

Kentucky Interagency Groundwater Monitoring Network

*Annual Report
July 2017–June 2018*



Bart Davidson, Compiler
Kentucky Geological Survey
University of Kentucky
Lexington, Kentucky

October 2018

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Acknowledgments

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- Suzette Walling, University of Kentucky Environmental and Natural Resource Issues Task Force
- Steve Kull, Kentucky Division of Forestry

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On the cover: Left: Royal Spring (spring number 32 on Figure 2) in Georgetown, Scott County, is the primary water supply for the city and is one of the monitoring sites for the Kentucky Interagency Groundwater Monitoring Network. The inset shows the outfall of the spring leading to the water plant at left-center of the photo. Right: Kentucky Geological Survey geologist Richard Smath samples groundwater from Royal Spring across from the water plant. Photos by Bart Davidson.

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Kentucky Interagency Groundwater Monitoring Network Annual Report July 2017–June 2018

Introduction

Groundwater is a vital natural resource used extensively across Kentucky for domestic, public, agricultural, commercial, and industrial purposes. Because of its connection with rivers, lakes, and wetlands, groundwater is also essential to the health of surface-water ecosystems. Determining the quality of this resource and protecting it from contamination are of paramount importance to the commonwealth. To this end, the Kentucky Interagency Groundwater Monitoring Network was established in 1998 by the Kentucky General Assembly through KRS 151.625 to provide a means to characterize and increase knowledge about the commonwealth's groundwater resources. In order to provide oversight for the groundwater monitoring network, the 1998 General Assembly also established an Interagency Technical Advisory Committee through KRS 151.629. This committee was tasked with assisting the Kentucky Geological Survey in the development, coordination, and implementation of the groundwater monitoring network. The following agencies and organizations were asked to appoint a representative to the Interagency Technical Advisory Committee:

- Kentucky Department for Environmental Protection
- Kentucky Department for Natural Resources
- Kentucky Department of Agriculture, Division of Environmental Services
- Kentucky Division of Conservation
- Kentucky Division of Forestry
- Kentucky Division of Public Health Protection and Safety
- Kentucky Division of Waste Management
- Kentucky Division of Water
- University of Kentucky, College of Agriculture, Food and Environment
- University of Kentucky, Kentucky Geological Survey

- University of Kentucky, Kentucky Water Resources Research Institute
- U.S. Geological Survey, Ohio-Kentucky-Indiana Water Science Center.

The participating Network agencies have continued to fulfill their obligation of collecting and providing groundwater-quality and other water-related data throughout the 20 years of the Network's existence. Annual reports summarizing these activities since 1999 are available on the Network website at www.uky.edu/KGS/water/gnet.

From July 2017 through June 2018, more than 33 groundwater investigations and data-collection activities were carried out by ITAC member agencies. Groundwater and related surface-water information was communicated to the scientific and regulatory communities and to the public through various publications and presentations, as well as through postings on websites. Exchange of groundwater data, including electronic transfer of analytical results between Division of Water and Kentucky Geological Survey databases, has continued on a regular basis through close cooperation between the Division of Water and the Kentucky Geological Survey.

2017-18 Activities and Accomplishments

The ITAC committee met twice during the fiscal year. The first meeting was held at the Division of Water in Frankfort on Feb. 8, 2018, from 10 a.m. till noon. Twenty-one representatives from 13 agencies attended the meeting. Two presentations were given: first, an overview of ITAC and its regulatory background by Steve Evans of the Kentucky Water Resources Research Institute, and second, the results of a trend analysis of 20 years of monitoring data collected for the Network by Dr. Caroline Chan of the Division of Water. A second meeting was held April 18, 2018, at the Kentucky

Geological Survey Well Sample and Core Library in Lexington from 10 a.m. till noon. Presentations were given by David Jackson of the Division of Water on expanding sampling locations for the Ambient Groundwater Monitoring Network and by Charles Taylor of the Kentucky Geological Survey on the Kentucky Groundwater Observation Network, which is part of the Kentucky Groundwater Monitoring Network, along with the DOW's ambient network.

Summaries of water-related projects performed by the ITAC agencies during the 2017-18 state fiscal year are presented below as an indication of how the Network goals are being addressed. Additional information about any of these projects can be obtained by contacting the reporting agency.

Groundwater Data Collection

Groundwater data are generated through many avenues. Drilling wells, collecting and analyzing water samples, measuring water levels in

wells, and mapping recharge and discharge areas of karst systems provide the fundamental data needed to determine current groundwater quality, detect changes over time, and evaluate hydrogeologic hazards.

Below are summaries of projects related primarily to groundwater that were conducted by ITAC member agencies during the 2017-18 fiscal year. Surface-water projects are listed in the "Other Activities" section of this report.

Kentucky Division of Water, Watershed Management Branch, Groundwater Section

The Groundwater Section of the Kentucky Division of Water, Watershed Management Branch, maintains an active groundwater sampling and analysis program, and conducts research on groundwater quantity, quality, and use. These studies range in scope from statewide to basin management unit (BMU) scale (Fig. 1). Table 1 lists the number of sites by physiographic region and basin management unit and Figure 2 shows

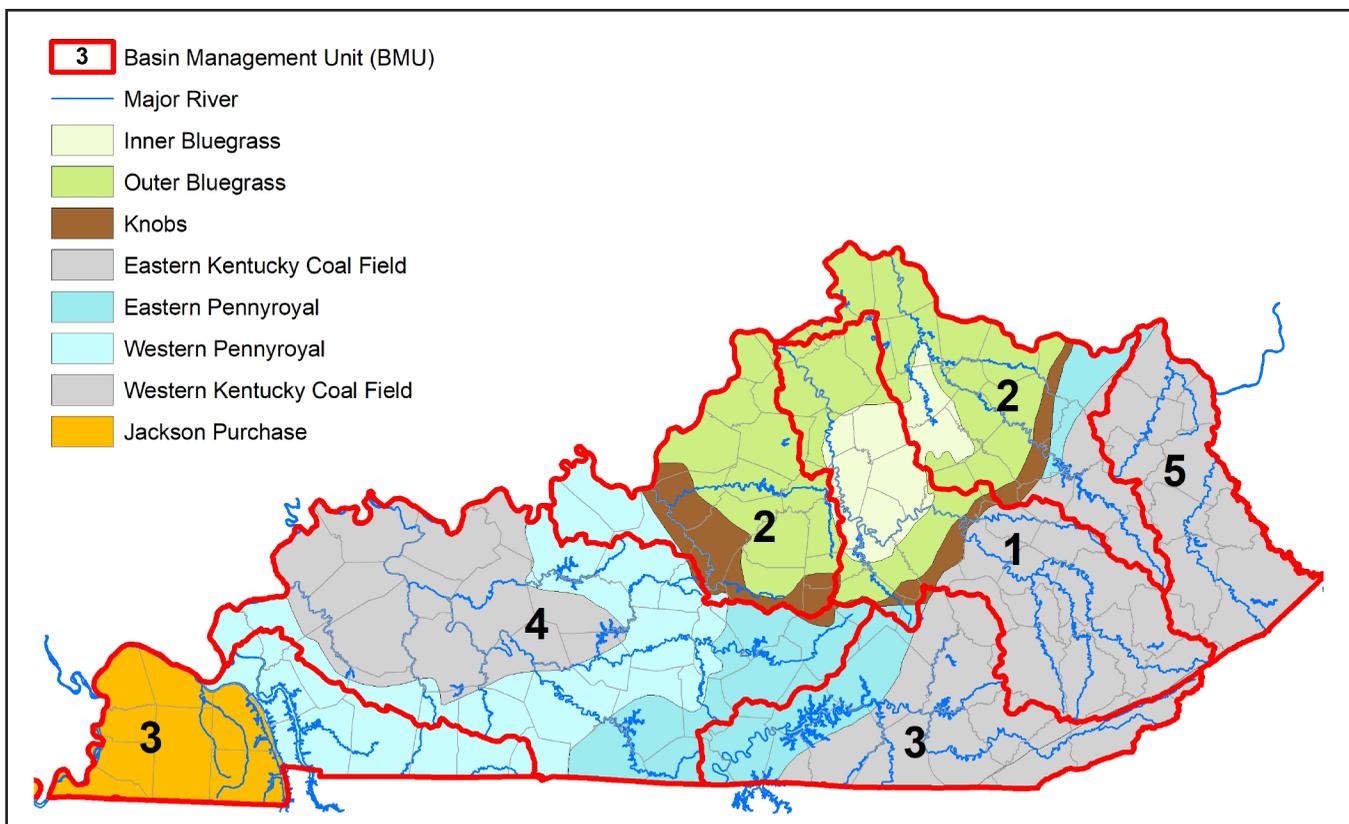


Figure 1. Major rivers, basin management units, and physiographic regions in Kentucky.

