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Numerical simulation of the karst spring dynamics using a single continuum model

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Karst aquifers are characterized by rapid flow through solution conduits. The conduit system thus plays an important role for the transport of pollutants in karst aquifers. Management and protection of karst groundwater therefore must be based on sound knowledge about the location, geometry and hydraulic properties of the conduit system. Unfortunately, such information is rarely available. To obtain information about the properties of karst aquifers, global models are often employed for analyzing spring hydrographs. However, a direct verification of the interpretation obtained with global methods is very difficult. Therefore, process-based distributive models are often used to provide an indirect verification of the validity of the interpretation. To this end, continuum models, discrete models, or hybrid models combining continuum and discrete approaches can be applied to design hypothetical but realistic spring catchments. Each of these modelling approaches has their own advantages and disadvantages with respect to the simulation of karst spring dynamics. Single-continuum models are very common in other hydrogeological applications and readily available, but are believed to have only limited capability to simulate karst spring dynamics. For this reason, hybrid models in which the conduit system is represented by a discrete pipe network are often applied. These models, however, are computationally more demanding and require higher investigation efforts to quantify the model parameters.

In this work, it is attempted to simulate the discharge hydrographs and the flow fields of hypothetical karst spring catchments in which conduit systems are embedded in fissured porous rock using the single continuum model MODFLOW. The conduit system is represented by high-conductivity cells in the single continuum model (smeared conduit approach), and the CFP (Conduit Flow Process) package recently released by the USGS is employed to account for the effects of turbulent flow. The feasibility of this approach is assessed by comparison with simulation results from a hybrid model as well as with observations from field sites. The model is further employed to examine the effects of the location and geometry of the conduit system, the aquifer heterogeneity, and the spatial and temporal distribution of recharge on the karst spring hydrographs.