Investigating Telogenetic Karst Aquifer Processes and Evolution in South-Central Kentucky, U.S., Using High-Resolution Storm Hydrology and Geochemistry Monitoring

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Abstract
Recent studies have investigated the hydrological and geochemical characteristics of karst aquifers in different settings; however, telogenetic karst aquifer processes remain poorly understood. In south-central Kentucky, the iconic Lost River Cave and Valley represents a large, complex telogenetic karst drainage basin with a series of discharge points along a collapsed section of the cave. Two Campbell Scientific® CR1000 automated dataloggers were installed at Blue Hole Four, a primary discharge point of the Lost River Karst Aquifer (LRKA). These dataloggers recorded spring discharge, water temperature, specific conductance (SpC), and pH at ten-minute intervals from January to November, 2013. During the year, data for 34 storm events were captured, including water samples that were analyzed for major cation/anion concentrations. These concentrations were correlated to SpC to yield a continuous record of ionic concentrations. Rainfall data were acquired from the Kentucky Mesonet’s Warren County Site within the LRKA basin. Dissolution rates, Ca\(^{2+}\)/Mg\(^{2+}\) ratios, and a mass flux of dissolved CaCO\(_3\) were calculated to assess aquifer evolution processes and identify seasonal and storm event variability throughout the year. A two end member mixing analysis (EMMA) is used to analyze storm flow conditions versus baseflow conditions, and a predictive model is presented that is used to predict peak springflow based upon rainfall totals. A detailed water budget analysis and comparison to historical data is used to assess groundwater storage and aquifer complexity.

The annual data reveal both seasonal and storm event patterns in geochemical and hydrologic conditions of the aquifer. The data indicate distinct responses to storm events. These responses, as well as EMMA results, indicate that storm event flows are composed initially of water formerly stored in the aquifer flushed through the aquifer by incoming meteoric water; this gradually gives way to a mixture of meteoric water and storage water that becomes gradually more similar to pre-storm conditions as discharge recedes to baseflow levels. The highest proportion of meteoric water is coincident with the highest potential for CaCO\(_3\) dissolution, indicating that storm events drive dissolution in the LRKA. Water budgeting for the full study period and individual storm events indicate that a large proportion of water in the LRKA is not discharged at Blue Hole Four, but rather is stored in the aquifer or follows another flowpath through the aquifer. Additionally, the higher rainfall totals during storm events tend to increase the proportion of water discharged from the aquifer rather than that stored within it. The predictive model indicates a strong correlation between total rainfall and peak discharge. The results overall indicate two critical times at which contaminant transport may occur: first, any contaminants stored in the aquifer will be flushed out first with storage water as discharge peaks, followed by a period in the falling limb of the discharge hydrograph that coincides with the peak proportion of meteoric water carrying contaminants that entered the aquifer during this event. This study helps to improve understanding of telogenetic
karst aquifer processes and evolution, particularly in large, complex drainage basins. Future research is necessary to understand the dynamics of these important groundwater reserves and their response to continuing pressures from climate change, human impacts, and natural processes.

Disciplines
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