Chapter 25: Southern Springs

Introduction

The Southern Springs is the name given to the area of groundwater and associated springs in the area bounded by New Renwick Road, Middle Renwick Road, the Taylor River and Woodbourne (Fig. 25.1). Previously the area had been described as part of the Wairau Aquifer on the southern boundary with the Southern Valleys catchments. It was defined as a separate aquifer sector in 2005 based on its unique hydrology. Of particular significance is that virtually all groundwater leaves the area via a series of springs. These springs maintain the base flow of the Taylor River upstream of the High Street bridge. The Southern Springs have a naturally lower aquifer storage and a dependence on recharge from the drier Southern Valleys catchments in addition to the Wairau River water.

The flow of Fairhall Co-op Drain, Yelverton Stream, Camerons Creek and the Old Fairhall River is all sourced by groundwater springs. Doctors Creek and Golf Course Creek have a base flow from emergent groundwater but the flow is also supplemented by runoff from hill catchments. All waterways in the Southern Springs area flow into the Taylor River upstream of the High Street bridge.

The Southern Springs area was historically an impenetrable wetland called the Great Fairhall Swamp and its extent is marked on the original proposed settlement survey drawn up by Budge as *"Deep Raupo Swamp"* (Fig. 25.2). Budges map also shows the approximate location of rivers prior to European settlement and drainage and realignment works that have been carried out to allow agricultural development.

Figure 25.2: Historical landcover and river network

From the 1890s onwards a network of channels and tile drains were constructed to drain the wetlands into the Taylor River system. The waterways are now highly modified and consist of deep drainage channels.

The springs exist in part because this is a topographically low-lying area. This was graphically illustrated during the July 2008 flood by the area of ponded water surrounding the Fairhall Co-op Drain and Doctors Creek (Fig. 25.3).

The Southern Springs area is distinct from the springs area between Middle Renwick Road and the Wairau River as hydrogeologically, the Southern Springs area is the eastern extension of groundwater found in the lower yielding Woodbourne, Benmorven and Taylor River area. Aquifer transmissivities in these areas are low compared to the high values characteristic of the Rapaura gravels situated north of Middle Renwick Road.

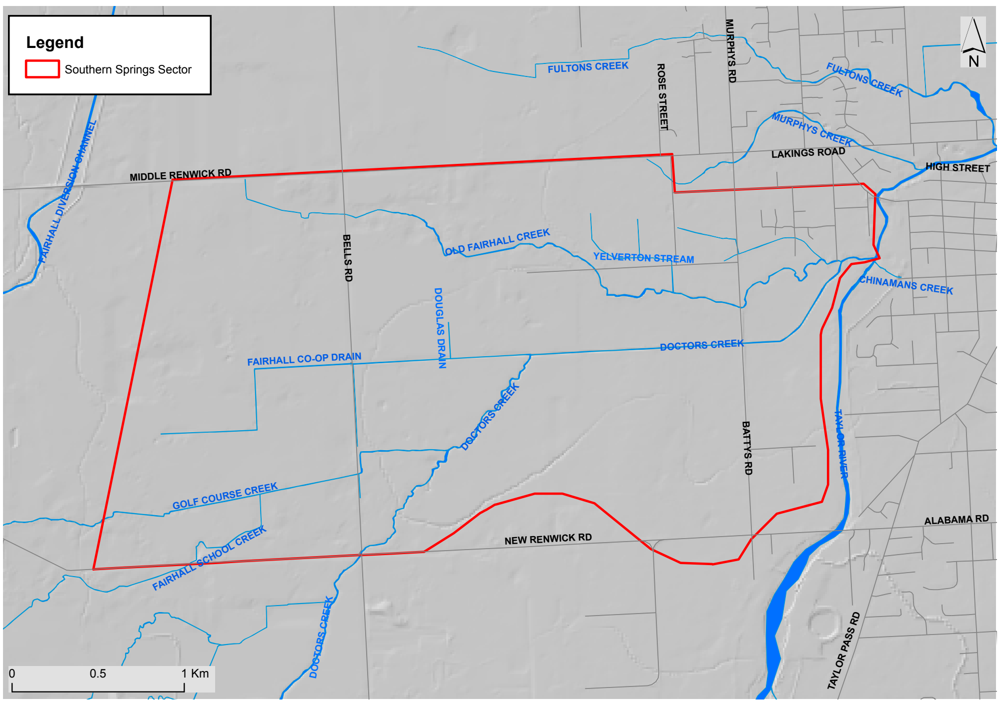

Figure 25.1: Southern Springs boundary.

