

# Kentucky Interagency Groundwater Monitoring Network

*Annual Report  
July 2014–June 2015*



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

October 2015



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- Daniel Skillman, Kentucky Division of Mine Reclamation and Enforcement
- Charles J. Taylor, Kentucky Geological Survey, Water Resources Section
- Stewart West, Kentucky Division of Forestry

**On the cover:** Two views of the Short Creek karst window near Stab in Pulaski County. The spring, or resurgence (left), and swallow hole (right) are only separated by about 75 feet. Groundwater flows out from the spring and back into the swallow hole, creating a “window” into the underground karst conduit system of the limestone in this area. Photos by Emily Denlinger, Kentucky Division of Water, Groundwater Section.

# Contents

Introduction .....	1
2014-15 Activities and Accomplishments.....	1
Groundwater Data Collection .....	2
Kentucky Division of Water, Watershed Management Branch, Groundwater Section.....	3
Ambient Groundwater Monitoring Network.....	4
Pesticides Memorandum of Agreement Project.....	4
Complaint Sampling.....	4
Nonpoint-Source Groundwater Assessments .....	5
Special Projects .....	5
Certified Well Drillers Program.....	5
Well-Drilling Activities .....	6
U.S. Geological Survey.....	6
Louisville Water Company, Ohio River Alluvial Aquifer, Jefferson County .....	6
Groundwater-Level Data Collection.....	7
Well-Integrity Survey of Abandoned Gas Wells Near West Point, Hardin County .....	7
Hydrogeologic Reconnaissance, Well Inventory, and Aquifer Tests to Assess the Feasibility of Stormwater Injection Wells, Northern Kentucky Sanitation District No. 1 Service Area, Boone, Campbell, and Kenton Counties.....	7
Kentucky Department of Agriculture .....	8
Kentucky Geological Survey, Water Resources Section .....	8
Groundwater Availability and Water Quality .....	8
New Statewide Groundwater Observation Network.....	9
Karst and Sinkhole Research.....	10
Groundwater Data Repository .....	12
Collaboration with Kentucky Division of Water Sampling.....	12
Groundwater Atlas of Kentucky .....	12
Rock and Water Analytical Laboratory .....	12
Kentucky Division of Mine Reclamation and Enforcement.....	14
Distribution of Groundwater Information .....	14
Publications .....	15
Presentations .....	15
Website Information.....	17
Interagency Coordination .....	18
Groundwater Data Sharing.....	18
Other Activities.....	19
University of Kentucky Environmental and Natural Resource Issues Task Force.....	19
The Kentucky Well Education Website .....	19

## **Contents (continued)**

ENRI Website .....	19
“See Blue Go Green” Website .....	19
ENRI Quarterly E-News .....	19
Taking Runoff by Storm: Rain Garden and Rain Barrel Lessons.....	19
Taking Runoff by Storm: Residential Rain Garden Program.....	19
Kentucky Water Awareness Month Packet .....	20
Over the River and Through the Wood Project WET and Project Learning Tree Educator Certification .....	20
Project WET Workshops .....	21
Robinson Center Natural Resources and Environmental Science Academy .....	21
Kentucky Division of Forestry.....	21

## **Figures**

1. Map showing counties in which ITAC member agencies had groundwater-related projects during the 2014-15 fiscal year .....	2
2. Map showing counties in which ITAC member agencies had surface-water-related projects during the 2014-15 fiscal year .....	2
3. Map showing locations of major rivers, basin management units, and physiographic regions in Kentucky .....	3
4. Map showing sites of the Kentucky Interagency Groundwater Monitoring Network .....	4
5. Photographs of spring and swallow hole of the Short Creek karst window near Stab .....	6
6. Photograph showing Division of Water geologist sampling Vaught Spring near Somerset.....	6
7. Photograph of USGS personnel downloading data from a transducer installed in an abandoned gas well near West Point .....	7
8. Photograph of KGS geologists sampling water from a pond on a reclaimed surface-mined area in Muhlenberg County .....	9
9. Photograph of KGS hydrogeologist installing real-time monitoring equipment in a water well at the Kentucky Horse Park in Fayette County .....	10
10. Photograph of KGS hydrogeologist and University of Kentucky graduate students inspecting a cover-collapse sinkhole in Midway .....	11
11. Photograph of Kentucky Division of Water and Kentucky Geological Survey geologists taking a water sample for the Kentucky Interagency Groundwater Monitoring Network at McConnell Springs blue hole in Lexington.....	13
12. Photograph of a KGS laboratory scientist running groundwater samples from Muhlenberg County using the organic carbon analyzer.....	14
13. Photograph of a landslide in Floyd County on a steep hillside, determined to be the result of mining activities.....	15

## **Figures (continued)**

14. Photograph of water from a 30-year-old domestic well in Floyd County that has never had never had any well maintenance or disinfection.....	16
15. Photograph of a stream bed in Perry County encrusted with a calcium carbonate mineral called tufa, which coats rocks, soil, and any organic material in the stream .....	17
16. Photograph of a Woodford County rain garden and rain barrel installed in the spring of 2013 during a Residential Rain Garden Program.....	20
17. Map showing locations of Kentucky forest priority areas and watersheds .....	21

## **Tables**

1. Spatial distribution of permanent groundwater-quality monitoring sites .....	3
2. Assembled Kentucky GroundWAtter numbers and sampling frequency for the network sites shown in Figure 4.....	5



# Kentucky Interagency Groundwater Monitoring Network

## Annual Report

### July 2014–June 2015

#### Introduction

Groundwater is a vital resource to Kentucky. It is used extensively throughout the state for domestic, 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 and its citizens. 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 Pesticide Regulation
- 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

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

The participating network agencies continue to fulfill their obligation of collecting and providing groundwater-quality and other water-related data, as they have through the 17 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](http://www.uky.edu/KGS/water/gnet).

From July 2014 through June 2015, more than 23 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 postings on websites. The committee met once during the year on Sept. 9, 2014, at the Kentucky Geological Survey Well Sample and Core Library. 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 Kentucky Division of Water and the Kentucky Geological Survey.

#### 2014-15 Activities and Accomplishments

Summary statements of water-related projects performed by the ITAC agencies during the 2014-15 State fiscal year are presented below as an indicator of how the network goals are being addressed. Additional information regarding any of these projects can be obtained by contacting

the reporting agency. Figure 1 shows the counties in which ITAC agencies conducted groundwater studies or projects during the fiscal year. Counties in which surface-water projects were conducted are shown in Figure 2.

## 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 qual-

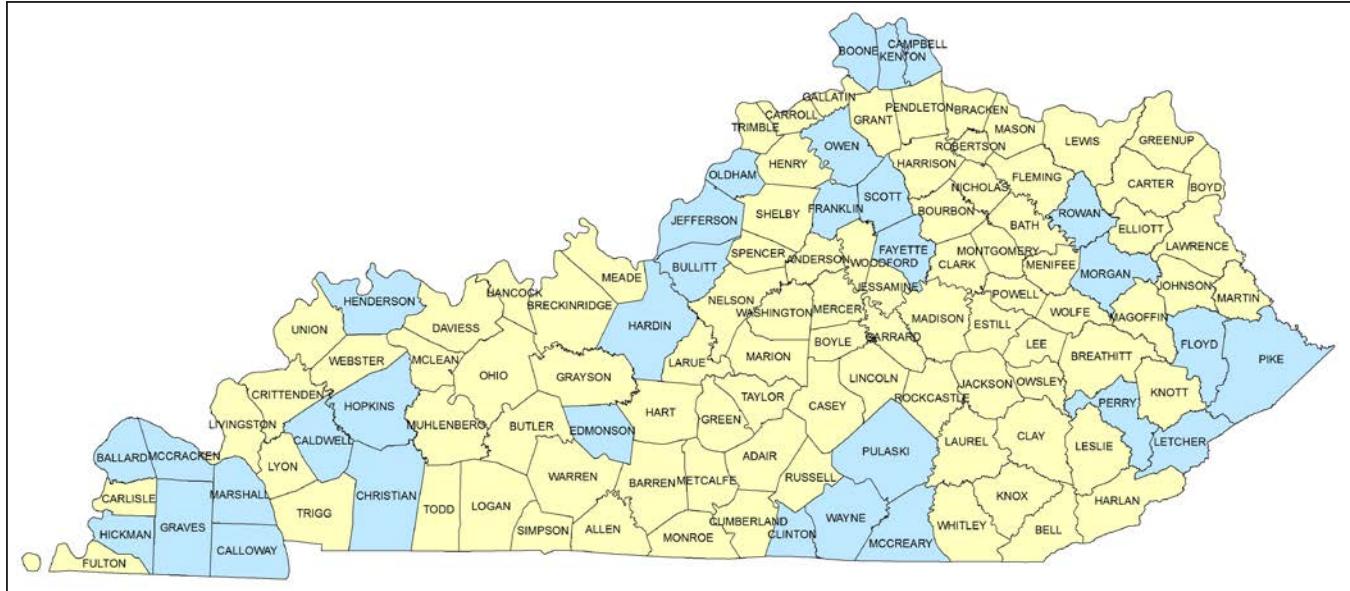


Figure 1. ITAC member agencies had groundwater-related projects in the counties shown in blue during the 2014-15 fiscal year.

