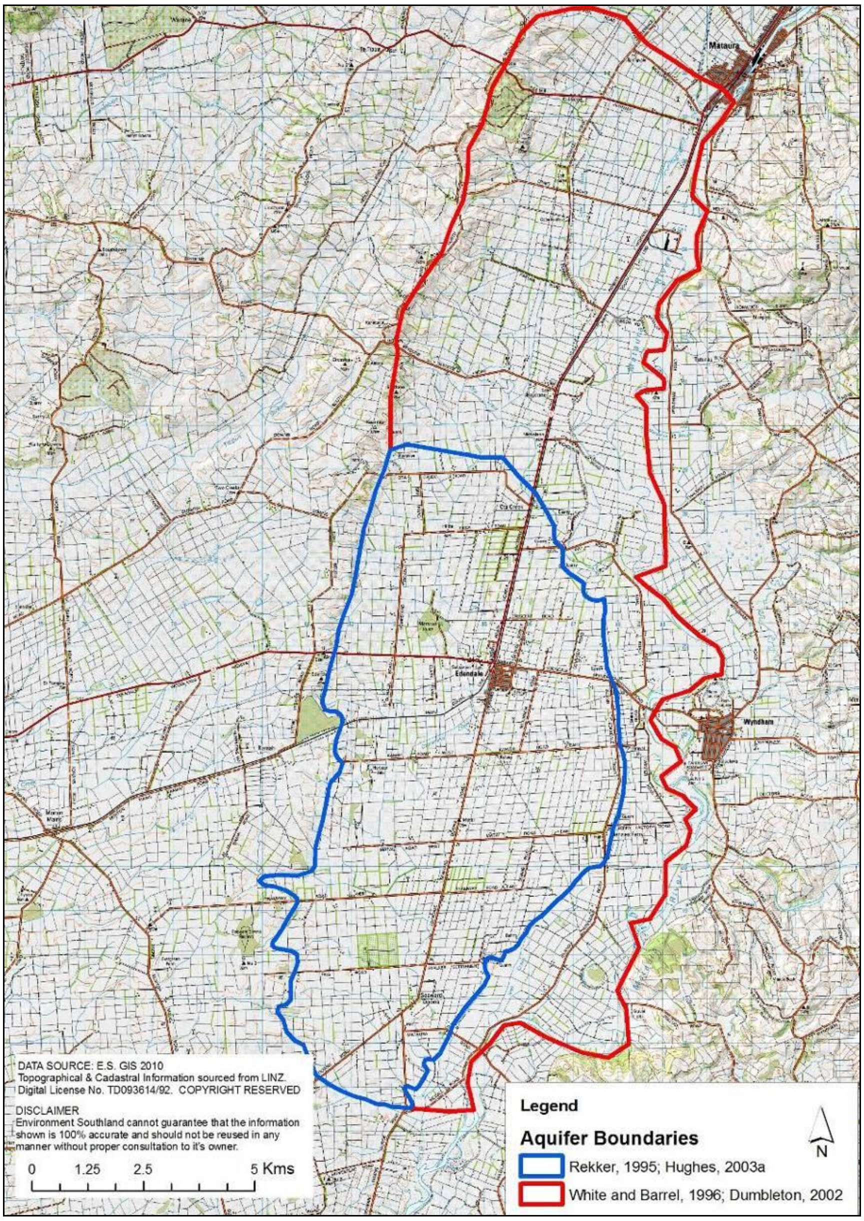

Figure 2: Map of the various Edendale Aquifer boundaries

When delineating the groundwater management zones for the RWP (Hughes, 2003a), the boundary proposed by Rekker (1995) was preferred, due to observed differences in groundwater level fluctuationsm which indicated some form of hydraulic divide in the vicinity of Ota Creek. Subsequent data, including piezometric surveying data (discussed further in Section 2.5), geochemical data and bore log data, supports the Ota Creek boundary, which has been adopted for this report.

2.4 Soils

Figure 3 shows the distribution of the major soil types on the Edendale terrace, based on data collected for the Topoclimate soil survey. Edendale (brown) and Waikoikoi, Arthurton and Jacobstown (palic) are the dominant soil types covering over 95 percent of the land area.

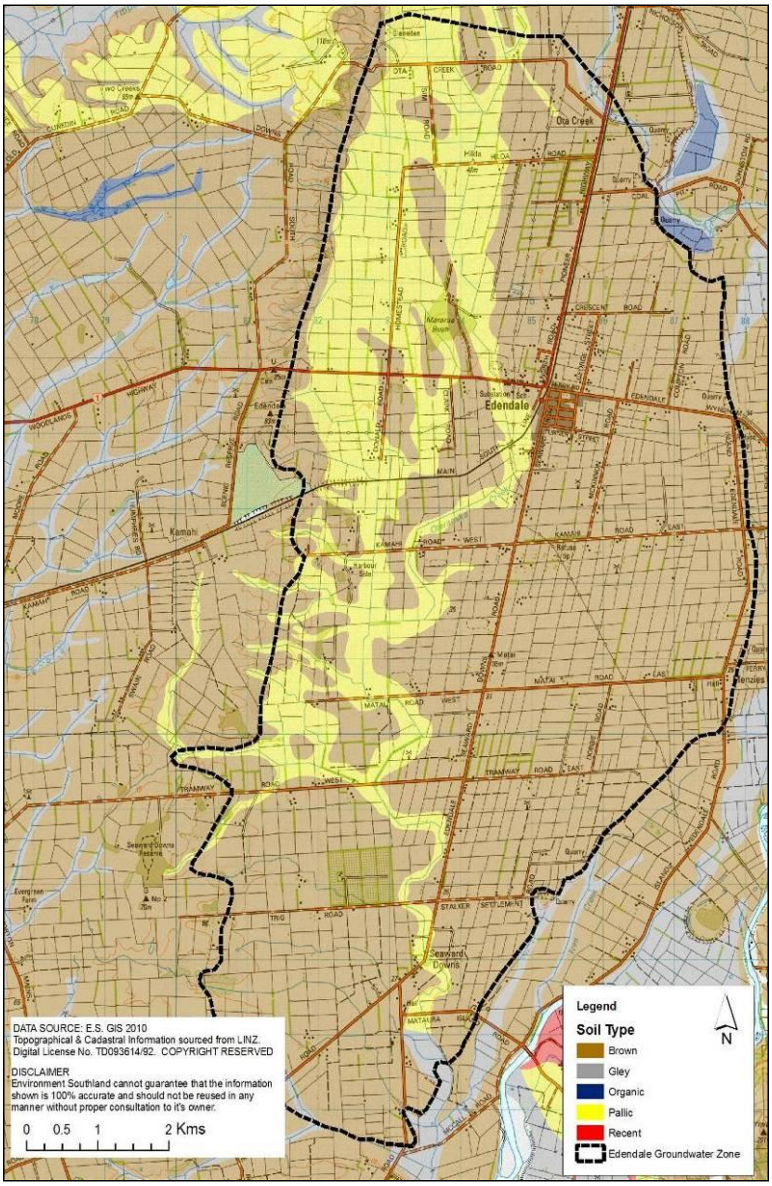

Figure 3: Map of the soils of the Edendale terrace

Edendale soils are typically well drained but can contain slow permeability layers within the subsoil, which can result in short-term waterlogging after heavy rainfall. They are generally stoneless with a deep rooting depth. Waikoikoi, Arthurton and Jacobstown soils are formed in loess (wind-blown) deposits up to 5 metres thick. As a result, these soils are poorly drained, with a dense fragipan, which restricts water drainage. These soils may be mole and tile drained if there is sufficient fall between the land surface and nearby streams (principally the Oteramika Creek).

2.5 Hydrogeology

Groundwater deposits have been found in all of the major geological units discussed in Section 2.3. A limited groundwater resource occurs in the coarser-grained gravel and sand layers within the East Southland Group sediments and in areas where greywacke bedrock has sufficient jointing and fracturing within the rock mass. However, due to the much higher yields and closer proximity to the surface, the principal groundwater resource is hosted in the Quaternary alluvial gravel deposits. As all (known) resource use is restricted to the unconfined alluvial gravel aquifer, the previously named Edendale aquifer is synonymous with the Edendale groundwater zone.

The Edendale groundwater zone is classified as a terrace aquifer (ES, 2010). This aquifer type primarily occurs in the remnant Quaternary gravel terraces along the margins of the main alluvial valleys. As shown in Figure 4, terrace aquifers are not generally in direct hydraulic connection with surface waterways due to their elevation above the main river channel (in this case the Mataura River). Surface water drainage is also limited so streams present on the terrace are commonly few, ephemeral and perched above the underlying water table, which typifies the Oteramika Creek on the Edendale terrace. Groundwater drainage occurs as spring-fed streams that originate along the base of the terrace riser where the water table intersects the land surface (e.g. Ives Creek and Clear Creek which are discussed further in Section 3.2).

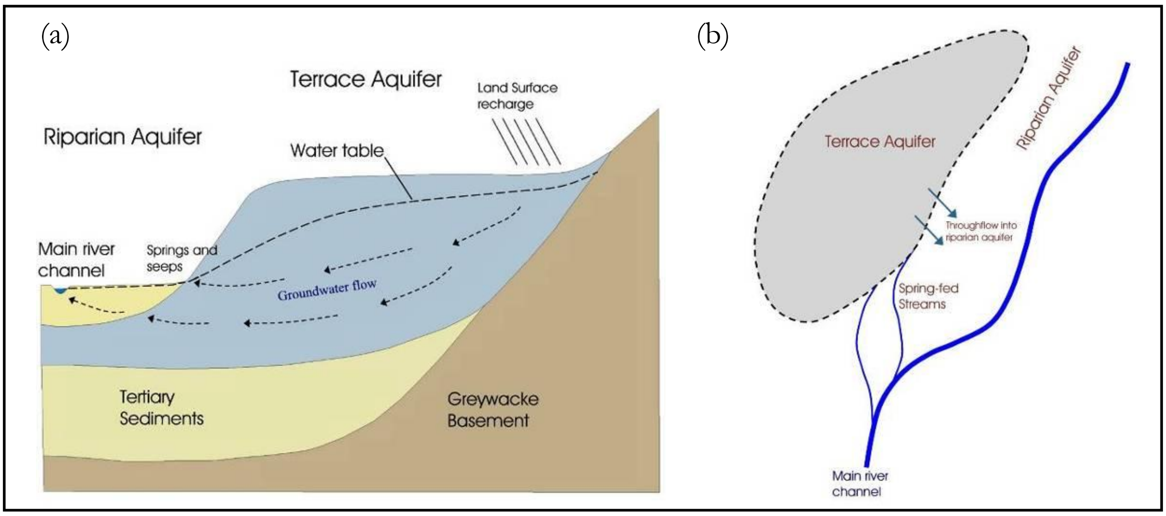

Figure 4: Schematic representation of a (a) cross-section and (b) plan view of a terrace aquifer system

Due to aquifer geometry, terrace aquifers exhibit a water table that increases in depth towards the outer terrace margin reflecting groundwater discharge at the base of the terrace riser, as illustrated in Figure 4(a). In the Edendale groundwater zone, the water table is generally 12 metres below the land surface north of the Edendale township and shallows to approximately 6 metres towards the southern margin.

Due to their age and origin, gravel deposits in terrace aquifers typically have a high proportion of clay and silt in the gravel matrix limiting material permeability. This reflects a lower degree of reworking of sediments during deposition and subsequent weathering of the gravel materials. However, in this regard, the Edendale groundwater zone is potentially anomalous as previous studies (e.g. White and Barrell, 1997) have identified the presence of a buried river channel (paleochannel) running parallel approximately north-south along the axis of the terrace, which has comparatively high permeability. This feature has been interpreted to represent an abandoned channel of the ancestral Mataura River incised into the upper surface of the underlying Gore lignite measure sediments.

Aquifer pump tests are used to determine an aquifer's basic hydraulic parameters and are a standard requirement for applications for large-scale groundwater takes in Southland. To date, about seven pump tests of varying quality have been undertaken in the Edendale groundwater zone. In order to improve spatial resolution, specific capacities have also been used to roughly estimate transmissivity values for other areas of the aquifer, as shown in Figure 5. The results generally show relatively high aquifer transmissivity in the order to 3,000 to 10,000 m^2/day near the central axis of the aquifer and decreases by an order of magnitude to approximately 100 to 500 m^2/day towards the aquifer margins. This is interpreted to reflect, in part, the heterogeneity of gravel matrix, but is also consistent with previous observations which found both aquifer thickness and permeability increased markedly along the inferred paleochannel feature.

In general, coarser, more highly transmissive gravel units are encountered near the base of the gravel deposits (Hughes, 2008b). Overall, aquifer yields are more than sufficient for domestic, stock and dairy-shed scale water takes while the higher permeability areas of the aquifer are able to support larger-scale abstraction for industry, irrigation and community supply.

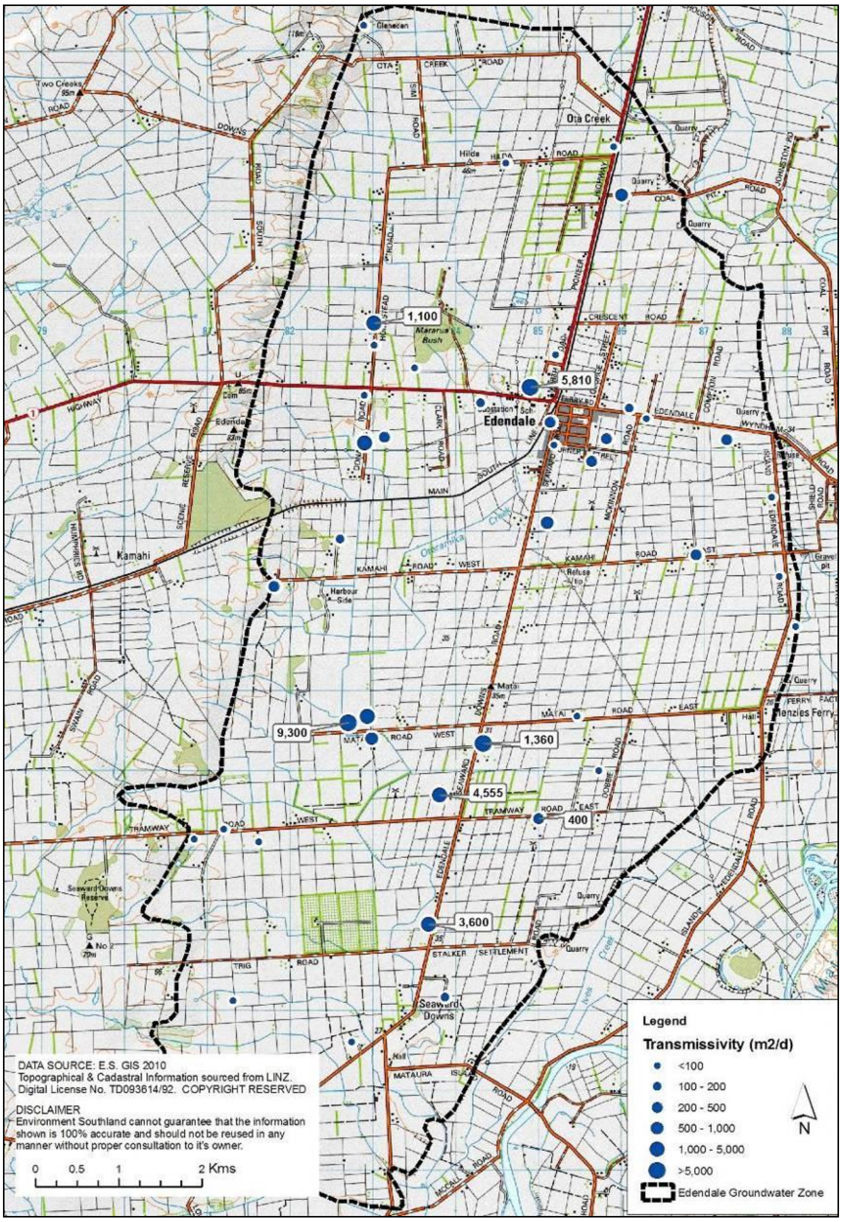

Figure 5: Map of transmissivity estimates[1] for the Edendale groundwater zone

2.6 Groundwater Hydrology

There have been several piezometric (or water table) surveys of the Edendale groundwater zone (e.g. Rekker, 1995; Dumbleton, 2002), however, the most comprehensive survey was undertaken by Environment Southland on 28 March to 5 April 2007 and covered the area from Mataura to Mokotua. The results from the Edendale area, illustrated in Figure 6, show the general groundwater flow direction is to the south across the northern section of the terrace and swings more to the south-east in the southern section reflecting the influence of the spring discharge in this area. This general pattern is consistent with previous surveys, however, the contours show some complexity near the Edendale township and northwards

[1] Transmissivity values determined from aquifer pump test analysis have been labelled. Unlabelled points have had transmissivity calculated from specific capacity values (based on Driscoll, 1986).

towards Ota Creek not previously reported. This is inferred to reflect the effects of pumping (discussed further in Section 4) and/or the relatively abrupt changes in groundwater level elevation around the terrace margins near Ota Creek creating an artefact in the modelling of contours.

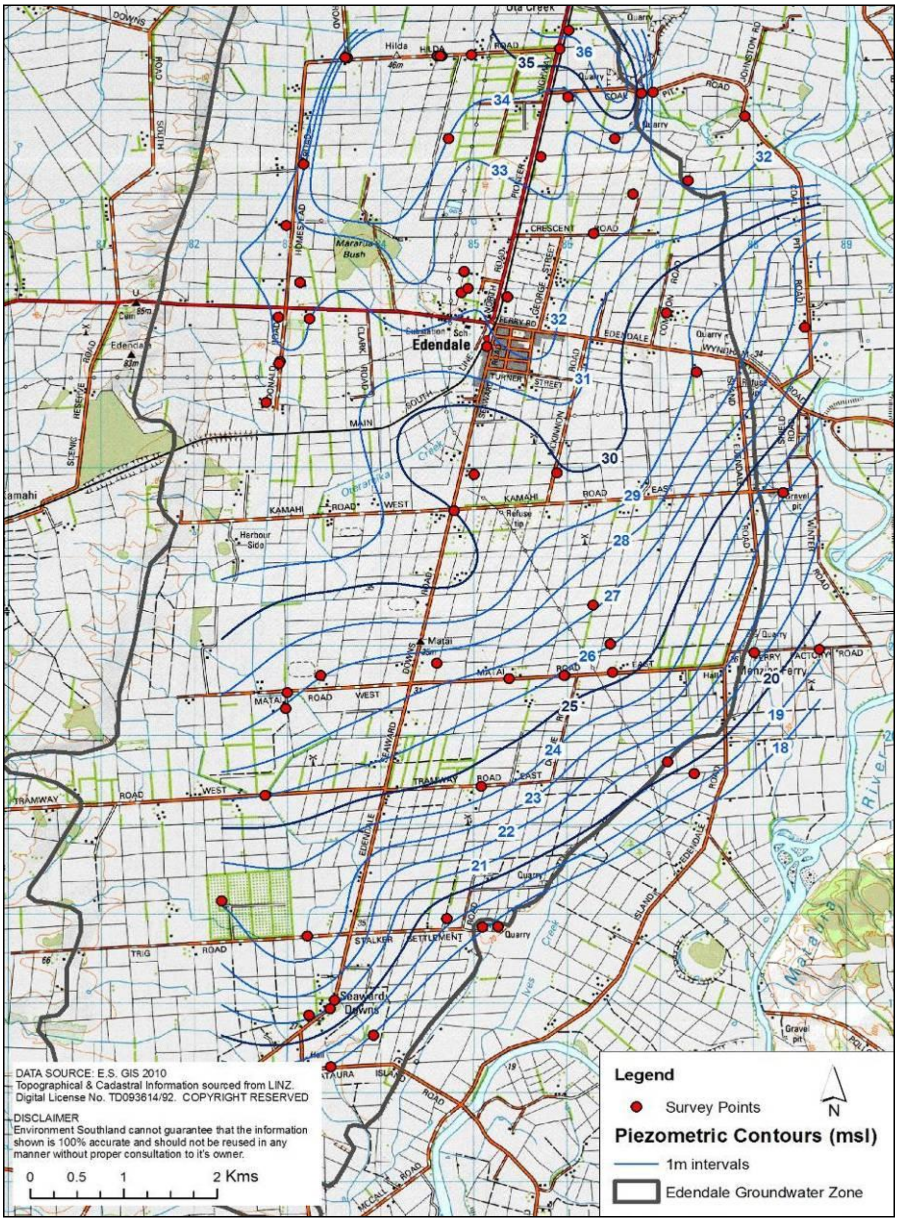

Figure 6: Map of piezometric surveying results for April 2007[2]

Assuming an average saturated thickness of 8 metres (estimated from bore log and groundwater level monitoring data), an average aquifer transmissivity of 1,000 m^2/day (based on data shown in Figure 5), an interpolated hydraulic gradient of 0.0031[3] (based on data shown in Figure 6) and an assumed porosity of 0.2, the average bulk seepage velocity through the aquifer was calculated using Darcy's Law at 1.94 metres per day or approximately 700 metres per year. This is a relatively

[2] Contours were mapped using a regularised spline method in ArcGIS (ESRI software)
[3] This is similar to the gradient of 0.002 reported in Rekker (1995)

rapid bulk flow rate compared to estimates for other similar aquifer types in Southland. For example, the bulk groundwater seepage velocity for the Balfour area has been calculated at 480 metres per year (Wilson, 2010b). It is important to remember estimates of bulk aquifer flow rate are indicative only and do not necessarily reflect the flow rate at all points in a given aquifer system, which may exhibit considerable variability due to geological heterogeneity.

2.7 Recharge and Discharge

The Edendale groundwater zone is recharged exclusively from direct rainfall drainage and infiltration of runoff from the escarpment forming the western aquifer boundary. Estimates of rainfall recharge vary from 305 mm/year based on water balance calculations (Rekker 1995) to 453 mm/year based on soil moisture water balance modelling (Morgan and Evans, 2003). Table 1 contains a summary of the different aquifer recharge estimates, which indicate that somewhere between 30 to 40 percent of rainfall infiltrates through the land surface into the underlying aquifer. This equates to between 23.8 to 31.7 million m^3 of water per year. Environment Southland adopted the most recent estimate (i.e. 453 mm/year) for the RWP.

