STREAMBED CONDUCTANCE SURVEY

- Final
- 21 December 2006

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1. Introduction

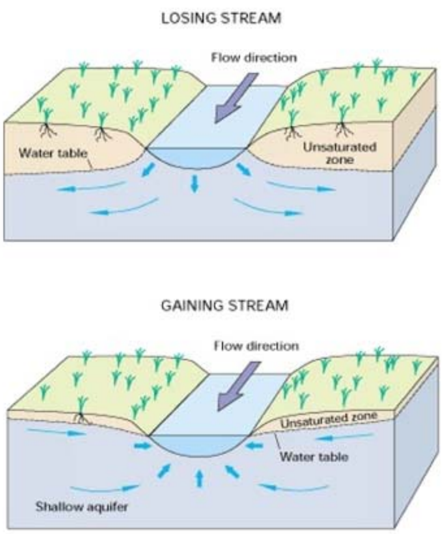
The Marlborough District Council commissioned Sinclair Knight Merz to undertake field investigations to improve definition of streambed conductance in selected spring-fed streams in the Marlborough Region. The work was intended to improve definition of the nature and magnitude of groundwater/surface water interaction to assist management of the impacts of groundwater abstraction on flow in spring-fed streams.

This report documents results of field investigations and provides recommendations to guide future investigations and assist the development of a framework for management of spring-fed streams.

1.1 Surface water - groundwater interaction

In situations where rivers or streams are hydraulically connected to an adjacent aquifer, water may flow into, or out of, the aquifer system according to the relative hydraulic gradient. Where groundwater levels are lower than river stage, flow will be lost from the stream into the surrounding aquifer. Conversely, where groundwater levels are higher than river stage, groundwater will flow into the stream.

The rate at which water is exchanged between a river or stream and a surrounding aquifer is governed by the relative difference in hydraulic head, the permeability of the streambed (termed the *bed conductance*) and the hydraulic properties of the aquifer materials. Figure 1 illustrates flow exchange between rivers and streams and surrounding aquifers under natural conditions



- **Figure 1. Schematic illustration of losing and gaining streams (USGS, 1998)**

Any reduction in groundwater levels resulting from abstraction will alter the relative head difference between stream and surrounding aquifer. As a result, groundwater abstraction may increase the rate at which flow is lost from a losing stream, or alternatively, reduce the volume of water discharged to a gaining river or stream. In situations where the resulting drawdown of groundwater levels is sufficient, groundwater abstraction may not only reduce groundwater discharge to rivers and streams but can reverse the hydraulic gradient resulting in water being lost from the stream. Figure 2 illustrates the depletion of stream flow as a result of groundwater abstraction.

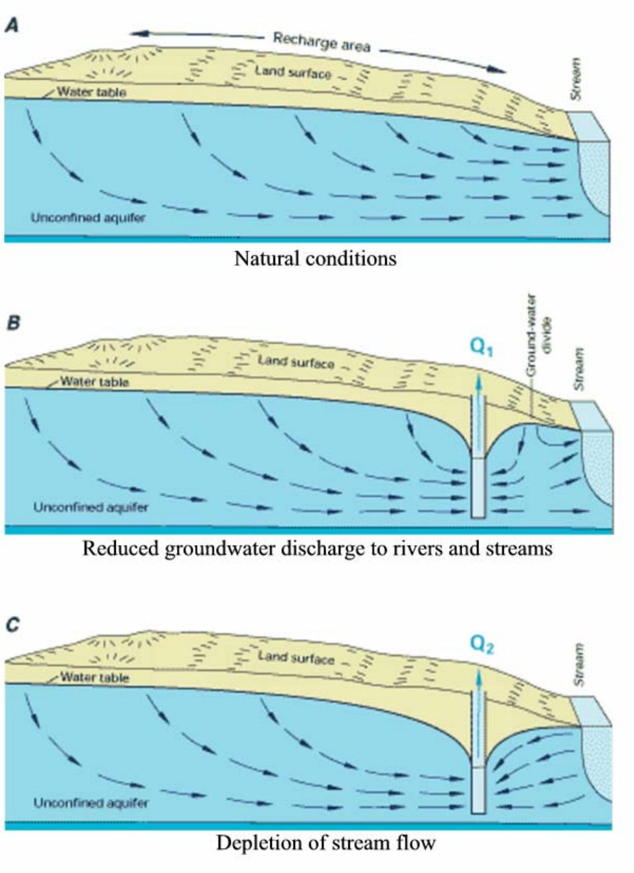


Figure 2. Depletion of streamflow as a result of groundwater abstraction (after USGS, 1998)

1.2 Spring-fed streams

The term spring-fed stream is generally applied to describe those streams for which groundwater discharge comprises a significant proportion of flow. This discharge may originate from either point source discharges of groundwater (i.e. springs) or from diffuse inflow of groundwater through the streambed materials.

Spring-fed streams generally exhibit a characteristic pattern of flow variability with relatively low peak discharge and stable baseflow. The rate of discharge is closely correlated to groundwater levels in the surrounding aquifer and may vary over time due to changes in groundwater levels resulting from natural climate variability or induced by groundwater abstraction.

Due to the influence of groundwater discharge, spring-fed streams form a unique aquatic habitat with distinctive flow variability and characteristic stream morphology. Stream baseflow and water temperature tend to be very stable reflecting the relatively constant nature of groundwater discharge. Due to the limited magnitude of high flow events streambed sediments also tend to be relatively fine and water clarity is often very high. The resulting stream habitat provides for a diversity of fish, insect and aquatic plants species which commonly have significant cultural, recreational and aesthetic values.

2. Methodology

2.1 Background

Investigation of streambed conductance values were undertaken utilising two methods as described in Guidelines for the *Assessment of Abstraction Effects on Stream Flow* (ECan, 2000):

- Concurrent Gauging Surveys
- Bed Seepage Measurements

2.1.1 Concurrent Gauging Surveys

The use of concurrent gauging surveys to estimate streambed conductance involves the measurement of stream flow at various points along a single reach to quantify the increase in discharge over a given distance. The change in stream flow is then combined with the measured head difference between stage height in the stream and groundwater level in the surrounding aquifer to provide an estimate of the hydraulic properties of the streambed materials.

$$\text{Streambed conductance/unit length } (\lambda) = \frac{\Delta q}{L\Delta h}$$

Where: Δq = change in flow between gauging sites

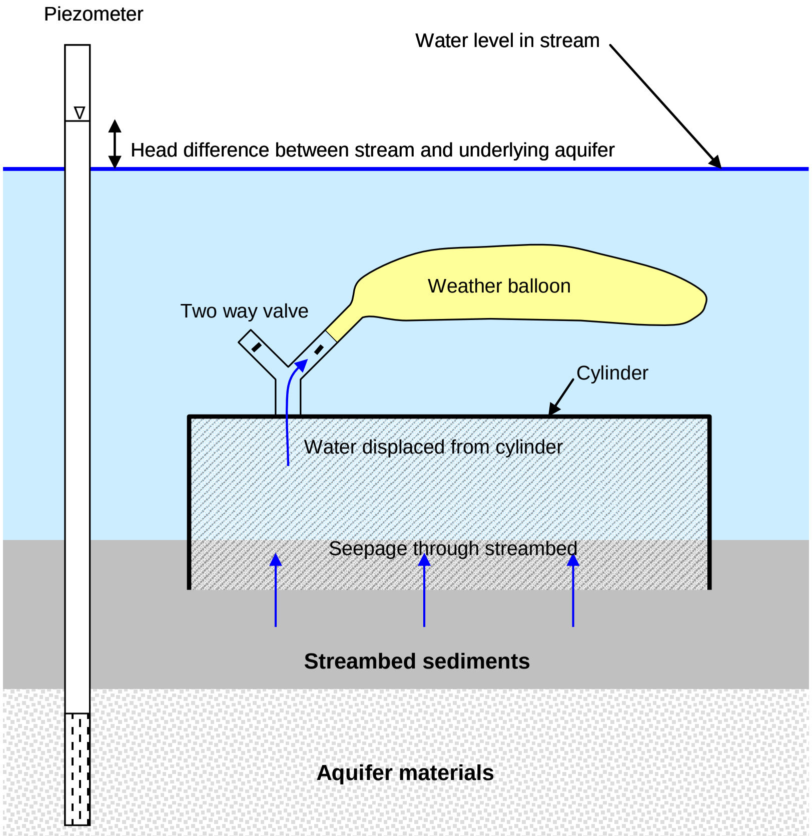
L = distance between gauging sites

Δh = difference in head between stream stage and groundwater level in the adjacent aquifer

Due to the heterogenous nature of stream sediments groundwater discharge may vary across the bed of a stream reflecting textural or physical characteristics of the bed materials. Concurrent gauging surveys provide an estimate of streambed conductance that ‘averages’ this variability over a given reach. Concurrent gauging surveys also avoid the need to physically disturb sediments on the bed of the stream to undertake measurements.

