Mar 25th, 1:30 PM

Session 2B: Groundwater and Karst

Kentucky Water Resources Research Institute, University of Kentucky

SESSION 2B: GROUNDWATER AND KARST

Incorporating Machine Learning with LiDAR for Delineating Sinkholes

Junfeng Zhu[1], Adam M. Nolte[1], Nathan Jacobs[2], Ming Ye[3]
[1]Kentucky Geological Survey, University of Kentucky
[2]Department of Computer Science, University of Kentucky
[3]Department of Earth, Ocean, and Atmospheric Science, Florida State University
Junfeng.zhu@uky.edu; adam.nolte@uky.edu; jacobs@cs.uky.edu; mye@fsu.edu

Karst sinkholes are a major natural hazard, and information on existing sinkholes is critical in evaluating sinkhole hazards and understanding mechanisms leading to the formation of sinkholes, especially catastrophic cover-collapse sinkholes. LiDAR provides accurate and high-resolution topographic information and has been used to improve delineation of sinkholes in many karst regions. LiDAR data, however, generate a large quantity of topographic depressions and identifying sinkholes from these depressions through manual visual inspection can be slow and laborious. To improve efficiency of identifying sinkholes from topographic depressions, we applied five machine learning methods (logistic regression, naive Bayes, neural network, RusBoost, and support vector machine) to a dataset of morphological characteristics of LiDAR-derived topographic depressions. Sinkhole data from three counties (Bourbon, Woodford, and Jessamine) in the Bluegrass Region of Kentucky were used to derive the dataset for training and testing the machine learning methods. This dataset consisted of 22,884 records with 10 variables for each record. For each method, a random subset of 80 percent of the records was used for training and the remaining 20 percent was used for testing. The test receiver operating characteristic curves (ROCs) showed that all five methods were applicable to the dataset, as demonstrated with all the area under the curves (AUCs) greater than 0.87. Neural network emerged as the best performing method with an AUC of 0.95 and a testing average accuracy of 0.85. This accuracy was not sufficient for sinkhole mapping, however. We subsequently developed a two-step process that combined the trained neural network classifier and the manual visual inspection and applied the process to data from Scott County in the same region. The two-step process located 97 percent of sinkholes with inspecting only 27 percent of the topographic depressions in the county. This study showed that machine learning is promising to help identify sinkholes in karst areas with available high-resolution topographic information.

Advances in Urban Karst Hydrological and Contaminant Monitoring Techniques for Real-Time and High-Resolution Applications

Jason S. Polk and James Shelley
Center for Human GeoEnvironmental Studies
Western Kentucky University
jason.polk@wku.edu

The City of Bowling Green, Kentucky, is one of the most studied urban karst systems in the world; yet, it still faces issues from stormwater quantity and quality impacting the groundwater and surface water systems. Within the City, multiple sites now have long-term datasets on storm event responses and their associated discharges and hydrogeochemistry to help provide insight to responses of a continuous karst aquifer system with multiple access points for monitoring. Over the past several years, advancement in the monitoring technology and adaptation of it to improved understanding of these systems, including the use of secondary data and additional types of data collection technology now available, has allowed for a deepened investigation of urban karst processes. This includes methods by which to calculate drainage basin area and effective recharge in rapidly responding karst systems during storm events, monitor water quality impacts during first flush and continuous flooding events, and promote education and outreach about stormwater in urban karst settings. Under continuous urban expansion and unpredictable storm events, this is particularly important, due to changes in flood frequency planning, groundwater residence times, water quality impacts, and stormwater infrastructure lagging behind the variability of storm events and their associated impacts.

Since the 1970s, Dr. Nick Crawford carried out extensive research on karst hydrogeology, geophysics, dye tracing, aquifer delineation, water quality mitigation, cave mapping, sinkhole detection and remediation, and developing monitoring techniques for stormwater impacts on groundwater and cave systems in Bowling Green. In building this knowledge, he pioneered several advances in using data sondes data loggers and evaluative techniques for karst areas and raised awareness about pollutant sources, best management practices, and new technologies to improve karst groundwater quality and methods for stormwater control and sinkhole repair. This includes the study and evaluation of injection wells for stormwater runoff, which are still being used in Bowling Green, and elsewhere, today. In partnership with the City of Bowling Green Public Works, WKU CHNGES has established the UnderBG project to integrate advanced scientific and technological approaches, along with new education and outreach activities, to promote the understanding of stormwater impacts on Bowling Green's urban karst aquifer, train new generations of karst scientists, and advance the field through more robust studies in the Bowling Green metropolitan area, which are all applicable to other similar areas. Several theses and new research collaborations have spawned the next generation of high-resolution hydrogeochemical studies, dye tracing techniques, GIS applications for well and karst feature geodatabases, water quality monitoring, and flood prediction in the City, as well as improved education and outreach methods regarding the fragility of karst landscapes from stormwater impacts using geocognition research and a rigorous outreach program. Combined with the scientific work, the use of educational signage, marketing materials, websites, and outreach activities and is being expanded in partnership with the City of Bowling Green to improve karst groundwater awareness and was recently named a 'Model Practice' by the American Public Works Association, which reflects well the pioneering nature of the work what it hopes to achieve in the future through partnership and collaboration.