Table 1. Spatial distribution of permanent groundwater monitoring sites.			
<i>Region</i>	<i>Number of Sites</i>	<i>Basin Management Unit</i>	<i>Number of Sites</i>
Bluegrass	11	1—Kentucky River	11
Eastern Kentucky Coal Field	8	2—Salt and Licking Rivers	7
Ohio River alluvium	10	3—Four Rivers, Upper and Lower Cumberland	22
Mississippian Plateau	23	4—Green and Tradewater Rivers	15
Western Kentucky Coal Field	2	5—Big and Little Sandy Rivers and Tygarts Creek	5
Jackson Purchase	6		

the locations of the sites within physiographic regions. Table 2 lists the AKGWA numbers (Assembled Kentucky Ground Water)—a Kentucky Division of Water identification number—map numbers, and sampling frequency of the Network sites shown in Figure 2. The following program activities were conducted during fiscal year 2017-18.

Trend Analysis of Ambient Groundwater Quality. Caroline Chan and Rob Blair of the Watershed Management Branch recently published “Report on the Condition of Ambient Groundwater in

Kentucky: Analysis of the Ambient Groundwater Quality Monitoring Network Data.” This report analyzed trends in ambient groundwater quality based on data that have been collected for the Network for the past 20 years.

The Network was established to provide baseline data, characterize the resource, and disseminate the information collected. For the first time, these data have been analyzed in order to characterize groundwater trends in Kentucky by physiographic region, source (well or spring), and

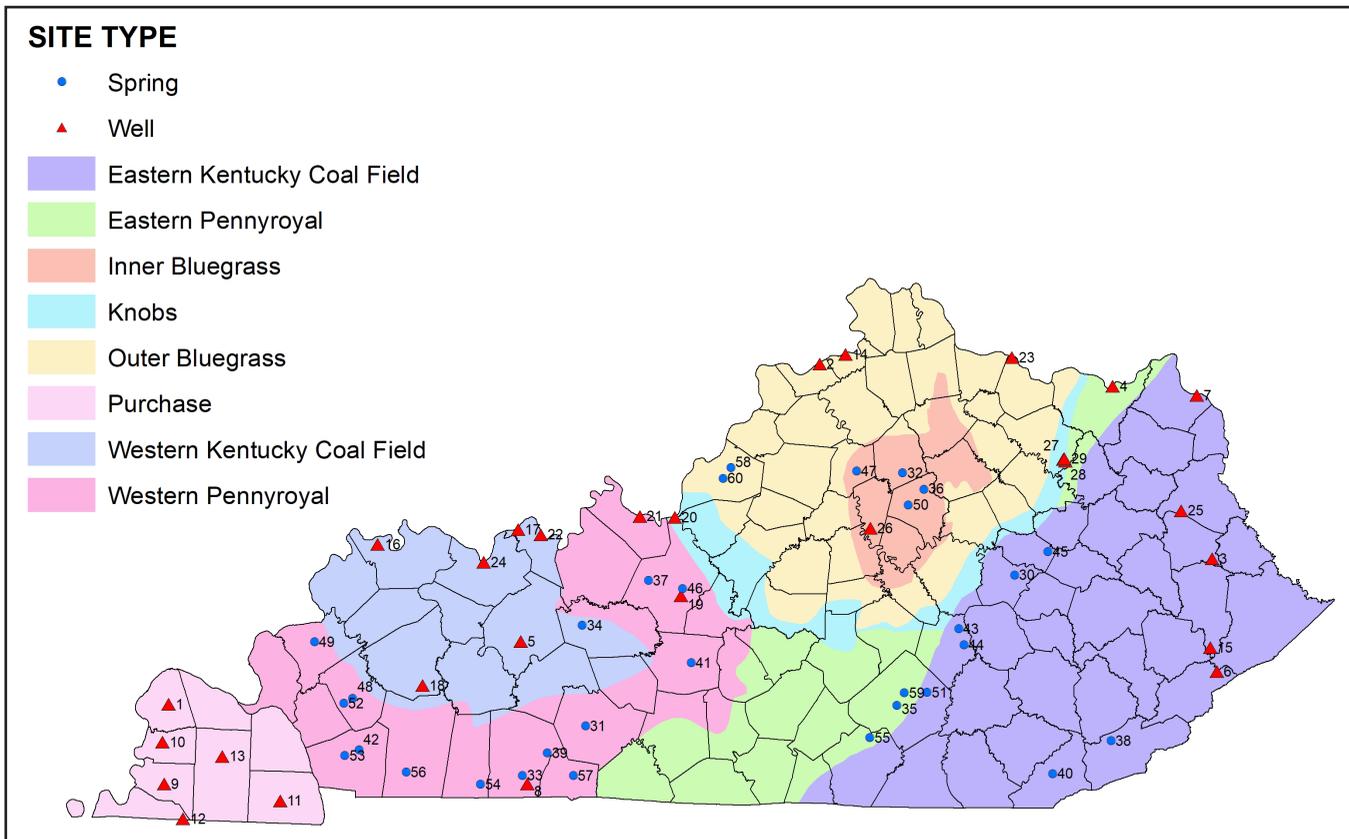


Figure 2. Kentucky Interagency Groundwater Monitoring Network sites maintained by the Kentucky Division of Water. Table 2 gives map numbers, Division of Water’s AKGWA numbers, and sampling frequency for these sites.

Table 2. AKGWA numbers and sampling frequency for the network sites shown in Figure 2. Sites corresponding to the AKGWA numbers can be located using the Kentucky Groundwater Data Repository website. Q=quarterly. M=monthly. 5Q=every fifth quarter. 2Q=every second quarter. Pest. MOA=Pesticides Memorandum of Agreement. AKGWA numbers starting with “0” are water wells, starting with “8” are monitoring wells, and starting with “9” are springs. Sample times vary.

Map No.	AKGWA No.	Sample Frequency	Map No.	AKGWA No.	Sample Frequency	Map No.	AKGWA No.	Sample Frequency
1	00000811	5Q	21	00061854	Q	41	90000798	M
2	00007133	5Q	22	00061858	Q	42	90000854	2Q
3	00012311	Q	23	00065002	Q	43	90001020	Q
4	00014293	2Q	24	00065149	Q	44	90001051	5Q
5	00019489	5Q	25	00068511	Q	45	90001134	Q
6	00028100	5Q	26	00069574	Q	46	90001137	Q
7	00029505	2Q	27	80046811	2Q	47	90001143	M
8	00029983	Pest. MOA	28	80046812	2Q	48	90001145	2Q
9	00033887	5Q	29	80046813	2Q	49	90001149	2Q
10	00033904	5Q	30	90000045	Q	50	90001161	Q
11	00033965	5Q	31	90000054	Q	51	90001254	5Q
12	00033972	5Q	32	90000055	M	52	90001343	2Q
13	00037330	5Q	33	90000315	Pest. MOA	53	90001344	2Q
14	00037376	5Q	34	90000456	5Q	54	90001475	Pest. MOA
15	00039374	5Q	35	90000544	5Q	55	90001822	Q
16	00040944	Q	36	90000552	Q	56	90001857	Q
17	00041471	Q	37	90000702	Q	57	90002823	Pest. MOA
18	00042984	Q	38	90000703	Q	58	90002934	Q
19	00043253	5Q	39	90000705	M	59	90003064	5Q
20	00049097	Q	40	90000710	5Q	60	90003355	Q

for the entire state. Forty-three parameters were monitored at 49 stations. The Mississippian Plateau had the most monitoring stations (24); because it covers a larger area, trends were easier to detect there, as reflected in the results.

The report delineates trends in concentration of several metals, nutrients, conductivity, and pH, across the state and in different physiographic regions. Continued monitoring will ensure early detection of problems so that they can be addressed before they get worse.

The full report can be found online at water.ky.gov/groundwater/Pages/default.aspx.

Ambient Groundwater Monitoring Network. Regularly scheduled sampling continued for the statewide Ambient Groundwater Monitoring Network. This fiscal year, 132 samples were collected from 52 permanent sites (25 wells and 27 springs); 56 of the samples were from water wells and 76 from springs (Fig. 3). Nineteen of these sites

are public water supplies (14 water wells and five springs). All sampling results are uploaded to the Kentucky Groundwater Data Repository and made publicly available. Groundwater-quality data were also provided in response to information requests, and used in-house for statistical analysis of regional and watershed data.

The Groundwater Section continues to work with the Kentucky Geological Survey to monitor water level and measure flow. Section personnel met with KGS and Hardin County District No. 1 personnel to collect groundwater-flow data from the Head of Rough Spring in Hardin County.

The Kentucky Division of Water and other members of ITAC are considering strategies to expand the Ambient Groundwater Monitoring Network in order to further characterize the state’s groundwater resource.