2.1.2 Seepage surveys

The rate of seepage through the bed of a stream can also be measured directly using a seepage meter. This involves placing a cylinder, closed at one end, over a known area of the stream bed. The open end of the cylinder is pressed into the streambed materials and the closed end connected to a weather balloon via a two way valve as shown in Figure 3. Weather balloons are utilised as a means to capture outflow from the seepage meter that provides little or no hydraulic resistance. Care is also required to ensure the outlet of the two-way value is placed under the stream water level to avoid the requirement to correct for atmospheric pressure differential.



- **Figure 3 Seepage meter**

Following placement in the streambed materials the two-way valve is opened to allow equalisation of pressure between the seepage meter and stream for a period of 20-30 minutes. The two-way valve is then switched to divert flow into the weather balloon and inflow measured over a set period. For this investigation a period of approximately 60 minutes was generally used to provide a representative inflow rate while allowing multiple replicates to be undertaken at each site. In areas of artesian spring discharge the period of measurement was significantly reduced as experience indicated that accumulations of more than 5 Litres in the weather balloon tended to result in significant flow drag balloon which interfered with measurement accuracy and security of seepage meter placement.

Figure 4 illustrates the typical deployment of a seepage meter, in this case in Fultons Creek, Pollard Park.

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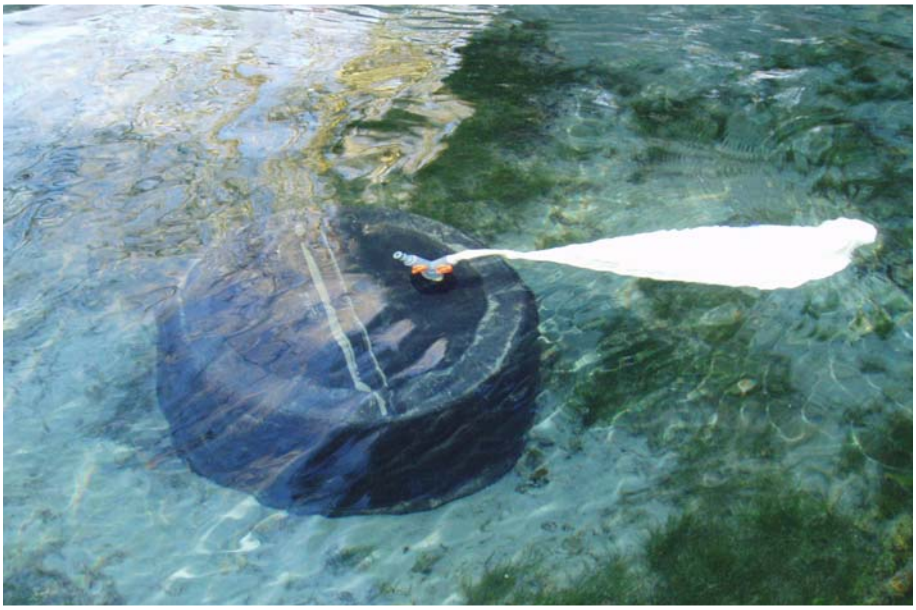


▪ **Figure 4 Deployment of seepage meter in Fultons Creek.**

Utilising the measured seepage meter inflow rates the hydraulic conductance of the streambed sediments is then calculated using Darcys law:

Streambed vertical hydraulic conductivity (K') = $\frac{q}{iA}$

Where: q = inflow to seepage meter (L^3/t)

A = area of seepage meter (L^2)

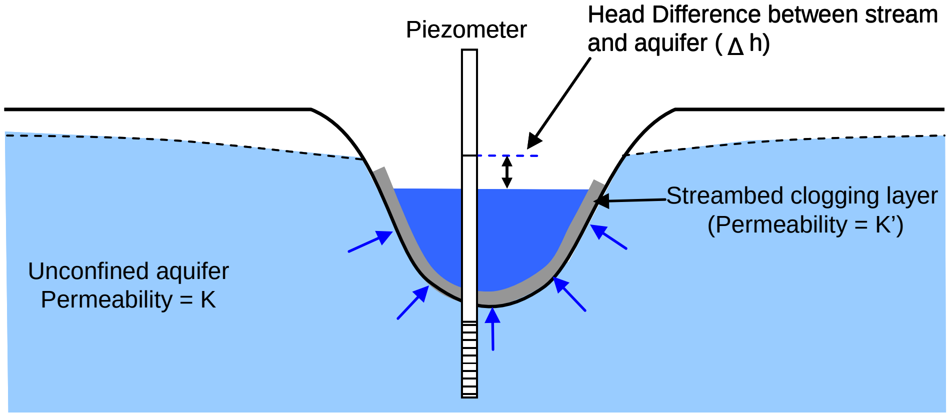
i = vertical hydraulic gradient measured by head difference between stream stage and piezometric level in underlying aquifer

K' = vertical hydraulic conductivity

The major disadvantages associated with the use of seepage meters for estimation of streambed permeability is the relative small sample volume given the heterogeneous nature of streambed sediments and the resulting disturbance of streambed materials resulting from the placement of the seepage meter. In areas of very soft sediment the potential also exists for compaction of sediments surrounding the seepage meter to result in displacement of water into the seepage meter. This was avoided where possible by not standing within 0.5 metres of the seepage meter when commencing measurement or measuring inflow to the weather balloon but cannot be ruled out as a source of variability in measurement results.

2.1.3 Relative head difference

The relative head difference between stage height in a stream and the groundwater level in the surrounding aquifer provides the driving force for flow into, or out of, a stream as shown in Figure 5. Measurement of relative head difference is required for calculation of streambed conductance from either concurrent gauging or seepage meter measurement.



- **Figure 5 Measurement of relative head difference**

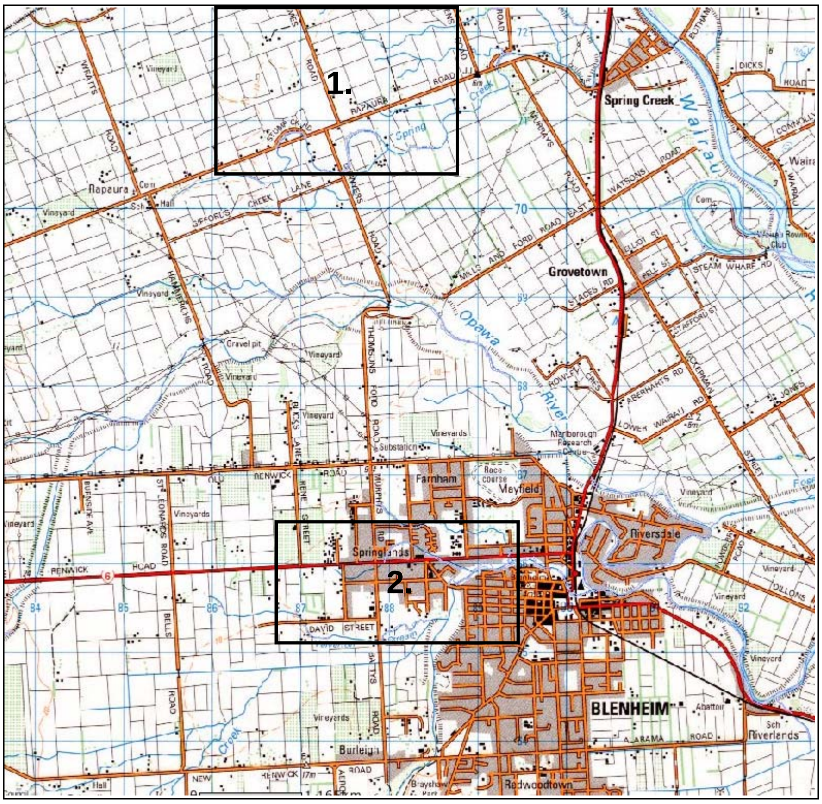
For this study a number of spearpoint piezometers were constructed for measurement of relative head difference. These were constructed of 50 mm diameter galvanised pipe with a pointed end to provide penetration through streambed and aquifer materials. Numerous 10 millimetre holes were drilled radially over the lower 200 millimetre section to provide hydraulic connection with aquifer materials.

