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Partners in Water Quality Monitoring at Mammoth Cave National Park, Kentucky

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Abstract

Water resources are essential to landscape development and maintenance of the extraordinary ecosystem at Mammoth Cave National Park, Kentucky. The National Park Service has implemented many policies and management practices in an effort to maintain and improve the water quality in the park. As part of their resources management, the Park evaluates current hydrologic conditions, as well as, anticipates and responds to emerging issues. With regards to that goal, Mammoth Cave National Park Service partnered with Tennessee State University, the Mammoth Cave International Center for Science and Learning, and the U.S. Geological Survey on a series of water-related projects from 2007-2013. The objective of this paper is to highlight some of the findings and lessons learned from the past 6 years. Many of the results presented in this paper have been presented at other conferences or published in other reports. Collaborative projects included storm-water runoff from parking lots and roads, evaluating storm-water filters, and transport of chemicals in the caves. These projects purposefully engaged students to provide professional experience and educational outreach opportunities. Over 50 student presentations related to these monitoring activities have been made at regional and national conferences in the past 6 years, resulting in numerous awards and publications. Major funding or in-kind services were provided by the partnering agencies and institutions. Additional funding for supplies and student support was provided by the National Science Foundation (Opportunity for Enhancing Diversity in Geoscience, 2007-8; Undergraduate Research and Mentoring, 2009-13), and, the Department of Energy (Massey Chair – NNSA, 2007-13). The following summaries are excerpts from previously published student papers (West et al., 2010; Diehl et al., 2012, Embry, et al., 2012, West et al., 2012).

Evaluating parking lot storm-water filters

There were two phases to the parking lot filter evaluation. The first evaluation took place seven years after the filters had been installed, prior to and after servicing the filter systems. The second phase occurred two years later, pre- and post-maintenance.

The parking lot storm filter systems use an oil and grit separator followed by filters filled with cartridges containing zeolite-perlite-activated carbon granules. The filter systems vary in size, depending on the size of the parking lots. The filters are designed to trap suspended particles and dissolved constituents, such as metals and oils, as runoff flows through the filter units. The manufacturer suggests swapping filter cartridges every 2 years (Figure 1).

The first phase project (West, et al., 2010) was conducted to determine if leaf-pack filter-systems attenuated storm runoff at seven parking lots in Mammoth Cave National Park. Grab samples were collected at the inlet and outlet of the filter systems, and analyzed for oil and grease, sediments, turbidity, gasoline compounds, nitrate,

Figure 1: Contractors serviced the storm-water filters by swapping the cartridges. (Hotel-east shown here)

ammonia, fecal bacteria, dissolved iron, and chemical oxygen demand (Figure 2). For the first sampling round, the filters had not been serviced for 8 years and did very little to remove contaminants. The contaminant concentrations at the outlet were similar to those at the inlet, with the exception of removing 20-70 percent of the oil and grease. After replacing the cartridge filters and cleaning debris out of the oil-grit separators, the re-conditioned filters did little to remove copper and ammonia from runoff waters. However, the re-conditioned filters removed up-to 99% of the benzene, toluene, ethyl-benzene and xylene, and, up to 90% of the turbidity, E. coli, Chemical Oxygen Demand and iron from the storm runoff. These results indicate that well-maintained filtration systems are more effective than clogged filters at removing many but not all contaminants from parking lot runoff.

The second phase (Diehl, et al., 2012) evaluated storm-water filters that had been serviced 2 years prior. The study focused on the first runoff waters during the storms (Figure 3). The filters were effective at removing petroleum aromatic ring compounds, but were less effective at removing zinc and copper. Regression analysis established a correlation between decreasing filter efficiency for copper with increasing parking lot size. Also, there was a positive correlation between increasing parking lot size and increasing copper concentration in the runoff. Quaternary ammonia compounds (QACs) are a new concern because of their use in White Nose Syndrome disinfection stations and in RV sanitation tanks. The filters that received the highest QAC concentrations during storm runoff were effective at reducing 40-90% of the QAC concentrations. Additional work is continuing to determine if new cartridge filters improve the efficacy of the storm-water filter systems.

Transport of Chemicals into the caves (West, et al., 2012, Embry et al., 2012)
In 2011, the National Park Service began deliberations concerning the application

Figure 2: TSU students prepared water samples and ran chemical analyses.

