the IGS Geode

ACTIVITIES OF THE IOWA GEOLOGICAL SURVEY, 2018–19

Understanding Streambank Erosion

The University of Iowa
Iowa Geological Survey

The IGS Geode

Activities of the
Iowa Geological Survey
2018–19

ON THE COVER: The IGS Director and State Geologist Keith Schilling observes extreme streambank erosion on Walnut Creek in Jasper County, Iowa.

THE IGS MISSION: To collect, reposit, and interpret geologic and hydrogeologic data; to conduct foundational research; and to provide Iowans with the knowledge needed to effectively manage our natural resources for long-term sustainability and economic development.

THE IGS VISION: To be a nationally recognized leader in geologic and hydrogeologic sciences, building upon our rich scientific heritage and serving Iowans through research, education, and outreach.

Director of Development and Communications:
Carmen Langel

Co-Editors:
Rosemary Tiwari
Jacqueline Hartling Stolze

Design:
Benson & Hepker Design

CONTACT US:
Iowa Geological Survey
The University of Iowa
300 Trowbridge Hall
Iowa City, Iowa 52242

Office: 319-335-1575
Email: iihr-iowa-geological-survey@uiowa.edu
Web: https://www.iowageologicalsurvey.org

www.facebook.com/IowaGeologicalSurvey

twitter.com/IowaGeoSurvey

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From the State Geologist

WELCOME TO THE 2019 ANNUAL REPORT from the Iowa Geological Survey (IGS)! As you may know, Iowa Code requires the state geologist to submit an annual report of the IGS activities to the Iowa Legislature. A couple of year ago, we decided that rather than submit a dull report that no one would enjoy reading, we'd spruce it up, and so our annual IGS *Geode* magazine was born. In the spirit of "killing two birds with one stone" (an odd phrase to actually see in writing), I'm pleased to submit our required annual report, which is also an eye-catching snapshot of our 2019 activities!

First, I need to highlight some staff changes at the IGS in the past year. In April 2019, Dr. Paul Liu retired from the IGS after working here for 25 years. Paul was primarily a bedrock geologist (noting that we're all generalists here) and a stalwart member of the STATEMAP team. We highlighted some of Paul's work in the first issue of *The IGS Geode* — you may recall that Paul co-discovered the Decorah Impact Structure in northeast Iowa and led the investigation and reporting of the world-renowned Ordovician fossil "Lagerstätte" (great word – look it up!) present in the Winneshiek Shale near Decorah.

A quick side story about Paul. This outcrop of Winneshiek Shale is found only along a partially submerged streambank of the Upper Iowa River. When the land containing this outcrop was up for sale, Paul worked tirelessly to get local preservationists to buy it because it is an extremely valuable, globally-significant fossil location. However, when no buyers emerged, Paul and his wife Xinying (Lisa) stepped in and bought the small parcel of land to preserve the area for posterity. I think this action speaks volumes about Paul's dedication to and love for

THE IOWA GEOLOGICAL SURVEY STAFF (clockwise from left) Ryan Clark, Mike Gannon, Keith Schilling, Matthew Streeter, Greg Brennan, Phil Kerr, Jason Vogelgesang, Rick Langel, Stephanie Tassier-Surine, Rosemary Tiwari, and Sophie Pierce.

Iowa geology, which is consistent with the mission of the IGS — to encourage stewardship of natural resources in the state. Congrats to Paul on a very successful career!

In addition, we lost hydrogeologist Nathan Holt, who moved on to greener (and hotter) pastures in his home state of Florida. Nathan was a valuable member of the IGS hydrogeology team, working closely with Mike Gannon on several groundwater investigation and modeling projects. On the positive side of the staffing ledger, we hired hydrogeologist Greg Brennan in June. Greg comes to us from a long career in environmental consulting and is stepping right in to help with our groundwater and geophysics projects. In addition, just this fall, we hired Sophie Pierce to help with fieldwork on many projects and to lead our efforts with new Iowa Nutrient Research Center and Iowa Department of Transportation projects. Sophie previously worked at the U.S. Geological Survey, where her stream gauging work prepared her very well for the joys of conducting fieldwork in Iowa conditions!

The rest of our IGS team has been working tirelessly on many different projects the past year; we're highlighting some of them in this report. The cover story is a project that I've been working on focused on developing a better understanding of the scope and scale of streambank erosion. The project began with funding from the Iowa DOT and later gained support from the Iowa Nutrient Research Center. Over time, it developed into a hugely collaborative effort to gain insights into something that we all see (streambank erosion). Yet we rarely grasp the full impacts of this erosion. In addition, the *Geode* includes articles on our geophysics and groundwater programs, a new web-based well forecasting tool, geologic mapping, and a slew of shorter articles on other aspects of IGS projects and services.

Finally, I want to call your attention to a page in the *Geode* that describes the IGS field trips and the establishment of a new IGS foundation account. Field trips have always been an important part of the IGS mission (and consistent with geologists everywhere — who doesn't love a good field trip to see our natural environment?). In the past, the IGS partnered with a nonprofit association to co-host field trips across the state. With the association gone and the short-staffed IGS focused on projects and state needs, our ability to host field trips is greatly diminished. We would love to begin hosting these field trips again, and this is the main reason we have set up a new IGS foundation account — so we can receive gifts that can be dedicated to the development of materials and hosting of geology field trips in Iowa. Please consider a tax-deductible donation to the IGS foundation account to support these activities.

That's it from me! I hope you enjoy the 2019 edition of *The IGS Geode* and as always, please feel free to reach out to me or the IGS staff at any time with questions or concerns. You can also contact us through our social media accounts (listed at the bottom of the previous page).

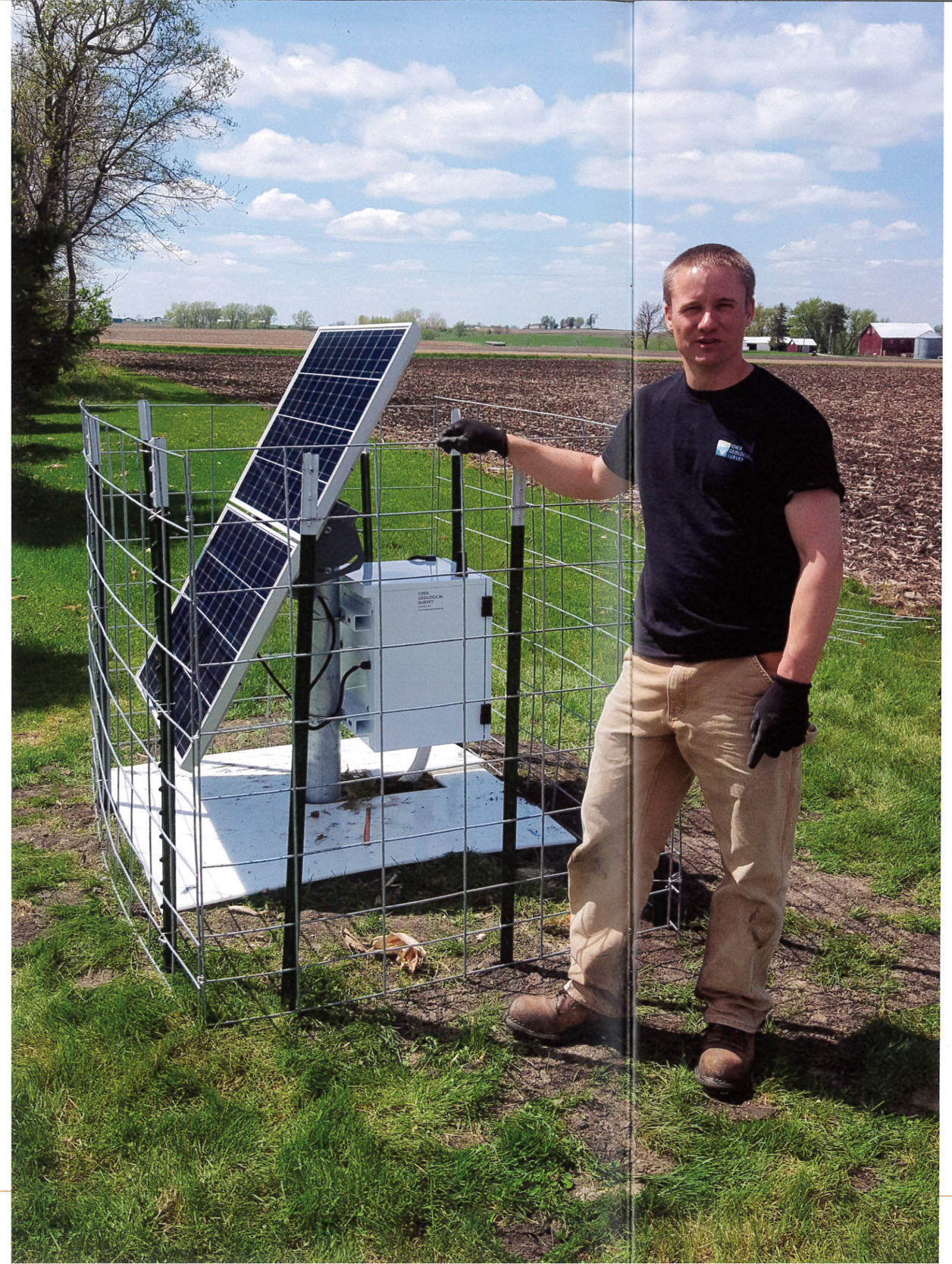
Keith Schilling

KEITH SCHILLING
State Geologist

Monitoring Micro-Earthquakes in Iowa

THE IGS IS EMBARKING UPON AN EXCITING new effort: seismic monitoring for micro-earthquakes. We installed a network of seismometers near Redfield, Iowa, to monitor a deep geologic structure used by Northern Natural Gas to store gas. Water injection operations at the site have the potential to induce or enhance micro-seismic activity. The IGS is working with Northern Natural Gas to continuously monitor the region to determine if micro-seismicity is occurring. We anticipate that induced micro-earthquakes, if observed, will have very small magnitudes that cannot be felt at the land surface.

