BOARD OF REGENTS
Governing Iowa's Public Universities

December 18, 2024

The Honorable Kim Reynolds
State Capitol
1007 East Grand Ave.
Des Moines, IA 50319

Mr. Charlie Smithson
Secretary of the Senate
State Capitol Building
Des Moines, IA 50319

Ms. Meghan Nelson
Chief Clerk of the House
State Capitol Building
Des Moines, IA 50319

Re: State Geologist Annual Report

Dear Governor Reynolds and Members of the Iowa General Assembly:

Pursuant to the 2022 Iowa Code §456.7, 2022 House File 2463 §108; 2022 Iowa Acts Ch. 1032 §108, enclosed is the State Geologist Annual Report for 2023-2024.

If you have any questions or need more information, please don't hesitate to contact me.

Sincerely,

Mark J. Braun

\Box Sync\Board of Regents Shared\BF\Legislative\2025 session\Reports\

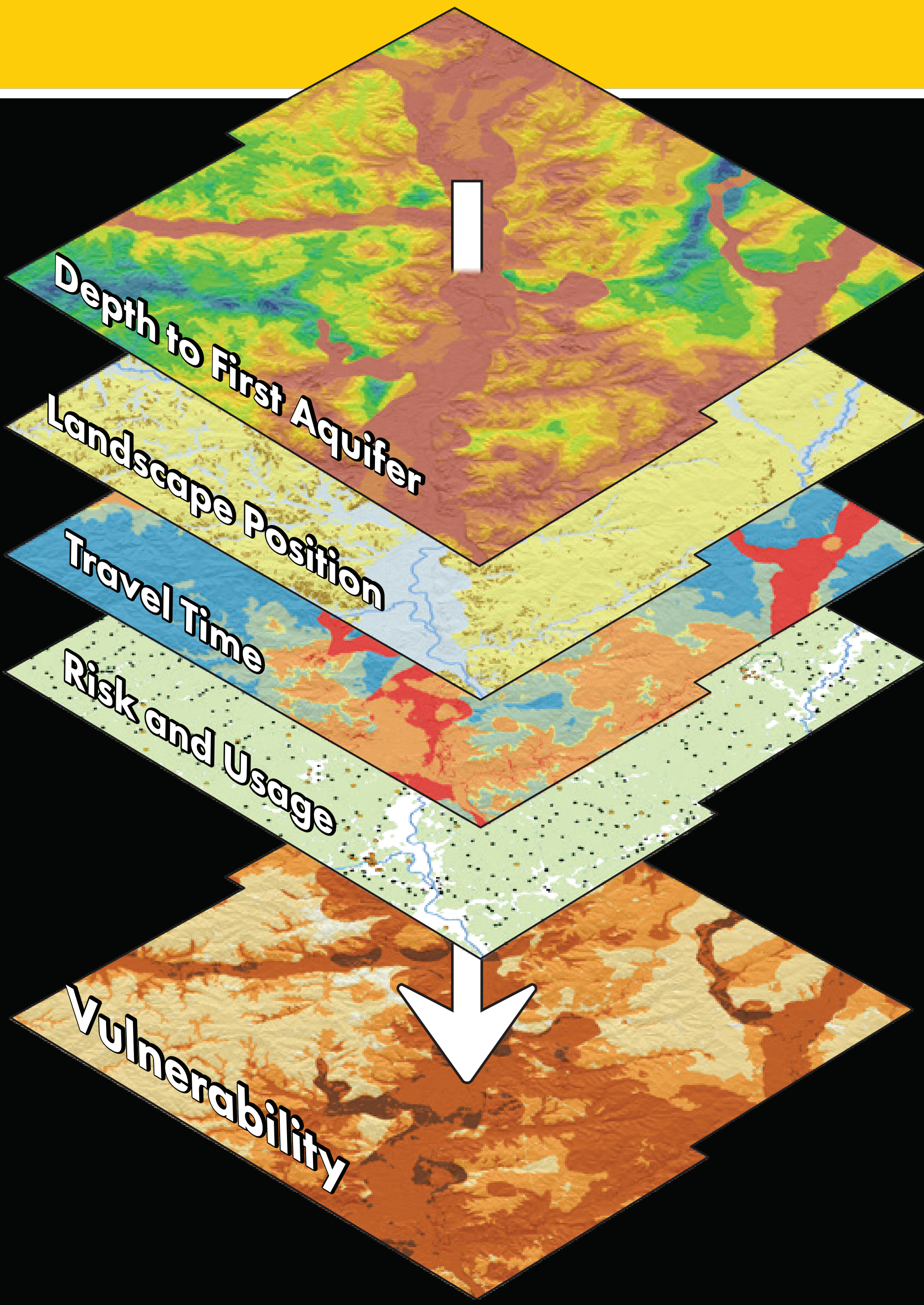
Attachments

cc: Legislative Liaisons
Legislative Log

IOWA

The IGS Geode

ACTIVITIES OF THE IOWA GEOLOGICAL SURVEY, 2023–24



Aquifer Vulnerability Mapping

PAGE 16

The IGS Geode

Activities of the
Iowa Geological Survey
2023–24

ON THE COVER: The factors used to develop the "Vulnerability Rank of the First Encountered Aquifer in Black Hawk County, Iowa" derivative map produced as part of the IGS's U.S. Geological Survey STATEMAP Program this past year.

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.

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From the State Geologist

While every year has its ups and downs, it is nice to be able to say that the 2023-2024 year that we are reporting on in this edition of *The IGS Geode* was dominated by "ups". From new legislative funding, to hiring new staff, and leading with new projects and initiatives, the past year will be one to remember.

As we all experienced, Iowa was mired in a multi-year drought that thankfully broke in the spring and summer of this year. During the latter stages of the drought, concerns were being raised that increasing water demands for agricultural irrigation and animal production, new data centers and ethanol plants, urban lawns, and other uses were challenging both urban and rural water systems to keep groundwater supplies on pace with demand. In December 2024, the *Des Moines Register* published a large, above-the-fold article on Iowa's preparations for water shortages, and I had a companion editorial recommending that Iowa develop a plan for safeguarding its precious groundwater supplies.

In January 2024, I had the opportunity to speak to two House committees of the Iowa Legislature about the need for the state to fund the research, mapping, and analyses needed to assess Iowa's aquifers and for the development of sustainable groundwater budgets. While the reception at the committee level was extremely positive, you never know what might happen during legislative session. As it turned out, near the final days of the session, the IGS was appropriated new funding of $250,000 to map and assess the conditions of the state's aquifers. While the new funding technically begins in the next fiscal year (work efforts will be reported in next year's *Geode*), we celebrate the conversations and

THE IGS TEAM, SUMMER 2024: (bottom row, left-to-right) Rosemary Tiwari, Elliot Anderson, Jack Malone, Joe Honings, Tom Stoeffler; (middle row, left-to-right) Jason Vogelgesang, Rick Langel, Phil Kerr, Thomas Doyle; (top row, left-to-right) Keith Schilling, Calvin Wolter, Ryan Clark, Greg Brennan, and Alyssa Bancroft. Staff not present for this photograph include Stephanie Tassier-Surine, Matthew Streeter, and Valerie Diaz-Gibertini.

legislative support that have occurred to make this new appropriation happen.

As a result, internal IGS discussions unfolded over the summer, and we decided to “hit the ground running” and utilize the new funding to expand upon recent IGS groundwater work at the local community level to map and assess the groundwater supplies across the entire Iowa River alluvial valley from Marshalltown to Iowa City. This focus is allowing us to capitalize on ongoing projects as we develop methodologies and approaches for use in future groundwater assessments. IGS hydrogeologist **Greg Brennan** was tapped to lead this mapping effort. In addition, the new funding combined with ongoing support for the levee mapping project allowed us to hire **Thomas Doyle** as a new IGS hydrogeologist. Thomas comes to us from the City of Marion where he was a stormwater coordinator but, more importantly, his Iowa-hydro pedigree is assured with degrees from both Iowa State University and the University of Iowa.

Another new IGS staff position was filled by **Elliot Anderson**. Elliot worked for the IGS as a post-doctoral scholar the past two years, but in the spring, he was promoted to assistant research scientist. Elliot jumped into the IGS with funding from Polk County to assist with a comprehensive source water study and continues to work on a variety of water projects funded in part by the Iowa Nutrient Research Center (INRC). Elliot highlights recent INRC work with a focus on Iowa reservoirs in *The Geode*.

We’ve highlighted some of the work done this past year, and you’ll again be impressed by the scope and proficiency demonstrated by IGS staff. Among the articles, **Ryan Clark** describes new hydrogen exploration in Iowa, **Phil Kerr** and **Stephanie Tassier-Surine** report on unique surficial geology mapping projects, **Jack Malone** reports on a new mine waste mapping project in Dubuque, **Calvin Wolter** showcases new mapping of streambank erosion, and **Jason Vogelgesang** provides an update on the levee mapping project. **Matthew Streeter** and **Rick Langel** focus on increasing IGS productivity with updates on IGS labs and data handling, and I even get in the game this year with articles focused on prairie pothole hydrology and mapping aquifer vulnerability.

As a final note on this past year, I would like to draw attention to an event we held in September 2024 that should technically be in next year’s issue. However, it has been a long while since the IGS hosted an official field trip for the public, so I wanted to focus our spotlight on this event since it is fresh in our minds and points to a bright IGS future. Phil Kerr and I, along with contributions from several IGS staff, hosted folks on a field tour of the Lower Cedar River Valley in Muscatine County where we investigated the landform history of the region and discussed the implications for groundwater supply. The event was a great success, and it demonstrated the passion for Iowa geology by everyone involved, from IGS staff to the public. Funded, in part, by the IGS Foundation Account, we hope to, again, make field trips an integral part of our outreach efforts in the future.

With added new funding by the Iowa Legislature, the IGS will continue to work on behalf of all Iowans to better understand and assess Iowa’s geologic and groundwater resources. Lots of work remains to be done in the state and the IGS remains committed to making sure that sustainable water, soil, and mineral resources are available for Iowa’s future generations.

Keith Schilling

KEITH E. SCHILLING, PhD
State Geologist and Director

Recap: Year One of the Levee Surveying Program

JASON VOGELGESANG

RECENT FLOODING EVENTS in Iowa have cost billions of dollars in damages and lost economic activity. As a result, assessing the condition of the state's levees is vital for ensuring that these structures remain steadfast during floods. To this end, the IGS has embarked upon a five-year directive to survey all of Iowa's levees in partnership with the newly created Office of Levee Safety, within the Iowa Department of Homeland Security and Emergency Management (HSEMD). Geophysical imaging is a non-destructive, efficient, and thorough way to assess levee integrity, especially for areas of these structures that just cannot be seen by the naked eye. These data help determine the condition of each of Iowa's levees, helping focus remediation efforts and direct new funding to those systems in need of repair. Furthermore, this methodology has the potential to help fine-tune repair efforts — instead of overhauling an entire levee system, only the anomalous (potentially problematic or weak) area(s) become the focus, saving on both costs and labor down the line.

To survey Iowa's levees, the IGS is using electromagnetic terrain conductivity (EM) imaging, which is an effective way to measure the conductivity of the subsurface. To fully survey a levee system (**Figure 1**), the IGS: 1) collects EM data along the top and toe slope of the levee; 2) follows up with electrical resistivity (ER) tomography surveying in areas flagged as 'anomalous'; and 3) creates a map depicting an(y) anomaly(ies), such as regions along the levee that are facilitating water flow rather than inhibiting it. Anomalies discovered by geophysical imaging can inform levee managers of where porous materials, voids, or areas susceptible to underflow might reside within the system. The final map and results are followed up with an engineering assessment and the levee authority to determine if and/or what preventive action(s) should be taken in each area.

Iowa has nearly 900 miles of levees protecting its towns, agricultural land, and critical infrastructure. Based on information listed in the National Levee Database, a publicly-accessible online database managed by the U.S. Army Corps of Engineers (USACE), approximately 100 miles of levees were surveyed by the IGS in Year One of this project (**Figures 2 and 3**). A total of 25 levee segments representing 11 systems were assessed, and these were split between geographic areas of Iowa in both urban and rural settings. Surveying completed during Year One of this effort has allowed the IGS to develop protocols, refine mapping and analysis procedures, and troubleshoot the levee mapping process. With these aspects of the levee surveying program now fine-tuned, our attention turns to Year Two, during which approximately 200 more miles of Iowa's levees will be surveyed.

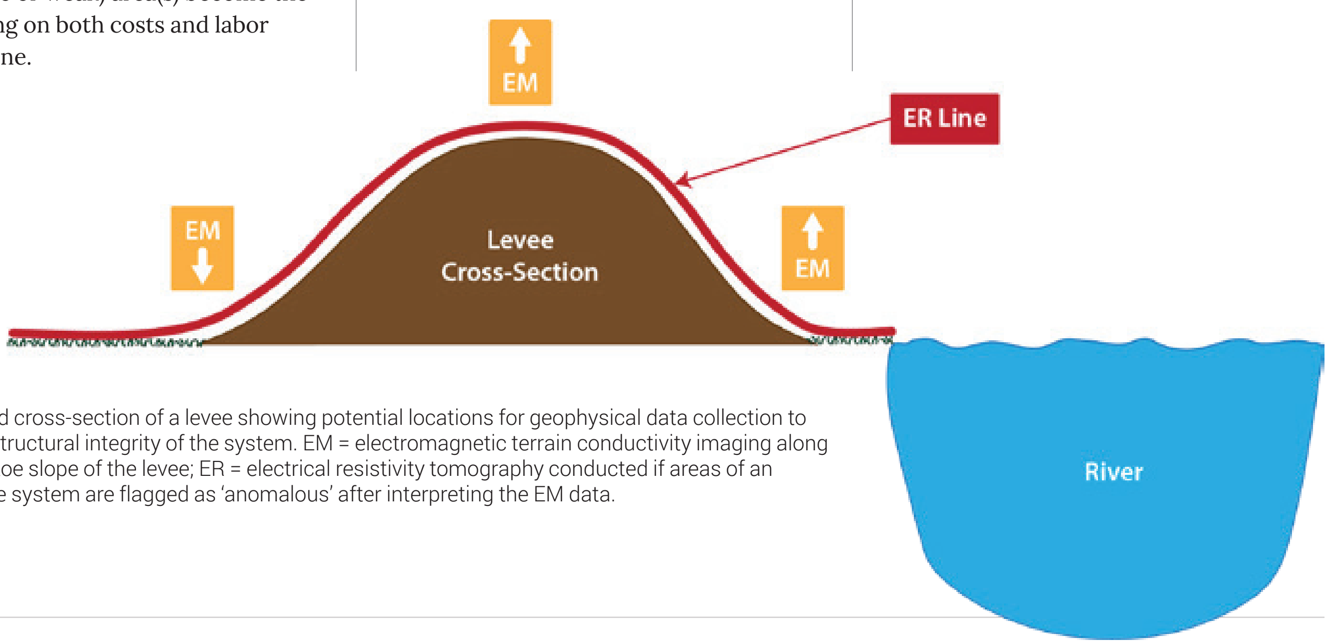


FIGURE 1.
A generalized cross-section of a levee showing potential locations for geophysical data collection to assess the structural integrity of the system. EM = electromagnetic terrain conductivity imaging along the top and toe slope of the levee; ER = electrical resistivity tomography conducted if areas of an imaged levee system are flagged as 'anomalous' after interpreting the EM data.