Pesticides Memorandum of Agreement Project (Pest MOA). The Pest MOA with the Kentucky



Figure 3. Tekoyia Brown and Wei Ji of the Division of Water's Groundwater Section sample Hobson Spring, an Ambient Groundwater Monitoring Network site.

Department of Agriculture was renewed for fiscal year 2017-18. The MOA funds four permanent sampling sites (three springs and one well) in the Mississippian Plateau Region of western Kentucky. Each site was sampled quarterly for a total of 16 samples during the fiscal year. Pesticide data from these sites are submitted to the Department of Agriculture annually.

Complaint and Technical Assistance Sampling.

Groundwater Section personnel respond to complaints and requests for technical assistance concerning groundwater, and investigate as requested by the public, industry, and other government agencies (Fig. 4). In fiscal year 2017-18, the Section responded to 30 complaints and requests for technical assistance, resulting in 19 samples being collected from 13 wells and six springs. If samples were not collected, recipients received technical assistance and their domestic water source was inspected.

Nonpoint-Source Groundwater Assessments.

The Groundwater Section is currently involved in three nonpoint-source studies, which are in various stages from review of the final report to area reconnaissance and site selection.

The Statewide Pathogens Study determines the occurrence of pathogens in groundwater, particularly in wells and springs used as domestic water supplies. Two hundred ten sites—202 wells and eight springs—across Kentucky were sampled for

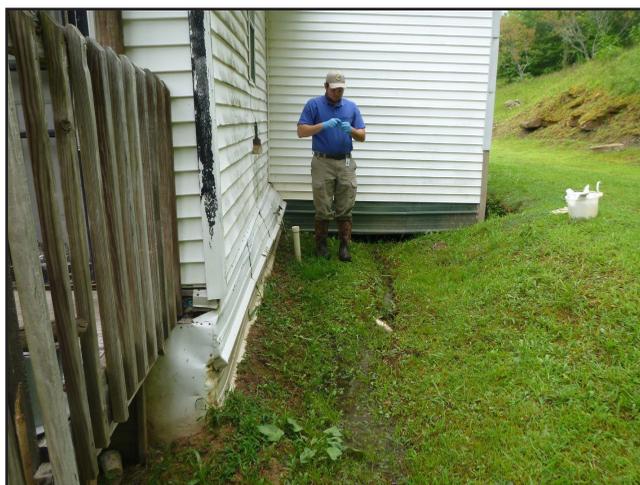


Figure 4. Groundwater Section geologist Kurtis Spears collects a water-quality sample to respond to a request for technical assistance.

total coliform, *E. coli*, iron-related, sulfate-reducing, and slime-forming bacteria, as well as caffeine. Results indicate that the presence of bacteria correlates with the type of well construction and maintenance practices. A secondary goal is to educate well owners about proper maintenance and disinfection practices. A report is under administrative review and is expected to be completed by Dec. 30, 2018.

The South-Central Karst Study has expanded karst groundwater mapping south of Lake Cumberland. The study area covers parts of Pulaski, Clinton, Wayne, and McCreary Counties. Current work focuses on groundwater dye tracing and delineation of karst basins. Thus far, 48 tracer tests have been recovered at 40 springs. Further delineation of spring basins is needed, after which large spring monitoring sites will be selected. The project will integrate surface-water and groundwater assessments. Five additional springs, mainly from the study area, were also examined during the 2017-18 fiscal year.

The Onsite Sewage Disposal Systems and Their Potential Effects on Groundwater evaluates potential impacts of home septic systems on groundwater. The study has passed the literature review stage, and site selection and evaluation are underway. Seven sites have already been evaluated, and some initial water-quality sampling has been conducted.

Special Projects

Craft Lane Investigation. During fiscal year 2017-18, the Groundwater Section helped the Haz-

ard regional office of the Division of Water perform a site assessment along Craft Lane, in Hazard, Perry County. The community along Craft Lane, which consists of eight homes, is located on the banks of the North Fork of the Kentucky River, and uses groundwater from a mine adit as its public drinking-water supply. Septic waste from all but one of the homes was routed to a community septic tank below the homes and within the floodplain of the river. Sampling of the water supply documented *E. coli* concentrations that exceeded Safe Drinking Water Act standards. Tracer dyes flushed into the septic systems of several of the homes bypassed the communal septic tank and leaked to the environment (Fig. 5). As a result, an agreement has been reached between the Division of Water and the property owners to connect all the homes to Hazard's public drinking-water system and to repair and connect all leaking septic-tank lines from the homes to the communal septic tank.

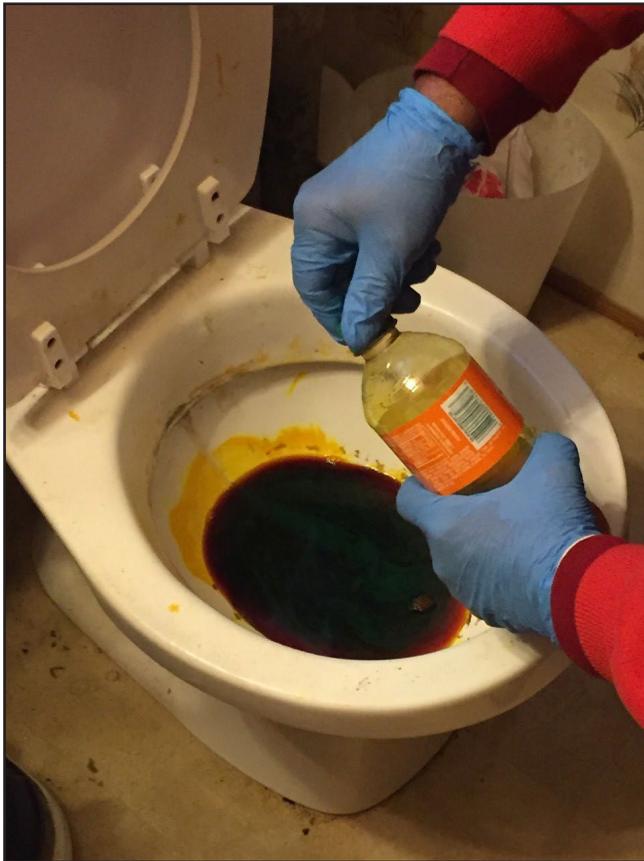


Figure 5. Groundwater Section personnel introduce tracer dye into a toilet to check for leaks in a septic system during the Craft Lane investigation.

Old Brownsboro Crossing. In response to a citizen's complaint and a request from the Water Quality Certification Section of the Division of Water, the Groundwater Section investigated several stormwater detention basins at Old Brownsboro Crossing in Louisville, and also reviewed new design plans. The proposed detention basins at Old Brownsboro Crossing, on Old Brownsboro Road near the intersection with Chamberlain Lane, were being redesigned because of retail and commercial expansion in the area. The new design eliminated an existing basin and incorporated two smaller basins into one comprehensive basin that would collect runoff from current and future commercial development. The site of the new stormwater basin, in the Middle Silurian Louisville Limestone, containing numerous sinkholes and springs, is an extension of the watershed basin headwaters of Wolf Pen Branch (Fig. 6). Wolf Pen Branch is predominantly a reach of losing stream characterized by several in-stream sinkholes in this area. The de-



Figure 6. In-stream sinkholes in the proposed stormwater detention basin site at Old Brownsboro Crossing.

sign of the new stormwater basin proposed enhancing and using several of the existing sinkholes as natural discharge points for inflow into the basin. The Division's field investigation documented two large springs on Wolf Pen Branch approximately 1,000 feet north of the proposed basin. Stormwater enters the groundwater system via sinkholes in the area of the proposed stormwater basin, and then flows north to the two springs the Division documented. The Groundwater Branch recommended that the sinkhole discharge points be classified as Class V stormwater injection wells; that a dye trace be conducted to confirm groundwater connections from the sinkholes to the springs on Wolf Pen Branch; that water quality be analyzed to determine sediment and nutrient loads before, during, and after construction of the stormwater basin; and that a Groundwater Protection Plan be developed for the stormwater basin as a whole.

Burgin Sinkhole Flooding. The City of Burgin in Mercer County requested technical assistance for sinkhole flooding. The mayor and city council were concerned that a recently installed sanitary sewer system had somehow exacerbated sinkhole flooding at several locations throughout the community. Burgin is located in the Inner Bluegrass physiographic region, which is characterized by the Ordovician Lexington Limestone Grier Formation.

To date, the Groundwater Section has gathered background data on historical flooding in the area, correlated rainfall with sinkhole flooding, and measured groundwater discharge at Burgin Spring (Fig. 7).

Groundwater Protection Plan Program. The Groundwater Protection Plan Program focuses on public outreach and education about threats to groundwater. Technical assistance is being offered to facilities and the public to identify best management practices that will protect groundwater from contamination. A wide variety of activities require Groundwater Protection Plans, but most inspections conducted thus far have been at industrial sites that store large quantities of chemicals or fuel (Fig. 8). Table 3 shows the number of these plans received, reviewed, and approved, and how many field reviews were completed by month during fiscal year 2017-18.