Water injection operations at the site have the potential to induce or enhance micro-seismic activity.

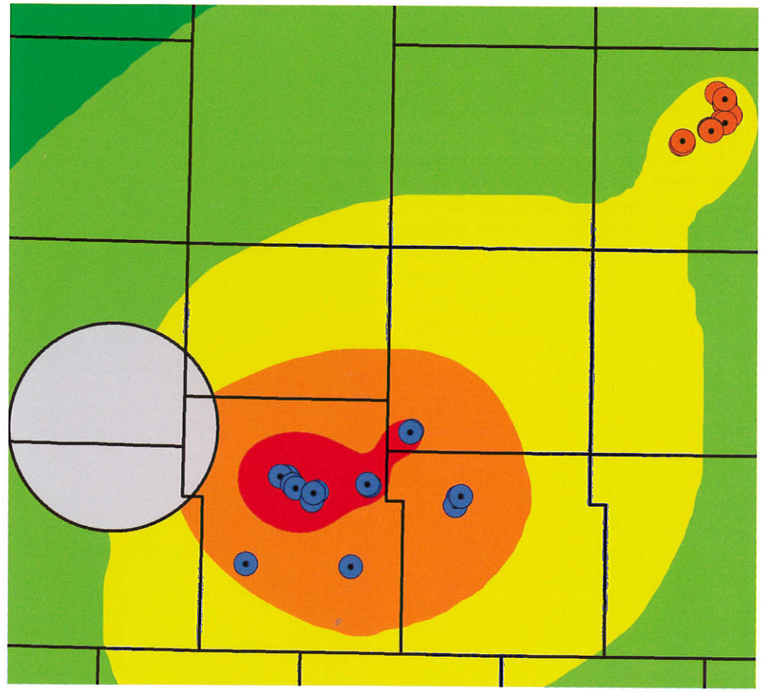


IGS' Jason Vogelgesang, standing near one of the newly-installed seismometers.

IGS Modeling Predicts, Protects Water Resources

THE CITY OF FORT DODGE IS ONE OF THE largest users of water from the Cambrian-Ordovician (CO) aquifer in Iowa. In 2017, Fort Dodge was the state's largest individual user of CO water, with reported usage totaling 2 billion gallons. The city hired the Iowa Geological Survey (IGS) to evaluate further expansion of its water supply. This would involve drilling new CO aquifer wells near the industrial park six miles west of the city.

The IGS developed a groundwater flow model to evaluate potential water availability in the industrial park area. Adding new wells at the industrial park may provide the city a way to expand its use of the CO aquifer. Model results found that if Fort Dodge distributed usage between existing and new wells, the city could obtain a 50% increase of its 2017 CO aquifer usage while remaining in regulatory compliance. Because of the effects of the Manson Impact Structure nearby, water production from the CO aquifer in the industrial park area could be variable.



Model output showing the additional drop in groundwater levels if Fort Dodge increased its Jordan water usage by 50 percent.

New IGS Sediment Laboratory Opens

THE IGS SEDIMENT LABORATORY IS A fully-functioning Quaternary materials lab managed by IGS Soil Scientist Matthew Streeter. The lab opened in 2014 and is housed at the IGS Oakdale facility.

The lab provides a broad spectrum of analyses, including soil particle size analysis (pipette and x-ray absorption); sand fractionation; total carbon, nitrogen, sulfur, and hydrogen (chromatography); and soil organic matter (loss on ignition). The lab also maintains a large inventory of field monitoring equipment, including monitoring well instrumentation, water-quality meters, and the IGS drill rig.

While the sediment lab primarily runs samples and manages equipment deployments for IGS projects, it also provides valuable data for several IGS collaborators. Over the past five years, the IGS sediment lab has provided multiple opportunities for students to gain real-world experience in soil collection, analysis, and interpretation techniques.

TOP: Soil scientist Matthew Streeter prepares to run a total carbon analysis.

BOTTOM: University of Iowa student Brennan Slater describes a soil core in the lab.

GeoLab Makes Data Accessible to All

THE IGS HAS DEVELOPED A NEW WEB application, GeoLab, that allows users to perform customized searches of geologic laboratory data. The IGS has historically acquired laboratory data from outcrops and cores collected for various geologic investigations and research projects, but a lot of these data were previously unavailable to the public, and in many cases the information was in danger of being lost.

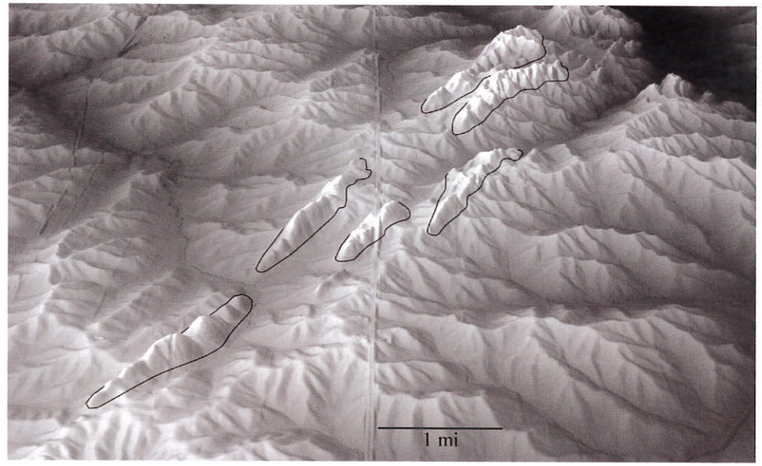
Data are now available to users and are viewable online. Information can also be downloaded as a KML or Excel file. The available data include grain-size, radiocarbon dates, clay mineralogy, pXRF data, soil carbon and nitrogen, matrix carbonate, bulk density, and clast lithology associated with existing well records. The online interface is searchable by analysis type, location, or stratigraphic unit.

In all, a total of 7,849 laboratory results are available in the database, with more coming online soon. Additionally, the project scanned more than 2,000 pages of lab data for preservation and added 175 new logs to GeoSam. The USGS National Geological and Geophysical Data Preservation Program provided partial funding for the project.

The available data include grain-size, radiocarbon dates, clay mineralogy, pXRF data, soil carbon and nitrogen, matrix carbonate, bulk density, and clast lithology associated with existing well records. The online interface is searchable by analysis type, location, or stratigraphic unit.

Paha: Iowa's Distinctive Hillocks

By Phil Kerr



A 3D digital elevation model generated by LiDAR that shows a group of paha intersected by Highway 30 in Benton County. This view looks east toward Cedar Rapids. The vertical exaggeration is 5x.

THE ROLLING LANDSCAPE OF THE IOWAN Surface (found east of the Des Moines Lobe, north of the Iowa River, and west of the Paleozoic Plateau) has many northwest-to-southeast trending linear features that stand out from the surrounding landscape. W.J. McGee named these "elongated swells of soft and graceful contour" paha in the 1890s based on the Dakota Sioux term for "hill." These loess (windblown silt) capped ridges were once thought to represent areas around which a thin ice sheet had diverted. However, this interpretation did not stand up to scrutiny, and in the 1960s geologists determined that they were areas that had escaped the erosional processes that formed the gently rolling topography of the landscape. There was one missing component of this explanation — the source of the loess.

New detailed topographic information has allowed geologists to see the landscape as never before. The Iowa Department of Natural Resources has collected light detection and ranging data (LiDAR) for the entire state. This information has proven invaluable for identifying surficial deposits. We can combine these digital elevation models with other sources of information to illuminate old questions. Joseph Mason, a University of Wisconsin researcher, has suggested that the formation of paha deals in part with the relationship of the land and the wind. His model of eolian transport simulates areas of rolling topography with high wind events and sediment loads, which can be applied to the Iowan Surface.

Recently, the Iowa Geological Survey has shown a strong connection between the rivers that drained outwash in the Des Moines Lobe and eolian sediments on the Iowan Surface. In this area, strong winds carried sand, abrading the landscape. Finer silt-sized particles could not accumulate on the landscape because of this erosion. However, loess accumulated downwind in areas where there is an upwind impediment to the sand, much like a snow fence. Steep stream valleys, river valleys, or tall bedrock outcrops acted as wind breaks. Vegetation also played a role by catching the loess and trapping sand. Even paha themselves seemed to propagate more paha! These hills formed groups on the landscape; the most northwestern hill would have caused turbulence, blocking sand and allowing the loess to accumulate downwind (see picture). These enigmatic ridges still have secrets to unlock, and continued work by the Iowa Geological Survey will help unravel more of their story.

Advancing Modeling Science for Shallow Alluvial Aquifers

by Jason Vogelgesang

While we recommend a certain amount of field verification through driller samples and pump tests at any local site, using ERT provides a potential avenue to improve quantity and spatial distribution of the measured K dataset in a time-efficient, non-intrusive way.

SHALLOW ALLUVIAL AQUIFERS ARE important local and regional water resources but obtaining sufficient hydrogeologic data to properly characterize their spatial extent and hydraulic conditions can often be difficult, time-consuming, and expensive. The IGS has been extensively investigating these shallow aquifers in the past several years and has published a new journal paper correlating electrical resistivity geophysical data to aquifer hydraulic conductivity.

Using electrical resistivity tomography (ERT) data to estimate hydraulic conductivity (K) can provide an efficient, cost-effective way to increase data available for use in groundwater models and characterization of aquifer heterogeneity (Figure 1). We used over 40,000 measurements of ERT data and K information from 33 pump tests across eight shallow alluvial and glacial outwash aquifer field sites in Iowa to: (1) assess the relationship between K tests and electrical resistivity (ER) in alluvial and glacial outwash systems; and (2) evaluate the application of the ER-K relationship as input data for local-scale groundwater flow modeling.