FIGURE 2.

FIGURE 3.

FIGURE 2.
Collecting an electromagnetic terrain conductivity survey (EM) along the top of a levee near downtown Des Moines, Iowa.

FIGURE 3.
Collecting an electromagnetic terrain conductivity survey (EM) along the top of a levee near Hamburg, Iowa.

IGS Sediment Lab Updates

MATTHEW STREETER AND MARTY ST. CLAIR

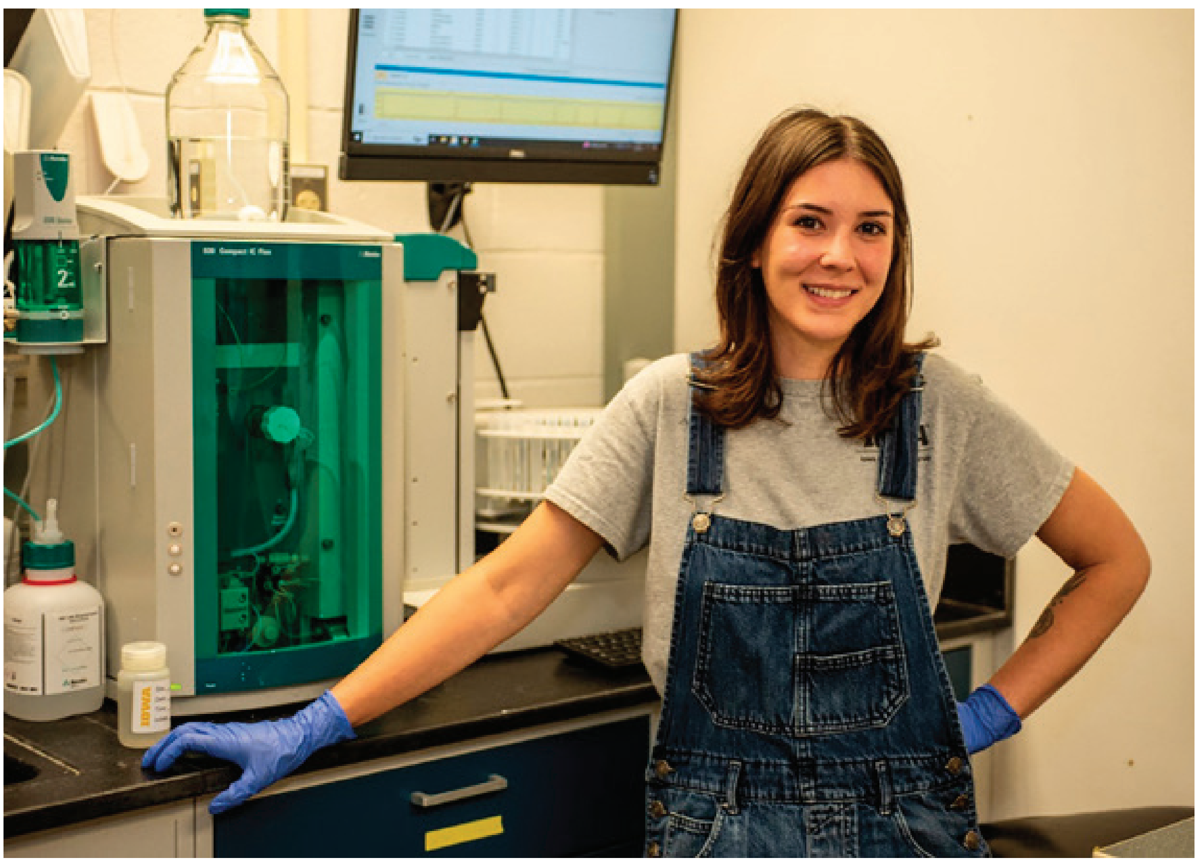
THE IGS SEDIMENT LABORATORY is a fully functioning Quaternary materials lab managed by IGS soil scientist Matthew Streeter. This facility was established in 2014 and is housed at the IGS Oakdale facility. The lab is operated primarily for research and yet undergraduate and graduate students often have opportunities to work in the lab alongside IGS researchers to gain real-world experience outside of the traditional classroom setting.

The lab has the capacity to perform a broad spectrum of analyses, including soil particle size analysis (pipette and x-ray absorption), sand fractionation, soil elemental analyses including 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 devices, water-quality meters, and the IGS's drill rig.

This past year, the lab acquired a new Metrohm Compact Ion Chromatograph (Metrohm IC), and it has already become a mainstay of our operations (**Figure 1**). The instrument is primarily used for analysis of anions and is equipped with an Autosampler Plus with ultrafiltration. The Metrohm IC has a double suppression design, which allows for detection of orthophosphate down to 0.05 mg/L while simultaneously measuring chloride, nitrate, sulfate, and other anions. The autosampler has a capacity of 56 samples and filters every sample prior to injecting it into the chromatograph. The IGS is using the Metrohm IC for analysis of surface waters, ground water, and tile drainage from installations of nutrient reduction practices.

Since its installation in February 2024, the instrument has been used to analyze more than 2,000 samples. Not only has the Metrohm IC been used on a variety of IGS projects, IIHR research scientist Marty St. Clair, working with the Center for Health Effects of Environmental Contamination (CHEEC) has been using it to analyze samples from several watershed management authorities (WMAs), in support of their nutrient reduction efforts.

FIGURE 1. IGS research assistant Valerie Diaz-Gibertini operating the newly acquired Metrohm Compact Ion Chromatograph.



Iowa's Ongoing Contributions to a National Geologic Map Using GeMS

RICK LANGEL

GEOLOGIC MAPS PROVIDE critical information that supports resource management, hazards resilience, infrastructure design, and research to address the changing needs of our society. In partnership with the Association of American State Geologists (AASG) and as mandated by the National Geologic Mapping Act of 1992, the National Cooperative Geologic Mapping Program (NCGMP) was established within the U.S. Geological Survey (USGS). The NCGMP's vision, as outlined in the 2018-2027 Decadal Strategic Plan, is to produce an integrated, three-dimensional, digital geologic map of the United States and its territories by the year 2030.

To accomplish this goal, the data from geologic maps across the country that have been produced by hundreds of authors representing federal, state, and academic interests must all be integrated, which presents a myriad of challenges. The NCGMP developed the Geologic Map Schema (GeMS), a database design, to establish consistency in the digital publication of geologic maps and to aid in the creation of a national archive of standardized geologic map content. GeMS requires submitting a minimum of six database elements that store the information depicted on a geological map, for example, stratigraphic units and the contacts between those units. More elements can be added as necessary to store information for more complex map products.

The Iowa Geological Survey (IGS) has been an active participant in working towards the NCGMP's goal of creating a national geological map. Funding assistance from the USGS National Geological and Geophysical Data Preservation Program (NGGDPP) and the USGS STATEMAP Program have allowed the IGS to develop the tools, techniques, and processes necessary for creating GeMS-compliant geologic map databases. To date, eleven bedrock (**Figure 1**) and eight surficial geological maps have been converted to GeMS map databases.

The conversion of each map poses its own unique challenges. Overlapping geologic units or gaps between geologic units are discovered and need to be corrected on many of the maps. Locating all of the data represented on historical geologic maps produced by the IGS requires time and patience as many maps were created years ago by staff who have since retired. Some maps contain erroneous data that are corrected during the creation of a GeMS map database. Despite the various challenges presented when bringing a new map into GeMS-compliance, these maps are now ready for compilation with other GeMS-compliant maps around the country.

Submission of GeMS map databases is a requirement for all new USGS STATEMAP mapping projects. Historical IGS geologic maps will also be converted to GeMS map databases as part of future projects.

→ **ALL GEMS MAP DATABASES ARE AVAILABLE TO THE PUBLIC EITHER BY CONTACTING THE IGS DIRECTLY OR BY DOWNLOADING THEM FROM THE NATIONAL GEOLOGIC MAP DATABASE (HTTPS://NGMDB.USGS.GOV/).**

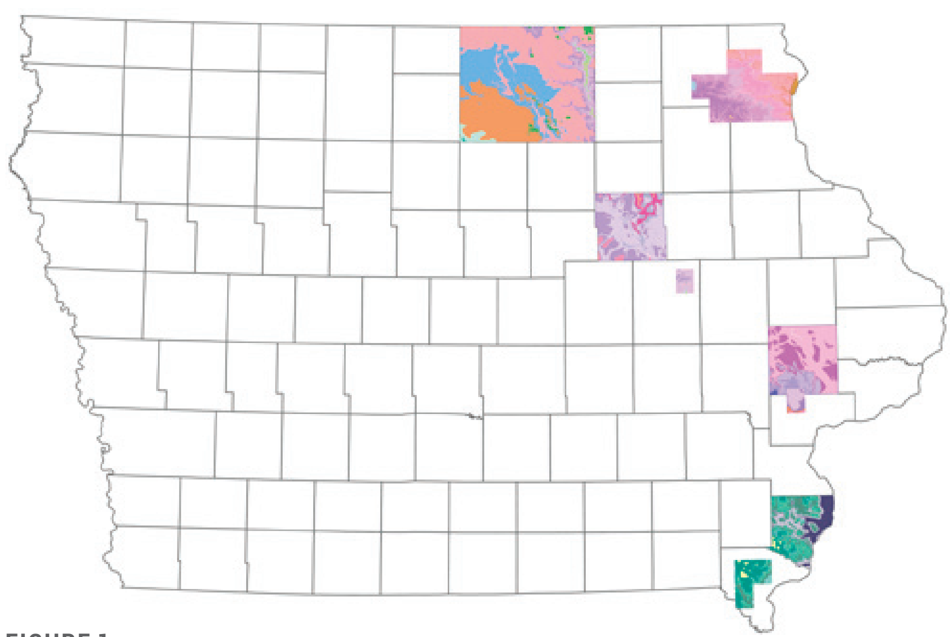


FIGURE 1.
Location of bedrock geologic map products the IGS has completed with funding from the USGS NGGDPP and the USGS STATEMAP programs that are now compliant with the NCGMP Geologic Mapping Schema (GeMS).

Is There Hydrogen in Iowa's Subsurface?

RYAN CLARK

WITH AN EVER-INCREASING DEMAND FOR CLEAN, CARBON-FREE ENERGY RESOURCES, THE SEARCH FOR HYDROGEN IS RACING TO THE FRONT OF THE PACK.

HYDROGEN IS THE FIRST ELEMENT on the periodic table. It is the simplest, lightest, and most abundant element in the Universe, but hydrogen rarely exists in its pure form, as a gas, on Earth. With an ever-increasing demand for clean, carbon-free energy resources, the search for hydrogen is racing to the front of the pack. The primary way to harness hydrogen as an energy source is by using a fuel cell where it is combined with oxygen to produce electricity while exhausting water. There are a variety of ways to produce economic quantities of hydrogen, and a color scheme has become the standard metric to identify each type (**Figure 1**). Although more colors seem to be added to the hydrogen production classification each year, the three primary types are gray, blue, and green. Gray is by far the most common source, accounting for more than 90% of current hydrogen production. The caveat with gray hydrogen is that it also contributes to carbon emissions. However, white hydrogen, which occurs naturally, has the potential to make a significant impact on the global market and play an important role in a clean energy future — we just need to find it!

Not all rocks can generate hydrogen. The best candidates are mafic igneous rocks that contain the mineral olivine, an iron-magnesium silicate [(Mg, Fe)$_2$SiO$_4$]. Olivine typically occurs in igneous rocks that crystallized from molten magma deep underground. When groundwater (H_2O) interacts with olivine-rich rocks, a chemical reaction causes the iron to bond with the oxygen (O) in the water, thereby releasing hydrogen (H_2) gas. Ideally, in the right geologic conditions, the hydrogen becomes trapped underground and accumulates in large quantities. However, because hydrogen molecules are so small, it could be exceedingly difficult to find a geologic setting in which there is an overlying rock formation tight enough to trap and seal a large pocket of hydrogen. Alternatively, researchers have proposed that injecting hot water into suitable mafic igneous rock formations could potentially stimulate hydrogen production.

The U.S. Geological Survey (USGS) has identified two major regions of the country where large volumes of mafic igneous rocks occur, off the eastern coast and right here in the Upper Midwest. The Midcontinent Rift System (MRS) formed about 1.1 billion years ago when the North American continent *almost* ripped in half. During the rifting stage, enormous volumes of magma erupted as basaltic (mafic) lava flows filling the rift valley. The central axis of the MRS, where thick accumulations of ancient basalt currently reside, is the most prospective region to explore for natural (or white) hydrogen (**Figure 2**).

In the 1960s, geologists discovered a "dome-like" structure within sedimentary rocks (sandstones, limestones, and shales) overlying uplifted MRS basalts near the town of Vincent, Iowa in northeastern Webster County. Dozens of deep holes were drilled in the area to characterize the structure for potential injection and storage of natural gas underground. Ultimately the "Vincent Dome" was not approved for commercial natural gas storage and the project was abandoned. However, two of the characterization wells drilled through the Vincent Dome and into MRS basalts reportedly showed elevated hydrogen (one well had 34% and another had 96%).

Hydrogen exploration has already begun in Iowa, and one exploration well was drilled in the Vincent Dome area in November 2022. If a natural accumulation of hydrogen is discovered and/or if suitable geologic conditions for hydrogen generation are found, the vast breadth of the MRS could slingshot Iowa into a new era of clean energy production.

Types of Hydrogen

GRAY: Produced from burning fossil fuels, which emits CO_2.

BLUE: Also made from fossil fuels, but the CO_2 is captured.

GREEN: Uses renewable energy to split water via electrolysis.

WHITE: Natural hydrogen from geologic rock formations.

FIGURE 1.

FIGURE 1.
Classification scheme for the different types of hydrogen production/generation.

FIGURE 2.
Extent of the Midcontinent Rift System (MRS) in Iowa. Central axis volcanics (i.e., basalt) are in purple, flanking sedimentary basins are in green, and the red star marks the location of a recent hydrogen exploration well. Inset map depicts the extent of the MRS in the Upper Midwest (Source: USGS).

