A new inverse method for the simultaneous estimation of aquifer thickness and boundary conditions based on borehole and hydrodynamic measurements

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Abstract. A new inverse method is developed to simultaneously estimate aquifer thickness and boundary conditions using borehole and hydrodynamic measurements from a homogeneous confined aquifer under steady-state ambient flow. This method extends a previous groundwater inversion technique which had assumed known aquifer geometry and thickness. In this research, thickness inversion was successfully demonstrated when hydrodynamic data were supplemented with measured thicknesses from boreholes. Based on a set of hybrid formulations which describe approximate solutions to the groundwater flow equation, the new inversion technique can incorporate noisy observed data (i.e., thicknesses, hydraulic heads, Darcy fluxes or flow rates) at measurement locations as a set of conditioning constraints. Given sufficient quantity and quality of the measurements, the inverse method yields a single well-posed system of equations that can be solved efficiently with nonlinear optimization. The method is successfully tested on two-dimensional synthetic aquifer problems with regular geometries. The solution is stable when measurement errors are increased, with error magnitude reaching up to +/- 10% of the range of the respective measurement. When error-free observed data are used to condition the inversion, the estimated thickness is within a +/- 5% error envelope surrounding the true value; when data contain increasing errors, the estimated thickness become less accurate, as expected. Different combinations of measurement types are then investigated to evaluate data worth. Thickness can be inverted with the combination of observed heads and at least one of the other types of observations such as thickness, Darcy fluxes, or flow rates. Data requirement of the new inversion method is thus not much different from that of interpreting classic well tests. Future work will improve upon this research by developing an estimation strategy for heterogeneous aquifers while drawdown data from hydraulic tests will also be incorporated as conditioning measurements.