Figure 7. Groundwater Section Supervisor David Jackson measures the groundwater discharge rate at Burgin Spring.



Figure 8. Groundwater Section geologist Susan Mallette (now retired) performs a Groundwater Protection Plan field review in Pikeville.

Table 3.—Statistics for the Groundwater Protection Plan Program during fiscal year 2017-18.

Month and Year	Number Received	Number Reviewed	Number Approved	Field Reviews
July 2017	151	4	4	0
Aug. 2017	7	158	154	0
Sept. 2017	2	10	7	4
Oct. 2017	10	6	3	10
Nov. 2017	5	6	1	6
Dec. 2017	10	11	8	5
Jan. 2018	8	8	3	5
Feb. 2018	12	7	1	13
March 2018	7	6	5	15
April 2018	9	11	4	12
May 2018	5	6	4	17
June 2018	8	8	4	0
Totals	234	241	198	87

Certified Well Drillers Program. Use of domestic wells remains consistent throughout Kentucky. The Eastern Kentucky Coal Field and Jackson Purchase Region continue to have the highest percentage of households that rely on domestic wells as their primary source for drinking water. In 2017-18, 748 wells were drilled and reported to the Division. Plugging records were submitted for 535 decommissioned wells.

The Groundwater Section issued licenses to 159 certified drillers: 24 water-well, 73 monitoring-well, and 62 dual licenses. The official licensing renewal period was from July 1 to Aug. 31, 2017. Drillers are allowed to continue to submit new and renewal applications beyond the end of the official reporting period without penalty, however. Groundwater Section personnel continue to assist the Kentucky Groundwater Association with their annual Drillers' Tradeshow and Workshop by presenting information on proper protocols

for abandoning water and monitoring wells and organizing a discussion on ethical behaviors and how to be successful without breaking the rules. Approximately 100 drillers received continuing education credits, which are needed to meet licensure requirements in Kentucky, at this gathering. The Groundwater Section continues to explore new ways of reaching the public to increase awareness of and educate the public on groundwater issues that may affect them. Groundwater Awareness Week and Protect Your Groundwater Day are two such outreach opportunities, during which maintenance and protection of private drinking-water wells, as well as protection of the groundwater resource, are emphasized.

U.S. Geological Survey

USGS Climate Response Network. The U.S. Geological Survey, as directed by Congress, is establishing a national climate-response network of groundwater wells. Each climate division in the country is to have at least one real-time monitoring well in an aquifer that responds to climate changes, but is not affected by groundwater withdrawals or interactions with nearby surface water. Kentucky has one climate-response network well in each of its four climate divisions, in Graves, LaRue, Fayette, and Bell Counties. Data from these wells, compiled by the USGS's Ohio-Kentucky-Indiana Water Science Center, describe the natural variability in groundwater levels attributable to weather and climate. These data are available to the public through websites operated by the USGS (waterdata.usgs.gov/ky/nwis/current/?type=gw) and the USGS Climate Response Network (groundwaterwatch.usgs.gov). Monitoring of Groundwater Resources of the Northeast Portion of the Ohio River Alluvial Aquifer, Near Louisville, Jefferson County. In cooperation with the Louisville Water Co., the USGS monitors groundwater levels in the northeastern part of the alluvial aquifer near Louisville in Jefferson County. Tasks and field activities are designed to improve understanding of the various aspects of groundwater and surface-water interaction, especially riverbank infiltration.

Specifically, the program compiles groundwater-level data and infiltration rates for the water company's riverbank filtration system and compares them with previous years' data, monitors

groundwater quality to ensure proper wellhead-protection planning, evaluates groundwater-level data to estimate the contributing areas to the river-bank filtration system, and develops groundwater flow-modeling capabilities.

West Point Well Field Monitoring, Hardin and Meade Counties. Water treatment facilities at Fort Knox receive source water from drinking-water supply wells located along the Ohio River near West Point. The alluvial deposits in this area are typically 100 feet thick and are underlain by bedrock formations known to contain natural gas and high chloride concentrations. Previous investigations by the USGS and the U.S. Army have determined that improperly abandoned gas wells have provided a means for brines, under pressure within the underlying bedrock, to migrate upward and contaminate the groundwater in the alluvial deposits.

The USGS is collecting data in the well field to monitor groundwater conditions. These activities include measurement of water levels and chloride concentrations in groundwater, surveillance of active and abandoned gas wells, periodic geophysical surveys to track the size and movement of chloride plumes, and computer simulations of groundwater flow for wellhead protection management strategies.

Groundwater Monitoring and Aquifer Testing of the Alluvial Deposits in Boone, Campbell, and Kenton Counties. The USGS continues to work in cooperation with the Northern Kentucky Sanitation District as the District evaluates the feasibility of injecting stormwater infiltration into the area's alluvial deposits. Three pilot sites (Ludlow, Bellevue, and Covington) were selected for evaluation. One test well was installed at each site to gather groundwater-level data and test the aquifers. In previous years, the USGS conducted a series of pumping and injection tests at each pilot site to provide data that will be used to evaluate the injection capacity of the alluvial deposits, which will factor into the design of a proposed stormwater injection system.

Currently, the USGS maintains a network of four groundwater observation wells in the alluvial deposits in northern Kentucky near Covington.

Data on groundwater levels and temperature are continuously collected in three of the wells, and water-level measurements are collected quarterly for the fourth well.

Identifying Groundwater/Surface-Water Interactions in Nolin River Lake, Bee Spring, Kentucky.

In cooperation with the U.S. Army Corps of Engineers, the U.S. Geological Survey is investigating potential groundwater inflows to Nolin River Lake. Previous studies have indicated that these inflows may be a substantial source of nutrients to the lake. Nutrients can fuel biological productivity, which can result in harmful algal blooms and limit some uses of the lake. Karst features and fault zones may provide preferential pathways for groundwater to reach the lake. This study examines historical data and uses integrated synoptic water-quality surveys to identify groundwater inflows. The integrated synoptic surveys include discrete-depth measurements of water-quality properties from a manned boat and from an autonomous underwater vehicle.

Monitoring Groundwater Levels for a U.S. Army Corps of Engineers Earthen Dam Restoration Project at Rough River Lake, Breckinridge and Grayson Counties.

The Louisville District of the U.S. Army Corps of Engineers is rehabilitating a large-scale earthen dam at Rough River Lake in Breckinridge and Grayson Counties. As part of the effort to track the progress of the restoration, the USGS monitors groundwater levels in 60 piezometers equipped with continuously recording pressure transducers. Changes in pressure are also monitored with vibrating-wire transducers grouted in place at 60 sites throughout the dam. The Corps uses these data to determine priorities for repair and to monitor groundwater-level changes related to construction.

Kentucky Department of Agriculture

The Kentucky Department of Agriculture-Technical Support Branch continues to receive monitoring data from the Division of Water under a memorandum of agreement. The memorandum covers 16 samples yearly from four sites. This sampling is supplemented by the Division of Water's Ambient Groundwater Monitoring Network.

Kentucky Geological Survey, Water Resources Section

During 2017-18, Water Resources Section staff continued working on projects to characterize groundwater and surface water, started the previous year, and began several new projects in collaboration with the U.S. Department of Agriculture–Natural Resource Conservation Service, Kentucky Division of Water, and UK College of Agriculture, Food and Environment. Summaries and highlights of these activities are provided below.

Aquifer Designation Project. In the fall of 2017, the Survey began a new collaborative project with the Kentucky Division of Water, funded by the USGS Water-Use Data and Research Program, to identify and characterize aquifers used for public and industrial water supplies. The project will help improve the Division of Water’s program to manage Kentucky’s groundwater and the Division’s permit processing by creating a new digital hydrogeologic framework of major Kentucky aquifers; the aquifers will be designated by identification codes used in the USGS National Water Information System database. Existing data, including water-well construction logs, oil and gas well re-

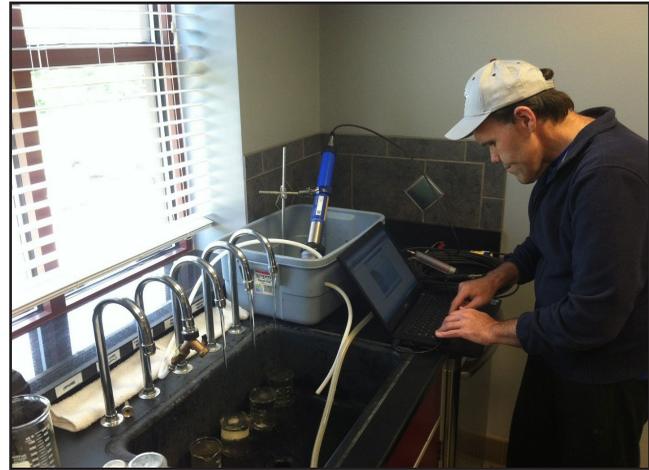


Figure 9. Kentucky Geological Survey hydrogeologist Steve Webb calibrates a multiparameter water-quality data sonde to monitor changes in temperature, pH, specific conductance, and turbidity of water pumped from Head of Rough Spring to Hardin County Water District No. 1’s treatment plant near Cecilia.

ords, geophysical logs, and other digital geologic mapping data presently archived by KGS, will be compiled and synthesized. The project is funded through June 2019.