Table 1: Estimates of rainfall recharge to the Edendale Aquifer

Reference	Model	Rainfall Recharge (mm/year)	% of Mean Annual Rainfall
McIntosh (1995)	Soil water balance	350 - 375	33 – 36%
Rekker (1995)	Water balance	305 - 390	29 – 37%
Rekker (1998)	Spring discharge	398	38%
Morgan and Evans (2003)	LEL Irrigation Model	453	43%
Average:		**390**	**37%**

Groundwater levels in the Edendale groundwater zone typically range from 12 to 14 metres below ground in the northern section of the aquifer system to between 5 to 7 metres below ground in the southern portion. Temporal variations in groundwater level fluctuations show a clear seasonal pattern where levels increase during winter and spring once soil moisture levels reach field capacity and rainfall infiltration. Following the seasonal peak, groundwater levels then decline in an almost linear fashion through summer and autumn reflecting progressive drainage of the aquifer system via spring discharge and through-flow into the riparian aquifer adjacent to the Mataura River. There is often a substantial time lag between rainfall, soils reaching field capacity and associated response in groundwater levels, as illustrated in the example hydrograph shown in Figure 7. The observed time-lag is interpreted to reflect the thick loess layer (up to 5 metres thick in places) and 6 to 12 metres of unsaturated gravels drainage water needs to percolate through before reaching the water table to influence groundwater levels. The time lag generally ranges between 2 to 6 weeks depending on the soil water content, rainfall intensity and water table depth.

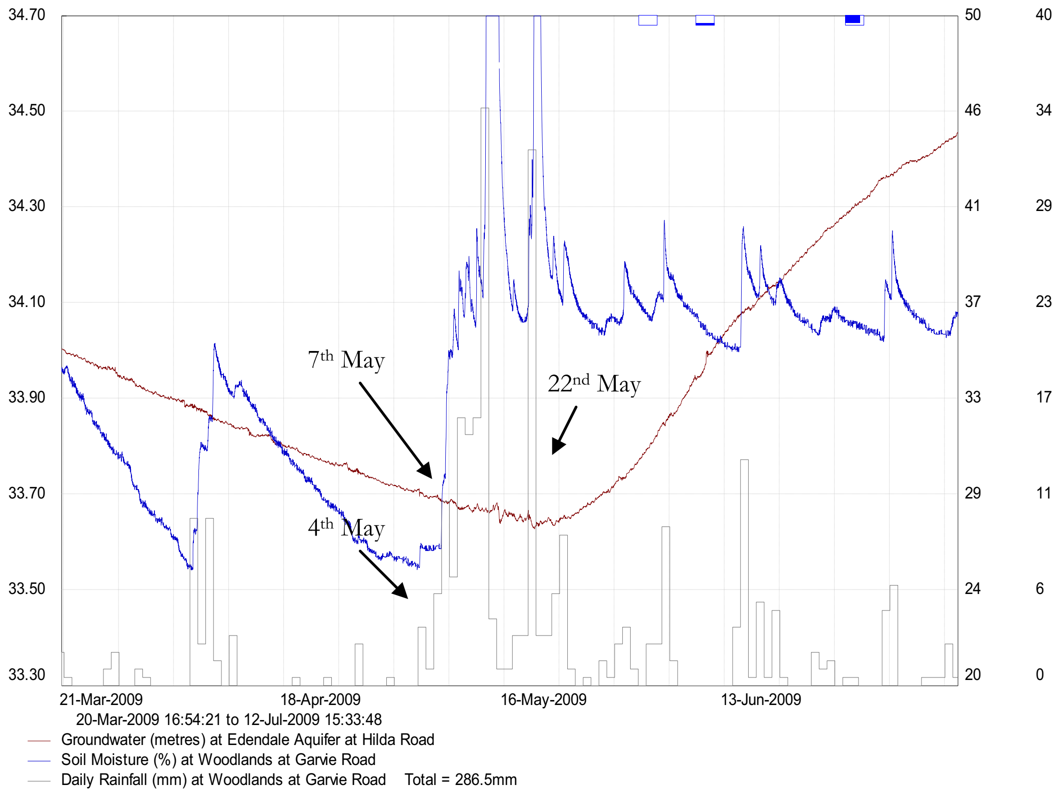

Figure 7: An example of the time-lag between rainfall (4 May), soil moisture (7 May) and aquifer recharge response (22 May)

Groundwater is discharged from the Edendale aquifer via a series of springs which occur along the outer terrace margin along the southern portion of Edendale terrace. As illustrated in Figure 4(a), the springs occur where the water table intersects the level of the lower Wyndham terrace. The springs act as a constant head boundary and effectively moderate seasonal variations in aquifer storage towards the terrace margins. Groundwater is also discharged as through-flow into the shallow riparian aquifer underlying the recent floodplain of the Mataura River.

3. Groundwater Quantity

Regular monitoring of groundwater levels and spring discharge began in the Edendale groundwater zone in 1995 as part of the Sustainable Farming Fund (SFF) Oteramika catchment study. Upon completion of this project in 1998, monitoring ceased until 2000 when Environment Southland established its groundwater SOE monitoring programme. The groundwater quantity monitoring data from the Edendale groundwater zone represents the longest semi-continuous monitoring record of any aquifer in Southland.

3.1 Groundwater Levels

Environment Southland regularly monitors six bores in the Edendale groundwater zone. Four of these bores are dipped each month (F46/0193, F46/0185, F46/0190, F46/0192 and F46/0708) and one (F46/0250) is the reference monitoring site for the aquifer. This site, shown in Figure 8, contains instrumentation to automatically record groundwater levels every 30 minutes and the data is telemetered to Environment Southland hourly. The monitoring sites are spread fairly evenly across the entire length of the Edendale groundwater zone as illustrated in Figure 9.

Figure 8: Photograph of the reference monitoring bore F46/0250 (taken June 2002)

It is acknowledged that groundwater level monitoring is also undertaken by other organisations (e.g. Fonterra Co-operative Group Limited), however, this data has not been used in this section, as the available monitoring data is generally monitored at a lower frequency and matches water levels recorded in existing Environment Southland monitoring sites.

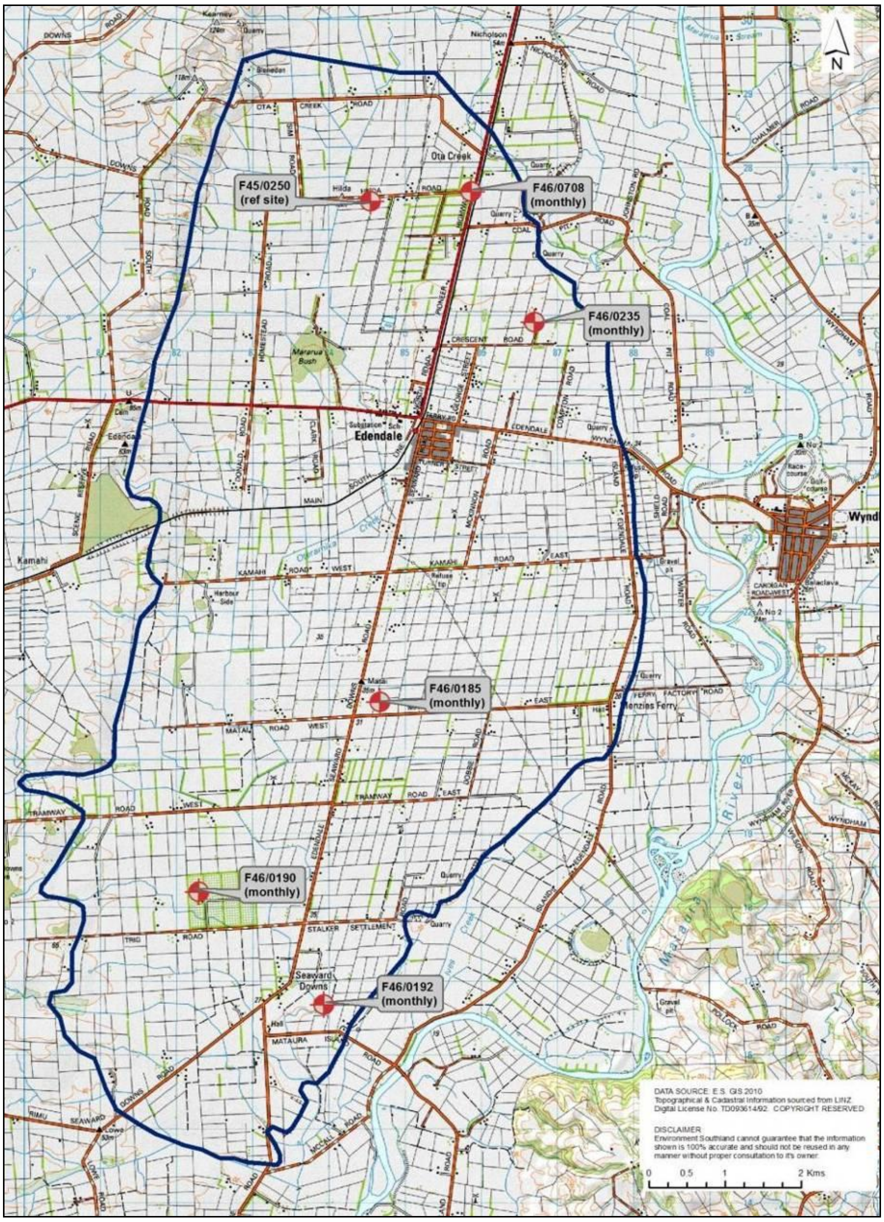

Figure 9: Map of groundwater level monitoring sites in the Edendale groundwater zone

As shown in Figure 10, groundwater levels have been regularly monitored in the Edendale groundwater zone since 1995. Typically, groundwater levels fluctuate within a 2 to 3 metre range and observed temporal variations are reasonably consistent across all monitoring sites. The data shows the lowest groundwater levels are typically observed between April and July while groundwater levels peak between August and October. The groundwater recession rate is fairly linear declining at about 250 mm per month. This even recession is interpreted to reflect constant drainage of the aquifer into spring-fed streams along the terrace margin and discharge into the adjacent floodplain aquifer. Appendix 2 contains additional groundwater level statistics for the monitoring sites.

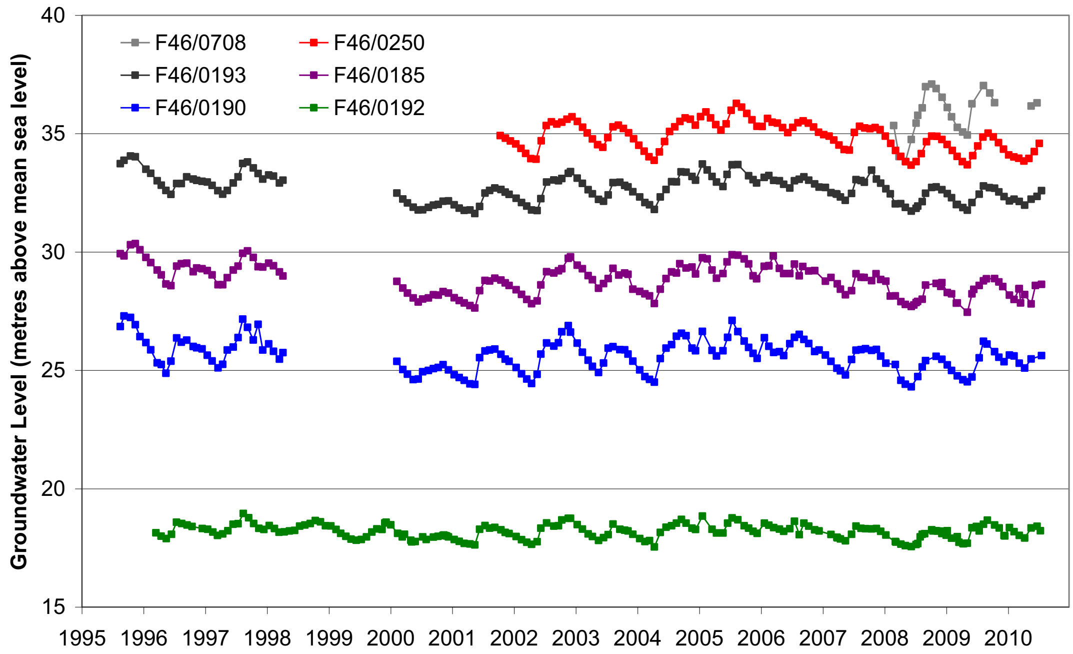

Figure 10: Groundwater level monitoring data from the Edendale groundwater zone

The data show no obvious long-term declining trends that would indicate unsustainable levels of abstraction. However, the data does show groundwater levels in the Edendale groundwater zone were on average about 0.5 metres higher during the late 1990s compared to more recent times, and that since 2005, the seasonal peaks and troughs have been getting progressively lower. This pattern is similar to that observed in other aquifers in the region (e.g. Wilson, 2010a).

As can be seen in Figure 11, temporal groundwater level variations follow long-term rainfall patterns with the decline in levels observed between 1998 to 2002 and 2006 to 2009 corresponding to extended periods of below average rainfall (illustrated by a downward trend in the cumulative rainfall departure plot). Conversely, groundwater levels generally increased between 2002 and 2006 during a period of above average rainfall. The data also shows that carry-over of aquifer storage may occur between successive years following periods of elevated aquifer recharge such as during winter 2002 and spring 2004 when groundwater levels increased by up to 2 metres following above average rainfall.

Since 2008, groundwater levels in the Edendale groundwater zone have been lower than normal due to a combination of a drier than usual climate (shown in Figure 11) and shortened recharge periods resulting from dry autumns and springs. Normally the Edendale groundwater zone will recharge at a fairly consistent rate over an average period of 20 weeks during winter and spring each year. However, the 2007/08 drought shortened the 2008 recharge season to 16 weeks and the very dry spring in 2009 shortened the recharge season to 15 weeks. Hence, the timing of rainfall events has also contributed to the recent lower than usual groundwater levels.

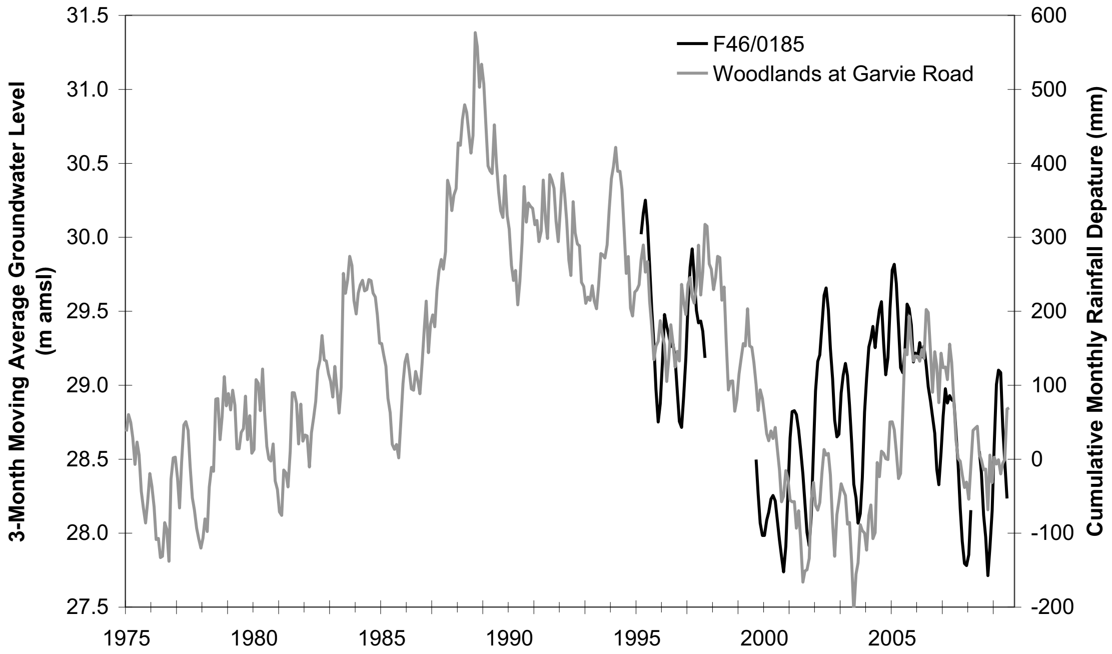

Figure 11: Long-term rainfall patterns and groundwater level trends for Edendale

3.2 Spring Discharge

Springs and spring-fed streams form important ecosystems for many aquatic species, due to high water clarity, restricted flow variability and cool, stable water temperatures. Springs can also be useful be indicators of long-term changes in aquifer storage.

Regular monitoring of spring discharge from the Edendale groundwater zone began in 1995 as part of the SFF Oteramika catchment study. Upon completion of this project in 1998, monitoring recommenced on an irregular basis in 2000 when Environment Southland established its groundwater monitoring programme. Following an initial regional scoping survey undertaken during an extended dry period during February and March 2001, regular flow measurement of major spring-fed streams across the Southland region began in 2002.

Currently, the spring gauging programme involves approximately 100 gaugings undertaken at 15 sites across the region each year, with additional monitoring during very dry conditions or in response to increased water use. The regularly monitored sites are typically measured on a six weekly basis during winter and spring and monthly during summer and autumn. Additional spring discharge monitoring is undertaken when groundwater levels are particularly low or during extended dry periods.

Spring gauging sites associated with the Edendale groundwater zone are shown in Figure 12. All available gauging data has been used in the following section and is tabulated in Appendix 3.

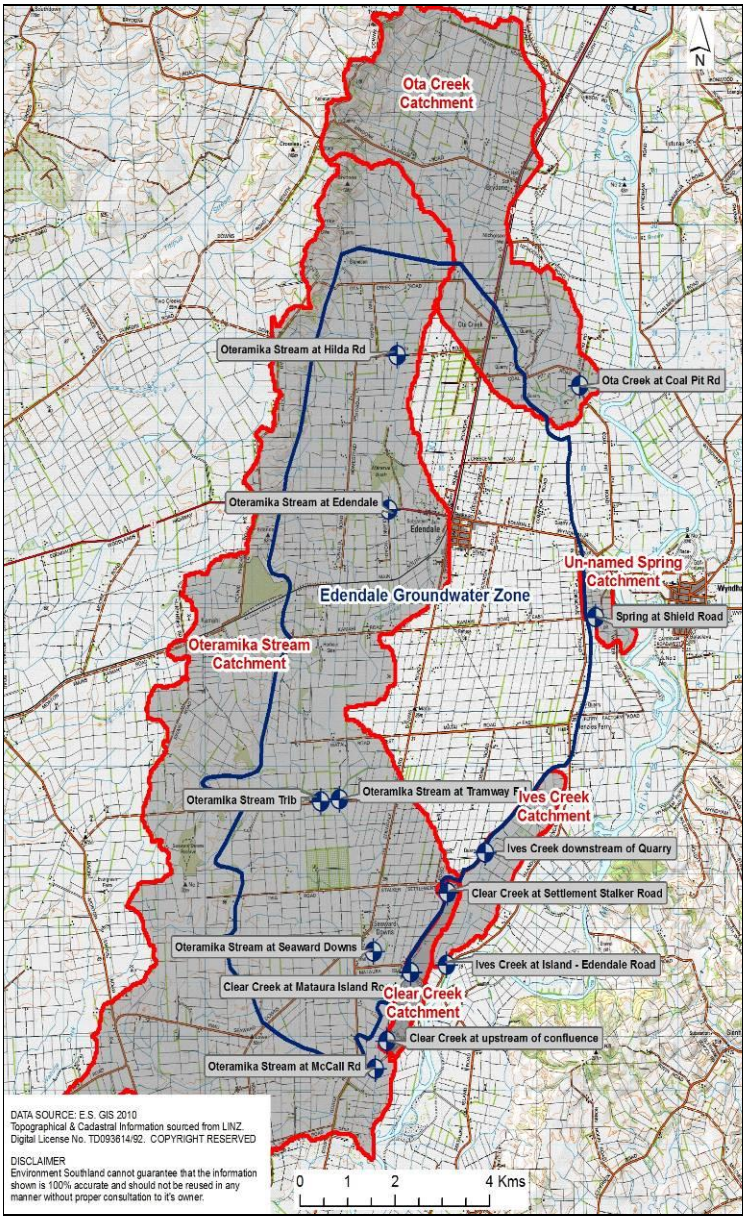

Figure 12: Map of Edendale groundwater zone spring gauging sites

3.2.1 Oteramika Creek

The Oteramika Creek originates approximately 5 km north of the Edendale township and flows in a southerly direction across the Edendale terrace before flowing in a south-easterly direction across the Mataura floodplain towards its confluence with the Mataura River. The catchment area of the Oteramika Stream extends across an area of approximately 9,500 hectares, a majority of which is intensively farmed.

The Oteramika Creek is highly modified. Large sections of the stream have been straightened and drop structures (small dams) have been constructed in the lower catchment as shown in Figure 13. In some places, the stream has been deepened in order to create natural fall for surface drainage on the relatively flat terrace surface surrounding the stream channel. As a result, the stream is narrow and channelised with few meanders, riffles or pools.

The drop structures, of which there are five, restrict fish passage up the stream (Hamill, 1998).

Figure 13: Photograph of one of the Oteramika Creek drop structures (source: Hamill, 1998)

The Oteramika Creek is perched approximately 10 metres above the underlying water table to the north of Edendale township gradually reducing to approximately 5 metres across the southern portion of the aquifer system. Downstream of Seaward Downs, the Oteramika Creek gains appreciable flow between the base of the Edendale terrace and its confluence with the Mataura River due to drainage of groundwater from the Edendale aquifer and the riparian aquifer adjacent to the Mataura River (i.e. the lower Mataura groundwater zone). The relative geometry of the water table and terrace surface elevations is shown in Figure 14 along a cross-section extending between Ota Creek and McCall Road.

As there is no hydraulic connection with the underlying water table, flow in the Oteramika Creek upstream of Seaward Downs is primarily derived from land surface drainage (e.g. mole and tile drains as discussed in Section 2.4 and interflow through the soil). Due to the relatively impermeable nature of the silt and clay material comprising the stream bed, the Oteramika Creek appears to lose little or no flow into the underlying aquifer across its entire length upstream of Seaward Downs. As a consequence, the Oteramika Creek does not constitute a notable recharge source for the Edendale aquifer. Downstream of Trig Road (near Seaward Downs), the stream substrate is observed to become increasingly gravel dominated, which coincides with the reach where increases in discharge occur due to groundwater infiltration.

