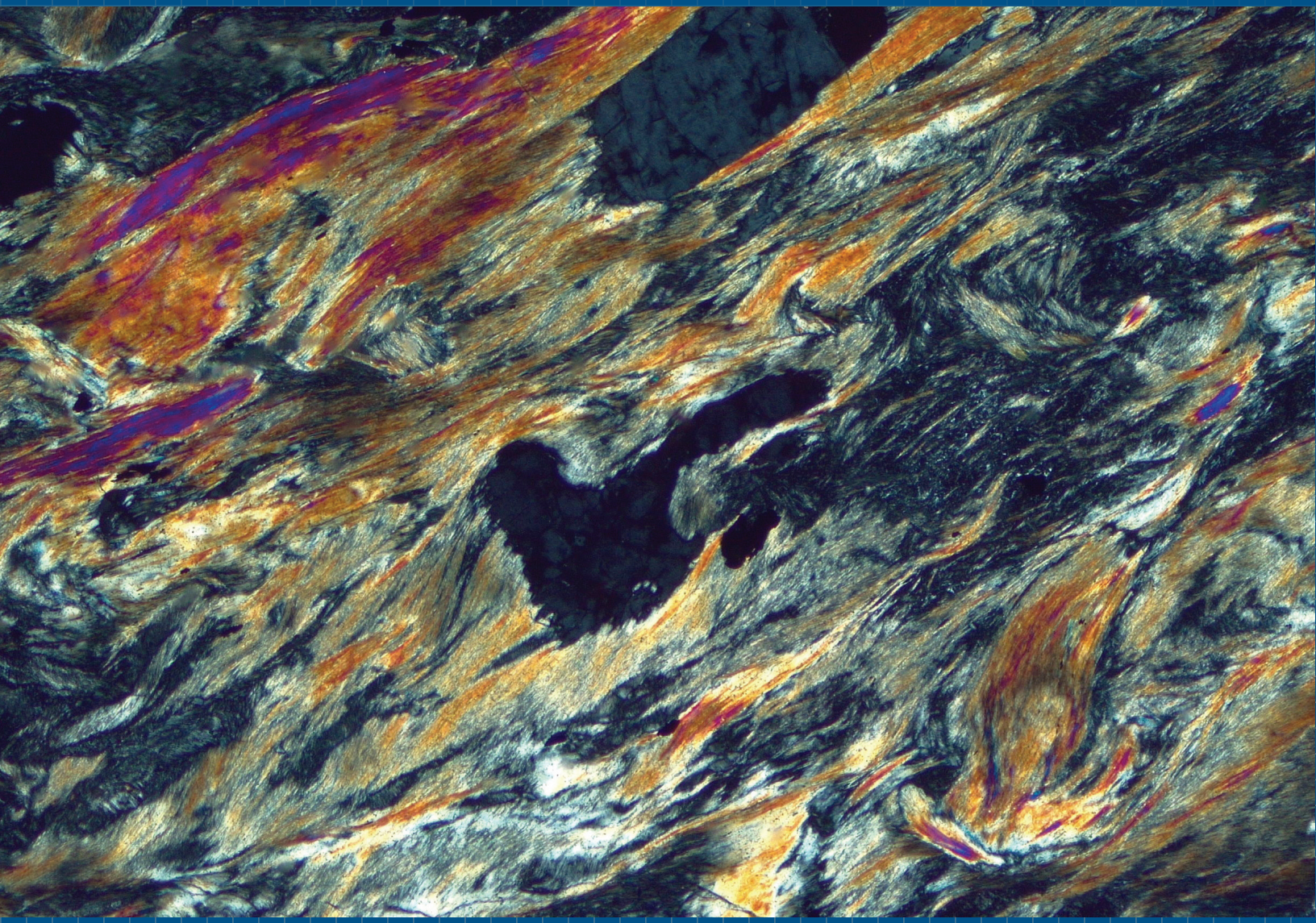
Delaware Geological Survey

ANNUAL REPORT OF PROGRAMS & ACTIVITIES

2017-18



Photomicrograph of Delaware's state mineral, sillimanite, under crossed polarized light. The mineral habit is bundles of needles of sillimanite crystals, commonly called fibrolite, that have been deformed along with surrounding rock during the Taconic Orogeny 450 million years ago during the formation of the ancient Appalachian Mountains and the super continent of Pangaea. This photomicrograph by William "Sandy" Schenck was chosen for the Art in Science exhibit at the University of Delaware Harker Laboratory.

OUR MISSION

The Delaware Geological Survey's mission is, by statute, geologic and hydrologic research and exploration, and dissemination of information through publication and public service.

Delaware Geological Survey

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Message from the Director

Welcome to the Anthropocene

According to many prominent geoscientists, we have entered the Anthropocene, which defines the current Epoch where mankind's collective actions altering and modifying the earth's surface have surpassed those of nature. The world is indeed changing. It always has and it always will. Unfortunately, it's now changing at a faster rate than in previous human history. We have increased the concentration of carbon dioxide to its highest level in the last 800,000 years, which is leading to global warming and rising sea levels.

At a more local level, growth and development has increasingly taken agricultural and forested land and converted them into subdivisions, commercial properties, transportation corridors, and recreational areas, such as golf courses. Collectively, these actions alter the atmospheric carbon balance, enhance runoff, increase surface temperatures, and strain surface and groundwater resources. How are we, as a society, going to respond to these changes? No matter how you cut it, sound, germane geoscience information will be critical to inform and direct our efforts to minimize or mitigate these changes.

The Delaware Geological Survey's (DGS) mission to collect data and geoscience information will be vital for policymakers, planners, engineers, and the general public to adapt. Let's consider the long-term effects of sea-level rise. Delaware has the lowest mean elevation of any state in the country at a mere 60 feet above sea level. The Delaware Department of Natural Resources and Environmental Control (DNREC) states that up to 11 percent of our coastal land area (including wetlands, property, and infrastructure) could be inundated by sea-level rise of 1.5 meters (5 feet), which is possible under some scenarios predicted for the mid-Atlantic region over the next 100 years.

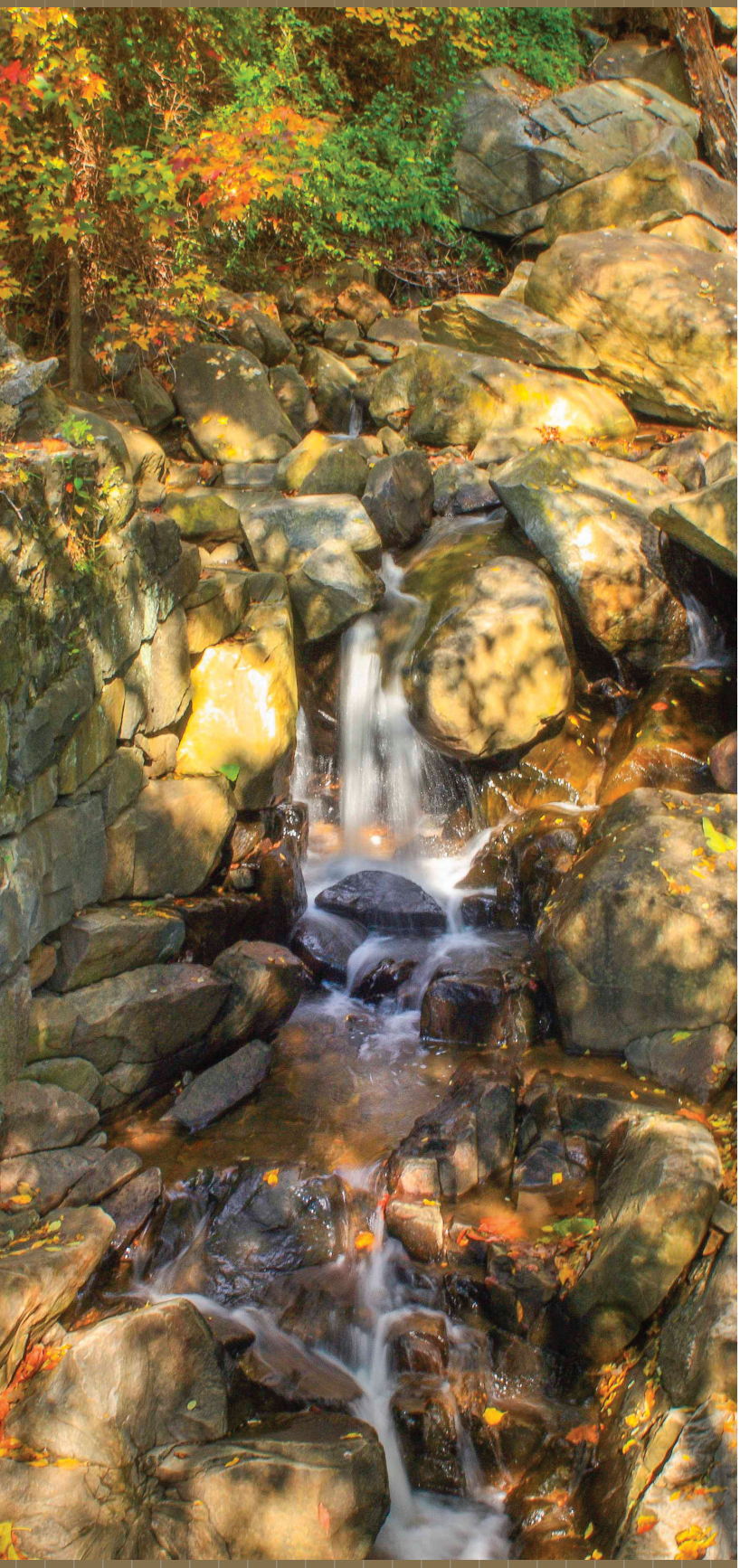
In response to an executive order, and guided by the DNREC Coastal Program, the DGS coordinated the recent Delaware Sea-Level Rise Technical Committee charged with updating the state's sea-level rise planning scenarios for the state. The committee consisted of academics, and representatives from state and federal agencies, and created a compendium of the most recent peer-reviewed literature and reports. Their work also resulted in updated projections for sea-level rise specific to Delaware so that local government planners and policymakers can make wise choices for managing their coastal land areas and resources in light of this threat.

In many ways, all DGS programs provide important information that will help numerous stakeholders adapt to a changing planet. For example, currently we have instrumented wells in coastal areas to monitor fresh groundwater in areas that may be threatened by saltwater intrusion. Our cooperative geologic mapping program focuses on surficial geology which allows us to produce maps that accurately depict geologic formations, as well as geomorphic characteristics such as preserved beach-cut ridges and dunes that provide us with a better understanding of the influence of previous high sea-level stands on sedimentary structures. Our cooperative efforts with the federal Bureau of Ocean and Energy Management to map offshore sand resources will help identify potential resources for beach replenishment for communities hammered by coastal storms. Our coastal wetland studies using LiDAR and thermal imagery reveal a detailed understanding of the interaction of groundwater and encroaching saltwater from ever rising tides. We also monitor storm surge, and manage the state's stream and tide gage network.