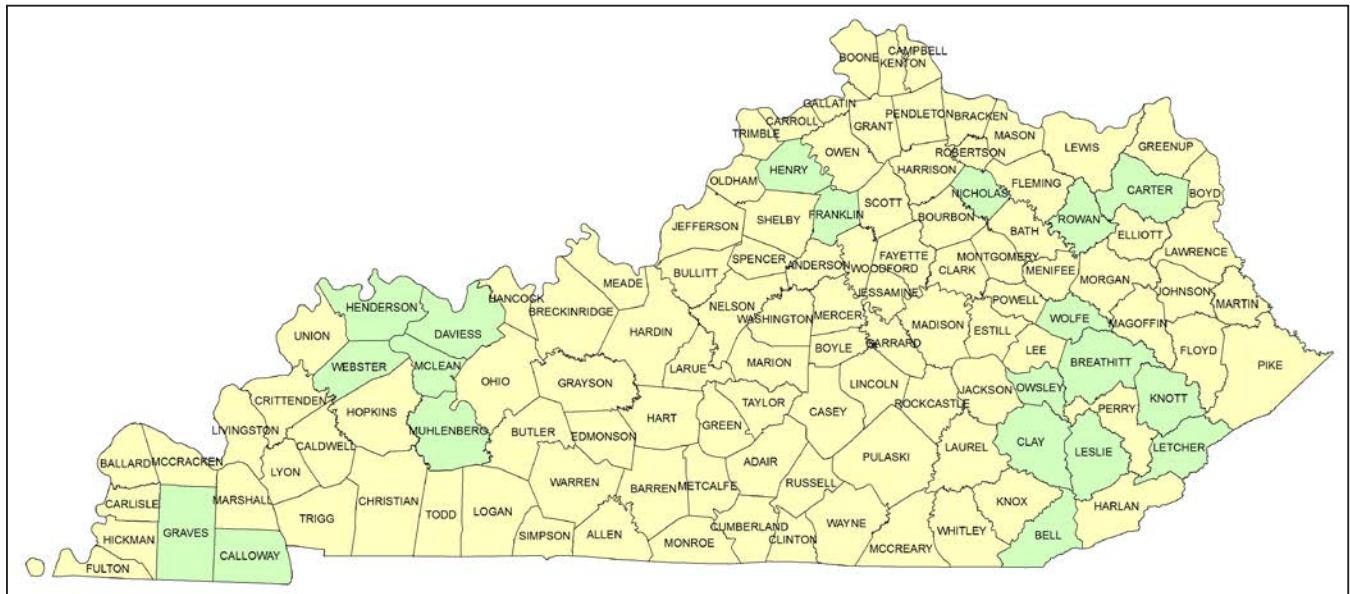


Figure 2. ITAC member agencies had surface-water-related projects in the counties shown in green during the 2014-15 fiscal year.

ity, 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 2014-15 fiscal year. Surface-water projects are listed in the "Other" section of this report.

### **Kentucky Division of Water, Watershed Management Branch, Groundwater Section**

The Groundwater Section of the Kentucky Division of Water's Watershed Management

Branch maintains groundwater-quality monitoring and analysis programs. These studies range in scope from statewide to basin management unit scale (Fig. 3). In fiscal year 2014-15, 159 samples were collected from 73 sites (42 wells and 31 springs) across the state. Groundwater-quality data were provided in response to numerous information requests. Table 1 shows the number of sites by physiographic region and basin management unit and Figure 4 shows the location of the sites within physiographic regions. The following projects have been active during the reporting period.

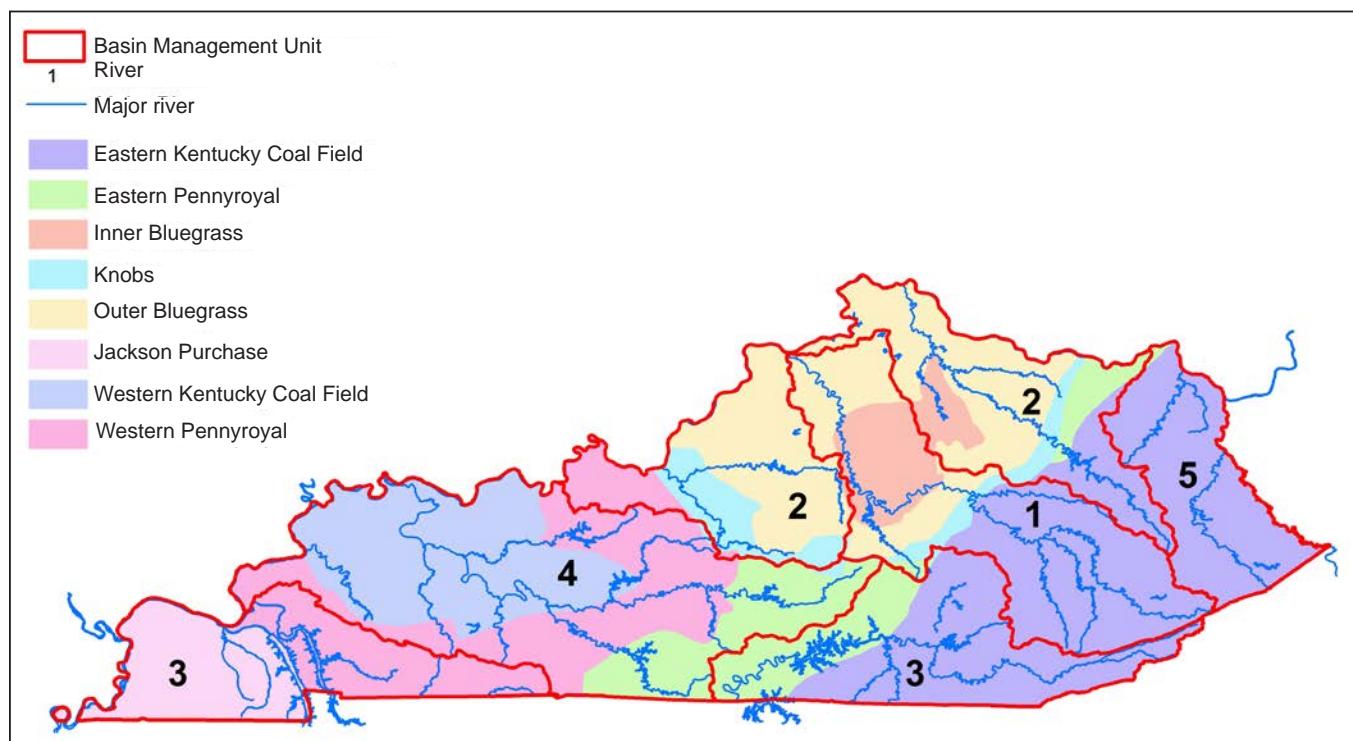


Figure 3. Major rivers, basin management units, and physiographic regions in Kentucky.