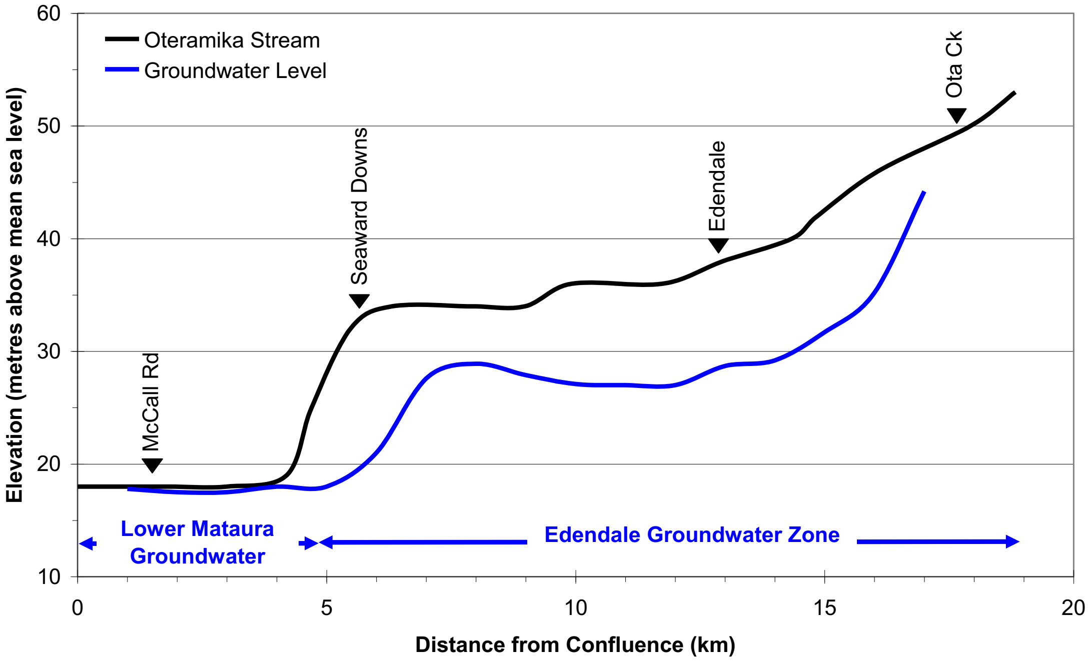

Figure 14: Long-section of the Oteramika Creek and Edendale Aquifer water table

The flow statistics from spot gaugings of the Oteramika Creek are summarised in Table 2. The data show a wide range of flows from 0 l/s upstream of Edendale to 10,318 l/s, which was measured at Seaward Downs during the large November 1999 flood. The data show relatively low median discharge upstream of Seaward Downs, at which point the specific yield increases appreciable due to groundwater discharge (specific yields are summarised in Appendix 4). All sites show an extremely poor linear correlation with groundwater levels in the Edendale aquifer.

Table 2: Flow statistics from spot gaugings of Oteramika Creek

Site	Record Period	Number of Gaugings	Min Gauged Flow (l/s)	Mean Gauged Flow (l/s)	Median Gauged Flow (l/s)	Max Gauged Flow (l/s)	Linear Regression[1] (r^2)	SEE[2] (l/s)
Hilda Road	1995 - 1997	20	2	124	48	723	0.01	236
Edendale Bridge	1980 - 2009	42	0	117	50	885	0.00	220
Tramway Road	1995 - 1998	31	14	173	68	1,315	0.01	288
Tributary at Tramway Rd	1995 - 1997	22	6	122	69	524	0.00	147
Seaward Downs	1954 - 2009	130	8	402	164	10,318	0.00	1,058
McCall Road	1972 - 2009	37	89	866	680	3,376	0.00	638

[1]Linear regression between flow and groundwater levels in F46/0192. The co-efficient of determination (r^2) is an estimate of the "goodness of fit" of the regression. It measures the exact percentage of variation shared by two variables.
[2]Standard error of the estimate (SEE) is a measure of the accuracy of the predictions. It measures the dispersion of the actual Y values about the regression line.

3.2.2 Clear Creek

Clear Creek is a contact spring, which originates at the base of the Edendale terrace near Settlement Stalker Road (shown in Figure 12) and flows in a southerly direction parallel to the base of the Edendale terrace towards its confluence with the Oteramika Creek above McCall Road. Although Clear Creek has a very small catchment area of 140 hectares, it is the larger spring-fed stream draining the Edendale groundwater zone. As the name suggests, Clear Creek is characterised by high water clarity, as shown in Figure 15.

Figure 15: Photograph of Clear Creek at Mataura Island Road (taken 27 January 2010)

Available gauging data for Clear Creek, summarised in Table 3, show discharge increases appreciably over the 1.5 km reach upstream of Mataura Island Road reflecting drainage of groundwater through-flow from the Edendale groundwater zone along the base of the Edendale terrace across this reach.

Table 3: Flow statistics from spot gaugings of Clear Creek

Site	Record Period	Number of Gaugings	Min Gauged Flow (l/s)	Mean Gauged Flow (l/s)	Median Gauged Flow (l/s)	Max Gauged Flow (l/s)	Linear Regression[1] (r^2)	SEE[2] (l/s)
Settlement Stalker Rd	2006 - 2010	22	8	26	27	47	0.60	8
Mataura Island Rd	1995 - 2010	58	231	325	326	459	0.57	34
Oteramika Creek confluence	1995 – 1998	11	238	362	373	429	0.20	45

[1]Linear regression between flow and groundwater levels in F46/0192. The co-efficient of determination (r^2) is an estimate of the "goodness of fit" of the regression. It measures the exact percentage of variation shared by two variables.
[2]Standard error of the estimate (SEE) is a measure of the accuracy of the predictions. It measures the dispersion of the actual Y values about the regression line.

Gauging data from Clear Creek, shown in Figure 16, shows no clear trend over time. It is note, however, that the lowest flows were recorded during periods of low groundwater levels during 2001/02 and 2008/09 reflecting the moderate correlation (R^2~0.6) between discharge and groundwater levels measured in the Seaward Downs area. The observed relationship between temporal variations in Clear Creek discharge and groundwater levels measured at F46/0192 is shown in Figure 17.

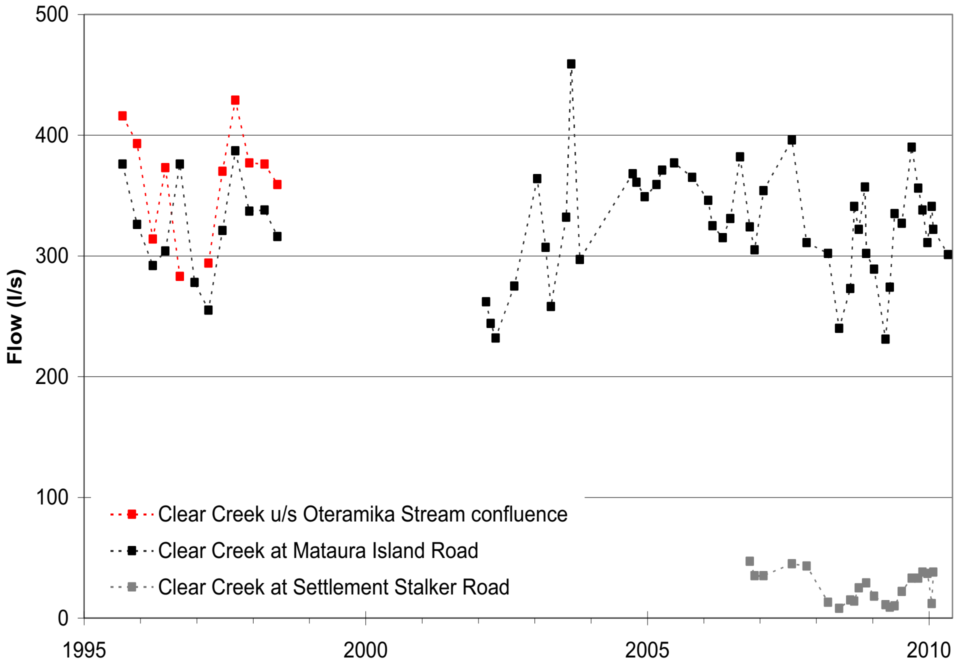

Figure 16: Measured discharge in Clear Creek, 1995-2010

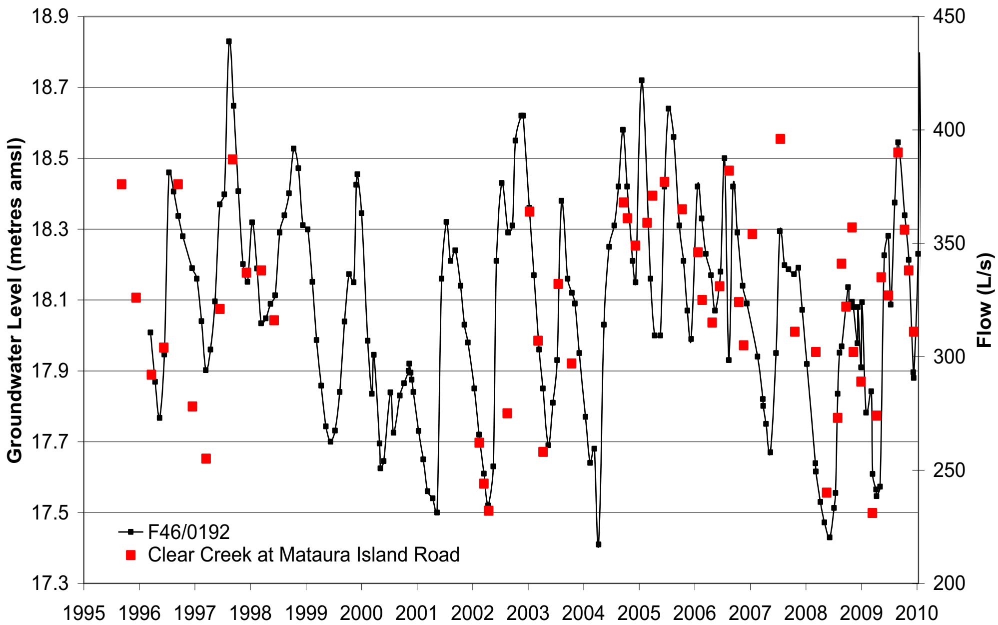

Figure 17: F46/0192 groundwater levels and discharge in Clear Creek

3.2.2 Ives Creek

Ives Creek is another relatively large spring-fed stream that drains the Edendale aquifer in the Seaward Downs area. Ives Creek is a contact spring originating at the base of the Edendale terrace near Tramway Road East (shown in Figure 12) and flows in a southerly direction across the Mataura floodplain towards its confluence with the Mataura River near Island-Edendale Road. Measured discharge in Ives Creek, summarised in Table 4, ranges between 147 l/s downstream of the Quarry to 365 l/s near its confluence with the Mataura River.

Table 4: Flow statistics from spot gaugings of Ives Creek

Site	Record Period	Number of Gaugings	Min Gauged Flow (l/s)	Mean Gauged Flow (l/s)	Median Gauged Flow (l/s)	Max Gauged Flow (l/s)	Linear Regression[1] (r^2)	SEE[2] (l/s)
Downstream of Quarry	1995 - 1997	10	147	195	192	262	0.34	33
Island-Edendale Rd	1995 - 2009	28	166	275	283	365	0.77	26

[1]Linear regression between flow and groundwater levels in F46/0192. The co-efficient of determination (r^2) is an estimate of the "goodness of fit" of the regression. It measures the exact percentage of variation shared by two variables.
[2]Standard error of the estimate (SEE) is a measure of the accuracy of the predictions. It measures the dispersion of the actual Y values about the regression line.

Concurrent gaugings of Ives Creek appear to indicate a relatively consistent increase in flow along its entire length, as illustrated in Figure 18, where the mid-reach quarry site carries between 50 to 70 percent of the discharge measured at the downstream end of the catchment (i.e. Island-Edendale Road).

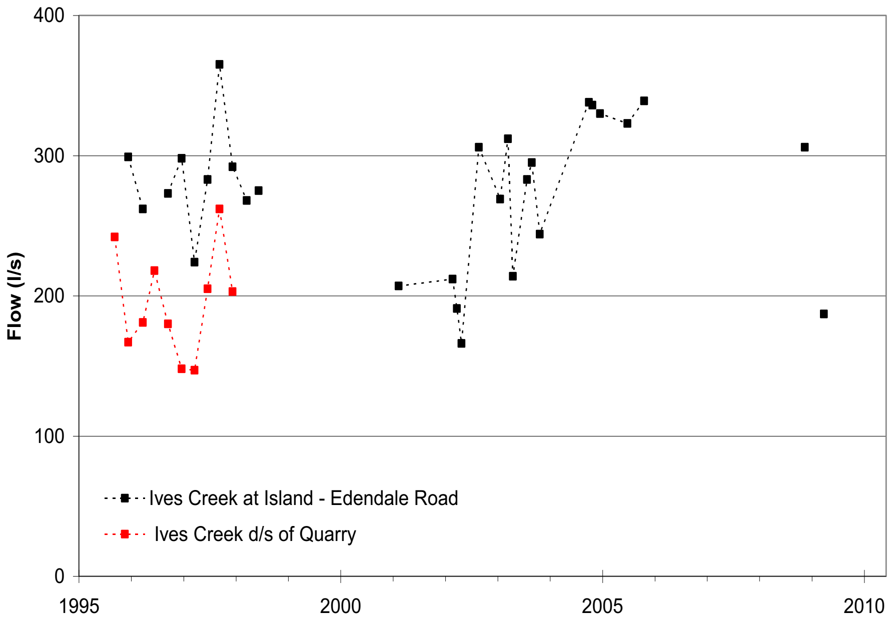

Figure 18: Measured discharge in Ives Creek

Figure 19 shows the relatively good correlation (R^2~0.8) observed between groundwater levels in the Edendale aquifer and discharge in the downstream section of Ives Creek. The reason for the better correlation between groundwater level variations and discharge in Ives Creek compared to that observed in Clear Creek is uncertain, but may, in part, reflect a combination of channel geometry, hydraulic characteristics of the streambed sediments and differences in relative hydraulic head towards the southern end of the terrace. It is noted that the springs in the Seaward Downs area act as a constant head boundary effectively moderating seasonal variations in aquifer storage towards the terrace margins. This buffering effect is less likely to be pronounced where the hydraulic head is relatively lower, possibly resulting in greater variation in flow in Ives Creek in response to groundwater level fluctuations.

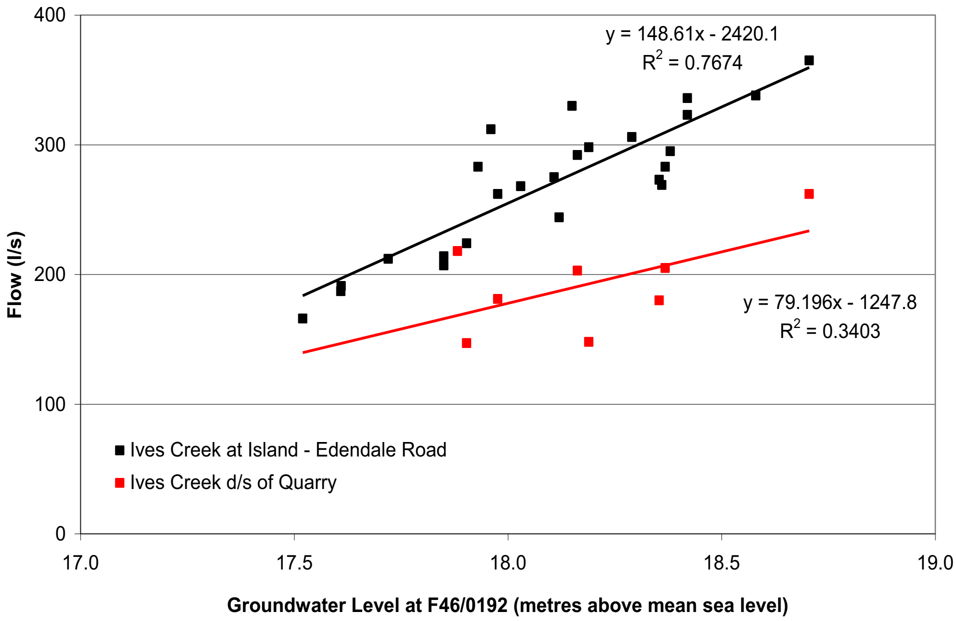

Figure 19: Linear regression of groundwater levels in bore F46/0192 and Ives Creek discharge

3.2.3 Ota Creek and Unnamed Springs

Ota Creek originates north of the current Edendale groundwater zone boundary flowing in a south-easterly direction across the Edendale terrace before joining with the Low Burn and flowing into the Mataura River approximately 3 km north of Wyndham. Upstream of the Edendale-Mataura Highway, Ota Creek carries relatively limited discharge during low rainfall periods with stream flow interpreted to be primarily sourced from a combination of runoff and interflow supplemented by artificial drainage. Downstream of the Edendale-Mataura Highway, Ota Creek flows over the terrace edge at which point it appears to gain significant input from groundwater discharge resulting in a significant increase in base flow discharge. The appreciable gain in flow downstream of the terrace edge is illustrated in Figure 20, which shows results of a concurrent gauging survey undertaken in February 2007.

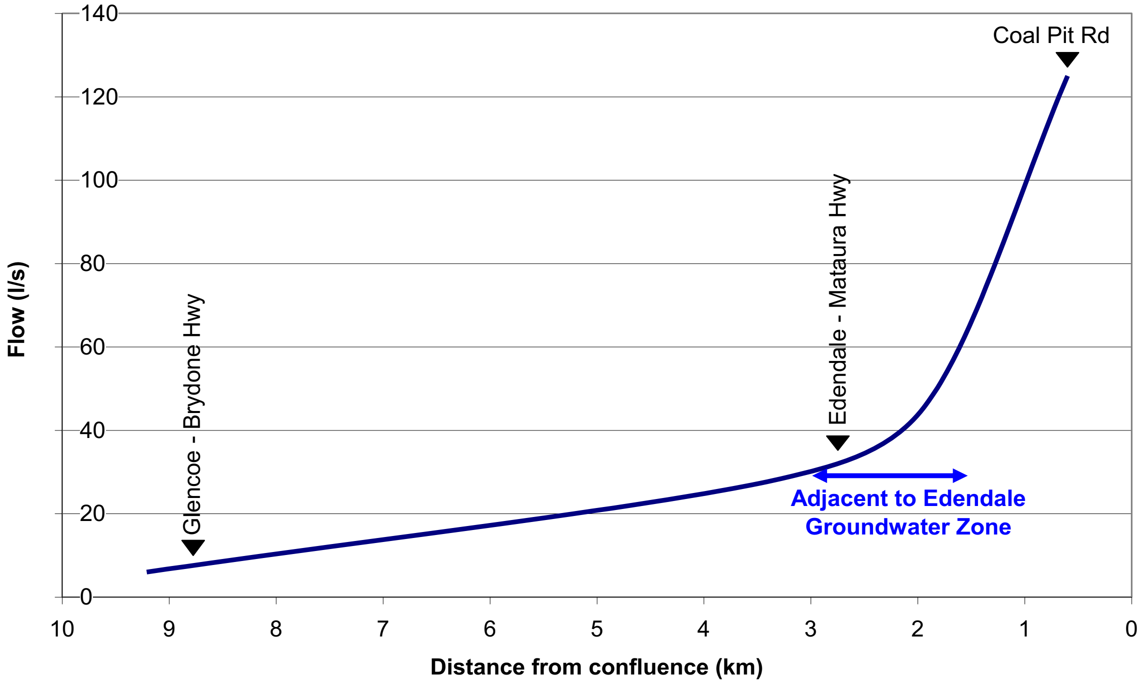

Figure 20: Long-section of Ota Creek flow (based on 17 February 2007 concurrent gauging results)

Ota Creek is a little unusual in that it is the only surface waterway between Brydone and Edendale with permanent flow. Previous reports (e.g. Rekker, 1995) have suggested Ota Creek follows vertical offset of the underlying tertiary sediments by a buried fault line. However, it would appear equally plausible that channel morphology is controlled by a basement high (discussed in Section 2.3). Regardless of the origin, it can be reasonably concluded that some form of geological control diverts surface water flow around the northern boundary of the Edendale groundwater zone. This geological control on groundwater flow is also apparent in the discrepancy in relative groundwater level elevations measured between Hilda Road and Ota Creek Road to the north. As a consequence, it is also interpreted that groundwater inflows into the lower section of Ota Creek reflects the lateral diversion of groundwater flow in the section of the Edendale terrace north of the current groundwater zone boundary.

One of the smaller unnamed spring-fed streams that drains the Edendale aquifer originates at the base of the Edendale terrace between the Edendale and Wyndham townships. The spring, which crosses Shield Road (refer to Figure 12) has a small catchment area of 101 hectares and flows across the floodplain in a south-easterly direction towards its confluence with the Mataura River about 500 metres south of Wyndham. The spot gauging data summarised in Table 5 shows measured flows in this stream range between 16 and 70 l/s suggesting relatively constant groundwater discharge.

Table 5 summarises available gauging data from Ota Creek and the Shield Road spring.

Table 5: Flow statistics from spot gaugings of Ota Creek and unnamed springs

Site	Record Period	Number of Gaugings	Min Gauged Flow (l/s)	Mean Gauged Flow (l/s)	Median Gauged Flow (l/s)	Max Gauged Flow (l/s)	Linear Regression[1] (r^2)	SEE[2] (l/s)
Ota Ck at Coal Pit Rd	2007 - 2009	4	23	60	45	125		
Spring at Shield Rd	1995 - 2009	40	16	37	37	70	0.55	7

[1]Linear regression between flow and groundwater levels in F46/0192. The co-efficient of determination (r^2) is an estimate of the "goodness of fit" of the regression. It measures the exact percentage of variation shared by two variables.
[2]Standard error of the estimate (SEE) is a measure of the accuracy of the predictions. It measures the dispersion of the actual Y values about the regression line.

