Groundwater age gradient to infer flow rates, hydraulic parameters, aquifer abstraction limits, and storage in the Wairau Plain, New Zealand

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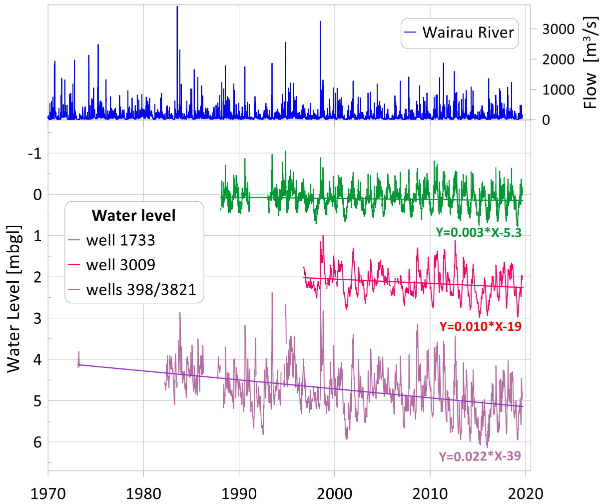
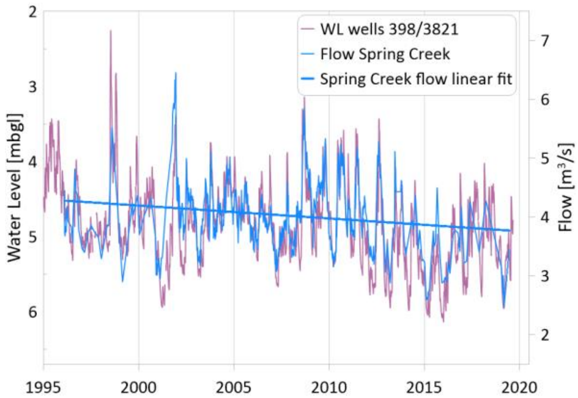
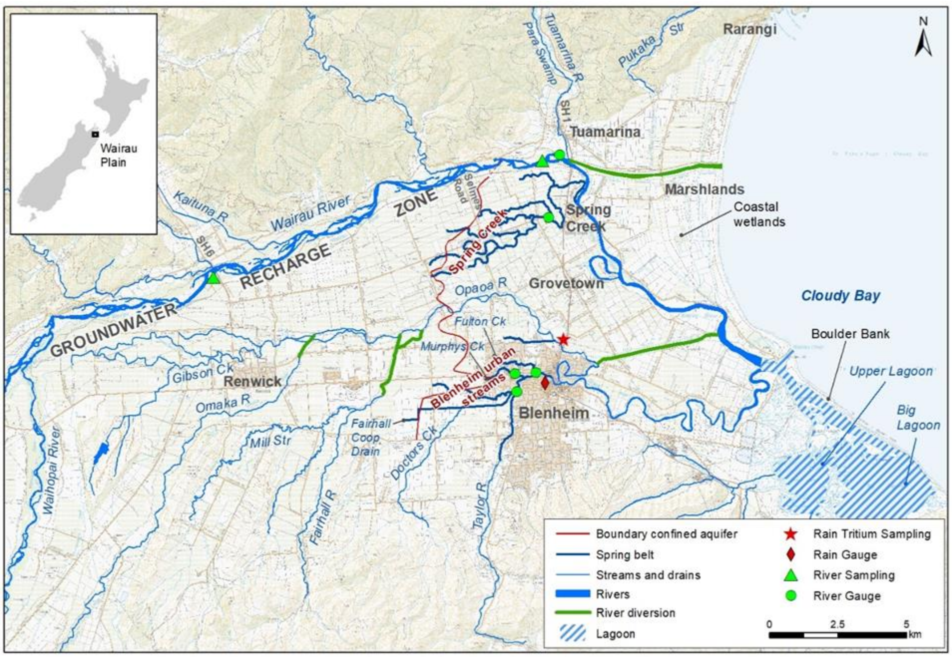
Groundwater is an important source of water for the Wairau Plain, and there is concern about its sustainable yield because of declining water levels and spring flows in the Wairau Fan.