This past year, the DGS hosted the Association of American State Geologists 110th Annual Meeting in Rehoboth Beach, with the theme "Applied Geoscience for a Changing Planet." This very successful meeting highlighted DGS's research programs aimed at gaining a better understanding of our coastal geology, particularly with response to natural hazards and allowed us to learn from research being conducted by other state and federal partners. These and other projects are highlighted within our 2017-18 Annual Report of Programs and Activities. We hope this report will help you discover the important information that DGS collects for the benefit of our state, and that it will empower you to address some of the challenges we face on this rapidly changing Earth. Welcome to the Anthropocene!

David R. Wunsch,
Director and State Geologist

1. Water Resources



Groundwater and Saline Water Intrusion Monitoring Network Infrastructure Improvements: Kent County, Delaware - Update

Project Contacts: A. Scott Andres, Rachel W. McQuiggan, Changming He, Thomas E. McKenna, and David R. Wunsch

New monitoring well and stream station infrastructure has been installed that allows DGS and DNREC to track groundwater and surface-water conditions in a part of Delaware that has significant water-availability issues

DGS has begun a three-year project to install new water-monitoring infrastructure and collect baseline data in Kent County, Delaware. Recommended by the Delaware Water Supply Coordinating Council in 2015, the project was funded by the FY2017 DNREC Bond Bill appropriation. To date, more than 8,000 linear feet of monitoring wells have been installed at 11 sites.

Expansion of water monitoring infrastructure in Kent County is critical because existing infrastructure is sparse and because population, economic and environmental conditions, and agricultural practices (irrigation) have changed how we use water since regional studies were completed in the 1960s and 1970s. In addition, we now have a more detailed understanding of aquifers and confining beds and vastly improved computer methods to simulate, analyze, and predict the availability of groundwater and the impacts of increased groundwater use. Completion of the project will address the issue that existing wells are too sparsely distributed and data are not temporally adequate to support the use of these computer methods for the major water supply aquifers in Kent County. In recognition of the close links between groundwater and surface water and the potential for wells to become contaminated by saline streams, water-monitoring infrastructure will be placed in both wells and streams. This joint monitoring approach is important because of the linkage between sea-level rise and landward migration of saltwater.

Data from water level and salinity monitoring, and hydraulic and water quality testing are now being analyzed. Interim results of this work has prompted the Governor's Water Supply Coordinating Council to form a Kent County working group that is discussing responses to rapidly declining water levels in the Piney Point aquifer and elevated risks of salinity intrusion and dewatering of the Columbia aquifer in the East Dover area.

The project is being conducted in cooperation with the Water Supply Section of the Delaware Department of Natural Resources and Environmental Control (DNREC). Our

partners at the U.S. Geological Survey (USGS) are providing stream-gaging services. Work is being coordinated with the Maryland Geological Survey.

DGS Service to the Delaware River Master Advisory Committee - Update

Activity Contacts: David R. Wunsch and Stefanie J. Baxter

Ensuring Delaware is represented in Decree Party discussions and negotiations

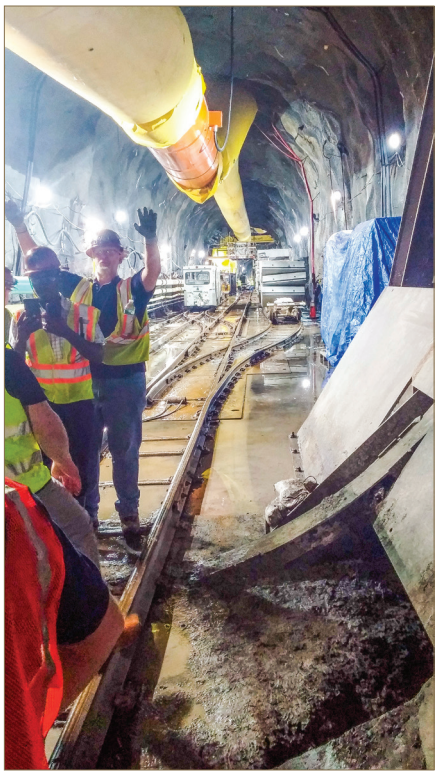
A U.S. Supreme Court decree in 1954 settled an interstate water conflict between New York City (NYC) and the states of New York, New Jersey, Pennsylvania, and Delaware. The decree allows NYC to transfer up to 800 million gallons of water per day out of the Delaware River Basin to provide water supply to the city. The decree also created a body for governance, the River Master Advisory Committee, that consists of five Decree Party Principals (one from each of the states that are party to the decree, and NYC) who must be unanimous in their votes for all decisions related to water allocations, release quantity schedules, and agreements.

By state statute, the Delaware State Geologist is the state's designee and represents the Governor on the Delaware River Master Advisory Committee. The State Geologist, with support from DGS staff, deals with the complexities of interstate water management issues regarding one of the largest and most complex water-supply systems in the world. The Decree Party Principals often address issues involving conflicting water needs, such as reducing releases to potentially mitigate flood risks, while near simultaneously being asked to increase release quantities to provide thermal relief for cold-water fisheries and recreational opportunities.

In October 2017, the Decree Parties committed to a long-term agreement that balances the myriad interests connected to the Delaware River. The 10-year program protects public health for millions of Americans by sustaining their supplies of high-quality drinking water. The agreement also expands efforts to enhance flood attenuation and support the outdoor recreation economy of the upper Delaware River through the protection of its natural ecology and wild trout fishery.

The new agreement requires the Decree Parties to pursue a number of scientific studies related to salinity intrusion in the lower Delaware River, the calculation of water available to be released downstream of New York City's reservoirs, and other topics related to the natural resources of the basin.

This year the annual meeting of the Advisory Committee was held in Marlborough, New York, and included a tour of the new NYC diversion tunnel under construction beneath



Ventilation system and tracks used during tunnel construction.

View looking from floor of tunnel up toward elevator shaft.

David Wunsch and Stefanie Baxter waiting for tunnel tour.

the Hudson River, which is being built to bypass a leaking section of the Rondout-West Branch Tunnel portion of the Delaware Aqueduct system. The group took an elevator down an 885-foot shaft to view the progress of the tunnel construction.

The DGS, in concert with the DNREC Commissioner to the Delaware River Basin Commission, worked diligently to represent Delaware's interest in maintaining equitable access to the, at times, limited water resources within the Delaware River Basin. This includes ensuring adequate flows of fresh water in the Delaware River to provide for water supply and ecological needs, as well as to prevent saltwater intrusion into aquifers, or the upstream advancement of the saltwater front in the Delaware Estuary.

Stratigraphy and Geological Characterization of Aquifers in the Potomac Formation, New Castle County - Update

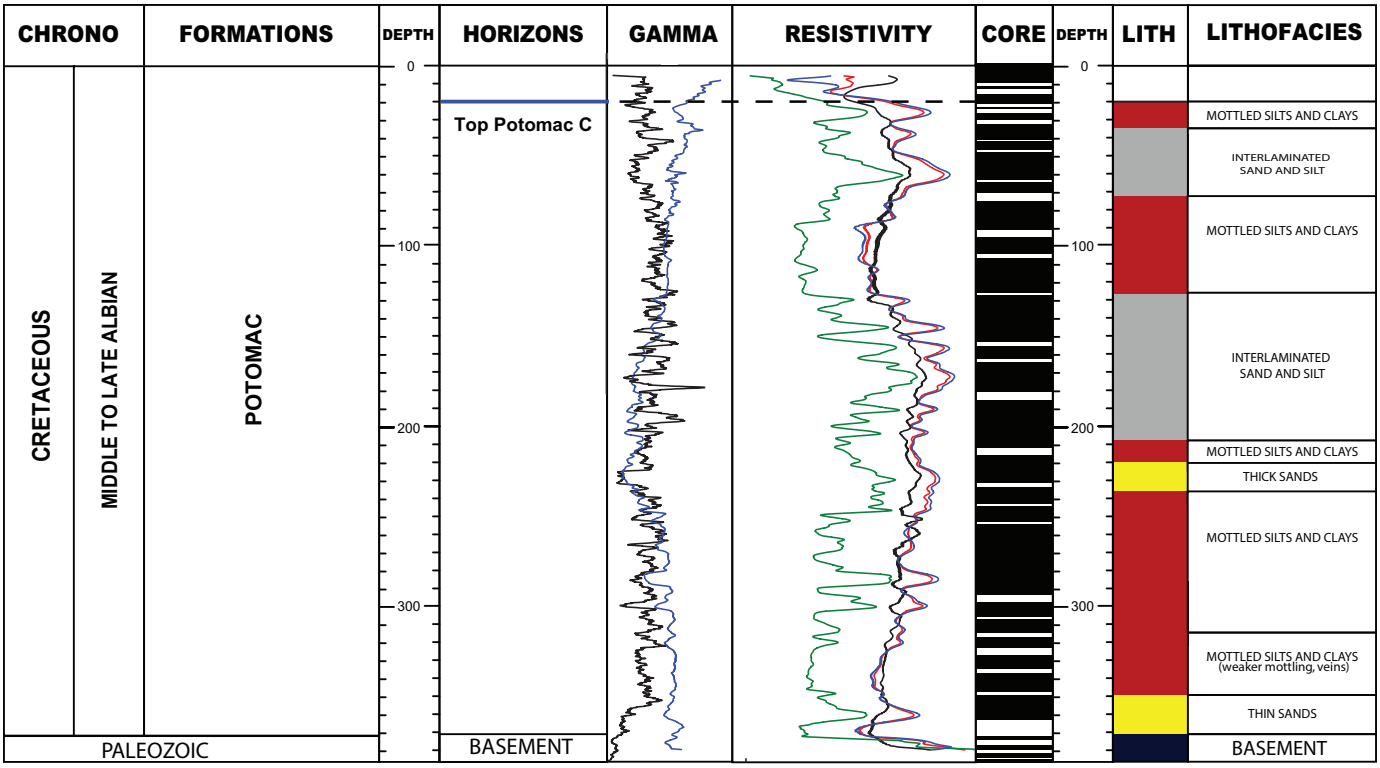
Project Contact: Peter P. McLaughlin, Jr.

An ongoing research theme aimed at understanding the geological controls on aquifer connectivity in the subsurface of northern Delaware

Recent DGS studies of the Potomac Formation in the subsurface of northern Delaware has yielded valuable new insights into the distribution of lithologies and the connectivity of sand bodies in this important, aquifer-bearing unit. This work is currently being documented in a master's thesis project supervised by DGS staff and in material for forthcoming DGS reports summarizing the results of several drilling projects.

