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Laboratory and Field Test of Heat-Pulse Flowmeter for Characterizing Heterogeneous Aquifer and Fracture Flow

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Heat-pulse flowmeter is a developing logging tool for measuring the flow velocity in a borehole under a constant pumping or injection rate. A water circulation system was established to evaluate the measurement of flow velocity through a pipe by a heat-pulse flowmeter in the laboratory. The measured flow velocity was estimated based on forced convection, which is considered the major mechanism to drive the heat flow during the measurement. Test results indicate that the measured flow velocity is generally faster than the averaged flow velocity. As the flow velocity decreases, the coefficient of variation of repeated measurements decreases, but the measurement error increases. We found the error resulted primarily from free convection, which plays an important role in driving the heat flow at a low flow velocity. Based on the laboratory test data, an empirical formula was developed for calibrating the measured flow velocity.

Field measurements using heat-pulse flowmeter were then conducted in three test sites. First two sites are in an alluvial heterogeneous aquifer to characterize the distribution of hydraulic conductivity along the well screen. The vertical flow velocity was measured at an interval of 25 cm or 50 cm along the wellbore. Measurement result at the first site indicates that groundwater flow is concentrated in two highly permeable sections. Their horizontal hydraulic conductivities are 3.7 to 6.4 times greater than the equivalent hydraulic conductivity of the whole aquifer. The heat-pulse flowmeter was conducted in two pumping rates at the second site. The measurement result indicated a vertical natural flow in the well and the existence of different hydraulic heads in the screened range. The other field test was conducted in a 150-m deep open-hole in the fractured rock formation to characterize the preferential flow pathway. Integrating the results of flowmeter measurement with the information obtained from various hydraulic tests and well loggings, several flow pathways were identified. The position of the highly permeable fracture zone can be delineated within the range of 25 cm. Evidently the heat-pulse flowmeter can characterize the position of permeable zones or fracture flow paths efficiently.