**Table 1.** Spatial distribution of permanent groundwater-quality monitoring sites.

Physiographic Region	Number of Sites	Basin Management Unit	Number of Sites
Bluegrass	10	1—Kentucky River	7
Eastern Kentucky Coal Field	8	2—Salt and Licking Rivers	10
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		

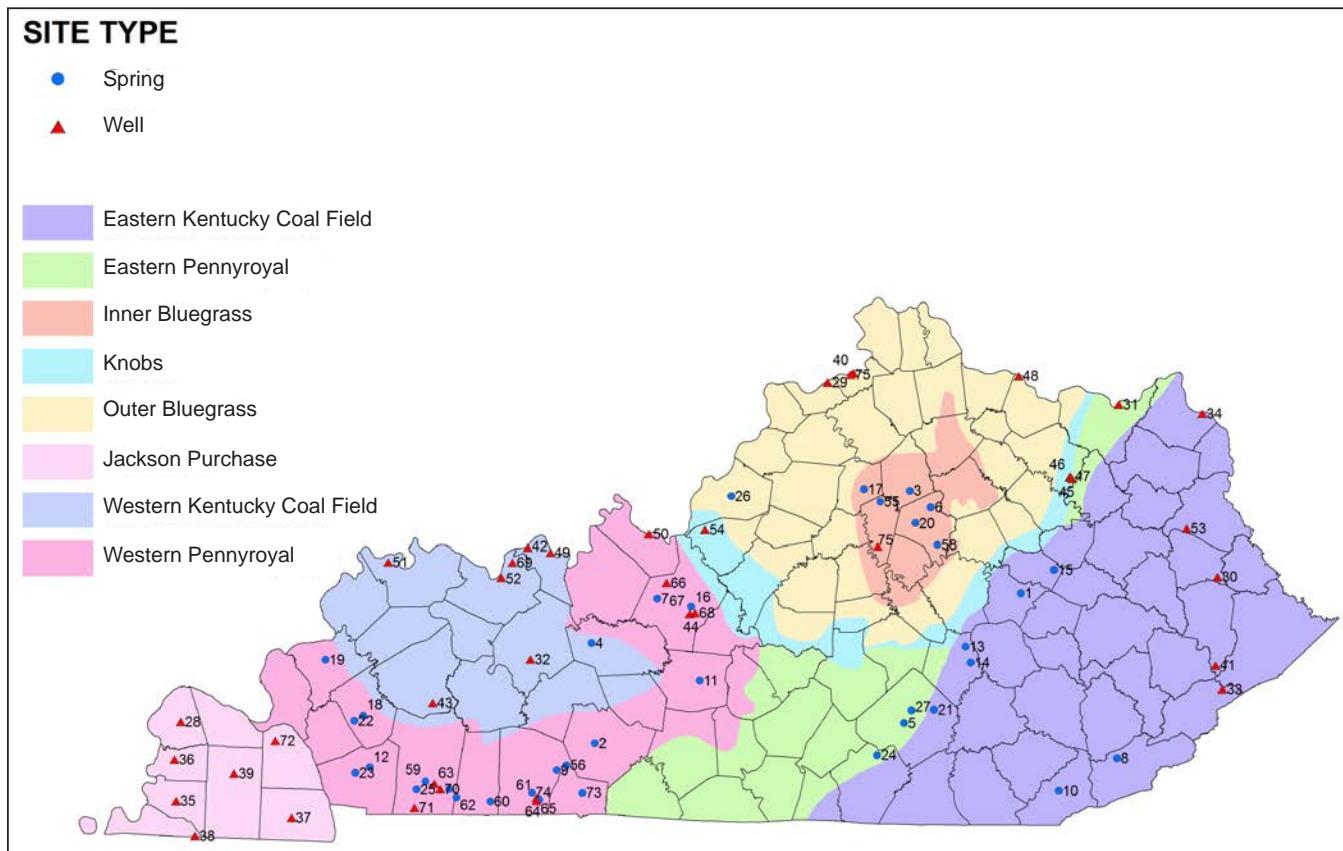


Figure 4. Sites of the Kentucky Interagency Groundwater Monitoring Network maintained by the Kentucky Division of Water. Table 2 indicates map number, Division of Water's AKGWA (Assembled Kentucky GroundWAter) number, and sampling frequency for these sites.

**Ambient Groundwater-Quality Monitoring Network.** There were 131 samples collected from 56 permanent sites (28 water wells and 28 springs) across the state during the fiscal year (Figs. 5-6), of which 61 were from water wells and 70 from springs. Twenty-three of these sites are public water suppliers (18 water wells and five springs).

**Pesticides Memorandum of Agreement Project.** The Pesticides Memorandum of Agreement with the Kentucky Department of Agriculture funds groundwater-quality monitoring at four permanent sites (three springs and one well). Each site was sampled quarterly, for a total of 16 samples during the fiscal year. Pesticide data from all permanent monitoring sites are submitted to the Department of Agriculture annually.

**Complaint and Technical Assistance Sampling.** During fiscal year 2014-15, the Groundwater Section responded to 41 complaints about water-well

and monitoring-well drilling, installation, construction, maintenance, and water-quality issues.

In response to these 41 complaints, five samples were collected from five wells. The majority of the samples were collected by Groundwater Section personnel. As part of many water-well and spring inspections, the domestic drinking-water source is inspected and onsite technical assistance is provided.

**Nonpoint-Source Groundwater Assessments.** The Groundwater Section has two active nonpoint-source projects in various phases from final report drafting to reconnaissance to site selection. The *Statewide Pathogens Study* focuses on the occurrence of pathogens in domestic groundwater supplies. Approximately 200 sites across Kentucky were sampled for total coliform, *E. coli*, iron-related, sulfate-reducing, and slime-forming bacteria, and caffeine. Results indicate that the presence of bacteria correlates with the type of well construction and well-maintenance

**Table 2.** Assembled Kentucky GroundWAtter numbers (Kentucky Division of Water identification number) and sampling frequency, if available, for the network sites shown in Figure 4. 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. Sample times vary.

Map No.	AKGWA No.	Sample Frequency	Map No.	AKGWA No.	Sample Frequency	Map No.	AKGWA No.	Sample Frequency
1	900000045	Q	26	90002934	Q	51	00040944	Q
2	900000054	Q	27	90003064	5Q	52	00065149	Q
3	900000055	M	28	00000811	5Q	53	00068511	Q
4	90000456	5Q	29	00007133	5Q	54	00066926	Q
5	90000544	5Q	30	00012311	Q	55	90001200	Pest. MOA
6	90000552	Q	31	00014293	2Q	56	90000624	Pest MOA
7	90000702	Q	32	00019489	5Q	57	90001150	Pest. MOA
8	90000703	Q	33	00028100	5Q	58	90001201	Pest. MOA
9	90000705	M	34	00029505	2Q	59	90001460	Pest. MOA
10	90000710	5Q	35	00033887	5Q	60	90001475	Pest. MOA
11	90000798	M	36	00033904	5Q	61	00055953	Pest. MOA
12	90000854	2Q	37	00033965	5Q	62	90001485	Pest. MOA
13	90001020	Q	38	00033972	5Q	63	00011280	Pest. MOA
14	90001051	5Q	39	00037330	5Q	64	90000458	Pest. MOA
15	90001134	Q	40	00037376	5Q	65	00029983	Pest. MOA
16	90001137	Q	41	00039374	5Q	66	00043250	Pest. MOA
17	90001143	M	42	00041471	Q	67	00043253	Pest. MOA
18	90001145	2Q	43	00042984	Q	68	00043258	Pest. MOA
19	90001149	2Q	44	00043253	5Q	69	00047172	Pest. MOA
20	90001161	Q	45	80046811	2Q	70	00047175	Pest. MOA
21	90001254	5Q	46	80046812	2Q	71	00048659	Pest. MOA
22	90001343	2Q	47	80046813	2Q	72	00055310	Pest. MOA
23	90001344	2Q	48	00065002	Q	73	90002823	Pest. MOA
24	90001822	Q	49	00061858	Q	74	90000315	Pest. MOA
25	90001857	Q	50	00061854	Q	75	000697574	Q

practices. A secondary goal was to educate well owners about proper water-well maintenance and disinfection practices during sample collection. Follow-up samples were collected at eight sites during this reporting period to clarify ambiguity in the data set.

The *South-Central Karst Study* is expanding karst groundwater mapping south of Lake Cumberland. The study area includes parts of Pulaski, Clinton, Wayne, and McCreary Counties. Current work focuses on groundwater dye tracing and delineation of karst basins. Thus far, 27 tracer tests have been recovered at 25 springs. The next step will be to choose monitoring sites. The project will

use an integrated surface-water and groundwater assessment approach.

**Special Projects.** Dye traces were provided to 14 county health departments, the Lexington-Fayette Urban County Government, and Division of Water regional offices to investigate subsurface hydraulic connections. The Groundwater Section also made several presentations about geology and groundwater at elementary schools in Woodford County for their annual Science Day events.

**Certified Well Drillers Program.** In 2014-15, the Kentucky Division of Water's Groundwater Section issued 136 licenses to certified drillers: 30 wa-



*Figure 5. The spring (left) and swallow hole (right) of the Short Creek karst window near Stab, Pulaski County. These sites are separated by only about 75 feet as groundwater flows from left to right, creating a "window" into the karst conduit system in the limestone underlying this area.*

ter-well, 57 monitoring-well, and 49 dual licenses. The license-renewal period continues beyond the end of the fiscal year, however, so this may not be a full accounting of drillers certified in Kentucky.

**Well-Drilling Activities.** A total of 647 wells were drilled and reported to the Division in fiscal year 2014-15. They may be broadly classified into

nine major categories: agriculture (38), domestic (49), monitoring and remediation (510), public (eight), industrial/commercial (22), geothermal (one), and other (19). Plugging records were submitted for 755 wells that were decommissioned. The majority of the plugging records were from the monitoring and remediation category (709), but records were also submitted for domestic (six), industrial/commercial (17), agriculture (two), public (three), and other (18) wells.