We observed a linear relationship across the eight field sites in glacial outwash and alluvial depositional environments (Figure 2). The IGS team developed an equation to estimate hydraulic conductivity from electrical resistivity: K = 0.23 x ER + 25.1, where K is field-average hydraulic conductivity in m/day and ER is field-averaged electrical resistivity in ohm-m. We found that values of K from the ER-K relationship were reasonable estimates for use in a local-scale groundwater flow model.

While we recommend a certain amount of field verification through driller samples and pump tests at any local site, using ERT provides a potential avenue to improve quantity and spatial distribution of the measured K dataset in a time-efficient, non-intrusive way. A better characterization of local hydraulic conductivity improves the quality of local-scale groundwater models and remediation projects, especially for sites that do not have existing observation wells and pump tests or sites with extreme aquifer heterogeneity.

FIGURE 2: Relationship between hydraulic conductivity and aquifer resistivity across shallow alluvial and glacial outwash aquifer field sites in Iowa.

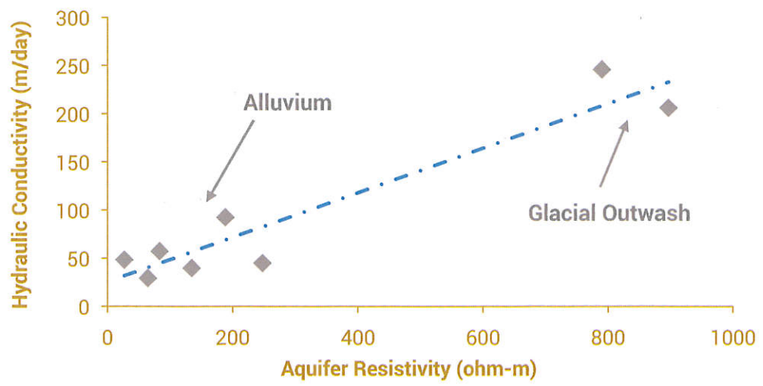
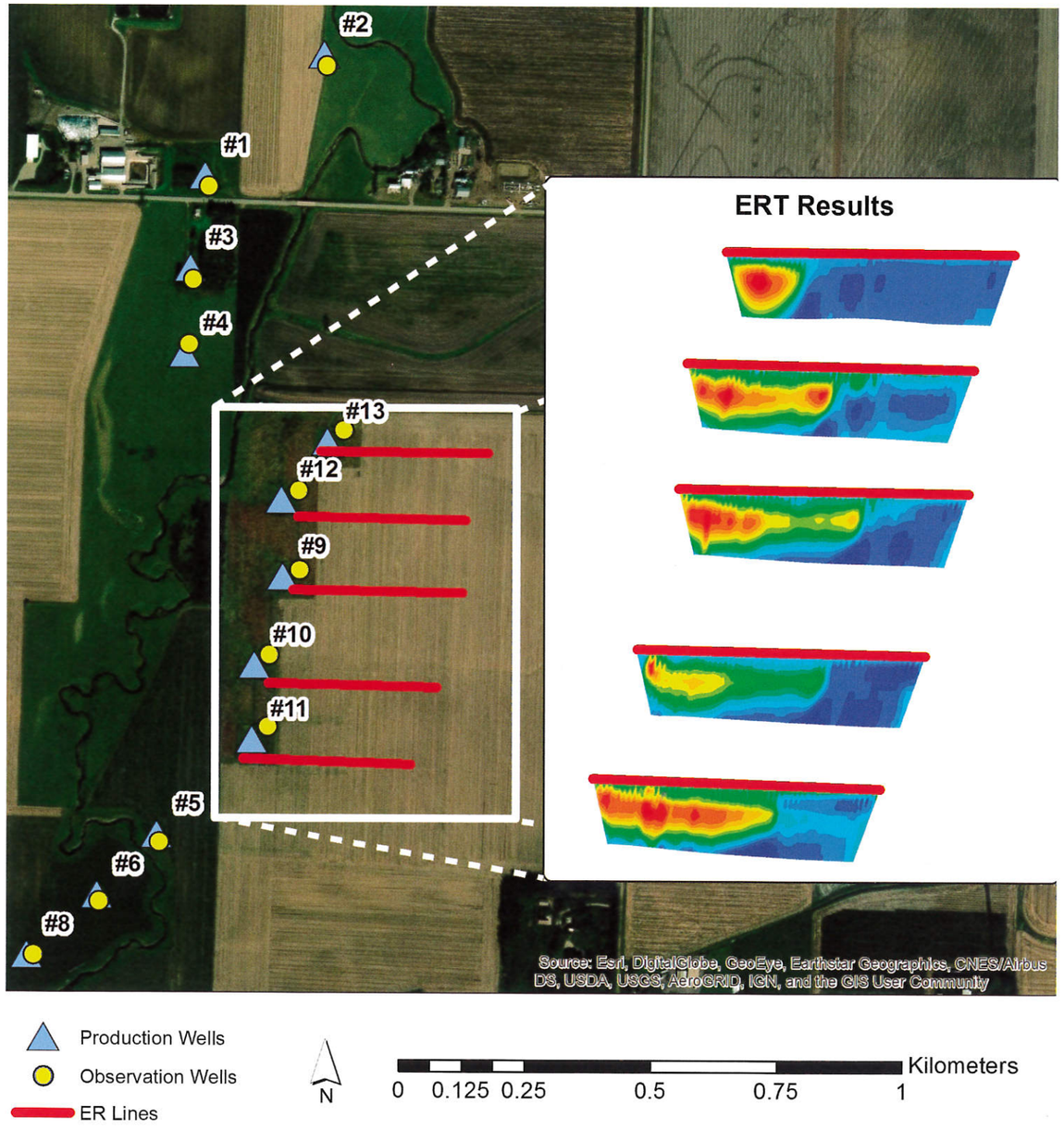


FIGURE 1: Map showing the pump test wells, geophysical line locations, and ERT results for the Sioux Center study site.



STATEMAP Supports Industry, Research, and More

by Ryan Clark and Stephanie Tassier-Surine

PRODUCING GEOLOGIC MAPS IS fundamental to the practice of geology. Although most people no longer "read" road maps, opting instead for a voice dictating their turn-by-turn directions, maps remain a vital source of information. The U.S. Geological Survey established the National Cooperative Geologic Mapping Program (STATEMAP) in 1993 to provide funding support for state geological surveys to map the geology in their own backyards.

The Iowa Geological Survey (IGS) has been participating in this program since its beginnings and over the years has produced more than 140 different mapping products. However, the benefits of STATEMAP do not stop at the publication of a map. Ripples from the detailed geologic mapping extend into Iowa's social network and economy as well.

The process of making detailed geologic maps involves combing through and refining existing data, collecting new data, and applying the latest interpretations to formulate a sharper understanding of the geology of an area. The IGS hosts a database of over 90,000 geologic data points that includes water wells, exploratory borings, quarry sections, and outcrop descriptions.

While mapping a given area, we scrutinize the data points for locational accuracy and vet the information (driller's log, strip log, outcrop description, etc.) for completeness and validity. This refinement of the publically available online database (GeoSam: https://www.iihr.uiowa.edu/igs/geosam/home) benefits water well drillers, consultants, and anyone in need of subsurface information. In areas recently mapped, we can refine the topography of the bedrock surface from the existing 50-foot contour interval (Figure 1a) to 25-foot (Figure 1b). Extrapolation of the same data can yield a more accurate depth to bedrock estimate, which is very useful when characterizing alluvial aquifers or identifying areas where shallow bedrock may be used for future aggregate production.

Surficial and bedrock geologic maps can help answer many questions on their own, but the enhanced data produced in the mapping process can be useful in other ways too. Since the historic flooding that struck eastern Iowa in 2008, several Watershed Management Authorities (WMAs) formed in an effort to understand the root causes of, and ways to mitigate, flooding events. In Benton County, the Middle Cedar River WMA has partnered with science-based institutions such as IIHR—Hydroscience & Engineering at the University of Iowa to build predictive models of how heavy rain events lead to flooding in the watershed. These models need information such as surface topography, slope vectors, stream morphology, and geology. Thanks to high-resolution maps of the surficial geology of Benton County produced by the IGS, modelers have the tools to mimic actual subsurface conditions within the watershed.

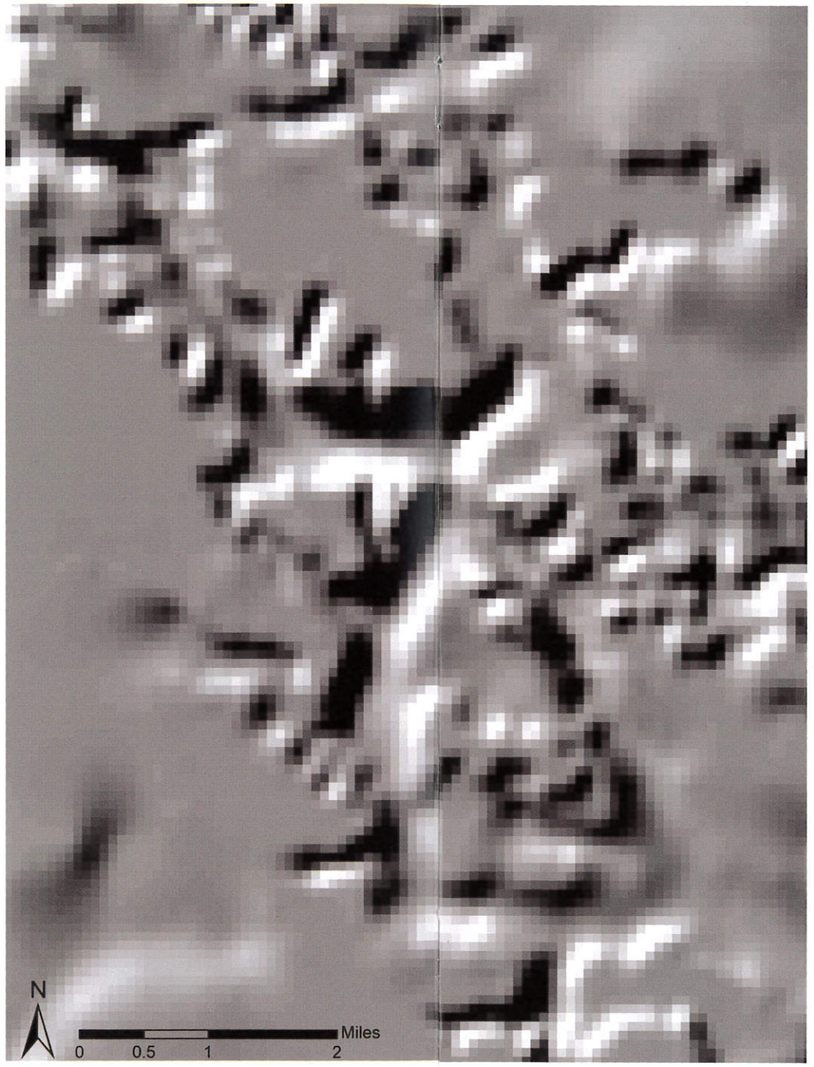


FIGURE 1A: Old bedrock topography map based on 50-foot contours. Note the blurry appearance. Image is a raster produced by topographic line file created for the Bedrock Geologic Map of the Mt. Pleasant 7.5" Quadrangle, Henry County, Iowa.