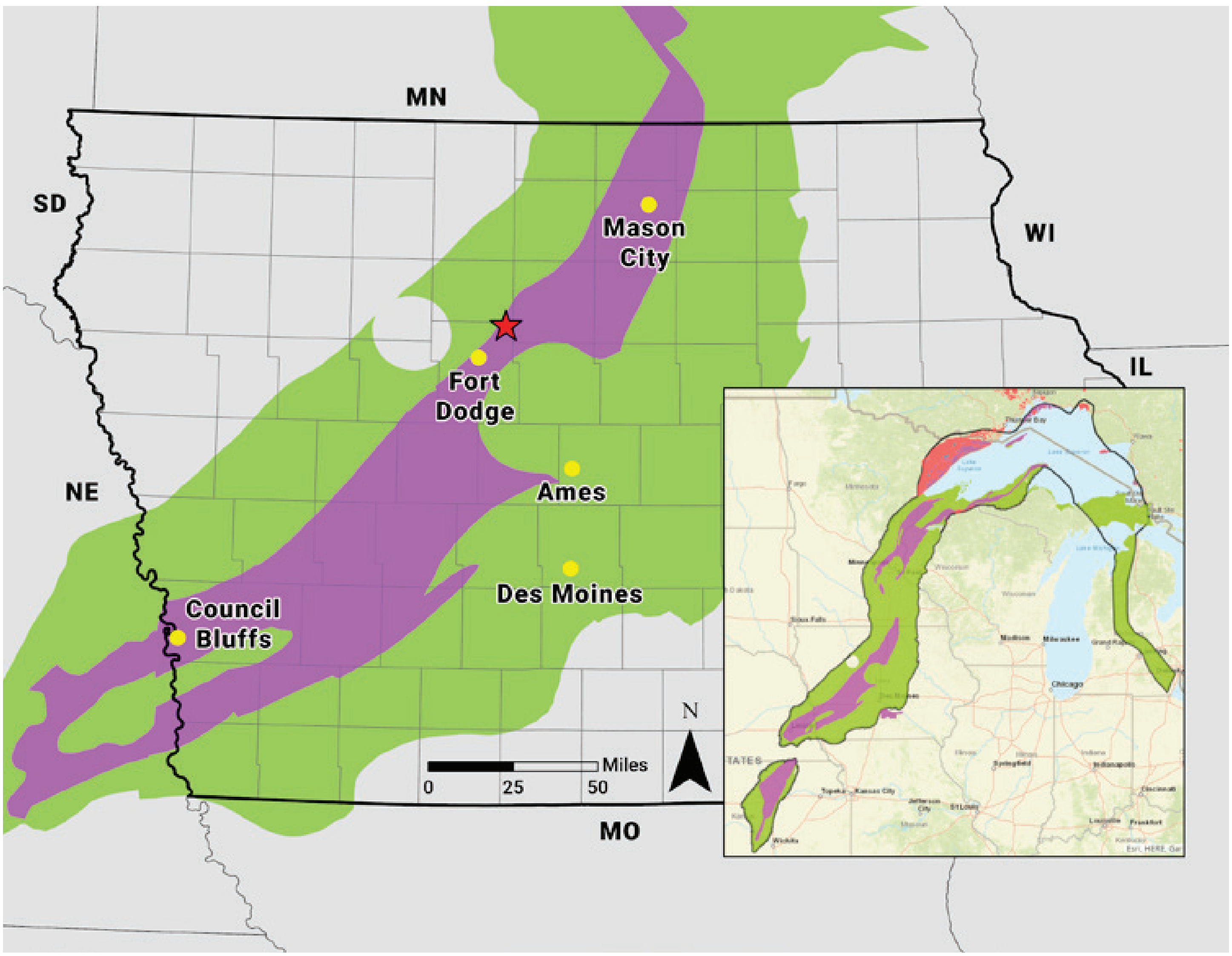


FIGURE 2.

Using LiDAR-based DEMs to Estimate Stream Bank Erosion

CALVIN WOLTER

SEDIMENT IS CONSIDERED the number one pollutant in Iowa rivers, yet little is known about the relative magnitude of sediment sources. Sheet and rill erosion from uplands and stream bank and gully erosion typically dominate sediment sources. Watershed studies provide a range of annual contribution from sheet and rill erosion ranging from 30% to 70%, with the remaining contribution range assumed to be bank erosion. There are some models to estimate bank erosion contributions, but they typically apply only to short river segments and not to an entire stream network.

High-resolution topographic data using Light Detection and Ranging (LiDAR) technology is revolutionizing the capacity to detect sediment erosion in watersheds. LiDAR uses an airborne laser to accurately measure the elevation of the Earth's surface at a high resolution, typically 1 m^2 or smaller. The State of Iowa has LiDAR topographic data available for the entire state for two time periods spaced about one decade apart (2007-2010 and 2020), and the difference in elevation of the land surface between these two periods can be used to estimate sediment losses in a watershed.

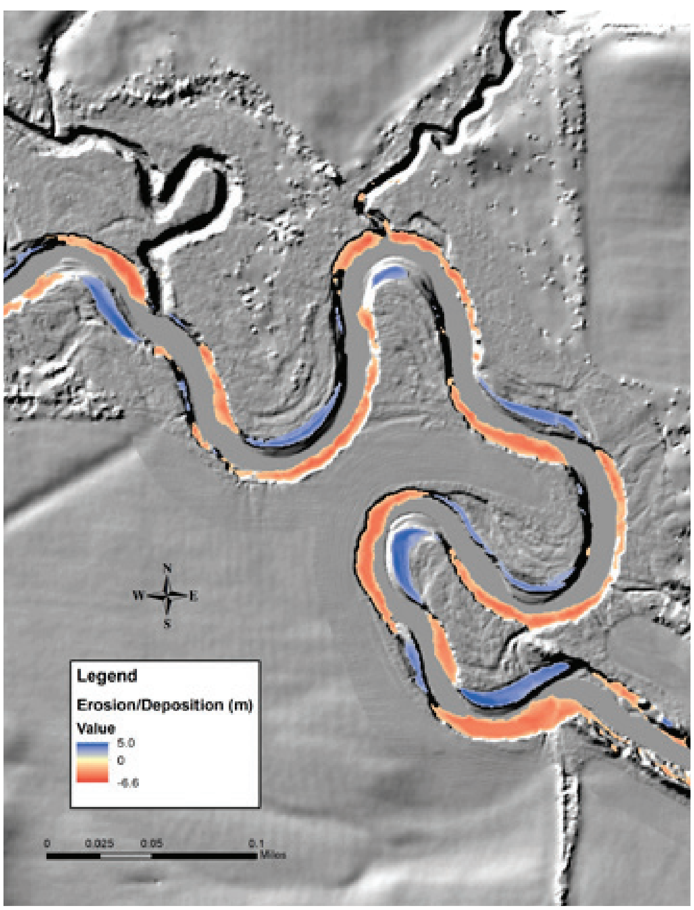


FIGURE 1. Segment of Old Mans Creek highlighting where bank erosion (red) and deposition (blue) occurred between 2009 and 2020.

Digital elevation models (DEMs) created from the raw LiDAR data provide a continuous surface of elevation that can be analyzed in a geographic information system (GIS). We recently used a GIS technique called Geomorphic Change Detection (GCD) to perform a difference calculation between these two DEMs. An important feature of the difference calculation is that the method not only identifies areas that have eroded but also areas where sediments have been deposited. In a watershed or along a river corridor, the amount of sediment eroded or deposited can be added together to determine the net difference.

The GCD technique was recently used to evaluate net streambank erosion along Old Mans Creek located just south of Iowa City in southeast Iowa. An important benefit of using the GCD technique is that areas of erosion and deposition can be mapped. The reach of Old Mans Creek depicted in **Figure 1** is very meandered and shows areas of erosion on the outside of meander bends (red) and areas of deposition on the inside of meander bends (blue). The results showed a net erosion of ~570,000 m^3 of sediment from streambanks for the 11-year period. To put this number in context, the total sediment load exported from Old Mans Creek estimated using monitoring data was ~774,000 m^3. This suggests that over the 11-year period, streambank erosion contributed ~74% of the total sediment load from Old Mans Creek. Based on the success and utility of doing the analysis on Old Mans Creek, we will be applying this methodology to assess stream bank erosion in other areas of the state.

Groundwater Flow in the Iowa Great Lakes Area

KEITH SCHILLING, STATE GEOLOGIST AND DIRECTOR

THE IOWA GREAT LAKES (IGL) region is one of Iowa's premier tourist destinations – it consists of a group of seven natural lakes in northwestern Iowa, including West Okoboji, East Okoboji, and Big Spirit lakes. The IGS is working with the Iowa Department of Natural Resources on a diagnostic study of the IGL area to evaluate the sources and pathways of nutrients into the lakes from land surface runoff and groundwater seepage.

Unraveling groundwater flow patterns in complex glaciated terrain is difficult, and in an area as large as the IGL watershed (~25,000 hectares), the challenge is even greater. To overcome this, the IGS first investigated groundwater flow patterns within a small wetland complex located east of East Okoboji Lake – Spring Run. This much smaller area (~130 hectares) is comprised of lake, marsh (wetland), and upland areas and was the ideal microcosm to begin to delineate local hydrogeology and groundwater flow pathways. Understanding the surficial hydrology of the Spring Run Wetland Complex will allow for the extrapolation of groundwater flow conditions throughout the entire IGL basin.

Over a two-year period (2022-2023), the IGS evaluated the hydrogeology and groundwater flow system of the hummocky Spring Run Wetland Complex. Using a network of 16 shallow monitoring wells installed by the IGS into upland glacial till and interspersed throughout the organic-rich wetlands (**Figure 1**), we were able to determine that groundwater flow within the upland till primarily follows local topography and discharges to local wetlands under steep hydraulic gradients at the till-wetland interface. The wetland areas throughout the Spring Run Complex intercept the water table and are areas of local groundwater discharge. Once groundwater flows into the wetlands, the wetland vegetation returns much of the groundwater seepage back to the atmosphere via plant transpiration. Some water in the wetland flows laterally out of the area through connected surface water wetlands, whereas the rest flows downward into regional sand aquifers. A simplified conceptual model depicted in **Figure 2** highlights groundwater flow pathways at the Spring Run Wetland Complex.

While shallow groundwater appears to be localized in many areas, regional transport of groundwater nutrients to the lakes still occurs by tile drainage systems and via deeper sand aquifers. Overall, the IGS will continue working to develop a better hydrologic model for the IGL watershed and the larger Prairie Pothole region of Iowa.

FIGURE 1.

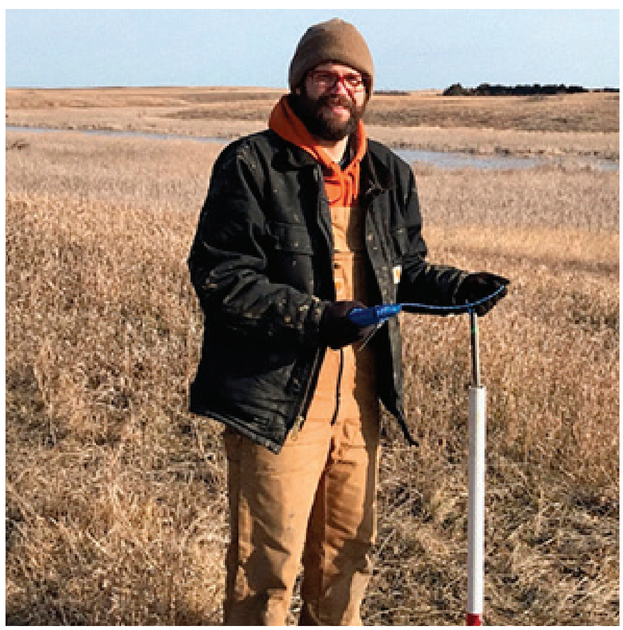


FIGURE 1. IGS soil scientist Matthew Streeter installing a water level sensor in a monitoring well at Spring Run Wetland Complex.

FIGURE 2. Conceptual model of the hydrogeology of the Spring Run Wetland Complex. Generalized groundwater flow paths are shown by the arrows in Panel 1. The white circles along the cross-section line represent wells that are depicted in Panel 2.

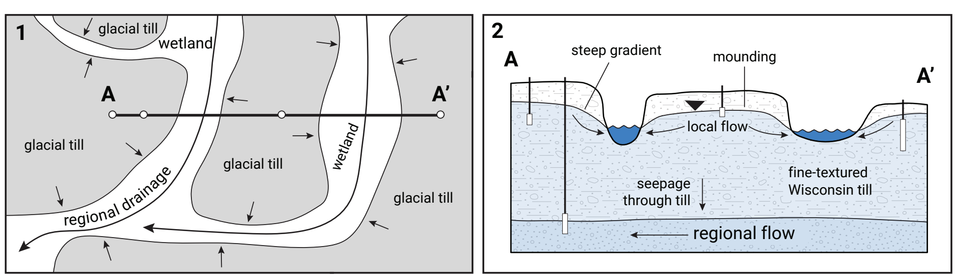


FIGURE 2.

Source Water Supply is Informed by Predictable Processes and Geology

GREG BRENNAN

THE IOWA GEOLOGICAL SURVEY (IGS) conducted an evaluation of the Iowa River alluvial aquifer to support the City of Iowa City as they manage this important source water resource. This study was focused on meander bends along the Iowa River identified as the Waterworks Prairie Park (Water Plant Park, at Dubuque Street Bridge), Peninsula Park, Normandy Neighborhood, and City Park (Park Road Bridge). The goal was to assess the potential for adding new vertical wells or upgrading existing collector well infrastructure to increase water supply from the alluvial aquifer.

GEOLOGIC SETTING

IGS geologists have recognized how the Iowa River Valley was shaped by glacial processes, particularly by meltwater events during the last continental ice advance into Iowa about 12,000-15,000 years ago. While this most recent advance into north-central Iowa did not cover eastern Iowa with glacial ice, the eroded sediments sourced from this advance were deposited along the entire length of the river. Multiple glacial meltwater events that included large, high-energy volumes of water flowing off the glaciers, carved into the pre-existing surficial sediment deposits and underlying bedrock. This shaped the modern landscape and altered the configuration of the river valley, while also depositing the some of the sediments that form the alluvial aquifer Iowa City now uses for its water supply.

The deposits that comprise the aquifer include coarse-grained sands and gravels (glacial outwash) interspersed with fine-grained alluvium (river deposits). Groundwater flow in the aquifer is influenced by the river, which serves as a recharge source, and by stratigraphic units such as clay-rich glacial till overlying carbonate bedrock that bound the lateral and vertical limits of the aquifer and serve as groundwater flow boundaries.

EXPLORATORY METHODS

Data collected from a variety of different investigative techniques, including geophysical surveys, drilling, and soil testing, were all integrated to characterize the subsurface conditions of the Iowa River alluvial aquifer. The IGS's Tromino® BLU tromograph was used at 96 locations across the study area to passively to record natural vibrations within the Earth. These seismic data were then analyzed to develop estimates of bedrock depth. Active seismic surveys were also completed using the tromograph, but in a different configuration. The ground was energized to generate shear-wave velocity profiles which were then analyzed to estimate sediment types and layering (**Figure 1**). The IGS's electrical resistivity (ER) geophysical equipment was employed to collect twelve cross-sectional profiles along the bank of the river and delineate the lateral and vertical variation of

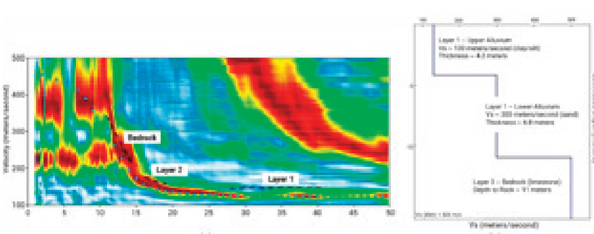


FIGURE 1.
Seismic dispersion and surface wave velocity data collected using a Tromino® BLU unit. Panel A is a recording of a shear wave velocity dispersion curve. Panel B is the corresponding shear wave velocity profile (Vs) depicting the calculated thickness and composition of the geologic materials. The model shows bedrock depth at approximately 11 meters (33 feet) and identifies a second layer within the alluvium. Layers are indicated on the curve (Panel A) by how many slopes (black dashed lines) are needed to fit the model to the data.