Use of domestic wells remains consistent on a county basis throughout Kentucky. The Eastern Kentucky Coal Field and Jackson Purchase Region continue to have the greatest percentage of households that rely on domestic wells as their primary source for potable water. According to 2010 census data, approximately 4 percent of Kentucky's population uses wells or springs as its primary drinking-water source.



*Figure 6. Division of Water geologist Emily Denlinger, the new Groundwater Monitoring Network coordinator, samples Vaught Spring near Somerset in Pulaski County; the spring is used for agricultural purposes.*

**U.S. Geological Survey**  
**Louisville Water Company,**  
**Ohio River Alluvial Aquifer,**  
**Jefferson County.** The U.S.

Geological Survey, in cooperation with the Louisville Water Co., maintains a network of 43 water-level observation wells in the northeastern part of the Ohio River alluvium in Jefferson County. Ten of the wells are equipped with continuously recording pressure transducers that measure depth to water and water temperature. Water-level measurements are taken at the other 33 observation wells on a quarterly basis. These data help the Louisville Water Co. operate and maintain a riverbank filtration system using a network of supply wells constructed to draw and naturally filter river water through the sand and gravel aquifer near the Payne Water Treatment Plant.

**Groundwater-Level Data Collection, Graves County.** The USGS collects real-time continuous water-level measurements from an observation well in Graves County that is included in the USGS National Ground-Water Climate Response Network, a nationwide network of long-term observation wells intended to monitor the effects of drought and other climate variability on the nation's groundwater resources. The water-level data for this well can be accessed at [groundwaterwatch.usgs.gov](http://groundwaterwatch.usgs.gov) or [ky.water.usgs.gov](http://ky.water.usgs.gov).

Two additional long-term observation wells in downtown Louisville also maintained by the USGS are used to collect continuous water-level data from the Ohio River alluvial aquifer. Historical water-level data from other observation wells and additional information about the activities of the USGS's Kentucky Water Science Center are available on the USGS website at [ky.water.usgs.gov](http://ky.water.usgs.gov).

**Well-Integrity Survey of Abandoned Gas Wells Near West Point, Hardin County.** Abandoned and unrecorded

natural-gas wells may act as conduits for the contamination of groundwater supplies by oil- and gas-field brines and other pollutants. The casings of abandoned wells may eventually develop leaks, which, if not properly plugged, can allow pollutants to reach freshwater aquifers that supply drinking water (Fig. 7). Such is the situation in the Fort Knox well field near West Point. Many of the drinking-water supply wells for Fort Knox have chloride concentrations in excess of secondary maximum contaminant levels of 250 mg/L, some as high as 11,000 mg/L. In cooperation with the Directorate of Public Works-Environmental Management Division at the U.S. Army Garrison, Fort Knox, the USGS is using geophysical and hydrogeologic methods to identify abandoned or improperly plugged oil and gas wells that may be contaminating the freshwater aquifer with brine and to characterize the migration and dispersion of chlorides.

**Hydrogeologic Reconnaissance, Well Inventory, and Aquifer Tests to Assess the Feasibility of Stormwater Injection Wells, Northern Kentucky Sanitation District No. 1 Service Area, Boone, Campbell, and Kenton Counties.** Hydrogeologic

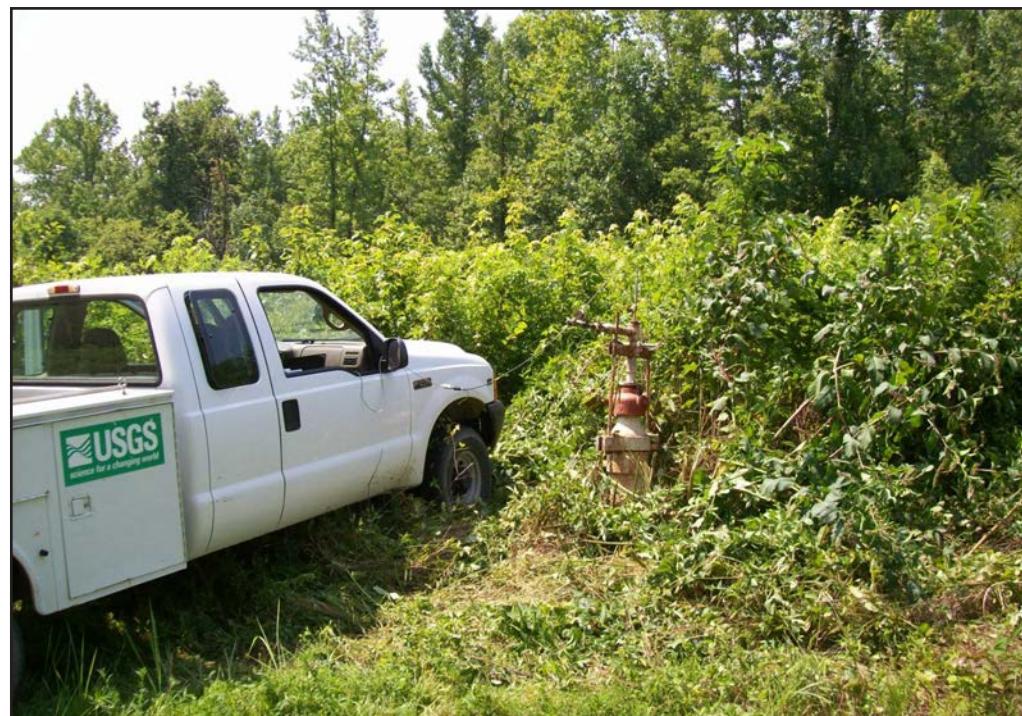


Figure 7. USGS personnel download data from a transducer installed in an abandoned gas well near West Point.

reconnaissance, well inventory, and site-specific aquifer test data are needed so that Northern Kentucky Sanitation District No. 1 managers can assess whether use of stormwater injection wells is technically or economically feasible for Class V underground injection and to develop the necessary engineering-design specifications. The USGS is working through a local partnership to identify pilot locations for stormwater injection wells. Once the locations are identified, test wells will be installed and a series of aquifer tests will be conducted and water-quality samples will be taken to characterize the hydrogeologic conditions and quantify the groundwater quality. Resulting data and information will be used to further assess stormwater injection potential.

### **Kentucky Department of Agriculture**

The Kentucky Department of Agriculture-Technical Support Branch continued to receive monitoring data from the Division of Water under its memorandum of agreement. The memorandum covers 16 samples yearly from four sites. It is supplemented by the Division of Water's Ambient Groundwater Monitoring Program.

### **Kentucky Geological Survey, Water Resources Section**

The Water Resources Section's mission is to collect and disseminate information vital to the proper use, management, and protection of the commonwealth's groundwater and surface-water resources. As a nonregulatory water-monitoring and research unit, the Water Resources Section is the commonwealth's principal source of unbiased water data and analysis. The Section is charged by legislative mandates to manage the state's official repository for groundwater information (KRS 151.035) and to oversee establishment of a long-term groundwater monitoring network (KRS 151.625). In 2014-15, the Section conducted research to better characterize Kentucky's groundwater and surface-water resources, document and assess sinkhole and karst-related hazards, and provide scientific information and technical assistance on a variety of water and related environmental issues to State, federal, and local agencies, University of Kentucky and other university researchers, geoscientists, and engineers

working in the public and private sectors, and the general public.

### **Groundwater Availability and Water Quality**

Water Resources personnel, working in collaboration with Dr. Ed Woolery and student Marie Cooper of the University of Kentucky Department of Earth and Environmental Sciences, began a project to collect data to better delineate aquifer zones and confining units in parts of the Jackson Purchase Region. Groundwater withdrawals are increasing in this part of Kentucky, largely as a result of increased agricultural irrigation. Numerous water-supply and irrigation wells were inventoried, and gamma-ray logs of selected wells were obtained. Section personnel and Dr. Woolery have also collaborated to use seismic-reflection and electrical-resistivity surveying methods to map the Middle Claiborne confining unit. Resulting data are being used to create more accurate and detailed hydrostratigraphic cross sections of the Purchase Area aquifer system, help identify water wells completed in the Upper Claiborne and Middle Claiborne aquifers, and will guide plans for additional groundwater monitoring and research needed in the Jackson Purchase Region.