The Southern Springs area is also unique in that aquifer recharge comes from a variety of catchment sources. The area is a convergence zone for groundwater sourced from the Wairau River, Omaka River Fan, and Southern Valleys catchments. This is an area of seasonal extremes with an excess of water in wetter months and shortages in drier periods.

An important characteristic of the Southern Springs area is the position of spring emergence relative to the confining layer and

Figure 25.3: Doctors Creek catchment looking west from above Battys Road in July 2008

the position of springs fluctuates in accordance with ground water levels throughout the year. For most of the year the seepage face extends west of Bells Road into the unconfined part of the aquifer. However, during summer months, the position of spring emergence approaches the leading edge of the confining layer and spring flow becomes increasingly restricted as groundwater levels fall. This renders springflows vulnerable to depletion when aquifer levels are low during summer months. This phenomenon, combined with low aquifer yields creates an environment that is more sensitive to groundwater abstraction than elsewhere on the Wairau Plain.

Much of what we know about the Southern Springs area was based on investigations by the MDC in 2004 and reported in Gyopari (2005). A combination of fieldwork and modelling represented the most comprehensive assessment of the area and significantly advanced hydrological understanding.

Groundwater systems

The Southern Springs area straddles the boundary between groundwater originating from the Wairau Aquifer and the Southern Valleys Catchments. The boundaries of the Southern Springs area are not marked by clear topographic features. The aquifer on the other hand is defined by distinct changes in characteristics such as recharge source or water chemistry and summer hydraulic properties.

The southern margin is largely based on geology and corresponds with the northern extent of the Speargrass Formation (Brown - 1981). This boundary follows New Renwick Road except for an incursion north of Green Lane. The western margin runs from near Paynters Road to opposite the Fairhall Diversion. This boundary corresponds with the flattening of surface topography at the foot of the Fairhall and Omaka fans and adjoins the Woodbourne Sector. The northern boundary with the Wairau Aquifer follows Middle Renwick Road as far east as the head of the Murphys Creek catchment at Severne Street. The boundary then follows Lakings Road to the Taylor River which forms the eastern boundary.

The geology hosting the Southern Springs groundwater is a mixture of Wairau River and Southern Valleys delta deposits. To date the dominant geological influence in the Southern Springs area has been the Omaka River, which has historically deposited and reworked gravels in a large delta extending eastwards from Hawkesbury Road to the Taylor River.

The Omaka River has a much smaller mean flow than the Wairau River. As a result, the Omaka River has considerably less energy to remove the fines from the gravels. Gravels associated with the Wairau River are cleaner and more transmissive than those of the Southern Springs area.

The hydrogeology of the Southern Springs area is relatively complex (Fig. 25.4). West of Bells Road the aquifer is unconfined and becomes progressively more confined by the thickening of the Dillons Point Formation aquitard

