Preliminary Spring Creek Depletion Assessment

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Report Prepared for Marlborough District Council by

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1 INTRODUCTION

This report reviews the available data on the Spring Creek catchment and provides a preliminary assessment of the impact of groundwater pumping on flows. The approach taken in this report is to apply analytical stream depletion equations developed by Bruce Hunt (2008) to individual pumping wells to determine their direct impact on stream flow.

A map of Spring Creek catchment showing tributaries referred to in the text is shown in Figure 1. The western edge of the aquitard is also shown. This has been drawn from available well logs and is accurate to approximately ±100m in the Spring Creek catchment.

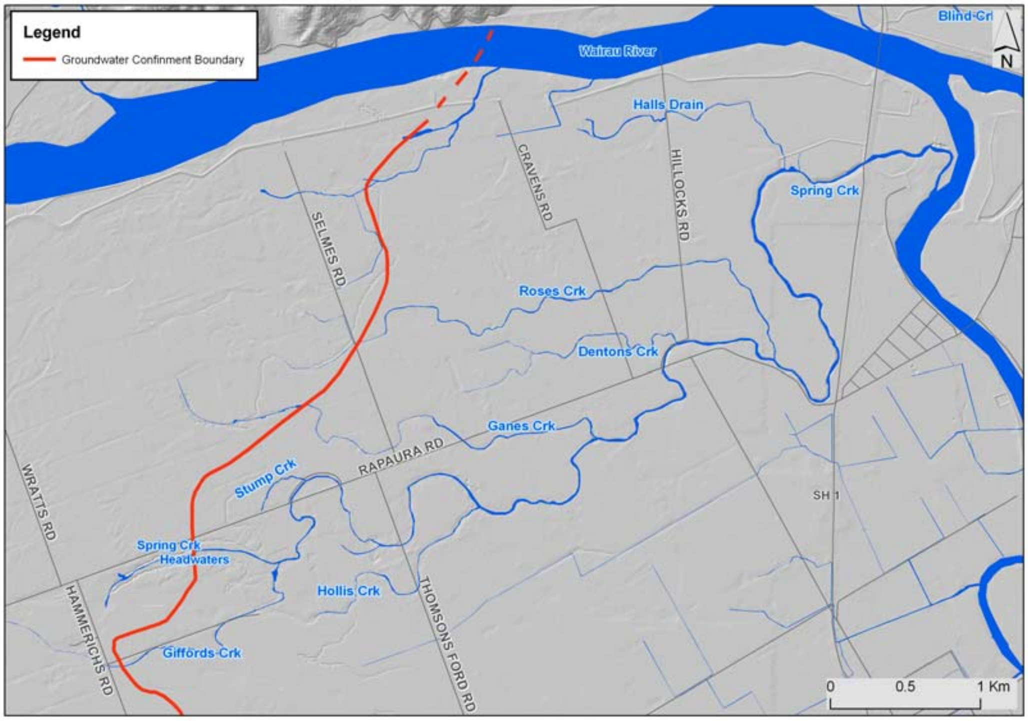

Figure 1 Spring Creek catchment and aquitard boundary

1.1 Spring Creek flow profile

Flow has been manually gauged at the Motor Camp since 1991. From 2001 onwards flow gaugings have been conducted on a weekly basis. After 462 manual flow gaugings the median flow was 4,030 l/s, with a standard deviation of 554 l/s. The observed low flow in February 1999 was 2,900 l/s, and the lower quartile flow was 3,730 l/s.

The flow profile along the main Spring Creek Channel is shown in Figure 2. The section of Spring Creek with the greatest gain in flow per unit length is between the Salmon Hatchery upstream of Stump Creek Road, and Dodsons Farm, 750m east of O’Dwyers Road. This section of Spring Creek lies on top of the aquitard, but is sufficiently leaky, and the channel is sufficiently deep, for high groundwater seepage rates to occur.