3.2.4 Summary

The Edendale groundwater zone hosts a relatively simple unconfined aquifer system hosted in a reasonably thin sequence of permeable alluvial gravels underlying the Edendale terrace. The aquifer system is recharged by infiltration of rainfall on the terrace surface with groundwater flowing in a south-easterly direction under the terrace before being discharged via a series of large springs in the Seaward Downs area. Not unexpectedly, discharge in these springs exhibits a positive correlation with groundwater levels in the Edendale groundwater zone.

As outlined in Table 6, gauging data indicate the cumulative median discharge of these spring-fed streams (Clear Creek, Ives Creek, and an unnamed spring at Shield Road) of approximately 22 million m^3/year accounts for between 70 to 90 percent of current estimates of aquifer recharge outlined in Section 2.7.

Table 6: Summary of Edendale Aquifer spring discharge

Site	Median Gauged Discharge (l/s)
Ives Creek at Island – Edendale Road	283
Clear Creek upstream of Oteramika Creek confluence	373
Spring at Shield Road	37
Total	**693**
Oteramika Creek downstream of Seaward Downs (flow gain	516

When groundwater input into the lower section of Oteramika Stream is taken into account, total median groundwater discharge from the Edendale groundwater zone is approximately 38 million m^3/year, which exceeds the current recharge estimates. This discrepancy may suggest that a proportion of spring discharge is sourced from local recharge to the riparian aquifer adjacent to the Mataura River. Alternatively, the discrepancy between recharge and discharge estimates may suggest that the current northern boundary of the Edendale groundwater zone in the vicinity of Ota Creek does not form a complete hydraulic boundary with partial through-flow of groundwater occurring from areas north of Ota Creek. Such a situation may account for some of the seemingly anomalous groundwater quality analysis results seen near Hilda Road (in particular F46/0195).

Both the uncertain nature of the geological control on groundwater flow near Ota Creek and the apparent discrepancy in aquifer water budget suggest that further investigations of location and nature of the current northern boundary of the Edendale groundwater zone are warranted, particularly when this area is relatively close to the highest concentration of groundwater abstraction in the vicinity of the Edendale township.

Groundwater levels in the Edendale groundwater zone show a relatively regular pattern of seasonal variation reflecting recharge during the winter and early spring followed by progressive drainage of water from the aquifer during summer and autumn. Some inter-annual variations in aquifer storage are noted, primarily reflecting the duration of the winter recharge period. In general, temporal trends in groundwater levels (and corresponding spring-fed stream discharge) appear to track long-term rainfall variability with limited evidence to suggest current levels of groundwater abstraction are having any significant impact on aquifer storage.

4. Groundwater Allocation

4.1 Groundwater Demand

The Edendale aquifer has been utilised as a source of domestic and stock water since the area was first settled in the 1800s, and for use for a dairy factory since 1883, making it New Zealand's oldest cheese factory.

Environment Southland's WELLS database currently records 153 bores used for water supply in the Edendale groundwater zone, with an additional 86 bores used solely for investigation or monitoring purposes (most of which are associated with Fonterra's water supply investigations or monitoring of wastewater disposal areas). As illustrated in Figure 21, approximately one-quarter of all active bores are currently used for potable water supply (stock and domestic). Bores utilised for potable supply have a median depth of 11.6 metres[4] so typically penetrate between 50 to 80 percent of the average aquifer thickness.

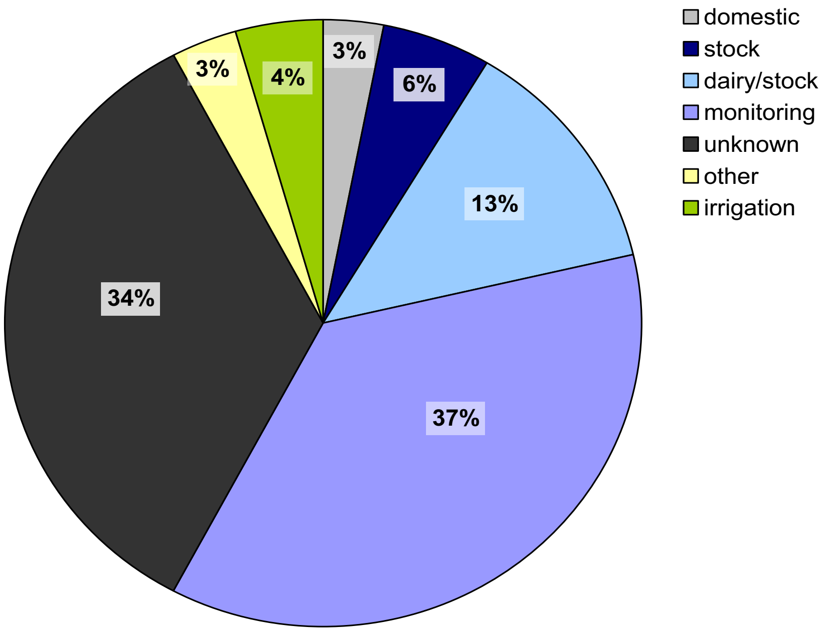

Figure 21: Bore use for the Edendale groundwater zone[5]

In 1995, Rekker calculated a maximum groundwater allocation of 7,250 m^3 per day for the Edendale aquifer (of which 175 m^3/day would be classified as permitted use under the current resource management framework). Accepting this estimate, groundwater allocation from the Edendale groundwater zone has increased 7-fold over the subsequent 14 year period to a current total of approximately 50,000 m^3/day. As shown in Figure 22, the increase in groundwater allocation over this period has primarily been by irrigation (mainly to support horticultural

[4] Average depth is 11.6 metres with n = 57
[5] This excludes exploration drilling (e.g. lignite survey)

production), along with a steady increase in industrial demand (primarily due to ongoing expansion of the Fonterra dairy factory) as well as development of the Edendale-Wyndham water supply scheme in 2009. Groundwater allocation for dairy shed supply and stock water has actually decreased by about 20 percent over the 10 year period, which may reflect the increased land area used being used for disposal of wastewater from the dairy factory and the associated cut-and-carry and/or sheep farm operations.

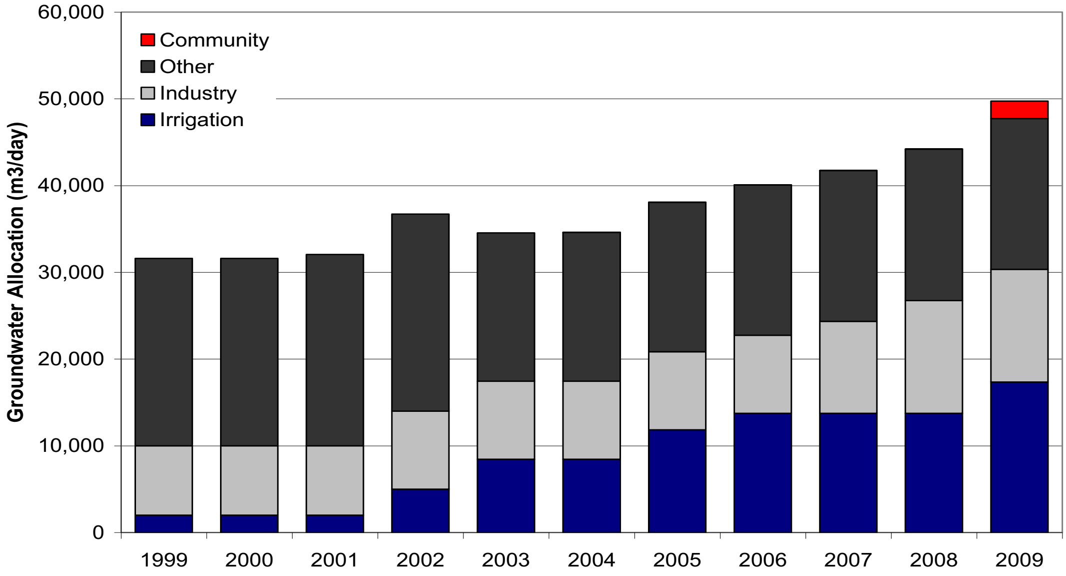

Figure 22: Daily consented groundwater allocation for the Edendale groundwater zone

Figure 23 shows that groundwater takes are spread fairly evenly across the entire Edendale groundwater zone with the largest takes tending to cluster along the central axis. This coincides with the higher aquifer permeability of the inferred paleochannel (discussed in Sections 2.2 and 2.5).

The RWP establishes a preliminary allocation threshold for terrace aquifers at 25 percent of the mean annual land surface recharge (LSR). Currently,[6] groundwater allocation from the Edendale groundwater zone is calculated to be 6,152,923 m^3 per annum, or 19 percent of LSR, which is within the preliminary limit.

[6] As at 25th August 2010 with groundwater allocation calculated according to the methodology described in Rule 23 in the RWP.

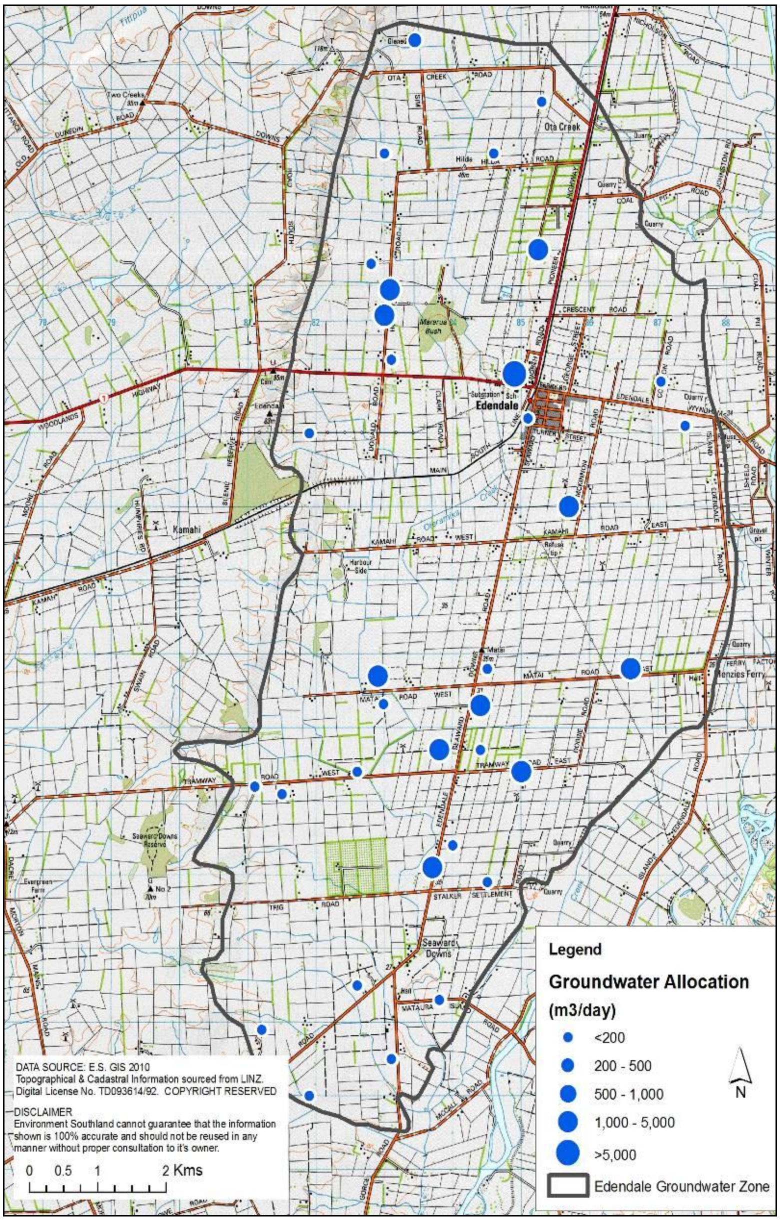

Figure 23: Map of 2009 groundwater take consents for the Edendale groundwater zone

However, the estimates of land surface recharge do not include an allowance for irrigation net use. The net use concept describes the increased recharge that occurs on soils which are irrigated. This increased recharge does not directly result from the application of irrigation water (typically managed to ensure field capacity is not exceeded) but rather occurs as a consequence of the higher soil moisture levels maintained by irrigation. The higher soil moistures under irrigated land mean field capacity are reached sooner during rainfall events resulting in a higher proportion of rainfall infiltrating through the soil profile to recharge underlying aquifers. As a consequence, a significant proportion of the irrigation water applied to land is actually retained in the catchment with the only losses being water being from evapotranspiration from plants.

Studies in other parts of the country suggest that net evapotranspirative losses may account for up to 40 percent of the total volume of irrigation applied to land with the balance of water retained within the soil zone and underlying groundwater system (Morgan *et al*, 2002). As can be seen in Table 7, irrigation of wastewater and groundwater covers 40 percent of the land area of the Edendale groundwater zone so it is likely that an appreciable component of water currently utilised for irrigation (in excess of 60 percent of current allocation) will ultimately contribute to an increase in natural aquifer recharge across the Edendale groundwater zone.

Table 7: Edendale groundwater zone irrigated area

Consent Number	Consent Holder	Type	Irrigated Area (ha)
200197	Fonterra (Mararua)	Wastewater	230
200198	Fonterra (Leondale)	Wastewater	147
200778	Fonterra (Inglemere)	Wastewater	317
201571	Matai Farms Ltd	Water	32
201719	Edendale Nursery	Water	20*
202278	Haakman NZ Bulbs	Water	17
203135	J A & B E Hillis	Water	35*
203281	Triflor NZ Ltd	Water	40
204143	Triflor NZ Ltd	Water	25
205501	Fonterra (Pedrian)	Wastewater	95
207022	Triflor NZ Ltd	Water	30
207023	Triflor NZ Ltd	Water	30
Total Irrigated Area (ha)			**1,018**
Area of Edendale groundwater zone (ha)			**2,529**
Irrigated Area (%)			**40%**

*Irrigated area has been estimated as it is not recorded in the application or subsequent reports

4.2 Groundwater Use

Appendix 5 contains the annual water use data for the Edendale groundwater zone. This information is summarised in Figure 24, which shows that while annual groundwater allocation has doubled in the past three years water use has actually remained comparatively constant at approximately 20 percent of the current total allocation. The comparatively low level of current water use (compared to allocated volumes) in part reflects the relatively large volumes of water granted by recent resource consent applications for public and dairy factory supply, which are still in the development phase. Overall, current water use equates to approximately 9 percent of the mean annual LSR (using the estimates outlined in Table 1).

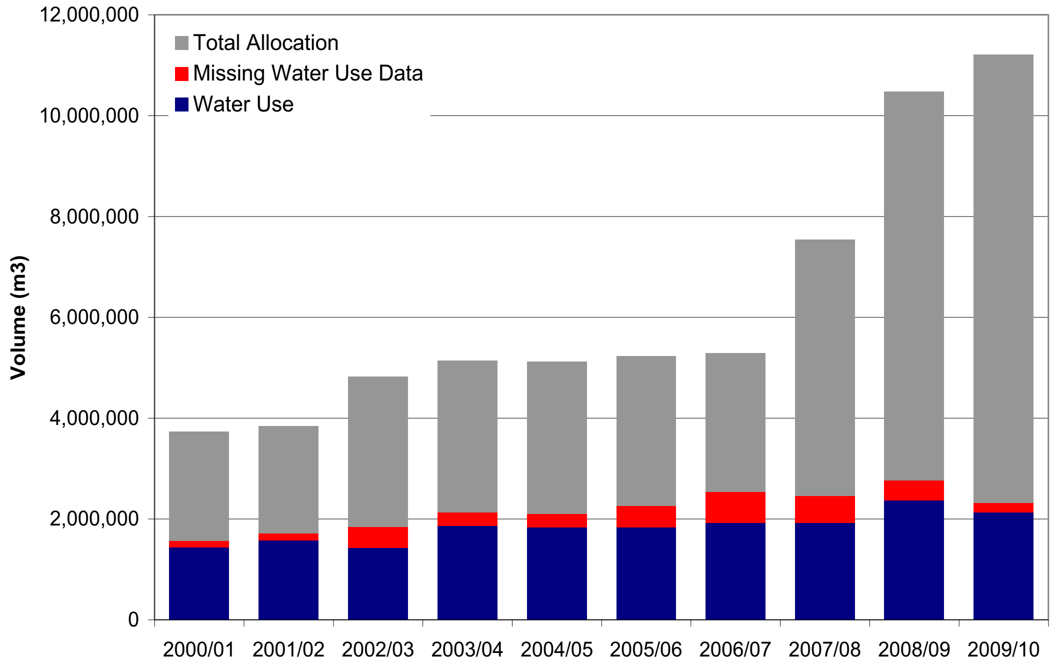

Figure 24: Graph of groundwater use from the Edendale groundwater zone

It is interesting to note that non-compliance of supply of water use data (shown in Figure 25) has been steadily improving over the past four years and that for the last two seasons (2008/09 and 2009/10), less than 5 percent of the total allocated volume of water had unmeasured water use. This partially reflects the fact that a significant portion of the allocation (30 percent of the total annual volume) is held by a small number of consent holders (i.e. Fonterra and Southland District Council).

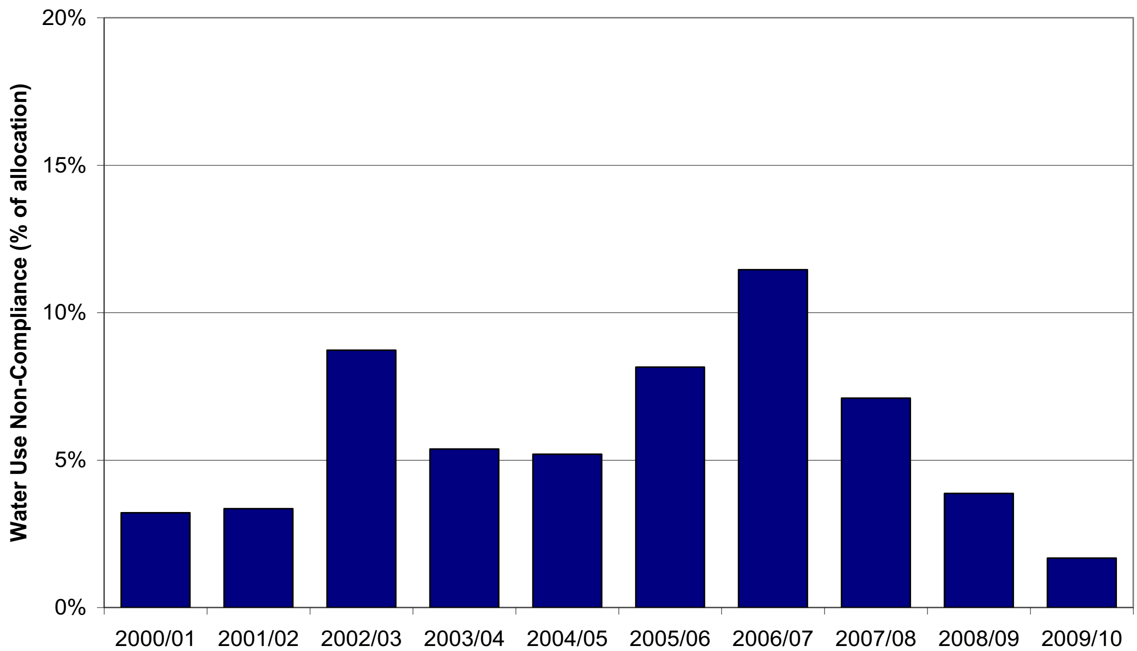

Figure 25: Non-compliance with consent requirements for supply of water use data as a percentage of total allocation

5. Groundwater Quality

All water contains dissolved constituents and of all freshwater sources, groundwater generally contains the largest amounts of dissolved solids. The range and relative concentration of the dissolved constituents reflect a range of factors including the nature and source of aquifer recharge, the rate and characteristics of groundwater flow through an aquifer system as well as geochemical processes resulting from the interaction between groundwater and the physical environment. Human (anthropogenic) influences on groundwater quality include the introduction of contaminants associated with land use activities and wastewater discharges as well as alterations to the natural flow of groundwater as a result of groundwater abstraction.

Groundwater is extensively used for drinking supply throughout the Southland region, with over 60 percent of rural properties reliant on groundwater to some extent for domestic and/or stock supply (Hamill, 1999). The widespread use of groundwater for potable supply reflects its relative abundance and ease of access, as well as an expectation within the community that groundwater is generally suitable for both human and stock consumption without the need for treatment. The importance of groundwater as a source of drinking water supply is reflected in Objective 8 in the RWP, which states groundwater quality should be maintained for aquifers which already meet the Drinking Water Standards for New Zealand (DWSNZ) and enhanced to a drinkable quality for aquifers which have been degraded due to land use and discharge activities (excepting situations where groundwater quality naturally exceeds relevant standards).

Environment Southland currently undertakes a range of groundwater quality monitoring throughout the Southland region to characterise spatial variability across the region, identify trends in the condition of groundwater resources and to better understand the source, behaviour and effect of contaminants. All available data from these monitoring programmes collected in the Edendale area have been used in the following section to characterise groundwater quality. This baseline environmental monitoring data is supplemented by sampling results from resource consent compliance monitoring (including additional data supplied by Fonterra).

5.1 Water Quality Characterisation

Nearly all groundwater originates as either rainfall or snowmelt that infiltrates through the soil into underlying geological materials either directly from rainfall or infiltration of runoff. While both rainfall and runoff generally contain relatively low concentrations of dissolved ions, concentrations of minerals and nutrients may increase in water infiltrating into underlying groundwater as a result of natural chemical and biological processes in the soil zone. These processes typically result in an increase in the total concentration of dissolved ions, which is reflected in a shift in the dominant ions from sodium and chloride (naturally present in rainfall) to calcium and bicarbonate ions reflecting the preferential dissolution of carbonate relative to other minerals present (Daughney and Wall, 2007). Due to isolation from the atmosphere, it is common (but not universal) for natural microbiological and chemical processes to deplete oxygen from deeper groundwater (groundwater with low concentrations of dissolved oxygen is commonly referred to as *reduced*). In some instances, the degree of oxygen depletion can be used as a guide to the relative age of groundwater. The occurrence of reduced conditions in an aquifer is commonly accompanied by an increase in concentrations of elements only soluble in low-oxygen conditions (e.g. iron, manganese, arsenic and ammonia).

The occurrence and relative concentrations of dissolved ions resulting from geochemical processes within an aquifer system can be used to characterise groundwater quality into water "types". This classification allows inferences to be made with regard to the source and nature of groundwater flow through an aquifer system.

