Convolution modeling of two-domain, nonlinear water-level responses in karst aquifers

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Convolution modeling is a useful method for simulating the hydraulic response of water levels to sinking streamflow or precipitation infiltration at the macro scale. This approach is particularly useful in karst aquifers, where the complex geometry of the conduit and pore network is not well characterized but can be represented approximately by a parametric impulse-response function (IRF) with very few parameters. For many applications, one-dimensional convolution models can be equally effective as complex two- or three-dimensional models for analyzing water-level responses to recharge. Moreover, convolution models are well suited for identifying and characterizing the distinct domains of quick flow and slow flow (e.g., conduit flow and diffuse flow). Two superposed lognormal functions were used in the IRF to approximate the impulses of the two flow domains. Nonlinear response characteristics of the flow domains were assessed by observing temporal changes in the IRFs. Precipitation infiltration was simulated by filtering the daily rainfall record with a backward-in-time exponential function that weights each day’s rainfall with the rainfall of previous days and thus accounts for the effects of soil moisture on aquifer infiltration. The model was applied to the Edwards aquifer in Texas and the Madison aquifer in South Dakota. Simulations of both aquifers showed similar characteristics, including a separation on the order of years between the quick-flow and slow-flow IRF peaks and temporal changes in the IRF shapes when water levels increased and empty pore spaces became saturated.