The Section also began a project in collaboration with the Kentucky Department of Military Affairs/Kentucky Army National Guard to assess the surface-water quality for Training Areas 7 and 8 at the Wendell H. Ford Regional Training Center in Muhlenberg County. Hydrogeologists are collecting wet- and dry-season water-quality samples from approximately 98 sites at streams and ponds at the Training Center (Fig. 8). The project will provide National Guard resource managers with baseline data needed to assess the quality of surface water at the Training Center, and help identify areas where management practices or remedial actions can be implemented or improved to minimize degradation and ensure good environmental stewardship of the Training Center's land and water resources.

Water Resources Section hydrogeologists continued providing technical assistance to the Kentucky Research Consortium for Energy and the Environment, using groundwater-flow and contaminant-transport modeling to simulate and test the potential outcomes of different remedial



Figure 8. KGS geologists (one is taking the photo while holding the "beaker on a stick") sample water from a pond on a reclaimed surface-mined area in Muhlenberg County.

actions being used at the Paducah Gaseous Diffusion Plant. This modeling will allow U.S. Department of Energy and other federal and State resource managers, as well as private environmental contractors, to evaluate and improve actions being considered and implemented to remediate a variety of radioactive and nonradioactive groundwater contaminants at the site.

Section hydrogeologists co-authored the groundwater monitoring section of the Kentucky Agricultural Science Monitor Committee 2014 Draft Work Plan, an overview of present and planned water-quality and -quantity monitoring activities and a strategy for improved interagency collaboration to gather needed scientific and environmental data. In addition, Section personnel participated in the Kentucky Farm Bureau's Water Management Working Group, a 20-member task force assembled to develop recommendations that will enhance the quality and quantity of water resources accessible for agricultural production in the state. The task force's mission is to research the emerging critical issue of inadequate water supplies available for agricultural production, examine potential actions to solve this defi-

ciency, and make recommendations for bringing new and reliable water sources to key areas of farm production in Kentucky.

**New Statewide Groundwater Observation Network.** This year the Water Resources Section began work to create a new long-term observation well network needed to assess the quantity and availability of the state's groundwater resources. Data collected by the planned network should help predict the occurrence and severity of droughts and evaluate the potential impacts of drought conditions on groundwater and surface-water resources throughout Kentucky. Groundwater samples will also be routinely collected from the network wells to help provide

baseline data needed to better characterize natural variations in groundwater quality and help identify, assess, and track possible effects of nearby human activities related to energy-production, agriculture, or urban development. Continuous observation stations are planned at a minimum of 14 existing or newly drilled well sites during the 2015-16 fiscal year. Each well will monitor naturally occurring changes in groundwater levels and quality that are representative of the major aquifer in a particular area of the state. All network wells will be equipped with pressure transducers and data loggers capable of continuously recording changes in groundwater levels at 15- to 30-minute increments. Approximately seven of the wells will also be equipped with telemetry that will automatically transmit recorded groundwater-level data to the Survey each day, enabling more rapid tracking and evaluation of current groundwater conditions. All groundwater data collected from the network's wells will eventually be posted to the KGS groundwater repository website and available for the public's use.

Water Resources Section hydrogeologists have begun inspecting and testing a number of currently unused wells in various parts of the state for inclusion in the network. At the time of this report's publication, one observation station with telemetry had been established in the Inner Bluegrass karst aquifer system at a KGS-owned well at the Kentucky Horse Park (Fig. 9), and another observation station had been established in the central Kentucky karst at a well at Mammoth Cave National Park. In some parts of the state, there are no suitable wells for monitoring; KGS plans to drill up to five new monitoring wells in 2015-16 in areas of critical need. For example, a memorandum of agreement with Murray State University will enable up to three observation wells to be drilled at Murray State's West Farm Complex, each monitoring a different aquifer zone. When completed in early fall of 2015, this

observation well cluster will provide important information on groundwater levels in the major aquifer zones in the Jackson Purchase's Mississippian Embayment aquifer system, which is heavily used for agricultural and public water withdrawals.

**Karst and Sinkhole Research.** Public interest in and concerns about potential hazards associated with karst and sinkholes remained high in 2014-15. Because of increased awareness by the public of what karst is and how it can affect buildings and infrastructure, Water Resources staff members have responded to many requests for information from concerned homeowners and others who reported sinkholes and requested help in assessing potential hazards and remedies. KGS received more than 100 reports or inquiries on cover-collapse sinkholes during the year, and staff visited about 50 percent of these sites. In many cases, a report was first submitted by the property owner through the KGS online sinkhole reporting form ([www.uky.edu/KGS/water/general/karst/coverCollapse.htm](http://www.uky.edu/KGS/water/general/karst/coverCollapse.htm)). Since 1997, the section has actively collected information about the occurrence of cover-collapse sinkholes in Kentucky and maintained an inventory of these features describing their locations, physical characteristics, and topographic and geologic settings. A statistical analysis of these sinkhole data is now under way. A preliminary calculation used GIS analysis to combine data from the karst potential area map and census data to determine that approximately 67 percent of Kentucky's population lives in sinkhole-prone karst areas.

Water Resources personnel continued using LiDAR data and new terrain-processing methods developed previously to improve sinkhole identification and mapping in Kentucky, particularly in urbanized and suburbanized areas. Section personnel and UK Department of Earth and Environmental Sciences students applied new data-processing methods to map sinkholes in surface watersheds in Bullitt, Jefferson, and Oldham Counties. Results thus far demonstrate that the number of probable sinkholes identified from LiDAR mapping is approximately four times greater than the number identified using contoured depressions visible on topographic



Figure 9. KGS hydrogeologist installs real-time monitoring equipment in a water well at the Kentucky Horse Park in Fayette County, as part of the Kentucky Groundwater Observation Network.

maps. The work in Bullitt County is almost done. In that county, 822 sinkholes were identified from LiDAR. Random field checks of 25 LiDAR-identified features found that 24 of them were true karst sinkholes. The objectives of this ongoing research are to refine the method and extend the mapping area to other sinkhole areas in the Bluegrass Region.

Other karst research being conducted by KGS focuses on characterizing karst hydrogeologic flow systems and water quality. Research funded by the UK College of Agriculture, Food and Environment continued for the Royal Spring-Cane Run karst basin hydrology project. This year, field studies were in collaboration with the UK College of Civil Engineering and the UK Department of Earth and Environmental Sciences (Fig. 10). Various field, computer modeling, and statistical methods were applied to evaluate the complex hydrologic mechanisms in nutrient transport and fate in both groundwater and surface water of the basin. Data were gathered that were needed to measure the discharge of groundwater and potential contaminants such as nitrate,

phosphorus, fecal bacteria, and suspended sediments in the karst aquifer beneath the Cane Run surface drainage basin in Fayette and Scott Counties. Quantitative dye-tracer tests, Doppler sonar, borehole flowmeter, and continuous water-quality monitoring were used to obtain data at a monitoring station at the Kentucky Horse Park. Continuous high-resolution data have been collected from wells drilled directly into the Royal Spring karst conduit (the major cave stream passage that underlies and drains part of the approximately 15,000 acres of the Cane Run Basin) in order to quantify and track changes in the discharge of subsurface water and contaminant concentrations through the conduit. The data and findings from this project are helping the UK College of Agriculture, Food and Environment and the Lexington-Fayette Urban County government design and implement best management practices to improve stormwater disposal and water quality in the basin of Cane Run, a tributary of North Elkhorn Creek. Data collected from 2011 to 2014, including periodic and event-related data, are being evaluated, and a KGS Report of Investigations is anticipated in mid to late 2015. Future KGS studies will

focus on the relationships between various water-quality parameters (e.g., total suspended sediments and nutrients) and the dynamics of groundwater and surface water mixing in the Cane Run-Royal Spring Basin.

In addition, the section published the Hopkinsville 30 X 60 minute quadrangle karst groundwater basin map (scale 1:100,000), compiled and drafted dye-traced karst flow paths for the yet-to-be-published Louisville, Elizabethtown, and Morehead karst groundwater basin maps, and provided technical advice for a volunteer project sponsored by Friends



Figure 10. A KGS hydrogeologist (left) and University of Kentucky graduate students inspect a cover-collapse sinkhole in Midway.

of Wolf Run, conducted by a student in the UK Department of Earth and Environmental Sciences, to map the groundwater basin of Gardenside Spring, in a suburban area in west-central Lexington. To date, three groundwater traces have been attempted for the Gardenside Spring project, but none have been successful; the karst groundwater basin may be hydrologically more complex than first thought, and additional investigations could greatly improve our understanding of karst hydrogeology in western Fayette County.

