Variable-Density Flow and Transport in MODFLOW 6

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ABSTRACT

MODFLOW 6 is the latest version of the U.S. Geological Survey's hydrologic simulator. The program was developed using an object-oriented design to provide a platform for supporting multiple models and multiple types of models within the same simulation. The first model programmed for MODFLOW 6 was the Groundwater Flow (GWF) Model, a constant-density model that combined many of the capabilities available in MODFLOW-2005, MODFLOW-NWT, and MODFLOW-USG. The GWF model allows unstructured grids, and so it has the flexibility to work with a wide variety of model grids. It has an optional Newton-Raphson formulation to handle difficult water-table problems, and it has several advanced packages for simulating multi-aquifer wells, streams, lakes, and the unsaturated zone. MODFLOW 6 with the constant-density GWF Model is available for download from the U.S. Geological Survey.

Work is now underway to develop variable-density groundwater flow and transport capabilities for MODFLOW 6. The variable-density groundwater flow capabilities are being added as a new package to the GWF Model. Multi-species transport capabilities are being developed as a new model for MODFLOW 6, called the Groundwater Transport (GWT) Model. The GWT Model represents standard transport processes, such as advection and dispersion. However, there are several challenges for simulating transport with the existing capabilities of the GWF Model. One primary goal is to allow the GWT model to simulate transport within generalized unstructured grids. This is straightforward for advection, but representation of dispersion on unstructured grids requires development of new schemes, or adaptation of existing schemes, such as the XT3D formulation in the GWF Model. Another goal for the GWT model is to simulate transport when the Newton-Raphson approach is used. With the Newton-Raphson approach, some model cells may be dry, but there may still be water flowing through them. Different schemes are being tested with the GWT Model to handle this case. A final goal for the GWT Model is to be able to simulate solute transport within the advanced GWF packages, which will allow solute to be routed through lakes and streams, for example, or within a multi-aquifer well.

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