Report for 2004KY45B: Characterizing pollution impacts to urban karst aquifers from artificial and enhanced recharge

There are no reported publications resulting from this project.

Report Follows

Problem and Research Objectives

Urbanization on Kentucky's karst landscape has increased pollution problems associated with springs in the region. The main objective for the project was to monitor three urbanized karst springs in the Inner Bluegrass Region that have previously shown anomalously high base flow levels, and to test for a suite of hydrologic parameters and contaminants. Detailed discharge and contaminant testing were intended to help quantify groundwater impacts resulting from urban recharge potentially originating from infrastructure leakage.

Russell Cave Spring and McConnell Spring in Lexington, and Big Spring in Versailles were originally proposed as the target urban monitoring points. Monitoring of the McConnell Spring basin was moved to Prestons Cave Spring for the study as that is the final resurgence point for the McConnell aquifer. McCalls Spring, draining a non-urbanized area near Lawrenceburg, was added as a control monitoring point.

Methodology

The three main data gathering tasks included: 1) ambient field water quality monitoring, 2) sample collection for laboratory analysis to evaluate suspected urban runoff constituents, and 3) collecting more extensive discharge measurements from urban springs than had previously been accomplished.

A bi-weekly monitoring schedule was originally proposed, with additional testing planned during at least two storm events to document first flush effects and high-flow loads. Field measurements included temperature, pH, conductivity, and turbidity. Stage recorders were installed at each spring, and discharge rating curves were calculated in order to determine mass fluxes of contaminants and analyze hydrograph anomalies.

Chemical constituents chosen for laboratory analysis were based on similar previous studies of surface water and ground water impacts in urban areas. Metals, BTEX, nitrate, orthophosphate, chloride, fluoride, optical brightener, caffeine, and the herbicide 2,4-D were originally proposed for monitoring. 2,4-D was replaced by simazine because of better detection limits and the widespread use of simazine for urban applications in the study area.

2004 turned out to be a poor year for the study because base-flow conditions were needed for characterization of urban effects at low flow. Above normal precipitation throughout most of the year resulted in a change in the monitoring plan from the original bi-weekly schedule. Near base flow conditions occurred a few times between August and October 2004, and then again during February 2005. Although this reduced the total number of sampling runs from the original plan, the results were adequate to make the proposed characterizations. Eight base flow sampling events and two high flow samplings were conducted at each of the four springs. Discharge measurements were conducted 14 times during the study at each spring.

Principal Findings and Significance

Caffeine, orthophosphate, and optical brightener showed a strong inverse correlation with discharge in the three urban springs, with r^2 values approaching 0.9. Fluoride and simazine showed a moderately strong inverse correlation with urban spring discharge, and nitrate and chloride both showed weak inverse correlations with discharge in the three urban springs. Fluoride, which may have been from natural sources and chloride, which may have been derived from salting of the nearby highway, were noted in the control spring (McCalls). Both BTEX and metals showed a moderate positive correlation with discharges at all springs.

Constituent	Range of Results
Caffeine	ND to 9.2 micrograms/liter
Fluoride	ND to 2.4 milligrams/liter
Chloride	7.4 to 78 milligrams/liter
Orthophosphate	ND to 0.11 milligrams/liter
Optical Brightener	ND to 422 fluorescence units
Nitrate	0.12 to 3.8 milligrams/liter
Simazine	ND to 0.36 micrograms/liter

The chemical results suggest that base-flow at urban springs is augmented by leaking infrastructure – both water supply lines and sewage disposal lines. Results also suggest that storm flow from impervious surfaces into swallow holes and sinks provide the highest hydrocarbon and metal concentrations with first-flush runoff. Big Spring in Versailles had the highest levels of most of the constituents analyzed, with Prestons Cave Spring a close second. Russell Cave Spring showed only moderate levels of contaminants – probably due to the fact that only about 45 percent of its recharge area is urbanized.

Fourteen sets of discharge measurements were used to evaluate the volume of excess recharge within the urban areas. Urbanization appears to have radically altered the hydrographs of the studied springs. Storm events were followed almost immediately by flood spikes at Prestons Spring and Big Spring, with Russell Cave Spring showing a short lag time from peak rainfall to peak discharge, and McCalls a normal lag time and broader curve. Prestons Spring and Big Spring discharge dropped rapidly after the rainfall ceased, but the Russell Cave recession curve was less steep, and McCalls showed a typical recession slope.

Normalized base level discharges were calculated for each spring based upon their recharge areas. Average normalized base flow for Bluegrass Region springs during this period was approximately 0.09 cubic feet per second per square mile (cfsm) (0.98 $l/s/km^2$). Big Spring showed the most significant deviance, with the lowest measured normalized flow during the study at 0.5 cfsm (5.5 $l/s/km^2$). Prestons Spring normalized base flow was as low as 0.35 cfsm (3.8 $l/s/km^2$), and Russell Cave Spring base flow was 0.2 cfsm (2.2 $l/s/km^2$). This suggests that artificial urban recharge accounts for about 82% of Big Spring discharge, 74% of Prestons Spring discharge, and 55% of Russell Cave Spring discharge during low flow conditions.