Head-of-Rough Spring Discharge Monitoring.

Working in collaboration with the Hardin County Water District No. 1, Survey staff are collecting discharge measurements and water-quality data at a monitoring station at Head-of-Rough Spring near Cecilia. Monitoring equipment set up in December 2016 continuously tracks changes in water level, temperature, specific conductance, pH, and turbidity (Fig. 9). These data, along with periodic spring discharge (flow) measurements and analysis of water samples collected for total suspended solids concentration, provide information for the water district to improve its management of the spring as a public water source (Fig 10). The project is funded through



Figure 10. Kentucky Geological Survey hydrogeologist Steve Webb measures discharge in the outlet channel of Head-of-Rough Spring near Cecilia.

June 30, 2018, by a grant from the Kentucky Division of Water's Source Water Protection Assistance Program, but monitoring will continue at least through the end of 2018.

Karst Spring Investigation at The Homeplace on Green River, Campbellsville. An investigation of the hydrogeology of the karst spring at The Homeplace on Green River farm, near Campbellsville, is funded through December 2018 by a Natural Resource Conservation Service Conservation Innovation Grant. Survey hydrologists installed a data sonde capable of measuring multiple water-quality parameters in the spring of 2018. The sonde continuously monitors changes in pH, specific conductance, temperature, and turbidity (Fig. 11). In June 2018, the Survey began making preparations for dye-tracer tests, which will delineate subsurface groundwater flow paths and basin boundaries, as well as identify sinkholes that contribute stormwater runoff to the spring (Fig. 12). The dye-tracer tests will continue through the remainder of 2018. These data will help characterize the spring's hydrology in anticipation of a future water-quality sampling project to develop and demonstrate edge-of-field monitoring techniques for water quality and soil-health assessments in sinkhole-dominated crop fields.



Figure 11. Kentucky Geological Survey hydrogeologist Chuck Taylor installs a multiparameter water-quality data sonde in water flowing out of a cave spring at The Homeplace on Green River.

Monitoring Soil Moisture and Groundwater Conditions Under Pivot Irrigation. Kentucky Geological Survey staff collaborated with researchers from the UK College of Agriculture, Food and Environment to monitor soil moisture in a fragipan (impermeable zone) soil under pivot irrigation in Hickman County. Soil-moisture data collected from a corn field indicate that depth of the fragipan and landscape position influence soil-moisture capacity. In addition to soil-moisture data, groundwater-elevation data are collected prior to, during, and after the growing season by a transducer installed in the production water well. A flow meter records the volume of groundwater used to irrigate the corn crop. Transducer data indicate that the local groundwater elevation dropped during irrigation (July–August 2017), plateaued for several months after irrigation stopped (August–December 2017), and fully recovered to pre-irrigation levels by April 2018. Flow-meter data indicate that 8.2 million gallons of groundwater were used to irrigate approximately 105 acres in July and August 2017. The results will be published in a bulletin by the UK Cooperative Extension Service. The project is funded in part through a Conservation Innovation Grant from the Natural Resource Conservation Service and a Kentucky Water Resources Research Institute 104B Program Student Enhancement Grant.



Figure 12. Kentucky Geological Survey karst hydrogeologist Ben Tobin and geologic technician Adam Nolte prepare to flush a fluorescent tracer dye into the partly blocked swallet (throat) of a sinkhole at The Homeplace on Green River.

Evaluation of Groundwater Availability at the University of Kentucky Research and Education Center at Princeton. A project funded in part by the University of Kentucky College of Agriculture, Food and Environment will drill test wells and test aquifers in a follow-up investigation of groundwater availability at the University of Kentucky Research and Education Center at Princeton. In 2017, Survey staff collected fracture-trace, electrical-resistivity, and dye tracer test data to help identify the best potential locations for new irrigation wells within a 255-acre row-crop field recently purchased as part of the new UK Grain and Forage Center of Excellence. In January 2018, four test holes ranging in depth from 80 to 160 feet below ground surface were drilled to determine whether the local limestone aquifer is capable of supplying the groundwater needed for planned pivot irrigation research. The research determined that groundwater availability was severely restricted at the site; three of the test holes were dry and one produced only minimal amounts of groundwater (approximately 5 gallons per minute). Because the groundwater supply there was inadequate, the Center is investigating other potential water sources.

Sinkhole Mapping Using LiDAR Data. Work to create a digital map of sinkhole locations in Kentucky, which began in 2014, continues, and is using the now-complete LiDAR coverage for Kentucky. Three more counties, Bourbon, Hardin, and Madison, were mapped in 2017-18, adding locations for an additional 17,500 sinkholes to the database. Ten counties have now been mapped. The sinkhole mapping team is turning to machine-learning techniques to help automate and expedite the process. In a separate but related effort, maps showing sinkhole locations and information about sinkhole occurrence and other karst-related hazards were revised for the update of the state's hazard mitigation plan.

Corrosiveness of Drinking Water Study. Survey staff, collaborating with UK Department of Earth and Environmental Sciences faculty and students, completed a study of the quality of the Lexington-Fayette County public water supply, with an emphasis on water corrosiveness. This study was in response to the highly publicized water crisis

in Flint, Mich., and was supported by the U.S. Geological Survey through the Kentucky Water Resources Research Institute at UK. The project team collected and analyzed 24 tap-water and source-water samples throughout Lexington in spring and fall 2017. Results indicated that corrosiveness was generally low, but can increase significantly during icy or snowy winters when large amounts of road salt are applied. Correlation analysis suggested that metal concentrations increase with pipe distance and also are influenced by pipe materials. A model was developed to locate potential areas of concern for metals leaching in Lexington's water distribution system. The final report was submitted to the Institute in May 2018. Posters on the project were presented at the 2017 Geological Society of America annual meeting and the 2018 Kentucky Water Resources Research Institute's annual symposium.

Groundwater Modeling Activities for Paducah Gaseous Diffusion Plant Site. Working with Steven Hampson from the Kentucky Research Consortium for Energy and the Environment and Lindell Ormsbee and Kelly Pennell from the Kentucky Water Resources Research Institute, Junfeng Zhu reviewed the groundwater flow model for the Paducah Gaseous Diffusion Plant. The current model is a recent update of a model used as a tool to remediate groundwater that was contaminated by decades of uranium enrichment at the plant. The review was to ensure that the model properly represents the groundwater flow system at the site. This modeling project, supported by the U.S. Department of Energy, began in September 2017 and finished in March 2018 when the report was submitted to the Department of Energy.

Collaboration With Kentucky Division of Water Groundwater Sampling Program. The Kentucky Division of Water is responsible for sampling water quality at about 60 sites, including both wells and springs, across Kentucky as part of the Kentucky Interagency Groundwater Monitoring Network (www.uky.edu/KGS/water/gnet). Most samples are collected quarterly or twice a year by Division of Water personnel on 12 different sampling runs across the state. Survey geologists assist the Division by sampling at three sites: McConnell Spring and Russell Cave Spring in Fayette County, and Royal Spring in Scott County (Figs. 13-14). The



Figure 13. Kentucky Geological Survey geologist Richard Smath assists with sampling the McConnell Spring bluehole in Lexington using a telescoping sampling beaker. The instrument on the tree in front of him records basic field parameters of the water, including temperature, conductivity, and pH. Flow of the spring is also estimated before the sample is taken.

Environmental Services Branch Laboratory in Frankfort analyzes the samples, and the resulting groundwater-quality data are uploaded into the Kentucky Groundwater Data Repository.

Groundwater Data Repository and Monitoring Mandates. The Kentucky Geological Survey is legislatively mandated to serve as the state's official repository for groundwater information (KRS 151.035) and oversee establishment of a long-term groundwater-monitoring network (KRS 151.625).

The Kentucky Groundwater Data Repository contains well-construction and water-quality sampling data for more than 105,000 sites across Kentucky, including more than 43,000 domestic wells, 1,300 public wells, 875 industrial wells, 4,400 agricultural wells, 35,400 monitoring wells, and more than 5,300 springs. Thousands of analytical results are available for many of these wells and springs.