In the last two years, DGS Potomac studies have closely examined sediment core, geophysical logs, and fossil pollen and spores from three continuously cored holes through the Potomac Formation, one near Red Lion (Prest Property), one between Bear and Christiana (DelDOT yard), and one near Glasgow (Glasgow Park). The aquifer-quality sands in this formation were deposited by ancient rivers and are encased in muddier deposits that represent ancient soils and floodplain deposits. As a result, the formation is extremely heterogeneous, making it difficult to understand and predict where the aquifer sands are located. The boreholes contain non-marine alluvial plain deposits composed of muds, silts and clays, with scattered sands. These reflect changing ancient environments during their deposition, with about 50 percent of the deposits being paleosols (ancient soils), 25 percent being fluvial sands, and 25 percent being distal levee or wet floodplain deposits. The overall proportion of sand increases in the deeper part of the formation.

Due to the heterogeneity of the Potomac Formation, geophysical logs and sediment cores alone do not allow aquifer zones in the formation to be confidently correlated. The study of the biostratigraphy of fossil spores and pollen provides



Stratigraphic log of the Bear-Christiana DelDOT Yard borehole (from master's thesis of Michael Fulton, 2018).

essential, additional constraints on subsurface geologic correlations. The new biostratigraphic data suggest the need to revise some of the subsurface correlations within the Potomac Formation, including the interpreted stratigraphic position of aquifer sands.

Delaware Ground-Water Monitoring Network

Project Contacts: Changming He, A. Scott Andres, Rachel W. McQuiggan, and Thomas E. McKenna

DGS currently monitors groundwater levels in a network of wells that support myriad uses by the environmental management, engineering, water supply, and science communities. Data collected by DGS are available on the NGWMN web portal

The DGS has operated a network of observation wells for more than 50 years that allows us to monitor groundwater levels around the state. Long time-series of water levels in major aquifers serve as important baseline data for resource management and analyses of aquifer response to pumping, climatic variability, drought, seawater intrusion, and interaction with streams and their ecosystems. The number and placement of wells and data-recording instruments that constitute the network are routinely reassessed in order to be responsive to water demands and environmental issues. New automated instrumentation that measures salinity has been incorporated into the network to monitor the effects of sea-level rise on water resources. Nine salinity sensors have been deployed and plans are to add one to two additional sensors per year for the next several years.

Our database contains nearly 19 million water level, temperature, and salinity records, and recent upgrades to our monitoring equipment now allow us to add more than 1 million new records per year. DGS now uses automated instrumentation to measure water salinity in a number of wells and streams to look for impacts of sea-level rise and saltwater intrusion. We now hold more than 0.5 million salinity records. A web interface that allows our stakeholders to access over 250,000 manually measured and daily average data online has been in operation for the past decade. The network supports evaluation of the long-term availability and sustainability of the groundwater supply, management of the resource, and multiple uses by the environmental management, engineering, and science communities.

DGS has been awarded three grants from the USGS to participate in the National Ground-Water Monitoring Network, a consortium of state and local agencies that contribute expertise and data to a national program that distributes information from an internet portal. The program is managed by the USGS and currently is focused on establishing data transmission infrastructure. If funding is maintained, then there is potential for acquiring resources to enhance Delaware's monitoring activities. DGS has provided water-level data from 36 wells and water-quality data from six wells that are displayed on the portal.

This project is partially funded by the Water Supply Section in the DNREC Division of Water Resources and the USGS.

Delaware Stream and Tide Gage Program

Project Contacts: Stefanie J. Baxter, Kelvin W. Ramsey, and John A. Callahan

Ongoing DGS program to advise state and local agencies on stream conditions and flooding on the basis of a cooperative DGS-USGS program to operate stream and tide gages

The USGS, in cooperation with the DGS, has been operating and maintaining continuous-record stream and tide gages throughout Delaware for decades. This year, 10 streamgages and seven tide gages were operated for this program. The data are used for a multitude of purposes such as water-resources planning and management, evaluation of drought conditions, and flood forecasting, warning, and response, including early warning systems. The warning systems are used by the DGS, Delaware Emergency Management Agency (DEMA), all three county emergency management offices, most municipalities, and the National

USGS streamgage on the St. Jones River at Dover, Delaware. Photo courtesy of the USGS.

Weather Service.

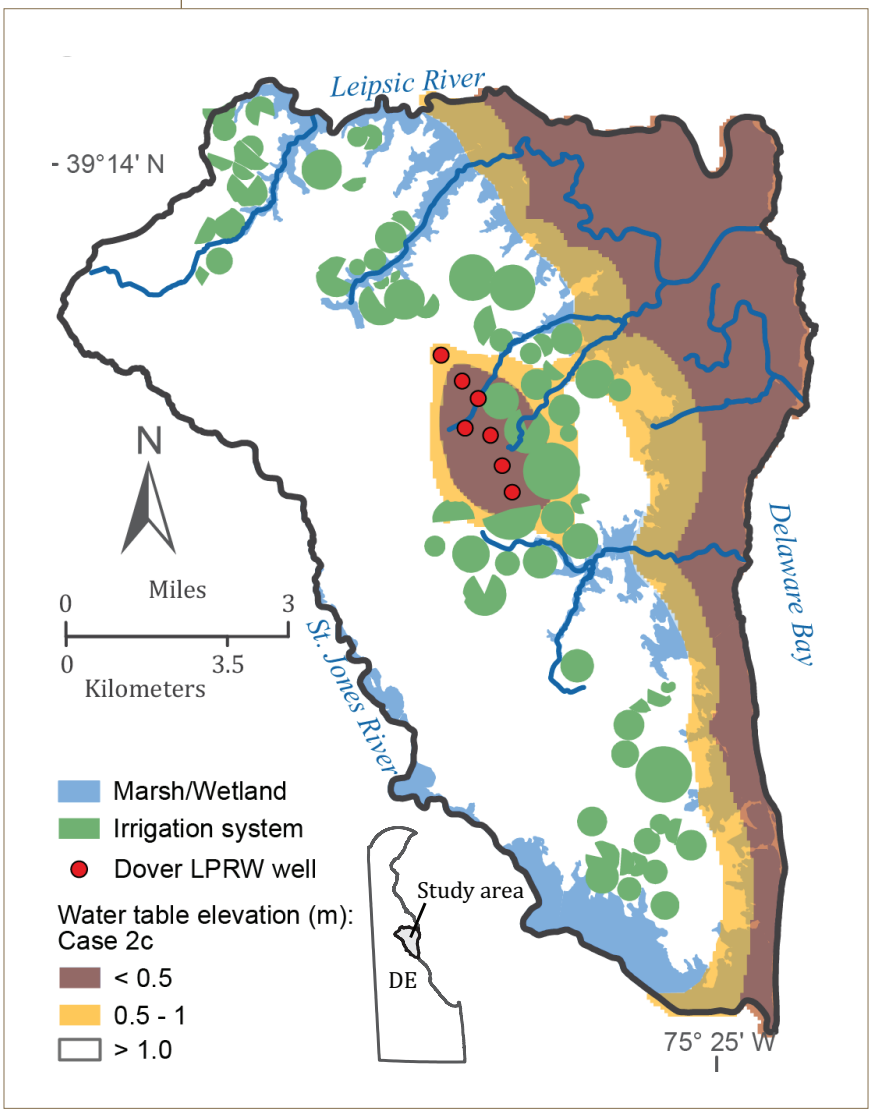
The DGS also assists other Delaware government agencies by coordinating USGS resources through the DGS-USGS cooperative program related to water resources. This includes: coordinating the continued operation of and maintenance of real-time streamflow gages for the DNREC Watershed Assessment Section at Millsboro Pond Outlet, Beaverdam Ditch near Millville, and Silver Lake Tributary at Middletown, tide gages at Indian River at Rosedale Beach and Indian River near Bethany Beach, and one tide and discharge gage on the Murderkill River at Bowers. Also included in the DGS-USGS cooperative program is the installation and operation of water-quality monitoring stations for DNREC Watershed Assessment Section on the Brandywine Creek at Wilmington, Christina River at Newport, Appoquinimink River near Odessa, Millsboro Pond Outlet at Millsboro, and Massey Ditch at Massey Landing; intensive water-quality monitoring in the Murderkill Watershed for Kent County; and a three-year project with the Delaware Department of Transportation (DelDOT) to integrate USGS and DelDOT real-time data through testing and use of data-logger technology. The DGS adds significant value to projects undertaken for Delaware agencies by the USGS by ensuring appropriate coordination and scoping of work, and technical review of products before contract payments are released.

East Dover Groundwater Flow Model Constructed to Monitor East Dover's Wellfield - Update

Project Contacts: Changming He and A. Scott Andres

Digital groundwater flow model constructed to show results of pumping in East Dover

In 2015, DGS became aware of a situation east of Dover where there exists the potential for overpumping of the Columbia aquifer by the City of Dover's Long Point Road wellfield (LPRW) and numerous large-capacity irrigation wells in the surrounding area. Overpumping is a cause for concern because it may 1) increase the risk of saltwater intrusion into the aquifer from saline tidal creeks and marshes, and 2) reduce the transmissivity of the aquifer and decrease well yields.



Model-predicted zones for high risk of saltwater intrusion. High-risk areas exist where the water-table elevation is less than 0.5 meters. DGS Open File Report No. 52, Results of Groundwater Flow Simulations in the East Dover Area, Delaware, Figure 12.

To investigate the potential for overpumping, a digital groundwater flow model was constructed and run in steady state and transient modes. As is the case with most models, many assumptions and simplifications had to be applied because of data limitations. The model was calibrated to a spatially limited set of data. Much of groundwater pumping for irrigation is not reported and has been estimated from irrigation demand estimates. Consequently, model outputs are meant to inform how the aquifers behave given the assumptions and simplifications and will not represent precise predictions of water pressures in the area characterized by the model. Additional data are now being collected in the model domain to refine the accuracy and precision of model results.

Model results show that pumping by the City of Dover and irrigation wells have a significant impact on groundwater elevations and flow directions in the Columbia aquifer within the study area. The magnitude of the impact varies with modeled pumping rates, with larger pumping rates causing greater drawdown and larger areas where flow directions change more than 90 degrees.

Impacts of current and projected water use result in two main concerns. Areas associated with water-table elevations near or below sea level and located in proximity to saline tidal creeks and marshes are at risk for intrusion of saline water. Areas where pumping significantly reduces the thickness of the saturated aquifer are at risk for reduced well yields due to decreased aquifer transmissivity and increased pumping costs due to lower dynamic heads in the wells. For both concerns, the risks are greatest during the irrigation season when pumping rates are greatest and lowest when irrigation is not occurring.

DGS Retirements

Steven V. Bertsche retired from the DGS following 14 years of service as System Administrator providing network and desktop computing support. Steve's areas of expertise included application development and digital data systems administration.

Karen L. D'Amato retired from the DGS after almost 13 years of service as the Assistant to the Director. She started working at the DGS in February 2005. Prior to joining the Survey, Karen worked in the General Accounting department at the University of Delaware for 17 years.

The DGS Support Team

Behind every program and activity is a fantastic support team

Denise T. Heldorfer

Assistant to the Director

Denise is responsible for establishing, managing, and coordinating the integrated fiscal and administrative operations of the Survey. She assists the DGS Director with fiscal management, monitors and reconciles all accounting revenue and expenditures, and administers all DGS grant proposals.