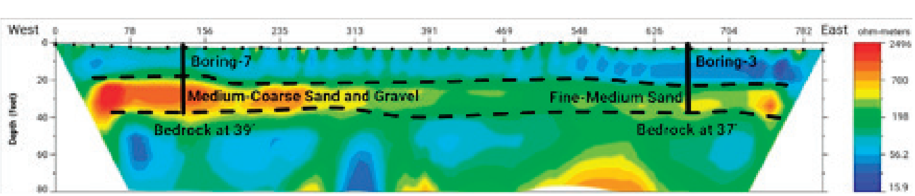


FIGURE 2.
Interpretation of an electrical resistivity (ER) geophysical profile used to infer geologic contacts (black dashed lines) and the presence and lateral continuity of the alluvial aquifer (red-yellow colors). These data were collected along the Iowa River near Collector Well CW-4 (depicted in **Figure 3**).

subsurface electrical properties. The magnitude of the measured values were then correlated to earth materials (e.g., sand versus clay) to help define the alluvial aquifer (**Figure 2**).

Additional field characterization included drilling 12 exploratory borings and converting five of them to temporary monitoring wells. For each location, a continuous soil profile was collected from 4-inch diameter drill augers and then logged. A total of 91 discrete soil samples were collected from these continuous profiles and sieved. The resultant data was plotted for grain size distribution and classified according to the Unified Soil Classification System. The soil boring logs were then used to aid in the estimation of aquifer hydraulic conductivity and yield.

AQUIFER CHARACTERIZATION AND PREDICTIVE YIELD

Once all of the field work was completed, all of the various data were used to establish the overall extent of the Iowa River alluvial aquifer in the study area (**Figure 3**). The thicknesses and depths of finer-grained alluvium versus coarser-grained outwash were further delineated to identify favorable water supply areas (**Figures 4 and 5**).

A predictive yield analysis was conducted, and the results were used to evaluate the potential for new production well development at seven promising locations. Three of these locations were deemed suitable for installation of new vertical wells that, combined, could potentially yield an additional 2.1 million gallons of water, per day, for Iowa City. Two other sites were also reasonable for installation of a new well, however these were not selected to limit drawdown interference with existing wells. The feasibility of enhancing existing radial collector wells to increase capacity was also evaluated, but due to the thin nature of the aquifer and its limited available drawdown such an approach is currently inadvisable. Additional pumping tests are necessary to better hydraulically characterize the aquifer and the induced recharge potential if collector wells are to be enhanced.

Overall, the groundwater assessment conducted by the IGS demonstrated that the Iowa River alluvial aquifer has potential for increased water supply development. The key factor in this determination was recognizing the depositional patterns of the aquifer sediments based on the regional and local geologic history of the study area. Combined with the use of targeted, non-invasive, exploratory methods and direct testing, the IGS was able to delineate the extent of the aquifer and assess its water supply potential for the City of Iowa City and region.

ACKNOWLEDGEMENTS

The IGS would like to thank Nathan Platt, Avery Norman, Rachel Walenceus, Henry Frederick, Megan Kroeger, and Hallie Wirth (University of Iowa Department of Earth and Environmental Sciences students) for all of their help collecting and processing passive seismic data and conducting the other geophysical surveys for this study during the Summer of 2023.

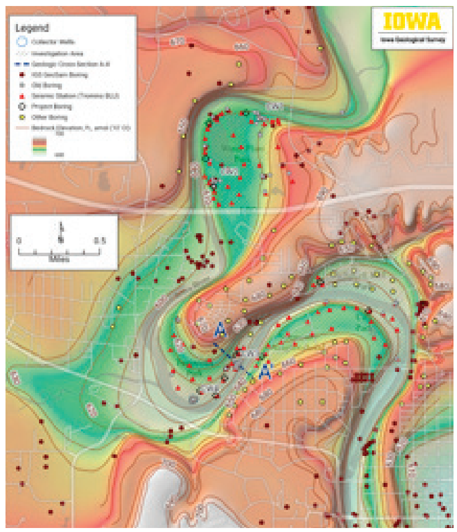


FIGURE 3.
Map of the bedrock topography beneath the Iowa River alluvial aquifer through Iowa City and the location of the geologic cross-section (A–A') depicted in **Figure 5**.

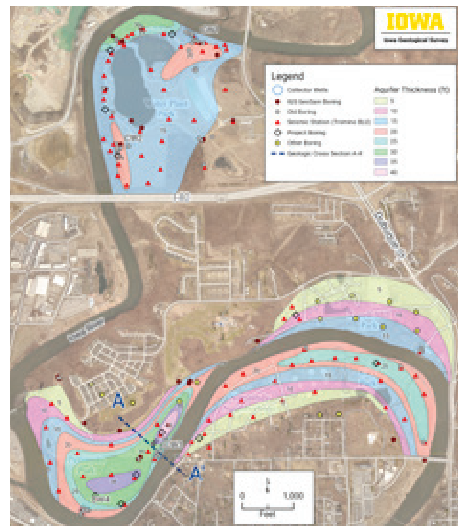


FIGURE 4.
Map depicting the thickness of the Iowa River alluvial aquifer through Iowa City and the location of the geologic cross-section (A–A') depicted in **Figure 5**.

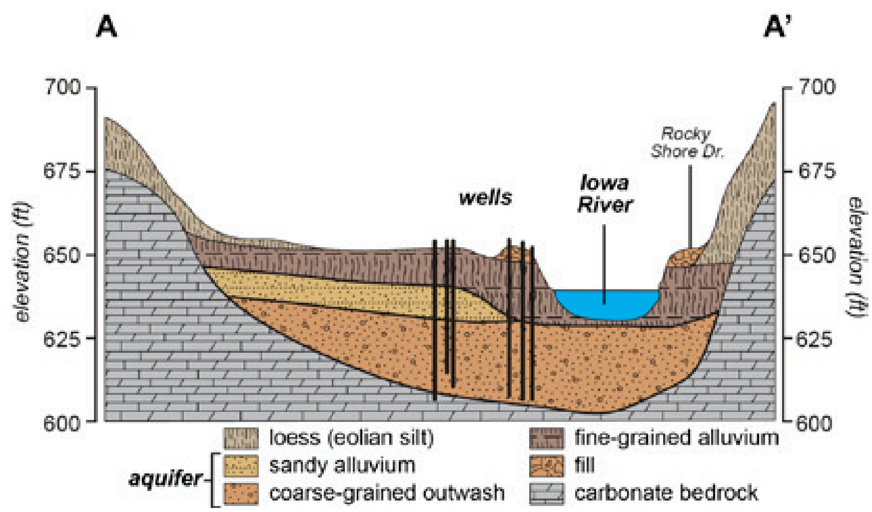


FIGURE 5.
Geologic cross-section A–A', showing a favorable outwash deposit that comprises the most productive zone of the Iowa River alluvial aquifer. This is the aquifer tapped by the City of Iowa City for their drinking water supply. The depicted wells are existing borings and production wells (depicted in **Figures 3 and 4**), the data from which were used to help construct this cross section.

Estimating the Amount of Sediment and Nutrients Captured by Iowa's Reservoirs

ELLIOT ANDERSON

MOST OF IOWA'S RIVERS AND LAKES were formed through natural geologic processes, but some of its most well-known waterbodies are entirely manmade. Three large reservoirs, designed and built by the U.S. Army Corps of Engineers (USACE), are located along Iowa's major rivers (**Table 1**), and they include: 1) Coralville Lake, located just north of Iowa City along the Iowa River; 2) Lake Red Rock, located southeast of Des Moines along the Des Moines River; and 3) Saylorville Lake, located in Des Moines's northern suburbs along the Des Moines River. These reservoirs were formed by constructing dams along major rivers to hold back water in large storage pools, and their primary purpose is flood control. A significant amount of water typically flows into a reservoir following a heavy rainfall event upstream. When this occurs, USACE operators will restrict the amount of water leaving the reservoir, reducing downstream flows and flood risk.

These manmade reservoirs also serve other ancillary purposes, such as providing recreational opportunities and aquatic habitat. The USACE manages outflow to ensure the reservoirs maintain a minimum level that supports both recreation and ecological health. The amount of water stored in each reservoir is immense, with pool volumes exceeding hundreds of millions of cubic meters (**Table 1**).

Due to their size and location, these reservoirs have a considerable impact on water quality. Perhaps most well-known is their ability to capture sediment. The free-flowing water entering the reservoirs carries large quantities of sediment, via soil erosion, from streambanks or fields upstream. When this water enters a reservoir, it becomes stagnant, and some sediment settles to the bottom. Total suspended solids (TSS) describe all solid particles in a water column. TSS concentrations have long been observed to be greater upstream of a reservoir than downstream. Reservoirs also substantially influence the nutrients nitrogen (N) and phosphorus (P), which are among Iowa's most problematic waterborne pollutants. Some of these nutrients are in a particulate form and settle out alongside sediment. Others are dissolved and undergo several biological processes within a reservoir system.

Recent research conducted by the IGS has estimated the amount of TSS and various nutrient forms that are captured by each of these three reservoirs. The process involved constructing a mass balance for TSS, N, and P at each of the reservoirs—essentially estimating the mass of each analyte entering and exiting each of these basins every year. Alongside TSS, three forms of N (nitrate, organic nitrogen [ON], and ammonia) and two forms of P (orthophosphate [OP] and particulate P [PartP]) have all been regularly measured by the USACE upstream and downstream of each reservoir. Streamflow is also monitored at these same locations by U.S. Geological Survey streamgauges.

Incoming and outgoing loads were estimated using statistical modeling techniques that predict sediment and nutrient concentrations. From these loads, we defined two useful metrics: Net Load

TABLE 1.
Iowa's three major flood-control reservoirs.

				Normal Pool		Full Flood Pool	
Reservoir	River	Completion Year	Drainage Area (km^2)	Surface Area (km^2)	Volume (m^3)	Surface Area (km^2)	Volume (m^3)
Coralville	Iowa	1958	8,068	21.97	35,000,000	100.4	519,000,000
Red Rock	Des Moines	1969	31,916	61.71	233,000,000	260.9	1,771,000,000
Saylorville	Des Moines	1977	15,081	22.34	91,000,000	65.15	791,000,000

TABLE 2.
Influence of Iowa's Coralville, Red Rock, and Saylorville reservoirs on statewide nutrient loads (2001 - 2023). Of note, "Net Load" is the average annual mass of nutrients removed by these three reservoirs combined, whereas "Statewide Load" is the average annual mass of nutrients exported by all of Iowa's rivers.

Nutrient Form	Net Load (metric ton/year)	Statewide Load (metric ton/year)	% Reduction of Statewide Load
Orthophosphate	246	5,990	3.94%
Particulate Phosphorous	2,150	16,100	11.78%
Total Phosphorous	2,400	22,100	9.80%
Ammonia	-499	4,400	-12.79%
Nitrate	10,600	250,000	4.07%
Organic Nitrogen	5,220	56,100	8.51%
Total Nitrogen	15,300	311,000	4.69%

and % Reduction. Net Load is simply the inputs minus the outputs, and a positive Net Load indicates that more mass entered a reservoir than exited it. The % Reduction is the Net Load divided by the inputs. This metric helps contextualize the amount of analyte a reservoir removes by comparing it to the incoming mass. A % Reduction of 100% indicates a reservoir has captured all incoming loads, while a negative % Reduction indicates more mass exited a reservoir than entered it.

Figure 1 summarizes the % Reduction for each of the analytes over the last 23 years. TN and TP refer to total nitrogen and total phosphorus, respectively, which are summations of the individual N and P nutrient forms. The reservoirs captured approximately 80% of incoming TSS. This amount of sediment retention can lower capacity in these reservoirs during typical storage conditions. To a lesser extent, nutrient forms were also reduced. The exception was ammonia, which saw increased loads of about 30% across the reservoirs. Interestingly, not all particulate analytes settled out at the same rates. PartP and ON reduction rates were 65% and 30%, respectively—much less than the 80% value for TSS. Flows were roughly balanced, highlighting that the reservoirs retain only the sediment and nutrients, not the water itself.

We also summarized the impact of these flood-control reservoirs on nutrient loads exported by Iowa's rivers, an important metric used to track progress in lowering nutrient pollution. Using similar methods, we compared the Net Load of nutrients to the Statewide Load (**Table 2**). TN and TP exports would have been 4.7% and 9.8% higher, respectively, if not for the reductions by the three reservoirs. These values are quite significant, as they are equivalent to thousands of best management practices (e.g., wetlands and bioreactors) used to limit nutrient transport.

The USACE can only control the amount of water stored in a reservoir—not how much flows into it—with their operation decisions. Thus, we explored how sediment and nutrient reduction rates relate to water storage (**Figure 2**). We calculated annual residence times (an estimate of how long water typically stays within a basin) and found that particulate analytes are not affected by storage times. Settling likely occurs on such short timescales that TSS and particulate forms of nutrients are unaffected by USACE decisions. Conversely, greater storage times seem to result in more nitrate and OP removal. Therefore, USACE operators can potentially increase nutrient removal by increasing reservoir storage times without incurring additional sedimentation. The USACE has many considerations when determining storage volumes, but our research has demonstrated the potential of altering management strategies to improve water quality. The IGS will continue to partner with USACE as it investigates strategies for operating its infrastructure more sustainably.

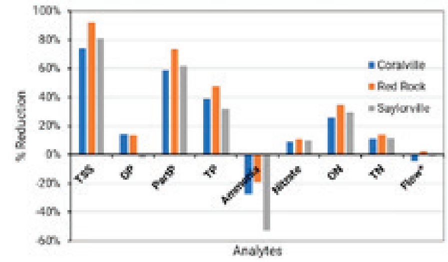


FIGURE 1.
The percentage of sediment and nutrients removed by Iowa's three major reservoirs (2001 - 2023). Flow is the percentage of the water volume retained.

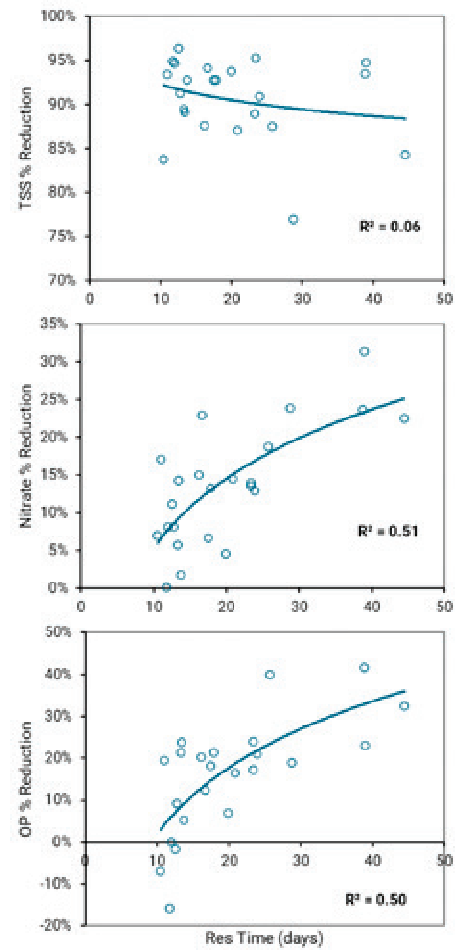


FIGURE 2.
Coralville Lake is a manmade, flood-control reservoir along the Iowa River, just north of Iowa City. These three graphs depict the Annual % Reduction versus Residence Time (Res Time) in Coralville Lake for total suspended solids (TSS; top), nitrate (middle), and orthophosphate (OP; bottom).