Since the Repository's inception in 1990, data have been compiled from more than 15 agencies, including the Survey. The largest annual contributions come from the Kentucky Division of Water, and data compiled by the Division's Well Drillers Certification Program and the Kentucky Interagency Groundwater Monitoring Network



Figure 14. Kentucky Geological Survey geologist Bart Davidson adds nitric acid to a sample from Russell Cave Spring in Lexington. The acid reduces the pH of the sample to prevent bacteria from growing in the water before it is analyzed for total metals by the Environmental Services Branch laboratory in Frankfort.

are uploaded to the Repository approximately once every quarter. Scanned copies of water-well drillers' logs are uploaded approximately every six months.

All available Repository data for wells and springs are publicly accessible at www.uky.edu/KGS/water/research/gwreposit.htm and can be searched, downloaded, and displayed online using various base maps. Users can generate comprehensive hydrologic site assessments for multiple purposes, such as groundwater resource exploration, environmental monitoring and remediation, land-use development, recreation, and agricultural planning.

During 2017-18, Survey hydrogeologists collected groundwater-level data as part of an ongoing effort to rebuild a statewide groundwater ob-

ervation network. Water levels were continuously recorded using automated water-level logging equipment at 10 observation wells in Caldwell, Calloway, Edmonson, Henderson, Hickman, Marshall, and Scott Counties. Sites for other potential observation wells are being sought in parts of the state where information on groundwater availability is critically needed by groundwater users and water-resources managers. The Survey is currently developing a new webpage to display water-level hydrographs for the observation network wells and enable public access to the data.

Activities in KGS Water and Rock Laboratory. The Kentucky Geological Survey analytical laboratory supports the research of Survey geologists, faculty and graduate students from the University of Kentucky, and students from other Kentucky universities by providing analytical expertise, as well as training on and access to analytical instruments. During the fiscal year, the laboratory analyzed water, mineral, coal, and biological samples from across the state for 14 ongoing projects. Water-quality monitoring projects in Hardin County, at Cane Run, and at the Kentucky National Guard's Harold L. Disney Training Center, near Barbourville, send samples to the Survey lab. The lab also provides analyses for Kentucky Watershed Watch, and has done so since 1998. Many Kentucky River samples were analyzed for nutrients and metals in fall 2017. The UK Mining Engineering Department and Center for Applied Energy Research also supply samples for a project to quantify rare earth elements in coal ash and refuse. The lab also analyzed biological samples for several researchers in the UK College of Medicine.

New instrumentation and enhancements this fiscal year will greatly enhance the lab's ability to meet the analytical needs of the Survey's research scientists. A portable, field-capable gas chromatograph will enable Survey scientists to analyze volatile hydrocarbons, gases, and other types of organic compounds occurring in both gas and water samples. A new radiation tube was installed on the X-ray diffractometer that the Survey shares with other departments at UK; the diffractometer is housed in our laboratory and maintained by the Survey. More than 20 different researchers used the diffractometer this fiscal year. Lab personnel train

students from several Kentucky universities on how to use scientific equipment and instrumentation. For example, students from Morehead State University learned about sample preparation, X-ray fluorescence, and X-ray diffraction; students from Western Kentucky University were trained in X-ray fluorescence techniques used the X-ray fluorometer; and several students from the UK Department of Earth and Environmental Sciences were trained to use the carbon analyzers.

Kentucky Division of Mine Reclamation and Enforcement

The Field Support Section of the Division of Mine Reclamation and Enforcement investigates reports of diminished quality or quantity of groundwater at the request of citizens of the commonwealth. In addition, the Division investigates surface water in connection with diminished quality, stream loss, or flooding. Investigations are also conducted as a result of landslides, methane migration, or other problems related to coal mining in the Eastern and Western Kentucky Coal Fields.

Distribution of Groundwater Information

One of the most important functions of the Interagency Technical Advisory Committee and the Groundwater Monitoring Network is translating analytical data from water-level measurements and groundwater analyses into readily available, useful information and presenting it to the public. During the 2017-18 fiscal year, groundwater information was communicated via short reports, oral and poster presentations at meetings and conferences, and posting on websites. Publications and presentations generated by ITAC agency members or affiliated personnel are listed below.

Publications

- Chan, M.C., and Blair, R.J., 2017, Report on the condition of ambient groundwater in Kentucky: Analysis of the Ambient Groundwater Quality Monitoring Network data: Kentucky Division of Water, 84 p.
- Davidson, B., comp., 2018, Kentucky Interagency Groundwater Monitoring Network annual report, July 2017-June 2018: Kentucky Geological Survey, 15 p.

- Reyes, J., Wendroth, O., Matocha, C., Zhu, J., Ren, W., and Karathanasis, A.D., 2018, Reliably mapping clay content coregionalized with electrical conductivity: *Soil Science Society of America Journal*, v. 82, no. 3, p. 578–592, doi:10.2136/sssaj2017.09.0327.
- Sherman, A., Merrick, J., Zhu, J., Fryar, A., and Lee, B., 2017, GIS ArcMap cost distance tool used to determine public water supply relative risk metals sampling sites in Lexington, Kentucky [abs.]: *Geological Society of America Abstracts with Programs*, v. 49, no. 6, doi:10.1130/abs/2017AM-303524.
- Zhu, J., Parris, T.M., Taylor, C.J., Webb, S.E., Davidson, B., Smath, R., Richardson, S.D., Molofsky, L.J., Smith, A.P., and Kromann, J.S., 2018, Occurrence and origin of methane in shallow groundwater in Berea and Rogersville play areas, eastern Kentucky [abs.]: *Geological Society of America Abstracts with Programs*, v. 50, no. 3, doi:10.1130/abs/2018SE-312050.
- Presentations**
- Adams, E., Husic, A., Fox, J., Taylor, C., Agouridis, C., Currens, J.C., and Workman, S., 2018, Coupled hydraulic and sediment transport modeling of a fluvial karst aquifer in the Bluegrass Region of Kentucky [poster]: *Kentucky Water Resources Annual Symposium*, Lexington, Ky., March 19, 2018.
- Beasley, K., Nolte, A., and Zhu, J., 2017, Sinkhole mapping of Woodford County, Kentucky, utilizing LiDAR [poster]: *Tracy Farmer Institute for Sustainability and the Environment 7th Annual Sustainability Forum*, Lexington, Ky., Dec. 6, 2017.
- Boling, J., Lee, B., Beck, E.G., Knott, C., Grove, J.H., Ritchey, E., and McIntosh, J., 2018, Soil moisture conditions and yield across fragipan soils under irrigated management in western Kentucky: *Kentucky Water Resources Annual Symposium*, Lexington, Ky., March 19, 2018.
- Buskirk, R.E., Borowski, W.S., and Malzone, J.M., 2018, Characterization of groundwater and surface water geochemistry in an agricultural setting at ECU Meadowbrook Farm, Madison County, Ky. [poster]: *Kentucky Water Resources Annual Symposium*, Lexington, Ky., March 19, 2018.
- Chan, M.C., 2018, Kentucky One Stop Business Portal ... Kentucky Uniform Well Construction Record reform ... and how to set up One Stop user account: *Kentucky Groundwater Association Annual Drillers' Tradeshow and Workshop*, Louisville, Ky., March 1, 2018.
- Chan, M.C., 2018, Report on the condition of ambient groundwater in Kentucky: *Interagency Technical Advisory Committee quarterly meeting*, Frankfort, Ky., Feb. 8, 2018.
- Chan, M.C., and Blair, R.J., 2018, Analysis of the Ambient Groundwater Quality Monitoring Network data: *Kentucky Water Resources Annual Symposium*, Lexington, Ky., March 19, 2018.
- Haneberg, W.C., 2018, Water resources applications of KyAPED airborne LiDAR data: A new era for hydroscience in Kentucky: *Kentucky Water Resources Annual Symposium*, Lexington, Ky., March 19, 2018.
- Husic, A., Adams, E., Fox, J., Ford, W., Backus, J., Pollock, E., Taylor, C.J., Rexroat, A., Agouridis, C., Currens, J.C., and Workman, S., 2018, Water, sediment, and nutrients data streams in a fluviokarst watershed in the Kentucky Bluegrass: Insights from elemental, isotopic, and high resolution sensor data: *Kentucky Water Resources Annual Symposium*, Lexington, Ky., March 19, 2018.
- Jackson, D.A., 2018, Water well and monitoring well abandonments ... The do's and don'ts: *Kentucky Groundwater Association Annual Drillers' Tradeshow and Workshop*, Louisville, Ky., March 1, 2018.
- Ji, W., 2018, Ambient Groundwater Monitoring Network ... Characterization and ideas for moving forward: *Interagency Technical Advisory Committee quarterly meeting*, Lexington, Ky., April 18, 2018.
- Nolte, A., Beasley, K., and Zhu, J., 2018, Sinkhole mapping of Woodford County, Kentucky, utilizing LiDAR: *17th Annual Posters-at-the-Capitol*, Frankfort, Ky., Feb. 8, 2018.
- Sherman, A., Merrick, J., Zhu, J., Fryar, A., and Lee, B., 2018, Water quality analysis in municipal water supply system for Lexington, Ky., with a focus on corrosivity: *Kentucky Water Resources Annual Symposium*, Lexington, Ky., March 19, 2018.