The major groundwater ion concentrations for monitoring sites in the Edendale aquifer and the Southland region are shown in Figure 26 where the ion concentrations are represented as percentages of the total equivalents per litre (meq/l). Triliner diagrams like the Piper plot used in Figure 26 are useful for visually demonstrating differences in major-ion chemistry as similar groundwater types will cluster together (because the plot is based on the relative rations between the major ions.

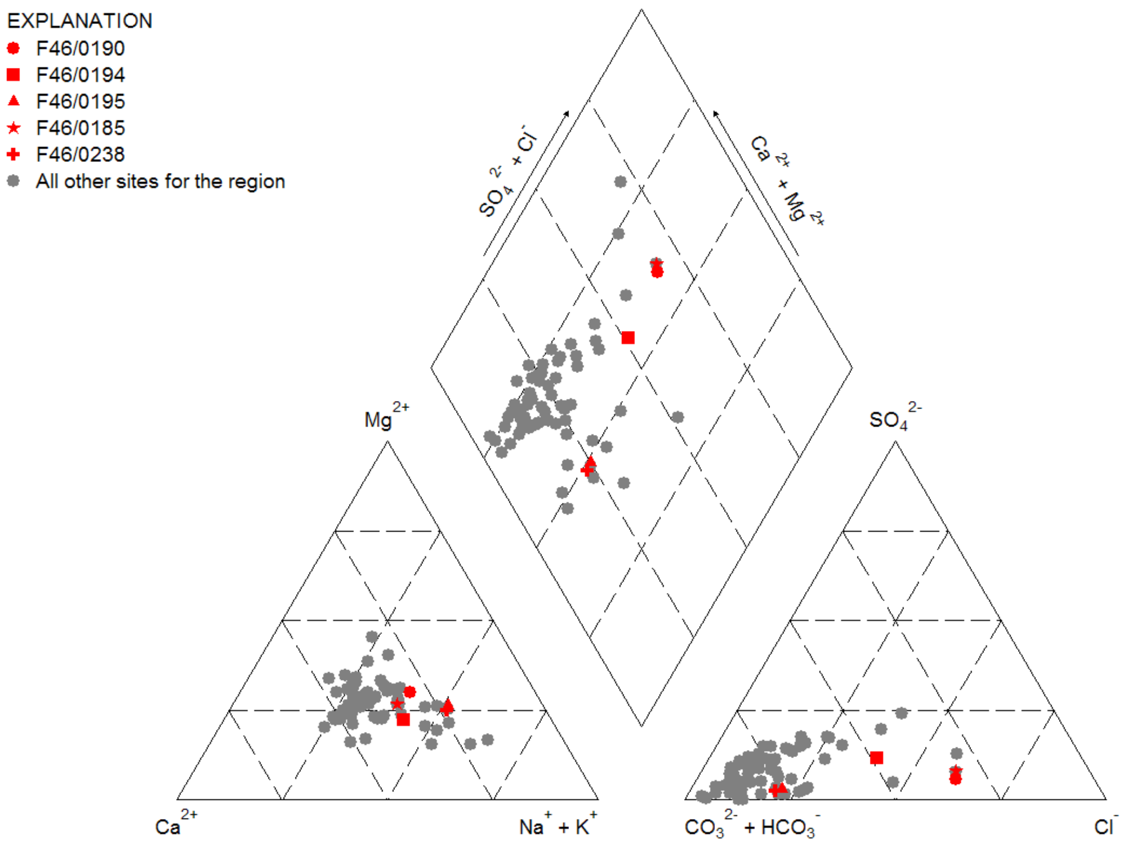

Figure 26: Piper-plot of the median value of the major ion chemistry from the Edendale groundwater zone (red data points) and other Southland monitoring sites (grey data points)

The concentrations of major ions in most of the Edendale groundwater zone monitoring sites are relatively low and are typical of other terrace aquifer systems. In general, the groundwater is characterised as being sodium-bicarbonate type water which is typical of groundwater with a low residence time flowing through relatively inert aquifer media. It is, however, noted that the Edendale aquifer sites do not all cluster together. Although cation concentrations plot in a relatively tight cluster (i.e. the bottom left triangle) the relative anion concentrations exhibit considerable spread amongst the Edendale sites (i.e. the bottom right triangle). This discrepancy is interpreted to reflect the influence of elevated chloride associated with historic wastewater disposal discussed further in Section 5.1.1.

The following section reviews the actual concentrations of several key ions.

5.1.1 Chloride

Chloride is a good indicator of general groundwater quality as it is a conservative ion and not greatly influenced by chemical or biological processes in the soil zone or underlying groundwater (Hughes, 2010). Naturally occurring chloride in groundwater in the Southland region is generally derived from aerosol deposition in rainfall, with some minor contribution from rock-water interaction. Anthropogenic sources of chloride include wastewater and effluent discharges and to a lesser extent, some fertilisers.

Recent analysis indicates 60 percent of SOE sites across the region exhibit increasing chloride trends with the number of sites exhibiting an increasing trend for chloride significantly higher than for any other parameter (Hughes, 2010). In the Edendale aquifer, elevated chloride concentrations are primarily attributed to the influence of historical land disposal practice for dairy factory wastewater. In this context, chloride has particular utility as an indicator of the magnitude and extent of groundwater contamination resulting from current and historical wastewater irrigation (Hughes, 2008b).

Historically, Mararua Farm (immediately north of the Edendale dairy factory) was the only area used for land disposal of dairy factory wastewater. During the 1990s, issues were experienced with soil structure and health on Mararua Farm due to the nature and rate of wastewater application, which resulted in poor soil infiltration, ponding and nutrient leaching. These issues were reflected in the quality of underlying groundwater, which exhibited elevated concentrations of the major chemical constituents present in the wastewater discharge (sodium, chloride and nitrate).

Soil quality issues and associated impacts on underlying groundwater quality on Mararua Farm were addressed through a move from grazed pasture to a cut and carry management regime and the addition of additional land irrigation area in 2000 (Inglemere Farm, approximately 2 km south of Edendale township). This change in land management practice on the wastewater irrigation areas was also combined with improvements to wastewater quality through additional treatment, as well as improved management of hydraulic and nutrient loading rates (Hughes, 2008b). However, observations in the spatial and temporal changes in groundwater quality (particularly chloride concentrations) provide useful information to illustrate the hydrogeological characteristics of the Edendale groundwater zone which reflect the nature of groundwater movement through the aquifer system.

Figure 27 shows the spatial distribution of the maximum chloride concentration for the Edendale Aquifer. The data show highest concentrations have been observed in bores located on the dairy factory site (immediately downgradient of Mararua Farm) and in monitoring bore (F46/0709) approximately 2 km to the south near the corner of Edendale-Seaward Downs and Kamahi Roads. South of this point, elevated chloride concentrations are observed to occur in a more south-easterly direction. This pattern of elevated chloride concentrations is interpreted to reflect the passage of a "plume" of chloride rich groundwater through the aquifer system downgradient of Mararua Farm.

The interpreted flow direction of the chloride "plume" matches the piezometric contours shown in Figure 6, with groundwater flow in a southerly direction in the vicinity of the Edendale township swinging to a more south-easterly direction across the southern section of the groundwater zone reflecting groundwater discharge via springs in the Seaward Downs area.

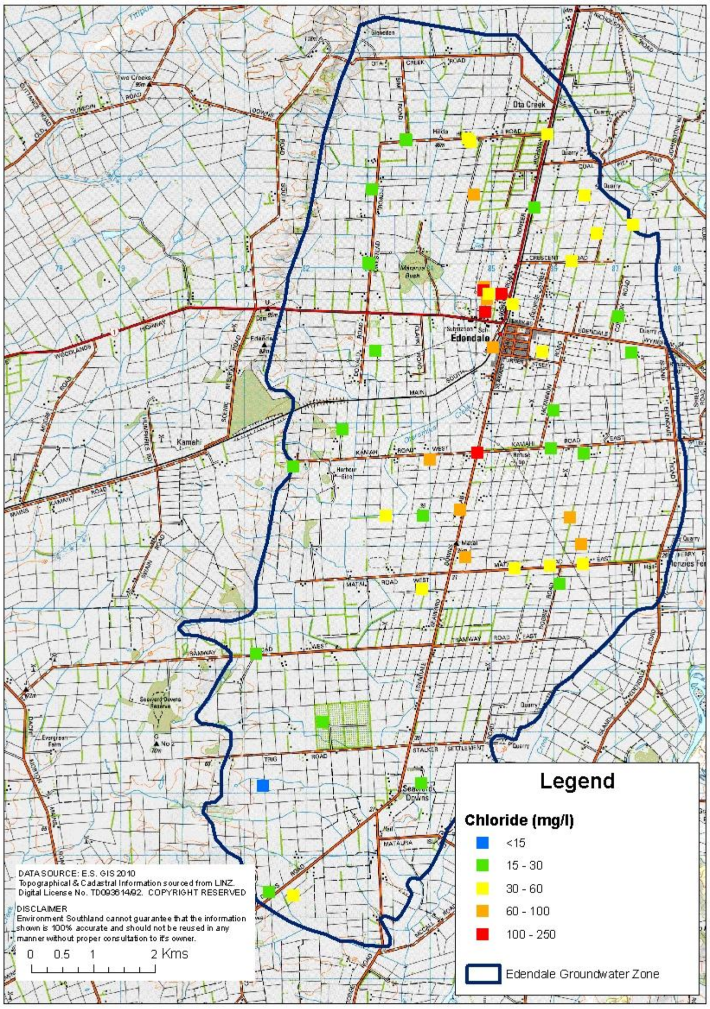

Figure 27: Map of maximum chloride concentrations in the Edendale Aquifer

Figure 28 shows temporal variations in chloride concentrations in bores immediately downgradient of Mararua Farm. Three of the bores shown (E46/0246, E46/0344 and E46/0386) are located near the dairy factory site and show a peak in chloride concentrations between 150 to 200 mg/L in 2001 followed by a progressive reduction over time reflecting the passage of groundwater containing elevated chloride concentrations through the aquifer system at this point.

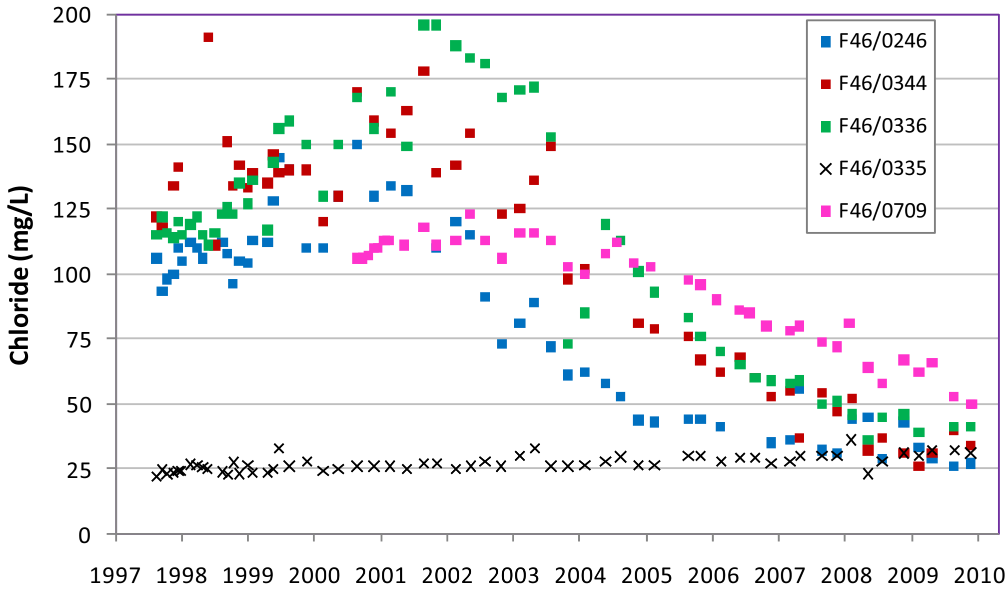

Figure 28: Chloride concentrations immediately downgradient of the Fonterra Mararua Farm, 1997-2010

Chloride concentrations in F46/0709 located 2 km to the south exhibit a broader peak between 2002 and 2004 reflecting the passage of groundwater containing elevated chloride concentrations. The broader peak and lower overall concentrations at this site likely reflecting dilution and dispersion within the aquifer system over the intervening distance. The difference in the timing of peak chloride (between 18 months and three years suggests a bulk groundwater flow velocity of between 700 to 1,300 m/year which are of a similar order (or slightly higher) than groundwater flow velocity estimates derived from aquifer hydraulic properties (refer to Section 2.6).

Figure 28 also shows a gradual increasing trend in chloride concentrations in F46/0335, a monitoring bore located upgradient of Mararua Farm. The gradual increasing chloride trend in this bore is similar to that observed elsewhere in the Southland region and is interpreted to reflect the cumulative effect of increasing land use activities in the contributing recharge area.

Figure 29 shows a similar plot of chloride concentrations in monitoring bores located on the Fonterra Inglemere Farm which encompasses the area south-east of the Edendale-Seaward Downs/Kamahi Road intersection. Data from these sites show a broad peak in chloride concentrations during the 2004/05 period which is interpreted to reflect the passage of the chloride plume through this area. Again, peak concentrations are lower and the timing of peak concentrations delayed compared to upgradient areas reflecting both the rate of groundwater flow through the aquifer system as well as dilution and dispersion processes associated with advective transport.

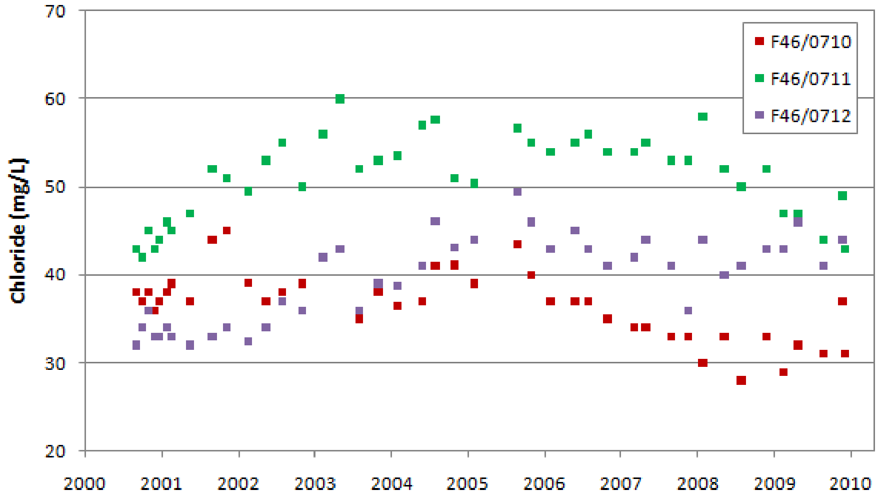

Figure 29: Chloride concentrations in monitoring bores located on the Fonterra Inglemere Farm

Another aspect of groundwater flow illustrated by the chloride monitoring data is the extent of vertical mixing within the aquifer system. Figure 30 shows a plot of chloride concentrations at two nested piezometer sites (F46/0336 and F46/0337 located on Mararua Farm, and F46/0712 and F46/0713 located on Inglemere Farm) where samples are collected at different depths within the aquifer system. At both sites chloride concentrations are similar in both screened intervals with little, if any, time delay in temporal response suggesting significant vertical mixing within the aquifer system.

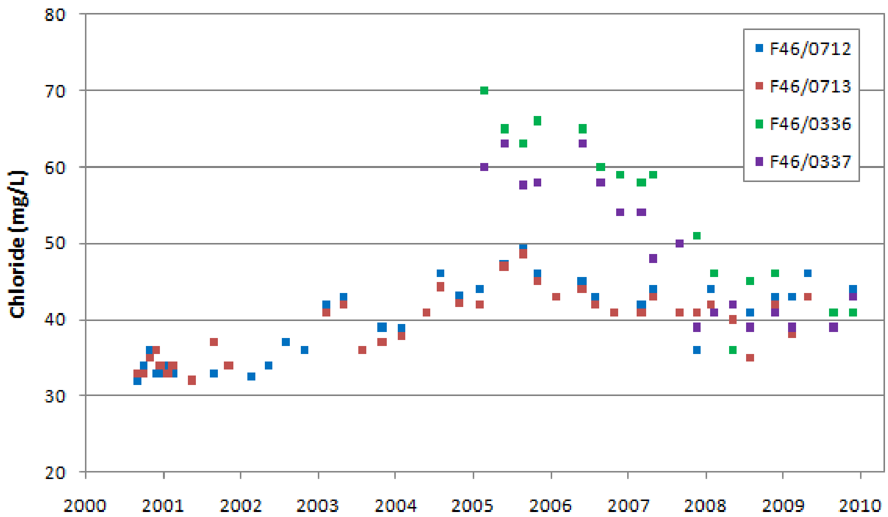

Figure 30: Temporal variations in chloride concentrations in nested piezometers on Mararua (F46/0336 and F46/0337) and Inglemere Farms (F46/0712 and F46/0713)

Further discussion of groundwater quality effects associated with historical wastewater discharge on Mararua Farm is provided in Hughes (2008b) and Kingett Mitchell (2005).

5.2 Drinking Water Standards

Access to good quality drinking water is essential for public health. Groundwater from the Edendale aquifer is used for stock and domestic purposes including the Edendale-Wyndham community scheme, and industrial supply for the Fonterra dairy factory, which processes milk from farms throughout the Southland region and is the third largest dairy manufacturing plant in New Zealand. These supplies rely on groundwater in the Edendale groundwater zone being of a suitable standard to meet the Drinking Water Standards for New Zealand (DWSNZ) and relevant food safety guidelines.

The DWSNZ were first published in 2000 and subsequently updated in 2005 and 2008 and establish maximum acceptable values (MAV) for a range of potential contaminants including microbial, chemical and radiological parameters. Consumption of water containing concentrations of parameters exceeding MAV are considered to present a significant risk to human health.

5.2.1 Micro-organisms

Micro-organisms, including bacteria, viruses and protozoa, can result in short-term acute impacts on human and animal health through a variety of diseases which range from mild gastroenteritis to severe, potentially fatal illnesses. Numerous studies undertaken both within New Zealand and overseas (e.g. Pang 2009, Wall *et al* 2008, Pang *et al* 2005) show that natural processes of filtration, adsorption and die-off reduce microbe concentrations in groundwater so that contamination tends to be localised near the contaminant source. The exception occurs where groundwater flow rates are particularly rapid or when viruses attach themselves to colloids. As a consequence, the majority of instances of micro-organism contamination in groundwater can be attributed to localised impacts downgradient of a point source discharge (e.g. septic tank, effluent pond) or where the bore or wellhead is poorly constructed or maintained allowing contamination of the abstraction point.

Although there are a wide range of micro-organisms that may result in waterborne illnesses, the presence of micro-organisms in groundwater is generally measured in terms of the presence/absence of the bacteria species Escherichia coli (commonly referred to as *E. coli*). This bacteria is commonly found in large numbers in the lower intestine of warm blooded animals and is utilised as an indicator of potential faecal contamination due to their persistence outside of the body (Hughes, 2010). The DWSNZ specify that *E. coli* should not be present in water used for potable supply to minimise the potential for adverse health effects.

Figure 31 shows the number of sites at which indicator bacteria have been detected for groundwater samples from the Edendale aquifer between 2001 and 2009. These data indicate the *E. coli* detection rate has gone from

55 percent of sites in 2005 to no detections at any sites over the past three years. This is consistent with regional observations reported in recent SOE reports (Environment Southland and Te Ao Marama Inc, 2010 and Hughes, 2010) which noted the incidence of faecal contamination had reduced from 55 percent of sites sampled across the Southland region in 2003 to 22 percent of sites in 2009.

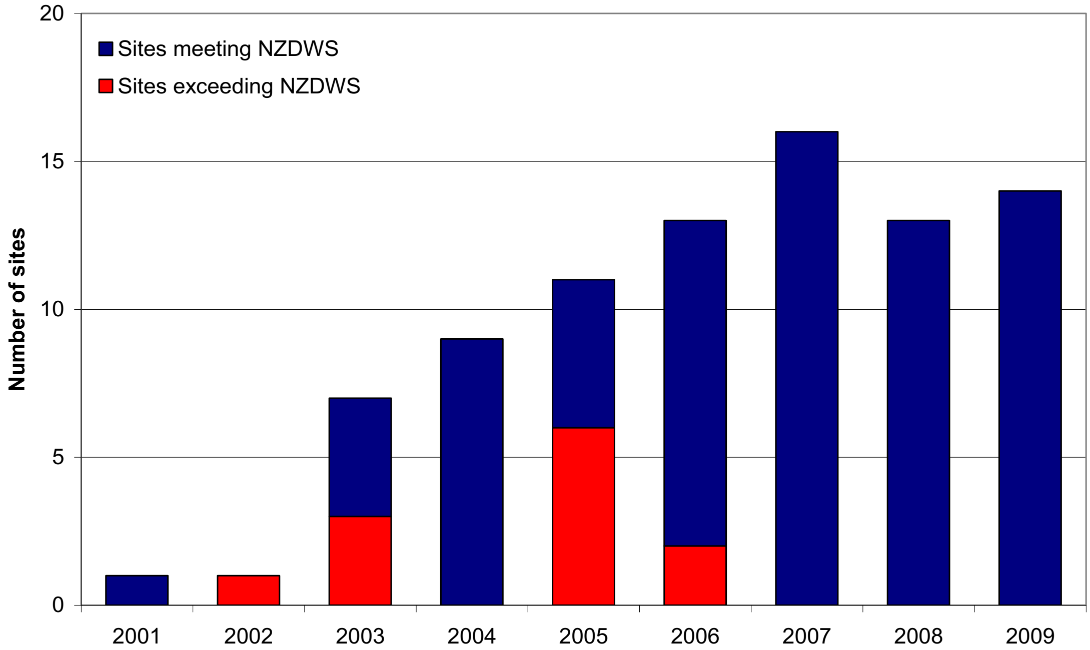

Figure 31: Plot of *E. coli* exceedances of the DWSNZ for all bores sampled between 2001 and 2009

5.2.2 Nitrogen

Nitrogen can exist in the environment in many forms and is a key element required to support plant growth and biological activity. Nitrate (or ammonia depending on geochemical conditions) is soluble in water and can be lost from the soil profile and build in groundwater or surface water receiving environments. This can affect the potability of water and aquatic ecology of surface waters due to the promotion of aquatic plant growth and may be toxic in elevated concentrations.