Aquifer Vulnerability Mapping in Black Hawk County

KEITH SCHILLING, STATE GEOLOGIST AND DIRECTOR

GROUNDWATER IS USED by nearly 80% of Iowans for water supply and it is important that valuable groundwater resources be protected from contamination for future generations. Identifying areas where groundwater is particularly vulnerable to contamination can be used to help guide land use and resource planning at county or regional scales. Vulnerable areas can be mapped using a geographic information system (GIS) that overlays different factors that may contribute to vulnerability such as soil type, water table depth and other variables. Groundwater vulnerability is determined by adding ranking scores for individual factors together and determining high- and low-risk areas based on the accumulated total score of all the factors.

The IGS recently completed an aquifer vulnerability map for Black Hawk County as part of last year's U.S. Geological Survey STATEMAP Program. The county was an ideal location to test a new methodology since the county includes a mix of urban and rural land use, and municipal and private wells, and a uniquely diverse geologic history. The geology of Black Hawk County was mapped as part of a multi-year STATEMAP Project which culminated with the production of surficial and bedrock geologic maps in 2013 (Tassier-Surine et al., 2013; Rowden et al., 2013). These maps created an ideal foundation to develop and test a new methodology for assessing the aquifer vulnerability.

Geologic mapping information was combined with other geospatial data and related hydrologic research to assess the vulnerability and risk of aquifers to contamination. It is important to clarify that our vulnerability map assessed the risk to aquifers and not the risk to groundwater. Many traditional vulnerability assessments focus on risks to shallow groundwater at the water table, but in the case of Black Hawk County, much of the area is overlain by fine-grained glacial tills that are not used for water supply. Hence, our vulnerability assessment was focused on aquifers that are being used by county residents, primarily either the floodplain alluvium associated with the Cedar River or the uppermost Devonian bedrock aquifer.

Rather than using a generic, off-the-shelf assessment method, we developed a new methodology for assessing groundwater vulnerability that was more directly related to Iowa's geology and groundwater. The IGS aquifer vulnerability map included four main geospatial layers that were compiled at a 30-m resolution in the county (**see front cover of *Geode***). The layers consisted of 1) groundwater recharge; 2) groundwater travel time to the uppermost aquifer; 3) contaminant risk from point and nonpoint sources; and 4) groundwater use components.

Groundwater recharge was delineated based on whether a 30-m cell was located in an upland, sideslope, or floodplain landscape position. Previous work in Iowa established that more groundwater recharge occurs in the floodplain, followed by flat uplands, and then on sideslopes (Schilling et al., 2018).

Groundwater travel time to the aquifer was evaluated using a one-dimensional approach that considered geologic stratigraphy and an estimate vertical groundwater flow velocity. First, the primary aquifers being used in Black Hawk County were identified and mapped and the layers of stratigraphic units overlying the uppermost aquifer were delineated. Depending on the location in the county, overlying stratigraphic layers included alluvial sand and gravel (modern alluvium), glacial outwash (coarse sand and gravel), oxidized pre-Illinoian till, interbedded sand and gravel within the till, and unoxidized pre-Illinoian till. Vertical groundwater flow velocities were then calculated for each unit and the velocity was multiplied by the stratigraphic unit thickness to produce a travel time per stratigraphic unit. These times were summed to produce a groundwater travel time for the entire sequence from the ground surface to the uppermost aquifer.

A new element, groundwater risk, was added to the vulnerability map. Risks for groundwater contamination by point and nonpoint sources were determined using available geospatial data. Point sources were located and mapped by the Iowa Department of Natural Resources (IDNR) as part of the U.S. EPA Source Water Protection (SWP) Program. Point sources extracted from the IDNR database included the locations of leaking underground storage tanks, landfills, hazardous waste sites, and other potential sources. The nonpoint source risk to groundwater contamination was determined by the presence or absence of row crop agriculture in the grid cell. A landcover data set hosted by the IDNR was used for this assessment.

Another novel element was an evaluation of groundwater use. Groundwater use was assessed by determining whether a cell was located within a 10-year time of travel capture zones for a public water supply well (as delineated by the IDNR SWP Program) or it contained a private well.

The scores for the four factors (recharge, time of travel, risk and use) were added together within a cell for a maximum score of 50 (**Figure 1**). Overall, the final map shows that aquifer vulnerabilities within Black Hawk County are not evenly distributed. For instance,

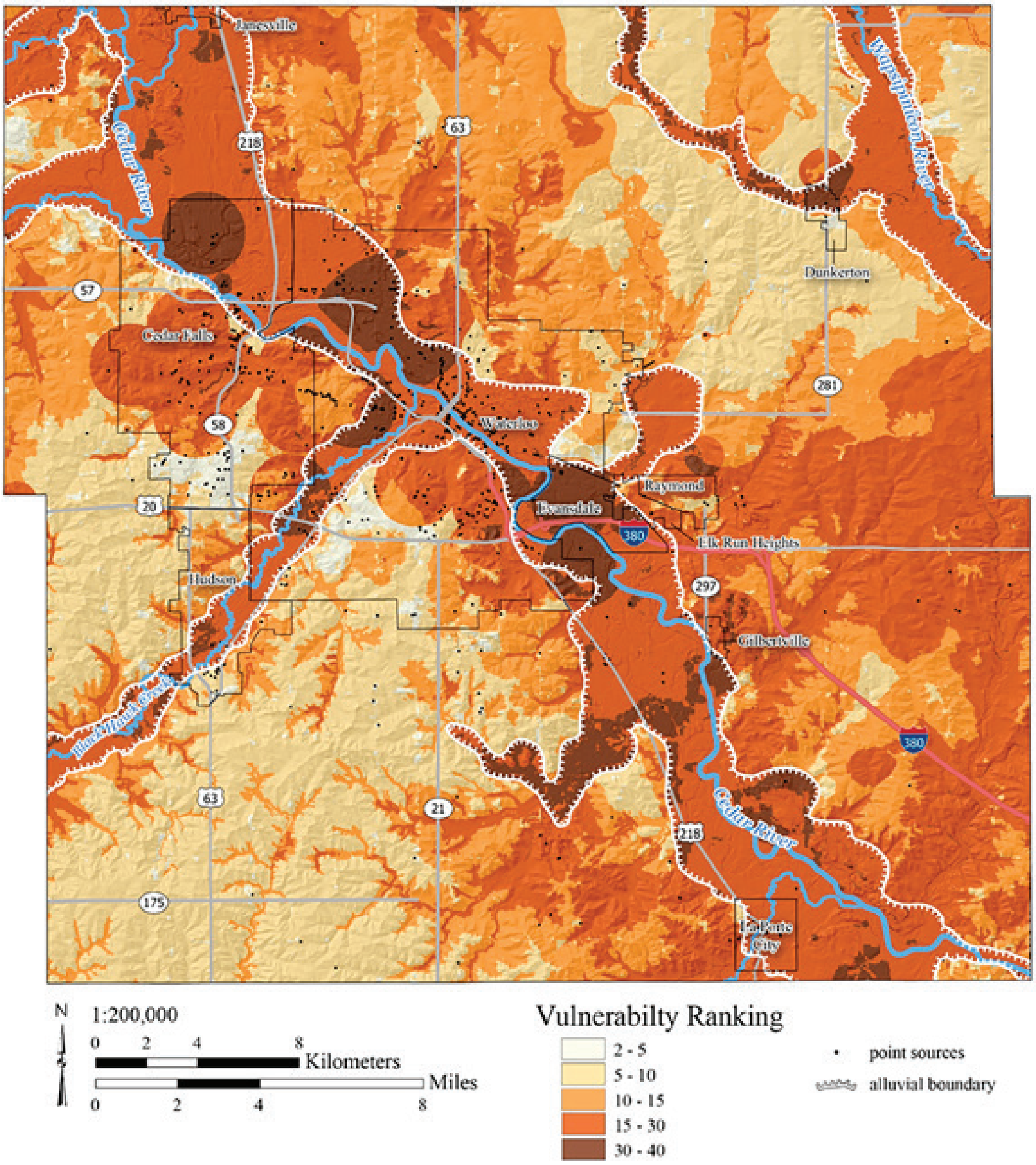


FIGURE 1.
The aquifer vulnerability map of Black Hawk County, Iowa. This figure is scaled down from the original 1:64,000-scale map, OFM-24-10.

increased vulnerability was associated with the Cedar River floodplain where there is greater recharge, faster vertical groundwater travel times, the presence of point or nonpoint risks, and a location within a known capture zone. In contrast, other regions of the county underlain by unoxidized glacial till are largely protected from groundwater risks.

This map can help guide land use planning within Black Hawk County for protection of valuable groundwater aquifers. Other counties or regional entities with an interest in mapping groundwater vulnerability should contact the IGS for more information.

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North America's Missing Mountain Range — The Laurentide Ice Sheet

PHIL KERR

CONTRARY TO POPULAR BELIEF, all of Iowa was covered by continental glaciers at some time during the Pleistocene. These massive, moving bodies of ice emplaced sediments across Iowa called *till* (Trowbridge, 1966). This dense diamict is a mixture of clay-sized particles all the way up to boulders the size of a bus. Monoliths scattered across the landscape, known as *erratics*, are igneous and metamorphic rocks clearly distinct from the shallow marine bedrock found across most of Iowa. These hard rock boulders are now most commonly found in yards as landscaping rocks; however, they were originally the bedrock of Canada (Ontario and Manitoba) and Minnesota. The presence of these giants in Iowa reveals a glimpse at the overwhelming nature of continental glaciers. The erratics now found in central Iowa were delivered from the frozen north by the most recent ice advance into Iowa. That glacier terminated in Des Moines and is fittingly called the Des Moines Lobe.

This was not the only ice to advance into the state. In fact, most of Iowa was covered numerous times by ice sheets of the Pleistocene. Evidence for this is that most areas in Iowa have multiple tills (**Figure 1**). However, discerning the exact number of glaciations is difficult, as the last ice advance erodes and buries evidence of past glaciers. Moreso, rivers and valleys also carve through these till sheets, further obfuscating the glacial record. Surprisingly, the best chronicle of terrestrial ice is stored within ocean sediments. Undisturbed deep-sea deposits record fluctuations in water chemistry caused by continental ice activity over the entirety of the Pleistocene. The oscillations during this interval of Earth's history indicate that dozens of ice domes grew and vanished in North America, unlike Antarctica.

The most recent of these ice sheets to grow in North America was the Laurentide Ice Sheet. This colossal feature is estimated to have been more than two miles thick at its maximum (between 26-19 thousand years ago; Lacelle et al., 2018). In essence, a new, frigid mountain range was created. Unlike typical mountain belts with peaks and valleys, the Laurentide was a continuous body of ice (**Figure 2**). Astonishingly, the sheer volume of the Laurentide eclipsed the Rocky Mountains. During the last glacial maximum there was potentially three times more ice above sea level than mountain ranges in North America.

Both the till and glacial landforms, like the moraine the golden dome of our State Capitol sits upon, mark the geographic extent of the Laurentide Ice Sheet. But how was the volume of ice that advanced over the landscape deduced? Two clues: 1) each passing decade, Hudson Bay is rising by approximately one inch, and 2) around the world, former coastlines are hidden beneath the waves. Some areas, such as the Bering Strait, have coastlines that are now hundreds of miles offshore. The "extra" shorefront was, counterintuitively, caused by a drop in sea-level as a huge volume of water was being stored as ice in the polar regions. At the height of the last glacial period, the global sea level is estimated to have been nearly 400 feet lower than today (Clark et al., 2009). The majority of the water was sequestered in Canada as the Laurentide Ice Sheet. The weight of which was so great at its maximum volume that it depressed the Canadian crust hundreds of feet. The land began to rise as the ice sheet melted. One could say that Ontario and Manitoba are on the rebound.

While this methodology may seem to be inexact, this level of control for ice sheet reconstruction only exists for the last glacial cycle. Archives from the ocean depths record a recurring series of glacial episodes before the last, yet these distal sediments cannot indicate the location of former ice sheets on land. Our understanding of most of the Pleistocene ice advances cannot rely upon rates of rebound and former coastlines. Furthermore, efforts to demark the extent and elucidate the behavior of older ice sheets is fraught. As previously noted, more recent glaciers erode or bury older glacial landforms and sediments. So where can we find evidence for the numerous ice sheets that sculpted North America? The landscape of Iowa, of course. While the state was entirely covered by ice, only one-third was beneath a glacier during the last two glacial cycles. Consequently, the remainder of the state's topography was molded by earlier, more cryptic ice advances. This older landscape then contains vestiges of these former ice sheets. Here, within the rolling green hills of our state, the annals of North American Pleistocene glaciation are kept.

FIGURE 1.
A photo of multiple tills from Klein Quarry, River Products Company, just west of Iowa City, Iowa.

FIGURE 2.
A reconstruction of the size of the Laurentide Ice Sheet around 24,000 thousand years ago based on Lacelle et al. (2018). Note that the Des Moines Lobe had not yet advanced into Iowa. The modern-day coastlines are depicted. Vertical exaggeration of one-hundred times.

FIGURE 1.

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FIGURE 2.

Hydrologic Unit Code (HUC) 12 Mapping in a Unique Geologic Setting of Northwest Iowa

STEPHANIE TASSIER-SURINE

BLACK HAWK LAKE is the southernmost natural lake in Iowa and is plagued by numerous water quality issues (elevated nutrients, high suspended solids, low water clarity, and high bacteria). Additionally, the area surrounding Black Hawk Lake and the nearby Boyer River have been the focus of several environmental and groundwater resource investigations in recent years (Downing et al., 2010; Kolb, 2015; Gannon and Brennan, 2020). A West Central Iowa Rural Water Association well field located at Wall Lake depends on the buried and unconfined alluvial aquifers to provide source water to public water supplies nearby. To aid in the continued investigations of watershed-specific questions, the IGS used watershed boundaries, instead of traditional quadrangle boundaries, to map the Lime Creek and Wall Lake Inlet hydrologic unit code (HUC) 12 watersheds in Sac and Caroll counties (**Figure 1**).

Geologically speaking, this map area is very unique. These two HUC 12 watersheds occur at the confluence of three landform regions of Iowa (**Figure 1**): the Southern Iowa Drift Plain (SIDP), Northwest Iowa Plains (NIP), and Des Moines Lobe (DML). Furthermore, they also include deposits from three different glacial advances: Wisconsin Episode Dows and Sheldon Creek formations and multiple tills deposited during the Pre-Illinois Episode. Glacial advances and associated processes shaped the landscape in the map area, and the resulting geomorphic features all illustrate the geologic complexity and history of the region.

