PATTLE DELAMORE PARTNERS LTD
295 Blenheim Rd, Upper Riccarton, Christchurch
PO Box 389, Christchurch, New Zealand

Tel: +3 **345 7100** Fax: +3 **345 7101**
Web Site **http://www.pdp.co.nz**
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Memorandum

TO: Marlborough District Council

ATTENTION: Peter Davidson

FROM: Peter Callander

DATE: 25 November 2014

RE: MDC Wairau Aquifer Riparian Margins Hydraulic Properties and Alluvial Aquifer Structure

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Your email to us on Friday 14 poses three questions. Our responses are set out below.

Question 1. Aquifer test analyses near the Wairau River show low values for the aquifer storage coefficient. What do the low storage values represent physically in terms of the structure, porosity and homogeneity of the sediments?

It is important to recognise that when a bore is first pumped, water is initially released from elastic storage, which has a very low storage value (commonly around 1×10^{-4}). With prolonged pumping the drawdown effect propagates to the water table and drainage of the pore space at the water table commences and is defined by the term specific yield. However many aquifer tests do not continue long enough to accurately determine the specific yield, or the background water level fluctuations are sufficiently large as to mask the true drawdown response during the middle and later stages of a test. As a result, many aquifer tests do not provide a unique or accurate determination of specific yield. The different components of the water level response to pumping are shown in the following plot (Figure 1).

It is also worth recognising that the aquifer test solutions assume homogeneous and isotropic conditions, whereas the reality of the strata in the Wairau aquifer is a heterogeneous arrangement of gravel with various finer grained sandy and silty strata that is likely to exhibit anisotropy in the vertical direction and possibly horizontally too.

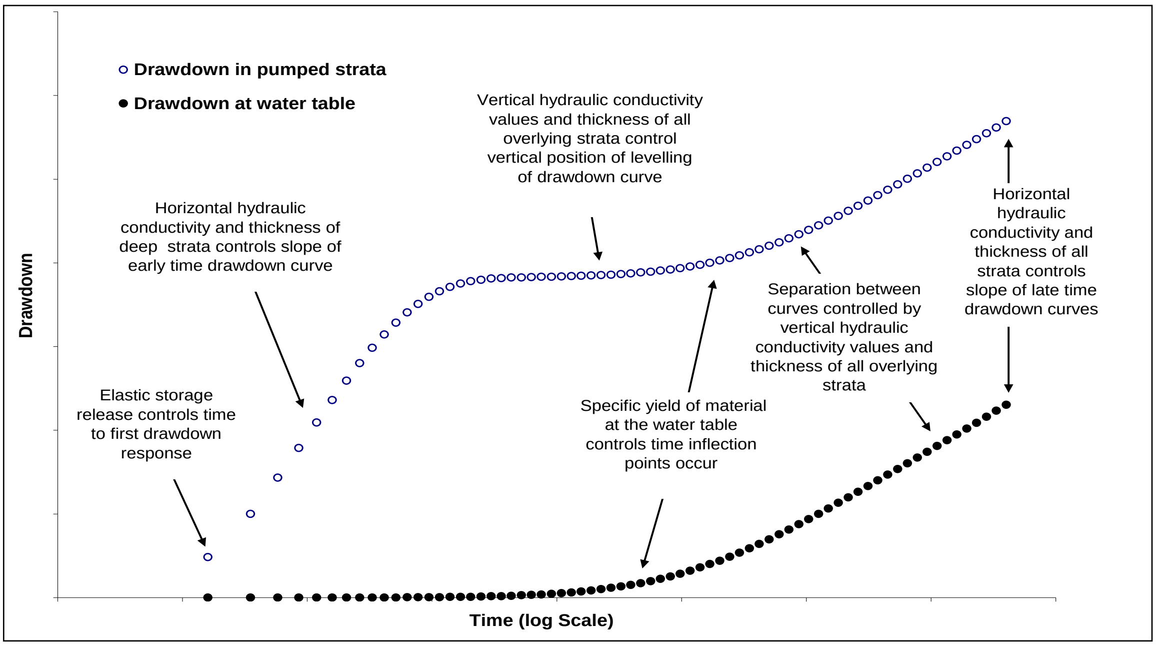


Figure 1: Drawdown sensitivity to hydrogeological parameters of a layered system with pumping from a semi-confined aquifer (from Lough and Williams (2009))