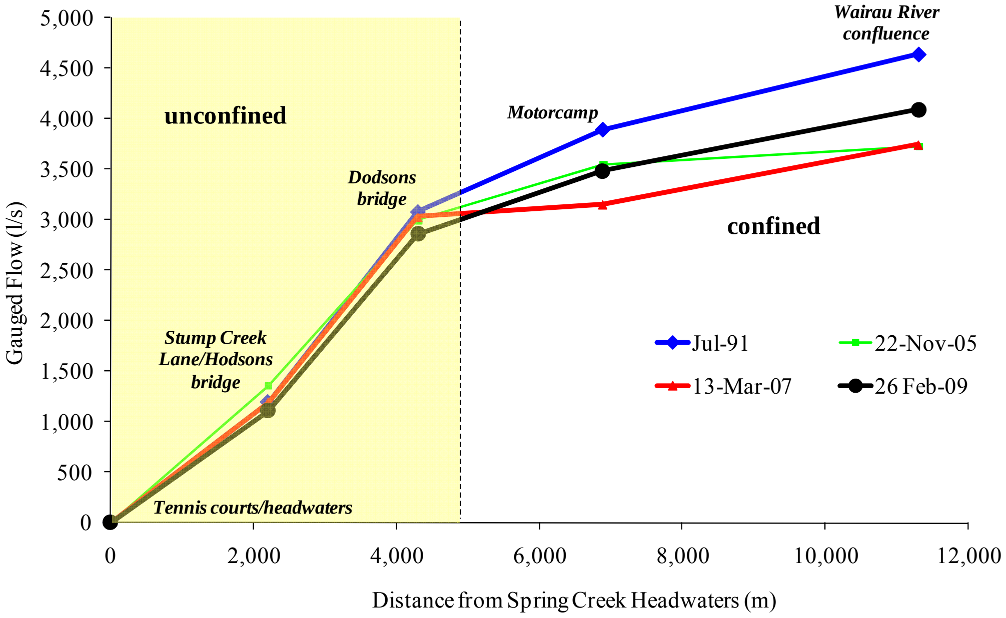

Figure 2 Flow profile of Spring Creek

1.2 Catchment allocation

The current allocation in the Spring Creek catchment is shown in Table 1. The total allocation is only a small proportion of the flow in Spring Creek, as measured at the Motor Camp. The allocated volume is only 25% of the observed low flow (2,900 l/s), and 20% of the lower quartile (3,730 l/s).

Table 1 Spring Creek catchment allocation

Location	Allocation Q (l/s)
Surface	330
Unconfined	70
Confined/leaky	319
Total	719

There are two important considerations to make when comparing the total allocation to Spring Creek flow. Firstly, that the measured low flow is affected to some degree by groundwater and surface water pumping. Secondly, the MDC flow gauging point at the Motor Camp is located in the middle reaches of the catchment. Flows are considerably less in tributaries of Spring Creek, particularly in the headwaters of the catchment in the vicinity of the seepage face. It is these headwaters that are most vulnerable to pumping.

Actual water use is expected to be between 20% and 40% of allocation during the irrigation season (150-300 l/s). This is only 5-10% of the low flow, which is similar to the flow gauging error of 8%. As a result pumping effects are not apparent in the

Motor Camp stage record. Note that specific monitoring for flow responses to pumping has not been carried out in Spring Creek like it has in the Southern Springs catchment (Phreatos, 2005).

2 Cumulative Assessment

An estimation of the cumulative impact of groundwater pumping on Spring Creek flow at the Motor Camp has been made. The duration of the simulation is for 30 days of continuous pumping. This is consistent with simulations carried out in the Southern Springs Catchment (MDC, 2008). The fairly short duration has been used to give an indication of how sensitive stream flow is to groundwater pumping.

The assessment assumes that all spring flow is derived from dispersed seepage through the aquitard rather than distinct spring sources. Aquifer transmissivity was maintained at a constant representative value of 3,500 m^2/d for the assessment. The storage coefficient was also kept at representative values of 0.001 for confined conditions and 0.1 for unconfined conditions. A streambed conductance value (λ) of 100 m/d was used, which is consistent with values measured by streambed conductance surveys (SKM, 2006 & 2008).

The only physical property that was varied in the cumulative assessment was aquitard leakage. This was estimated by dividing vertical conductivity in the aquitard by an estimated aquitard thickness for each bore. Pumping tests carried out in the springs zone indicate that vertical conductivity in the aquitard is on the order of 1 m/d (PDP, 2004).