FIGURE 1B: New map based on 25-foot contours. Image is a raster produced by topographic line file created for the Bedrock Geologic Map of the Mt. Pleasant 7.5" Quadrangle, Henry County, Iowa.

Understanding Streambank Erosion in Iowa

by Keith Schilling, State Geologist

STREAMBANK EROSION IS KNOWN to be a major source of sediment and phosphorus in rivers, but quantifying its scope and impact across a region has been a challenge for scientists for many decades. Although research has been done at individual streambanks to understand processes controlling the rate and timing of erosion, rarely has work been done to characterize bank erosion at a watershed or statewide scale. Working with a variety of collaborators, IGS geologists are developing new insights on regional patterns of streambank erosion and the contributions from bank erosion to sediment and phosphorus (P) loads to Iowa's rivers. The Iowa Department of Transportation and the Iowa Nutrient Research Center provided support for the projects, which included research partners from the Iowa Department of Natural Resources (IDNR), Iowa State University, U.S. Department of Agriculture, University of Tennessee, Iowa Soybean Association, and students from the University of Iowa.

MAPPING STREAMBANK EROSION

Identifying where severely eroding streambanks are occurring in watersheds is a crucial first step to assess their potential impact. Field mapping in small watersheds can document streambank lengths but it is exhaustive and time-consuming.

To estimate streambank erosion at a larger scale, we developed a new geographic information system (GIS) routine to estimate severe streambank erosion based on light detection and ranging (LiDAR) data available for the state. Led by DNR GIS specialist Calvin Wolter, we used a GIS model based on bank heights and the streambank slope (in a nutshell — greater bank angles indicate more vertical banks) to quantify the extent of severely eroding streambanks in Iowa's 3rd to 6th order streams (Figure 1).

Using model criteria, we estimated that 35,200 km (21,870 miles) of streambanks along 3rd to 6th order rivers are severely eroding in Iowa. Compared to 85,970 km (53,420 miles) of available streambanks, our data suggests that approximately 41% of the streambanks in Iowa are severely eroding. More streambank erosion appears to be occurring in southwest and southern Iowa than in other areas of the state (Figure 2). We found that larger rivers have more eroding banks because they receive discharge from larger watershed areas. This increase in discharge increases stream power and contributes to greater bank erosion.

With this new data in hand, we are working with researchers from University of Tennessee to quantify the potential risk of streambank erosion to road and bridge infrastructure. In a second application, we are working with Iowa State University and USDA to use the bank erosion mapping to quantify the contribution of streambanks to total phosphorus loads in Iowa.

FIGURE 1: Using streambank slopes to identify potential bank erosion.

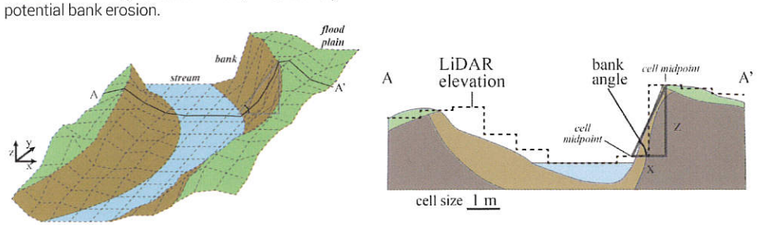
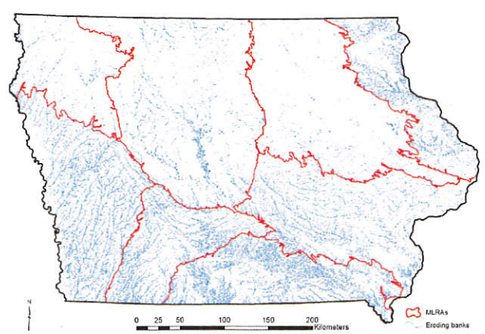


FIGURE 2: Extent of eroding streambanks in Iowa.



CONTRIBUTION OF BANK EROSION TO P LOADS IN IOWA RIVERS

Estimating the contribution of bank erosion to riverine P loads is not a simple task. This issue was specifically left out of the Iowa Nutrient Reduction Strategy because of the uncertainty of how to develop an accurate estimate. The IGS led a multi-stepped, INRC-funded project (with assistance from many collaborators) to develop a statewide estimate.

First, we used ambient water-quality data from the Iowa DNR stream-monitoring program to estimate the total P loads exported from 46 Iowa rivers. Over an 18-year period, we found that approximately 25,000 metric tons (Mg) of P are exported from Iowa rivers every year. Next, to estimate bank recession rates, we worked with ISU scientists to summarize erosion pin data collected from a variety of sites across the state. Although recession rates were found to vary between wet and dry years, we estimated that severely eroding banks are receding about 11 cm per year (Figure 3).

Finally, to account for the soil properties of eroding banks, the IGS geologists and UI student Brennan Slater traveled across Iowa to sample exposed banks (Figure 4). With help from the USDA National Laboratory for Agriculture and Environment and making use of the IGS sediment lab (see story p. 6), we found that bank soils have an average P content of about 470 mg/kg.

So, what does all this mean? Now nearing the completion of a multi-year effort, we estimate that streambanks contribute approximately 8,000 mg of P to Iowa's rivers every year. Compared to the annual total P export from Iowa, this suggests that streambanks could account for about one-third of the P export. Interestingly, this estimate confirms what a lot of us have suspected but have never had the regional data or evidence to support this contention.

Overall, the IGS efforts to quantify streambank erosion in Iowa have benefited greatly from collaborations with many different scientists from different institutions and agencies. The new information we've gathered from these projects is advancing the science of river geomorphology and nutrient loading in new and exciting directions.

FIGURE 3: Box plot of annual streambank erosion rates measured at Walnut Creek, Iowa.

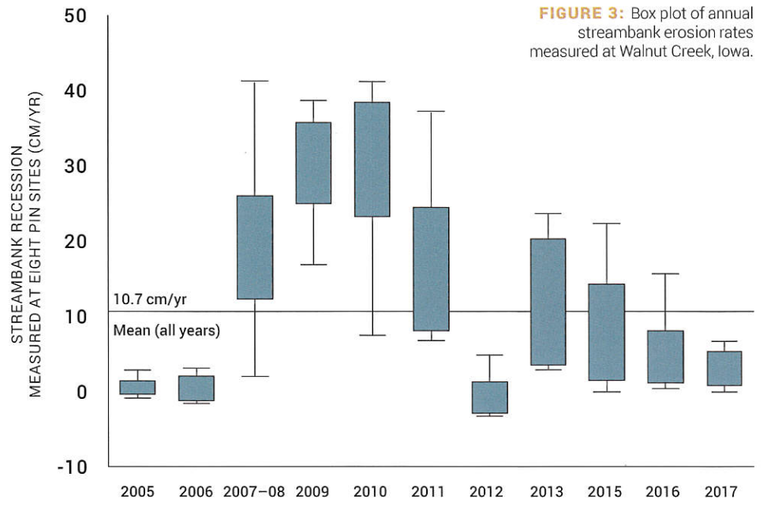


FIGURE 4: Brennan Slater sampling a streambank along the Cedar River.

New Online Well Forecasting System Debuts

by Rick Langel

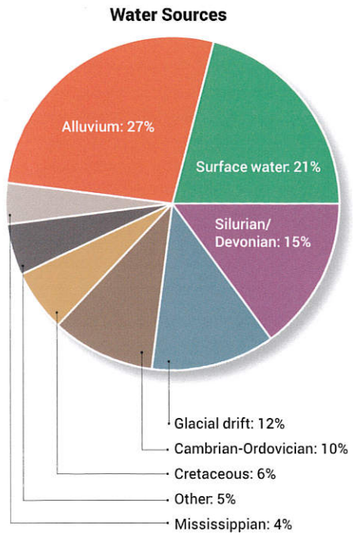


FIGURE 1: Iowans use a variety of sources for their water supply.

THE IOWA GEOLOGICAL SURVEY (IGS) has a long history of creating free well forecasts for the general public, well contractors, engineers, and other interested parties. The IGS partnered with other university groups to develop a new online system that is making the well forecasting process faster and more accessible to all Iowans.

A well forecast is an evaluation of potential groundwater quantity and quality for any given location. The forecast identifies the expected depth and thickness of each aquifer and provides information on the anticipated water quality from the aquifer(s) (Figure 1). The goal of such a forecast is to provide information to help users make informed decisions about potential well depth and construction.