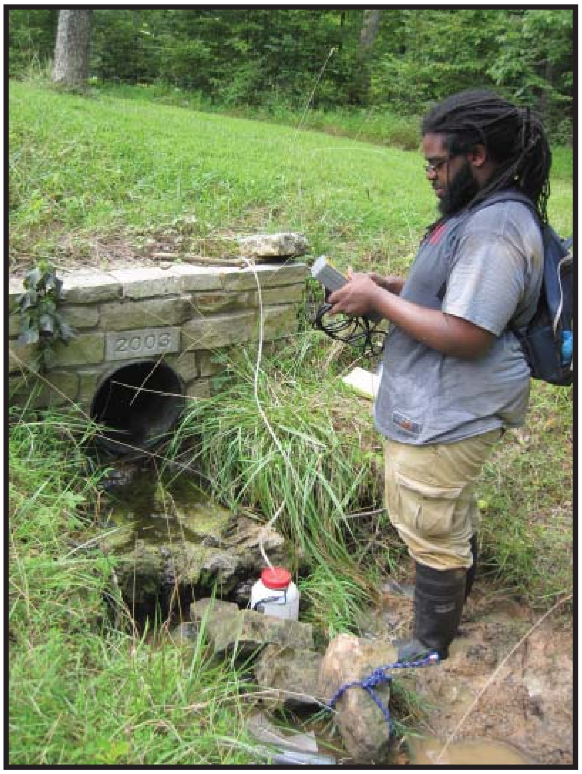

Figure 3: TSU student setting up a monitoring station at the storm-filter outlet.

of road deicers on primary roads through the Park. However, the NPS lacked some essential quantitative information with regards to contaminant transport from land surface into the cave ecosystem. The objective of this investigation was to characterize storm flow from potential source areas on the surface into the cave. The preliminary results were achieved by monitoring water chemistry and bacteria near source areas, along the surface flowpaths, and along known flowpaths in the cave (Figure 4). A quantitative tracer study found it took one hour for dye to move from land surface, along the main flowpath, and into the cave (Figure 5). Constituents, such as quaternary ammonia compounds (QACs), chemical oxygen demand, ammonia, and diesel range aromatic ring compounds, decreased exponentially along the flowpath, to below detection levels in the cave. Zinc, copper, and nitrate decreased along the surface, but then held steady at low concentrations in the cave flowpath. Phosphate and sulfate decreased along the surface flowpath, but increased slightly in the cave. This is reasonable considering there are natural sources of sulfate and phosphate in the limestone at Mammoth Cave National Park. Bacteria were cultured and evaluated for resistance to the microbicides called quaternary ammonia compounds (Figure 6). Soil-water bacteria collected near the White Nose Disinfection Stations and RV Dump Station had a much greater resistance to QACs than bacteria collected in pristine areas, indicating they are devloping antibiotic resistance. Specific conductance in flowing cave waters ranged from 200-250 uS/cm. Storms had a temporary dilution effect on specific conductance in those same cave waters. An extreme storm that showered 2 inches in 24 hours caused the conductivity to

Figure 4: TSU students installed instruments to monitor road runoff at Silent Grove.

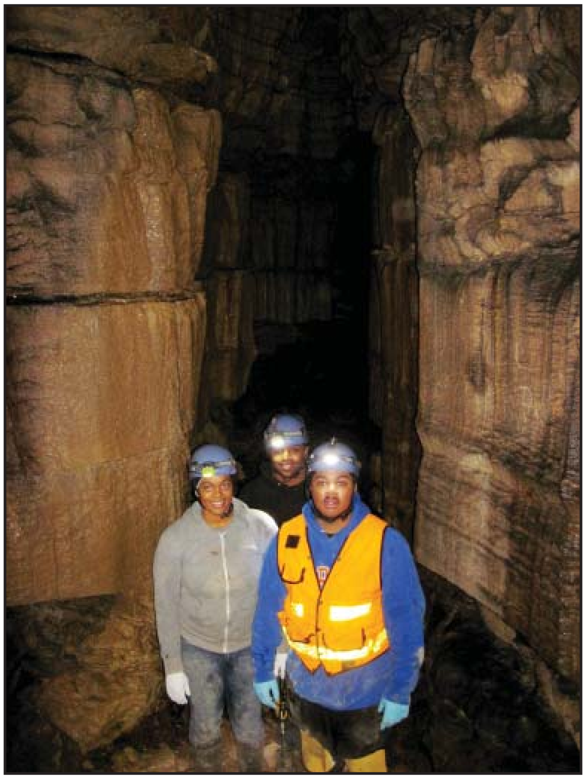

Figure 5: TSU students walked many miles in the cave to gather water samples and collect data.

Figure 6: Honors high school students helped run microbial tests on the cave samples.

drop to 40 uS/cm. A pool perched in Gratz Avenue (in the cave) had a stable specific conductance of 315-335 uS/cm regardless of storms. These preliminary results help us to understand the current conditions in the cave prior to road salt treatment and how various chemical concentrations adjust along the flowpath into the cave.

Conclusions

This partnership between Mammoth Cave National Park, U.S.G.S., Mammoth Cave International Center for Science and Learning, and, Tennessee State University to investigate water-quality in the Park had many positive outcomes. Some results were very tangible, such as, the monitoring results used to influence management decisions or document current ecosystem conditions. Results that were difficult to quantify include the benefits received by engineering and environmental students as they interacted and worked with professionals from the partnering institutions. Counting the vast number of student awards, presentations, and publications, or counting the number of internships, is one way to quantify the benefits of this project. But even that approach undervalues the results of this unique partnership. These monitoring activities helped to train the next generation of scientists and engineers and provided a very positive experience for all the participants.

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(all photos by T. Byl and R. Toomey)