In New Zealand, the Ministry of Heath has set a MAV for (nitrate + nitrite) – nitrogen (henceforth called nitrate-N) of 11.3 mg/l for drinking water (2008). This is based on World Health Organisation recommendations and is for short-term exposure to protect against methaemoglobinaemia (or *"blue baby syndrome"*) in bottle fed infants.

As discussed in Section 5.1.1 nitrate-N concentrations in the Edendale groundwater zone have been significantly influenced by historical discharges of dairy factory wastewater to land. As a consequence, spatial and temporal nitrate-N concentrations exhibit a relatively complex pattern that reflects the cumulative effects of current and historical land use activities associated with both wastewater discharge activities and other land uses in the local area.

Figure 32 shows a map of maximum nitrate-N concentrations for bores in the Edendale groundwater zone sampled during 2009. These data show areas of elevated nitrate-N concentrations associated with three dairy factory wastewater discharge areas (Mararua Farm, Leondale Farm and Inglemere Farm). The elevated nitrate-N concentrations in these areas are interpreted to reflect the cumulative effect of historical and current wastewater disposal practice (both locally and in upgradient areas) due to the complex nature of nitrogen leaching from soils with elevated soil organic carbon and nitrogen concentrations.

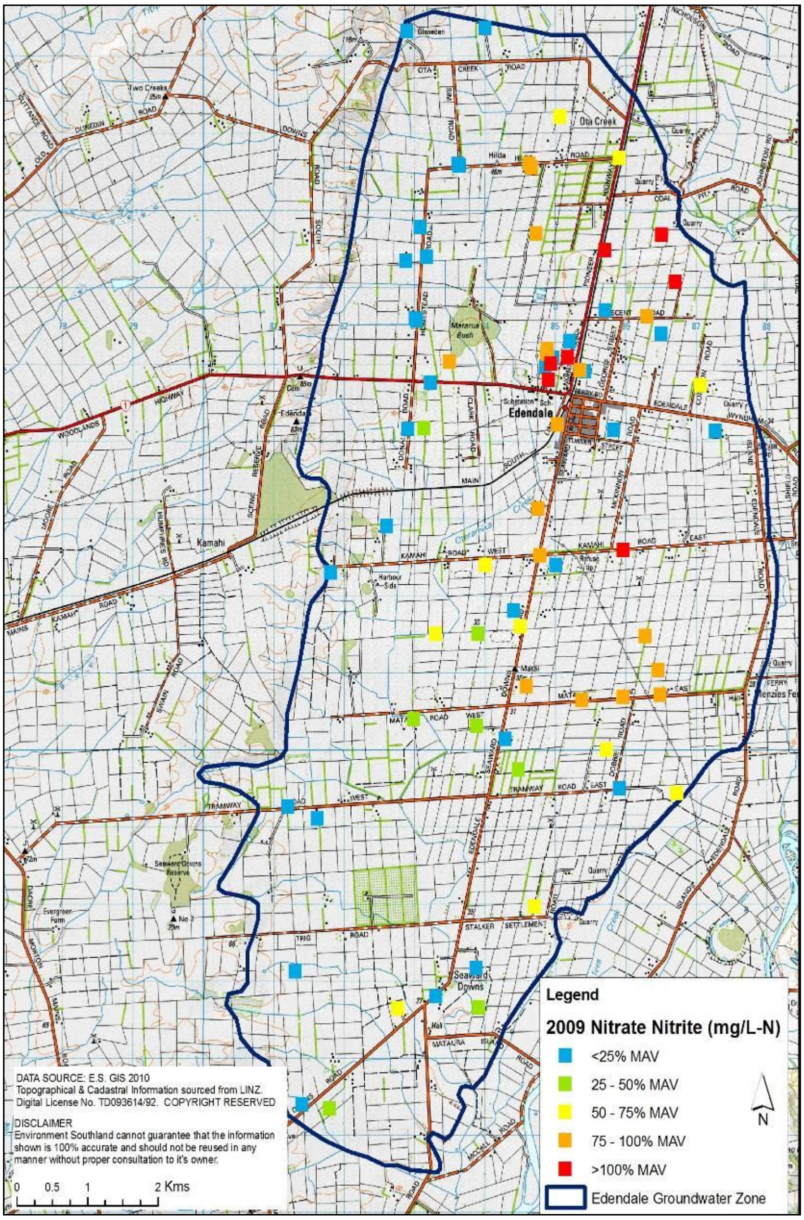

Figure 32: Map of the 2009 maximum nitrate-N concentrations for the Edendale Aquifer

Figure 33 shows the percentage of sites exceeding the DWSNZ nitrate-N MAV annually since 1994. At the current time (2009), it is observed that approximately 20 percent of sites samples exceeded the MAV, a figure which has remained relatively constant since 2005. It is noted that these data are likely to be biased by the dominance of data from monitoring sites located either within or immediately downgradient of wastewater disposal areas so may not present an accurate representation of nitrate-N concentrations across the wider aquifer.

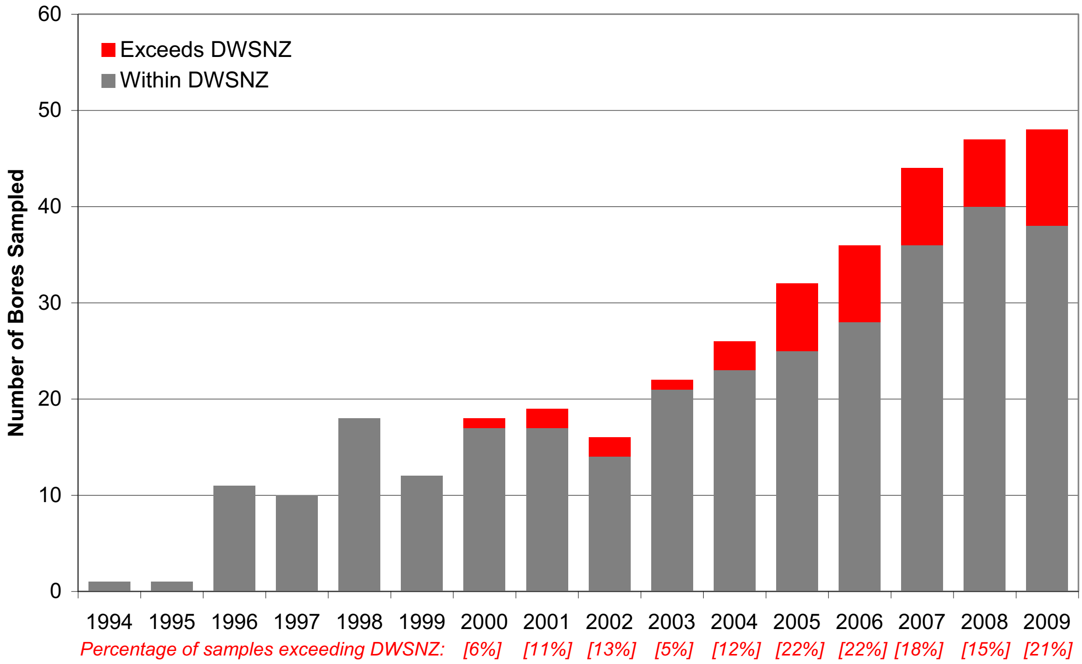

Figure 33: Exceedances of DWSNZ nitrate-N MAV from 1994 to 2009

In this regard, the envelope plot shown in Figure 34 may provide a more useful representation of the median and range of nitrate-N concentrations measured across the wider Edendale groundwater zone. These data show the median nitrate-N concentration has been relatively consistent over the 15 year monitoring period ranging between 7 to 9 mg/l. While this represents generally elevated nitrate-N concentrations across the entire aquifer, both the median and upper quartile concentrations remain below the DWSNZ MAV. This assessment highlights nitrate-N concentrations above the MAV essentially represent localised areas within the aquifer system where the maximum concentrations are showing a decreasing trend over time.

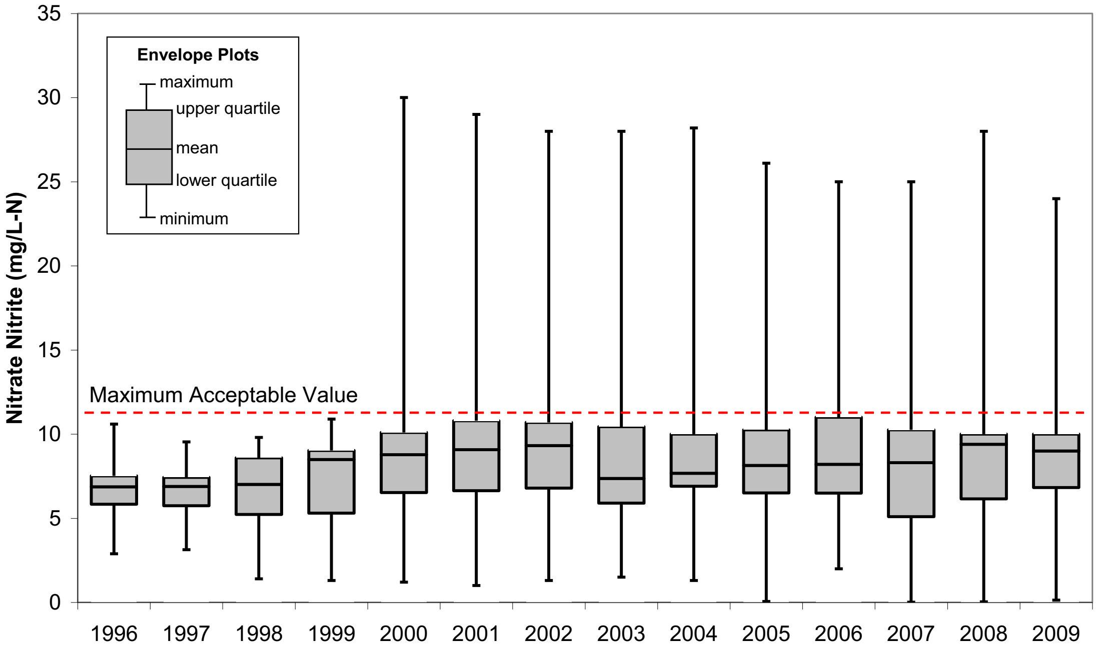

Figure 34: Envelope plots of nitrate-N for all bores sampled 1994 to 2009

In terms of temporal trends, Figure 35 shows an interesting plot of nitrate concentrations at three representative monitoring sites distributed across the Edendale groundwater zone. The plot shows a clear linear trend with an annual increase of the order of 0.3 mg/L/year nitrate-N evident at all three sites. While it could be inferred the increasing trend observed at F46/0709 and F46/0185 (located along Kamahi and Matai Roads respectively) may represent the downgradient effects of current and historical wastewater discharge in the upgradient area, it is interesting to note that both relative concentrations and temporal trends observed at these sites match that observed at F46/0335 located on Hilda Road upgradient of dairy factory wastewater discharge areas. This may suggest the presence of an underlying increasing trend in groundwater nitrate-N concentrations due to general land use, which is exacerbated in areas by localised effects of historical wastewater discharge operations.

Overall, groundwater nitrate-N concentrations in the Edendale groundwater zone present a relatively complex picture. Clearly, localised areas were impacted in the past by the effects of historical dairy factory wastewater disposal activities and the effects of these activities are still having some influence on groundwater quality in downgradient areas. These legacy effects are potentially complicated by both the complex nature of nitrogen leaching from the soil profile and the time taken for groundwater to flow through the aquifer system. However, there also appears to be an underlying increasing trend in groundwater nitrate-N concentrations which may not be directly associated with current and historical wastewater discharge activities. The interaction of these influences results in complex variations in spatial and temporal nitrate-N concentrations.

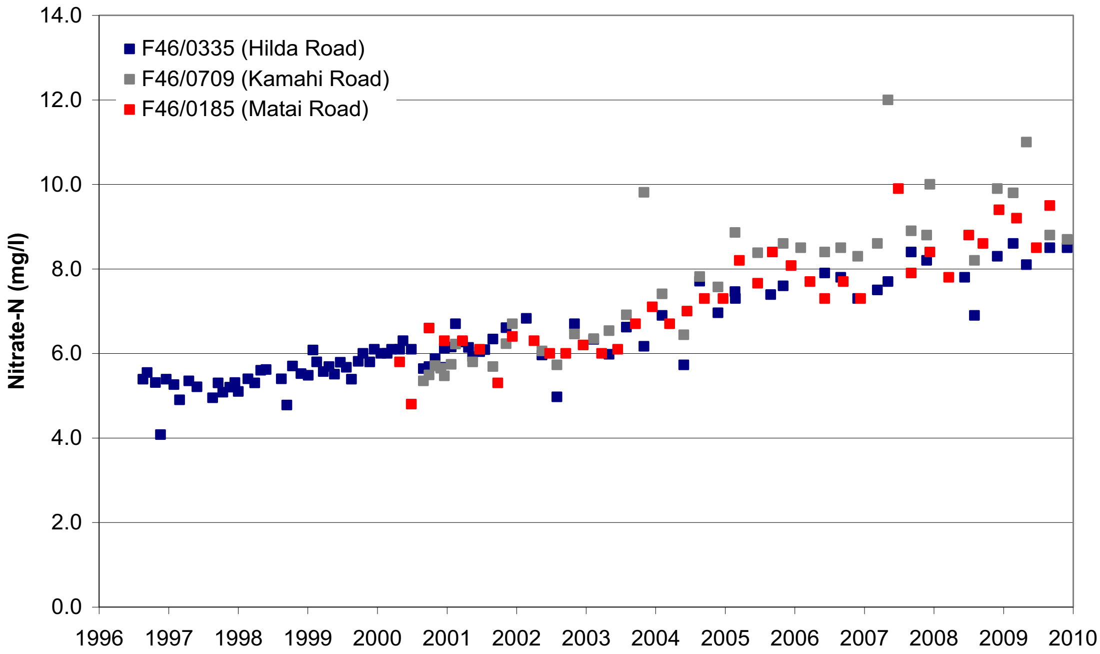

Figure 35: Nitrate-N results from monitoring bores F46/0335, F46/0709 and F46/0185

5.2.3 Pesticides

Low concentrations of pesticide residue were first detected in groundwater in the Edendale area in samples collected for the 1994 national groundwater survey (Close, 1996). Results of a follow-up national survey in March 1999 suggested that the contamination was ongoing. Following results of these initial surveys in June 1999, Environment Southland established a investigation programme to determine the origin, magnitude, extent and potential significance of the pesticide contamination and to assess temporal variation. The results of this study were complied into a report in 2000 and the conclusions at the time were:

- trace concentrations of up to eight organonitrogen herbicide active ingredients were detected in the bores sampled;
- the maximum concentrations detected were between 5 to 20 percent of the maximum acceptable value (MAV) listed in the Drinking Water Standards for New Zealand;
- the area affected extended from Hilda Road to the Edendale township (approximately 3 km in distance), following the natural groundwater flow;
- the contamination sources identified were horticultural operations and railway spraying. The widespread usage of soak holes for surface drainage was identified as a possible mechanism allowing mobile pesticide active ingredients to bypass treatment in the soil zone and leach directly into the underlying aquifer; and
- the downgradient pesticide concentrations indicated that once in groundwater, these substances are persistent and may be transported over a considerable distance.

Following the initial investigation, semi-regular monitoring of pesticide concentrations was continued to determine spatial and temporal patterns occurrence in the aquifer in response to changing land use patterns.

In 2008, the initial technical report was updated to include assessment of samples collected over the subsequent period. This report (Hughes 2008c) concluded that the number and concentration of pesticide active ingredients detected in the groundwater near Edendale showed an obvious decline since 1999 and that the maximum pesticide active ingredient concentrations detected were less than 15 percent of MAV indicating the contamination was unlikely to pose significant health concerns for potable groundwater supplies. The highest pesticide active ingredient concentration recorded in all of the samples was simazine at only 30 percent of MAV. The report also highlighted the persistence of these compounds in the groundwater system with Hexazinone still being detected almost 10 years after it was last known to be used despite the relatively high rate of through-flow within the aquifer system. This was interpreted to reflect the longevity of pesticide active ingredients in the groundwater environment, with dilution being the primary mechanism responsible for reducing contaminant concentrations.

5.3 Stable Isotopes and Environmental Tracers

An isotope is an element, which has more than one form, but its form only differs with regard to the number of neutrons it has. This affects the relative atomic mass of an element and can result in different isotopes behaving slightly differently, which is what allows us to use them for a number of measurements relating to understanding past conditions[7]. Since the early 1950s, naturally occurring isotopes have been used in investigations of groundwater and surface water systems (Freeze and Cherry, 1979). Oxygen 18 (^{18}O) and deuterium (^{2}H) are mainly used as indicators of groundwater recharge source while tritium (^{3}H), carbon 14 (^{14}C), sulphur hexafluoride (SF_6) and chlorofluorocarbons (CFC) serve mainly as indicators of groundwater age. Stable (or nonradioactive) isotope ratios can also be used to help determine the source of an element as in the case of nitrogen (^{15}N:^{14}N ratio).

Limited stable isotope and environmental tracer data is available to characterise the potential origin and residence time of groundwater in the Edendale groundwater zone.

5.3.1 Recharge source

Oxygen in the atmosphere occurs in two naturally occurring isotopic forms - Oxygen 18 (^{18}O) and Oxygen 16 (^{16}O). The relative abundance of these two forms changes according to well documented temperature-related effects (termed *fractionation*) during evaporation and condensation (Stewart and Morgenstern, 2001). As a consequence, the ratio between ^{18}O and ^{16}O can be utilised to provide an indication of likely recharge source for an aquifer system with recharge from lowland rainfall being enriched with

[7] Isotope definition sourced from www.tuition.com.hk/geography/i.htm

respect to ^{18}O compared to that occurring in alpine precipitation (the major source of flow in the main river systems).

^{18}O samples have been analysed in two bores in the Edendale groundwater zone (F46/0185 and F46/0194). Both sites show values in the range of -7.3 to -7.5, which are consistent with recharge from local rainfall.

5.3.1 Age-dating

Available age dating results from three sites in the Edendale groundwater zone provide somewhat ambiguous results that indicate groundwater residence time in the range of 10 to 100 years. At the current time, it is uncertain if these results are representative of actual residence time or are more a reflection of the sampling techniques utilised (CFCs and tritium) and associated uncertainty with application of the associated mixing models.

Despite the uncertainty of existing age estimates, given the potential importance of an understanding of groundwater age to interpretation of both observed groundwater quality variations and the potential nature of through-flow across the northern aquifer boundary it is recommended that further age-dating investigations be undertaken once techniques are considered sufficiently robust to yield unambiguous age estimates.

5.3.2 Nitrate source

Similar to oxygen, nitrogen also naturally occurs in two isotopic forms, Nitrogen-14 (^{14}N) and Nitrogen-15 (^{15}N), and the ratio between these forms can be used as a general indicator to distinguish nitrogen source (δ15N). As a general rule, δ15N values in groundwater less than 5‰ reflect input from artificial fertiliser while values between 5‰ to 10‰ reflect soil mineralisation (breakdown of organic material within the soil zone) and values greater than 10‰ indicate an animal effluent source.

Nitrogen-15 results are currently available from two sites in the Edendale groundwater zone (F46/0185 and F46/0194), which have been sampled twice. At both sites δ15N values fall in the range of 4‰ to 8‰, which suggests soil mineralisation is the primary nitrate-N source.

5.4 Summary

Groundwater quality in the Edendale groundwater zone is generally high with a majority of groundwater being suitable for potable supply without treatment. However, groundwater nitrate-N concentrations exceed MAV in some areas due to historical land use activities. While it is clear that elevated nitrate-N concentrations are associated with historical wastewater discharge activities, these effects also appear to be superimposed on an underlying trend of increasing nitrate-N concentrations possibly associated with more general intensification of land use across the wider Edendale groundwater zone. Due to the complicated nature of nitrate-N leaching from the soil profile, legacy effects of wastewater historical wastewater discharge activities combined existing land use present a relatively complex pattern of spatial and temporal variation in groundwater nitrate-N concentrations.

Overall, groundwater quality monitoring data from the Edendale groundwater zone illustrate the vulnerability of this aquifer system to the cumulative impacts of overlying land use. This vulnerability reflects a range of factors including the nature of aquifer recharge and the relatively restricted saturated thickness of the aquifer system. Available monitoring data provide a good illustration of the nature of contaminant transport within the aquifer system with water quality impacts associated with land use activities potentially impacting on a relatively extensive downgradient area over an extended period.

6. Summary and Recommendations

The Edendale groundwater zone is hosted in Quaternary alluvial gravel deposits underlying an elevated river terrace within the lower Mataura River valley. The boundaries of the groundwater zone are currently defined as encompassing the entire surface area of the Edendale terrace to the south of Ota Creek.

The gravel materials forming the Edendale terrace comprise of inter-bedded quartz/greywacke sandy, pebbly, cobbly gravel beds with accessory lenses of silt and clay which range in thickness from approximately 10 to 30 metres. The gravel sediments are underlain by fine-grained sediments of the East Southland Group. In the Edendale area, these Miocene age sediments largely comprise of firm sand, mudstone and lignite of the Gore lignite measures, which dip at a low angle to the south-west. The hydraulic connection between the lignite measure sediments and overlying alluvial gravels is unknown. However, due to the significant contrast in permeability, the upper surface of the lignite measures is considered to effectively form the base of the Edendale groundwater zone. To the west and the south the lateral extent of the Edendale groundwater zone is also truncated by lignite measure sediments occurring along the margins of the Mataura River valley.

Available aquifer test information from the Edendale groundwater zone reflect the relatively coarse-grained texture of the aquifer materials. Estimates of aquifer transmissivity range by up to two orders of magnitude from 100 to 10,000 m^2/day reflecting the general heterogeneity of the gravel deposits as well as the increased saturated thickness and higher permeability along the central axis of the aquifer system. Aquifer tests also indicate the aquifer is unconfined with a typical storativity in the range of 0.1. In general, coarser, more highly transmissive materials are typically encountered near the base of the gravel deposits.

The aquifer system is recharged exclusively by direct rainfall recharge and infiltration of runoff from the escarpment forming the western aquifer boundary. Estimates of the annual average rate of rainfall recharge vary from approximately 22 to 34 million cubic metres per annum.