The results of the assessment are summarised in Table 2. The response in the confined aquifer is very rapid. The percentage of water sourced from Spring Creek by wells screened in the confined aquifer is close to 100% after 30 days of pumping.

By contrast, the percentage of water sourced from Spring Creek by wells screened in the unconfined aquifer is around 66% after 30 days of pumping. The additional storage available in the unconfined aquifer means that there is more water available for each bore to draw from. As a result, pumping effects take much longer to impact on the stream.

Table 2 Cumulative stream depletion effect

	Allocation, Q (l/s)	30-day stream depletion, q (l/s)	q/Q (%)
Confined	319	312	98
Unconfined	70	46	66
Total	**389**	**358**	**92**

3 Sensitivity Analysis

A sensitivity analysis has been carried out to estimate the stream losses caused by bores pumping at different distances from Spring Creek. The stream depletion response for the confined and unconfined aquifers is shown in Figure 3 and Figure 4 respectively. The results are presented as a percentage of the pumping rate of the bore.

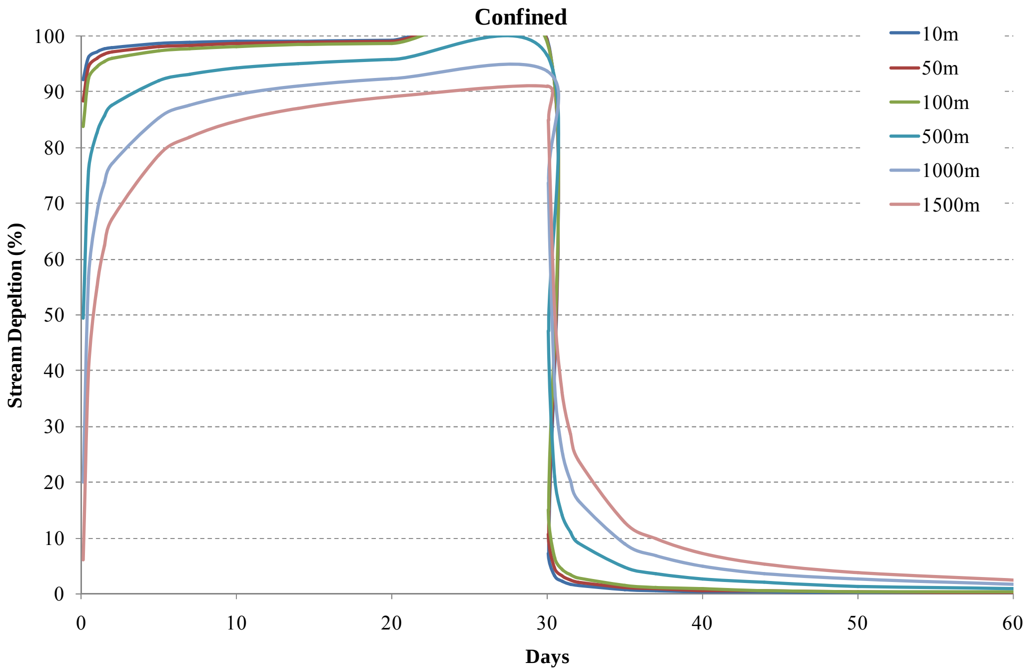

Figure 3 Stream depletion sensitivity analysis for the confined aquifer

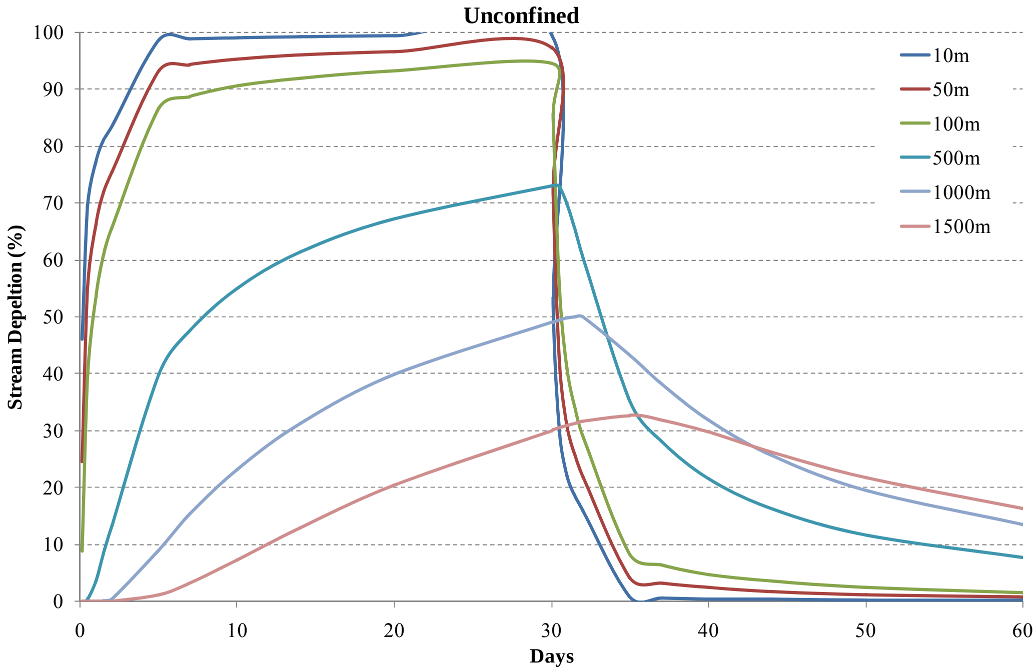

Figure 4 Stream depletion sensitivity analysis for the unconfined aquifer

The results show that the effect on the stream is different in the confined and unconfined aquifers. In the confined aquifer groundwater is separated from the spring bed by confining sediments. This confinement produces a storage coefficient that is two orders of magnitude lower than in the unconfined aquifer. This strongly influences the timing of the response to pumping.

Bores in the unconfined aquifer located within 100m of the stream have an immediate depletion effect. Beyond 500m the effect becomes delayed with 70% stream depletion after 30 days of continuous pumping. At 1000m the stream depletion is 50% of the pumping rate.

While the rate of stream depletion is quite high in the unconfined aquifer, the delay in the stream response is significant. This means that if bores located further than 500m from the stream were pumped intermittently, the impact on the stream would be very small. The reason for this is that water is initially sourced from groundwater storage in the vicinity of the pumped bore. Hydraulic connectivity with the stream is increased the longer the bore is pumped.