For the test data we have recently sent you, we have the following comments about the reported storage values:

- May 2001, Montana bore, screened from 23.5-27.5 m deep. The drillers log shows some clay above the screen. Whilst a reproduction of the drawdown was achieved with a storage coefficient of 1 x 10^{-4} the report states: “Due to the fact that drawdown was only measured in the pumping well, these parameters are very much of an approximate nature.”

  Therefore, that storage value cannot be taken as representing the specific yield, but it is a realistic value for the initial elastic release of water from storage.

- December 2009, Oyster Bay bore screened from 26.01-29.01 m deep. Aquifer parameters were derived from the observation wells, and the storage values and some other monitoring bore details are summarised below.

Observation Well	P28w/3162	P28w/3161
Screened Depth	16.51-19.51	17.3 – 20.3
Distance from Pumped Well	13 m	173 m
Storage Coefficient (S)	4 x 10^{-3}	7 x 10^{-4}
Specific Yield (S_y)	0.15	7 x 10^{-3}

There is some uncertainty in these parameters due to the vertical offset between the screened section of the pumped bore and the shallower observation bores. The nearest observation bore, P28w/3162, defines realistic parameters. The more distant observation bore, P28w/3161, gives a lower than expected specific yield, which may reflect silty strata above the screen in the area of that observation bore.

- September 2014, Matua bore, screened from 16.48-19.21 m deep. This test indicated an elastic storage coefficient of 8 x 10^{-5} and a specific yield of 0.02 – 0.03.

In terms of the specific yield, which represents water table drainage, these three tests indicate values ranging from 0.007 to 0.15. The higher end of this range represents typical text book values for an unconfined aquifer. The lower values are representative of some partial release of water from storage rather than full drainage of the pore space at the water table. This could be due to low permeability silty sediments overlying the depth of the pumped bore screen in the general area of the pumping test and at the water table, or could indicate a test where the longer term drawdown effect is not clearly established due to background water level fluctuations.

In general, we expect the strata exhibits considerable heterogeneity with the occurrence of lower permeability silty and sandy lenses amongst the gravelly strata. The information from the pumping tests is consistent with this, but does not provide any specific definition of the pattern of the strata due to the variability in the testing and the difficulty of determining long term drawdown relative to background water level fluctuations during testing.

Question 2. If longitudinal hydraulic conductivity is much higher than lateral K and many magnitudes higher than vertical K, is this sufficient to explain why the level of the Wairau River is perched around 3 m above the surrounding groundwater and is the Waimakariri River perched above local groundwater?

I don't think it is unusual for the general aquifer groundwater level to be at a different level to the river. The river level is determined by the river flow, channel shape and slope within which the water can move with significantly less impedance than it can through the strata within a groundwater system. Similarly within the active riverbed there is a zone of permeable gravels which are regularly re-worked and mobilised at high flows. At greater depths and widths beyond the channel there is likely to be a build-up of more silty strata in the zone of strata that is not mobilised at time of high flow. The Waimakariri River has levels above the surrounding groundwater, as shown by the separate dashed contours on the following piezometric map.