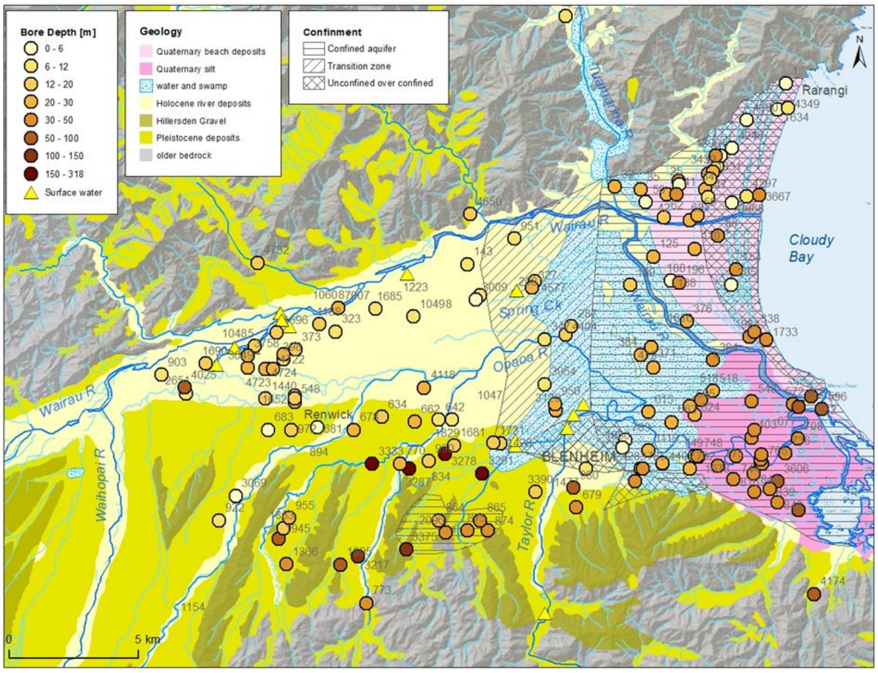




The Wairau Fan is comprised of highly permeable fluvial gravels. The main source of groundwater is loss from the Wairau River channel.

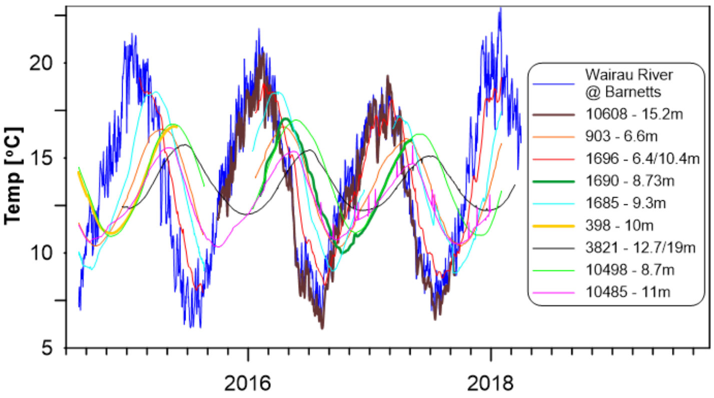


The underlying Pleistocene gravels form a significantly less permeable aquifer. Near the coast, estuarine sediments form an aquiclude over the Pleistocene gravels.

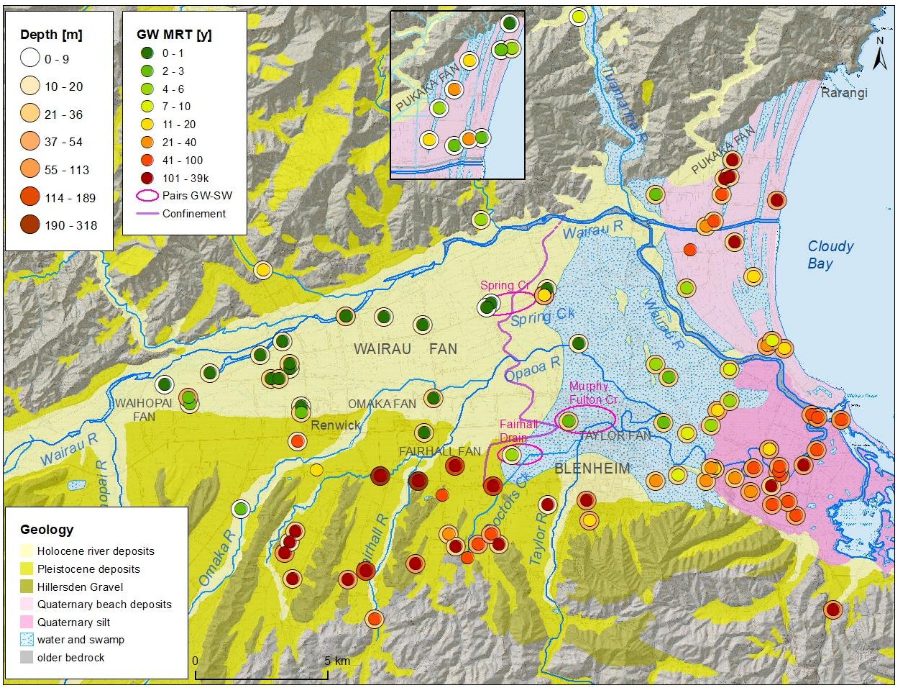


The main groundwater flow from the gravel fan is forced back to the surface near the confinement boundary feeding highly valued streams with crystal-clear water but declining flow.

