Bayesian and maximum entropy inversion of highly heterogeneous aquifers

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The Bayesian inverse approach proposed by Woodbury and Ulrych (2000) is extended to estimate the transmissivity fields of highly heterogeneous aquifers for steady state groundwater flow. A first-order approximation of Taylor's series for the exponential terms introduced by sinks and sources or Neumann conditions in the governing equation is adopted. Such a treatment leads to a linear finite element formulation between hydraulic head and logarithm transmissivity [denoted as ln (T)] perturbations. The new inversion algorithm is examined against generic examples. It is found that the linearized partial difference equations yield acceptable head approximations for ln (T) variance up to 9 for the test case. The addition of the hydraulic head data is shown to improve the ln (T) estimates, in comparison to simply interpolating the sparse ln (T) data alone.

The Bayesian approach is subsequently applied to the calibration of the Edwards Aquifer. This aquifer is a highly heterogeneous karst aquifer located in south central Texas, and is the sole source of drinking water for more than one million people. Hydraulic conductivity (K) measurements in the Edwards Aquifer are sparse, highly variable (log-K variance of 6.4), and are mostly from single-well drawdown tests that are appropriate for the spatial scale of only a few meters. To support ongoing efforts to develop a groundwater management (MODFLOW) model of the San Antonio segment of the Edwards Aquifer, a multi-step procedure was developed to assign hydraulic parameters to the 402 m × 402 m computational cells intended for the management model. The approach used a combination of nonparametric geostatistical analysis, stochastic simulation, numerical upscaling, and automatic model calibration based on Bayesian updating. The posterior ln (T) field from this application yields a better hydraulic head fit when compared to the prior ln (T) field determined from upscaling and co-kriging. We believe that traditional MODFLOW grids could be imported into the new Bayes inverse code fairly seamlessly and thereby enhance existing calibration of many aquifers.