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Calibration of the hydrogeological model of the Baltic Artesian Basin

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Let us consider the calibration issue for the Baltic Artesian Basin (BAB) which is a complex hydrogeological system in the southeastern Baltic with surface area close to 0.5 million square kilometers. The model of the geological structure contains 42 layers including aquifers and aquitards. The age of sediments varies from Cambrian up to the Quaternary deposits. The finite element method model was developed for the calculation of the steady state three-dimensional groundwater flow with free surface. No-flow boundary conditions were applied on the rock bottom and the side boundaries of BAB, while simple hydrological model is applied on the surface. The level of the lakes, rivers and the sea is fixed as constant hydraulic head. Constant mean value of 70 mm/year was assumed as an infiltration flux elsewhere and adjusted during the automatic calibration process. Averaged long-term water extraction was applied at the water supply wells.

The calibration of the hydrogeological model is one of the most important steps during the model development. The knowledge about the parameters of the modeled system is often insufficient, especially for the large regional models, and a lack of geometric and hydraulic conductivity data is typical.

The quasi-Newton optimization method L-BFGS-B is used for the calibration of the BAB model. Model is calibrated on the available water level measurements in monitoring wells and level measurements in boreholes during their installation. As the available data is not uniformly distributed over the covered area, weight coefficient is assigned to each borehole in order not to overestimate the clusters of boreholes. The year 2000 is chosen as the reference year for the present time scenario and the data from surrounding years are also taken into account but with smaller weighting coefficients. The objective function to be minimized by the calibration process is the weighted sum of squared differences between observed and modeled piezometric heads. The parameters of the calibration are the horizontal and vertical hydraulic conductivities of the hydrogeological layers, which are assumed uniform throughout the whole individual layer. The initial values of conductivities are taken from the available field pumping test measurements or based on the lithology of individual hydrogeological layers.

The allowed variation range (multiplicative coefficient applied to respective initial parameter value) of conductivities for all layers and of infiltration rate is from 0.01 to 100 times. The minimization of objective function converges in several hundreds of iterations and the mean squared difference in one layer is 7 m. The ratio between the horizontal and vertical conductivity is kept fixed in each optimization run and the effect of different ratios on objective function is shown. The influence of initial values of hydraulic conductivities on the objective function is analyzed. The calibration results are validated using different data sets for calibration and validation.

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