2.2 Field Measurements

Field measurements were undertaken over the period 21-24 August 2006. Flow gauging and seepage meter measurements were undertaken in three areas:

- Ganes Creek, Dentons Creek and Roses Creek located approximately 4 kilometres north of Blenheim
- Old Fairhall Stream located approximately 1 kilometres west of Blenheim
- Fultons Creek in Pollard Park, Blenheim

The location of fieldwork areas are illustrated in Figure 6 below.



- **Figure 6 Field work areas. Area 1. (Ganes Creek, Dentons Creek, Roses Creek); Area 2. (Old Fairhall Stream, Fultons Creek)**

2.2.1 Ganes Creek

Gains Creek is a small tributary of Spring Creek that originates in the area to the west of Selmes Road and north of Rapaura Road. Figure 7 illustrates the reach immediately upstream of Selmes Road. This section of the stream is relatively slow-flowing with a depth of between 300-500 millimetres. Sreambed materials consist of relatively soft mud which becomes increasingly gravely upstream. For estimation of streambed conductance, flow gaugings were undertaken at three points and seepage measurements collected at six locations on 21/8/2006 as shown in Figure 8 below.

Relative head difference was measured between groundwater level in a MDC monitoring well (4577) located adjacent to the culvert on Selmes Road and stage height in the stream immediately adjacent.

▪ **Figure 7 Ganes Creek looking downstream toward Selmes Road**

▪ **Figure 8 Location of field measurements in Ganes Creek**

2.2.2 Dentons and Roses Creek

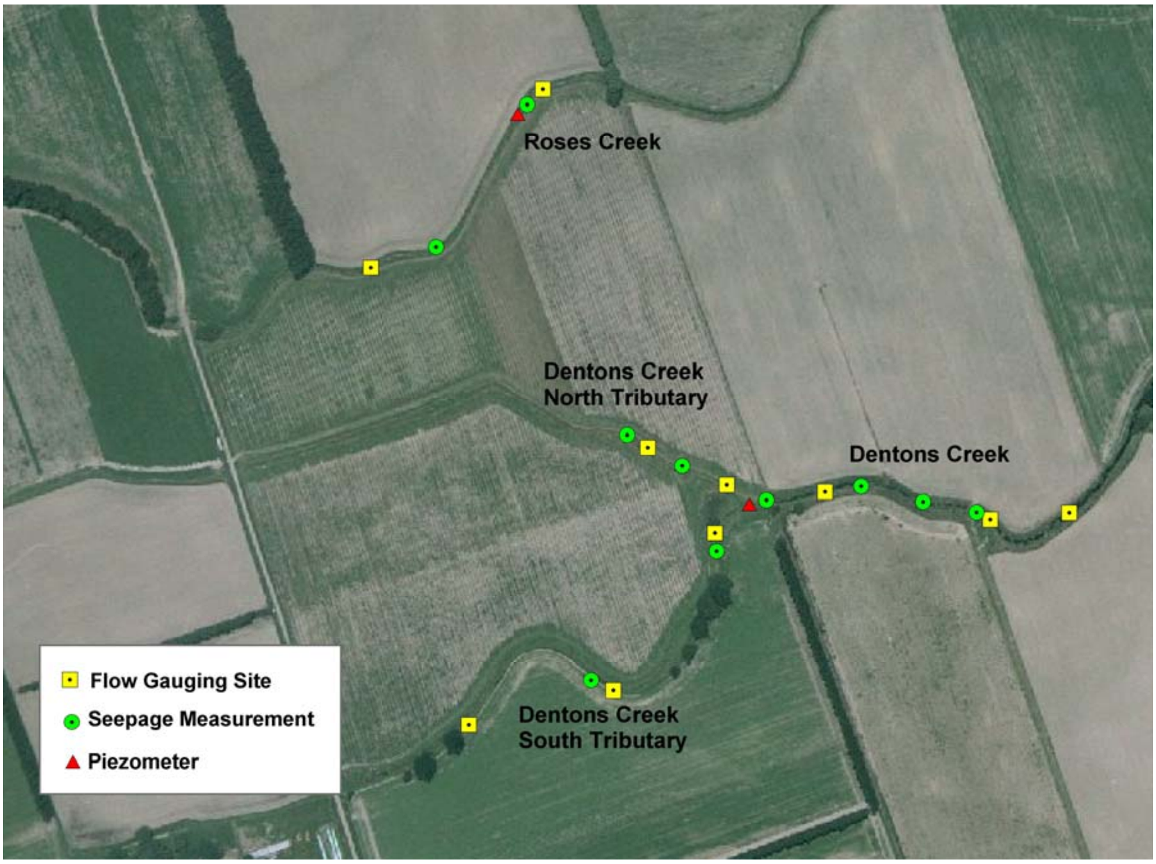
Dentons and Roses Creeks originate in the area immediately to the east of Selmes Road. Field measurements were undertaken in both streams approximately 1 kilometre upstream of Cravens Road. Figures 9 and 10 show the typical morphology of Roses Creek and the downstream section of Dentons Creek respectively.

- **Figure 9 Roses Creek**

- **Figure 10 Dentons Creek**

Although relatively close, Roses and Dentons Creeks exhibit rather different bed materials and flow characteristics. Roses Creek is relatively wide (~2 to 2.5 metres) and slow flowing with a soft muddy bed containing significant amounts of woody debris. In contrast, Dentons Stream is relatively fast-flowing with a gravely bed in the upper reaches and an extremely soft silty bed (in excess of 500 millimetres) containing organic material below the confluence of its two main tributaries.

Figure 11 shows the location of flow gauging and seepage meter measurements undertaken in Dentons Creek and Roses Creek over the period 21 to 22/8/2006. Two piezometers were also placed in the stream to estimate relative head difference as shown in the figure.



■ **Figure 11 Location of field measurements in Dentons and Roses Creek**

2.2.3 Old Fairhall Stream

Old Fairhall Stream originates between Bells Road and Battys Road, approximately 2 kilometres to the west of Blemheim. As shown in Figure 12 this reach is relatively shallow (200-300 millimetres) with bed materials comprising a mix of mud and sand. The ephemeral nature of flow in this reach is shown by grass and other terrestrial vegetation present on the bed of the stream.

▪ **Figure 12 Old Fairhall Drain showing grass and other terrestrial vegetation on the stream bed**

Two flow gauging and three seepage meter measurements were undertaken in the vicinity of Davids Road as shown in Figure 13.

▪ **Figure 13 Location of field measurements in Old Fairhall Stream**

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2.2.4 Fultons Creek

Fultons Creek originates within the Blenheim urban area and drains into the Opawa River upstream of Hutcheson Street. A number of tributaries of Fultons Creek consist of artificially modified 'drains' formed during urban development. Bed materials vary significantly from fine pebbly gravel in the lower reaches through to fine sand with some silt in the mid to upper reaches. Stream flow is relatively rapid.