Recovery is also much slower in the unconfined aquifer. The recovery for closer bores, 100m or less is quite rapid. However, a significant delay is seen at a distance of 500m from the stream or greater. For bores located a kilometre or more from the spring, the stream depletion effect actually increases after the pump is stopped. The reason for this is that recharge from the stream is replenishing groundwater storage lost through pumping.

The sensitivity analysis shows that the confining sediments provide little protection for the spring, and the stream depletion response is immediate. This presents an enigma because the stream depletion effect is actually greater in the confined aquifer than in the unconfined aquifer.

The explanation lies in the fact that while the confining layer physically isolates groundwater from Spring Creek, the yield of the confined aquifer is far less than the unconfined aquifer. This means that pumping from wells generates a much larger drawdown in the confined aquifer, and the stream depletion effect is also greater.

4 Upper Reaches

4.1 Reach Vulnerability

The upper part of the Spring Creek catchment consists of a number of different branches. It is the upper reaches of these small branches that are most at risk from stream depletion because their flows are considerably smaller than the main channel. Reaches at most risk are:

- *Spring Creek (u/s of Rapaura Road).* Spring Creek gains over a cumec from the Salmon hatchery to Stump Creek Lane, and continues to gain through to Dodsons. The reach above the Salmon hatchery is most at risk. Flows in this reach have been measured at 162 to 314 l/s. Maximum water depths at the hatchery have been measured at ~0.62m in the summer and 0.25m in winter.

- *Hollis Creek (whole length).* Hollis Creek gains around 200 l/s from O'Dwyers Road to the Spring Creek confluence. While there is little data available, the median flow at Dwyers Road is estimated to be about 50 l/s, with a maximum water depth of around 0.4m.

- *Dentons Creek (upstream of Cravens Road).* Flow was measured as 397 l/s in July 1991 when the maximum depth was 0.79m. Most of the available information for the upper reaches was gathered by SKM (2006 & 2008). The minimum and median observed flows at the forks upstream of Cravens Road are 101 and 143 l/s respectively. Most of the SKM flow gaugings were carried out during winter.

