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Data Analysis and Simulation of In-Situ Permeable Flow Sensors for Measuring Groundwater Velocity

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We have monitored data from three Hydrotechnics® in-situ permeable flow sensors (ISPFSs) installed in a shallow aquifer at the former Fort Ord Army Base near Monterey, California. The in-situ permeable flow sensor operates by constant heating of a nearly one-meter-long, 5 cm diameter cylindrical probe which contains 30 thermistors in direct contact with the formation that has fully collapsed around the instrument during installation. The temperature evolution at each thermistor can be inverted to obtain an estimate of the groundwater flow velocity vector (i.e., horizontal and vertical components, and azimuth). The unconfined aquifer we monitored is in unconsolidated dune sand bounded below by a clay aquitard. The magnitudes of the vertical velocities were expected to be much less than the horizontal velocities at this site because of the underlying clay layer. However, standard data analysis of the ISPFS data suggested a strong and unexpected component of downward flow. We have carried out numerical simulations with TOUGH2 of three-dimensional non-isothermal flow around the instrument to investigate temperature profiles along the instrument that might give rise to spurious indications of downward flow. We studied the effects of different combinations of permeability and thermal conductivity around the instrument. A decrease in the thermal conductivity or permeability of the formation near the bottom of the sensor can perturb the temperature profiles along the instrument in such a manner that the temperature shift could be interpreted as downward flow. The TOUGH2 simulations demonstrate that estimates of downward velocities from the flow sensors should be interpreted with caution and compared with estimates from other methods if possible.

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