Flow gauging and seepage meter measurements were undertaken in Pollard Park where the stream retains much of its natural form apart from a large pond excavated in the downstream section

- **Figure 14 Location of field measurements in Fultons Creek**

3. Results

The following section provides a summary of field investigations at each field site and an overall assessment of the measurements undertaken. Results of field measurements are detailed in Appendix 1 and summarised in Table 1 below

- **Table 1 Calculated streambed conductance values**

Stream	Reach	Streambed Conductance (m/day)	
		Seepage Meter	Flow Gauging
Ganes Creek[1]	Upstream of Selmes Road	0.20	7
Dentons Creek	Southern tributary	0.46	89
	Northern tributary	0.66	194
	Downstream of confluence	1.69	210
Roses Creek		0.60	99
Old Fairhall Stream	Upstream of Davids Road	-	130
Fultons Creek	Pollard Park	na	na

[1] Based on an assumed head difference of 0.1 metres

3.1 Ganes Creek

Flow gaugings on undertaken in Ganes Creek on 21 August 2006 indicate a flow gain of approximately 7 L/s over the reach extending 700 metres upstream of Selmes Road. A majority of this flow gain was recorded between the middle and upper gauging sites, with little change in flow between the middle and lower gauging sites. This observed variation in stream discharge matched an apparent change in the nature of the streambed sediments from a mix of gravel, sand and silt in the upper section to fine-grained silt and mud in the lower section.

Seepage meter results generally match the gauging results with limited inflow recorded in the four measurement locations in the lower section of the stream with more significant inflows in the upper reach.

A MDC monitoring well (4577) located immediately adjacent to Ganes Creek at the Selmes Road culvert was intended to provide an indication of the head difference across the stream bed. Based on relative wellhead and culvert elevations the stream stage was observed to be approximately 0.26 metres higher than piezometric level in the adjacent unconfined aquifer.

The observed negative head difference (i.e. stream stage higher than groundwater level) would indicate the stream is perched in the lower section. This is consistent with gauging and seepage meter results which show limited flow gain immediately upstream of Selmes Road. The observed flow gain upstream of the middle gauging site would therefore indicate a significant change in relative head difference over a relatively short interval. An alternative explanation may be that the monitoring bore is locally semi-confined by lower permeability sediments above the screened interval and the limited flow gain in the lower section simply reflects the thickness and fine-grained nature of the streambed sediments.

Assuming a relative head differential of 0.1 metres a streambed conductance of 8 m/day is calculated for Ganes Creek from the flow gauging results. Further investigation of streambed conductance on Ganes Creek should include provision for mini-piezometers to be installed through the streambed clogging layer to improve spatial resolution of changes in relative head difference.

3.2 Dentons Creek

Investigations of streambed conductance were undertaken on Dentons Creek both above and below the confluence of its two main headwater tributaries. Above the confluence water depths were generally less than 300 millimetres with the loosely-bound silt sediments becoming increasingly gravely approximately 300 metres upstream of the confluence in the south branch and 100 metres upstream of the confluence in the north branch. Gauging results indicate a flow gain of approximately 48 L/s over a distance of 370 metres above the confluence (average flow gain 0.13 L/s/m) in the south tributary and 22 L/s over a distance of 75 metres (average flow gain 0.3 L/s/m) in the northern tributary. The difference in inflow between the closely spaced tributaries may reflect the coarser texture of sediments in the northern tributary and the morphology of the respective stream channels with the northern tributary being narrower and more incised.

A piezometer installed immediately below the confluence of the two main tributaries indicated piezometric levels in the unconfined aquifer were approximately 0.125 metres higher than stream stage. Based on the observed head difference, streambed conductance values calculated from flow gauging results were estimated to lie in the range of 40 to 200 m/day. This relatively high conductance was consistent with the significant flow gain observed in both tributaries.

Seepage meter results generally indicated streambed conductance values in the range of 0.5 to 1 m/day, approximately two orders of magnitude lower than those calculated from gauging results. One potential explanation for the difference in calculated bed conductance values is the distribution of fine-grained bed sediments in the upper reach of Dentons Creek. While these sediments are generally relatively thick on the bottom of the stream (where the seepage meters were installed) they appear to decrease in thickness along the margins of the stream channels. This may suggest a significant proportion of inflow may occur along the lateral channel margins as illustrated in Figure 15.

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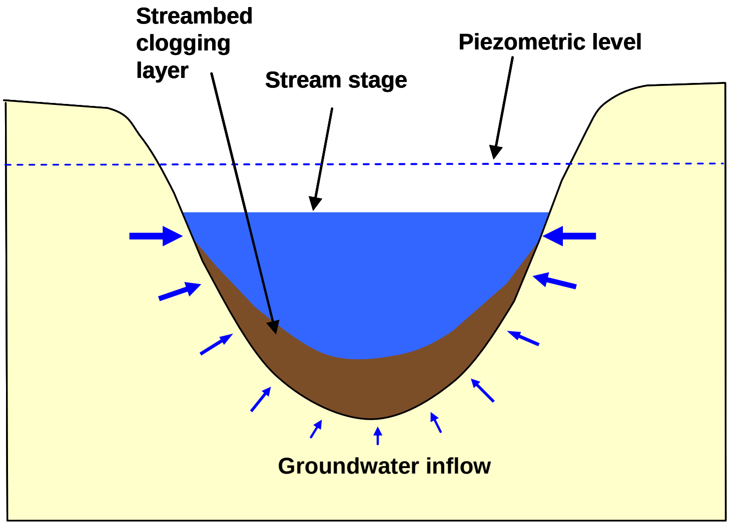


▪ **Figure 15 Schematic illustration of groundwater inflow to Dentons Creek**

Seepage meter results also indicate significant heterogeneity in streambed sediments with significantly different rates of groundwater inflow measured between the various measurement locations.

Below the confluence of the two main tributary streams the nature of the streambed sediments in Dentons Creek changes to thick (up to 700 millimetres), very loosely consolidated silt deposited around abundant macrophyte growth. As shown in Figure 16 these sediments exhibit large scour features possibly related to points of significant groundwater discharge. The unconsolidated nature of the silt material is also likely to reflect positive pore pressure resulting from groundwater inflow through the stream bed.

Gauging results in the downstream reach of Dentons Creek showed a flow gain of 56 L/s over a distance of approximately 210 metres (average flow gain of 0.27 L/s/m). Based on the head difference measured immediately upstream streambed conductance values in this reach of Dentons Creek were estimated to be in the range of 134 to 311 m/day.

Streambed conductance values calculated from seepage meter measurements in the lower reach of Dentons Stream were in the range of 0.9 to 2.5 m/day.

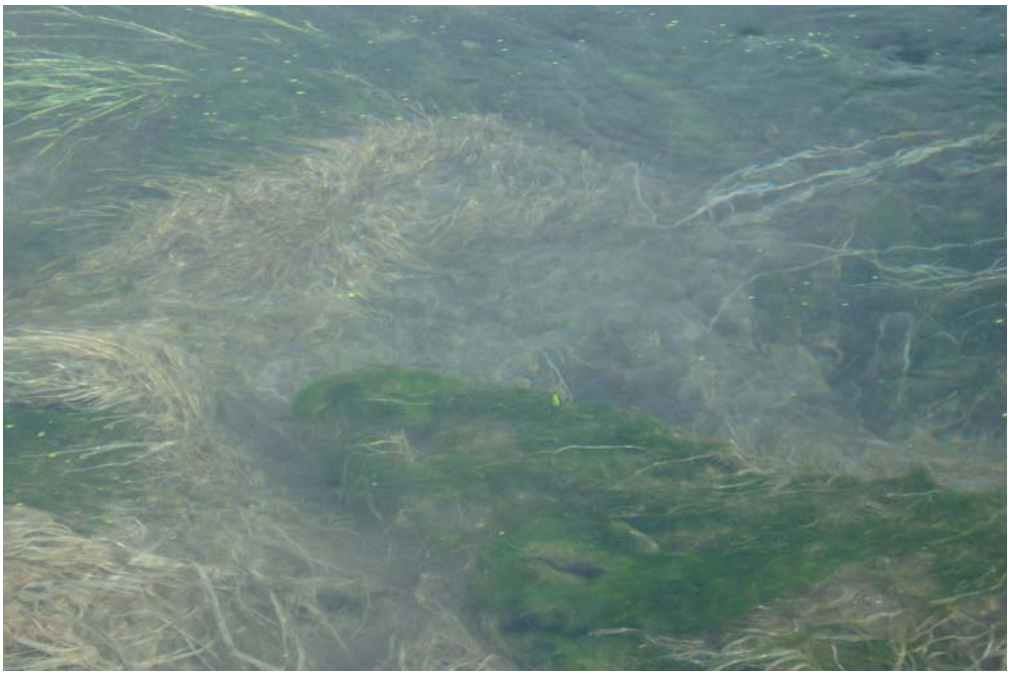


Figure 16 Streambed sediments in the downstream reach of Dentons Creek (Note scour feature in centre of photo, abundant macrophyte growth and loose unconsolidated nature of stream sediments)

3.3 Roses Creek

Roses Creek traverses a similar area to Dentons Creek and is similar in character to the southern tributary of Dentons Creek. As illustrated in Figure 17, Roses Creek is relatively wide and shallow (water depth <250 mm) with soft muddy sediments and abundant woody debris. The stream is incised by between 0.5 to 1.5 metres over the reach surveyed.