Until recently, development of a well forecast required a manual review of nearby well data. A recent collaboration between the University of Iowa Center for Health Effects of Environmental Contamination (CHEEC), the UI Hydroinformatics Lab, and the IGS took a first step toward computer-generated well forecasting. The group produced an online application called the Iowa Well Forecasting System (IWFoS) that allows users to view information regarding groundwater aquifer depths and groundwater quality for any location in Iowa.

The IGS' GeoSam database is a key component of IWFoS. Tables within GeoSam contain information on the top and bottom depths of aquifers. A simple click of a location in the IWFoS interface begins the process to calculate aquifer depths. IWFoS quickly searches in GeoSam for wells containing data associated with up to five different bedrock aquifers. From these wells, IWFoS triangulates the depths of the aquifers.

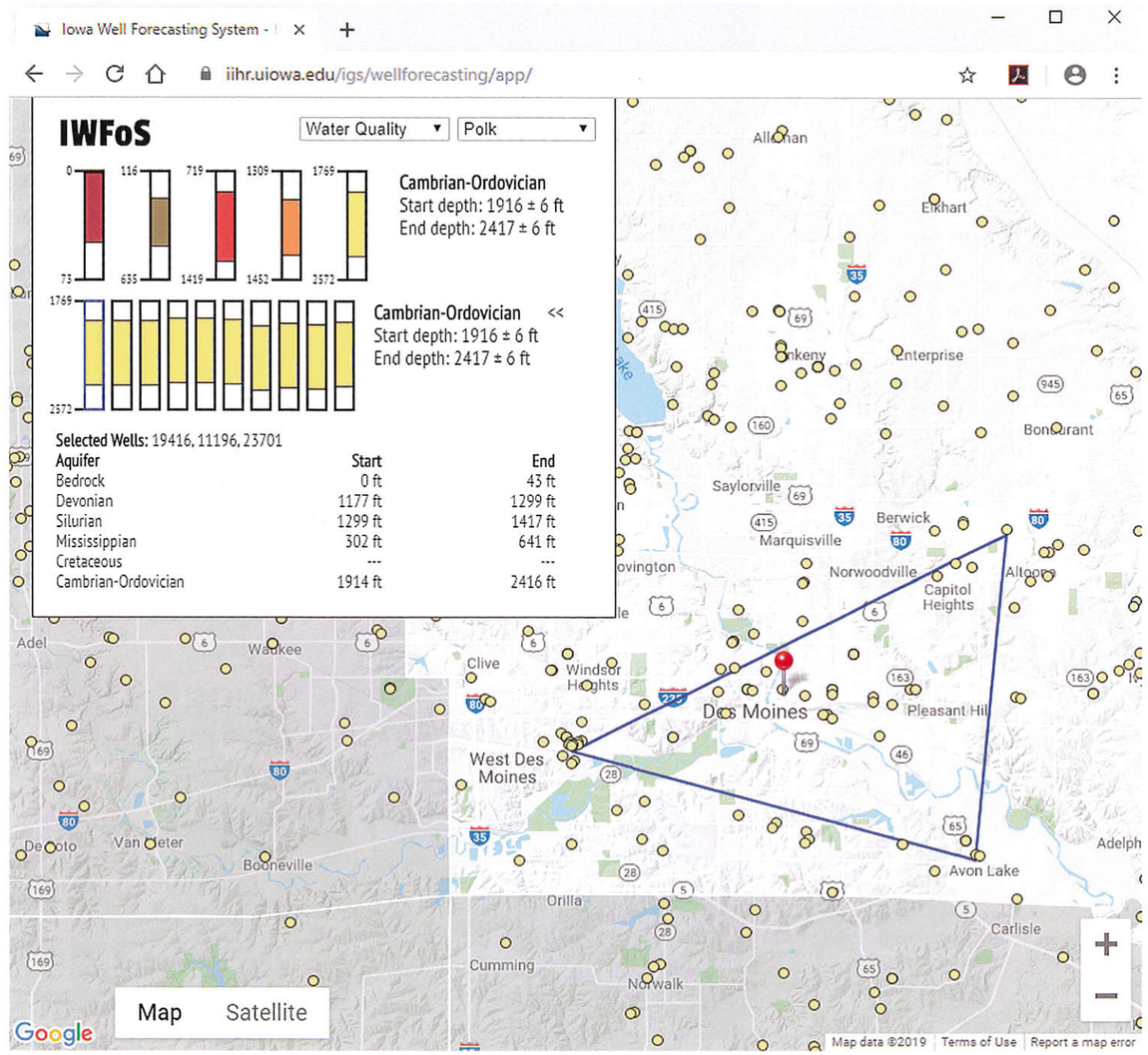
IWFoS displays the aquifer depths of the top 10 nearest well triangulations out of potentially thousands. Figure 2 shows a sample forecast for the Cambrian-Ordovician aquifer at the Iowa State Capitol. IWFoS also shows the exact wells each triangulation uses and provides direct access back to the GeoSam database. This gives users a chance to interact with the data and make their own assessment of the accuracy of the forecast.

IWFoS connects to GeoSam in real-time. Well location changes, aquifer information updates, or new well additions automatically appear in IWFoS. Consequently, IWFoS is always using the most current geological data for its forecasts.

The Iowa Department of Natural Resources' Private Well Tracking System (PWTS) is another key IWFoS component. Tables in PWTS contain groundwater quality results. IWFoS displays the results of the most commonly tested groundwater parameters (e.g., nitrate and arsenic), as well as bacteria. IWFoS displays the nearest wells that have results for the desired parameter.

> "This system makes the data more accessible to Iowans, allowing better decision-making for new well construction and helps to raise awareness about water quality. Groundwater is an important resource, which provides drinking water for about 60 percent of all Iowans."
>
> — David Cwiertny, Director, CHEEC

FIGURE 2: IWFoS was designed as a public resource for well users and is available 24/7 at: https://www.iihr.uiowa.edu/igs/wellforecasting.



IOWA'S GROUNDWATER:
Meeting the Needs, Now and in the Future

by Mike Gannon

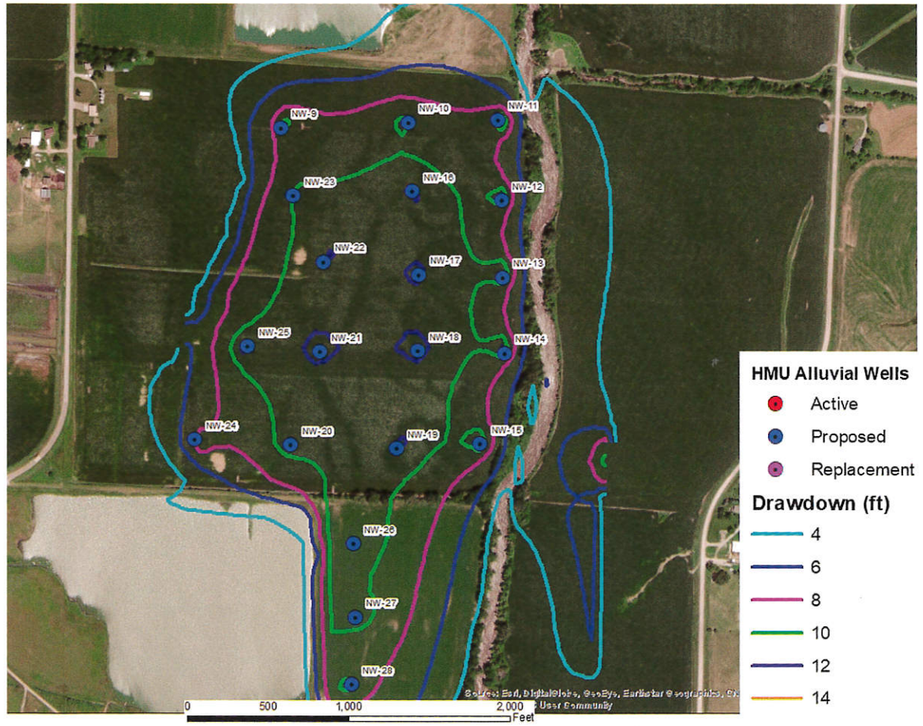
THE CITY OF HARLAN, WITH A POPULATION of 5,400, is the county seat of Shelby County in southwest Iowa. Harlan's water supply comes from 21 public wells that range in age from 30 to 85 years old. The city needs additional water capacity to meet peak water demand during hot summer days and to be available for new economic development. In the summer of 2018, Harlan Municipal Utilities (HMU) reached out to the Iowa Geological Survey (IGS) for a comprehensive assessment of the Harlan water supply. The assessment involved using geophysics, installing test wells, conducting pump tests, and developing a groundwater flow model.

To meet Harlan's future water needs, the IGS recommended a phased approach. Phase I would involve the replacement of several production wells with new, more efficient wells that could potentially add 1,500 gallons per minute (gpm) of instantaneous water production to HMU. Phase II would involve the installation of several new wells adjacent to the current wellfield.

The IGS developed a groundwater flow model to simulate the impact of adding new production wells. The model's maximum pumping rate for five proposed wells was 150 gpm per well, with a total instantaneous pumping rate of 750 gpm. Phase III would involve the installation of approximately 20 new production wells approximately 0.5 miles south of the current wellfield. The groundwater flow model was also used to simulate the impact of the new production wells. Maximum simulated pumping rates in the model ranged from 75 to 200 gpm per well, with a total instantaneous water production of 3,150 gpm.

At the conclusion of the project, the IGS worked with HMU to develop a long-term plan in which new production wells will be added and existing wells will be maintained on a regular basis. Maintaining the production wells protects the city's capital investment and allows for maximum future water production, especially during hot and dry summers.

IGS Geologist Rick Langel conducts a pump test to evaluate future water production (left and opposite page).



Groundwater modeling results for HMU wellfield.

