Modeling heat transport in two-domain karst ground-water flow

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Two-domain flow in many karst aquifers consists of quick flow in conduits and slow flow in the interconnected network of smaller pores and fractures. Chemical ground-water tracers frequently are used to understand, quantify, and separate quick flow and slow flow to a spring or well. Heat-transport modeling using continuous water temperature data as a tracer is presented as an inexpensive alternative to chemical tracers for cases where water temperature at the discharge point has a measureable response to temperature fluctuations in recharge water. The objectives of this study were to explore the effectiveness of heat transport modeling for karst aquifers and to estimate transit times and the volumetric fraction of quick flow. Measured data used in this model include a continuous temperature record of water recharging the aquifer and discharging from a spring or well. The model uses a physically-based finite-difference approach for quick-flow advective heat transport in a conduit and allows for mixing with slow flowing ground water of relatively constant temperature. Model parameters include the temperature of the slow flowing ground water, temperature of the conduit wall, heat-transfer coefficient between the conduit water and wall, and the quick-flow volumetric fraction at the discharge point. The model was applied to 12 years of temperature data for a sinking stream and a pumped well open to the Madison aquifer in South Dakota. Quick flow was estimated to range from 10-50 percent of total flow with transit times of less than 5 days. This method can be useful to assess contaminant vulnerability and to determine the presence of a quick-flow component.