Iowa was glaciated at least seven times during the Pre-Illinois Episode (0.5 Ma to 2.6 Ma). These deposits are grouped into the Wolf Creek and Alburnett formations, although in most areas these units cannot be easily differentiated and the more general 'Pre-Illinoian' term is utilized. Pre-Illinoian till deposits are present throughout the map area (**Figure 2**) but are only the uppermost till in the southwestern portion, elsewhere these sediments are covered by younger deposits (**Figure 3**). Glacial advances during the Wisconsin Episode deposited two till formations, the Sheldon Creek during the Middle Wisconsin (~29-55 ka) and the Dows Formation during the Late Wisconsin (~14-18 ka). Middle Wisconsin Sheldon Creek deposits overlie the Pre-Illinoian till throughout most of the map area, and are subsequently overlain by the Late Wisconsin Dows Formation. In the central portion of the map area, including the NIP and part of the SIDP, the Sheldon Creek is the uppermost till. Along the SIDP, these till deposits are mantled with loess, but farther north (including the NIP and DML landform regions) loess deposits are thin or absent. Both of these Wisconsin Episode glaciers advanced from the north and their terminal positions (moraines) are evident in the mapping area (**Figure 2**). The youngest advance, depositing the Dows Formation, still exhibits surface features indicative of glaciation and are designated as three different mapping units: till ridge, till plain, and till plain with discontinuous elongated hummocky ridge forms.

The NIP was in a periglacial environment during the Wisconsin Episode (~15-26.5 ka) and significant erosion and deflation occurred across the surface of this landform region. Peoria Formation loess deposits, wind-blown material sourced from glacial outwash, mantles much of the landscape and was deposited between 18-25 ka.

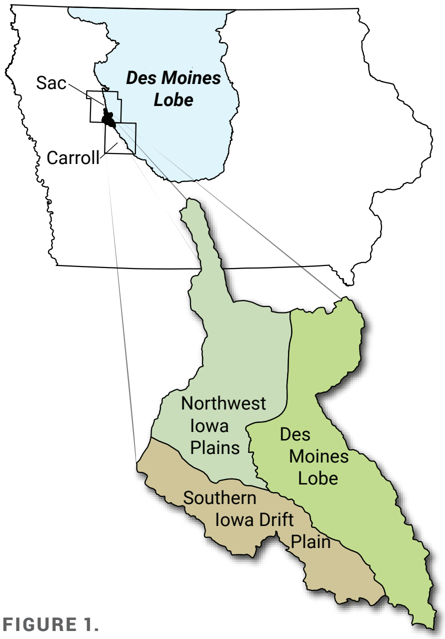

FIGURE 1.

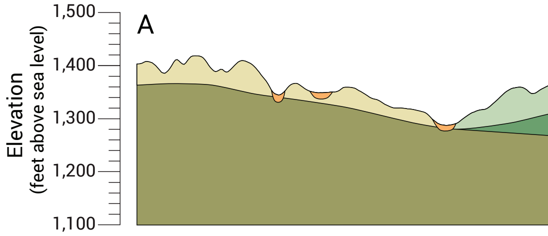

FIGURE 3.

The Lime Creek and Wall Lake Inlet HUC 12 watersheds have a complex geologic history because they lie in an area with more than one glacial margin. However, the integration of geomorphic, stratigraphic, and lithologic evidence has provided insight into the sequence of events that have sculpted this terrain. Not only is it important to discern the ordering and timing of the glacial deposits, the glacial advances themselves significantly influenced the orientation of drainage networks in these watersheds. The Boyer River carried glacial meltwater during the last glacial advance into Iowa. Presumably, Lime Creek was also carrying meltwater at one time. These drainages were likely rearranged during the most recent glacial advance, whereby Des Moines Lobe ice blocked drainages in the mapping area. Black Hawk Lake, which sits behind the terminal position of the Des Moines Lobe ice advance, also resulted from a blocked drainage.

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FIGURE 1.
The mapping area includes three landform regions of Iowa, the Southern Iowa Drift Plain (SIDP), the Northwest Iowa Plains (NIP), and the Des Moines Lobe (DML).

FIGURE 2.
The 1:24,000-scale surficial geologic map of the Lime Creek and Wall Lake Inlet hydrologic unit code (HUC) 12 watersheds in Sac and Carroll counties, Iowa and the location of the geologic cross-section (A-A') depicted in **Figure 3**.

FIGURE 3.
Geologic cross-section A-A' illustrating the stratigraphic superposition of deposits from the three glacial advances into the mapping area during the Quaternary (in ascending order): Pre-Illinoian tills (Wolf Creek and Alburnett formations), the Middle Wisconsin Sheldon Creek Formation, and the Late Wisconsin Dows Formation. Vertical exaggeration of ten times.

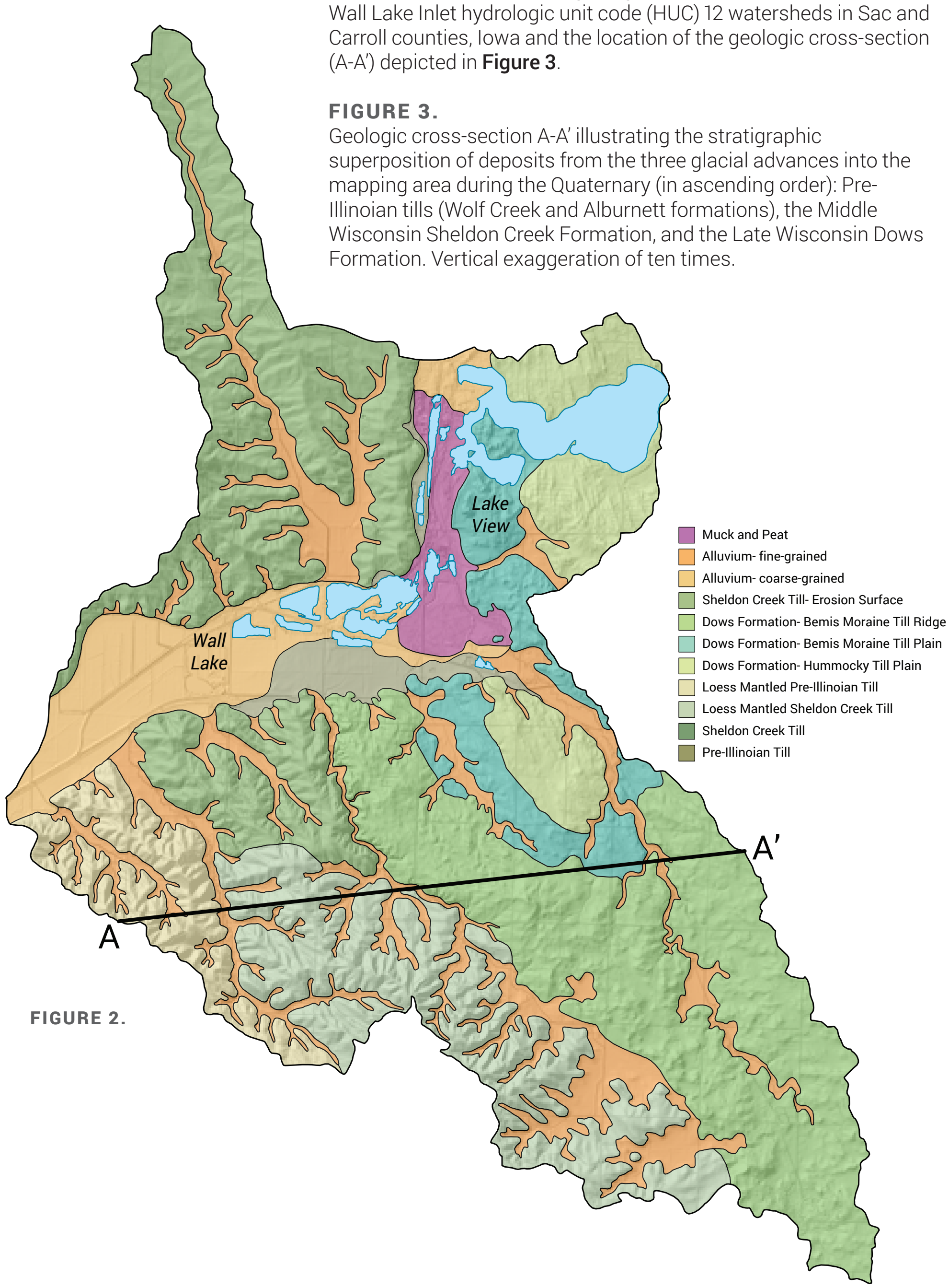
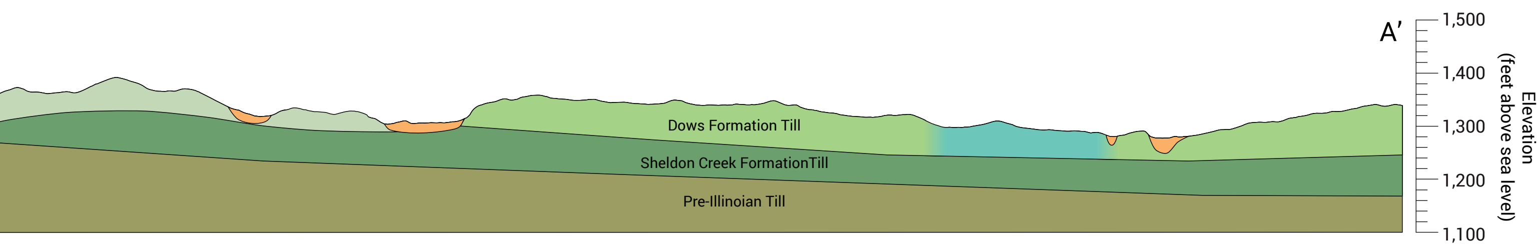


FIGURE 2.



Assessing Mine Waste as a Critical Mineral Resource

JACK MALONE AND RYAN CLARK

FIGURE 1.

IN 2023, the Iowa Geological Survey (IGS) was awarded funding from the U.S. Geological Survey (USGS) Earth Mapping Resources Initiative (Earth MRI) to conduct a 24-month project to evaluate the potential critical mineral enrichment of waste rock at the Browns Bottom Quarry (BBQ) in Dubuque, Iowa. Since the 1970s, crushed stone aggregate produced at BBQ and the neighboring Weber Quarry have targeted the Ordovician-age carbonates of the Galena Group that outcrop and underlie most of the Dubuque area. The overburden at the site consists of thin, unconsolidated, glacial sediments overlying phosphatic bedrock of the lower Maquoketa Formation. This overburden waste rock is stockpiled onsite within berms acting as sediment pond barriers and in a reclaimed abandoned quarry pit. The objective of this study is to characterize the mine waste at BBQ and determine if a readily available critical mineral source exists in Dubuque. The outcome of this study has the potential to restore the former Zinc-Lead Mining District as a critical mineral hub in an area that already hosts the infrastructure to support new industry.

The Elgin Member of the lower Maquoketa Formation has been the focus of numerous research endeavors to assess the critical mineral enrichment of phosphatic shales and phosphorite occurrences. In addition to phosphorus being a vital resource for phosphoric acid and fertilizers used in agriculture, studies have shown that phosphate minerals can incorporate substantial rare earth elements (REEs) during their formation in oxygen-poor, biologically productive, nutrient-rich seawater and during subsequent diagenetic alteration processes. REEs are a group of metallic elements that are critical for the development of clean energy technologies, but current global supply is limited and demand is high. A regional geochemical reconnaissance study of the lower Maquoketa Formation (also funded by USGS Earth MRI) found that the highest concentrations of heavy REEs (HREEs) within this stratigraphic unit occur in Clayton, Dubuque, and Jackson counties, averaging over 400 parts per million (ppm).

At BBQ, an estimated thickness of eight feet of phosphatic rock has been stripped from an approximately 0.15-square-mile area. Based on these parameters, the volume of mine waste at this site is estimated to contain more than 1,000 metric tons of HREEs. To quantify the hypothetical endowment at BBQ, the IGS has collected bulk composite samples for geochemical analyses and resource volumetric calculations. This endeavor has included surface sampling of berms (conducted during autumn 2023) and drilling seven boreholes (during the summer of 2024) to characterize and determine the thickness of the overburden waste rock stockpiled onsite at BBQ (**Figure 1**). Preliminary geochemical results from the berm samples indicate moderate enrichment, with hypothetical endowments of nearly 80 metric tons of HREEs.

In addition to assessing the critical mineral potential of the mine waste at BBQ, the geophysics arm of USGS Earth MRI is also conducting an Airborne Electromagnetic Survey and has funded a new IGS-led mapping initiative to determine the grade and thickness of the REE-enriched phosphatic rocks of the lower Maquoketa Formation across northeastern Iowa. These combined efforts will undoubtedly improve our understanding of the mineral system, distribution, and critical mineral resource potential around Dubuque (**Figure 2**), which could enhance the economic vitality of the surrounding communities and our domestic critical mineral supply.

FIGURE 2.

FIGURE 1.
Crew from Cascade Drilling® using a Boart Longyear LSTM450 Sonic Drill Rig to core unconsolidated fill material from a reclaimed pit at Browns Bottom Quarry (BBQ).

FIGURE 2.
IGS geologist Ryan Clark providing students with an explanation about the Mississippi Valley Type mineralization of the Dubuque Formation (which underlies the Maquoketa Formation) at BBQ. This photograph was from a Saturday, October 12, visit to the quarry during the 2024 Tri-State/SEPM-Great Lakes Section Geology Field Conference led by IGS geologist Jack Malone (for further information about this field trip, please refer to the write-up about Bellevue State Park in this issue of *The Geode*).

Bellevue State Park

JACK MALONE

NESTLED ALONG THE PICTURESQUE bluffs of the Upper Mississippi River (UMV), Bellevue State Park offers scenic overlooks of an area that abounds in history and natural resources. To fully grasp the cultural, economic, and recreational aspects of the park, one must first travel back in time 450 to 433 million years.

Shallow seas advanced across the U.S. Midcontinent during the Late Ordovician, flooding and depositing thick packages of sedimentary carbonate rocks. At the park, the uppermost stratigraphic unit of the Galena Group is the Dubuque Formation, which is found only at the base of Mill Creek adjacent to Potter's Mill. These strata are overlain by a regionally extensive, shale-dominated succession known as the Maquoketa Formation. This unit is poorly exposed and occupies the lower slopes of the bluffs in the park. A significant erosional unconformity exists at the top of the Maquoketa Formation, likely related to the Late Ordovician glaciation.

The prominent cliff faces in the park, which can be clearly seen when driving south of Bellevue along U.S. Highway 52, are dominated by strata of the lowermost Silurian Mosalem Tete des Morts and Blanding formations. The base of the Mosalem Formation is a significant erosional unconformity that marks the boundary between the Ordovician and Silurian systems and is likely related to the Late Ordovician (Hirnantian) glaciation. The Mosalem and Tete des Morts are dolomite-dominated lithologies that consist of wavy-bedded argillaceous dolostone to massive vuggy dolostones, respectively. The youngest bedrock unit at the park is the Blanding Formation, characterized as a medium-bedded dolostone with abundant bedded and nodular chert. These Silurian strata were extensively quarried during the mid-1800s through early 1900s, and abandoned quarries around Bellevue provided much of the dimensional stone that was used to construct the buildings of the town, many of which are still standing.