Collaboration with the Iowa Department of Natural Resources

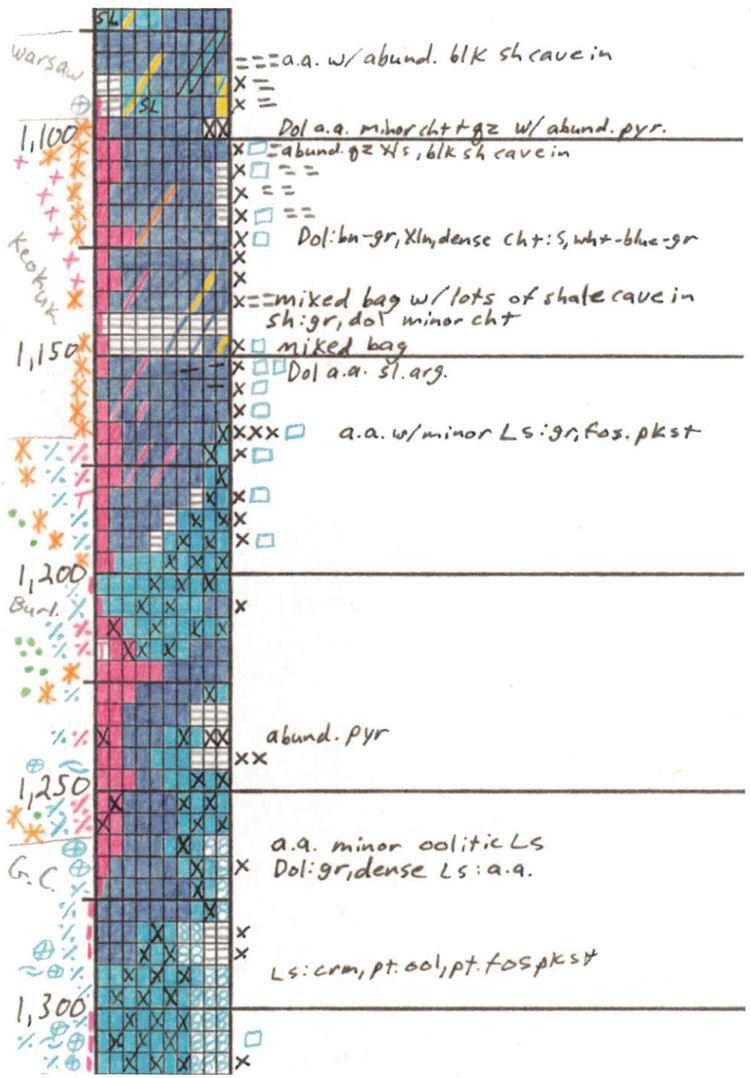
by Rick Langel and Ryan Clark

THE IGS COLLABORATES WITH THE IOWA Department of Natural Resources (IDNR) on many issues related to Iowa's water and natural resources. The IGS and IDNR staff share data and expertise across several different platforms, including information related to well records, geologic samples, pump test results, and other geospatial data. During the 2018–19 fiscal year, the IGS provided IDNR with the following services:

- Updated GeoSam with records from over 1,600 wells. Thirty-five (35) of the records were specifically for the IDNR's Water Use and Public Water Supply programs. Eighty-three (83) were specifically for the IDNR's Animal Feeding Operation program.
- Cataloged and archived well samples collected from 99 Water Use and Public Water Supply program permitted wells.
- Provided lithologic strip logs of two deep water wells totaling 3,515 feet (right).
- Analyzed and entered 17 pump tests to the IGS PumpTest database for IDNR to access.
- Evaluated shallow groundwater levels on a monthly basis for inclusion in the IDNR's Drought Summary update.
- Provided technical assistance to the IDNR's AFO group for a site in karst terrain in northeast Iowa.
- Updated the statewide Cambrian-Ordovician groundwater flow model to local conditions found in north central Iowa.

In addition, in October 2018 at the request of the Iowa DNR and the Environmental Protection Commission, the IGS staff led a field trip through northeast Iowa to view karst features and discuss environmental issues related to karst hydrogeology. Participants visited an old quarry to view the region's geology and saw multiple roadside karst features (sinkholes, losing streams) before concluding with discussions near the Big Spring Fish Hatchery (opposite page).

BELOW: Portion of a lithologic strip log showing the variability of rock types in the Mississippian-age formations encountered in the new well for the City of Walnut.



OPPOSITE PAGE: Field trip participants view a sinkhole in northeast Iowa.

Give to the Iowa Geological Survey

The Iowa Geological Survey foundation account allows your tax-deductible gift to support future field trips and outreach events. Give online at https://donate.givetoiowa.org and search for Iowa Geological Survey under "Areas to Support" or contact one of the individuals listed below:

To make your tax-deductible gift, contact:
Matt Kuster
(Matt.Kuster@foriowa.org, 319-467-3720)

State Geologist Keith Schilling
(keith-schilling@uiowa.edu, 319-335-1422)

Carmen Langel
(carmen-langel@uiowa.edu, 319-335-5841)

Please add "IGS" to the memo line of your check.

Thank you!

IOWA GEOLOGICAL SURVEY

Gifts to the IGS Support Public Field Trips

SINCE ITS INCEPTION IN 1892, the Iowa Geological Survey (IGS) has made the collection and dissemination of geologic information one of its core functions. The IGS has a long and storied history of leading field trips, which provide a unique opportunity for the public to interface with the IGS staff and for us to share our collective knowledge with the citizens of Iowa. In conjunction with various universities and state agencies, the IGS has led more than 200 field trips, many with associated guidebooks that preserve the information.

Field trip destinations have included quarries, public areas, and state parks. Topics have focused on areas such as geology, water quantity and quality, watershed management, landforms of Iowa, and natural history. The Geological Society of Iowa conducted 95 of these field trips, many of which focused on the natural history of an Iowa State park, incorporating the park's geology, archaeology, flora, fauna, and cultural aspects.

IOWA GEOLOGICAL SURVEY FOUNDATION ACCOUNT

Current funding and staffing levels have made it increasingly difficult for the IGS to organize, prepare educational materials for, and host field trips on geology and water resource topics. For this reason, last year the IGS established a gift account with the UI Center for Advancement for the collection of donations that will be used to develop educational materials and host field trips. The funds will not be tapped for operating expenses, but will be used solely to spread the news of Iowa geology to citizens of the state through innovative educational materials and/or exciting IGS-led field trips.

You can make a donation of any size to the fund at http://donate.givetoiowa.org (search for Iowa Geological Survey).

Publications by the IGS Staff in 2018–19

Ayers, J.R., G. Villarini, C.S. Jones, and **K.E. Schilling**, 2019. "Changes in monthly baseflow across the U.S. Midwest," *Hydrological Processes*, doi: 10.1002/hyp.13359.

Beck, W.J., P.L. Moore, **K.E. Schilling**, C.F. Wolter, T.M. Isenhart, K.J. Cole, and M.D. Tomer, 2019. "Changes in lateral floodplain connectivity accompanying stream channel evolution: Implications for sediment and nutrient budgets," *Science of the Total Environment*, 660:1015-1028.

Clark, R., S. Tassier-Surine, P. Kerr, and **H. Liu**, 2019. Bedrock geologic map of the Mount Pleasant 7.5' Quadrangle, Henry County, Iowa: Iowa Geological Survey, Open File Map OFM-19-1, 1:24,000 scale map sheet.

Clark, R., S. Tassier-Surine, P. Kerr, and **H. Liu**, 2019, Bedrock Geologic Map of the Salem 7.5' Quadrangle, Henry and Lee Counties, Iowa: Iowa Geological Survey, Open File Map OFM-19-3, 1:24,000 scale map sheet.

Jones, C.S., C.W. Drake, C.E. Hruby, **K.E. Schilling**, and C.F. Wolter, 2019. "Livestock Manure Driving Stream Nitrate," *Ambio*, doi.org/10.1097/s13280-018.1135-5.

Jones, C.S., **K.E. Schilling**, and A. Seeman, 2019. "Relating Carbon and Nitrogen Transport from Constructed Farm Drainage," *Agricultural Water Management*, 213:12-23.

Kerr, P., S. Tassier-Surine, H. Liu, and **R.J. Clark**, 2019. Surficial Geologic Map of the Center Point NW Quadrangle, Benton County, Iowa: Iowa Geological Survey, Open File Map OFM-19-8, 1:24,000 scale map sheet.

Kerr, P., S. Tassier-Surine, H. Liu, and **R.J. Clark**, 2019. Surficial Geologic Map of the Vinton Quadrangle, Benton County, Iowa: Iowa Geological Survey, Open File Map OFM-19-6, 1:24,000 scale map sheet.

Liu, H., P. Kerr, R.J. Clark, and **S. Tassier-Surine**, 2019. Bedrock Geologic Map of the Vinton Quadrangle, Benton County, Iowa: Iowa Geological Survey, Open File Map OFM-19-5, 1:24,000 scale map sheet.

Liu, H., P. Kerr, R.J. Clark, and **S. Tassier-Surine**, 2019. Bedrock Geologic Map of the Center Point NW Quadrangle, Benton County, Iowa: Iowa Geological Survey, Open File Map OFM-19-7, 1:24,000 scale map sheet.

Moustakidis, I.V., **K.E. Schilling**, and L.J. Weber, 2019. "Soil Total Phosphorus Deposition and Variability Patterns Across the Floodplains of an Iowa River," *Catena*, 174:84-94.

Schilling, K.E., C.S. Jones, **R.J. Clark**, R.D. Libra, X. Liang, and Y.K. Zhang, 2019. "Contrasting NO_3-N Concentration Patterns in Two Karst Springs in Iowa (USA)," *Hydrogeology Journal*, 27:1389-1400.

Schilling, K.E. and C.S. Jones, 2019. "Hydrograph Separation of Subsurface Tile Drainage," *Environmental Monitoring and Assessment*, 191:231.

Schilling, K.E., P.W. Gassman, A. Arenas-Amado, C.S. Jones, and J. Arnold, 2019. "Quantifying the Contribution of Tile Drainage to Basin-Scale Water Yield Using Analytical and Numerical Models," *Science of the Total Environment*, 657:297-309.