Finding the Edge: How Can We Apply Edge of Field Monitoring to Karst?

Benjamin Tobin, Charles Taylor, Adam Nolte, Steve Webb
Kentucky Geological Survey
University of Kentucky
(859) 323-0530
Benjamin.Tobin@uky.edu

Edge-of-field monitoring techniques have frequently been applied to understand the impacts of agricultural techniques on water quality immediately adjacent to the fields. This allows for a deeper understanding of the direct impact of these farming practices on water quality adjacent to the fields. Karst terrain often lacks areas where overland runoff occurs; instead water typically flows to sinkholes and drains into the subsurface, ultimately emerging at springs. These subsurface flow paths are often difficult to quantify and it is even difficult to determine direct connections between surface sinkholes and their associated springs. Using a field site in Taylor County, Ky., we were able to quantify basic flow parameters and delineate groundwater basins for Homeplace on the Green River farm. Through this process we developed a set of critical preparatory measures to allow for interpretation of spring water-quality data and the associated edge-of-field impacts of the overlying agriculture. These consist of (1) conducting full karst hydrogeologic inventories, (2) delineating groundwater basins, and (3) quantifying system response. Additional work to understand water quality prior to water entering the subsurface will be critical to understanding how it changes through the groundwater system.

An Urban Karst Groundwater Evaluation and Monitoring Toolbox*

Jason Polk and Rachel Kaiser
Department of Geography and Geology
Western Kentucky University
(270) 745-5015
Jason.polk@wku.edu; Rachel.kaiser389@topper.wku.edu

In urban karst areas, such as the City of Bowling Green, Kentucky and the Tampa Bay Metropolitan Area, groundwater quality faces a variety of threats. The development of residential, commercial, and industrial landuse types allows for a wide variety of groundwater pollutants to enter the karst groundwater systems. Various different models and indices, including, but not limited to, the Karst Disturbance Index (KDI), Karst Aquifer Vulnerability Index (KAVI), EPA DRASTIC method, and the Karst Sustainability Index (KSI), have attempted evaluative approaches to identify issues in urban karst areas, but the methods vary by location and lack a focus on urban karst groundwater quality, as well as a lack of a data-driven approach that is able to capture short- and long-term changes in threats to groundwater quality as a result of urbanization. The overall purpose of this study was to develop a holistic, data-driven threat, vulnerability, and monitoring assessment tools for urban karst groundwater systems to better determine the possible threats, data collection needs, monitoring parameters, and analytical approaches needed to ensure groundwater quality is maintained in urban karst regions. This study focused on: 1) determining what indicators, parameters, and data quality need to be prioritized to create an effective, holistic monitoring framework for urban karst groundwater, and 2) developing an effective threat assessment and evaluative tools for urban karst groundwater quality sites using historic and modern data in an urban karst setting. The outcomes include an index and evaluation tool review, historical data evaluation and review, a threat, vulnerability, and monitoring evaluation system for the urban karst landscapes using GIS and a Karst Feature Inventory (KFI), and primary data collection in the City of Bowling Green and the Tampa Bay Metropolitan Area of water quality parameters. The final results of this study will be used to create a data-driven Urban Karst Aquifer Resource Evaluation toolbox that can be used universally.

*Supported by 2018-2019 USGS 104b grant funds.

Center-Pivot Irrigation in Western Kentucky: Adding Context to the Discussion

E. Glynn Beck[1], Amy Bleichroth-King[1], and Mark Akland[2]
[1]Kentucky Geological Survey (Western Kentucky Office), University of Kentucky
[2]Department of Plant and Soil Sciences, University of Kentucky
ebeck@uky.edu; bleichroth@uky.edu; markakland@uky.edu

During the summer of 2012, drought conditions in western Kentucky ranged from severe to exceptional. Also, during the years leading up to the drought of 2012, corn and soybean prices were at historical highs. These factors created a favorable scenario for some farmers to install center-pivot irrigation systems. A survey of 85 counties identified 603 center-pivot systems and that the majority of pivots are located in three different geographical areas of western Kentucky. The survey also found that 69,630 acres in the 85 counties were irrigated by center-pivot systems.

Prior to the drought there was one continuous, long-term groundwater-elevation observation well in Kentucky. The observation well, located near Viola in north-central Graves County, is administered by the U.S. Geological Survey and is part of the National Climate Network. Since 2012, as part of the Kentucky Groundwater Observation Network, the Kentucky Geological Survey has installed and instrumented four observation wells and instrumented two existing wells to collect continuous groundwater-elevation data associated with various aquifers in the Jackson Purchase Region. Hydrographs from the U.S. Geological Survey Viola well and Kentucky Groundwater Observation Network wells in the Jackson Purchase indicate that groundwater elevations do not appear to be decreasing over time.