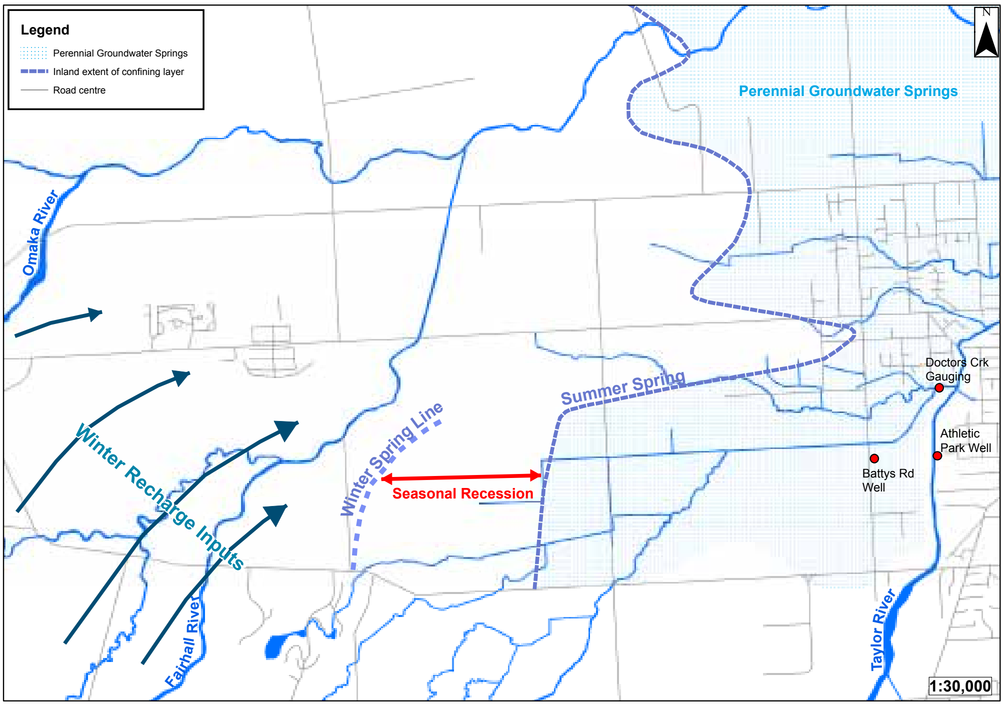

Figure 25.4: Southern Springs confining layer and recharge locations

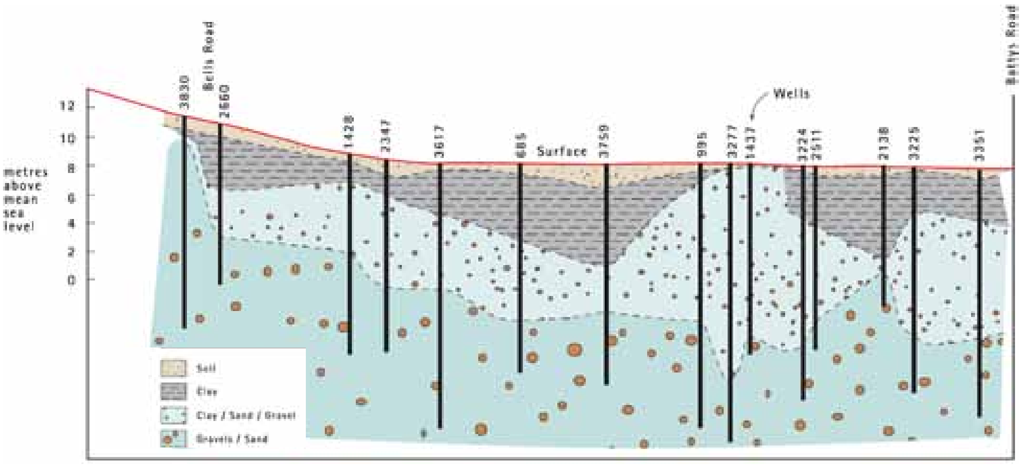

Figure 25.5: West to east geological cross-section along Fairhall Co-op Drain

east of Bells Road. The leading or western edge of the aquitard is composed of terrestrial clays associated with old buried wetlands, while east of Battys Road the dominant aquitard lithology becomes shallow marine sands and silts (Fig. 25.5).

The aquifer becomes pressurised resulting in the emergence of artesian springs in the confined area. These artesian springs are highly sensitive to pumping from the confined aquifer due to the naturally low storage characteristics of the aquifer. Overall, vertical leakage appears to be diffuse rather than as discrete spring emergences.

Geological cross-sections based on an interpretation by PDP (2003) show a thickening of the confining layer east of Bells Road. The upper three units of fine grained material form a confining layer, but are not a complete barrier to vertical groundwater flow to local springs. The base of the wells all penetrate below these layers to access groundwater from the gravels and sand layer. The surface soil layer has been deposited during river floods, or when the area was part of the Great Fairhall Swamp.

