Quantitative Analyses of Groundwater Flow from Thermal Tests and Temperature Logs

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Temperature-time curves recorded during thermal tests in borehole heat exchangers are commonly analysed with the infinite line source (ILS) model assuming a purely conductive thermal regime. Results can be biased by the possible occurrence of groundwater flow. We investigated this flaw by simulating temperature-time signals with a moving line source (MLS) model under different hypothesis of Darcy velocity. A random noise was included in the synthetic data obtained with the MLS model in order to mimic high-frequency disturbances caused by several possible sources (e.g. testing conditions and geological variability) that often occur in real signals. The subsurface thermal conductivity, the Darcy velocity and the borehole thermal resistance were inferred by minimising the root mean square error between the synthetic dataset and the model. The calculated thermal and hydraulic parameters were consistent with the "a priory" values. The optimisation procedure was then tested with synthetic signals originated by the ILS model. For a Darcy velocity exceeding 10^{-7} m s^{-1}, it turns out that ILS largely overestimates thermal conductivity. The approach relying on the MLS model was finally tested on temperature-time data from boreholes drilled in sedimentary aquifers. This produced reliable estimates of thermal conductivity, Darcy velocity and borehole thermal resistance. The magnitude of the inferred groundwater flow was checked by means of an independent method based on the analysis of temperature-depth logs recorded under thermal equilibrium conditions. The matching of thermal logs with analytical models incorporating both heat and mass transfer gave Darcy velocities in agreement with those inferred from the analysis with the MLS model.

Keywords:, thermal response test, Thermal conductivity, Darcy velocity, shallow aquifer