**Groundwater Data Repository.** The Kentucky Groundwater Data Repository, hosted at the KGS website, contains data for more than 101,000 wells, including domestic, public, industrial, monitoring, and agricultural wells. In addition, data for more than 5,000 springs and 44,000 sample suites (representing millions of individual analytical results) are available. The data in the Repository were compiled from more than 15 agencies, but the largest contributor continues to be the Kentucky Division of Water. Groundwater data uploads from the Division are added quarterly—wells, springs, and groundwater-quality data (including pesticide sampling from approximately 20 sites as a result of the Division of Water's memorandum of agreement with the Kentucky Department of Agriculture). Well and sample data collected through the Division of Water's certified well driller program and the Kentucky Interagency Groundwater Monitoring Network are uploaded to the Repository approximately once every quarter, providing users with continuous access to the most recent groundwater data available. Scanned drillers' logs and associated documents are uploaded to the Repository approximately every six months. The Repository can be accessed at [kgs.uky.edu/kgsweb/DataSearching/watersearch.asp](http://kgs.uky.edu/kgsweb/DataSearching/watersearch.asp).

**Collaboration with Kentucky Division of Water Sampling.** The Kentucky Division of Water is responsible for sampling wells and springs at about 60 sites across Kentucky. These sites comprise the Kentucky Interagency Groundwater Monitoring Network. Most samples are collected once a quarter or twice a year by Division of Water personnel on about 11 different sampling runs. Kentucky Geological Survey hydrogeologists assisted with

collecting some of these samples. To date, Survey personnel have accompanied Division of Water personnel in the Midwest, North Central, and South Central sampling runs (Fig. 11). The Kentucky Geological Survey has been invited to take over the quarterly sampling of three sites in the North Central run: McConnell Springs and Russell Cave Spring in Fayette County, and Royal Spring in Scott County. The Environmental Services Branch Laboratory in Frankfort will continue to analyze these samples. The Kentucky Geological Survey wishes to express its appreciation for the Division of Water's collaborative spirit. Public access to the data collected for the Division of Water sampling program and the Kentucky Interagency Groundwater Monitoring Network is at [www.uky.edu/KGS/water/gnet](http://www.uky.edu/KGS/water/gnet).

**Groundwater Atlas of Kentucky.** The Survey is currently developing a series of web pages designed to disseminate information about the availability, quantity, and quality of Kentucky's groundwater resources. Designed to work in conjunction with the Kentucky Groundwater Data Repository and the Kentucky groundwater resource reports, these pages will include aquifer location maps, groundwater-quality maps based on data from the Repository, and information from aquifer tests conducted by the Kentucky Geological Survey across the state in recent years. In the near future, near-real-time groundwater-level observation data from wells and springs in the newly developed Kentucky Groundwater Observation Network may be available through the Groundwater Atlas website. The Groundwater Atlas, when completed, will be accessible via the Repository at [kgs.uky.edu/kgsweb/DataSearching/watersearch.asp](http://kgs.uky.edu/kgsweb/DataSearching/watersearch.asp).

**Rock and Water Analytical Laboratory.** In the fall of 2013, the Kentucky Geological Survey laboratory was restructured and placed under the administration of the Water Resources Section. This enables the laboratory to better support the research and data-collection needs of the Water Resources Section while continuing to provide important analyses of rock, oil, gas, and water samples collected throughout the state by other Survey geologists. Laboratory personnel also collaborated with researchers from other UK academic departments



Figure 11. Kentucky Division of Water and Kentucky Geological Survey geologists take a water sample for the Kentucky Interagency Groundwater Monitoring Network at McConnell Springs blue hole in Lexington.

and state universities, various State and federal agencies, Kentucky Water Watch groups, and private citizens to provide laboratory services that met their individual needs and also contributed useful analytical data to the water, rock, oil, and gas databases maintained by the Kentucky Geological Survey (Fig. 12). This year, the laboratory:

- Analyzed water samples collected from 98 sites for major ions, trace metals, nutrients, and other water-quality constituents needed for the Wendell H. Ford Regional Training Center project.
- Performed total organic carbon and inorganic carbon analysis on approximately 200 shale samples for the KGS Energy and Minerals Section to support ongoing and planned research to characterize the regional geology and hy-

drocarbon production of the Berea Sandstone oil play in eastern Kentucky ([www.uky.edu/  
KGS/emsweb/berea\\_ss/Upper\\_Devonian\\_Berea\\_SS.htm](http://www.uky.edu/KGS/emsweb/berea_ss/Upper_Devonian_Berea_SS.htm)).

- Conducted a large project with the UK Mining Engineering Department to determine concentrations of rare earth elements in coal ash and byproducts. Approximately 1,000 samples were processed.
- Analyzed samples from Dr. Ming Gong of the UK Medical Center for sodium and potassium using inductively coupled plasma-optical emission spectroscopy. The analysis helped determine the uptake and transport of these elements by certain organs in mice.
- Continued analyzing water-quality samples submitted through the Kentucky Watershed



Figure 12. A KGS laboratory scientist runs groundwater samples from Muhlenberg County using the organic carbon analyzer.

Watch program. Spring and fall water-quality samples collected by the Kentucky River and the Four Rivers Watershed Watch groups were analyzed for nutrients, metals, and atrazine concentrations.

- Participated in the STEM (science, technology, engineering, and mathematics) project led by Dr. Alan Fryar of the UK Department of Earth and Environmental Sciences. Water samples from several sites were submitted for analysis every 2 weeks over the spring 2015 semester, and the project will continue into the near future. This project brought high school and middle school science teachers into the University research community for hands-on experience.
- Gave tours of the lab to nine groups, including professionals, high school students, graduate geology students, and candidates for professor in the UK Department of Earth and Environmental Sciences.
- Taught numerous students, which is becoming a larger responsibility of the lab. The lab instructed 18 University of Kentucky students in analysis techniques and helped with their research. Six students were taught total organ-

ic carbon/shale analysis; seven were taught X-ray diffraction and X-ray fluorescence analytical principles and techniques; and five graduate students were taught X-ray fluorescence principles and techniques.

### **Kentucky Division of Mine Reclamation and Enforcement**

The Field Support Section of the Division of Mine Reclamation and Enforcement conducts groundwater investigations at the request of citizens of the commonwealth (Figs. 13–15). The investigations may be a result of diminished water-well quality or quantity. 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.

During the 2014–15 fiscal year, the Division received 33 new requests for inspections. Twenty-eight inspections were completed; of these, six concluded that mining activity had had an adverse impact on a citizen's well or property. Of the six adverse-impact determinations, none were the result of diminished water quality or quantity, four were related to seeps or landslides (or both), one was related to subsidence of a mine, and one was caused by methane in the well.

### **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 2014–15 fiscal year, groundwater information was communicated via short reports, oral and poster presentations at meetings



*Figure 13. A landslide in Floyd County near a private residence occurred on a steep hillside and was determined to be the result of mining activities.*

and conferences, and posting on websites. Publications and presentations generated by ITAC agency members or affiliated personnel are listed below.

### **Publications**

- Beck, E.G., 2014, Shallow groundwater monitoring associated with the western Kentucky deep saline reservoir CO<sub>2</sub> storage test in Hancock County, Kentucky: Kentucky Geological Survey, ser. 12, Report of Investigations 31, 28 p.
- Crawford, M.M., Zhu, J., and Webb, S.E., 2015, Geologic, geotechnical, and geophysical investigation of a shallow landslide, eastern Kentucky: Environmental & Engineering Geoscience, DOI: 10.2113/EEG-1642.
- Landrum, C., Castrignano, A., Mueller, T., Zourarakis, D., Zhu, J., and De Benedetto, D., 2015, An approach for delineating homogeneous within-field zones using proximal sensing and multivariate geostatistics: Agricultural Water Management, v. 147, p. 144–153.
- Sawyer, A.H., Zhu, J., Currens, J.C., Atcher, C., and Binley, A., 2015, Time-lapse electrical

resistivity imaging of solute transport in a karst conduit: Hydrological Processes, DOI: 10.1002/hyp.10622.

- Zhu, J., Taylor, T.P., Currens, J.C., and Crawford, M.M., 2014, Improved karst sinkhole mapping in Kentucky using LiDAR techniques: A pilot study in Floyds Fork watershed: Journal of Cave and Karst Studies, v. 76, no. 3, p. 207–216.