Flow gaugings undertaken on 22 August indicated an increase in flow of approximately 21 L/s over a 220 metre reach (average flow gain of 0.13 L/s/m). Based on the head difference of 0.145 m measured in a piezometer installed close to the downstream gauging site, a streambed conductance value of 99 m/day was calculated from the gauging results.

Seepage meter results showed a relatively consistent inflow rate of between 1.0 to 1.6 x 10^{-7} m^3/s. Based on the seepage meter results streambed conductance was estimated in the range of 0.5 to 0.7 m/day.

Overall, in terms of stream morphology, sediment and estimated streambed conductance values, Roses Creek appears to be very similar in character to the southern tributary of Dentons Creek.

▪ **Figure 17 Streambed sediments in Roses Creek**

3.4 Old Fairhall Stream

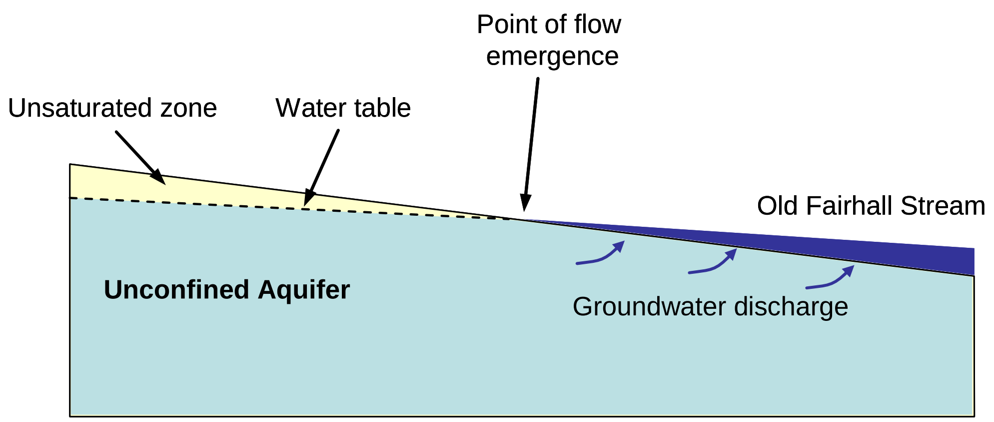
Flow gaugings and seepage meter measurements were under taken in a relatively short reach of Old Fairhall Stream immediately upstream of the Davids Road culvert. Over this reach the streambed sediments generally comprised silt with some coarser sand and fine pebbles. The streambed was covered with grass and other vegetation indicating that this reach of the Old Fairhall drain is commonly dry during the summer months.

Flow gaugings were undertaken at the David Street culvert and at a point approximately 200 metres upstream. Results of these measurements indicated a flow loss of approximately 7 L/s over this reach (average flow loss of 0.035 L/s/m). Although this result was somewhat unexpected in a reach assumed to be gaining, a piezometer installed near the downstream gauging site indicated stream stage was slightly higher (0.03 metres) than the surrounding groundwater level. Based on the measured flow loss and negative head difference a streambed conductance value of 130 m/day was estimated for this section of Old Fairhall Stream.

Seepage meter measurements tend to confirm the gauging results with two of the three locations showing negligible flow gain. The other site (immediately adjacent to the piezometer) showed a relatively consistent gain of between 1.5 to 2.0 x 10^{-7} m^3/s between successive measurements.

Overall, results from Old Fairhall Stream indicate this reach of what otherwise appears to be a gaining stream was actually losing water at the time field measurements were undertaken. The fact that the measured head difference was consistent with the observed flow loss tends to indicate that gauging error was not a major source of error. As a result, the apparent discrepancy in the observed flow gain is likely to reflect the sensitivity of relative flow gain/loss to variations in bed elevation. In this section of Old Fairhall Stream the natural stream/aquifer gradient appears to be disrupted by alterations to stream stage resulting from the accumulation of gravel and fill material in the stream bed under the Davids Street culvert. This may result in a sufficient increase in stream stage to alter the natural relative head difference between Old Fairhall Stream and the surrounding unconfined aquifer.

Figure 18 shows a conceptual illustration of groundwater discharge in Old Fairhall Stream. The point at which surface flow commences migrates up and down the stream bed depending on groundwater levels in the unconfined aquifer. Due to the sensitivity of both the extent and magnitude of stream discharge on groundwater levels in the unconfined aquifer, localised drawdown due to groundwater abstraction may act to reduce flow in the stream and increase the area of dry stream bed over and above that occurring as a result of natural seasonal variations in groundwater levels.



- **Figure 18 Conceptual model of groundwater discharge to Old Fairhall Stream**

3.5 Fultons Creek

Streambed conductance measurements were undertaken on the reach of Fultons Creek between the upstream footbridge in Pollard Park and Nelson Street. This reach includes a large pond excavated near the downstream boundary of Pollard Park. Streambed materials over this reach range from soft mud with abundant macrophyte growth downstream of Parker Street, through well sorted compact fine gravel and sand between Parker Street and the second footbridge in Pollard Park (upstream of Parker Street) to relatively soft silt and compact fine to medium sand in the upstream reach.

Park staff reported the presence of the large spring shown in Figure 19 approximately 30 metres downstream of the third footbridge. This feature and the observation of areas of mobile sand on the bed of the stream indicate significant groundwater discharge at discrete points the reach of Fultons Creek in this area. Given the location of Pollard Park above the confining layer (Dillons Point Formation) and the positive piezometric head observed in the underlying Wairau Aquifer in the Blenheim area, these observations were consistent with the presence of artesian springs discharging to Fultons Creek..

- **Figure 19 Artesian spring in bed of Fultons Creek (note piezometer installed into spring vent)**

Flow gaugings undertaken in Fultons Creek on 23 August 2006 indicate an overall flow gain of 38 L/s between the upstream footbridge in Pollard Park and Nelson Street, a distance of approximately 180 metres.

However, further gaugings undertaken on the 24 August at several reaches within Pollard Park indicate considerable flow variability over relatively short sections of the stream. For example, gauging results indicate that flow upstream of the third footbridge was 17 L/s greater than that observed at the upstream footbridge and in excess of 20 L/s greater than that observed both downstream of the large spring and at the downstream footbridge. The reason for the observed flow variability is uncertain however, given the geology of the surficial gravel deposits in the local area, it is unlikely that the observed flow variation would result from significant bank storage or bypass flow. It is therefore suspected that the observed flow variability may result from gauging error and it is recommended further concurrent gaugings be undertaken on this section of Fultons Creek to improve definition of spatial flow variability.