Groundwater levels in the Edendale groundwater zone typically range from 12 to 14 metres below ground in the northern portion of the aquifer system to around 5 to 6 metres near Seaward Downs. Temporal variations in groundwater level show a clear seasonal fluctuation of up to 2 metres reflecting higher rainfall recharge rates during winter and spring. Groundwater level monitoring data suggest temporal groundwater level variations in the Edendale groundwater zone are largely driven by a combination of seasonal and long-term rainfall patterns with limited evidence of any changes due to existing levels of abstraction from the aquifer system.

Groundwater is discharged from the Edendale groundwater zone via a series of springs along the eastern margin of the Edendale terrace. The largest of these springs feed Clear Creek and Ives Creek in the Seaward Downs area and have a combined median discharge in the order of 700 L/s. These springs act as a constant discharge boundary and effectively moderate seasonal variations in aquifer storage. In combination with observed groundwater discharge to the lower reaches of the Oteramika Creek, median surface water discharge from the Edendale groundwater zone is estimated to be approximately 38 million m^3/year, which is higher than estimated rainfall recharge volumes. This potential discrepancy in aquifer water balance may be indicative of potential through-flow across the northern groundwater zone boundary in the vicinity of Ota Creek.

Piezometric contours indicate groundwater flows in a southerly direction north of Edendale township swinging to a more south-easterly direction reflecting the discharge of water via springs in the Seaward Downs area. This interpreted groundwater flow direction is consistent with observed variations in historical groundwater chloride concentrations, which show the passage of a "plume" of groundwater containing elevated chloride concentrations associated with historical dairy factory wastewater discharge through the aquifer system. Temporal variations in observed chloride concentrations suggest a bulk flow velocity of between 700 to 1,300 m/year.

Groundwater quality in the Edendale groundwater zone is generally high, with a majority of groundwater being suitable for potable supply without treatment. However, significant temporal and spatial variations in groundwater quality illustrate the vulnerability of this aquifer system to the potential impacts of overlying land use activities. Due to the complicated nature of nitrate-N leaching from the soil profile, legacy effects of wastewater historical wastewater discharge activities combined existing land use present a relatively complex pattern of spatial and temporal variation in groundwater nitrate-N concentrations. In particular, elevated nitrate-N concentrations associated with wastewater discharge appear to be superimposed on an underlying trend of increasing nitrate-N concentrations possibly associated with more general intensification of land use across the wider Edendale groundwater zone.

Recommendations for future monitoring and investigations in the Edendale groundwater zone include:

- continuation of existing groundwater level monitoring including maintenance of a key automatic groundwater level reference site (F46/0250) supplemented by manual monitoring of groundwater levels at representative points across the aquifer system;

- continuation of the existing current spring-fed stream gauging programme at representative sites in the Ives Creek, Clear Creek and the Shield Road spring catchments;

- concurrent gauging in the lower reaches of the Oteramika and Ota Creek catchments to improve definition of groundwater inflows;

- refinement of existing rainfall recharge estimates through refinement of soil moisture water balance modelling and/or physical measurement of infiltration rates (e.g. using lysemeters);

- refinement of current estimates of the aquifer water balance including updated estimates of aquifer recharge/discharge;

- investigations to improve definition of the nature hydraulic connection across the northern boundary of the Edendale groundwater zone, particularly in vicinity of Ota Creek. These investigations could include drilling, aquifer testing, geophysical and piezometric surveys as well as water quality and stable isotope investigations;

- investigations, including aquifer testing and geophysical surveys to confirm the presence and hydraulic characteristics of the inferred paleochannel feature underlying the central portion of the Edendale terrace;

- additional tritium sampling (and/or alternative age dating methods) to improve current understanding of the spatial and depth distribution of groundwater residence time across the Edendale groundwater zone;

- additional groundwater quality monitoring sites focussed on key indicators (e.g. nitrate-N) located away from areas currently impacted by historical wastewater discharge activities to better define background groundwater quality trends;

- investigations to improve knowledge of the fate and transport of nutrients (particularly nitrate-N) in the soil zone particularly in relation to historical wastewater irrigation areas. This assessment may be informed by regular assessment of current and historical land management practice compared to groundwater quality compliance monitoring results. If required this could involve collaborative investigations with Fonterra to ensure current wastewater irrigation practice and associated land management are sufficient to ensure future groundwater quality meets the RWP Objective 8 in terms of suitability for potable supply;

- recording of land use across the Edendale groundwater zone at regular intervals to improve ability to attribute observed variations in groundwater quality with potential causative factors; and

- development of a numerical flow and transport model to improve definition of aquifer hydrology (including sustainable abstraction limits) and assimilative capacity. It is acknowledge that this project has been included in Environment Southland's Long-term Council Community Plan 2009-19 outcomes for the 2010/11 year.

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8. Glossary

Aesthetic: Dealing with those aspects of water that are perceivable by the senses.

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

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

Contact spring: a permeable, water-bearing stratum overlying an impermeable stratum and water discharges where the contact zone between the strata intersects the land surface (Fetter, 1980).

Depression spring: a topographical depression intersects an unconfined aquifer (Fetter, 1980).

Groundwater: subsurface water that occurs beneath the water table in soils and geological formations that are fully saturated.

Morphology: form, shape or structure of something. For example, it can refer to the branch of geology that studies the characteristics, configuration and evolution of rocks and landforms.

pH: value taken to represent the acidity or alkalinity of water.

Potable water: water suitable, on the basis of both health and aesthetic considerations, for drinking and food preparation.

Unconfined aquifer: an aquifer with no upper confining layer so the system is not under pressure and its water table levels fluctuate both seasonally and from year to year[8].

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[8] Definition sourced from Environment Canterbury website (31st August 2010): http://www.ecan.govt.nz/Pages/glossary.aspx?index=U

9. Appendices

Appendix 1: Groundwater Level Monitoring Data

Manual measurements recorded as depth below top of casing (m)

Date	F46/0185	F46/0190	F46/0192	F46/0193	F46/0250	F46/0708
09-Sep-80		-5.34				
16-Aug-95	-5.41	-4.60		-10.12		
07-Sep-95	-5.50	-4.15		-9.98		
16-Oct-95	-5.03	-4.21		-9.80		
13-Nov-95	-4.98	-4.52		-9.83		
11-Dec-95	-5.24	-5.02				
15-Jan-96	-5.56	-5.27		-10.36		
12-Feb-96	-5.78	-5.58		-10.53		
22-Mar-96	-6.10	-6.13	-9.92	-10.84		
15-Apr-96	-6.30	-6.20	-10.06	-11.03		
13-May-96	-6.69	-6.57	-10.16	-11.25		
11-Jun-96	-6.76	-6.06	-9.98	-11.42		
15-Jul-96	-5.93	-5.08	-9.47	-10.96		
12-Aug-96	-5.83	-5.26	-9.52	-10.96		
13-Sep-96	-5.81	-5.17	-9.59	-10.68		
21-Oct-96	-6.17	-5.44	-9.65	-10.77		
11-Nov-96	-6.01	-5.49		-10.83		
13-Dec-96	-6.04	-5.54	-9.74	-10.87		
13-Jan-97	-6.12	-5.81	-9.77	-10.90		
10-Feb-97	-6.30	-6.05	-9.89	-11.04		
17-Mar-97	-6.72	-6.34	-10.03	-11.26		
14-Apr-97	-6.72	-6.19	-9.97	-11.41		
12-May-97	-6.42	-5.59	-9.83	-11.25		
16-Jun-97	-6.10	-5.46	-9.56	-10.94		
14-Jul-97	-5.93	-5.06	-9.53	-10.68		
11-Aug-97	-5.39	-4.28	-9.10	-10.11		
08-Sep-97	-5.29	-4.63	-9.28	-10.05		
13-Oct-97	-5.56	-5.16	-9.52	-10.30		
10-Nov-97	-5.96	-4.50	-9.73	-10.54		
08-Dec-97	-5.97	-5.59	-9.78	-10.77		
12-Jan-98	-5.81	-5.33	-9.61	-10.60		
09-Feb-98	-5.92	-5.64	-9.74	-10.65		
16-Mar-98	-6.18	-5.97	-9.90	-10.94		

Date	F46/0185	F46/0190	F46/0192	F46/0193	F46/0250	F46/0708
06-Apr-98	-6.35	-5.70	-9.88	-10.82		
May-98			-9.84			
Jun-98			-9.82			
Jul-98			-9.64			
Aug-98			-9.59			
Sep-98			-9.53			
Oct-98			-9.40			
Nov-98			-9.46			
Dec-98			-9.62			
Jan-99			-9.63			
Feb-99			-9.78			
Mar-99			-9.94			
Apr-99			-10.07			
May-99			-10.19			
Jun-99			-10.23			
Jul-99			-10.20			
Aug-99			-10.09			
Sep-99			-9.89			
Oct-99			-9.76			
Nov-99			-9.78			
01-Dec-99			-9.51			
09-Dec-99			-9.48			
05-Jan-00			-9.59			
10-Feb-00	-6.58	-6.07		-11.36		
15-Feb-00			-9.95			
14-Mar-00			-10.10			
17-Mar-00	-6.86	-6.41		-11.61		
27-Mar-00			-9.99			
13-Apr-00	-7.07	-6.61		-11.78		
03-May-00			-10.24			
09-May-00			-10.31			
17-May-00	-7.28	-6.84		-11.96		
27-Mar-00			-9.99			
13-Apr-00	-7.07	-6.61		-11.78		
03-May-00			-10.24			
09-May-00			-10.31			
17-May-00	-7.28	-6.84		-11.96		
30-May-00			-10.29			

Date	F46/0185	F46/0190	F46/0192	F46/0193	F46/0250	F46/0708
16-Jun-00	-7.45	-6.81		-12.08		
12-Jul-00	-7.32	-6.51		-12.07		
13-Jul-00			-10.09			
03-Aug-00			-10.21			
15-Aug-00	-7.28	-6.45		-11.97		
14-Sep-00	-7.14	-6.37	-10.10	-11.87		
12-Oct-00			-10.07			
13-Oct-00	-7.16	-6.33		-11.84		
10-Nov-00	-7.01	-6.21	-10.03	-11.71		
15-Nov-00			-10.01			
24-Nov-00			-10.04			
01-Dec-00			-10.06			
12-Dec-00	-7.07	-6.43	-10.09	-11.69		
15-Jan-01	-7.27	-6.63	-10.20	-11.86		
14-Feb-01	-7.39	-6.75	-10.28	-12.00	-12.83	
15-Mar-01	-7.49	-6.87	-10.37	-12.09		
18-Apr-01	-7.60	-7.02	-10.39	-12.08		
17-May-01	-7.70	-7.04	-10.43	-12.23		
15-Jun-01	-6.97	-5.91	-9.77	-11.93		
17-Jul-01	-6.54	-5.63	-9.61	-11.36		
13-Aug-01	-6.56	-5.59	-9.72	-11.25		
13-Sep-01	-6.44	-5.55	-9.69	-11.15		
19-Oct-01	-6.52	-5.77	-9.79	-11.21		
13-Nov-01	-6.64	-5.97	-9.90	-11.32		
08-Nov-01					-11.99	
06-Dec-01	-6.75	-6.07	-9.95	-11.42		
14-Dec-01					-12.15	
27-Dec-01					-12.18	
17-Jan-02	-6.93	-6.33	-10.08	-11.58	-12.28	
08-Feb-02					-12.42	
18-Feb-02	-7.13	-6.59	-10.21	-11.76		
21-Feb-02					-12.50	
06-Mar-02					-12.60	
19-Mar-02					-12.70	
21-Mar-02	-7.34	-6.81	-10.32	-11.91		
18-Apr-02	-7.52	-7.00	-10.41	-12.08	-12.93	
02-May-02					-13.03	
20-May-02					-12.90	

Date	F46/0185	F46/0190	F46/0192	F46/0193	F46/0250	F46/0708
22-May-02	-7.40	-6.62	-10.30	-12.10		
06-Jun-02					-12.55	
12-Jun-02	-6.73	-5.76	-9.72	-11.60		
28-Jun-02					-11.79	
12-Jul-02					-11.57	
17-Jul-02	-6.17	-5.29	-9.50	-10.90		
23-Jul-02					-11.39	
09-Aug-02					-11.33	
28-Aug-02	-6.22	-5.42	-9.64	-10.81		
04-Sep-02					-11.41	
12-Sep-02					-11.45	
25-Sep-02	-6.13	-5.28	-9.62	-10.84		
15-Oct-02	-6.04	-4.82	-9.38	-10.75		
18-Oct-02					-11.34	
30-Oct-02					-11.30	
15-Nov-02					-11.26	
22-Nov-02	-5.60	-4.56	-9.31	-10.53		
05-Dec-02	-5.54	-4.83	-9.31	-10.46		
18-Dec-02					-11.15	
08-Jan-03					-11.28	
14-Jan-03	-5.89	-5.30	-9.57	-10.73		
29-Jan-03					-11.44	
14-Feb-03	-6.04	-5.68	-9.76	-10.95		
20-Mar-03	-6.33	-6.02	-9.97	-11.22		
21-Mar-03					-11.87	
14-Apr-03	-6.51	-6.28	-10.08	-11.39		
06-May-03					-12.24	
20-May-03	-6.87	-6.54	-10.24	-11.63		
19-Jun-03	-6.67	-6.14	-10.12	-11.71		
01-Jul-03					-12.36	
17-Jul-03	-6.46	-5.51	-10.00	-11.44		
24-Jul-03					-11.82	
06-Aug-03					-11.62	
14-Aug-03	-6.03	-5.45	-9.55	-10.92		
27-Aug-03					-11.52	
17-Sep-03	-6.31	-5.57	-9.77	-10.91		
22-Oct-03	-6.22	-5.58	-9.81	-11.04		
04-Nov-03					-11.76	

Date	F46/0185	F46/0190	F46/0192	F46/0193	F46/0250	F46/0708
11-Nov-03	-6.28	-5.76	-9.84	-11.10		
18-Nov-03					-11.85	
27-Nov-03					-11.90	
10-Dec-03	-6.91	-6.06	-9.98	-11.31		
12-Dec-03					-12.02	
20-Jan-04	-7.00	-6.43	-10.16	-11.53		
05-Feb-04					-12.51	
17-Feb-04					-12.60	
19-Feb-04	-7.10	-6.71	-10.29	-11.76		
01-Mar-04					-12.71	
18-Mar-04	-7.19	-6.83	-10.25	-11.86		
05-Apr-04					-12.96	
15-Apr-04	-7.51	-6.95	-10.52	-12.05		
04-May-04					-12.82	
20-May-04	-6.91	-5.95	-9.90	-11.53		
01-Jun-04					-12.36	
24-Jun-04	-6.46	-5.51	-9.68	-11.21		
07-Jul-04					-11.86	
27-Jul-04	-6.18	-5.36	-9.62	-10.88		
05-Aug-04					-11.57	
24-Aug-04	-6.22	-5.01	-9.51	-10.89		
02-Sep-04					-11.44	
13-Sep-04	-5.83	-4.88	-9.35	-10.47		
06-Oct-04					-11.23	
20-Oct-04	-6.01	-4.98	-9.51	-10.48		
03-Nov-04					-11.17	
25-Nov-04	-5.97	-5.51	-9.72	-10.66		
07-Dec-04					-11.45	
08-Dec-04					-11.44	
15-Dec-04	-6.26	-5.62	-9.78	-10.82		
12-Jan-05					-11.21	
25-Jan-05	-5.58	-4.80	-9.21	-10.14		
03-Feb-05					-10.89	
23-Feb-05	-5.63			-10.39		
03-Mar-05					-11.07	
23-Mar-05	-6.10	-5.60	-9.77	-10.66		
07-Apr-05					-11.41	
19-Apr-05	-6.44	-5.84	-9.93	-10.90		

Date	F46/0185	F46/0190	F46/0192	F46/0193	F46/0250	F46/0708
05-May-05					-11.66	
27-May-05	-6.25	-5.62	-9.93	-11.09		
10-Jun-05					-11.60	
20-Jun-05	-5.75	-5.05	-9.51	-10.58		
05-Jul-05					-11.12	
20-Jul-05	-5.45	-4.34	-9.29	-10.17		
04-Aug-05					-10.56	
23-Aug-05	-5.47	-4.81	-9.37	-10.16		
09-Sep-05					-10.67	
29-Sep-05	-5.63	-5.21	-9.62			
05-Oct-05					-10.88	
26-Oct-05	-5.84	-5.48	-9.72	-10.63		
04-Nov-05					-11.16	
21-Nov-05	-6.34	-5.73	-9.86	-10.80		
07-Dec-05					-11.45	
12-Dec-05	-6.47	-5.94	-9.94	-10.94		
05-Jan-06					-11.72	
26-Jan-06	-5.94	-5.07	-9.51	-10.70		
01-Feb-06					-11.23	
23-Feb-06	-5.92	-5.43	-9.60	-10.62		
09-Mar-06					-11.34	
21-Mar-06	-5.50					
23-Mar-06		-5.69	-9.70	-10.83		
31-Mar-06					-11.38	
26-Apr-06	-6.03	-5.66	-9.76	-10.84		
02-May-06					-11.50	
22-May-06	-6.25	-5.82	-9.86	-10.99		
02-Jun-06					-11.72	
27-Jun-06	-6.25	-5.32	-9.75	-11.15		
03-Jul-06					-11.73	
24-Jul-06	-5.85	-5.05	-9.43	-10.84		
04-Aug-06					-11.46	
22-Aug-06	-6.34	-4.93	-10.00	-10.78		
01-Sep-06					-11.32	
06-Sep-06					-11.30	
12-Sep-06	-5.95					
18-Sep-06		-5.14	-9.51	-10.68		
05-Oct-06					-11.36	

Date	F46/0185	F46/0190	F46/0192	F46/0193	F46/0250	F46/0708
17-Oct-06	-6.14	-5.31	-9.64	-10.82		
03-Nov-06					-11.49	
21-Nov-06	-6.12	-5.65	-9.79	-10.98	-11.60	
15-Dec-06					-11.75	
18-Dec-06		-5.59	-9.84	-11.11		
24-Jan-07	-6.57	-5.80		-11.13	-11.89	
08-Feb-07					-12.17	
26-Feb-07	-6.41	-6.07	-9.99	-11.35	-11.99	
29-Mar-07				-11.39	-12.24	
02-Apr-07		-6.36	-10.11	-11.41		
05-Apr-07	-6.68		-10.13			
23-Apr-07	-6.91	-6.47	-10.18	-11.53	-12.37	
22-May-07	-7.14	-6.64	-10.26	-11.67	-12.56	
28-Jun-07	-6.97	-5.99	-9.98	-11.38	-12.36	
24-Jul-07	-6.26	-5.60	-9.64	-10.80	-11.57	
23-Aug-07	-6.41	-5.57	-9.73	-10.84	-11.54	
11-Sep-07	-6.41			-10.91		
18-Sep-07		-5.53	-9.74	-10.40	-11.62	
25-Oct-07	-6.55	-5.61	-9.76	-10.77	-11.67	
20-Nov-07	-6.26	-5.56	-9.74	-10.95		
22-Nov-07					-11.55	
18-Dec-07	-6.50	-5.85	-9.86	-11.18	-11.69	-11.01
17-Jan-08	-6.57	-6.14	-10.01	-11.39	-11.95	
30-Jan-08					-12.10	
07-Feb-08					-12.15	
08-Feb-08					-12.17	
12-Feb-08					-12.24	
13-Feb-08	-7.20		-10.29	-11.82		
04-Mar-08						-12.32
13-Mar-08	-7.19	-6.20	-10.31	-11.81	-12.53	
17-Mar-08			-10.40			-12.53
04-Apr-08						-11.60
14-Apr-08					-12.78	
15-Apr-08	-7.43	-6.87	-10.46			
12-May-08	-7.55	-7.04	-10.50	-11.97	-12.98	-10.90
16-Jun-08	-7.64	-7.15		-12.13	-13.20	-10.57
02-Jul-08	-7.58					
14-Jul-08	-7.48		-10.42	-12.01	-13.10	-10.26

Date	F46/0185	F46/0190	F46/0192	F46/0193	F46/0250	F46/0708
24-Jul-08	-7.42	-6.71	-10.38	-11.91		
08-Aug-08			-10.10			-9.36
20-Aug-08	-7.33	-6.30	-9.98	-11.72	-12.67	-9.25
03-Sep-08			-9.96			
09-Sep-08	-6.73	-6.03		-11.37	-12.26	-9.44
15-Oct-08			-9.79	-11.12	-12.01	
23-Oct-08			-9.84			
10-Nov-08	-6.66	-5.86	-9.84	-11.10	-11.94	-9.81
19-Nov-08			-9.85			
08-Dec-08	-6.79					
15-Dec-08	-6.63	-5.98	-9.95	-11.22	-12.06	-10.25
19-Dec-08			-9.85			-10.64
09-Jan-09			-10.02			
15-Jan-09	-7.05	-6.22	-9.84	-11.39	-12.28	-11.08
10-Feb-09	-7.10	-6.45	-10.15	-11.56	-12.50	
10-Mar-09	-7.50			-11.85		-11.28
16-Mar-09	-7.49	-6.68	-10.09	-11.84		
25-Mar-09			-10.32			-11.40
03-Apr-09					-12.94	
17-Apr-09		-6.84	-10.37	-11.97	-13.02	-10.08
21-Apr-09			-10.38			
14-May-09	-7.89	-6.93	-10.36	-12.08	-13.14	
10-Jun-09	-7.10	-6.73	-9.70	-11.76	-12.84	
22-Jun-09	-6.91					-9.32
07-Jul-09			-9.65			
23-Jul-09	-6.75	-5.92	-9.84	-11.41	-12.32	
18-Aug-09	-6.55	-5.22	-9.56	-11.07	-11.97	
04-Sep-09	-6.47					
08-Sep-09		-5.34				-9.63
10-Sep-09			-9.39			-10.04
22-Sep-09				-11.13		
24-Sep-09					-11.86	
23-Oct-09	-6.46	-5.66	-9.59	-11.16	-12.08	
17-Nov-09	-6.60	-5.89		-11.31	-12.25	
19-Nov-09			-9.72			
10-Dec-09	-6.80					
18-Dec-09		-6.08	-10.03	-11.51	-12.51	
22-Dec-09			-10.05			