### **Presentations**

- Atcher, C., Sawyer, A.H., Zhu, J., and Currens, J., 2015, A test of combining time-lapse electrical resistivity imaging and salt injection for locating karst conduits: Kentucky Water Resources annual symposium, Lexington, Ky., March 9, 2015.
- Beck, E.G., 2014, Groundwater elevation map for the Upper Claiborne aquifer in Hickman and Fulton Counties, Kentucky: Kentucky Small Grain Growers Association board meeting, Loretto, Ky., Aug. 7, 2014.
- Beck, E.G., 2015, Groundwater resources for the citizens of western Kentucky: Kentucky Geo-



*Figure 14. Water from a 30-year-old domestic well in Floyd County that has never had any well maintenance or disinfection.*

- logical Survey annual seminar, Lexington, Ky., May 15, 2015.
- Beck, E.G., 2014, Groundwater resources in Henderson, Daviess, and McLean Counties: Green River Area Irrigation Workshop, Owensboro, Ky., Dec. 15, 2014.
- Beck, E.G., 2014, Groundwater resources in the Jackson Purchase: Jackson Purchase Agriculture and Natural Resource Extension Agent Workshop, Benton, Ky., Dec. 18, 2014.

- Beck, E.G., 2014, Intro to rocks and sinkholes: Jeffers Bend Environmental Center, Hopkinsville, Ky., Sept. 19, 2014.
- Beck, E.G., 2014, Using nitrogen isotopes to determine sources of nitrate-nitrogen in shallow groundwater in western Kentucky: University of Kentucky Department of Earth and Environmental Sciences invited lecture, Lexington, Ky., October 29, 2014.
- Beck, E.G., 2015, Groundwater-quality and groundwater-elevation data for the Jackson Purchase, Kentucky: Knowns and unknowns: University of Kentucky Department of Plant and Soil Sciences seminar, Lexington, Ky., Feb. 13, 2015.
- Beck, E.G., 2015, Overview of groundwater resources related to agricultural irrigation wells in western Kentucky: Certified Crop Advisors Workshop, Evansville, Ind., Jan. 7, 2015.
- Currens, J.C., Taylor, C.J., Webb, S., Zhu, J., Workman, S., Agrourdis, C., Fox, J., and Husic, A., 2015, Initial findings from the karst water instrumentation system station, Royal Spring groundwater basin, Kentucky Horse Park: Kentucky Water Resources annual symposium, Lexington, Ky., March 9, 2015.
- Davidson, B., and Overfield, B., 2015, Bedrock basics: Bedrock interactions with our water system – An overview of Kentucky River aquifers: Kentucky River Water Watch annual conference, Eastern Kentucky University, Richmond, Ky., Feb. 7, 2015.
- Davidson, B., and Zhu, J., 2014, Groundwater occurrence and quality in the Berea Sandstone unconventional oil and gas play region of northeastern Kentucky: Eastern Unconventional Oil and Gas Symposium, Lexington, Ky., Nov. 5–7, 2014.
- Grider, J., and Parris, T.M., 2015, Updating the fresh-saline water interface map in eastern Kentucky: Kentucky Water Resources annual symposium, Lexington, Ky., March 9, 2015.
- Husic, A., Fox, J., Agrourdis, C., Currens, J.C., Workman, S., Ford, W., and Taylor, C.J., 2015, Sediment organic carbon fate and transport mechanisms in a fluvial karst system in the Bluegrass Region: Kentucky Water Resources annual symposium, Lexington, Ky., March 9, 2015.

Jackson, D.A., 2015, The design and results of a statewide groundwater pathogen study: Environmental Protection Agency State Directors Meeting, Atlanta, Ga., April 14–16, 2015.

Jackson, D.A., 2015, Hydraulic fracking and how it may affect you: Kentucky Ground Water Association annual tradeshow and workshop, Louisville, Ky., March 5–6, 2015.

Price, D.J., 2015, Water quality monitoring of McConnell Springs' surface waters, 2011 through 2014: Kentucky Water Resources annual symposium, Lexington, Ky., March 9, 2015.

Robertson, S.E., 2015, Water wells in Kentucky and groundwater quality: Murray-Calloway Board of Realtors quarterly meeting, Murray, Ky., March 18, 2015.

Robertson, S.E., and Jackson, D.A., 2015, Water well construction in consolidated and unconsolidated materials: Kentucky Ground Water Association annual tradeshow and workshop, Louisville, Ky., March 5–6, 2015.

Taylor, C.J., and Polk, J., 2015, Overview of the collapse sinkhole occurrence at the National Corvette Museum, Bowling Green: Kentucky Water Resources annual symposium, Lexington, Ky., March 9, 2015.

Tibou, F., Zhu, J., and Dinger, J., 2015, LiDAR mapping sinkholes in Cane Run watershed: Kentucky Water Resources annual symposium, Lexington, Ky., March 9, 2015.

Zhu, J., 2014, Application of LiDAR data for fine-scale hydrologic feature delineation: Fall 2014 Rast-Holbrook seminar series, University of Kentucky Department of Earth and Environmental Sciences, Lexington, Ky., Nov. 20,



*Figure 15. A stream bed in Perry County encrusted with a calcium carbonate mineral called tufa, which coats rocks, soil, and any organic material in the stream.*

2014; Kentucky Division of Water seminar, Frankfort, Ky., Jan. 28, 2015.

Zhu, J., Currens, J.C., Webb, S.E., and Rister, B.W., 2014, Pavement subsidence in the Cumberland Gap Tunnel, USA: A story of groundwater chemistry: American Geophysical Union fall meeting, San Francisco, Calif., Dec. 15–19, 2014.

Zhu, J., and Taylor, C.J., 2014, Sinkholes and karst geohazards: Kentucky Engineering Center seminar, Somerset, Ky., Sept. 17, 2014.

Zourarakis, D., 2015, "Wetness" in Landsat scenes versus "wetness" on the ground: Uses of the tasseled cap transformation on archival imagery: Kentucky Water Resources annual symposium, Lexington, Ky., March 9, 2015.

### **Website Information**

Statewide groundwater data in the Kentucky Groundwater Data Repository can be accessed at [kgs.uky.edu/kgsweb/DataSearching/watersearch.asp](http://kgs.uky.edu/kgsweb/DataSearching/watersearch.asp). The Repository database covers water wells, springs, 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 Kentucky Interagency

Groundwater Monitoring Network ([www.uky.edu/kgs/water/gnet](http://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 by the public 6,491 times during fiscal year 2014-15, resulting in 817 downloads. This search engine remains the second most popular on the KGS 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 associated Water Wells and Springs map service was accessed 6,465 times during the year, and the Karst Potential Map layout on the KGS Geologic Map Service was accessed 2,412 times.

The Kentucky Groundwater-Quality Data search engine was accessed by the public more than 1,036 times during fiscal year 2014-15, resulting in 233 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 697 times, and the groundwater-quality data plotting service was accessed 125 times.

In addition to the Repository data, KGS has compiled information about hydrology, geology, topography, water supply, and water quality from maps, reports, and data collected from 1940 to the present at [www.uky.edu/kgs/water](http://www.uky.edu/kgs/water). For more information on groundwater-quality or water-well and spring data, contact the Survey at (859) 323-0524.

## 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 Kentucky Interagency Technical Advisory Committee on Groundwater provides a fo-

rum for participating organizations to meet on a quarterly basis 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 of Water 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. KGS staff have been meeting with county 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 Agricultural Water Quality Authority or cooperate with the Authority and participate in their meetings. Members 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, threats to groundwater quality, and 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 and between the Kentucky Geological Survey analytical laboratory and the Division of Water's Groundwater Section since 1992. There has also been a high level of collaboration and data sharing between KGS and the Groundwater Section during the reporting period, as the agencies are jointly reporting on groundwater quality throughout the state. During 2014-15, 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 were uploaded to the Kentucky Groundwater Data Repository, thereby 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 (Fig. 2). 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***

**The Kentucky Well Education Website.** This website ([www2.ca.uky.edu/enri/downwell](http://www2.ca.uky.edu/enri/downwell)) is a joint project between the Environmental and Natural Resources Issues Task Force and the Kentucky Geological Survey. The website contains information on well types and well construction, along with simplified descriptions of Kentucky Division of Water regulations about general well construction and specific types of wells. The website provides video and photographic examples of problems that may occur in wells and gives advice on solutions. This site is maintained by ENRI.

**ENRI Website.** The ENRI website ([www2.ca.uky.edu/enri](http://www2.ca.uky.edu/enri)) contains information such as publications on groundwater. In addition, the site includes information on watersheds, stormwater, nutrient management, the Kentucky Agriculture Water Quality Act, and the Kentucky Water Awareness Month packet. The site is maintained by ENRI.

**"See Blue Go Green" Website.** This website ([www2.ca.uky.edu/gogreen](http://www2.ca.uky.edu/gogreen)) contains information for all Kentuckians about "green" topics (e.g., drinking water, stormwater, wastewater, water quality). The site contains publications, fact

sheets, radio scripts, displays, lesson plans, activities, and links. It is maintained by ENRI.

