geoconvention
Calgary • Canada • May 15-19 2017

Adding Insight to Groundwater Source Model Calibration and Prediction with Application of a Two Phase Gas-Water Reservoir Model

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Summary

Hydrogeologists commonly develop and use sophisticated models of fully-saturated groundwater flow, at a variey of scales, to understand flow conditions and investigate effects of source and disposal activities. The cumulative impacts of a variety of pumping and injection activites can be investigated in order to evaluate the sustainability of current and/or proposed aquifer use. However, the confidence in the calibrations and predictions from these models can be problematic when the aquifer(s) of interest also contain dissolved and/or free gas. Several approaches have been developed by other researchers to approximate the resulting potential changes with time to key hydrogeologic parameters such as storativity (with high gas compressibility) and (relative) permeability in an iterative manner within a fully-saturated groundwater flow model. However, there are also multi-component / phase reservoir models, which are commonly used by reservoir engineers, that can explicitly simulate groundwater flow along with dissolved and free methane.

The purpose of this study was to develop and calibrate a local-scale, two-phase reservoir-type model, simulating historical production and observations from production of a gassy aquifer, to identify any potential learnings for long term aquifer use and development beyond that provided by an existing regional-scale groundwater flow model. The aquifer of interest is the Clearwater B Aquifer, which has been under production as a saline groundwater source for steam make-up at the Cenovus FCCL Ltd. Christina Lake Thermal Project in the South Athabasca Oil Sands (SAOS) area since 2005.

Key differences between the groundwater-type versus resevoir-type assumptions, boundary conditions, limitations and benefits will be highlighted. In particular, the reservoir model is easily able to incorporate an initial head condition that reflects depressurization of the aquifer by historical gas production in the nearby Leismer field. The reservoir model history match illustrates that increasing gas exsolution with depressurization has resulted in the development and/or expansion of a gas cap in the aquifer over time (as evidenced on logs from new boreholes and as suggested by seismic data). The presence of this gas cap within the model results in a more accurate reflection of the buffering effect of the free gas on the water level response to changes in pumping rate. It also provides a more accurate means for investigating potential long-term changes in aquifer deliverability, as changes to key flow parameters with time are directly determined.

Follow up work from this study will include further examination of model sensitivities, and improved calibration and parameterization. The local reservoir-scale model will be applied to further investigate predictions of long-term aquifer yield, as well as potential implications to source production. Ultimately, it would be useful to determine a methodology for incorporating the local-scale, 2-phase model findings back into the regional scale groundwater model, in order to better understand regional hydrgeologic conditions and effects to cumulative groundwater development in the area.