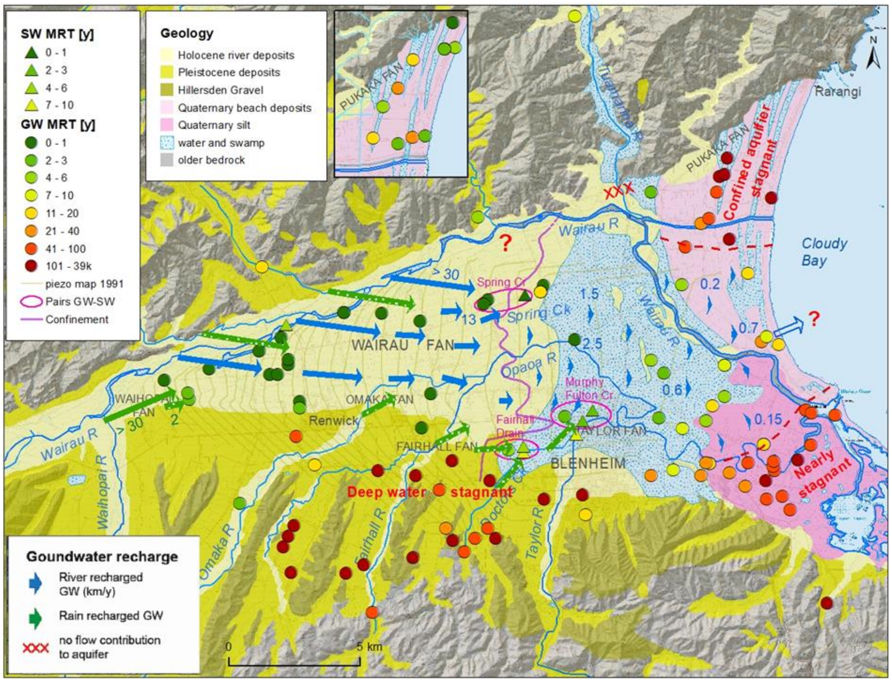
To understand the flow dynamics of the groundwater, we utilised tritium, SF6, and 14C. For the extremely young groundwaters in the unconfined Wairau Fan, <1 year, we developed a dating method that traces the seasonal river temperature variability through the aquifer. The lags of the temperature synodal signal were calibrated to true age via the 18O synodal signal.



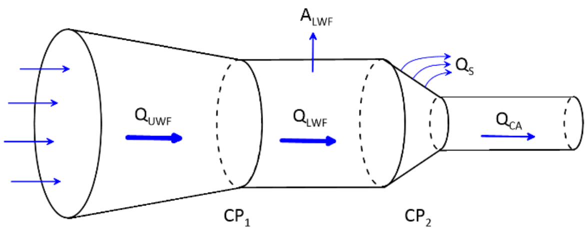
All groundwaters within the Pleistocene gravels are very old, >100 years, and up to 39,000 years in the Deep Wairau Aquifer. In contrast, throughout the unconfined Wairau Fan we observed only very young groundwater, with mean residence time of 0–1 years, even in the deeper wells of >20 m.



Flow rates estimated from groundwater age gradients show that in its upper part the unconfined Wairau Fan is well connected to the Wairau River. Extremely high flow rates of up to > 30 km/y in this area indicate extremely high hydraulic conductivity in these Holocene deposits near the river. Towards the coast, the flow rates reduce considerably, to 13 km/y at around the boundary of the confinement, thereafter slowing further to 0.7 km/y near the coast. The reduction in flow rate near the coast, by a factor >20, is related to the flow loss from the aquifer, mainly to the spring belt and through abstraction.



Hydraulic conductivities, derived from the flow rates, are c. 12,000 m/day in the unconfined Wairau Fan near the river and in the central part of the unconfined Wairau Fan. Near the coast the estimated hydraulic conductivity is 800 m/day. Despite relatively uniform hydraulic conductivities, the Wairau Fan becomes less transmissive downstream due to decreasing piezometric gradients. This is likely to cause the restriction in the flow system. The 'choking point' in the flow system of the unconfined Wairau Fan appears to be not the recharge zone near the river but the lower Wairau Fan due to its lower transmissivity by a factor of two.



Conceptualisation of the water flow through the Wairau Aquifer. The Wairau River loses approximately 7 m^3/s of water into the Wairau Fan. The Wairau Fan is well-connected to the river and the flow through the upper Wairau Fan Q_{UWF} could exceed the current flow. However, the lower Wairau Fan has a lower transmissivity by a factor of two, causing the first choking point (CP_1) and restricting the total flow to that of the flow through the lower Wairau Fan Q_{LWF}. At the start of the confinement, the flow becomes further restricted to that of the flow through the confined aquifer Q_{CA}, causing the second choking point (CP_2). The spring belt is the overflow of the unconfined Wairau Fan – of what does not fit through the confined aquifer, with the spring flow $Q_S = Q_{LWF} - Q_{CA}$. Abstraction in the lower Wairau Fan A_{LWF}, past the first choking point, cannot be compensated by additional recharge from the river, causing a decline in spring flow ($A_{LWF} = -\Delta Q_S$).

To understand the buffer of the entire system against prolonged drought, the mean transit time of the water through the Wairau River catchment was estimated from tritium time-series data to four years, and the active groundwater storage to approximately 6,200M m3. The Wairau catchment would be able to maintain baseflow in the river and the aquifer for several years.