Paul "Steve" McCreary

DGS Well Driller

Steve is a licensed well driller in Delaware whose responsibilities include obtaining all permits from state and local governments, drilling the holes necessary to obtain geologic and hydrologic data, abandoning holes or installing wells in accordance with state laws, and maintaining all DGS heavy equipment, including a CME drill rig. Steve is also responsible for obtaining and recording water levels for the DGS monitoring well network.

Charles "Tom" Smith

Senior Research Technician II

Tom is responsible for installing, maintaining, modifying, and repairing the various field instruments and communication links which are used to monitor Delaware's seismology, streams, aquifers, and rainfall. Tom is also responsible for obtaining and recording water levels for the DGS monitoring well network.

Laura K. Wisk

Administrative Assistant

Laura is the first contact when people call or visit our office, and responds to requests for information. She is responsible for managing DGS mailing lists, distributing publications and newsletters, and managing the inventory of DGS publications. Laura is also in charge of processing payroll records for the DGS student work force and ordering supplies.

Sheng Yao

Computing Support Specialist II

Sheng is the DGS IT specialist who provides network and desktop support, identifies technologies for future implementation, and guides technology cost analysis, system security, and purchasing.

2. Geology & Mapping

Delaware Geological Survey Hosts the 110th Annual Meeting of the Association of American State Geologists

The DGS hosted the 110th Annual Meeting of the Association of American State Geologists (AASG) at the Atlantic Sands Hotel and Conference Center in Rehoboth Beach, Delaware, from June 3-7, 2018. The AASG is a 501 (3)c organization that represents the chief executives of the geological survey agencies from the 50 states and Puerto Rico. The AASG convenes its annual meeting in a different state each year, and the Delaware Geological Survey last hosted the annual meeting in 1978.

The meeting was a four-day event with technical sessions, field trips, and a closing banquet designed to foster ideas and promote exchange and communication among state, federal, and non-profit partners. The theme of this year's meeting was "Applied Geoscience for a Changing Planet." The meeting also included keynote addresses by invited speakers from across the realm of science, energy, environment, and policy. Opening remarks were given by Dr. Tim Petty, the Assistant Secretary of the Department of Interior for Water and Science, and the recently confirmed director of the USGS, Dr. James Reilly.

The Delaware AASG Meeting included several field trips. The mid-meeting trip was a half-day event for all attendees, and included stops at the historic Indian River Life-Saving Station Museum at Delaware Seashore State Park, Indian River inlet bridge to view coastal engineering projects, Cape Henlopen State Park, and historic Fort Miles. Field trips were led by DGS staff with expertise in coastal geology and near-shore hydrology. In addition, several staff are hobbyist historians, and offered interesting historical notes related to the sites along with other anecdotes related to Delaware's rich maritime and colonial history. A post-meeting field trip was held mainly in the Piedmont region of northern Delaware and included stops at the historic Hagley Museum of early industry along the Brandywine Valley, and ended with geology by train, with stops at rock outcrops and sites of interest visible along the tracks of the Wilmington & Western Railroad.

This year there were state geologists and representatives from 41 state surveys, as well as representatives from many federal departments and agencies. The guest speaker for the closing banquet was UD professor Dr. Art Trembanis, who spoke on the development and use of autonomous vehicles for data collection and discovery. The meeting was a memorable and successful event that provided a forum for national leaders in geoscience and policy to convene in beautiful coastal Delaware.

(L to R) Dr. Tim Petty, the Assistant Secretary of the Department of Interior for Water and Science, Dr. David Wunsch, Delaware State Geologist and meeting host, and Dr. James Reilly, Director of the U.S. Geological Survey.

DGS geologists, Sandy Schenck and Kelvin Ramsey, discussing Piedmont geology at the Hagley Museum during the post-meeting field trip.

Mid-Atlantic Offshore Geologic Properties and Hydrologic Characterization

Project Contacts: Peter P. McLaughlin and Mojisola A. KunleDare

A collaborative study of the offshore geology of the Middle Atlantic region utilizing the DGS Outer Continental Shelf sample repository

One of the missions of the DGS is to understand the geology of the lands under the ocean adjacent to our state, providing information that can become the basis for our state government's input on federal government plans and activities on the U.S. Outer Continental Shelf (OCS). The DGS is nearing the end of a three-year collaborative study of the offshore geology of the Middle Atlantic region called the Middle Atlantic Offshore Carbon Storage Resource Assessment Project (MAOCSRAP). The project is supported by a grant from the U.S. Department of Energy that is administered by the Battelle Memorial Institute; project partners include the Maryland Geological Survey, the Pennsylvania Geological Survey, Columbia University, and Rutgers University.

The DGS has taken a lead role in the analysis of hydrologic properties of the offshore geological formations. The hydrologic properties characterization utilizes well and geophysical data collected by oil and gas exploration drilling in the U.S. North Atlantic, Middle Atlantic, and South Atlantic offshore regions between 1977 and 1984. The DGS OCS Sample and Data Repository is an important resource for this effort because the collection holds all remaining samples from 51 oil and gas wells drilled during that period. These samples were consolidated in the DGS collection after other repositories deaccessioned their Atlantic OCS sample holdings. Samples include cores, unwashed cuttings, vials containing samples processed for micropaleontology and palynology, and thin sections of core, cuttings, and micropaleontology and palynology splits.

Relying heavily on this collection, the DGS has taken the lead on coordination of sample-based analyses of hydrologic properties (principally porosity and permeability) and on the compilation of older data documented in well reports in the collection and in geological publications. The DGS has also participated in integration of well data with geophysical data and in the construction of geological maps and cross sections of the offshore region. After all analyses and compilation work is complete, the results of this project will be provided to the U.S. Department of Energy to assist in their national evaluation of carbon dioxide (CO_2) storage potential in offshore regions.

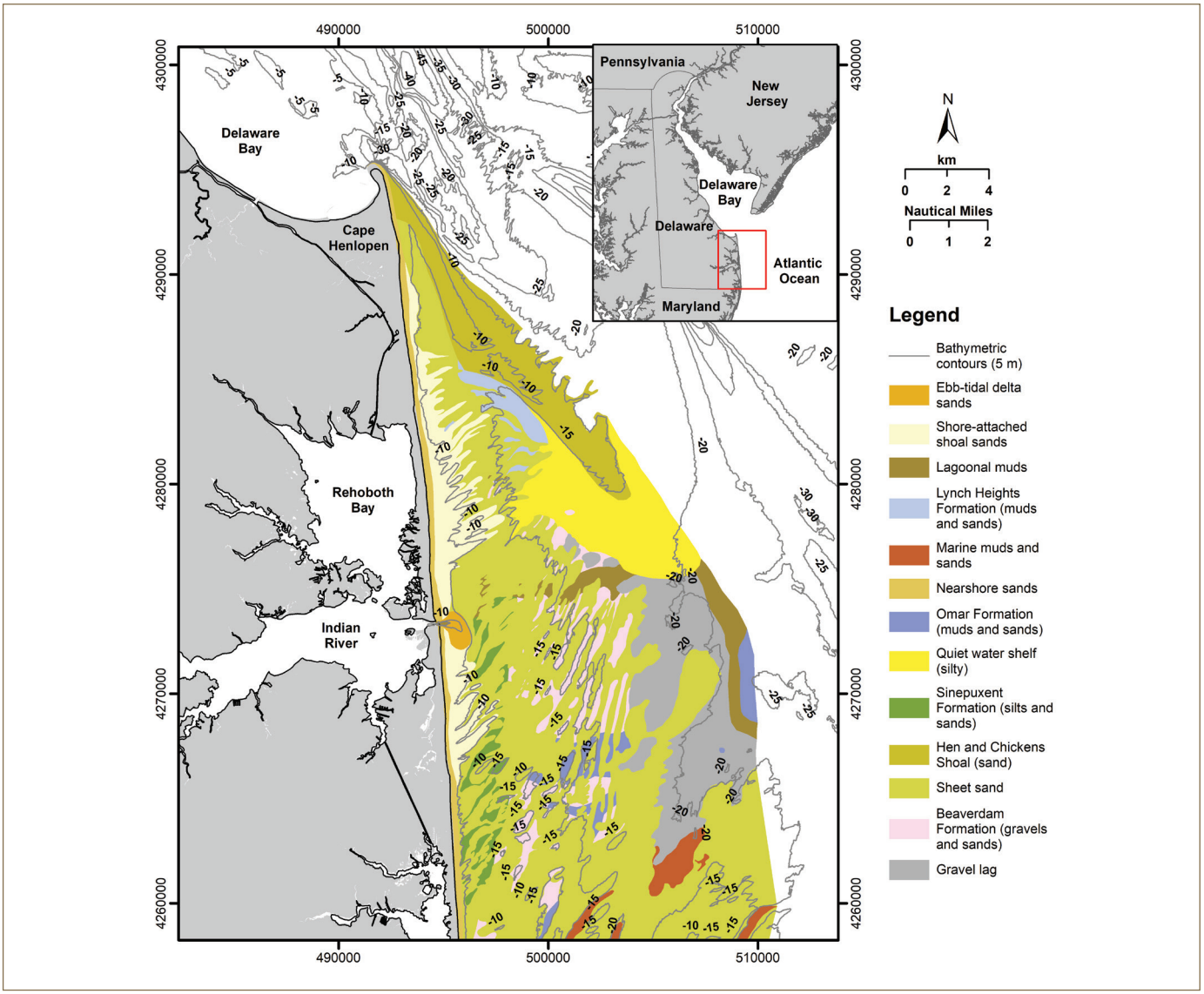
Delaware Offshore Sand Resources - Update

Project Contacts: Kelvin W. Ramsey and Robin Mattheus

Identifying sand resources for coastal resiliency and restoration efforts

The DGS is wrapping up its work as part of a cooperative agreement with the Bureau of Ocean Energy Management (BOEM) to map the geology of the continental shelf for resource allocation purposes. The Atlantic Sand Assessment Project (ASAP) seeks areas in federal waters (beyond three miles from shore) to serve as potential borrow sites for beach-quality sand. Sediment cores and subsurface reflection data provide insights into the three-dimensional distribution of different sediment types across the shelf. Maps generated from these data provide information about surface composition (e.g. muddy versus sandy units) and corresponding sediment thicknesses, which are used to estimate sediment volumes.

Newly acquired data have resulted in the refinement of previous geologic maps of the shelf and extended map coverage offshore by several miles. The boundaries between different map units are now also reconciled with seafloor topography, offering a more process-based understanding of the distribution of different sediment types across the seafloor. While beach-quality sands blanket more than 50 percent of the seafloor by surface area, thicknesses are highly varied and many areas are only covered by thin, discontinuous ribbons of sand. Underlying units, which include muddy valley fill deposits, gravel lags, and coarse-grained riverine sediments, are unsuited for beach replenishment. These are commonly encountered at the seafloor across the central portion of the study area.



