Field and Numerical Investigation of Surface Water Groundwater Exchange Using Natural Heat as a Tracer - Deviation From the 1D Flow Assumption

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OBJECTIVE

To investigate the use of natural heat as a tracer for surface water groundwater interactions and to assess the effects of deviations from the 1D vertical flow assumption used in most analytical and numerical evaluations of streambed temperature data.

BACKGROUND

Groundwater resources have increasingly been developed in recent decades. Many streams and rivers which were previously base-flow fed now lose water to the underlying aquifers. A proper estimation of this exchange flux is necessary for management of water resources. Darcy's law is often used to do this but is limited in application by lack of knowledge of streambed and aquifer heterogeneities. Analysis of streambed temperature data appears to be a promising alternative.

A: Dimensions of temperature array. **B:** Installation in the streambed. **C:** DGPS positioning.

METHOD

Streambed temperature variations were investigated along the ephemeral Maules Creek in north central NSW, Australia. Arrays of five temperature probes were constructed from a PVC pipe perforated at 150 mm intervals corresponding to the location of the temperature probe thermistors (A). The arrays were installed in the streambed, with the uppermost probe at the sediment surface and subsequent probes at 15, 30, 45 and 60 cm depth (B and C). All probes recorded temperatures every 15 min from 29 August to 2 November 2007.

The collected temperature time-series data were filtered through a two-pass (forward/backward) Tukey Window Filter in order to retain only the diurnal temperature variations. The filtered data were then analysed using the method of Hatch et al. (2006) which considers the amplitude ratio and phase lag between pairs of time-series data to obtain two independent and time variable vertical flow estimates.

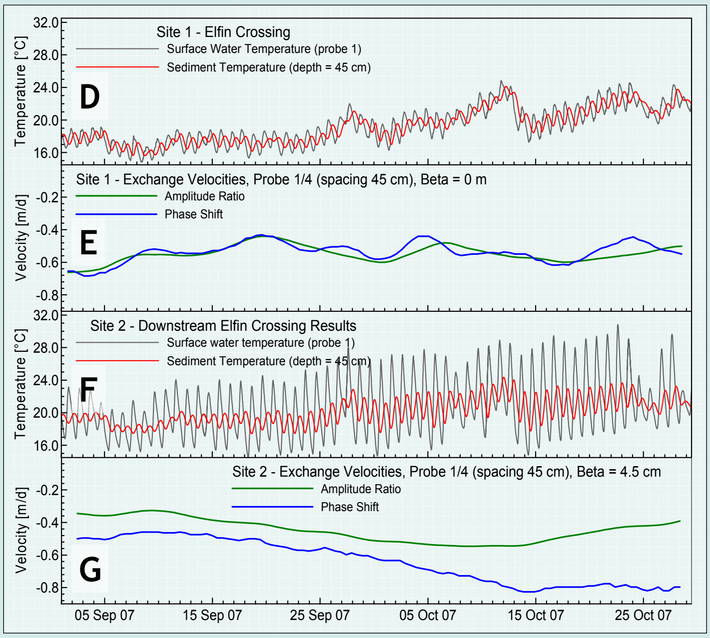
Finally 2D numerical modelling of heat and groundwater flow was conducted in VS2DI (Hsieh et al., 2000) to evaluate the effects of deviation from 1D vertical flow and the effects of heat dispersion.

RESULTS

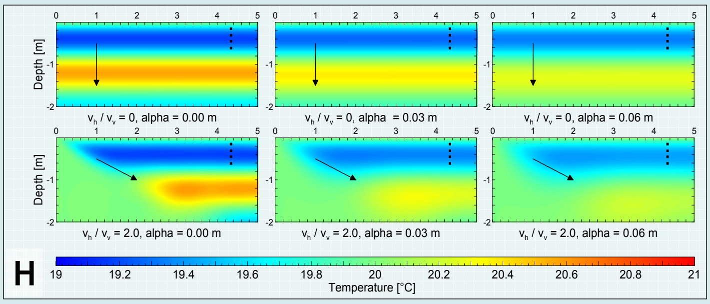
Shown in D to G are the results for two locations on Maules Creek. At the first location the independent velocity estimates based on amplitude ratio and phase lag are consistent, with an average value of approximately 0.6m/day downwards (E). At the second the two estimates appear to be diverging (G). The numerical modelling (H and I) suggests that increasing divergence is a function of increasing deviation from vertical flow and increasing dispersion.

CONCLUSION

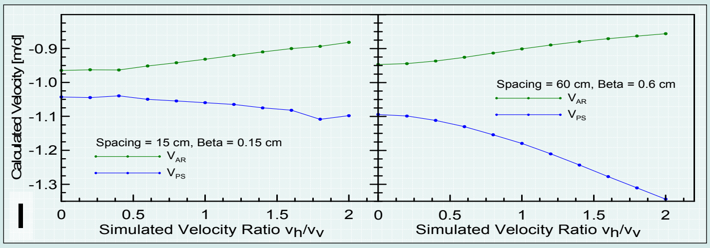
This study has illustrated the usefulness of using heat as a natural tracer to understand surface water groundwater interactions. The results suggest, however, that while significant information about exchange fluxes can be extracted from streambed temperature data, caution is required when flow deviates from the 1D assumption implicit in most analytical and numerical methods.



D: Site 1 Surface water temperature and streambed temperature at 45 cm. **E:** Exchange velocities at 45 cm based on amplitude damping and phase lag at Site 1. **F:** Surface water temperature, streambed temperature at 45 cm at Site 2. **G:** Exchange velocities at 45 cm based on amplitude damping and phase lag at Site 2.



H: Numerical simulation of heat transport in a 2D section of stream bed with variable degree of horizontal flow and dispersivity (α) using VS2DI.



I: Amplitude and phase lag velocities calculated for the simulated temperature data for variable degrees of horizontal flow and dispersivity.

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MORE INFORMATION

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