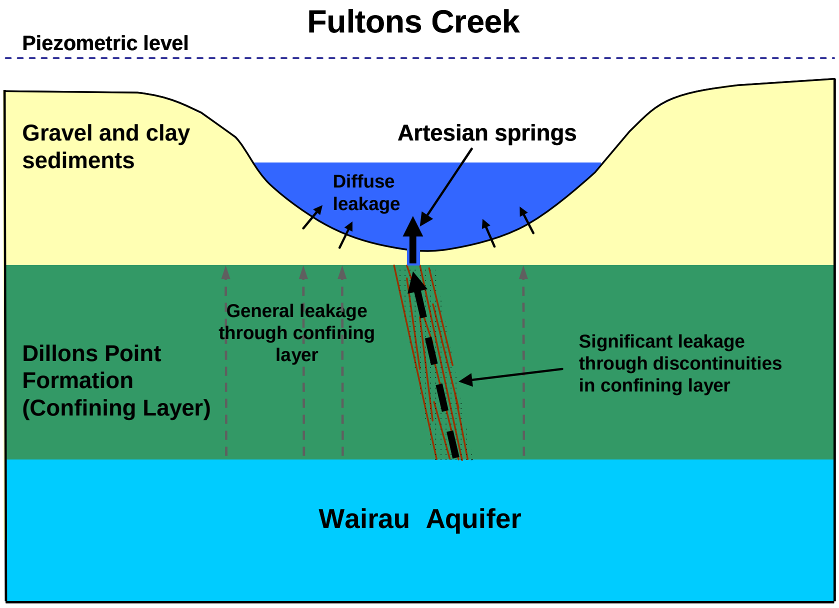
Further flow gauagings undertaken on 30 August at the upstream and downstream footbridge sites showed virtually identical discharge to that measured a week prior. This observation reflects the very stable nature of baseflow in streams fed by artesian springs which contributes to the unique character of these surface water features.

Given the nature of groundwater discharge to Fultons Creek, determination of streambed conductance is of limited value in improving definition of the nature of groundwater/surface water interaction. Piezometers installed in streambed sediments indicate a positive head of between 0.15 to 0.25 in the underlying sediments. This positive gradient is likely to reflect diffuse leakage through the confining layer materials.

Both visual observation and seepage meter measurements indicate significant spatial variability in groundwater discharge to Fultons Creek. While artesian springs were relatively obvious upstream of the second footbridge, seepage meter measurements indicate limited inflow in the reach below the first and second footbridges. This may suggest that a majority of leakage from the Wairau Aquifer occurs in 'zones' where discontinuities or textural changes in the confining layer materials allow greater upward leakage.

Due to its size, no measurements were possible to determine the discharge from the large spring feature observed although the rate of discharge was not observed to be excessive. Seepage meter measurements undertaken on a small spring upstream of the third footbridge indicated a discharge rate of approximately 1 L/min.

Figure 20 illustrates a conceptual model for the spring discharge observed in Fultons Creek in the vicinity of Pollard Park. Large artesian springs occur where discontinuities in the confining layer materials allow significant vertical leakage from the underlying confined aquifer. Lower rate diffuse leakage occurs more generally across the confining layer materials.



- **Figure 20 Conceptual model of artesian spring discharge to Fultons Creek.**

3.6 Summary of Monitoring Results

3.6.1 Seepage Meter Measurements

Results from seepage meter measurements are relatively consistent between individual measurements however results are generally two orders of magnitude lower than those derived from concurrent gauging results. The reason for this difference is not certain but may be related to variation in the thickness of the streambed 'clogging' layer. Thicker deposits of fine silt and mud tend to accumulate on the stream bed suggesting the potential for higher inflow along the stream margins where the seepage meter cannot be reliably utilised.

The variability in streambed conductance values between individual monitoring sites (even when spaced a relatively close intervals) is likely to reflect significant heterogeneity in streambed conductance values within individual stream reaches. This variability is likely to reflect variation in the texture and thickness of the 'clogging layer' materials in the case of streams such as Dentons and Roses Creek or the location of artesian discharge zones within streams such a Fultons Creek.

Used in combination with flow gaugings, seepage meter measurements provide a useful means of confirming groundwater discharge mechanism/rate in individual stream reaches although estimation of streambed conductance values is probably best undertaken using flow gauging results.

3.6.2 Flow Gaugings

Concurrent flow gaugings are likely to provide the best means of establishing a representative streambed conductance value for individual stream reaches. This method accounts for the heterogeneity in streambed conductance values that influence the spatial variability of groundwater discharge by providing an ‘average’ value for an individual reach.

However, reliable determination of representative streambed conductance values requires multiple gaugings at set points to eliminate gauging error and establish representative flow loss/gain over an individual reach. Ideally gaugings should be undertaken over a range of flows to improve knowledge of the temporal variability of groundwater/surface water interaction. Accuracy of streambed conductance estimates and improved understanding of groundwater/surface water interaction would also be aided by measurement of head differential at several points within the stream reach being investigated.

Recent investigations in the Southland Region have also shown the establishment of semi-permanent piezometers within or adjacent to the stream bed can significantly improve understanding of spring-fed stream discharge mechanisms. When combined with flow gaugings and more general monitoring of aquifer levels regular measurements of head differential provide valuable insight into the groundwater stage/head differential/stream discharge relationship.

3.6.3 Measurement of Head Differential

Accurate determination of head difference across the streambed clogging layer is a critical component of the estimation of streambed conductance. As shown by the anomalous head difference between Ganes Creek and the adjacent MDC monitoring well this is best achieved by the use of piezometers installed within or adjacent to the stream bed.

The piezometers utilised for this investigation were manufactured from 50 millimetre diameter galvanised pipe with 10 millimetre diameter holes drilled in the lower section of the pipe to establish a hydraulic connection with the surrounding gravel materials. In practice these piezometers proved difficult to place due to resistance encountered driving them through the gravel materials. Also, the screened sections frequently became clogged with material from the stream bed reducing the hydraulic connection established with the underlying aquifer materials and requiring a significant period for equalisation of hydraulic head.

For future investigations it is recommended smaller diameter (~25 mm diameter) galvanised pipe be used for piezometer installations with smaller diameter and more widely spaced holes to provide the screen.

3.6.4 Calculated Streambed Conductance Values

Flow gaugings and seepage meters were used to derive estimates of streambed conductance. Due to the apparent heterogeneity and accumulation of streambed materials, flow gaugings are likely to provide the most accurate means of determining representative streambed conductance values. However, seepage meter results also provide useful information to improve definition of the nature of groundwater/surface water interaction in spring-fed streams.

Overall, from measurements undertaken, the following observations can be made with regard to streambed conductance in the streams surveyed:

- Groundwater discharge in Ganes Creek appears to vary spatially according to the texture of streambed sediments and relative head differential. Based on flow gauging results streambed conductance in the upstream section of Ganes Creek is estimated to be in the order of 10 m/day. It is uncertain if the limited flow gain in the lower section reflects a localised change in relative head differential or a reduction in streambed permeability due to accumulation of thick muddy streambed sediments in this reach.
- The upper reaches of Dentons Creek and Roses Creek appear to conform to the typical spring-fed stream discharge mechanism with downstream flow increasing due to the diffuse inflow of groundwater through streambed sediments. Observed head differentials in both streams lie between 0.125 to 0.145 metres and estimated streambed conductivities are calculated to be in the range of 100 to 200 m/day with similar values estimated from separate reaches with similar textural and morphological characteristics.
- Based on flow gauging results and observed head difference a value of 130 m/day is estimated for streambed conductance on Old Fairhall Stream. The slightly anomalous stream discharge and relative head differential in the reach surveyed illustrates the sensitivity of flow in this stream to small variations in relative stream stage and groundwater level.
- Streambed conductance values were not estimated for Fultons Creek as artesian springs are attributed to be the main source of stream discharge. In this case it is the presence of discontinuities and/or textural anomalies in the underlying confining layer materials that is most likely to control the location and rate of groundwater discharge.

Streambed conductance values derived from this investigation compare well with previous estimates of streambed conductance (PDP, 2004) derived from aquifer test data on the Wairau Plain as outlined in Table 2. Overall these data suggest streambed conductance values in the range of 1 to 1440 m/day. From general observation it would be concluded that higher streambed conductance values would occur in gravel-bed rivers and streams such as the Wairau River with lower values occurring in spring-fed streams where a significant thickness of fine sediment is commonly accumulated within the stream channel.

