General Guidance Concerning Inverse Modeling Techniques and Value of Field Data Types for Seawater Intrusion Simulation

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EXTENDED ABSTRACT

In coastal aquifers subject to seawater intrusion, measurements of fluid pressure and concentration may be used to determine the parameters of a ground-water model of the aquifer system, which may then be used to manage the water supply. Due to the complexity of aquifer systems and the nonlinear nature of seawater intrusion physics, manual calibration is often not feasible. This necessitates having a capability to calibrate a numerical model with an automatic inverse algorithm. Automatic inverse modeling, also called parameter estimation, has become a standard tool for ground-water flow models, though there have been fewer applications to modeling of heat or solute transport, and even fewer for inverse modeling of variable-density fluid flow and solute transport, the basis of seawater intrusion into aquifers. This paper presents insight into practical difficulties and general guidance concerning inverse modeling techniques for seawater intrusion gained from analyses of basic 2D-inverse problems: the classic Henry variable-density ground-water model benchmark (Sanz and Voss, 2005) and the Aquiferia problem, a hypothetical coastal multi-aquifer system.

For inverse modeling, simultaneous use of different types of field observation data can improve ground-water model structure, features, and parameter values. With regard to coupled flow and transport modeling, there can be some advantages to concurrent use of both hydraulic head (or pressure) and concentration (or temperature) data for model refinement and parameter estimation. Transport always depends on flow, thus, for both constant- and variable-density flow, measurements of concentration can be used to help estimate classical flow-model parameters such as hydraulic conductivity. When flow processes depend on transport processes, such as in variable-density flow, measurements of pressure can provide information to help estimate transport parameters such as dispersivity that are normally assumed to be estimatable only from measurements of concentration.

Study of spatial distributions of sensitivities in an aquifer system (change of observed pressure and concentration as a function of parameter values) allows some important aspects of the value of various types of data to be explained. Sensitivities of pressures and concentrations are mapped for both the Henry problem and for a more-realistic coastal aquifer system, showing where the most information can be measured for each parameter. Except for permeability, which is most strongly estimated from measurements at greater distance from the sea, all other parameters are most strongly estimated when based on data collected in the freshwater-seawater transition zone. Sensitivity maps can also indicate which parameters can be independently estimated.

Estimation is usually a process that requires the modeler to work through a series of inverse modeling attempts to estimate different sets of parameters for the system, possibly using different subsets of observations, when early attempts are not successful or are somehow unsatisfactory. Early attempts often involve estimation of too many parameters (some of which are co-dependent), leading to non-convergence of the inverse iteration process or to weak estimates. Co-dependence is demonstrated for parameters of the simple Henry problem, for which these relations are known a-priori from its semi-analytical solution. For more complex

inverse problems with initially unknown parameter co-dependence, a procedure that is demonstrated successively eliminates co-dependent estimated parameters in the series of attempts, providing a way forward.

Inverse modeling is carried out using software that combines the US Geological Survey SUTRA code (Voss and Provost, 2002) for variable-density ground-water flow, UCODE (Poeter and Hill, 1998; Poeter and others, 2005) for managing the inverse calculations, and SutraGUI (Winston and Voss, 2004), which provides a convenient graphical interface for setting up inverse simulations.

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