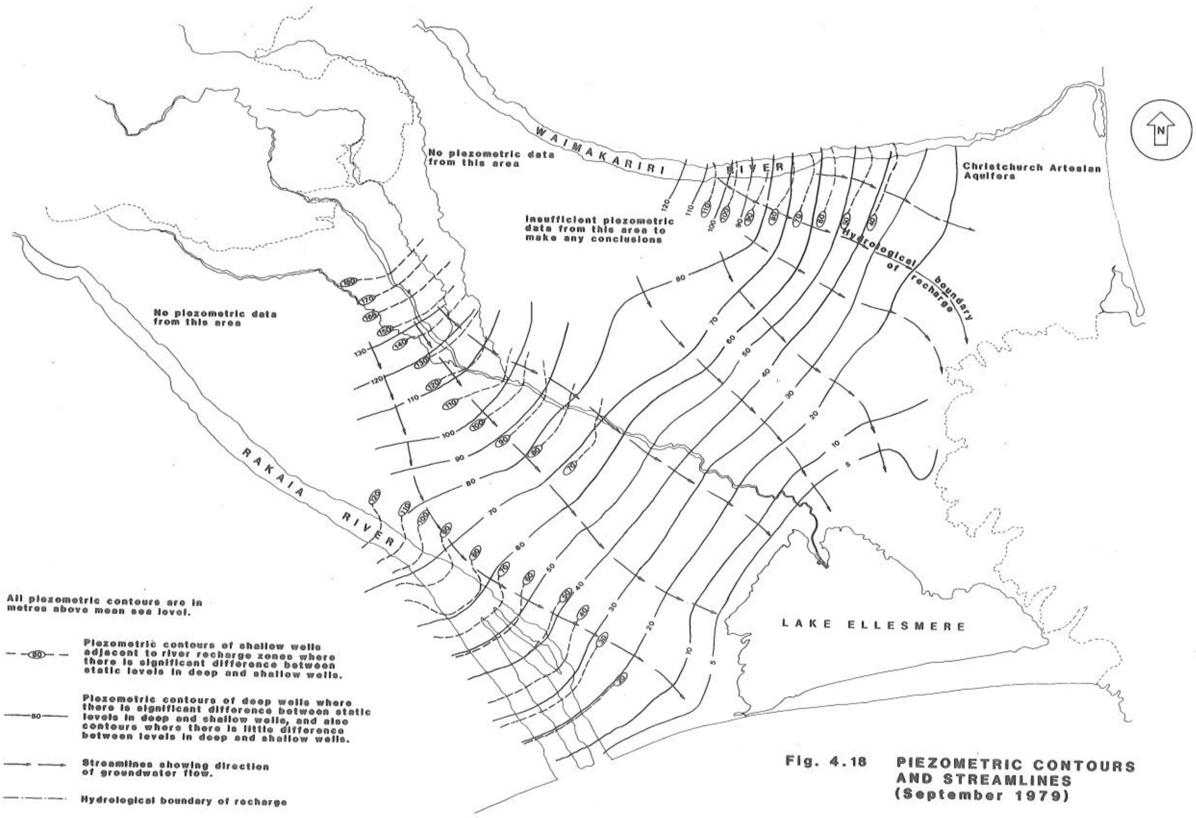


Fig. 4.18 PIEZOMETRIC CONTOURS AND STREAMLINES (September 1979)

The separation of the active river channel within its mobile bed has been postulated with an encapsulating silty layer, as shown in the schematic drawing at the end of this memo.

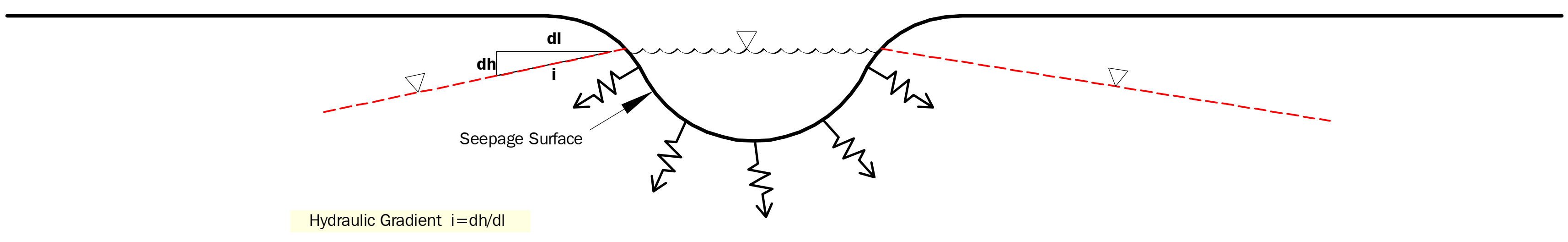
Therefore, the concept of the river being at a higher elevation than the surrounding aquifer that it recharges is not unusual. It could be achieved by the general impedance to flow provided by the strata and the anisotropic characteristics of hydraulic conductivity, as indicated by the question, but the development of a silty layer just outside of the mobile zone of river channel strata can also contribute to the different elevations between the river and the nearby strata.