- *Ganes Creek (whole length).* There is little information on Ganes Creek. A flow of 56 l/s was measured at Campbells in July 1991. The maximum water depth was 0.29m. There was 2-4 l/s at Rapaura Road in March 2001, and it was dry at Selmes Road. SKM measured 23 l/s at Selmes Road in August 2006.

- *Roses Creek (whole length).* The median measured flow at Spring Creek confluence is 100 l/s. Flows of 59 and 88 l/s were measured at distances of 660 and 850m upstream of Cravens Road by SKM in August 2006.Water depths are typically less than 0.5m for the whole of Roses Creek which makes it highly susceptible to pumping.

In addition to these reaches, Giffords Creek, which crosses Hammerichs RD to the south of the main Spring Creek channel, has not been gauged.

In summary, there are two main areas of the catchment that are vulnerable to low flows:

1. The upper section of the main Spring Creek channel. This area lies within the unconfined aquifer and possible the edge of the confined aquifer

2. All of the northern tributaries and Hollis Creek. These all overlie the confined aquifer

4.2 Quantitative Assessment

An assessment has been made to determine the impact that the current allocation has on individual branches. The results are presented in Table 3, where Q is the consented abstraction rate and q is the stream depletion effect. The assessment was made for a period of 90 days continuous pumping to give an indication of the degree of flow loss that could be expected over the course of an irrigation season.

The assessment assumes that a pumped well will only affect the nearest surface water body. The stream depletion effect has been compared to an estimated median flow for each branch to give an indication of the impact. These median flow values do need to be confirmed.

Roses Creek and Ganes Creek are both susceptible to large pumping effects under the current allocation. The allocation in Roses Creek is almost the same as the median flow, and the allocation in Ganes Creek is over 70% of the median flow.

Dentons, Hollis and upper Spring Creek are predicted to be less affected by pumping because the allocation is still less than the median flow in these reaches.

Table 3 Estimation of 90-day stream depletion compared to estimated median flow

Branch	Setting	n	Q (l/s)	q/Q %	q (l/s) 90-day	Med flow	Location	Impact (%)
Roses	Confined	11	92	99	91	100	Spring Ck	91
Dentons	Confined	1	10	99	9			
	Surface	2	19		19			
	Total	*3*	*29*		*29*	150	Cravens Rd	19
Ganes	Confined	7	29	95	28	40	Spring Ck	71
Hollis	Confined	1	38	98	38			
	Surface	5	3		3			
	Total	*6*	*41*		*41*	250	Spring Ck	16
Spring Ck	Unconfined	9	49	88	42			
	Confined	3	15	98	14			
	Total	*12*	*64*		*56*	150	Salmon H	37

5 Headwater Recession

In addition to reducing flow in the upper reaches, groundwater pumping will cause the headwaters of the catchment to recede. The stream depletion assessment only looks at the impact on flow, and the seasonal movement of the seepage face is not yet known.

Some indication of the seasonal change in the spring network can be made by looking at the relationship between groundwater levels and flow. Figure 5 shows this relationship, and the median flow is marked in red. There is considerable scatter in the data which is caused by pumping, surface runoff, and flow gauging error. A curve has been fitted to the data by hand, and it is clear from this curve that shape of the trend is not linear but concave.

The concave shape of the data trend is formed because flow levels out at lower water levels, and is boosted at higher water levels. In other words the change in flow per mm rise in water level increases as groundwater level increases. The reason for this is that the wetted area of the drainage network is increasing as groundwater levels increase. As the wetted area increases, the potential for flow is increased, and the flow per mm rise in water level becomes greater.

If the wetted area of the drainage network did not increase, we would expect the data to form a trend close to linearity. This means that the change in contribution of flow caused by the change in wetted area can be estimated from the departure in linearity on the graph.

The increase in wetted area between low flow and median flow provides an additional 200-300 l/s to flow at the Motor Camp. This is less than 10% of the observed low flow, so the seasonal change in wetted area has little effect on flow in the network as a whole. The estimation is approximate because of scatter in the data, but can be improved over time as more data becomes available.

