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A Karst Probability Map for the Western Mountain Aquifer (Israel & West Bank) using a stochastic modeling approach

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Investigating the structure of conduit networks in karst aquifers is a common challenge when working in these complex hydrogeological environments. The network geometry plays an important role in karst flow dynamics, but highly karstified areas are often difficult to characterize by field measurements. Here, we present a methodology that generates karst conduit network geometries reasonably quick without solving complex flow or dissolution equations, and that uses only little input information. The stochastic approach also enables the investigation of the uncertainty of generated networks in the form of a karst probability map.

The "Stochastic Karst Simulator" (SKS) is a stochastic modeling approach developed by Borghi et al. (2012) to generate a 3D karst conduit network by computing a minimum effort path between the given inlet and outlet points. This study uses such a modeling approach to characterize the karst network geometry of the Western Mountain Aquifer (WMA), a highly karstified and exploited carbonate aquifer located in Israel and the West Bank. The SKS simulations are based on a conceptual model of the aquifer's karst genesis, to identify the position of karst springs and recharge zones over past geological ages.

Three different phases of karst formation are identified for the WMA. Phase 1: a paleo-discharge zone exists, located close to the present-day coastline of Israel, phase 2: a period of extreme low sea levels during the Messinian salinity crisis, when paleo-canyons were reactivated along this coastline, and phase 3: the modern-day outlets of the aquifer. The iterative approach of the SKS algorithm accounts for these different phases and creates new conduit pathways by building on ones formed in earlier phases. The algorithm also uses the hydrological model of the study site as soft information, providing knowledge about the internal heterogeneities of the karst formations (e.g. statistical properties of fractures). The resulting karst probability map is compared to the location of the most productive pumping wells in the region, assuming a high yield in groundwater abstraction indicating major karst conduits near the pumped well.

We demonstrate the method by showing a reconstruction of the karst conduit networks at the WMA model area, an otherwise not available spatial information. The simulations show that the changes in karst spring and recharge locations have a great impact on the geometry and connectivity of the conduit network. Overarching trends in the conduit orientation of the resulting

probability map are in keeping with the proposed karst genesis model, resulting in the evolution of a hierarchical network. High karstification is indicated around modern-day springs, also in agreement with the location of numerous pumping wells in that region.

The SKS algorithm is a useful tool to test different hypotheses of karst genesis and to understand the evolution of karst network geometries. The methodology is numerically efficient, and its inputs can be easily adjusted. Soft information on karst development allows for the generation of a sound hydraulic parameter field, which can be implemented in hydrological models to better understand and manage these aquifer systems.