When the Pleistocene glaciations initiated about two and a half million years ago large ice sheets advanced and retreated from the Canadian Shield. These mountains of ice carved and milled the bedrock — eroding, transporting, and depositing immense volumes of rock and sediment and significantly altering the UMV drainage basin. In the Bellevue area, Pre-Illinoian till packages may be preserved in the uplands which often have a mantle of loess. Within the UMV floodplain there are two major terraces (Savanna and Kingston)

that preserve evidence of the retreat of the Laurentide Ice Sheet. The older Savanna Terrace is nearly 20 meters (65 feet) above the modern-day Mississippi River floodplain, and this outwash terrace was cut into by catastrophic draining of proglacial lakes as ice retreated. The surface created by these events later became the Kingston Terrace which sits about five meters (15 feet) lower than the older terrace. Both of these terraces were formed from sand and gravel deposited by a braided river fed by glacial meltwater from various lobes of the Laurentide Ice Sheet. Below this thick package of outwash lies a bed of fine-grained sediment (slackwater deposits) that accumulated when the Mississippi River was dammed by the Lake Michigan Lobe in western Illinois.

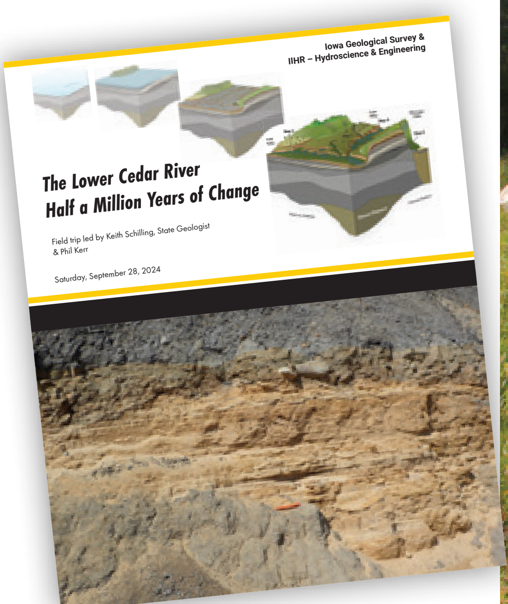
In addition to its natural beauty and rich geologic history, Bellevue State Park (dedicated in 1928) is conveniently located just south of the historic town of Bellevue, which is among the oldest settlements in Iowa (incorporated in 1851; **Figure 1**). Bellevue is also home to several sites on the National Register of Historic Places, two of the most well known are Potter's Mill (one of the earliest gristmills in Iowa, built in 1843) and the Lock and Dam No. 12 Historic District (constructed between 1934-1939). A comprehensive summary of *The Natural History of Bellevue State Park* is documented in the 2008 "Geological Society of Iowa, Guidebook 83" — a PDF version can be downloaded from the IGS Publications website.

FIGURE 1.
View from Bellevue State Park overlooking the Mississippi River Valley, with Lock and Dam No. 12 and Downtown Bellevue in the background. In the foreground are many of the participants of the 2024 Tri-State/SEPM-Great Lakes Section Geology Field Conference led by IGS geologist Jack Malone. This two-day field trip was attended by more than 80 students, university faculty, state survey geologists, and curious members of the public from across the Upper Midwest. The group visited several quarries (including Browns Bottom Quarry [BBQ] featured in this issue of *The Geode*) and classic roadcuts to discuss the complexities of the depositional and diagenetic histories of the Upper Mississippi Valley region. Bellevue State Park was the final stop of the field trip on Sunday, October 13.

Iowa Geological Survey Hosts Field Trip in Muscatine County

KEITH SCHILLING, STATE GEOLOGIST AND DIRECTOR

IN SEPTEMBER 2024, the IGS invited staff, local partners, and the general public to join together on a day-long field trip in Muscatine County to learn about the geologic history of the Lower Cedar River Valley and the implications for groundwater development. Led by Phil Kerr and Keith Schilling, along with contributions from several IGS staff, the field trip included multiple stops to look at how landforms and sediments in the valley have been shaped by half a million years of glacial and post-glacial erosion and deposition. The event was a great success, and Iowans should look forward to more IGS-hosted field trips in the years to come.



Cover of field trip guidebook.

PHOTO 1.
First stop of the field trip at The Nature Conservancy's Land of the Swamp White Oak Preserve to learn about modern floodplains (photo by M. St. Clair, IIHR).

PHOTO 2.

PHOTO 2.
Cone Marsh Wildlife Management Area — the most diverse wetland in southeast Iowa (photo by M. St. Clair, IIHR).

PHOTO 3.
IGS geologist Ryan Clark describes local bedrock geology at Wildcat Den State Park (photo by M. St. Clair, IIHR).

PHOTO 4.
IGS geologist Phil Kerr leads a discussion of Holocene terraces at Wiese Slough Wildlife Management Area (photo by M. St. Clair, IIHR).

PHOTO 3.

PHOTO 4.

PHOTO 5.
IGS hydrogeologists Joe Honings (left) and Thomas Doyle (right) show two young people how to measure the water level in a well at Cone Marsh Wildlife Management Area (photo by M. St. Clair, IIHR).

IGS Publications, Summer 2023 – Summer 2024

*IGS Student Intern

Anderson, E.S. and **K.E. Schilling**, 2024. "The Speciation of Iowa's Nutrient Loads and the Implications for Midwestern Nutrient Reduction Strategies," *Journal of Soil and Water Conservation*, 79(5):233-246.

Anderson, E.S. and **K.E. Schilling**, 2024. "Expanding the Applications of the Standardized Streamflow Index Through Regionalization," *Journal of the American Water Resources Association*, 60(4):837-850.

Anderson, E.S., **K.E. Schilling**, C.S. Jones, and L.J. Weber, 2024. "Estimating Iowa's Riverine Phosphorus Concentrations via Water Quality Surrogacy," *Heliyon*, 10(17):e37377.

Anderson, E.S., **K.E. Schilling**, C.S. Jones, L.J. Weber, and C.F. Wolter, 2024. "Iowa's Annual Phosphorus Budget: Quantifying the Inputs and Outputs of Phosphorus Transport Processes," *Land*, 13(9):1483.

Bancroft, A.M. and **P.J. Kerr**, 2024. Bedrock Geologic Map of the Wilton 7.5' Quadrangle, Muscatine and Cedar Counties, Iowa: Iowa Geological Survey, Open File Map OFM-24-1, 1:24,000 scale map sheet.

Bancroft, A.M. and **P.J. Kerr**, 2024. Bedrock Elevation and Quaternary Thickness Map of the Wilton 7.5' Quadrangle, Muscatine and Cedar Counties, Iowa: Iowa Geological Survey, Open File Map OFM-24-2, 1:24,000 scale map sheet.

Bancroft, A.M. and **P.J. Kerr**, 2024. Bedrock Geologic Map of the Muscatine NW 7.5' Quadrangle, Muscatine County, Iowa: Iowa Geological Survey, Open File Map OFM-24-3, 1:24,000 scale map sheet.

Bancroft, A.M. and **P.J. Kerr,** 2024. Bedrock Elevation and Quaternary Thickness Map of the Muscatine NW 7.5' Quadrangle, Muscatine County, Iowa: Iowa Geological Survey, Open File Map OFM-24-4, 1:24,000 scale map sheet.

Braun, M.G., **A.M. Bancroft**, N.J. Hogancamp, B.M. Stolfus, M.N. Heath, **R.J. Clark**, **S.A. Tassier-Surine**, J.E. Day, and B.D. Cramer, 2023. "Resolving Complex Stratigraphic Architecture Across the Burlington Shelf and Identifying the Devonian-Carboniferous (Hangenberg) and Kinderhookian-Osagean (Tournaisian) Boundary Biogeochemical Events in the Type Area of the Mississippian Subsystem," *GSA Bulletin*, 136(5-6):2157-2177.

Clark, R.J., **J.E. Malone**, and **P.J. Kerr**, 2024. Bedrock Geologic Map of the Dubuque South 7.5' Quadrangle, Dubuque and Jackson Counties, Iowa, and Jo Daviess County, Illinois: Iowa Geological Survey, Open File Map OFM-24-7, 1:24,000 scale map sheet.

Clark, R.J., **J.E. Malone**, and **P.J. Kerr**, 2024. Bedrock Elevation and Quaternary Thickness Map of the Dubuque South 7.5' Quadrangle, Dubuque and Jackson Counties, Iowa, and Jo Daviess County, Illinois: Iowa Geological Survey, Open File Map OFM-24-8, 1:24,000 scale map sheet.

Kerr, P.J., **S.A. Tassier-Surine**, and **A.M. Bancroft**, 2024. Surficial Geologic Map of the West Liberty 7.5' Quadrangle, Muscatine, Cedar, and Johnson Counties, Iowa: Iowa Geological Survey, Open File Map OFM-24-5, 1:24,000 scale map sheet.

Kerr, P.J., **S.A. Tassier-Surine**, ***R.S. Walenceus**, and **A.M. Bancroft**, 2024. Surficial Geologic Map of the Muscatine 7.5' Quadrangle, Muscatine County, Iowa, and Rock Island County, Illinois: Iowa Geological Survey, Open File Map OFM-24-6, 1:24,000 scale map sheet.

Malone, J.R., **J.E. Malone**, J.L. Isbell, D.H. Malone, J.P. Craddock, and K.N. Pauls, 2024. "Unmixing Detrital Zircon U-Pb Ages Reveals Tectonic and Climatic Depositional Influences on the Carboniferous Ansilta Formation, Calingasta-Uspallata Basin, Western Argentina," *Geoscience Frontiers*, 15(4):101807.

McLellan, E.L., K.M. Suttles, K.L. Bouska, J.H. Ellis, J.E. Flotemersch, M. Goff, H.E. Golden, R.A. Hill, T.R. Hohman, S. Keerthi, R.F. Keim, B.A. Kleiss, T.J. Lark, B.P. Piazza, A.A. Renfro, D.M. Robertson, **K.E. Schilling**, T.S. Schmidt, and I.R. Waite, 2024. "Improving Ecosystem Health in Highly Altered River Basins: A Generalized Framework and its Application to the Mississippi-Atchafalaya River Basin," *Frontiers in Environmental Science*, 12:1-19.

Moustakidis, I.V., **K.E. Schilling**, and L.J. Weber, 2024. "River Floodplains as Source or Sink for Fine Sediment and Total Phosphorus Export in an Agricultural Watershed," *Earth Surface Processes and Landforms*, 49(9):2677-2689.

Schilling, K.E., **P.J. Kerr**, **C.F. Wolter**, **S.A. Tassier-Surine**, ***R.S. Walenceus**, and ***H.W. Frederick**, 2024. Vulnerability Rank of the First Encountered Aquifer in Black Hawk County, Iowa: Iowa Geological Survey, Open File Map OFM-24-10, 1:64,000 scale map sheet.

Schilling, K.E., **M.T. Streeter**, **V.M. Diaz-Gibertini**, E. Betret, and A. Arenas-Amado, 2024. "Hydrogeology and Subsurface Water Flow Beneath Grass Waterways: Implications for Exploiting Waterways for Nitrate Reductions," *Agricultural Water Management*, 298:108847.

Schilling, K.E., **M.T. Streeter**, **E.S. Anderson**, J. Merryman, T. Isenhart, A. Arenas-Amado, and C. Theiling, 2024. "Potential for Managing Pool Levels in a Flood-Control Reservoir to Increase Nitrate-Nitrogen Load Reductions," *Journal of Environmental Quality*, 53(2):209-219.

Streeter, M.T., **K.E. Schilling**, T.V. Stoeffler, and **E.S. Anderson**, 2024. "Sedimentology of a Delta Formed by Agricultural Discharge into a Flood-Control Reservoir, Iowa," *River Research and Applications*, 40(8):1584-1594.

Tassier-Surine, S.A. and **P.J. Kerr**, 2024. Surficial Geologic Map of the Lime Creek and Wall Lake Inlet (HUC 12) Watersheds: Iowa Geological Survey, Open File Map OFM-24-9, 1:24,000 scale map sheet.

Tassier-Surine, S.A., **P.J. Kerr**, S.M. Kilgore, and B.D. Cramer, 2024. "Defining the Sheldon Creek Formation, a Middle Wisconsin (MIS 3) Till in Iowa, USA," *Journal of Quaternary Science*, 39(6):905-918.

Wilson, C.G., **M.T. Streeter**, W.E. Ettema, B.K. Abban, A. Gonzalez, **K.E. Schilling**, and A.N. Papanicolaou, 2024. "Assessing the Effectiveness of Alternative Tile Intakes on Agricultural Hillslopes," *Water*, 16(2):309.

IGS Presentations, Summer 2023 – Summer 2024

**IGS Student Intern Presentation*

Schilling, K.E., "Design Criteria for a New Tile Drainage Conservation Practice in Grass Waterways," Soil and Water Conservation Society International Annual Conference, Des Moines, Iowa, August 4, 2023.

Streeter, M.T., "Sedimentology of a Delta Formed by Agricultural Discharge into a Flood-Control Reservoir, Iowa," Soil and Water Conservation Society International Annual Conference, Des Moines, Iowa, August 4, 2023.

Anderson, E.S., "Mapping the Spatial Distribution of Natural Infrastructure Practices in the Mississippi River Basin," Soil and Water Conservation Society Annual Conference, Des Moines, Iowa, August 9, 2023.

Schilling, K.E., "Drought and the Development of Iowa's Drought Plan," University of Iowa, Iowa Flood Center Seminar, Iowa City, Iowa, September 21, 2023.

Anderson, E.S., "Using Streamflow to Monitor Drought in Iowa," University of Iowa, Iowa Flood Center Seminar, Iowa City, Iowa, October 18, 2023.

Malone, J.E., "Continental-Scale Glaciation During the Paleoproterozoic: Detrital Zircon Evidence from the Snowy Pass Supergroup, Wyoming," Geological Society of America Annual Meeting, Pittsburgh, Pennsylvania, October 18, 2023.

Clark, R.J., "The Potential for Geologic Carbon Sequestration in Iowa," Science Café, University of Iowa College of Public Health, November 28, 2023.

Vogelgesang, J.A., "Adventures in Geophysics: How the Iowa Geological Survey Uses Geophysics to Image Beneath the Ground," University of Iowa, Department of Earth and Environmental Sciences Guest Lecture, Iowa City, Iowa, November 29, 2023.

Anderson, E.S., "A Breakdown of Iowa's Nutrient Loads: N and P's Speciation and Spatial Variation," Iowa State University, Iowa Nutrient Research Center Seminar, Ames, Iowa, December 13, 2023.

Schilling, K.E., "Floodplains are Conservation Opportunities for Iowans," Sierra Club Iowa Chapter Monthly Meeting, Des Moines, Iowa, January 4, 2024.

Tassier-Surine, S.A., "Geologic Mapping in Muscatine County, Iowa," University of Iowa, Iowa Flood Center Seminar, Iowa City, Iowa, January 14, 2024.

Schilling, K.E., "Iowa Geological Survey Update," Agricultural and Natural Resources Appropriations Subcommittee, Iowa State Legislature, Des Moines, Iowa, January 22, 2024.

Langel, R.J., "Changes to 'GeoSam' Well Database with Driller Q&A," Iowa Water Well Association, Des Moines, Iowa, January 26, 2024.

Honings, J.P., "Geologic History of Iowa," Grinnell College, Center for the Humanities, Grinnell, Iowa, February 14, 2024.