An historic channel is known to have eroded into the terrestrial clay aquitard in the vicinity of David Street, and forms the spring source for Murphy's Creek. This paleochannel is evident in bore logs but does not appear to have any effect on aquifer flow in the David Street area.

Recharge and flow patterns

There are a number of sources of recharge to the Southern Springs which creates a highly dynamic water table. Flow is predominantly west to east and is largely controlled by springs. During summer when aquifer levels are low the area receives a larger contribution of groundwater inflows from the Wairau Aquifer to the northwest. It is also likely that the rewatering of Gibson Creek as part of the Southern Valleys irrigation scheme has contributed more recharge since its commissioning in April 2004.

During winter, the predominant recharge direction changes to the south and west as the ephemeral Omaka and Fairhall Streams flow past New Renwick Road. These patterns are shown by the contours of groundwater elevation for an MDC staff survey carried out in March 2004 (Fig. 25.6). Even in late summer, the area south of the Fairhall Co-op Drain relies on recharge from the Southern Valleys Catchments.

Each of the major groundwater fed springs that drain into the Taylor River is manually gauged on a weekly basis by the MDC.

It is not practical for the MDC to maintain a permanent flow recorder in any of the Southern Springs because of the abundant growth of aquatic weed, especially

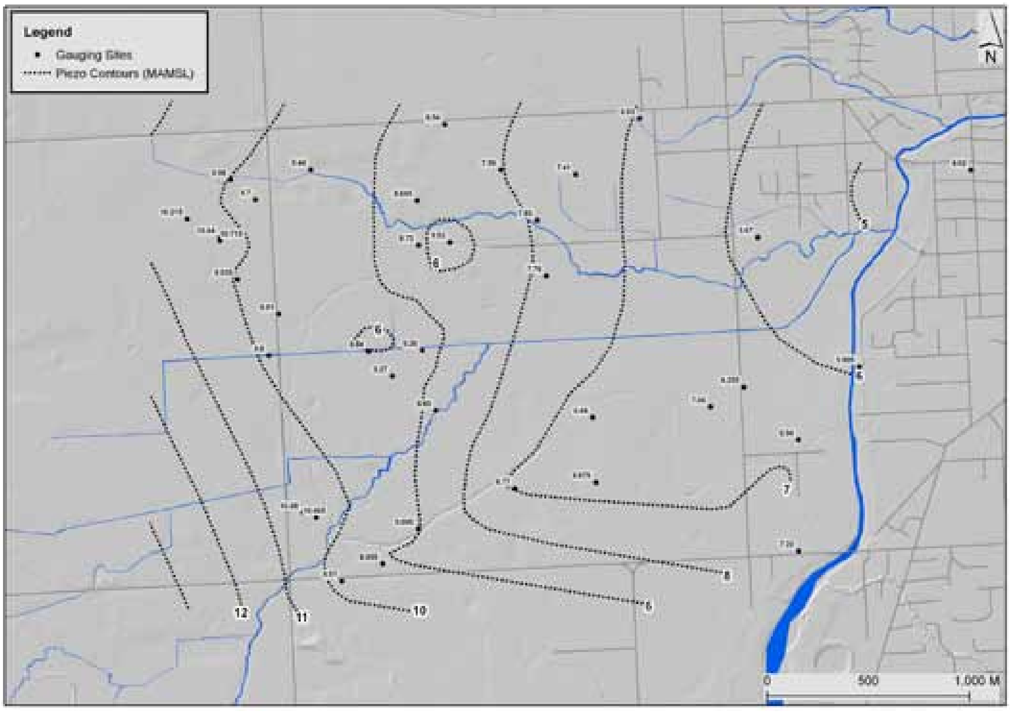

Figure 25.6: Groundwater elevations

Figure 25.7: Fairhall Co-op Drain looking downstream towards Battys Road. The channel is dry until opposite the white drum on the right hand bank, where water is ponding. Actual channel flow doesn't occur until the 3rd power pole in the distance where light can be seen reflecting off the water surface.

over the warmer months. The weed continuously alters the relationship between stage and water flow.