Updated geologic map of offshore Delaware generated using seismic and core data acquired during the BOEM sand resource project.

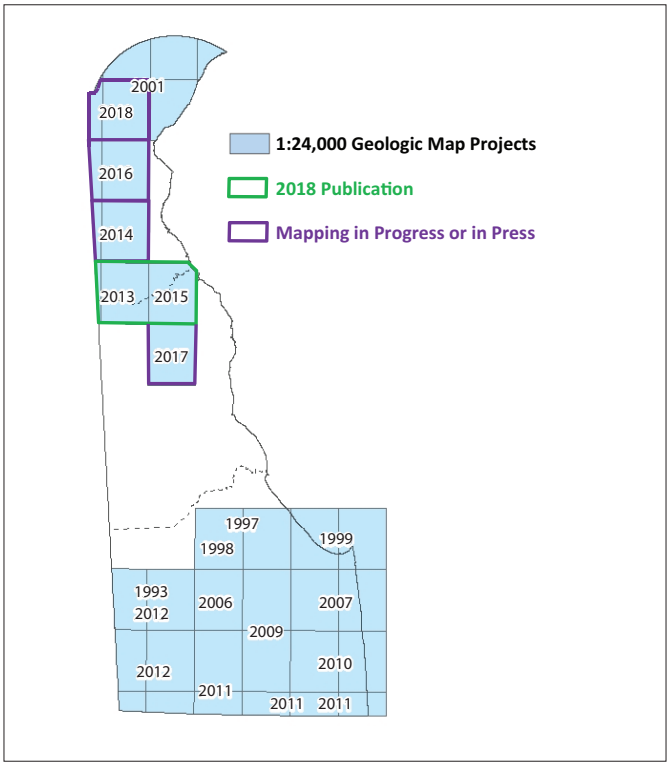
Delaware Geologic Mapping Program – Update

Project Contacts: Kelvin W. Ramsey and Jaime L. Tomlinson

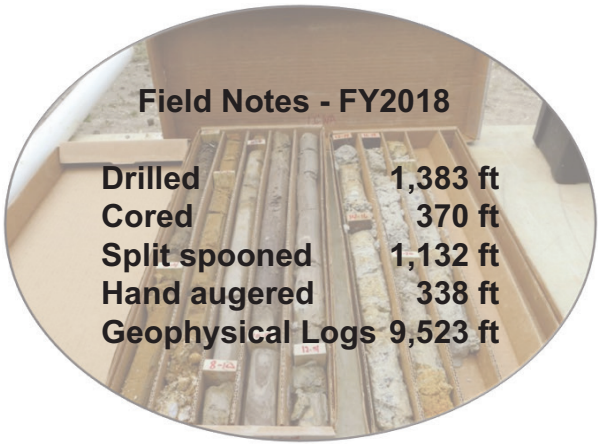
Mapping the surficial geology of Delaware through the STATEMAP federal cost-share program

The primary goal of the DGS geological mapping program is to map surficial geology of the First State at the detailed scale of 1:24,000. Geologic maps provide an understanding of the earth materials beneath our feet, benefiting Delawareans by defining the subsurface geologic framework that has applications for characterizing groundwater, land-use planning, natural hazards, environmental geology, soils/agriculture, and geotechnical engineering. The USGS STATEMAP Program provides federal dollar-for-dollar matching funds for most of DGS's geologic mapping efforts. Products from the mapping efforts include PDF map publications as well as digital data (shape and data point files) that can be downloaded and imported into GIS software.

The current map area is the Newark West and Newark East Quadrangles. Fieldwork for this project began in July 2018 and will be completed in June 2019. Geologic Map Number 24, Millington, Clayton and Smyrna Quadrangles, was published in April 2018.



Index map of Delaware showing 1:24,000-scale geologic maps funded by the STATEMAP Program. Dates indicate the STATEMAP project year.

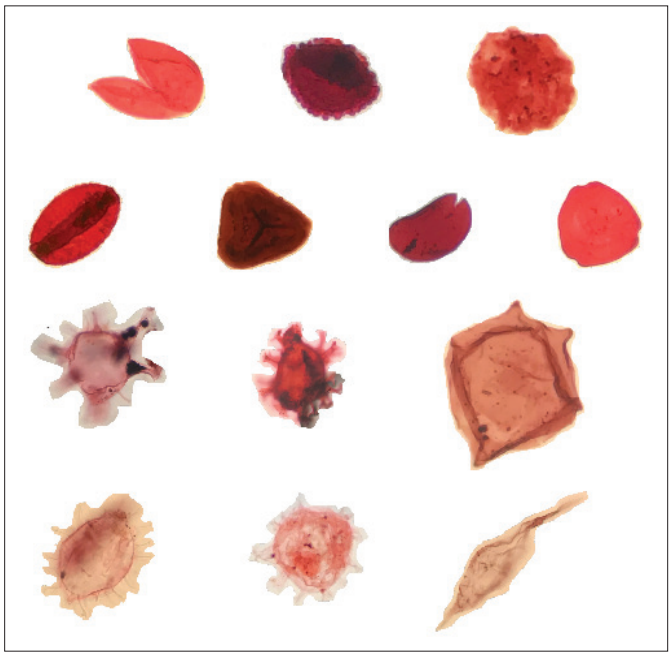


Geological Characterization of Aquifers and Depositional History of the Miocene Sediments of Northeast Sussex County, Abbott's Mill Core Site

Project Contact: Peter P. McLaughlin, Jr.

An investigation of confined aquifers important for the communities of southern Kent County and northern Sussex County

Four Miocene-age confined aquifers are important sources of groundwater in central and southern Delaware: Cheswold, "Federalsburg," Frederica, and Milford. These aquifers are composed of shelly sands and are superficially quite similar. However, local variations in their character and the presence



Fossil pollen (12 to 22 million years old) from the Calvert and Choptank Formations of the Abbott's Mill borehole (from master's thesis of Tyler Buchanan, 2018).

of minor local sand bodies in between some of them can create difficulties for detailed delineation in the subsurface. The DGS drilled a test-hole in 2016 at Abbott's Mill Nature Center southwest of Milford to obtain samples that would help us better understand the nature of underground connections between these aquifers. Research on the cores from Abbott's Mill form part of UD master's thesis project supervised by DGS staff. This project includes detailed description of the sediments in the cores and calibration of geophysical logs to the sediment types to better understand the geophysical character of the aquifers. The study also includes analysis of fossil pollen and dinoflagellates (a type of marine algae) to help guide subsurface correlation of the aquifer sands. The results of this work will enable the DGS to further refine our understanding of trends in aquifer quality and the nature of minor sand bodies between the major aquifers. The results of this work will be documented in a future DGS report.

Creation of an Improved Accuracy LiDAR-Based Digital Elevation Model for the St. Jones and Blackbird Creek Reserves

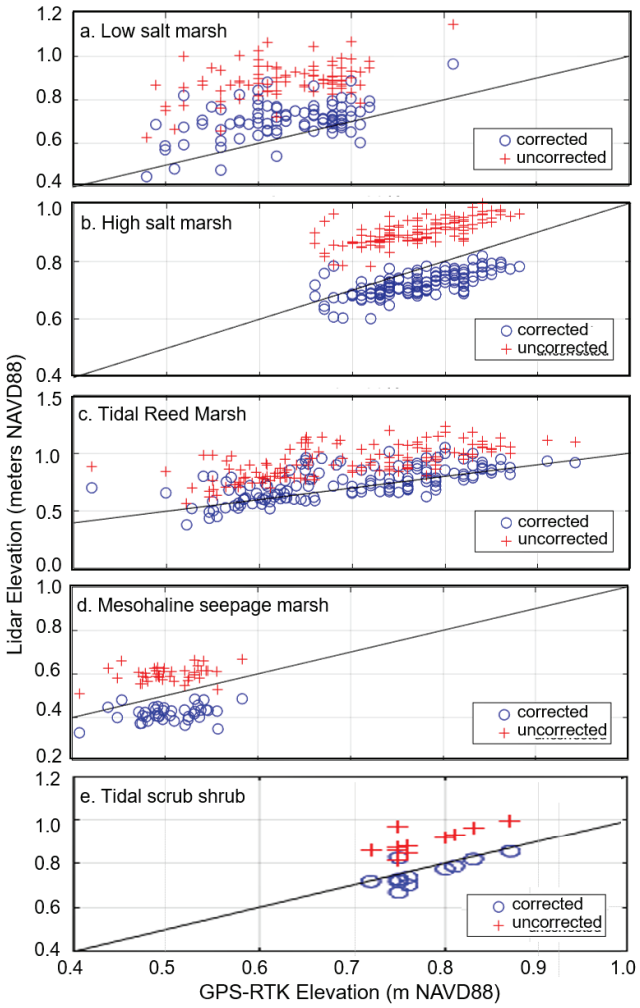
Project Contacts: Thomas E. McKenna, John A. Callahan, and Catherine L. Medlock

Developing a methodology to reduce elevation errors in saltwater tidal wetlands due to vegetation and provide a corrected DEM for the Delaware National Estuarine Research Reserve

In tidal wetlands, small differences in elevation can have large impacts on hydrology, vegetation, and habitat. Light Detection and Ranging (LiDAR)-derived Digital Elevation Models (DEM), currently used throughout Delaware as the best measure of elevations over large areas, suffer from errors in areas with dense vegetation, reducing their effectiveness in wetland applications. GPS-RTK measurements and GIS techniques are employed to better understand and reduce vertical bias in the 2014 Delaware LiDAR-derived DEM for saltwater wetlands in the watersheds containing the St. Jones and Blackbird Creek research reserves.

Three methods were evaluated in the current study: mean overall bias, mean bias per vegetation community, and minimum-value bins derived from the LiDAR point cloud, with the mean bias per vegetation type method reducing error the most.

Overall, the 2014 Delaware DEM was found to have a 13 centimeter (cm) to 26 cm positive elevation when compared to GPS-RTK points and the magnitude of the bias was dependent on vegetation communities. Bias correction factors were developed for the three correction methods and were



Uncorrected and corrected elevations using linear regression by vegetation community.

subtracted from the DEM to produce a corrected DEM. With accurate vegetation maps, the bias in LiDAR elevations in tidal marshes can be significantly reduced, leading to improved assessments of vegetation health and a better understanding of marsh behavior under changing hydrologic conditions.

This project was funded by DNREC Coastal Programs and by the DGS.