Streeter, M.T., K.E. Schilling, M. St. Clair, and Z. Demanett, 2019. "Soil Sedimentation and Quality Within the Roadside Ditches of an Agricultural Watershed," *Science of the Total Environment*, 657:1432-1440.

Streeter, M.T. and Schilling, K.E., 2019. "Assessing and Mitigating the Effects of Agricultural Soil Erosion on Roadside Ditches," *Journal of Soils and Sediments*, 1-11.

Tassier-Surine, S., P. Kerr, R.J. Clark, and **H. Liu**, 2019. Surficial Geologic Map of the Mount Pleasant 7.5' Quadrangle, Henry County, Iowa: Iowa Geological Survey, Open File Map OFM-19-2, 1:24,000 scale map sheet.

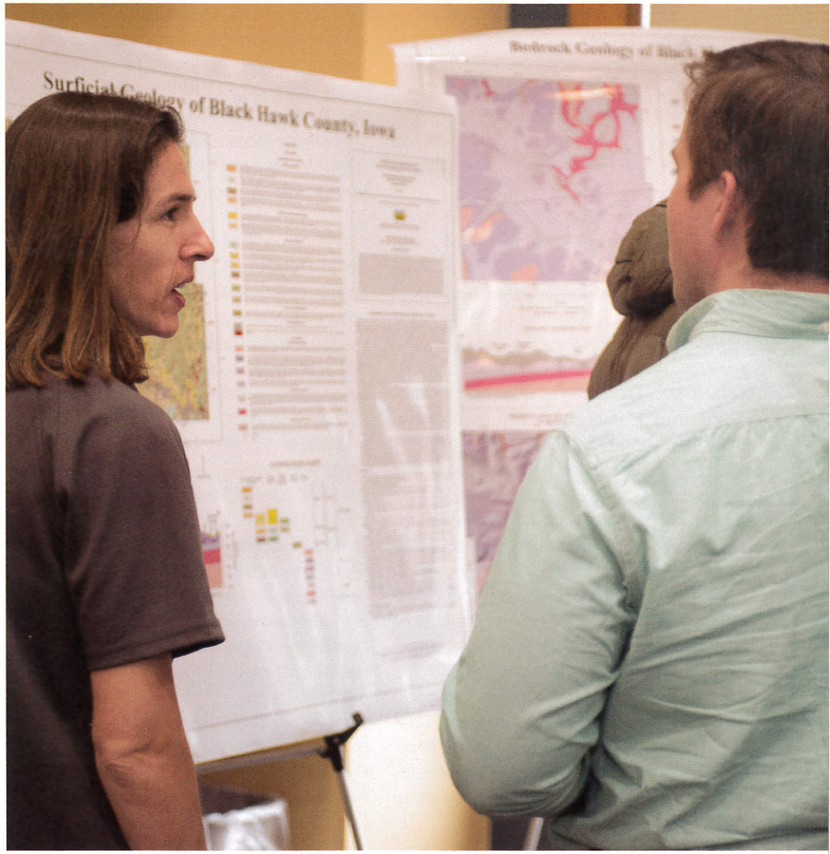
Tassier-Surine, S., P. Kerr, R.J. Clark, and **H. Liu**, 2019. Surficial Geologic Map of the Salem 7.5' Quadrangle, Henry and Lee Counties, Iowa: Iowa Geological Survey, Open File Map OFM-19-4, 1:24,000 scale map sheet.

Thomas, W.A., G.E. Gehrels, K.E. Sundell, S.F. Greb, E.S. Finzel, **R.J. Clark**, D.H. Malone, B.A. Hampton, and M.C. Romero, 2019. "Detrital Zircons and Sediment Dispersal in the Eastern Midcontinent of North America," *Geosphere*, in press.

Tomer, M.D., **K.E. Schilling**, and K.J. Cole, 2019. "Nitrate on a Slow Decline: Watershed Water Quality Response during Two Decades of Tallgrass Prairie Ecosystem Reconstruction in Iowa," *Journal of Environmental Quality*, 48:579-585.

Wilson, C.G., B. Abban, L.L. Keefer, K. Wacha, D. Dermisis, C. Giannopoulos, S. Zhou, A.E. Goodwell, D.K. Woo, Q.Y. Yan, M. Ghadiri, A. Stumpf, M. Pitcel, Y.F. Lin, L. Marini, B. Storsved, K. Goff, **J. Vogelgesang**, A. Dere, **K.E. Schilling**, M. Muste, N.E. Blair, B. Rhoads, A. Bettis, H. Pai, C. Kratt, C. Sladek, M. Wing, J. Selker, S. Tyler, H. Lin, P. Kumar, and A.N. Papanicolaou, 2018. "The Intensively Managed Landscape Critical Zone Observatory: A Scientific Testbed for Understanding Critical Zone Processes in Agroecosystems," *Vadose Zone Journal*, 17, 1.

Zambory, C.L., H. Ellis, C.L. Pierce, K.J. Roe, M.J. Weber, **K.E. Schilling**, and N.C. Young, 2019. "The Development of a GIS Methodology to Identify Oxbows and Former Stream Meanders from LiDAR-Derived Digital Elevation Models, *Remote Sensing*, 11, 12, doi:10.3390/rs1010012.



Selected Presentations by the IGS Staff in 2018–19

Clark, R.J., "Geology of Wildcat Den State Park," Master Conservationist Program, Sept. 6, 2018.

Clark, R.J., "Artesian Wells: How and Why They Form," Iowa Water Well Association Annual Conference and Trade Show, Jan. 31, 2019.

Clark, R.J., "The 'New' Iowa Geological Survey," Iowa Limestone Producers Association, Feb. 20, 2019.

Clark, R.J., "Everything You Need to Know about the Northeast Iowa Intrusive Complex," C.R. Daybreak Rotary Club, March 1, 2019.

Clark, R.J., "Reexamining the Osborne Core for New Insights into the Age and Petrology of the Northeast Iowa Intrusive Complex (NEIIC)," Institute on Lake Superior Geology Annual Meeting, May 9, 2019.

Gannon, J.M. "Applying Groundwater Modeling to the City of Marion Water Supply Needs," Marion Rotary Club, June 24, 2019.

Gannon, J.M. "Water Quantity Modeling for the City of Mason City-Results and Applications," City of Mason City, June 10, 2019.

Gannon, J.M. "City of Harlan Water Supply Expansion," Harlan City Council (Harlan, Iowa), June 28, 2019.

Kerr, P., "Trends in Eolian Features on the Iowan Erosion Surface," North Central Section Geological Society of America Meeting, Manhattan, Kan., March 25, 2019.

Kerr, P., "New Model for Paha Development," Cedar Valley Rock and Mineral Show, Cedar Rapids, Iowa, March 22, 2019.

Langel, R.J., "Information at Your Fingertips: The IGS' databases," Wisconsin Geologic and Natural History Survey, Nov. 13, 2018.

Schilling, K.E., "Inferring Local and Regional Hydrologic Processes from High-Frequency Water Table Monitoring," Seminar, Department of Agronomy, Iowa State University, Oct. 18, 2018.

Schilling, K.E., "Hydrological Insights from High-Frequency Nitrate Monitoring," Seminar in the Department of Earth and Environmental Sciences, University of Iowa, Feb. 6, 2019.

Schilling, K.E., "New Approaches to Solving an Old Problem — Opportunities for Innovation in Improving Water Quality," Iowa Academy of Science, Cedar Falls, Iowa, June 6, 2019.

Schilling, K.E., "Contrasting N Concentration Patterns at Two Iowa Karst Springs: Insights on Aquifer N Storage and Delivery," National Groundwater Association Agriculture and Water Quality Special Meeting, Cedar Rapids, Iowa, Oct. 1, 2018.

Schilling, K.E., "Paired Watershed Monitoring to Measure Water Quality Improvements from Conservation — Mixed Success in Iowa," Iowa Water Conference, March 12, 2019.

Schilling, K.E., "Old Till is Not Over the Hill for Groundwater Protection: Hydrogeology of Pre-Illinoian Till in Eastern Iowa," Minnesota Groundwater Association, April 24, 2019.

Schilling, K.E., "Groundwater Response Units: A New Approach to Evaluate Nonpoint Source Loading at the Watershed Scale," Iowa Groundwater Association, April 17, 2019.

Streeter, M.T., "Soil Sedimentation and Quality within the Roadside Ditches of an Agricultural Watershed," Soil Science Society of America International Soils Meeting, San Diego, Calif., Jan. 8, 2019.

Tassier-Surine, S., "Mapping the Middle Wisconsin Sheldon Creek Formation boundary in North Central Iowa," Geologic Mapping Forum, Minneapolis, Minn., April 10, 2019.

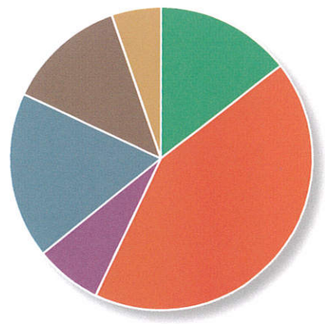
Tassier-Surine, S., "Application of Portable XRF to Stratigraphic Studies and Event Timing in Iowa Glacial Deposits," North Central Section Geological Society of America Meeting, Manhattan, Kan., March 27, 2019.

Vogelgesang, J.A., "Using Field Data to Characterize and Monitor Groundwater Beneath Row Crops," Agribusiness Showcase and Conference's Summer Workshop and Field Day, Cedar Rapids, Iowa, August 1, 2018.

Financials

THE IOWA GEOLOGICAL SURVEY (IGS) is dedicated to serving Iowans. The IGS had a diverse portfolio of projects from a variety of funding sources in 2018–19, including municipalities, U.S. Geological Survey, and Iowa Nutrient Research Center, among others. State appropriations fund about 40% of our annual operating budget, and we continue to leverage funding from other sources to supplement this. Along with pursuing new funded projects, an increase in our annual state appropriations would allow the IGS to focus on regional statewide initiatives to help ensure sustainable water resources for Iowans and provide science-based information to support well drillers, government officials, and individuals. As always, the IGS remains willing to collaborate with new and existing clients on exciting, impactful projects.