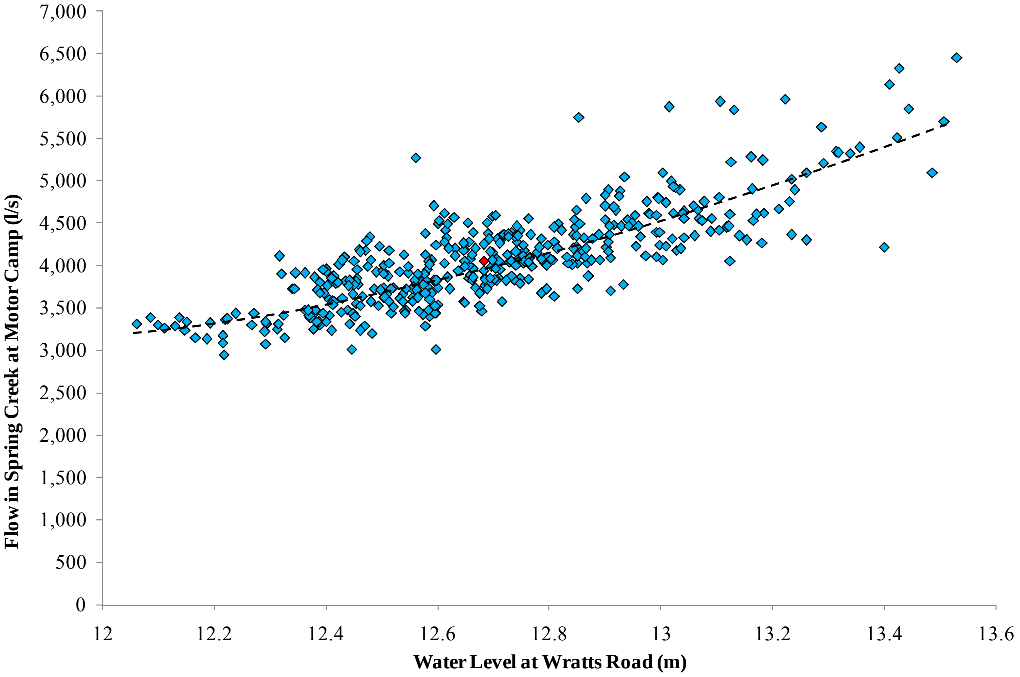

Figure 5 Relationship between Spring Creek flow and groundwater level

6 Conclusions

Over 700 l/s has been allocated from the Spring Creek catchment. This is about 25% of the observed low flow at the Motor Camp. The potential stream depletion effect of the total allocation is predicted to be large. However, the pumping impact on flow at the Motor Camp is small compared to the flow.

Most of the information available for Spring Creek is from the recorder at the Motor Camp which is situated in the middle reaches of the catchment. This information has been important for establishing relationships between groundwater levels and discharge to the springs. However, there is very little information available on the more vulnerable upper reaches of the catchment.

The headwaters of the Spring Creek catchment are far more sensitive to groundwater abstraction than the flow record for the Motor Camp indicates. If any system of managing groundwater and surface water allocation is to be adopted in the catchment, it needs to protect the flow and extent of these more vulnerable headwaters.

Simulations indicate that the stream depletion response in the leaky-confined aquifer is rapid, and these bores can essentially be considered to be surface takes. Bores in the unconfined aquifer can also be considered to be effectively surface takes if they are within 500m of a spring channel. Beyond 500m, the hydraulic linkage with the stream becomes more delayed, creating a more subdued response.

Managing the most direct effects could be achieved by local controls on a relatively small number of consents. This could either be achieved with regular flow monitoring, or by water levels at Selmes Road. The latter requires relationships to be made between flow and water level in the Selmes Road well. The most vulnerable reaches are Roses Creek (11 consents) and Ganes Creek (7 consents). Allocation in these two catchments could be clawed back if possible to protect these streams.

There are three items of valuable information that can be gathered to improve our understanding of the Spring Creek system:

- More gaugings for Roses, Dentons, Ganes, and Spring Creek unconfined reach
- Mapping the position of the seepage face through time
- Installation of a logger in the MDC Selmes Road well

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