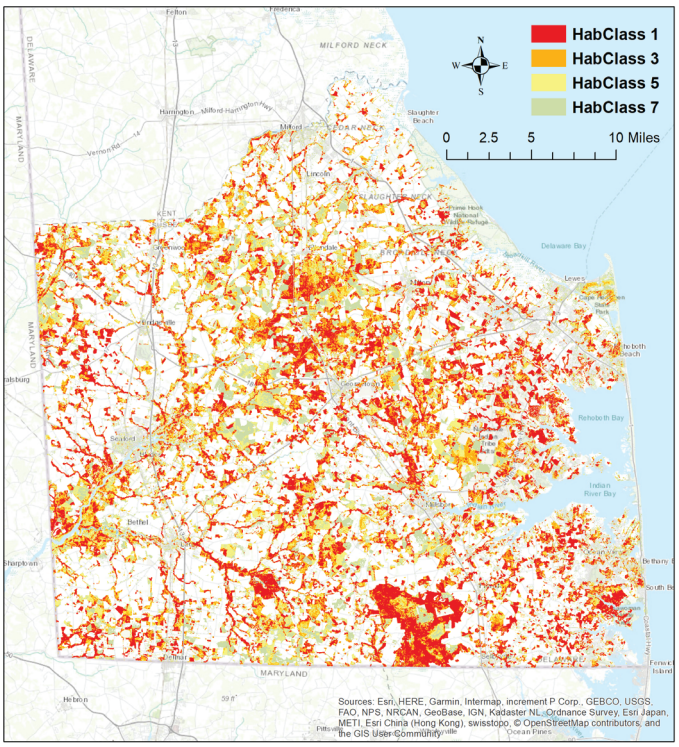
Development of Delmarva Fox Squirrel Habitat Maps from LiDAR Data for Sussex County, Delaware

Project Contacts: John A. Callahan

Habitat analysis from LiDAR-based data products offer a valuable tool for natural resource and wildlife management

The DGS worked with the DNREC Division of Fish and Wildlife to identify potential locations of suitable habitat for the endangered Delmarva fox squirrel (Sciurus niger cinereus). Part of the Delaware Division of Fish and Wildlife's conservation plan includes translocation of Delmarva fox squirrels (DFS) from Maryland to Delaware to increase Delaware population vitality. Suitable DFS habitat is characterized as mature forest stands of mixed hardwood and pines with closed canopy and somewhat open understory. Forest canopy height data from the NASA Carbon Monitoring System (CMS) project, derived from the 2014 statewide LiDAR acquisition, are used to identify potential DFS habitat in Sussex County, Delaware. The use of LiDAR data allows widespread inventory of forest stand height and canopy closure, which can be used as a surrogate for forest maturity and allow identification of potential DFS habitat.

Smooth, contiguous coverage layers and area statistics were produced for potentially suitable DFS habitat classes and the immediate surrounding areas in Sussex County. The most suitable habitat classes (HabClasses 1 and 3 in the map) were generally defined as: forest canopy height over 20 m and canopy closure greater than 80 percent (class 1), and forest canopy height 16.4 – 24.99 m and canopy closure 60 - 100% (class 3). These two classes total over 565 km² (304 km² for class 1 and 261 km² for class 3) within Sussex County. This type of analysis has the potential to allow for widespread habitat characterization for additional animal and plant species.



Potential Delmarva fox squirrel habitat based on analysis of forest height and canopy closure derived from LiDAR data for Sussex County, Delaware.

Delaware State Fossil

Belemnitella americana

Belemnite was established in 1996 by the Delaware General Assembly as the Delaware State Fossil, and is the common name applied to an extinct order of mollusks belonging to the cephalopod (squid, octopus) class. It was most closely related to the squid as it had an internal shell covered by a leathery skin and tentacles that pointed forward. Belemnoids reached their greatest abundance and diversity during the Jurassic and Cretaceous periods (approximately 200-65 million years ago).

The best place to look for Belemnitella americana in Delaware is in the dredge spoil piles on the north side of the Chesapeake and Delaware Canal.

Images obtained from http://www.geocities.com http://www.comune.gallio.vi.it

3. Natural Hazards

DGS Natural Hazards Emergency Response Program

Project Contacts: Stefanie J. Baxter, Kelvin W. Ramsey, John A. Callahan, and David R. Wunsch

Coordination of DGS activities related to assessing natural hazards and risks associated with earthquakes, floods, and storms, and providing support to emergency managers

A major responsibility of the DGS is to understand natural hazards in the First State that present risks to human life or property. Our Natural Hazards program includes scientific initiatives as well as event-driven advisement to emergency management agencies. For example, DGS staff participated in approximately 18 bridge calls with emergency managers in the last 12 months. DGS is a designated participant in the Delaware Emergency Operations Plan, and provides service to the State Hazard Mitigation Council.

Our most frequent emergency operations activity is storm response. DGS staff works with DNREC, DelDOT, and other federal, state, and county groups on the Delaware Storm Reporter Advisory Group, an online program that enables the rapid delivery of coastal storm damage information. The DGS also serves on the DEMA Emergency Response Task Force for flooding, nor'easters, and hurricanes. When storm threats require, DGS staff participate in response efforts at DEMA headquarters to monitor stream and tide gages as well as provide as-needed, real-time advice to New Castle, Kent, and Sussex County emergency managers. A key resource is the Delaware Coastal Flood Monitoring System (CFMS), which provides email and text alerts, as well as web-based inundation maps and elevation profiles of evacuation routes, based on real-time forecasts to communities along the Delaware

DGS associate scientist, John Callahan, speaks to DEMA staff about coastal flooding.

Bay coast. In addition, DGS continuously maintains storm books for 16 USGS stream gages—13 in Delaware and three in neighboring Pennsylvania—that record the date, time, and flow stage for all significant storms in the region so estimates can be made regarding the severity of flooding based on predicted precipitation amounts from approaching storms.

The DGS and the UD Center for Environmental Monitoring and Analysis (CEMA) hosted a day-long training session for DEMA officials, which highlighted how DGS and CEMA collect data used throughout the state by emergency managers. The experience enabled officials to gain an understanding of how seismic, streamflow, and weather data are collected and gave them a historical look at big storms that affect the East Coast.

I Feel the Earth Move

Project Contact: Stefanie J. Baxter

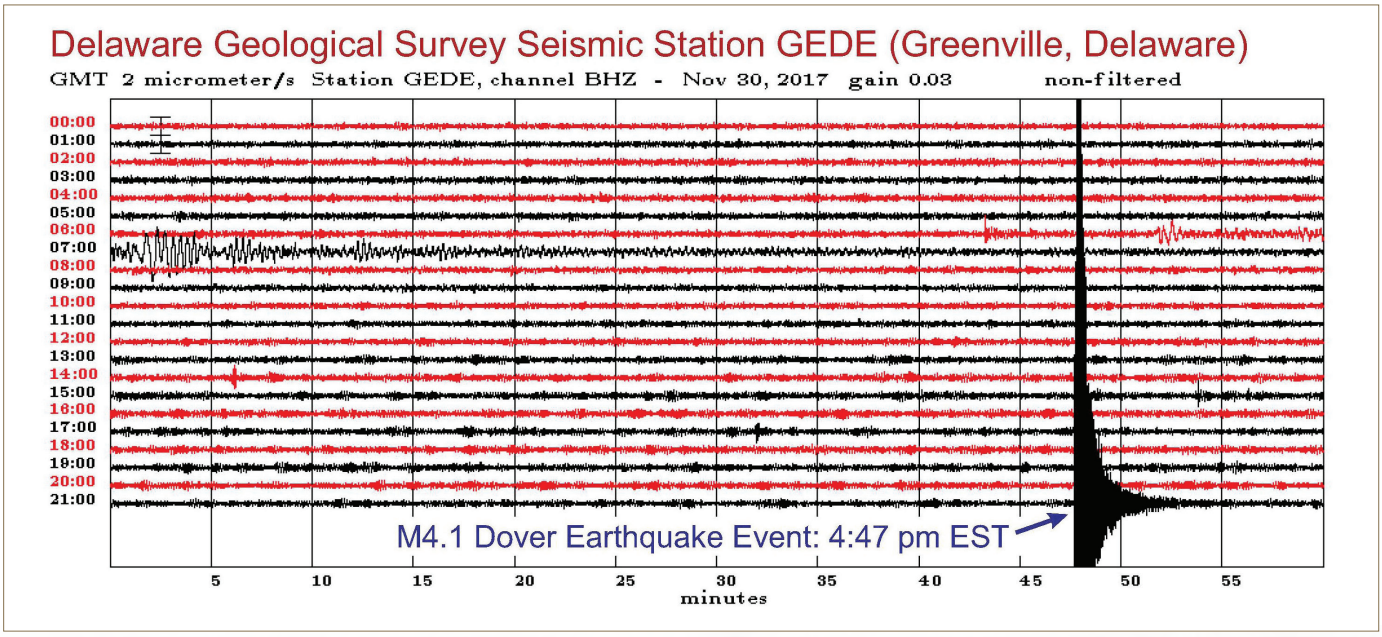
A historical 4.1 magnitude earthquake occurs in Dover, Delaware, on November 30th, 2017

The largest measured earthquake to occur within Delaware was recorded on November 30, 2017. The magnitude 4.1 event occurred at 4:47 p.m. with an epicenter located six miles northeast of Dover in Bombay Hook National Wildlife Refuge, according to data reported by the USGS. Analysis of the shaking associated with the Dover earthquake indicates that the source was approximately 3 km (10,000 ft) beneath the land surface in deep crystalline basement rocks and had a predominantly strike-slip direction of motion (side-ways movement along a fault zone) with a significant thrust component (some upward movement along the fault), probably along a deep pre-existing fault related to the past tectonic episodes.

DGS operates a network of seismic stations in the state of Delaware to monitor earthquakes and feeds data into the Lamont-Doherty Cooperative Seismographic Network as well as to the USGS. These stations provide publically available, real-time data on seismic signals that occur. The DGS seismic station, located in Greenville in New Castle County, was the first station to receive the seismic wave from this earthquake.

The Delaware earthquake of 2017 was felt in locations throughout the state and along the eastern seaboard from central Virginia to Massachusetts. Reports compiled on the internet by the USGS and DGS indicate a Modified Mercalli Intensity of IV felt closest to the epicenter and III around most of the region. An intensity of IV is generally associated with light shaking that is felt by many indoors but not as commonly felt outdoors. Dishes, windows, and doors may be disturbed; walls make cracking sound; and the earthquake may have a sensation like heavy truck striking a building. An intensity of III is commonly quite noticeable to persons indoors, especially on upper floors of buildings, but many people may not recognize it as an earthquake. It may feel similar to vibrations from the passing of a truck.

As of December 15, 2017, the DGS website had received approximately 260 "felt reports" from individuals in and around Delaware, with an average intensity reply between Mercalli III and IV. Higher intensities, commonly VI, were reported closer to the epicenter, mostly in Kent County, with many of the reports associated with shaking of dishes, teapots, and lamps. The USGS also received nearly 17,000 reports through the internet from throughout the northeastern United States.



The earthquake was the fifty-eighth documented event in Delaware since 1871, but it is only about every decade or so that there is an earthquake that people feel. To put that into perspective, approximately 3 million earthquakes occur worldwide each year, but 98 percent of them are less than a magnitude 3.