Taylor, C.J., 2018, Characterization of spring discharge and karst drainage at The Homeplace on Green River, Campbellsville, Ky.: Kentucky Water Resources Annual Symposium, Lexington, Ky., March 19, 2018.

Zhu, J., and Taylor, C.J., 2018, Improving karst/sinkhole hazard assessment for Kentucky: Kentucky Water Resources Annual Symposium, Lexington, Ky., March 19, 2018.

Website Information

Statewide groundwater data in the Kentucky Groundwater Data Repository can be accessed at kgs.uky.edu/kgsweb/DataSearching/watersearch.asp. The Repository database contains water-well, spring, and groundwater-quality data. Several alternatives are available for viewing groundwater information on both interactive and static maps, and for creating graphic representations of groundwater-quality data.

The Kentucky Geological Survey also maintains a website for the Interagency Groundwater Monitoring Network (www.uky.edu/kgs/water/gnet), which contains links to current and previous annual reports of the Network and to the websites of the ITAC agencies and organizations.

The Kentucky Water-Well and Spring search engine was accessed 8,250 times during fiscal year 2017-18, resulting in 506 downloads. This search engine remains the second most popular on the Survey's website, after the one for oil and gas records. Users can search for wells or springs by county, 7.5-minute quadrangle, or a radius from a latitude/longitude location. Resulting data can be displayed on maps or downloaded for use in GIS packages. The website also contains documents scanned by the Kentucky Division of Water, and these were downloaded 14,312 times. The associated Water Wells and Springs map service was accessed 5,188 times during the fiscal year, and the Karst Potential Map layout on the KGS Geologic Map Service was accessed 2,892 times.

The Kentucky Groundwater-Quality Data search engine was accessed more than 1,000 times during fiscal year 2017-18, resulting in 98 downloads. Users can select from hundreds of parameters in 14 major categories, some of which are herbicides, pesticides, inorganics, metals, nutrients, volatile organic compounds, and

petroleum hydrocarbons. Resulting data can be downloaded, displayed on maps, or used to generate graphs comparing groundwater-quality data by physiographic region or watershed basin. The water-quality map was accessed 478 times, and the groundwater-quality data plotting service was accessed 91 times.

In addition to the Repository data, information about hydrology, geology, topography, water supply, and water quality has been compiled from maps, reports, and data collected from 1940 to the present and is available at www.uky.edu/kgs/water. For more information on groundwater-quality or water-well and spring data, contact the Survey at (859) 323-0523.

Interagency Coordination

Cooperation among agencies and research organizations that collect, analyze, and use groundwater data reduces monitoring costs, improves program efficiency, and promotes data sharing. The Interagency Technical Advisory Committee on Groundwater provides a forum for participating organizations to meet and discuss groundwater issues.

Many programs benefit from the Division of Water's willingness to collect and analyze groundwater samples to support various projects. The Division also samples groundwater and surface water for nonpoint-source constituents in support of projects for the Division of Pesticide Regulation. The Division of Water and the Kentucky Geological Survey regularly answer inquiries from the public and communicate with staff of the Kentucky Rural Water Association. Kentucky Geological Survey staff have been meeting with Cooperative Extension Service agents and Area Development District personnel throughout the commonwealth to promote awareness of hydrogeologic issues. Some ITAC agencies are also members of the Kentucky Agriculture Water Quality Authority or cooperate with the Authority and participate in its meetings. Staff of both the Division of Water and the Kentucky Geological Survey regularly participate in meetings of state and federal agencies and citizens' groups that have interests in groundwater resources.

Groundwater Data Sharing

Sharing data is an essential function of the Interagency Groundwater Monitoring Network. Data transfers between agencies provide each group access to a larger data set than any agency could develop independently, thereby improving evaluations of groundwater quality and suitability for various uses, dealing with threats to groundwater quality, and mitigating the effects of mining, logging, agricultural practices, urbanization, waste disposal, and oil and gas production. Sharing data also reduces the overall expense and increases the efficiency of monitoring efforts.

Data have been transferred electronically between the Division of Water groundwater database and the Kentucky Groundwater Data Repository since 1992. During 2017-18, electronic files of water-well, spring, and groundwater-quality data were transferred from the Division of Water to the Kentucky Geological Survey quarterly, and scanned drillers' logs twice a year. These data and scanned images were uploaded to the Kentucky Groundwater Data Repository, allowing end-users to access the most recent well and spring data available.

Other Activities

ITAC agencies are involved in many activities concerning surface-water quality and public education about water resources. Although these projects do not directly address issues raised by the 1998 Kentucky General Assembly, they are important contributions because of the close interconnection of groundwater and surface-water systems in Kentucky. Some of these activities are listed below.

University of Kentucky Environmental and Natural Resource Issues Task Force "No P on My Lawn!": Residential Program on Lawn Nutrient Management. Nutrient pollution is one of America's most challenging environmental problems. Excess nutrients cause algae overgrowths or algal blooms that may be toxic to humans and pets and reduce oxygen levels in water for fish and other aquatic organisms. In urban environments, nutrients are carried to surface-water bodies via stormwater runoff.

Recent research shows that nutrient loads from urban areas meet or exceed those from the agricultural sector. Primary inputs to urban runoff are fertilizers, natural amendments, and lawn

debris, which contribute nitrogen and phosphorus to our stormwater systems. Educating homeowners on the relationship between over-fertilization and improperly timed nutrient applications is imperative to improve water quality. The University of Kentucky's Cooperative Extension Service has partnered with the Lexington-Fayette Urban County Government to implement a public education program, "No P on My Lawn!" to engage with the residential audience about proper nutrient management. Phosphorus fertilizer applications are targeted because 25 years (1990-2014) of soils data show that 96 percent of Fayette County lawns and gardens will not benefit from phosphorus applications. The program outlines the issues associated with over-fertilization, demonstrates the benefit and method of soil testing (Fig. 15), and emphasizes appropriate application of nutrients

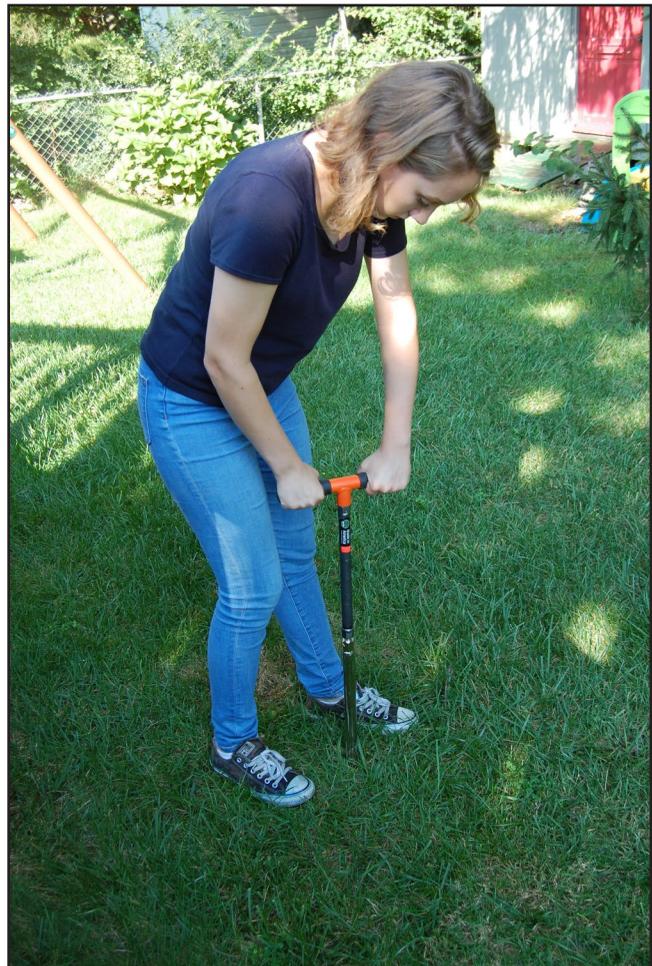


Figure 15. A homeowner collects a soil sample for testing.

to plants, using the “5R” approach to nutrient management: right source, right rate, right time, right place, right price. Program impacts are measured through pre- and post-workshop surveys that assess current homeowner understanding and management practices and resultant behavioral changes. Assessments of participants’ understanding prior to the workshop showed that more than half had an above-average understanding that excessive nutrients have a negative impact on water quality, yet most did not realize that urban areas contribute excess nutrients to stormwater. A survey after the workshop indicated that most participants are willing to change their current practices and adopt the 5R method, including conducting a soil test prior to applying phosphorous (94 percent of participants), applying at the right time and rate (100 percent), and properly placing fertilizer to minimize runoff (98 percent). These preliminary results confirm the need for increased public education about nutrient management and indicate that an informed public will select behaviors that will reduce nutrient contributions to stormwater.

