Groundwater flow and transport parameter estimation in a 2D laboratory-scale sand tank aquifer

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Abstract

Estimation of field representative groundwater flow and transport parameters is extremely difficult, mostly due to aquifer heterogeneity and to the local investigation scale of most characterization methods. The objective of this work was to estimate groundwater flow and transport parameters in a 2D laboratory scale sand tank. These controlled conditions are ideal to study the uncertainty associated with laboratory parameter estimation techniques and the need to upscale some of these parameters for field applications.

Five homogeneous sands are used in this study. Hydraulic conductivities (K) calculated from the Hazen equation vary from 0.04 to 0.63 cm/s. The main experimental device is a 2 m x 1.32 m x 0.25 m Plexiglas tank. The tank was filled with a spatially variable matrix of 0.04 m x 0.04 m x 0.25 m blocks of the five individual sands. The variability was structured using an exponential variogram, providing a low heterogeneity aquifer. In the sand tank, groundwater flows between two pre-determined constant heads. The sand tank is also equipped with a rain simulator to simulate recharge and when this is in use, groundwater flows towards both outlets. Groundwater flow experiments were performed on the heterogeneous aquifer using different hydraulic gradients. Heads were measured manually through 200 pressure tubes from the bottom of the tank and flow rates were measured at the tank outlets. Tracer tests were performed by constantly injecting a 2 g/l NaCl solution either at the upgradient limit or in the recharge. Tracer concentrations were measured at the outlets (average outflow concentration) and in 18 regularly spaced wells located at 25 and 15 cm depths in the sand tank. The flow and transport experiments were simulated numerically using Modflow and MT3DMS. K and dispersivities (α) of the five sands were estimated for 0.43 m x 0.25 m x 0.25 m samples on which the Darcy experiment (i=0.01) and a constant injection tracer test (2 g/l NaCl) were performed.

The flow experiments (with and without recharge) show that the K value necessary to reproduce measured heads and flows is reasonably similar to the equivalent K calculated using the geometric average of measured K values for the sand blocks matrix. The α estimated from restitution curves at the outflow face is approximately 35% larger than α values measured on the sand samples. Results from the numerical model show that K values for the individual blocks needed almost no calibration to simulate the spatial distribution of measured heads in all experiments. The calibrated α values necessary to reproduce measured concentrations are 30-60% larger than those measured on the sand samples. This was expected as α is largely influenced by the distance traveled by a tracer. These results show that laboratory estimation of hydraulic conductivities can be quite reliable when estimated at different scales. Dispersivities must be measured at scales as close as possible to the field representative elementary volume.

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