The Doctors Creek catchment is gauged just upstream of the Taylor River confluence. Flow in Doctors Creek at the manual gauging site also represents contributions from the Fairhall Co-op Drain which runs west from Bells Road to Battys Road. The Fairhall Co-op Drain joins Doctors Creek half way between Bells Road and Battys Road. The Fairhall Co-op Drain steadily gains in flow through inputs from agricultural drains and groundwater. Flood flows generated by Doctors Creek originate from runoff in distant areas at Benmorven and its hill catchments to the south.

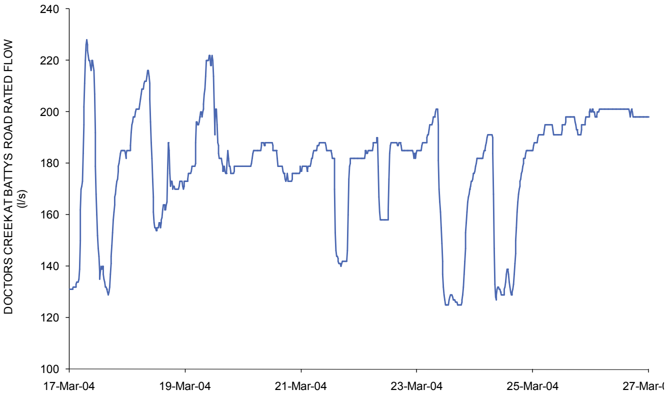

Figure 25.8: Temporary flow record for Doctors Creek

In summer the headwaters of the Fairhall Co-op Drain at Bells Road are typically dry. As the groundwater levels drop the headwaters recede towards the east (Fig. 25.7). While channel flow increases gradually as the groundwater table intercepts the base of the drain, there are rapid increases in flow associated with inputs such as agricultural drains. Douglas Drain is one of the artificial drains that contributes a significant input of flow to the Fairhall Co-op Drain. Changes in gradient or the permeability of the bed materials also influences the rate at which channel flow increases.

In order to determine how pumping from wells affects the flow in the Fairhall Co-op Drain or Doctors Creek, a short period of water level record for the Fairhall Co-op Drain was collected using a temporary electronic level recorder during March 2004 (Fig. 25.8). The sharp changes in level indicate that Fairhall Co-op Drain flow is affected by pumping with estimated flow losses of about 100 l/s, which is equivalent to the natural minimum flow in the spring each year on average.

Aquifer yield decreases to the south away from the Wairau River, which renders the Southern Springs more sensitive to pumping effects. Also, northern areas of the Wairau Plain have a fairly consistent recharge input from the Wairau River throughout the whole year, whereas more southerly areas are dependant on the less reliable runoff from the Southern Valleys Catchments.

In the Southern Springs area, the Southern Valleys ephemeral streams dominate aquifer recharge during winter and advance northwards past the margin of the Wairau Aquifer. This recharge is then drained throughout the summer season via the Doctors Creek system of springs. Doctors Creek has a large catchment area compared to the other springs. This explains the flood flows generated by hill catchment runoff and direct rainfall in the Benmorven area. The other springs do not experience this degree of variability because they are lowland waterways driven primarily by upwelling groundwater.

For Doctors Creek and its tributaries, the most important influences on seasonal flow variability are the status of up-gradient groundwater levels relative to the position of the leading edge of the aquitard. The location of the aquitard in the south is approximately two kilometres west of its position in the centre of the Wairau Plain.

Gauging surveys along the Fairhall Co-op Drain were carried out in summer 2009 and show a steady gain in streamflow downstream (Fig. 25.9). Flow increases dramatically downstream of Battys Road, with over double the flow recorded by the time it reaches the confluence with the Taylor River.

The Southern Springs are recharged by unconfined groundwater seepage in winter or spring, and by vertical leakage of confined groundwater in the drier months (Fig. 25.10). The nature of pressurised upwards leakage is typically diffuse rather than via obvious point-source spring emergences.