Date	F46/0185	F46/0190	F46/0192	F46/0193	F46/0250	F46/0708
19-Jan-10	-7.16	-5.80	-9.70	-11.70	-12.75	
15-Feb-10	-7.34	-5.84	-9.87	-11.63	-12.83	
17-Mar-10	-6.89					
18-Mar-10	-6.88	-6.14	-10.03	-11.72	-12.88	-10.18
26-Mar-10	-7.49					
19-Apr-10	-7.14	-6.35	-10.14	-11.87	-13.01	-10.04
27-May-10	-7.53	-5.97	-9.71	-11.62	-12.73	
21-Jun-10	-6.75					
01-Jul-10			-9.64	-11.51	-12.49	
21-Jul-10			-9.83		-12.20	
28-Jul-10	-6.71	-5.82		-11.26		

Appendix 2: Groundwater Level Statistics

Groundwater level statistics for Environment Southland's monitoring sites in the Edendale groundwater zone (in metres below top of casing)

Site	Record Start	Monitoring Frequency	Collar Elevation (m msl*)	Min Reading	Max Reading	Median Level	Range (m)
F46/0185	Aug-95	Monthly	35.33	-7.89 (May 09)	-4.98 (Nov 95)	-6.50	2.91
F46/0190	Aug 95	Monthly	31.45	-7.15 (Jun 08)	-4.15 (Sep 95)	-5.79	3.00
F46/0192	Mar-96	Monthly	28.05	-10.52 (Apr 04)	-9.10 (Aug 97)	-9.85	1.42
F46/0193	Aug-95	Monthly	43.85	-12.23 (May 01)	-9.80 (Oct 95)	-11.15	2.43
F46/0250	Oct-01	30 minutes	46.84	-13.17 (Jun 08)	-10.57 (Aug 05)	-11.95	2.60
F46/0708	Mar-08	Monthly	46.35	-12.53 (May 08)	-9.25 (Oct 08)	-10.25	3.27

*Metres above mean sea level using Bluff 1949 datum (source: piezometric surveying data April 2007)

Appendix 3: Spring Gauging Data

Date	Flow (l/s)				
Ota Creek					
	Glencoe - Brydone Hwy	**Edendale – Mataura Hwy**	**Coal Pit Quarry**	**Coal Pit Road**	
02-Feb-81	0				
28-Aug-81	27				
12-Mar-01		18			
12-Jan-07		85			
26-Feb-07	6	28	47	125	
25-Mar-09				63	
21-Apr-09				27	
07-Dec-09				23	
Clear Creek					
	Settlement Stalker Road	**Mataura Island Road**	**Oteramika Creek Confluence**		
07-Sep-95		376	416		
11-Dec-95		326	393		
22-Mar-96		292	314		
11-Jun-96		304	373		
13-Sep-96		376	283		
17-Dec-96		278			
17-Mar-97		255	294		
16-Jun-97		321	370		
08-Sep-97		387	429		
08-Dec-97		337	377		
16-Mar-98		338	376		
08-Jun-98		316	359		
19-Feb-02		262			
21-Mar-02		244			
22-Apr-02		232			
22-Aug-02		275			
17-Jan-03		364			
13-Mar-03		307			
16-Apr-03		258			
24-Jul-03		332			
26-Aug-03		459			
20-Oct-03		297			
27-Sep-04		368			
22-Oct-04		361			

Date	Flow (l/s)				
Clear Creek					
	Settlement Stalker Road	**Mataura Island Road**	**Oteramika Creek Confluence**		
14-Dec-04		349			
01-Mar-05		359			
06-Apr-05		371			
23-Jun-05		377			
18-Oct-05		365			
30-Jan-06		346			
27-Feb-06		325			
04-May-06		315			
22-Jun-06		331			
24-Aug-06		382			
26-Oct-06	47	324			
27-Nov-06	35	305			
23-Jan-07	35	354			
27-Jul-07	45	396			
30-Oct-07	43	311			
17-Mar-08	13	302			
28-May-08	8	240			
08-Aug-08	15	273			
03-Sep-08	14	341			
02-Oct-08	25	322			
11-Nov-08		357			
19-Nov-08	29	302			
09-Jan-09	18	289			
25-Mar-09	11	231			
21-Apr-09	9	274			
22-May-09	10	335			
08-Jul-09	22	327			
10-Sep-09	33	390			
22-Oct-09	33	356			
19-Nov-09	38	338			
22-Dec-09	37	311			
18-Jan-10	12	341			
28-Jan-10	38	322			
04-May-10		301			

Date	Flow (l/s)				
Ives Creek & Unnamed Spring					
	Downstream of Quarry	**Island – Edendale Road**		**Spring at Shield Road**	
07-Sep-95	242			45	
11-Dec-95	167	299		46	
23-Jan-96	8				
22-Mar-96	181	262		32	
11-Jun-96	218			40	
13-Sep-96	180	273		36	
17-Dec-96	148	298		29	
17-Mar-97	147	224		32	
16-Jun-97	205	283		33	
08-Sep-97	262	365			
08-Dec-97	203	292		40	
16-Mar-98		268		39	
08-Jun-98		275		31	
08-Feb-01		207			
19-Feb-02		212		20	
21-Mar-02		191		21	
22-Apr-02		166		22	
22-Aug-02		306		40	
17-Jan-03		269		36	
13-Mar-03		312		31	
16-Apr-03		214		26	
24-Jul-03		283		40	
26-Aug-03		295		48	
20-Oct-03		244		38	
27-Sep-04		338		51	
22-Oct-04		336		68	
14-Dec-04				45	
01-Mar-05		330		44	
23-Jun-05		323		38	
18-Oct-05		339		40	
25-Nov-05		270		41	
16-Dec-05		250		35	
30-Jan-06		291		27	
27-Feb-06		280		29	
04-May-06		298		70	

Date	Flow (l/s)				
Ives Creek & Unnamed Spring					
	Downstream of Quarry	**Island – Edendale Road**		**Spring at Shield Road**	
22-Jun-06		393		39	
24-Aug-06		378		44	
26-Oct-06		305		27	
27-Nov-06		266		30	
23-Jan-07		282		35	
13-Nov-08		306		40	
25-Mar-09		187		16	
21-Apr-09		211		17	
Oteramika Creek					
	Hilda Road	**Edendale Bridge**	**Tramway Road**	**Seaward Downs**	**McCall Road**
30-Aug-54				245	
14-Jun-72					162
22-Jun-72					89
21-Apr-80		23			
21-Apr-80		10			
02-Feb-81		0			
28-Aug-81		39			
19-Sep-95	69	84	201		1003
17-Oct-95	152	229	639		1651
21-Nov-95	24	33	58		696
19-Dec-95	54	85	155	197	860
23-Jan-96	38	8	55	92	564
02-Feb-96				88	
09-Feb-96				34	
20-Feb-96		9	25	26	564
19-Mar-96	2	2	24	33	450
01-Apr-96				20	
16-Apr-96	5	10	26	38	475
14-May-96	49	73	171	205	651
15-May-96				186	
16-May-96				1705	
17-May-96				1334	
20-May-96				293	
23-May-96				202	
04-Jun-96				758	
10-Jun-96	723	883			3376

Date	Flow (l/s)				
Oteramika Creek					
	Hilda Road	**Edendale Bridge**	**Tramway Road**	**Seaward Downs**	**McCall Road**
16-Jul-96		379	846	1054	
31-Jul-96				354	
07-Aug-96				227	
13-Aug-96	55	77	170	254	849
29-Aug-96				1224	
10-Sep-96	34	46	121	181	680
25-Sep-96				52	
02-Oct-96				52	
16-Oct-96				687	
18-Oct-96				359	
21-Oct-96				156	
22-Oct-96	690	885	1315	1758	2252
24-Oct-96				406	
08-Nov-96				75	
12-Nov-96	46	53	87	105	635
12-Nov-96				147	
14-Nov-96				80	
14-Nov-96				80	
18-Nov-96				88	
22-Nov-96				1056	
28-Nov-96				951	
03-Dec-96				208	
10-Dec-96	16	22	53	83	561
18-Dec-96				47	
06-Jan-97				33	
14-Jan-97	84	151	326	462	
03-Feb-97				23	
11-Feb-97	179	70		173	717
03-Mar-97				67	
18-Mar-97	13	23	68	98	504
21-Mar-97				229	
15-Apr-97	174	290	290	969	1700
13-May-97	24	36		146	646
17-Jun-97	46	54	54	247	811
15-Jul-97		153	153	585	1253
12-Aug-97		79	79	284	983

Date	Flow (l/s)				
Oteramika Creek					
	Hilda Road	**Edendale Bridge**	**Tramway Road**	**Seaward Downs**	**McCall Road**
09-Sep-97		35	35	141	777
12-Sep-97				179	
29-Sep-97				108	
14-Oct-97		25	25	98	
30-Oct-97		15	15	59	
11-Nov-97		122	122	376	966
26-Nov-97				808	
03-Dec-97				2042	
09-Dec-97		57	57	282	777
07-Jan-98				122	
13-Jan-98		25	25	79	603
23-Jan-98				24	
02-Feb-98				8	
10-Feb-98		13	14	75	589
17-Feb-98				15	
26-Feb-98				63	
17-Mar-98		69	69	244	754
15-Apr-98		37	24		637
27-Apr-98				116	
29-Apr-98				276	
30-Apr-98				239	
12-May-98		63	63	269	813
09-Jun-98				1317	
25-Jun-98				592	
03-Sep-98				398	
30-Sep-98				445	
02-Nov-98				176	
01-Dec-98				23	
22-Dec-98				1438	
29-Jan-99				1406	
29-Jan-99				8	
03-Feb-99				14	
25-Mar-99				40	
25-Mar-99				60	
20-Apr-99				144	
14-May-99				22	

Date	Flow (l/s)				
Oteramika Creek					
	Hilda Road	**Edendale Bridge**	**Tramway Road**	**Seaward Downs**	**McCall Road**
21-May-99				119	
01-Jun-99				261	
22-Jun-99				504	
01-Jul-99				218	
15-Jul-99				585	
05-Aug-99				148	
31-Aug-99				841	
16-Sep-99				115	
22-Sep-99				155	
06-Oct-99				280	
03-Nov-99				222	
18-Nov-99				10318	
01-Dec-99				87	
05-Jan-00				89	
01-Feb-00				341	
23-Mar-00				24	
03-May-00				58	
30-May-00				168	
06-Jul-00				141	
03-Aug-00				518	
28-Aug-00				175	
30-Oct-00				78	
01-Dec-00				116	
30-Jan-01				177	
08-Feb-01					454
23-Feb-01				38	
20-Mar-01				10	
05-Jul-01				263	
05-Sep-01				160	
02-Oct-01				211	
02-Nov-01				110	
07-Feb-02				44	
05-Mar-02				52	
24-Jul-02				278	
31-Jul-02				156	
04-Oct-02				1876	

Date	Flow (l/s)				
Oteramika Creek					
	Hilda Road	**Edendale Bridge**	**Tramway Road**	**Seaward Downs**	**McCall Road**
02-Dec-02				108	
27-Feb-03				29	
03-Apr-03				15	
11-Nov-08		80		328	677
25-Mar-09		33		135	553
21-Apr-09		17		39	384
21-May-09		505		1230	1937
Oteramika Creek Tributaries					
	Edendale	**Tramway Road**			
13/Jan/77	143				
19/Sep/95		108			
17/Oct/95		297			
21/Nov/95		27			
19/Dec/95		41			
23/Jan/96		145			
20/Feb/96		11			
19/Mar/96		6			
16/Apr/96		10			
14/May/96		61			
10/Jun/96		524			
16/Jul/96		193			
13/Aug/96		70			
10/Sep/96		64			
22/Oct/96		404			
12/Nov/96		49			
10/Dec/96		31			
14/Jan/97		74			
11/Feb/97		77			
18/Mar/97		63			
15/Apr/97		284			
13/May/97		68			
17/Jun/97		78			

Appendix 4: Stream Flow Specific Yield

Catchment area calculated using ArcGIS.

Site	Area (ha)	Median Gauged Flow (l/s)	Specific Yield (l/s/km^2)
Oteramika Creek			
Hilda Road	886	48	5
Edendale Bridge	1,791	50	3
Tramway Road	3,696	68	2
Tributary at Tramway Rd	202	69	34
Seaward Downs	5,701	164	3
McCall Road	5,813	680	12
Ives Creek			
Downstream of Quarry	136	192	141
Island – Edendale Rd	302	283	9
Clear Creek			
Settlement Stalker Rd	7.2	27	378
Mataura Island Rd	63	326	515
Oteramika Creek confluence	140	373	267
Other Streams			
Spring at Shield Rd	101	37	37
Ota Ck at Coal Pit Rd	2,100	63	2

Appendix 5: Water Use Data

(yellow)	No consent or no consent condition requiring data
(red)	Data not provided

Consent Number	Use	Allocation	Volume Used (m³/yr)									
		(m³/yr)	2009/10	2008/09	2007/08	2006/07	2005/06	2004/05	2003/04	2002/03	2001/02	2000/01
93773	Industry	3,095,200	1,013,865	1,172,191	882,007	888,606	898,328	911,727	983,480	956,936	1,278,950	1,440,302
93433	Nursery	120,000									18,582	
98300	Industry	876,000	851,537	871,463	896,360	890,307	834,639	800,275	708,303	324,484	270,851	
20000	Municipal	8.760		20,059		41,675						
200169	Dairy	51,100										
200568	Dairy	43,800							31,672	23,976		
200722	Dairy	15,768					15,664	14,183	8,322	13,161	12,638	
200809	Dairy	23,652								14,617		
200882	Dairy	10,220						9,344	8,655	9,441		
201196	Dairy	15,242		13,911	11,518	10,887	10,429			11,319		
201355	Dairy	35,040							28,102			
201365	Dairy	14,308					16,644		17,394	15,768		
201435	Dairy	20,440								11,062		
4201450	Dairy	40,880				28,616		29,061	29,946	35,144		
201499	Dairy	24,528						876	13,828	9,121		
201556	Dairy	61,320										

Consent Number	Use	Allocation	Volume Used (m^3/yr)									
		(m^3/yr)	2009/10	2008/09	2007/08	2006/07	2005/06	2004/05	2003/04	2002/03	2001/02	2000/01
201583	Dairy	*17,520*	*12,080*	*14,994*	*14,994*	*5,714*	*7,008*	*4,934*	*11,158*			
201602	Dairy	*16,352*	*8,226*	*6,757*	*13,704*	*6,529*	*7,613*	*5,172*				
201719	Irrigation	120,000	8,664	8,750	23,085		9,804	13,623	15,390			
201767	Dairy	*6,541*										
202203	Dairy	*31,828*										
202238	Dairy	*14,308*										
202249	Dairy	*23,360*	14,672	*14,355*	18,014	17,340	13,962	*7,699*				
202278	Irrigation	86,400	9,660			7,920	12,935	17,983				
202413	Dairy	*14,600*	*15,777*									
202516	Dairy	*18,396*	11,812	10,360								
202653	Dairy	*28,616*										
202726	Dairy	*18,396*	10,305	*11,199*	*4,990*	8,534		*4,880*				
202775	Dairy	*14,308*	19,770	19,853	18,547	17,687	10,309	*9,876*				
203135	Irrigation	49,500	7,741			2,596	13,450					
203281	Irrigation	61,250	1,021	53,580								
203290	Dairy	*49,500*	14,710	21,326								
203862	Dairy	*46,720*										
203906	Dairy	*17,520*										
204096	Dairy	*21,900*	35,519									

204143	Irrigation	85,500	32,020	55,000	22,912							
Consent Number	**Use**	**Allocation**	**Volume Used (m³/yr)**									
		(m³/yr)	**2009/10**	**2008/09**	**2007/08**	**2006/07**	**2005/06**	**2004/05**	**2003/04**	**2002/03**	**2001/02**	**2000/01**
204256	Dairy	*49,056*	19,427	38,694	22,488	*17,479*						
204333	Dairy	*15,534*	11,862	*9,481*	11,038							
204743	Dairy	*21,024*	15,817	9,954	332							
204997	Dairy	*20,989*	10,948	11,212								
205174	Dairy	*45,552*										
206238	Dairy	*18,221*	620									
206951	Municipal	400,000	0									
207022	Irrigation	75,000	4,360									
207023	Irrigation	75,000	0									
TOTAL:			**2,130,413**	**2,363,139**	**1,939,989**	**1,943,890**	**1,850,785**	**1,829,633**	**1,856,250**	**1,425,029**	**1,310,170**	**1,440,302**

Italicised means the value has been estimated*.* *Where no seasonal allocation limit has been set in a consent condition, it has been estimated by multiplying the maximum daily take by 80% over a calendar year except for 93433 which was multiplied by 60 days. Water take annual volumes for italicised dairy consents have been estimated by taking the average of daily readings over a 2 week period multiplied by 290 days. All water use data has been provided by the consent holder and not checks or audits have been made by ES.*

Appendix 6: Chloride Results

Analysis using Daughney (2007) with a Mann-Kendall trend confidence interval of 0.05

Bore ID	Data Period	Number of samples	Min	Median	Max	Trend	Rate (%/yr)
F46/0185	2000 - 2010	50	24	49	75	▲	**5.3**
F46/0190	1995 - 1998	12	25	27	28	No trend	
F46/0194	1996 - 2010	52	17	19	25	▲	2.8
F46/0195	2000 - 2010	38	18	25	30	No trend	
F46/0244	2005 - 2009	20	33	59	90	▼	**-16.4**
F46/0246	1996 - 2009	31	24	44	120	▼	**-19.3**
F46/0249	1996 - 2009	20	3	40	66	▼	**-22.2**
F46/0323	2006 - 2009	17	19	23	25	▼	**-5.8**
F46/0325	2006 - 2009	16	17	24	37	▼	-2.2
F46/0328	2006 - 2009	18	30	34	39	▼	-4.7
F46/0333	2006 - 2009	16	9	29	38	No trend	
F46/0335	1996 - 2009	35	17	28	36	▲	2.1
F46/0336	1996 - 2009	33	36	73	206	▼	**-26.1**
F46/0337	2005 - 2009	18	39	49	63	▼	**-11.6**
F46/0340	1996 - 2009	36	18	23	56	▼	-1.2
F46/0344	1996 - 2009	30	6	61	178	▼	**-24.9**
F46/0651	2006 - 2009	16	20	46	56	▼	**-12.1**
F46/0652	2005 - 2009	15	24	60	84	▼	**-11.8**
F46/0709	2000 - 2009	43	26	103	123	▼	**-6.4**
F46/0710	2000 - 2009	75	15	41	257	▼	**-8.1**
F46/0711	2000 - 2009	43	22	52	60	▲	0.8
F46/0712	2000 - 2009	43	26	41	49	▲	3.0
F46/0713	2000 - 2009	38	7	41	49	▲	2.1
F46/0714	2003 - 2009	24	10	37	45	▼	-0.8
F46/0715	2002 - 2009	29	16	36	70	No trend	
F46/0748	2007 - 2009	9	27	58	65	▲	1.1
F46/0749	2007 - 2009	9	16	34	39	▲	**5.5**
F46/0750	2007 - 2009	8	23	27	28	▲	1.4
F46/0751	2008 - 2009	8	47	56	64	▲	2.5
F46/0758	2000 - 2009	42	7	18	21	▼	-2.0
F46/0797	2001 - 2009	14	37	125	178	▼	**-12.0**

Appendix 7: Nitrate-N Results

Analysis using Daughney (2007) with a Mann-Kendall trend confidence interval of 0.05.

Bore ID	Data Period	Number of samples	Min	Median	Max	Trend	Rate (%/yr)
F46/0185	2000 - 2010	51	4.8	6.6	9.9	▲	4.0
F46/0190	1995 - 1998	14	4.4	5.1	8.3	▲	2.2
F46/0194	1996 - 2010	54	4.9	6.0	8.7	▲	2.5
F46/0195	2000 - 2010	38	0.8	1.2	2.7	No trend	
F46/0244	2005 - 2009	20	5.2	9.6	12.0	▼	**-11.9**
F46/0246	1996 - 2009	30	5.3	10.5	12.0	▼	-0.4
F46/0249	1996 - 2009	19	5.1	9.1	11.7	▲	0.9
F46/0323	2006 - 2009	16	7.7	10.4	14.0	▼	**-14.7**
F46/0325	2006 - 2009	16	4.0	7.6	13.0	▲	0.8
F46/0328	2006 - 2009	17	5.3	7.5	9.4	▼	**-10.0**
F46/0333	2006 - 2009	16	2.4	7.8	10.0	▼	-1.8
F46/0335	1996 - 2009	34	4.1	7.3	9.8	▲	4.1
F46/0336	1996 - 2009	33	5.9	10.2	13.6	▼	-0.8
F46/0337	2005 - 2009	17	6.8	8.8	14.0	▼	**-5.3**
F46/0340	1996 - 2009	34	4.3	9.5	14.0	▼	-2.1
F46/0344	1996 - 2009	29	3.9	10.9	15.0	▲	1.5
F46/0651	2006 - 2009	15	7.0	13.0	23.0	▼	**-25.9**
F46/0652	2005 - 2009	14	3.0	11.0	13.0	No trend	
F46/0709	2000 - 2009	41	5.4	7.8	12.0	▲	**6.5**
F46/0710	2000 - 2009	73	6.4	9.1	13.0	▼	-1.8
F46/0711	2000 - 2009	40	5.5	6.8	18.0	▲	**6.9**
F46/0712	2000 - 2009	41	4.0	7.5	10.0	▼	-0.4
F46/0713	2000 - 2009	36	6.0	7.6	10.0	▼	-0.1
F46/0714	2003 - 2009	21	5.3	8.2	12.0	▲	1.3
F46/0715	2002 - 2009	27	7.2	8.4	16.0	▲	1.2
F46/0748	2007 - 2009	9	5.4	7.5	8.7	▲	3.1
F46/0749	2007 - 2009	9	2.8	6.4	9.1	▲	**6.7**
F46/0750	2007 - 2009	8	4.5	5.5	6.3	▲	0.8
F46/0751	2008 - 2009	7	6.2	7.5	9.0	▲	**12.2**
F46/0758	2000 - 2009	40	9.7	9.4	30.0	▼	-0.2
F46/0797	2001 - 2009	14	6.9	10.1	11.2	▲	0.7