Schilling, K.E., "Iowa Geological Survey: Need for Groundwater Planning in Iowa," Agricultural and Natural Resources Appropriations Subcommittee, Iowa State Legislature, Des Moines, Iowa, February 15, 2024.

Malone, J.E., "History of the Iowa Geological Survey and Geology of Iowa," Augustana College, Geology Department Seminar, Rock Island, Illinois, February 23, 2024.

Schilling, K.E., "Streambank Erosion in Iowa: Mapping, Monitoring, and Implications for Nutrient Export," Keynote Presentation, Partnership for River Restoration and Science in the Upper Midwest, Annual Upper Midwest Stream Restoration Symposium, Stillwater, Minnesota, February 27, 2024.

Kerr, P.J., "Using Surficial Geologic Mapping to Reveal a Sandblasted Landscape in Eastern Iowa," Departmental Seminar, Clemson University, Clemson, South Carolina, February 29, 2024.

Kerr, P.J., "Where's the Dust? Using Surficial Geologic Mapping to Reveal a Sandblasted Landscape in Eastern Iowa," Cedar Valley Rocks and Minerals Society – Annual Rock, Mineral, and Fossil Show, Cedar Rapids, Iowa, March 23, 2024.

Honings, J.P., "Caves and Karst in Iowa," Swisher Community Library, Swisher, Iowa, April 16, 2024.

Honings, J.A., **A.M. Bancroft**, **G.J. Brennan**, **P.J. Kerr,** and **S.A. Tassier-Surine**, "Applications of Tromino® Passive and Active Seismic Techniques to Hydrogeological Questions Across Iowa," Geological Society of America Joint North-Central and South-Central Meeting, Springfield Missouri, April 22, 2024.

Vogelgesang, J.A., **J.P. Honings**, **G.J. Brennan**, and **K.E. Schilling**, "Canoe-Mounted Electromagnetic Survey in an Iowa River to Delineate Streambed Conductivity," Geological Society of America Joint North-Central and South-Central Meeting, Springfield Missouri, April 22, 2024.

Clark, R.J., P.I. McLaughlin, **A.M. Bancroft**, T.R. Paton, and P. Emsbo, "Characterization of REE-Enriched Mine Waste at the Browns Bottom Quarry in Dubuque, Iowa, USA," Geological Society of America Joint North-Central and South-Central Section Meeting, Springfield, Missouri, April 23, 2024.

Anderson, E.S., "A Breakdown of Iowa's Nutrient Loads: N and P's Speciation and Spatial Variation," University of Iowa, Iowa Flood Center Seminar, Iowa City, Iowa, April 24, 2024.

Vogelgesang, J.A., "Using High-Resolution ER to Estimate Hydraulic Conductivity and Improve Characterization of Alluvial Aquifers: A Dive into Hydrogeophysics at the IGS," Webinar Presentation, American Association of State Geologists Water Forum, April 24, 2024.

Langel, R.J., "The IGS Groundwater Level Monitoring Network: Results, Challenges, and Changes," Iowa Groundwater Association Spring Conference, Cedar Rapids, Iowa, April 30, 2024.

Schilling, K.E., "Iowa Geological Survey: Need for Groundwater Planning in Iowa," Iowa Groundwater Association Spring Conference, Cedar Rapids, Iowa, April 30, 2024.

Schilling, K.E., "Iowa Geological Survey: Mapping Groundwater Availability," Central Iowa Water Works Advisory Board, Des Moines, Iowa, May 7, 2024.

Clark, R.J., D.W. Peate, A.R. Kusick, L.K.S. Horkley, and C.R.M. MacFarlane, "Baddeleyite Age Reveals Timing of the Northeast Iowa Intrusive Complex (NEIIC)," Annual Meeting of the Institute on Lake Superior Geology, Houghton, Michigan, May 17, 2024.

Selected IGS Projects, Summer 2023 – Summer 2024

Malone, J.E., **R.J. Clark**, A. Harris-Bommarito, and D.H. Malone, “Baraboo Interval Quartzites in Iowa: Reassessing the Origin and Provenance of the Washington County Quartzite, SE Iowa,” Annual Meeting of the Institute on Lake Superior Geology, Houghton, Michigan, May 17, 2024.

Malone, J.E., “Mississippian Stratigraphy of the Keota Quarry and Structure of the Keota Dome Gas Storage Field, Washington County, Iowa,” Iowa Master Conservationist Program, Keota, Iowa, May 28, 2024.

Schilling, K.E., “Using Drainageways for Subsurface Nitrate Processing in Agricultural Landscapes,” Towards Sustainable Groundwater in Agriculture – Linking Science and Policy, 3rd International Conference, San Franscisco, California, June 18, 2024.

Kerr, P.J. and ***R.S. Walenceus**, “Evaluating the Interaction of Eolian and Periglacial Processes Using a Landscape-Wide Chronologic Assemblage from the Iowan Erosion Surface,” LoessFest, International Union for Quaternary Research (INQUA) Loess and Paleosol Working Group, Mainz, Germany, June 20, 2024.

***Walenceus, R.S.**, and **P.J. Kerr**, “A New Model for Interaction of Eolian and Periglacial Processes on a Transport Surface During the LGM,” LoessFest, International Union for Quaternary Research (INQUA) Loess and Paleosol Working Group, Mainz, Germany, June 20, 2024.

A Vision Toward a More Resilient Iowa Great Lakes: *Keith E. Schilling*: Iowa Department of Natural Resources (IDNR)

Delineation of the Buried Valley Aquifer, Marshalltown Water Works: *Greg J. Brennan*: Marshalltown Water Works

#DiverseCornBelt: Resilient Intensification through Diversity in Midwestern Agriculture: *Keith E. Schilling*: U.S. Department of Agriculture (USDA)

Earth Mapping Resources Initiative (Earth MRI): Mine Waste at Browns Bottom Quarry: *Ryan J. Clark*: U.S. Geological Survey (USGS)

Earth Mapping Resources Initiative (Earth MRI): Geochemical Reconnaissance of Devonian Black Shales of the Illinois Basin and Pennsylvanian Black Shales of the U.S. Midcontinent: *Alyssa M. Bancroft*: U.S. Geological Survey (USGS)

Earth Mapping Resources Initiative (Earth MRI): Geochemical Reconnaissance of the Upper Mississippi Valley Zn-Pb District: *Ryan J. Clark*: U.S. Geological Survey (USGS)

Electrical Resistivity Imaging in Carlisle, Iowa: *Jason Vogelgesang*: Innovative Groundwater Solutions, LLC

Electrical Resistivity and Passive Seismic Geophysical Surveys at a Fort Dodge Landfill Site: *Jason Vogelgesang*: SCS Engineers

Rachel Walenceus, a University of Iowa (UI) Department of Earth and Environmental Sciences (EES) undergraduate student and IGS intern, presenting a poster of work she did with IGS geologist Phil Kerr. This presentation was given at LoessFest (International Union for Quaternary Research [INQUA]), a Loess and Paleosol Working Group Meeting held in Mainz, Germany in June 2024.

Evaluating a Two-Stage Roadside Ditch Design to Improve Environmental Performance: *Keith E. Schilling*: Iowa Department of Transportation (IDOT)

Evaluating the Effectiveness of Stacked Practices: Utilizing Modified Blind Inlets at Terrace Sites for N and P Load Reductions: *Matthew T. Streeter*: Iowa Nutrient Research Center (INRC)

Evaluating the Nutrient Reduction Benefits of Farm Ponds: *Keith E. Schilling*: Iowa Nutrient Research Center (INRC)

Levee Imaging: A Pilot Assessment: *Jason Vogelgesang*: Iowa Department of Homeland Security and Emergency Management (HSEMD)

National Geological and Geophysical Data Preservation Program (NGGDPP) – Data Preservation and Critical Minerals Activities in Iowa 2023-2024: *Richard J. Langel*: U.S. Geological Survey (USGS)

National Ground-Water Monitoring Network (NGWMN) – Iowa FY2023 NGWMN Project: *Richard J. Langel*: U.S. Geological Survey (USGS)

Nitrate Reduction via Reservoir Water Level Management in Central Iowa: *Keith E. Schilling*: U.S. Army Corps of Engineers (USACE)

Polk County Science Advisory Committee: *Elliot S. Anderson*: Polk County, Iowa

Quantifying Nutrient Load Reduction Practices and Export at Field and Landscape Scales: *Keith E. Schilling*: Iowa Nutrient Research Center (INRC)

Regional Initiative to Accelerate CCUS Deployment in Midwestern and Northeastern USA: *Ryan J. Clark*: U.S. Department of Energy (DOE), Midwest Regional Carbon Initiative (MRCI)

Soil and Plant Health Analysis: *Matthew T. Streeter*: Perimeter Solutions LP

STATEMAP FY2023 – Geologic Mapping in Iowa: Including Projects in Muscatine, Des Moines, and Black Hawk Counties: *Stephanie A. Tassier-Surine*: U.S. Geological Survey (USGS)

IGS Financials

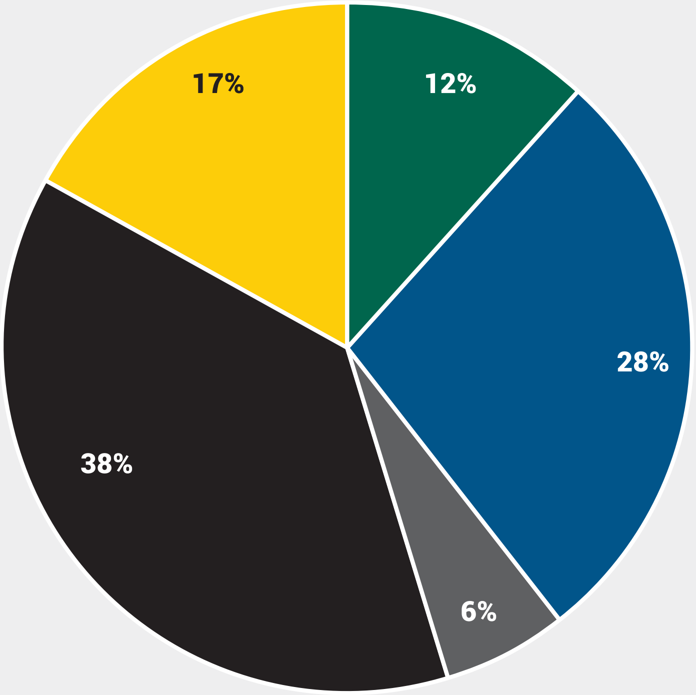
Funding for the Iowa Geological Survey (IGS) is provided through a combination of sources. A state appropriation provided approximately 28% of our annual operating budget during the past year, and while the amount has remained constant over the last few years it is declining as a percentage of our overall budget. The IGS leverages this base funding to obtain support for a diverse portfolio of projects from a variety of funding sources. In 2023–2024, these funding sources included local municipalities, state agencies, the U.S. Geological Survey (USGS), the Iowa Department of Transportation (Iowa DOT), the U.S. Army Corps of Engineers (USACE), and the Iowa Nutrient Research Center (INRC), among others.

The University of Iowa (UI) Department of Earth and Environmental Sciences (EES) continues to allow the IGS to leverage a portion of its own state appropriation to secure additional funding from the USGS — and we sincerely appreciate the continued collaboration and support of the UI-EES!

We are thrilled that an increase in our annual state appropriation, beginning with the 2024–2025 budget year, will allow us to begin work to further assess the state's groundwater. However, the budget increase really only starts the process of groundwater assessment. The IGS is currently focusing on the Iowa River alluvial aquifer for the 2024–2025 budget year (read about it in next year's *Geode*!), but there are upwards of 25 or more similarly-sized, major alluvial aquifers in the state. Assuming we are able to map and evaluate one alluvial aquifer per year, the pace of assessment will be on the order of several decades to get the job done. Additional state funding would be needed to complete these statewide groundwater resource assessments at a faster pace. Additional funding also allows us to leverage even more when applying for outside support — meaning that the state's return on its investment in the IGS also increases, as do the benefits for Iowans. Ultimately, state funding ensures that the IGS can focus on regional statewide initiatives and provide science-based information to manage Iowa's natural resources for long-term sustainability and economic development.

FY 2024 $2,458,209

- **Municipal** City Water Projects ($292,010)
- **State Appropriation** ($695,000)
- **INRC** Iowa Nutrient Research Center ($138,747)
- **Federal Agencies** U.S. Geological Survey, Natural Resources Conservation Service, Environmental Protection Agency, U.S. Department of Energy ($925,585)
- **Other** Non-Government Contracts, Iowa DNR, Iowa DOT, Iowa Department of Agriculture and Land Stewardship ($406,867)



FY2020	FY2021	FY2022	FY2023	FY2024
$1,596,525	$1,807,632	$1,715,862	$1,983,265	$2,458,209

Former State Geologist Donald L. Koch seated near a mass of flowstone in "The Gallery" of a Coldwater Cave passage. Don led Iowa's scientific exploration of Coldwater Cave during the mid to late 20th century (photo by J. Hytone).

IGS Geologists Then and Now

JOE HONINGS

For nearly six decades, Coldwater Cave in northern Winneshiek County has been a destination for cave and karst exploration, research, and education. In 1967, two University of Iowa geology students discovered the cave when swimming upstream from the head of Coldwater Spring. In 1972, a 94-foot entrance shaft to the cave was constructed on land belonging to Kenny and Wanda Flatland. The land was leased by the State until 1975, and the Flatland family graciously kept the entrance open. Soon after, the Coldwater Cave Project (CCP), led by a group affiliated with the National Speleological Society, constructed a compound over the entrance shaft and continues to manage the site today. In 1987, the cave was established as a National Natural Landmark.

Approximately 12 miles southeast of Coldwater Cave, the Iowa Department of Natural Resources (IDNR) operates a Fish Hatchery fed by Siewers Spring. After runoff events, sediment from the spring flushes into the hatchery and impacts trout rearing. The karst drainage system behind Siewers Spring is poorly understood and, unfortunately, it lies beneath mostly inaccessible private land. The IGS is currently conducting a study into the sources and mobilization of the sediment, using Coldwater Cave as an analogous system. In December 2023, a water quality sensor was deployed in the stream bed of the cave, and the data are available for viewing at the Iowa Water Quality Information System (IWQIS) website (https://iwqis.iowawis.org/app/). Sediment sampling from the land surface, from within the cave system, and from the clarification bins at the fish hatchery was recently completed, and should provide insight into the erosional and transport processes in the Siewers Spring Watershed.

PHOTO 1.

PHOTO 2.

PHOTO 3.

PHOTO 1.
State Geologist Keith Schilling monitoring the water quality sensors fastened to the concrete buttress built within the cave stream. The cables are lowered into the cave through a small diameter boring that extends through the overlying strata into the compound constructed over the cave entrance (photo by J. Honings, IGS).

PHOTO 2.
State Geologist Keith Schilling collecting a sediment sample from the cave for further analysis (photo by J. Honings, IGS).

PHOTO 3.
Current IGS staff (left-to-right) Tom Stoeffler, Keith Schilling, Calvin Wolter, and Joe Honings posing for a photograph next to a mass of flowstone in "The Gallery" of a cave passage (photo by C. Wolter, IGS).