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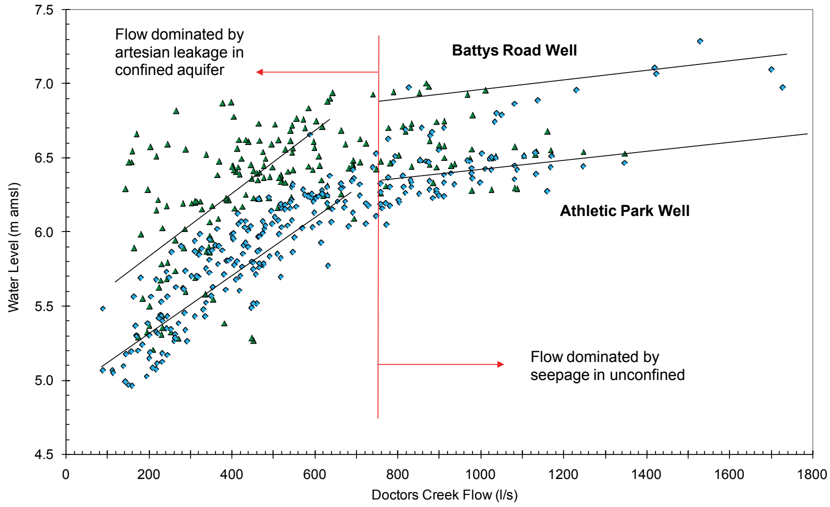

Figure 25.11: Doctors Creek flow at Taylor confluence versus confined aquifer level

Analysis of the relationship between spring flow and aquifer level shows that the relative dominance of these two processes changes throughout the course of the year (Fig. 25.11). A clear change in slope can be seen where the dominant spring recharge process shifts from an unconfined to a confined source of groundwater.

When groundwater levels are high, reductions in spring flow are most sensitive to changes in seasonal unconfined seepage. During periods of low groundwater level, the headwaters of Fairhall Co-op Drain recede eastwards.

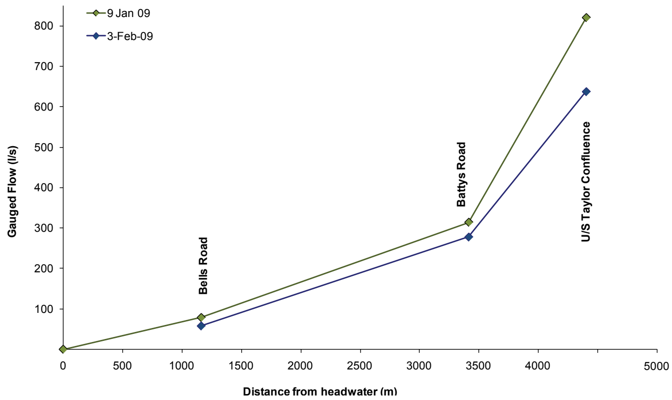

Figure 25.9: Flow gaugings along the Fairhall Co-op Drain

When flow at the Taylor confluence recedes below 550 to 600 l/s, the presence of the confining layer begins to restrict unconfined seepage at the headwaters of the springs. The dominant recharge process then changes to artesian pressure in the leaky confined aquifer.

The headwaters of the Fairhall Co-op Drain spring system receded as far east as Battys Road in autumn 2001 at the height of the summer drought. While there was ponded water at this point, there was very little channel flow.

Abstractions from the unconfined aquifer cause the position of spring headwaters to recede earlier and for longer, but have little effect when flow is below 500 l/s. This is because the unconfined seepage system is effectively disconnected from the springs by the leading edge of the confining layer.

When spring flow at the Taylor River confluence is less than 550 l/s, spring recharge becomes more sensitive to pumping from the leaky confined aquifer (stream depletion). The main reason for this is the reduction in aquifer storage coefficient from about 10^{-1} in the unconfined aquifer to about 10^{-4} in the leaky confined aquifer. Because there is less storage available the drawdown resulting from pumping the same volume of water is greater. As a result, Doctors Creek is highly vulnerable to stream depletion by abstractions from the confined aquifer during periods of low flow.

Groundwater interaction with surfacewater

The reason that pumping wells preferentially source water from the Southern Springs is that surfacewater represents an easier pathway than from groundwater.

