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Influence of karst genesis on aperture distributions determined by means of numerical modelling

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A considerable portion of the global drinking water supply originates from karst aquifers. However, karst waters often suffer from high vulnerability concerning contaminants due to the inherent characteristics of the aquifers, namely the rapid contaminant transport through solution conduits. Generic research on karst aquifers helps understanding how the processes of karstification determine the transport properties of the conduit systems.

Karst spring responses to precipitation events, isotopic measurements and tracer tests typically suggest different flow paths across the aquifers including very diverse residence times of solutes. Residence times are evidently dependent on the structure of the conduit system and the size of the openings. Yet direct field investigation provides only limited information about the properties of the conduit system. Thus, field investigations may be complemented by modelling of the evolution of conduit systems (karst genesis). In this work, a numerical model simulating karst genesis is used to investigate factors controlling the aperture distribution in karst aquifers. The karst aquifer is conceptualized as a network of different discrete, hydraulically connected and water filled voids representing solution conduits. The water flow and the dissolution rates are calculated for individual solution conduits and the conduits are widened accordingly.

The dissolutional widening of the apertures from the mm-range (and below) to the range of several metres is studied with respect to the influences of geological and hydrological boundary conditions. Variations of the initial aperture distributions lead to differences in the hydraulic conductivity throughout the aquifer and consequently the evolution of different preferred flow paths. Therefore, different scenarios representing very homogeneous to very heterogeneous networks are considered. At the early stage of karst evolution a fixed hydraulic gradient is assumed. Yet this leads to unrealistically high flow rates once the inflow and the outflow boundary are hydraulically connected by solution conduits at later stages. If the maximum inflow to the karst system is limited, the hydraulic gradient decreases at later stages and a stable bimodal aperture distribution develops, where only a limited number of conduits continues to grow while the other apertures stay small. The number of large-sized conduits that evolve is found to be dependent on both the heterogeneity of the initial aperture distribution and the amount of recharge that is available: The number of large-sized conduits tends to decrease with increasing initial heterogeneity and with decreasing maximum inflow rate. Thus, the model simulations reveal that geological as well as hydrological factors control the aperture distribution in mature karst aquifers.