Question 3. There are indications of two distinct layers of sediments. Is this a local phenomenon or does it correlate with the boundary between the Holocene and Pleistocene sediments and which represents the main hydraulically connected layer with the Wairau River recharge flow assuming it is perched all the way to SH1?

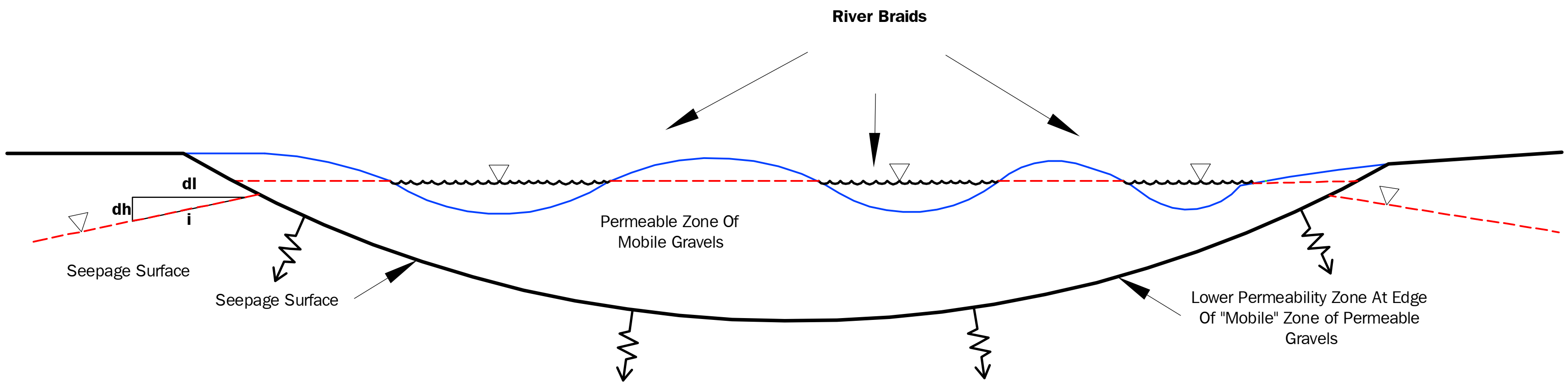
The occurrence of a shallower permeable layer associated with recent river bed gravels, underlain by a silty zone which provides separation from an underlying permeable gravel zone could be an indication of the type of arrangement shown in the schematic drawing at the end of this memo, if it occurs close to the current day river bed, as occurs in the Matua aquifer test situation. It is difficult to be certain about whether this is a continuous or localised situation or whether it represents a consistent boundary between the strata of different geologic ages. Whether or not the river is perched above the adjacent groundwater should be determined by water level elevation surveys. If the river levels are sitting at a higher elevation then that is not unusual. The likely reason for the higher elevation is due to some impedance of seepage flow into the adjacent aquifer, likely caused by a combination of anisotropy and the occurrence of silty lenses or layers, some of which will have developed due to river processes affecting the zone immediately below the mobile gravel bed.

The storage values from the aquifer tests provide an indication that there are lower permeability silty and sandy lenses at shallower depths in the area adjacent to the Wairau River, although that is also shown by the drillers logs. However the aquifer tests do not provide definitive proof of a continuous aquitard being present in the area.

STREAM — AQUIFER INTERACTION



(a) Typical River Aquifer Recharge Model



(b) Braided River Aquifer Recharge Model

Schematic Diagram Of River Seepage To Groundwater