The Southern Springs are sensitive to stream depletion mainly because of the low storage and moderate transmissivity of the aquifer which supplies them with water, and the proximity of irrigation wells. The rate of stream depletion from the Southern Spring network if all wells were to pump continuously for a month is predicted to be about 300 l/s (MDC - 2008).

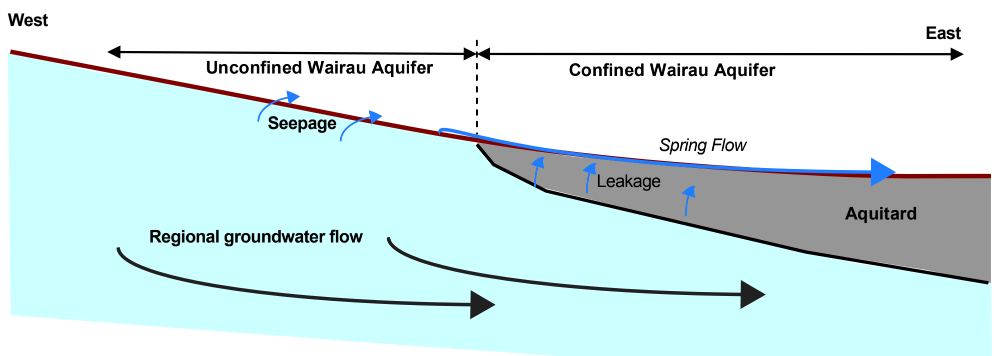

Figure 25.10: Southern Springs schematic section showing two main recharge processes

In order to manage stream depletion restrictions have been applied to some consent holders. The restrictions require the consent holders to reduce their pumping rate when flow at the Taylor River confluence reaches 150 l/s. The reason for managing stream depletion is to maintain aquatic habitat in the Doctors Creek catchment and the upper urban reach of the Taylor River during summer.

Under typical summer conditions the Doctors Creek catchment provides the majority of flow to the Taylor River upstream of the Murphys Creek confluence, and so this reach is very sensitive to pumping in the Southern Springs area.

Groundwater trends

Monitoring shows that the water table of the eastern confined Southern Springs have a smaller seasonal variation than in the unconfined aquifer (Fig. 25.12). The reason for this is that groundwater in the leaky aquifer is always under pressure. The drawdown caused by pumping in this area is clearly apparent during the summer period with well 1384 showing the greatest sensitivity to pumping as this well is closest to the Doctors Creek/Fairhall Co-op Drain area which has a high concentration of wells.

Hydraulic properties

Gravels in the Southern Springs have been deposited by a combination of sources but predominantly the Southern Valleys alluvial fans. These fan sediments are richer in clays than sediments sourced from the Wairau River. This means that the Southern Springs area has distinctly lower transmissivities than those of the high-yielding Wairau Aquifer gravels found north of Middle Renwick Road. Transmissivities are typically less than 2000 m^2/day during summer months when water demand is greatest. Higher values have been reported for the area in the past, but these test results have been largely influenced by stream depletion. Tests need to be analysed for stream depletion effects or they will give misleadingly high transmissivity values.

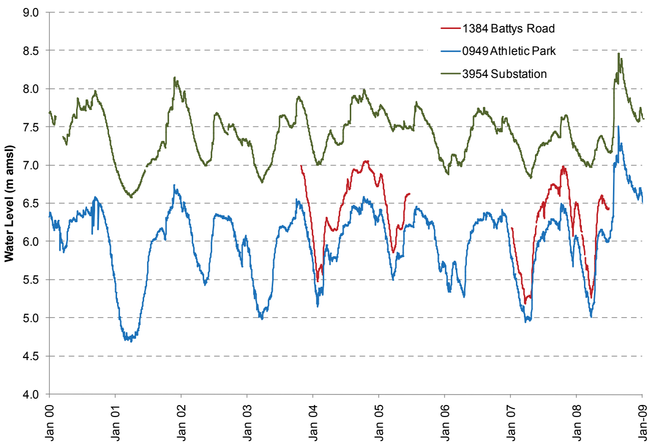

Figure 25.12: Monitoring record for MDC wells

High transmissivities have also been reported from many pumping tests conducted in the unconfined aquifer (Rae - 1987). Transmissivity varies seasonally depending on the saturated aquifer thickness which in turn reflects seasonal differences in recharge from the Southern Valley Catchments. In other words, summer values may be an order of magnitude lower than in spring or winter and testing needs to be scheduled to account for this seasonality.