FY 2019



Municipal: City water supply projects

State Appropr.: Funded through DNR prior to FY2019

INRC: Iowa Nutrient Research Center

Federal Agency: United State Geological Survey, Natural Resources Conservation Service

Other: Non-Government contracts, IDOT, IDALS

Unsupported

Selected FY19 Projects by the IGS Staff

Assessing the Effectiveness of ATIs in Three Representative Regions of Iowa: *Keith Schilling:* U.S. Department of Agriculture, Natural Resources Conservation Service

Baseline Assessment of Geisler Farm Site: Collection of Pre-BMP Monitoring Data: *Keith Schilling:* Iowa Nutrient Research Center (INRC)

Connecting the Iowa Geological Survey's Iowa Water-Level Network Wells with the National Ground-Water Monitoring Network: *Richard Langel:* United States Geological Survey (USGS)

Developing Areas and Impaired Watershed Mapping in Southeast Iowa: Bedrock and Surficial Geologic Maps of the Mount Pleasant and Salem Quadrangles: *Stephanie Tassier-Surine:* USGS

Development of a Local-Scale Groundwater Modeling Tool for the Management and Optimization of the Fort Dodge Jordan Wellfield(s): *Mike Gannon:* City of Fort Dodge

Development of a Local-Scale Groundwater Modeling Tool for the Management and Optimization of Koch Nitrogen's Water Supply: *Mike Gannon:* Koch Fertilizer, LLC

Development of a Local-Scale Groundwater Modeling Tool for the Management and Optimization of Mason City's Water Supply: *Mike Gannon:* City of Mason City

Geologic Hazards Mapping: Identifying Sinkholes and Karst Susceptible Areas in Worth, Cerro Gordo, Mitchell, and Floyd Counties: *Stephanie Tassier-Surine:* Iowa Department of Transportation (IDOT)

Geophysical, Drilling, and Evaluation Services near Durango, Iowa: *Jason Vogelgesang:* IDOT

Geophysical, Drilling, and Evaluation Services near Mason City, Iowa: *Jason Vogelgesang:* IDOT

Hydraulic Testing of NGWMN Wells by the Iowa Geological Survey: *Richard Langel:* USGS

Impaired Watershed Mapping in Benton County, Iowa: Bedrock and Surficial Geologic Maps of the Vinton and Center Point NW Quadrangles: *Stephanie Tassier-Surine:* USGS

IGS Analytical Database: Geologic Lab Results at Your Fingertips: *Jason Vogelgesang and Richard Langel:* USGS

Quantifying the Effects of BMPs on Sediment and Phosphorus Delivery to a Range of Eastern Iowa Rivers: *Keith Schilling:* INRC

Quantifying the Effectiveness of a Saturated Buffer to Reduce Tile Nitrate Levels in Eastern Iowa: *Keith Schilling:* Iowa Department of Agriculture & Land Stewardship

Seismic Monitoring Services at the NNG Redfield Facility: *Jason Vogelgesang:* Northern Natural Gas

Silurian Aquifer Groundwater Exploration and Modeling for the City of Fairfax: *Jason Vogelgesang:* Hall & Hall Engineers, Inc.

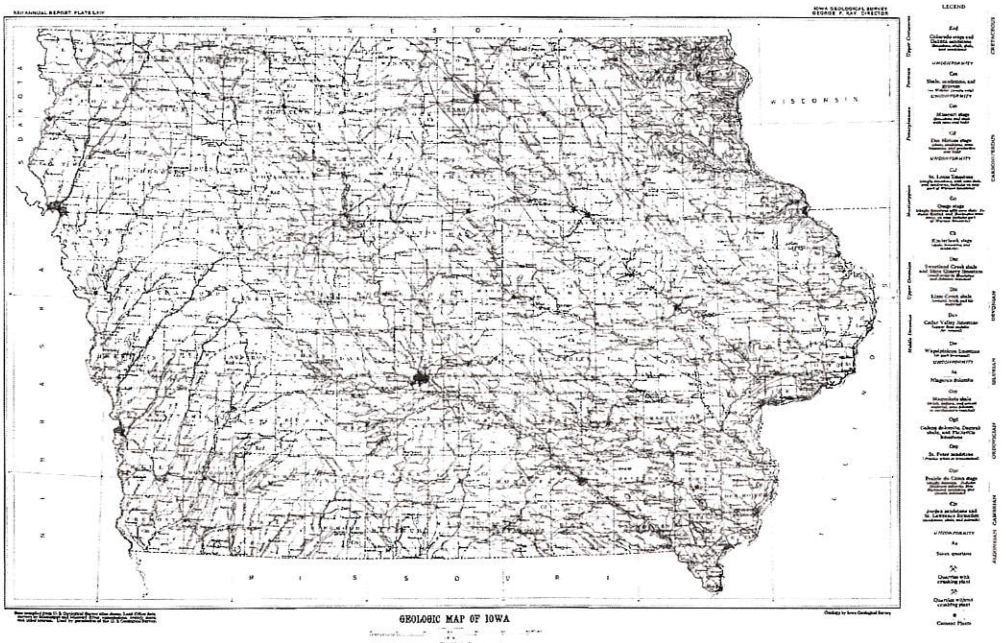
Total PhosphorusLoads in Iowa Rivers and Estimation of Steam Bank Phosphorus Contribution: *Keith Schilling:* INRC

Water Resource Evaluation and Exploration Effort along the West Nishnabotna River: *Mike Gannon:* Harlan Municipal Utilities

Wellfield Geophysical Investigations near Hospers, Iowa: *Jason Vogelgesang:* Rural Water System #1

	FY2015	FY 2016	FY2017	FY2018	FY2019
Municipal	$41,221	$148,435	$77,433	$212,803	$236,600
State Appropr.	$882,660	$793,640	$797,097	$707,445	$695,000
INRC	$54,956	$12,614	$80,191	$127,563	$116,943
Federal Agency	$243,701	$215,859	$193,857	$282,855	$290,354
Other	$43,253	$95,932	$76,927	$50,699	$208,421
Unsupported	$90,210	$73,835	$168,587	$69,362	$86,215
	$1,356,001	**$1,340,314**	**$1,394,092**	**$1,450,727**	**$1,633,533**

Geologic Mapping Through the Years



1914 GEOLOGIC MAP

Director: George F. Kay

Interesting fact: Most unit names still used in modern stratigraphy

RIGHT: 1937 GEOLOGIC MAP

State Geologist: Arthur C. Trowbridge

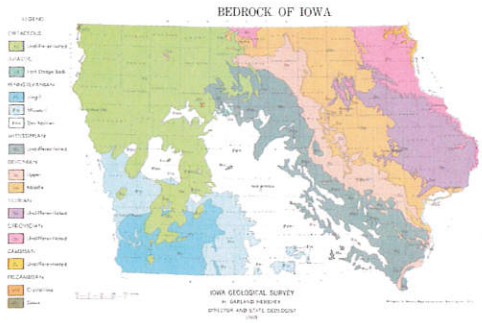
Author: Allen C. Tester

Interesting fact: Gypsum deposits near Fort Dodge mapped as "Permian" (but actually Jurassic)

FAR RIGHT: 1969 MAP

State Geologist: H. Garland Hershey

Interesting fact: Includes "Manson Anomaly," which was not yet recognized as an impact structure

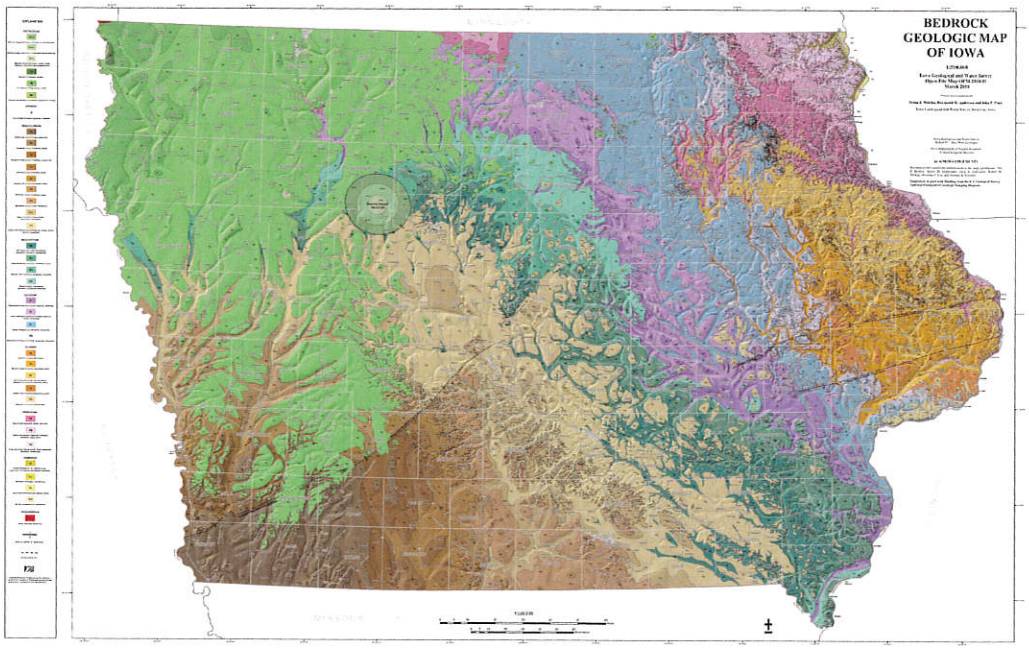


2010 BEDROCK GEOLOGIC MAP OF IOWA

State Geologist: Robert D. Libra

Authors: Brian J. Witzke, Raymond R. Anderson, and John P. Pope

Interesting fact: Has over 3,501 separate unit polygons



IGS

IIHR Hydroscience & Engineering

The University of Iowa