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Table 2. Summary of streambed conductance estimates in the Wairau Valley

Catchment	Site	Reference	T (m^2/day)	λ (m/day)
Wairau River	Salmon Farm	PDP#C01547401	12,000	200-800
	Montana @ Conders Bend	PDP#CJ679	4,600	144
	JT & AM Best	PDP#C01519402	3,050	1440
Tuamarina River	Tripe	PDP#CJ684	3,450	1.4
	MDC @ Speeds Road	PDP#CJ755	3,000?	1.4
Fairhall Co-op Drain	JPS Trust	PDP#CJ845	1,600	5-10
	Whitten	PDP#CJ738	1,300	2
Mill Stream	Anderson	PDP#CJ741	940	1440
Murphys Creek	MDC @ Middle Renwick Road	File P28w/3120	3.700	1080
Opawa River	MDC @ Mills & Ford Road East	MDC file	12,000	432
Omaka River	Redwood	PDP#CJ640	500	10
Ganes Creek	Upstream of Selmes Road	This report		7
Dentons Creek	~1 km upstream of Cravens Road	This report		164
Roses Creek	~1 km upstream of Cravens Road	This report		99
Old Fairhall Stream	Upstream of Davids Road culvert	This report		130

4. Conclusion and Recommendations

Investigations of spring-fed streams in the Lower Wairau Valley described in this report provide useful information to characterise the nature of spring-fed stream discharge and improve definition of streambed conductance values in certain stream types.

From measurements undertaken, and general observations of hydrogeology in the area, the streams surveyed can be categorised into three types based on the observed nature of groundwater/ surface water interaction:

Gaining Streams - streams located on the northern margin of the Wairau Plain in the Spring Creek catchment. These streams intercept groundwater throughflow in the unconfined aquifer by diffuse leakage through the stream bed. Discharge in these streams is relatively constant reflecting continuous flow loss from the Wairau River. These streams conform to the typical spring-fed stream model with discharge largely dependant on stream morphology as well as the texture and thickness of the streambed clogging layer.

Ephemeral Streams - streams draining southern areas of the Wairau Valley and along the margin of the confining layer to the west of Blenheim. Upper reaches of these streams are largely ephemeral and discharge only during seasonal highs in the surrounding water table. The interaction between these streams and the surrounding unconfined aquifer may be relatively complex with groundwater discharge/recharge sensitive to variations in relative streambed elevation and groundwater levels.

Coastal Streams - spring-fed streams to the east of the inland margin of the confining layer (Dillons Point Formation) appear to discharge via a combination of artesian springs and zones of diffuse leakage through the confining layer materials. Baseflow in these streams is likely to be very stable and largely dependant on piezometric head in the Wairau Aquifer. Discharge from these springs is likely to form a significant component of the water balance in the coastal section of the Wairau Aquifer.

4.1 Future Investigations

4.1.1 Gaining Streams

The streambed conductance measurements undertaken provide the basis for establishing representative values for use in estimation of potential impacts of groundwater abstraction on flow in the upper sections of the Spring Creek catchment. Concurrent flow gaugings indicate relatively consistent values for streambed conductance in stream reaches of similar morphology and sediment texture. This observation indicates the potential for establishing ‘type’ reaches where streambed conductance values are derived for application in all similar reaches.

In the case of Dentons Creek and Roses Creek (and possibly other tributaries of Spring Creek) this could be achieved by selecting a 'headwater', a 'second order' and 'main stream' reach that are broadly representative of the channel morphology and sediment types in the area. Once selected concurrent flow gaugings could be undertaken on these 'type' reaches over a range of groundwater stage and flow conditions to derived representative streambed conductance values. This may involve regular measurement of discharge and relative head differential over a period of several months.

4.1.2 Ephemeral Streams

In the case of ephemeral streams further work is required to confirm the mechanisms influencing the groundwater levels/stream discharge relationship. This work may be in the form of further flow gauging and relative head differential measurements in Old Fairhall Stream and other similar streams in the area. The ephemeral nature of these streams also provides opportunity for measurement of streambed permeability from infiltrometer measurements during periods of no flow.

However, as shown by the apparently anomalous flow gauging results for Old Fairhall Stream, understanding of the spatial variation in relative head difference is also critical to determining potential impacts of groundwater abstraction on these streams. In conjunction with normal ongoing measurement of groundwater levels in the unconfined aquifer, the placing of piezometers at regular intervals within sections of these streams where flow is ephemeral would provide a means to characterise temporal variability in head differential. This would allow identification of minimum groundwater levels required to maintain flow at given points within the stream catchment and, in the longer term, possibly provide a means to manage groundwater abstraction in terms of groundwater level triggers established to maintain stream flow.

In conjunction with groundwater level and flow gauging measurements, the extent of surface flow could also be recorded at regular intervals to derive a relationship between stream discharge/ groundwater levels and the extent surface flow in the stream channel.

4.1.3 Coastal Streams

Spring-fed streams originating to the east of the inland margin of the confining layer present quite a different management scenario. As well as deriving flow from artesian springs resulting from discharge through discontinuities in the confining layer these streams also provide a conduit for discharge of more general leakage through the confining layer. As a result, determination of streambed conductance is not relevant to management of these streams.

For these streams improved definition of the location, nature and magnitude of artesian discharge is an important component of developing an understanding of the overall discharge mechanism. This may be achieved by visual inspection/logging of spring locations, seepage meter measurements to determine discharge 'zones' and concurrent flow gaugings to quantify overall discharge. Once identified, location of abstraction with respect to these 'zones' may be utilised as a criteria to assess potential impacts of groundwater abstraction.

In terms of managing potential impacts of groundwater abstraction from the Wairau Aquifer on discharge from spring-fed stream in the coastal zone, determination of the relationship between piezometric levels and stream discharge is probably the most critical aspect of establishing a framework for managing flow in these streams. Quantification of the piezometric head stream discharge relationship in this coastal zone may also advance knowledge of the overall aquifer water balance to improve understanding of aquifer hydrogeology and sustainability.

Table 3 provides an outline of recommended future investigations to improve knowledge of groundwater/surface water interaction in spring-fed streams in the Marlborough Region.

- **Table 3 Recommendations for future investigations of spring-fed streams**

Area	Recommendations for future work
Spring Creek Catchment	Regular flow gaugings and measurements of relative head difference in 'type' reaches to derive representative streambed conductance values for headwater, second order and main stem streams.
Ephemeral Streams	Further flow gauging to improve definition of streambed conductance values
	Measurement of the spatial variation in stream flow, relative head difference and stream discharge to identify groundwater level/flow triggers to maintain flow in nominated stream reaches
Coastal Streams	Identification of artesian discharge 'zones'
	Measurement of flow in significant streams to determine the relationship between piezometric levels and stream discharge and improved definition of aquifer water balance

4.2 Management of Spring-fed Streams

The following section provides some broad of suggestions for for the development of a framework for the management of the effects of groundwater abstraction on spring-fed streams in the Lower Wairua Valley. Overall, it is recommended that consideration be given to the management of spring-fed streams in terms of the various hydrogeological settings identified to maintain the values associated with their different discharge characteristics.

Gaining Streams - managed in terms of standard stream depletion estimates such as outlined in Hunt (2003) with emphasis on the location and volume of groundwater abstraction

Ephemeral Streams - managed following standard stream depletion assessment methodologies such as Hunt (2003) but with greater emphasis on cumulative groundwater level drawdowns and resulting impacts on the extent and flow in upper reaches of ephemeral streams. This may include identification of groundwater level /stream flow triggers utilised to control groundwater abstraction to maintain discharge in critical reaches.

Coastal Streams - managed in terms of piezometric head in the Wairau Aquifer with consideration given to the location of groundwater abstraction with regard to artesian discharge ‘zones’.