Values of storativity for the Southern Springs vary by four orders of magnitude and reflect the degree of aquifer confinement. Typical values range from 0.1 in the unconfined aquifer to 10^{-4} in the leaky confined aquifer. Even at values of 10^{-4} the aquifer is not considered fully confined, and it is not until values of 10^{-5} are reached such as in the Riverlands area.

A recent test on wells near the southern margin of the Southern Springs at New Renwick Road measured transmissivity in Speargrass Formation gravels as low as 5 m^2/day and a storage coefficient of 10^{-4} (Water Matters – 2010).

The low storage properties of the confined aquifer were also demonstrated in the mid 1980s when the groundwater level in well 1475 located 150 metres east of Battys Road was observed to surge in response to intermittent pumping of neighbouring irrigation wells (Fig. 25.13).

Another hydraulic property that is particularly relevant to the Southern Springs area is the nature of the channel bed sediments and their ability to transmit water. Bed conductance is a recently defined term which is a measure of the permeability of the sediments on the bottom of a spring which controls the interaction between the underlying aquifer and spring flow. This is an important parameter in the Southern Springs area because bed conductance influences the amount of water lost from the springs when wells are pumped. Spring bed conductance values for the Southern Springs have been measured (PDP - 2004); (SKM - 2006).

Aquifer tests carried out along Fairhall Co-op Drain that have been analysed for stream depletion indicate that streambed conductance values are around 2-10 m/day (PDP - 2004). Flow gaugings for the same reach below Bells Road are consistent with these results, returning an average value of 22 m/day. Yelverton Stream, lower Doctors Creek and Taylor River at Beaver Road footbridge returned values of 100-200 m/day.

Stream bed conductance values are typically greater than vertical conductance through the aquitard, which

Figure 25.13: Surging water level at well 1475 in mid 1980s

is predicted to be 0.1 to 2 m/day in the Southern Springs area. This means that vertical seepage is primarily controlled by the permeability of the aquitard. Bed conductance may be more influential in areas where the aquitard is fractured or consists of more permeable sediments.

Groundwater chemistry

The chemical composition of groundwater from well 1384, located on the eastern side of Battys Road, just south of the Doctors Creek channel has been monitored since the early 1990s. Samples taken in February 2008 are similar in composition to those taken in 1994 indicating that water chemistry is relatively stable over time. This groundwater is classified as belonging to the Calcium-Sodium-Magnesium-Bicarbonate type (Fig. 25.14).

Well 1384 taps the confined aquifer and has some characteristics of reducing chemical conditions. These include detectable iron, but the groundwater is not as evolved as for other Marlborough systems of this type. This water is close to the edge of the confining layer and has been recharged relatively recently. This is supported by the presence of man-made levels of nutrients and microbes which would not normally be present in older groundwaters and reflects the influence of local agricultural activities

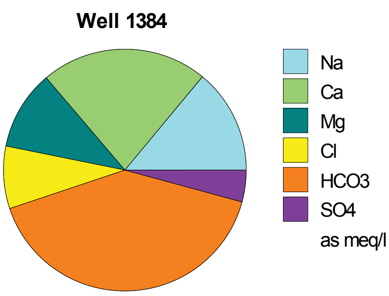

Figure 25.14: Well 1384 groundwater composition

and rural residential settlement. In a fully confined aquifer with old water, the fraction of sulphate would be small or non-existent. For instance, nitrate-nitrogen concentrations of 7.2 and 7.5 g/m^3 were measured in groundwater samples taken from well 4706 located west of Battys Road and midway between David Street and New Renwick Roads in winter 2007. These concentrations are above the background or naturally occurring level of 1 to 3 g/m^3 and represent the legacy of dairying and cropping farms in the Bells Road area and perhaps septic tank waste.

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