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Mathematical model of the Baltic artesian basin

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Baltic artesian basin (BAB) is a multi-layered and complex hydrogeological system underlying about 480'000 km2. BAB fully covers the territory of Latvia, Lithuania and Estonia, parts of Poland, Russia, Belarus as well as large area of the Baltic Sea, including island of Gotland. The thickness of sedimentary cover reaches 5000 m in the south-western part, while crystalline bedding reaches the surface in the northern part. There are several local modelling studies of ground water flow in Poland, Estonia, Latvia and Lithuania. The aim of the present work is development of a closed hydrogeological mathematical model of the whole BAB.
A lot of information is available on the geological structure of BAB. However, it is a challenge to unify the heterogeneous information from different sources, which are employed for building of the geometrical structure of the model. Such information includes:
(1) Maps of height isolines of geological layers for Latvia and Lithuania
(2) Maps of sub-quaternary deposits in Latvia and Lithuania
(3) Maps of fault lines on the basement surface
(4) Stratigraphic information for the Latvian boreholes (around 20'000)
(5) Layers from Estonian hydrogeological model
(6) Earth topography
(7) Depths of Baltic sea
(8) Data from published geological cross-sections, information from books and other sources.
Special algorithms are developed for this purpose considering the priority, importance and plausibility of each data source.
Model of geological structure consists of 24 layers including aquifers and aquitards from Cambrian up to Quaternary deposits. Finite element (FE) method was employed for the calculation of the 3-dimensional groundwater flows with free surface. The significant advantages of FE are the more accurate representation of stratigraphy and other internal boundaries as well as the possibility of the local mesh refinement. 3D mesh was constructed layer-wise. The triangular mesh in horizontal plane was constructed including characteristic lines such as rivers, borders of countries and areas of presence of geological layers. Fault lines are also taken into account considering the displacements along the fault. Most of the 3D finite elements are triangular prisms. Pyramids and tetrahedra are used near the fault lines and wedge lines of geological layers.
The hydraulic conductivity (horizontal and vertical) of geological materials was assumed constant in each of the layers. Filtration properties of the quaternary deposits were calculated from the borehole database where available. Steady state modelling was performed. No-flow boundary conditions were applied on the rock bottom and the side boundaries of BAB. Infiltration as a result of simple hydrological model was applied on the surface of the model domain. Averaged long-term water extraction was applied at the water supply wells. The results of simulation are the field of piezometric levels at mesh nodes and 3D field of filtration velocity.
Model was calibrated on the available time-averaged borehole water level measurements. The parameters of the calibration are horizontal and vertical hydraulic conductivities of geological layers. The semi-automatic parameter optimization procedure was applied.
The distribution of piezometric heads and principal flows inside BAB was analyzed based on the model results. The water budget of BAB comprising inter-regional and inter-layer exchange was also estimated.

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