**ENRI Quarterly E-News.** The ENRI E-News ([www2.ca.uky.edu/enri/newsletter.php](http://www2.ca.uky.edu/enri/newsletter.php)) is distributed to county Extension agents and other natural resource professionals throughout Kentucky. E-News distributes information about current research, resources (e.g., new publications, training), and events, and is coordinated by Ashley Osborne, ENRI extension associate. This information is provided online and sent via listserv to all 120 county Extension agents.

**Taking Runoff by Storm: Rain Garden and Rain Barrel Lessons.** Stormwater has a negative impact on water quality because its runoff contains contaminants from impervious surfaces (roads, parking lots, rooftops) in urban communities. Many Kentucky cities and towns are encouraging residents and businesses through tax incentives to reduce the impacts of urban runoff and improve water quality. The ENRI Task Force developed two lessons, one on rain gardens and one on rain barrels, for county Extension agents, assistants, and volunteer leaders to use in their counties to educate residents (Fig. 16). The lessons include a facilitator's guide, a PowerPoint presentation with talking points, Extension bulletins, activities, and evaluations. The rain garden lesson also contains a DIY video on how to build a rain barrel from a pickle barrel. These lessons are available through the ENRI Task Force.

**Taking Runoff by Storm: Residential Rain Garden Program.** Across Kentucky, 31 counties have more than 100 permitted Municipal Separate Stormwater Sewer Systems (MS4) communities. Each of these MS4's must meet EPA's six minimum stormwater control measures, including public involvement and public education. Many of the permit holders in these communities are not aware of the Cooperative Extension Service nor are the county Extension office staff aware of stormwater issues and MS4 permit requirements in their own communities. Extension Specialists Brad Lee and Rick Durham and Extension Associate Ashley Osborne have been working to increase awareness of stormwater issues among county agents. Recently they have begun mak-



*Figure 16. This Woodford County rain garden and rain barrel were installed in the spring of 2013 during a Residential Rain Garden Program. Since installation, the Woodford County Extension Office horticulture agent maintains the garden and barrel.*

ing connections between MS4 community permit holders and the Extension Service staff to discuss partnerships. Although results are preliminary, a number of successful MS4 working relationships have been established across the state, including in Calloway, Daviess, and Graves Counties. These examples were cited at a recent Kentucky Stormwater Association meeting at which MS4 permit holders were introduced to the Extension Service and told how the Extension Service can help them meet their permit requirements through partnerships.

**Kentucky Water Awareness Month Packet.** Each May, citizens across Kentucky celebrate Water Awareness Month. This program first began in 1996 as an educational tool of the University of Kentucky Cooperative Extension Service. Program materials are developed at the State level and distributed via listserv to each of the 120 county Extension offices. Counties participate in activities such as after-school programs, environmental day camps, and homemaker club meetings. The

2015 Kentucky Water Awareness Month materials are available online at [www2.ca.uky.edu/enri/kwam2015.php](http://www2.ca.uky.edu/enri/kwam2015.php). The packet is coordinated by Ashley Osborne, ENRI Extension associate. This information is provided online and is sent via listserv to all county Extension agents.

**Over the River and Through the Woods Project WET and Project Learning Tree Educator Certification.** Kentucky 4-H youth development agents are required to use curricula from the "Kentucky 4-H Core Curriculum Catalog," which includes Project Learning Tree and Project Water

Education for Teachers. These two nationally recognized environmental education curricula are only available by attending a 6-hour in-service training taught by certified facilitators.

In May of 2015, a 2-day in-service training was conducted in Franklin and Henry Counties with two main objectives: (1) certifying participants in PLT and WET and (2) connecting participants with the natural environment to increase their comfort level and confidence in taking youth outdoors. Program instructors included Extension personnel from the University of Kentucky and Kentucky State University, and comprised a wide array of expertise and experience in forestry, entomology, water quality, climate science, and sustainability. Twenty-four agents attended and were certified in PLT and WET curricula.

The in-service training was funded in part by the Barnhart Fund for Excellence. In May of 2016, the Over the River and Through the Woods in-service training will be offered in the Green River Basin and will focus on Project WET and

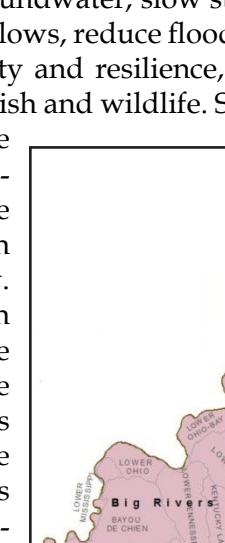
Project Underground. Project Underground is an environmental education curriculum on groundwater and karst resources.

**Project WET Workshops.** In addition to the Over the River and Through the Wood Project WET and Project Learning Tree Educator Certification, two other Project WET workshops were offered in 2015. The first was offered in January at Blue Licks Battlefield State Park in Carlisle, at which six educators were certified. The second was offered in June at Hancock Biological Station in Murray, at which seven educators were certified.

**Robinson Center Natural Resources and Environmental Science Academy.** The Robinson Center Natural Resources and Environmental Science Academy is a 3-year program designed for middle- and high-school youth from eastern Kentucky. Participants explore our environment and discover more about our water, forestry, soil, and wildlife resources in the Appalachian region. The water resources portion of the academy was led by the ENRI Task Force, and included classroom and hands-on instruction on watersheds, nonpoint-source and point-source pollution, and water quality.

Kentucky Division of Forestry

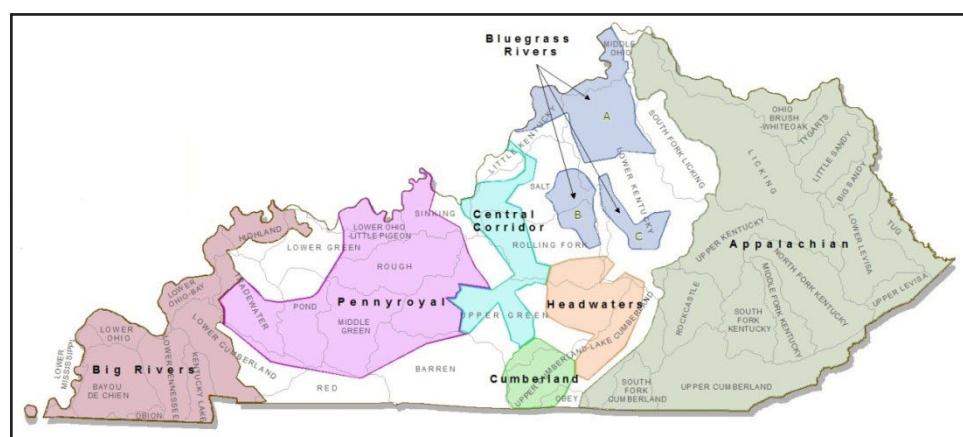
Forested land provides important benefits to both groundwater and surface water in rural and urban landscapes. Forests absorb rain, trap and filter pollutants, recharge groundwater, slow storm runoff, sustain late-season flows, reduce flooding, maintain watershed stability and resilience, and provide 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 also 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 was found to increase water yield by 40 mm in conifers, 25 mm in deciduous hardwoods, and 10 mm 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, also revealed that water quality and quantity was the second most important concern about forests of the citizens of the commonwealth, highlighted in a statewide survey of the most important issues facing the state's forest resources. The Division, along with stakeholder 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. 17).

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 quality from nonpoint-source pollution. This program enforces the minimum performance standards of BMP's mandated by the Kentucky Agriculture Water Quality Plan.



*Figure 17. Kentucky forest priority areas and watersheds.*

For the State fiscal year of July 1, 2014, to June 30, 2015, 3,646 harvest inspections were performed, resulting in 354 enforcement actions. A monitoring study from a recent statewide survey indicated that 68 percent of the applicable BMP's were implemented on the sites examined.

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 Resources 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, many times 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. Urban forestry specialists and foresters at the Division in fiscal year 2014-15 were involved in Lexington's Reforest the Bluegrass at the Kentucky Horse Park, Reforest Northern Kentucky in Covington's Devou Park, and Reforest Frankfort at Lakeview Park to address water-quality concerns within the urban interface.

Watershed restoration projects initiated this year in which technical assistance was provided include:

- Targeted bottomland hardwood management plans and educational outreach for landowners in the lower Green River in western Kentucky.
- Work on the Red Bird River restoration project, led by the U.S. Forest Service and the Kentucky Waterways Alliance in southeastern Kentucky.
- Cooperative Conservation Partnership Initiative in Rowan County (Triplett Creek watershed) to address water quality as well as forest health, wildlife habitat, and wildfire hazard conditions on public and private land.

Statewide, 64,810 tree seedlings were planted as part of Kentucky's 20/20 Vision for Restoration ... Planting 20 Million Seedlings in 20 Years.