Field investigation of surface water - groundwater interaction in a Canterbury Lowland Catchment

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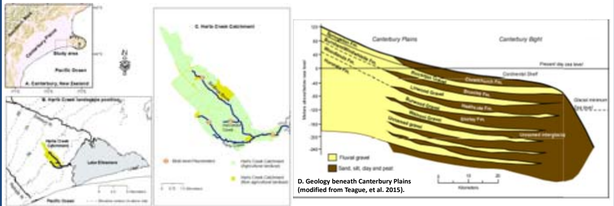
1 Introduction

This study focuses on complementary use of geologic, hydrogeologic and isotopic evidence to better understand and interpret the nature of groundwater-surface water interaction in the Harts Creek Catchment, South Island, New Zealand.

2 Study Area

Harts Creek catchment is located within the Lake Ellesmere/Te Waihora drainage basin in the lower Canterbury Plains on the east coast of South Island, New Zealand (Figures A & B). The catchment drains an area of about 23 km^2. Two major rivers, Rakaia and Selwyn bound the catchment to the north and south, respectively. Land use in the catchment (Figure C) is primarily agricultural with 60% for crop and seeds, 20% for beef and dairy, and 20% for other uses including pig and poultry and other miscellaneous uses. Mean annual precipitation over the study area is about 610mm with evapotranspiration accounting for approximately 92% (560mm) of the precipitation. Harts Creek has a minimum flow of 0.64 m^3/s in January (summer) and a maximum of 5.65 m^3/s in August (winter).



D. Geology beneath Canterbury Plains (modified from Teague, et al. 2015).

Hydrogeology: Taylor et al. (1989) provide a comprehensive summary of the geological strata of the Canterbury Plains noting faulted and severely jointed greywacke basement rock overlain by up to 1300m of undulating Cretaceous and Tertiary marine and estuarine sediments. These earlier deposits are overlain by 250m to more than 600m of Quaternary gravels that include early fluvial deposits derived from structural highs and Late Pleistocene coalescing fans of glacial and reworked outwash gravel. The surficial deposits have a gently eastward slope with a gradient of about 0.005 and form the regional groundwater recharge area as well as the major aquifer systems (Figure D). Rising sea levels during interglacial and postglacial periods deposited the intervening silt, sand and peat beds that confine the groundwater creating artesian aquifers in the catchment (Figure D). Groundwater in the area flows in a southeastward direction.

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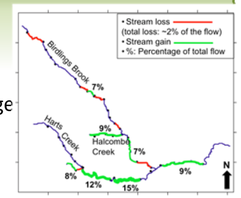
3 Observed streamflow gains and losses

Longitudinal streamflow gauging conducted during low flow conditions indicated several discrete areas of flow gain (green segments). The percentages indicate percentage of total flow from the particular stream segment. Relatively higher discharge zones were identified in either deeper sections of the stream caused by large topographic changes in the streambed or in localized discharge zones from artesian springs. Losing segments (identified in red) account for 1-2% of the total streamflow loss.



The finding has significant implications for water and land use management in the catchment. Groundwater discharge to the stream is highly localized and can be compared to "valves" in the system. For example, the catchment area for the small tributary that joins Harts Creek in the SW (Figure) accounts for only 1% of the total catchment but contributes to 8% of total flow. Any change in the output of these valves can have a significant impact on the quantity and quality of the streamflow.

4 Hydrostratigraphy and depth-specific groundwater sampling

The primary objective for the construction and installation of monitoring wells in the study area was to a) describe the lithologic heterogeneity and b) monitor groundwater chemistry through specific narrow depth intervals from isolated zones in the shallow aquifer system. Since groundwater chemistry in bedded deposits can vary markedly in vertical direction (i.e., a different source can occupy a small part of the total aquifer thickness), depth-specific groundwater samples were obtained using multilevel, single borehole piezometers (Photo).

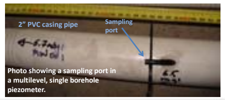
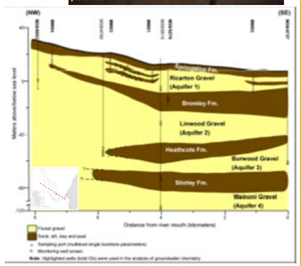


Photo showing a sampling port in a multilevel, single borehole piezometer.

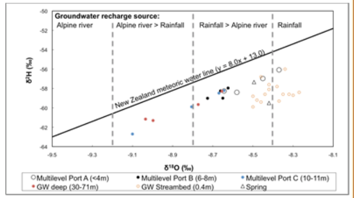
The design allowed us to collect representative samples from discrete zones in the aquifer and to accurately depict the vertical groundwater signature profiles. Older monitoring wells in the study area with long screens (1.5m to 3m) provided depth-integrated samples for deeper groundwater chemistry (data provided by Environment Canterbury Regional Council) . Detailed core sample analysis from the borehole piezometers as well as existing well logs were used to create the NW-SE hydrostratigraphic cross-section through Harts Creek catchment seen in the Figure (inset shows the location of the cross-section in the catchment).



5 Isotopic composition and source of groundwater

Measurements of Oxygen-18 (^{18}O) and deuterium (D) in the precipitation, rivers and groundwater of the Canterbury Plains date back to 1969. ^{18}O is a conservative, naturally occurring tracer that is extensively used to distinguish between river (alpine) and precipitation-recharged groundwater in the area (Stewart and Taylor, 1981; Taylor et al., 1989; Stewart et al., 2002). The approach relies on altitude effect, which results in depletion of ^{18}O in high-altitude precipitation. The Figure below shows the isotopic composition of groundwater in the study catchment and the range of potential recharge sources. The distinction between recharge sources is based on the δ^{18}O scale developed by Stewart et al. (2002), which helps distinguish alpine river-recharged groundwater (δ^{18}O more negative than –9.2‰) from more enriched precipitation recharged groundwater (δ^{18}O = –7.6 to –8.4‰) in the Canterbury Plains.

The presence of alpine-recharged groundwater in the shallow aquifer system suggests upward flow of deep groundwater through the aquitards, a conclusion that is extremely significant with regard to the potential effect that inland aquifer management can have on water resources in the study area.



The implication from this suggests that any impact from agricultural practices on the shallow groundwater within the study area will be dampened, unless the existing flow distribution is altered by excessive withdrawal further inland.

6 Conclusions

An understanding of the groundwater flow in a heterogeneous aquifer system is vital to proper management of surface and groundwater resources. This work indicates that while layered aquifer/aquitard system may provide some predictability to the flow, the heterogeneity in the system can have a major influence on the prevailing pressure gradients. The study shows the presence of deep alpine-recharged groundwater in shallow aquifer, which signify hydraulic connectivity and therefore potential impact to the lowland catchments that depend on deeper inland aquifers to maintain their flow.

7 References

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