Kentucky Division of Forestry

Forested land provides important benefits to both groundwater and surface water in rural and urban landscapes. Forests absorb rain, trap and filter pollutants, recharge groundwater, slow storm runoff, sustain late-season flows, reduce flooding,

maintain watershed stability and resilience, and provide critical habitat for fish and wildlife. Studies show that the percentage of forested land in a source-water area is one of the most important factors in determining water quality. The more forested land in a source area, the better the water quality and lower the treatment costs. Watersheds with less forested land have higher water temperatures and higher levels of fecal coliform bacteria, turbidity, and nutrients.

Reducing forest cover increases water yield, whereas establishing forest cover decreases water yield. Water yield is the amount of surface water and groundwater leaving a watershed. On average, removing 10 percent of forest cover increases water yield by 40 millimeters in conifers, 25 millimeters in deciduous hardwoods, and 10 millimeters in brush and grasslands. Although simply removing forest increases the water yield, placing an impervious barrier such as pavement, roofing, or exposed rocks from mining further increases these yields.

The Kentucky Statewide Assessment of Forest Resources and Strategy, known as the Kentucky Forest Action Plan, released in June 2010 by the Kentucky Division of Forestry, revealed that water quality and quantity was the second most important concern about forests of the citizens of the commonwealth, according to a statewide survey of the most important issues affecting the state’s forest resources. The Division, also using stakeholder

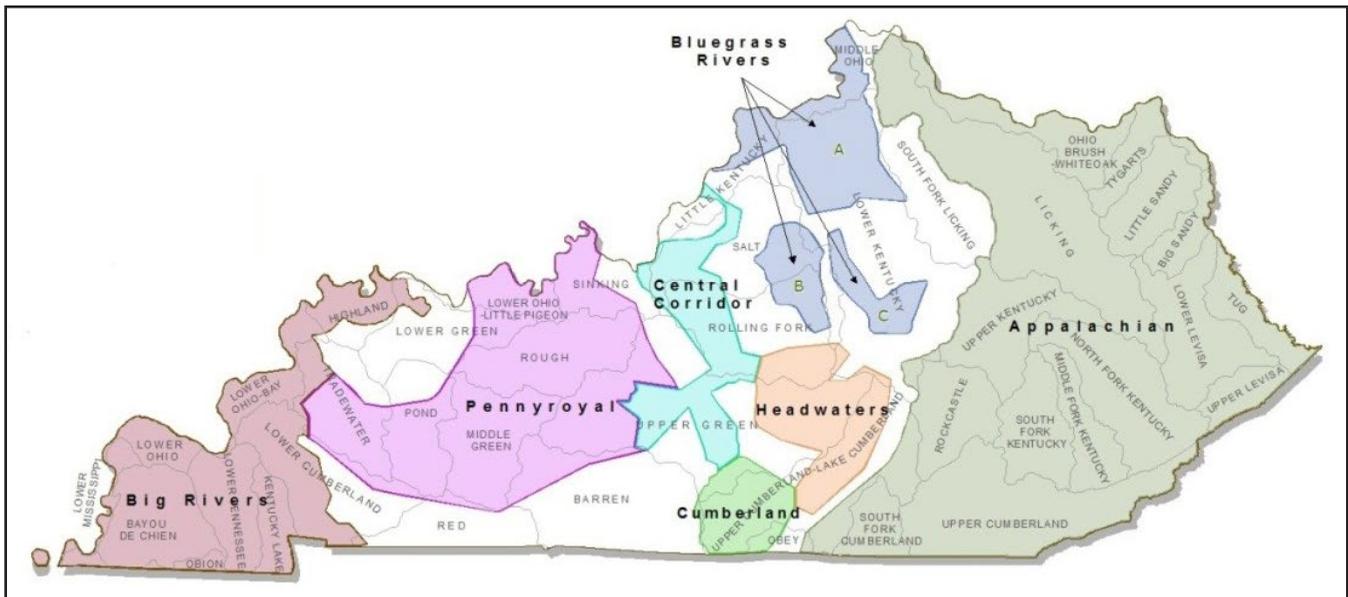


Figure 16. Forest priority areas and watersheds in Kentucky.

input, delineated seven major forest priority areas across the commonwealth in which to focus a collaborative strategy to maintain sustainable forests and as a basis for improving water quality and quantity (Fig. 16).

The primary objective of the Division's Timber Harvest Compliance Program is to ensure that commercial timber-harvesting operations use best management practices to protect water from nonpoint-source pollution. This program enforces the minimum performance standards of best management practices mandated by the Kentucky Agriculture Water Quality Plan.

For the 2017-18 fiscal year, 3,145 harvest inspections were performed, resulting in 338 enforcement actions.

The Division's Forestry Stewardship Program proactively mitigates water-quality concerns by providing technical assistance in practice plans for riparian buffer development under the auspices of the U.S. Department of Agriculture-Natural Resource Conservation Service's Conservation Reserve Program.

The Division also addresses water quality by promoting the agroforestry concept of strategically incorporating trees into the agricultural landscape in order to protect water resources and meet landowner objectives. This integrated watershed approach is very effective in promoting good water quality, often proving economical to the landowner when implemented.

Mitigating stormwater issues is a component of the Division's Urban Forestry Program. The Division's urban forestry specialists educate community leaders about the many benefits of trees in the urban setting, one of which is phytoremediation, or the use of trees to decontaminate soils or water. Thirty-eight Kentucky communities were certified as a Tree City USA community, which is a national designation sponsored by the Arbor Day Foundation and administered locally by state forestry agencies. Six of these communities were also designated as a Growth Award community for significantly expanding their urban forestry programs. Twelve universities and colleges received Tree Campus USA certifications. This Arbor Day Foundation program recognizes college campuses that show a commitment to campus tree care through dedicated planning, funding,

and collaboration with students, faculty, staff, and community organizations. Two utility companies received Tree Line USA designations; this Arbor Day Foundation program recognizes companies that use best management practices in public and private utility arboriculture.

Urban forestry specialists and foresters at the Division in fiscal year 2017-18 were involved in Lexington's Reforest the Bluegrass, in which more than 600 citizen volunteers planted more than 7,000 tree seedlings at Veterans Park. At the Reforest Northern Kentucky event in Sanitation District No. 1 in Alexandria, nearly 100 volunteers planted 1,500 tree seedlings; and at Reforest Frankfort at Josephine Sculpture Park, 400 volunteers planted 2,000 tree seedlings. At all of these reforestation events, Kentucky Division of Forestry personnel assisted with planning, coordination, layout, and technical recommendations, as well as serving as crew leaders.

County judge-executives from 114 counties signed Arbor Day proclamations for their respective counties, designating a specific day to celebrate Arbor Day. The Division sold or gave away 202,000 tree seedlings for use in a variety of Arbor Day activities.

Kentucky Geological Survey, Water Resources Section

Lower Green River Watershed Edge-of-Field Surface-Water Monitoring. The Survey is monitoring nutrient and sediment loss from active row-crop fields in the lower Green River watershed in a multiyear collaboration with the UK College of Agriculture, Food and Environment. This edge-of-field project, which should run through 2028, is funded in part by the Kentucky Soybean Board and through an Environmental Quality Incentives Program contract from the Natural Resource Conservation Service. Six suitable watersheds, ranging in size from 3.5 to 11.5 acres, were identified in late 2017. In March and April 2018, the researchers installed a flume, automated sampler, and ultrasonic flow meter (Fig. 17) in each watershed outlet. Nutrient and sediment sampling should begin in July 2018. The project will determine the nutrient and sediment loss from active row-crop fields under different nitrogen-application methods. A UK Department of Plant and Soil Sciences employee



Figure 17. One of six edge-of-field nutrient and sediment-loss monitoring stations in the lower Green River watershed.

who is stationed in the Survey's Western Kentucky Office in Henderson is conducting field work for the project.

Wetland Edge-of-Field Surface-Water Monitoring. The Survey is collaborating with UK Plant and Soil Sciences staff on a multiyear project to monitor nutrient and sediment runoff from retired row-crop fields that have been converted or are being converted to wetlands. This project, which should run through 2023, is funded through the Wetland Reserve Program administered by the Natural Resource Conservation Service. Six wetland watersheds, ranging in size from 1.5 to 13 acres and located in western Kentucky, have been selected and will be instrumented with a flume, automated sampler, and ultrasonic flow meter by the end of August 2018. The project will assess the nutrient and sediment runoff from wetlands that are in various stages of agricultural or land-use management (for example, soybean field converted to trees, tree and dense vegetation, or mature forest).