The 2017 Dover earthquake matched the previous largest event in Delaware, which occurred in 1871 and was estimated to have had a magnitude 4.1 based on the historical accounts of shaking. The largest previously recorded (by instrumentation) event in Delaware occurred in 1973 and had an estimated magnitude of 3.8.

The Delaware Coastal Flood Monitoring System

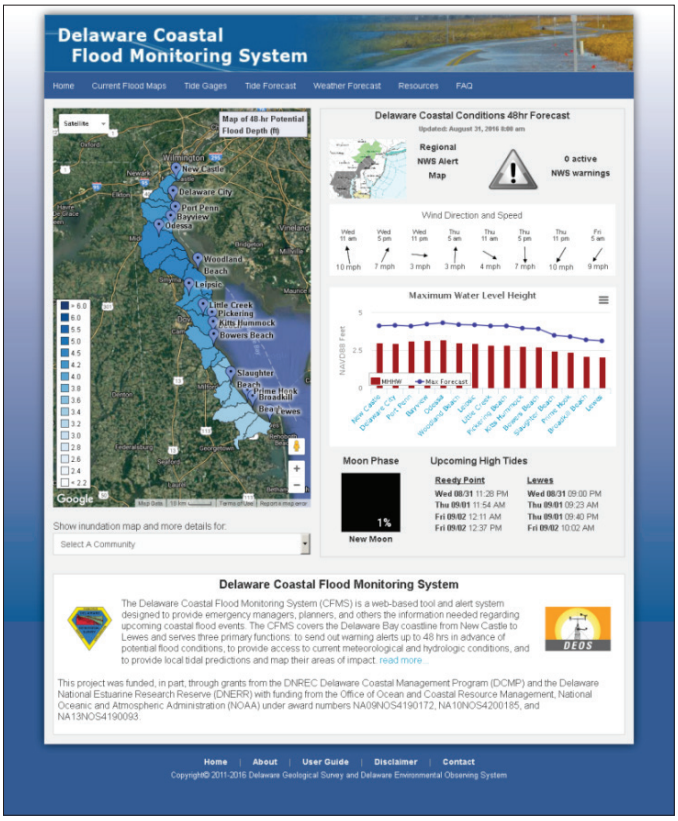
Project Contact: John A. Callahan

A real-time coastal flood monitoring and early warning system for Delaware coastal communities

The Delaware CFMS is a web-based early warning system designed to provide emergency managers, planners, and others information on the extent, timing, and severity of upcoming flood events. The CFMS is currently operated and maintained jointly by the DGS and CEMA, and was developed in partnership with the DEMA and DNREC Delaware Coastal Programs (DCP) in response to the significant damage caused by the Mother's Day Storm of 2008, which left at least one person dead and many people homeless causing evacuations in many communities within Kent County along the Delaware Bay coast. The CFMS has been in use since 2013 by Delaware state agencies and the National Weather Service in preparation for upcoming storms.

The CFMS covers the Delaware Bay coastline from the City of New Castle to Lewes (15 communities), and provides email or text alerts up to 48 hours in advance of potential coastal flooding. Each community includes real-time flood inundation maps, road elevation profiles, and current meteorological and hydrological conditions from local tide gages on the website. Information is available in real-time and updated every six hours from the NOAA hydrodynamic Delaware Bay Operational Forecast System (DBOFS). The CFMS is continuously being improved, with recent updates including the addition of forecasted wind speed and direction, integration of a new high-resolution Digital Elevation Model, new server hardware, and updated road elevation profiles.

In the last two decades, large tropical storms such as Hurricanes Katrina, Sandy, and Harvey, as well as numerous strong nor'easters along the mid-Atlantic coast, have resulted in significant loss of life, injuries, and property damage in the United States. Much of the damage was the result of severe coastal flooding. Sea-level rise, land subsidence, flat open coastal terrain, and significant coastal development and recreational activities leave the Delaware coastline extremely vulnerable to such events. The CFMS plays an important role in the planning, preparedness, and emergency response for many coastal communities in Delaware.



Screenshot of the home page of the Delaware Coastal Flood Monitoring System, which is a web-based tool and alert system designed to provide emergency managers, planners, and others the information needed regarding upcoming coastal flood events.

Determination of Future Sea-Level Rise Planning Scenarios for Delaware

Project Contacts: John A. Callahan, Thomas E. McKenna, and David R. Wunsch

Updating Delaware sea-level rise planning scenarios based on latest research and observations

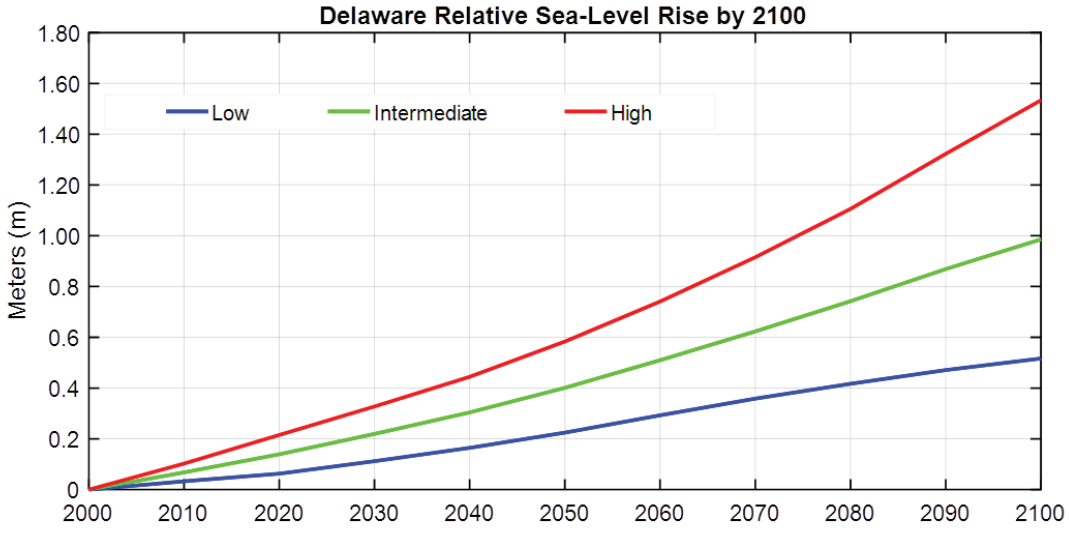
Sea-Level Rise (SLR) is one of the most significant impacts of climate change. Delaware is especially vulnerable to the effects of SLR due to its flat topography, low mean elevation, and significant community development and infrastructure investments along the coast. Rates of relative SLR measured

at tide gages in and around Delaware are approximately twice the rate of global mean SLR. Delaware has had future SLR scenarios (projecting SLR out to year 2100) in place since 2009 to use in long-term planning activities. Those scenarios were integrated into many town and county plans and formed the basis of two significant DNREC reports: the Delaware Sea-Level Rise Vulnerability Assessment in 2012 and the Delaware Climate Impact Assessment in 2014. However, Executive Order 41: Preparing Delaware for Emerging Climate Impacts and Seizing Economic Opportunities from Reducing Emissions, the "roadmap" for state agencies to prepare for the impacts of climate change, specifically calls for the periodic update of the SLR planning scenarios.

The DGS worked closely with DNREC DCP to lead the formation of the Delaware Sea-Level Rise Technical Committee, composed of regional scientific and local planning experts, to examine the 2009 SLR planning scenarios and recommend new SLR planning scenarios, if necessary. Much research has been conducted since 2009 regarding both historical reconstructions and computer modeling of various factors influencing rates of SLR, resulting in several key reports, such as the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report in 2013 and the third U.S. National Climate Assessment in 2014. DGS also led the development of a technical report that summarizes the impacts of SLR in Delaware, recent research on historic SLR reconstructions, data from tide gages located within the Delaware region, several recent international and national assessments on projecting future SLR conditions, and provides recommendations of new SLR scenarios to use in Delaware long-range planning activities.

The new SLR planning scenarios recommended in the report correspond to increases of mean sea level in Delaware by the year 2100 of 1.53 m / 5.02 ft (High scenario), 0.99 m / 3.25 ft (Intermediate scenario), and 0.52 m / 1.71 ft (Low scenario). These scenarios were based on a scientific methodology that combines the latest physical climate model results from the IPCC, locally observed tide gage data, and expert elicitation into a probabilistic approach. This methodology provides a physical basis of the time evolution of SLR, enabling estimates of SLR amounts at times before year 2100. Additionally, the report provides guidance on how best the state and local communities could use the new scenarios, including reasons why for some cases, planning for SLR amounts greater than the High planning scenario might be appropriate. This work will help planners, developers, coastal managers, and state regulatory agencies in Delaware make more informed decisions based on the level of risk planners are willing to assume regarding the effects of sea-level rise.

Concurrent to the development of the technical report containing the new SLR planning scenarios, DGS worked with DNREC DCP to produce a series of coastal inundation maps. These maps are based on the high-resolution, digital elevation model derived from 2014 LiDAR data. The bathtub-model based maps depict the potential extent of inundation at various water levels, starting from the current high tide (MHHW level) up to 7 feet above in 1-ft increments. These maps can be used as a planning tool for potential future effects of sea-level rise or storm surge due to coastal storms.



The 2017 SLR planning scenarios for Delaware to the year 2100.

More information regarding the development of the SLR technical report or coastal inundation maps can be found at https://www.dgs.udel.edu/slr.

