

Karst Groundwater Basins: An Abstract of Analysis

By Joe Meiman

The protection and conservation of aquatic resources poses special problems to resource managers; typically, drainage basins extend far beyond park boundaries. As any land use within the watershed is manifested in the water quality down-basin, the most effective resource management decisions are born from a watershed approach. A watershed strategy takes into account all land use activities occurring within a drainage basin and determines the effects of each activity on the water quality downstream. At Mammoth Cave NP, hydrologists have used a watershed strategy in analyzing karst* groundwater basins.

The analogy between a surface drainage system, with dendritic flow patterns converging on a master stream, and the transfer of groundwater through a cave system, is often used when describing flow through the karst aquifer of south-central Kentucky. Since in many fundamental ways a karst aquifer behaves as a surface stream network, similar sampling strategies, with important modifications, are used to document the water quality of a karst basin.

As the boundaries of a karst groundwater basin are being defined by qualitative dye tracing, non-conditional synoptic water quality sampling is conducted. Non-conditional synoptic sampling (extracting a sample on a fixed date regardless of flow condition) will provide the researcher with an inventory of contaminants in a cave stream or spring under the continuum of discharge conditions.

Furthermore, the investigator must measure, or at least best approximate, site discharge upon sampling. Discharge, when

combined with parameter concentrations, yields mass flux (mass per time), which may provide valuable information regarding contaminant transfer from the surface to the subsurface. For example, mass flux data at Mammoth Cave NP reveal that flood pulse-producing sudden recharge events (rainfall) are the primary agents of groundwater quality degradation. When we have the highest water quantity we have the lowest water quality.

After flood pulses are identified as instruments of karst groundwater contamination, they must be parametrically quantified. Without frequent sampling, it is difficult to accurately measure the large fluctuations in many water quality parameters that occur in karst waters during and following storm events. As products of conduit flow aquifers, these fluctuations are commonly of high amplitude and short wavelength. However, even brief increases in certain contaminants may yield serious consequences at water supply springs, and have lasting detrimental effects on aquatic cave life. Therefore, storm event spring sampling must be included in any karst groundwater characterization effort.

It is vital that flood pulse sampling include a series of sequential samples beginning prior to the recharge event and continuing until flow and water quality approach antecedent conditions. Repeated, rigorous circum-storm water sampling at a particular spring or cave stream may reveal a unique combination of parametric response traits. A spring's storm response is actually composed of numerous overlapping subset responses, each originating from individual inputs or groups of inputs. The chemical and physical waveforms of a flood pulse are modified by various attributes unique to individual karst basins. Antecedent phreatic water within the conduit system may cause a significant delay between a spring's discharge response and

the eventual arrival of storm-derived water. A flood wave may be compressionally propagated through a phreatic conduit possibly creating peak discharges well before the arrival of storm waters.

An analogy may lie as close as your backyard. A garden hose filled with water on a warm day immediately discharges warm water when the tap is turned on, and the arrival of the cool water, which actually caused the expulsion of warm water, may take some time. In the same way, it is possible that if the investigator only samples up to the peak discharge, a significant portion of the contaminant pulse will be missed.

Tracer dyes injected with the storm water runoff may help to identify the contribution of a particular subset of inputs to the whole storm response. In order to tag a flood pulse, the investigator must equip the spring with an automatic sampler. The sampling interval will be determined by factors such as the spring's relative response to recharge and groundwater flow velocities defined by previous quantitative tracing. At the onset of recharge, the fluorescent dye is injected into a sinkpoint with the runoff. Samples then will be analyzed for targeted parameters as well as the dye. An in-phase relation between the dye recovery curve and a contaminant pulse may not only identify the pollution source, but also suggest the amount of contaminant exported from that particular input.

A detailed account of flood pulse tagging and circum-storm sampling at Big Spring Groundwater Basin, Mammoth Cave NP has been written and is available to interested parties. An NPS Scientific Monograph also is being written by the author, describing holistic karst groundwater basin analysis. Write to: Joe Meiman, Mammoth Cave NP, Mammoth Cave, KY 42259

Meiman is Park Hydrologist at Mammoth Cave NP.

* Karst: A limestone region marked by sinks and interspersed with abrupt ridges, irregular protruberant rocks, caverns, and underground streams.