5. References

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Hunt, B. 2003; Unsteady Stream Depletion when Pumping from Semiconfined Aquifer. Journal of Hydrologic Engineering. Volume 8, Issue 1 pp. 12-19, Jan/Feb 2003

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Appendix A Seepage Meter Results

Site	Date	Easting	Northing	Start Time	Finish Time	Duration (sec)	Seepage Volume (L)	Average K' (m/day)	Stream Width (m)	Depth of clogging layer (m)	λ (m/day)
Dentons Creek 1	21 Aug	2588531	5971662	15:07	16:05	3480	0.575				
				16:07	17:10	3780	0.800				
				9:23	10:23	3600	0.800	0.40	2.2	1.0	**0.89**
Dentons Creek 2	21 Aug	2588492	5971679	15:11	16:10	3540	1.375				
				16:12	17:14	3720	1.400				
				9:27	10:26	3540	1.400	0.78	2.2	1.0	**1.72**
Dentons Creek 3	21 Aug	2588442	5971692	15:17	16:15	3480	1.950				
				16:16	17:19	3780	2.150				
				9:34	10:34	3600	1.950	1.13	2.2	1.0	**2.48**
Dentons Trib South	22 Aug	2588347	5971670	10:14	11:17	3780	0.250				
				11:19	13:05	6360	0.425	0.13	1.8	1.0	**0.24**
Dentons Trib South	22 Aug	2588286	5971547	10:18	11:23	3900	0.650				
				11:25	13:20	6900	0.725				
				13:22	14:06	2640	0.725				
				14:06	15:00	3240	0.650	0.38	1.8	1.0	**0.68**
Dentons Trib North	22 Aug	2588321	5971712	12:05	13:30	5100	1.050				
				13:52	14:32	2400	0.750				
				14:34	15:40	3960	0.825	0.49	1.6	1.0	**0.78**
Dentons Trib North	22 Aug	2588291	5971717	12:10	13:32	4920	0.550				
				13:34	14:29	3300	0.650				
				14:30	15:43	4380	0.700				
				15:44	16:26	2520	0.500	0.34	1.6	1.0	**0.54**
Dentons Confluence	22 Aug	2588363	5971680	13:09	13:57	2880	0.750				
				13:58	14:56	3480	0.575				
				14:56	15:47	3060	0.650	0.43	2.0	1.0	**0.86**
Roses Creek 1	22 Aug	2588197	5971963	12:15	13:47	5520	0.575				
				13:48	14:42	3240	0.475				
				14:43	16:10	5220	0.525	0.26	2.0	1.0	**0.51**
Roses Creek 2	22 Aug	2588150	5971863	15:20	16:18	3480	0.550				

				16:18	16:50	1920	0.300	0.35	2.0	1.0	**0.69**
Ganes Creek 1	21 Aug	2587398	5971048	11:27	12:34	4020	0.275				
				12:36	13:54	4680	0.500	0.18	2.0	1.0	**0.35**
Ganes Creek 2	21 Aug	2587362	5971033	11:30	12:41	4260	0.090				
				12:42	13:58	4560	0.050	0.03	2.0	1.0	**0.06**
Ganes Creek 3	21 Aug	2587346	5971029	11:33	12:44	4260	0.020	0.01	2.0	1.0	**0.02**
Ganes Creek 4	21 Aug	2587306	5971016	11:36	12:49	4380	0.125				
				12:51	14:03	4320	0.150	0.06	2.0	1.0	**0.13**
Ganes Creek 5	21 Aug	2586898	5971160	13:05	14:09	3840	0.175				
				14:11	15:44	5580	0.250	0.09	2.0	1.0	**0.18**
Ganes Creek 6	21 Aug	2586903	5971158	13:07	14:09	3720	0.050				
.				14:12	15:42	5400	0.040	0.02	2.0	1.0	**0.04**
Old Fairhall Stream	23 Aug	2587032	5965321	11:08	12:10	3720	0.450				
				12:12	13:16	3840	0.575				
Old Fairhall Stream	23 Aug	2587007	5965337	11:13	12:15	3720	0.100				
				12:17	13:23	3960	0.050				
Old Fairhall Stream	23 Aug	2586907	5965399	11:17	12:19	3720	0.030				
				12:20	13:32	4320	0.020				
Pollard Park - 1	23 Aug	2589279	5966294	15:00	15:46	2760	0.175				
				15:47	16:46	3540	0.100				
Pollard Park - 2	23 Aug	2589304	5966302	14:37	15:30	3180	0.100				
				15:31	16:22	3060	0.100				
Pollard Park - 3	23 Aug	2589225	5966354	14:55	15:37	2520	0.225				
				15:38	16:29	3060	0.300				
Pollard Park - 4	23 Aug	2589171	5966400	15:06	15:52	2760	0.250				
				15:53	16:42	2940	0.250				
Pollard Park - A		2589132	5966391	10:48	11:50	3720	0.010				
Pollard Park - B	24 Aug	2589104	5966377			120	1.025				
						120	1.300				
						120	1.000				
						180	2.150				
						120	1.050				

					120	0.900				
					120	1.250				
					120	0.800				
Pollard Park - C 24 Aug	2580131	5966394	10:56	11:51	3300	0.275				
			11:52	13:49	7020	1.000				
			13:50	14:59	4140	0.775				
Pollard Park - D 24 Aug	2589102	5966355	11:17	11:30	780	1.650				
			11:32	11:45	780	1.300				
			11:47	11:58	660	1.100				
			11:59	12:20	1260	2.175				
			12:22	12:35	780	1.500				
			14:06	14:20	840	0.800				
			14:21	14:31	600	0.800				
Pollard Park - E 24 Aug	2589090	5966359	11:35	12:39	3840	0.350				
			12:40	13:52	4320	0.400				
			13:53	15:04	4260	0.300				
			15:05	15:50	2700	0.250				
Pollard Park - F 24 Aug	2589031	5966334	12:41	13:55	4440	0.750				
			13:56	15:07	4260	0.500				
			15:08	16:14	3960	0.450				
Pollard Park - G 24 Aug	2589093	5966365	15:17	15:27	600	1.400				
			15:27	15:34	420	1.200				
			15:36	15:43	420	1.000				

Appendix B Flow Gauging Results

Stream	Date	Site	Easting	Northing	Flow (L/s)	Delta q (m^3/day)	L (m)	**λ (m/day)**	K'
Ganes Creek	21 Aug	Upstream	2586922	5971304	16.4				
Ganes Creek		Middle	2587186	5971059	23.1	579	495	**12**	6.5
Ganes Creek		Downstream	2587393	5971051	23.2	9	230	**0.4**	0.2
		Overall				588	725	**8**	4.5
								7	
Dentons Creek - Site 1	21 Aug	Upstream	2588387	5971680	188				
Dentons Creek - Site 2		Middle	2587395	5971047	217	2506	150	**134**	74.2
Dentons Creek - Site 3		Downstream	2586906	5971300	244	2333	60	**311**	172.8
		Overall				4838	210	**184**	102.4
								210	
Dentons Tributary - south	22 Aug	Upstream	2588130	5971497	35				
Dentons Tributary - south		Middle	2588283	5971545	74	3370	203	**133**	73.8
Dentons Tributary - south		Downstream	2588347	5971670	84	864	163	**42**	23.6
		Overall				4234	366	**93**	51.4
								89	
Dentons Tributary - north	22 Aug	Upstream	2588293	5971710	52				
Dentons Tributary - north		Downstream	2588348	5971686	73	1814	75	**194**	121.0
Roses Creek	22 Aug	Upstream	2588067	5971844	59				
Roses Creek		Downstream	2588204	5971964	88	2506	220	**99**	49.5
Old Fairhall Creek	23 Aug	Upstream	2586872	5965423	117				
Old Fairhall Creek		Downstream	2587038	5965314	108	-778	200	**130**	64.8
Pollard Park	23 Aug	Upstream footbridge	2589005	5966331	304				
Pollard Park		Footbridge upstream pond	2589291	5966308	332	2419	350		
Pollard Park		Upstream Nelson Street	2589364	5966095	342	864	230		
		Overall				3283	580		

Pollard Park	24 Aug	Upstream	2589031	5966359	348				
Pollard Park		Middle	2589102	5966360	366	1555	70		
Pollard Park		Downstream	2589142	5966391	343	-1987	52		
Pollard Park		Footbridge upstream pond	2589291	5966308	341	-173	188		