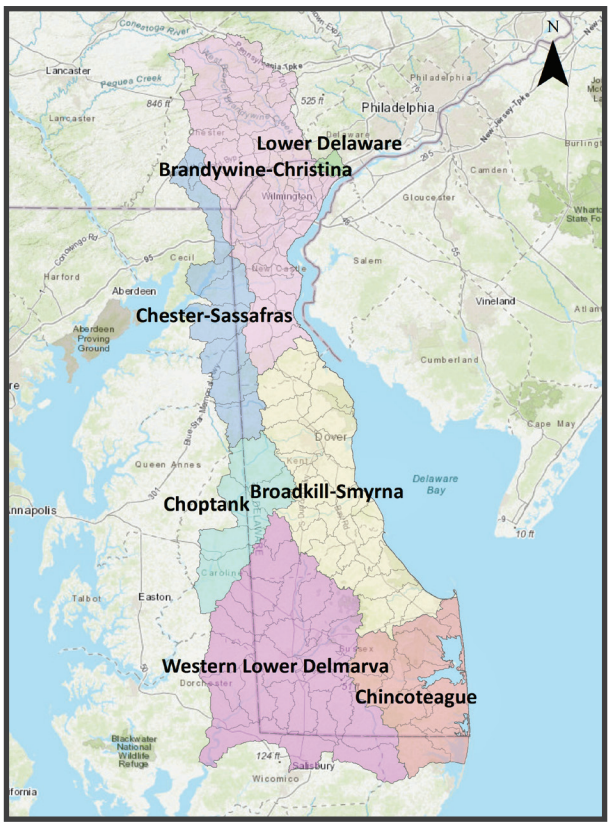
Delaware StreamStats

Project Contacts: John A. Callahan, Beatrice O'Hara, Daniel L. Warner, and David R. Wunsch

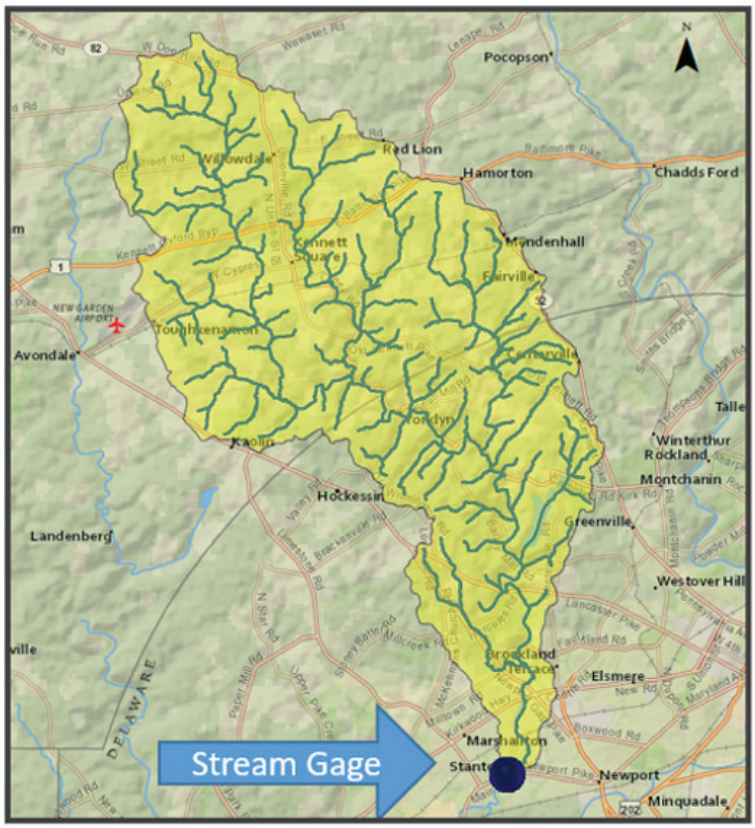
Digital Elevation Model, GIS, and Watershed Analysis to Support Update of USGS StreamStats

The USGS StreamStats application is a valuable online, map-based tool for water resource management and engineering design. StreamStats allows users to obtain drainage basin characteristics and peak streamflow statistics at any location along a stream, gaged and ungaged. The application takes advantage of statistical relationships between stream peak flow statistics and several drainage basin characteristics, such as basin size, average slope, percent of developed land cover, and more. For example, this allows the calculation of the 1% flood event at a location where a bridge may be constructed over an unmonitored stream, or at a location where planned development will occur.

Statistics behind the existing version of Delaware StreamStats was released by USGS in 2006. Numerous high flood events from coastal storms and heavy rains as well as changes in land use and land cover have occurred since that time. Supported by DelDOT, the DGS and USGS are jointly updating the data behind Delaware StreamStats. The DGS is integrating the LiDAR-derived 2014 DEM for Delaware with elevation data from surrounding states to develop a regional, seamless DEM. This DEM is then used to update the National Hydrography Dataset (NHD) and Watershed Boundary Dataset (WBD) in order to perform the watershed analysis. Once drainage basins are delineated for streamgages in and around Delaware, over 20 basin characteristics are clipped and summarized for each basin. Those data are ingested into regression equations to develop relationships with peak streamflow statistics, and ultimately to update the online StreamStats application.



Watersheds of Delaware from the National Hydrography Dataset.



Drainage basin of the Red Clay Creek at Stanton streamgage.

4. Information and Data Dissemination

Online Open Data Access

Project Contacts: John A. Callahan and Lillian T. Wang

DGS research data available online and via web mapping services

The DGS strives to continually improve the way we make our hydrologic, geologic, and other research data available online. Most datasets are available through the DGS website in tabular or GIS data formats. Downloadable data files are distributed in industry standard formats (e.g., zipped, comma-delimited, Excel) while the web mapping services allow for direct access to DGS data via GIS software (e.g., ESRI ArcGIS, Quantum GIS) or website applications (e.g., Google Maps) without the need for downloading data files—providing easy access for state agencies, academic research groups, industry, and the public. DGS distributes data and services via open, interoperable formats and protocols compatible with both proprietary and open-source GIS and programming packages, supporting as wide a user group as possible.

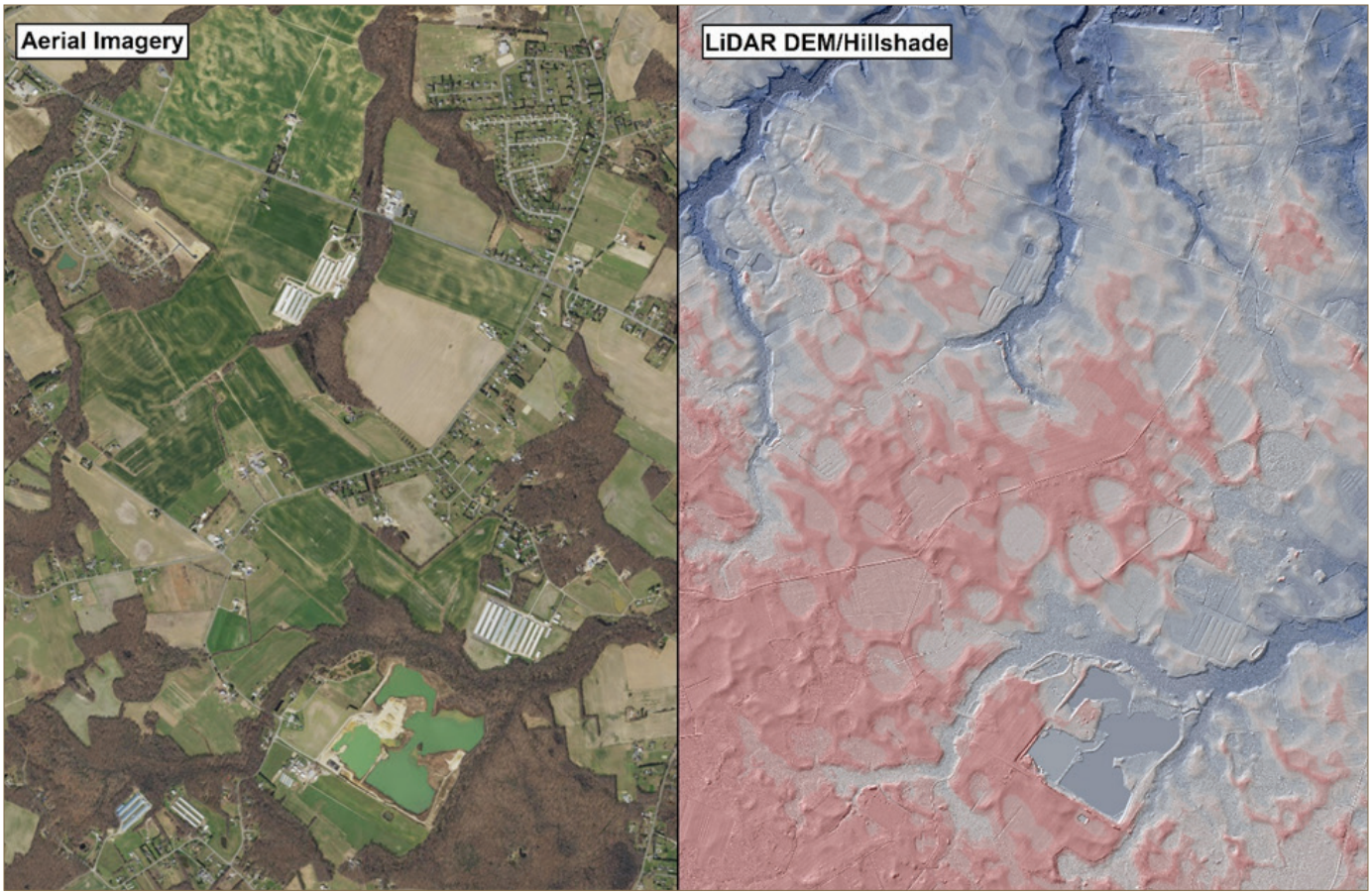
Statewide LiDAR Program for Delaware

Project Contacts: John A. Callahan and Daniel L. Warner

Distribution of LiDAR and elevation data products for Delaware

LiDAR is an active remote sensing method that uses a pulsed laser to measure distances from a source to a target object. Airborne LiDAR data for the entire state was collected in 2014 as part of a multi-agency state and federal effort (including the DGS, DNREC, USGS, and NOAA) and funded by the Hurricane Sandy Relief appropriation. Acquisition of the 2014 LiDAR met Quality Level 2 specifications with a sampling density of greater than 2 points per square meter and an open terrain accuracy of 6.3 cm. In addition to the raw LiDAR points, a classified point dataset, hydrographic breaklines, a LiDAR intensity image, and a hydro-flattened 1-meter DEM were derived by the vendor. All of these datasets are available from the DGS.

The 2014 LiDAR datasets are also being used for a number of studies at the DGS including development of topographic contours, modeling coastal inundation scenarios, updating topographic maps, salt marsh elevation studies, examination of potential bacterial and nutrient source areas, and habitat analysis. In addition, the LiDAR-derived DEM and hillshade allow excellent visualization of the land surface, even in heavily vegetated areas, which can be used for landscape feature identification, site reconnaissance, and



Carolina Bays, spread throughout Delaware yet nearly invisible in traditional aerial photography, can be easily identified and mapped using LiDAR-derived elevation and hillshade products.

identification of historical features such as mill races, roads, and building sites. The DGS will store and maintain the LiDAR dataset and derivatives as well as provide expertise for Delaware.

The Delaware Geologic Information Resource (DGIR)

Project Contacts: A. Scott Andres and John A. Callahan

Delivering DGS data to state agencies and the public using web-based technologies

DGIR is designed to deliver online the most commonly available and requested geologic and hydrologic information served by the DGS. The application provides an intuitive and comprehensive toolset for locating, quickly viewing, and downloading hydrogeologic information. DGIR includes a rich variety of DGS data and products, including point data such as well lithologic logs, geophysical logs, and groundwater levels as well as areal data such as geologic maps, water table depth, and aquifer thickness. DGIR also allows a user to combine DGS-published datasets alongside other external Delaware datasets (e.g., town boundaries, hydrology, roads, watersheds, orthophotography) into a single web-based map interface, with direct access to metadata, data files, and map services.

Although the project is currently focused on providing information to DNREC and the Delaware professional geosciences community, the application is open for public use. Approximately 7,300 wells with 38,000 lithologic descriptive records and 3,200 geophysical logs, and over 1,000 wells with hydrologic information are available via DGIR.

Cooperative Geoscience Data Networks

Project Contact: John A. Callahan

Distribution of DGS data through national and international networks

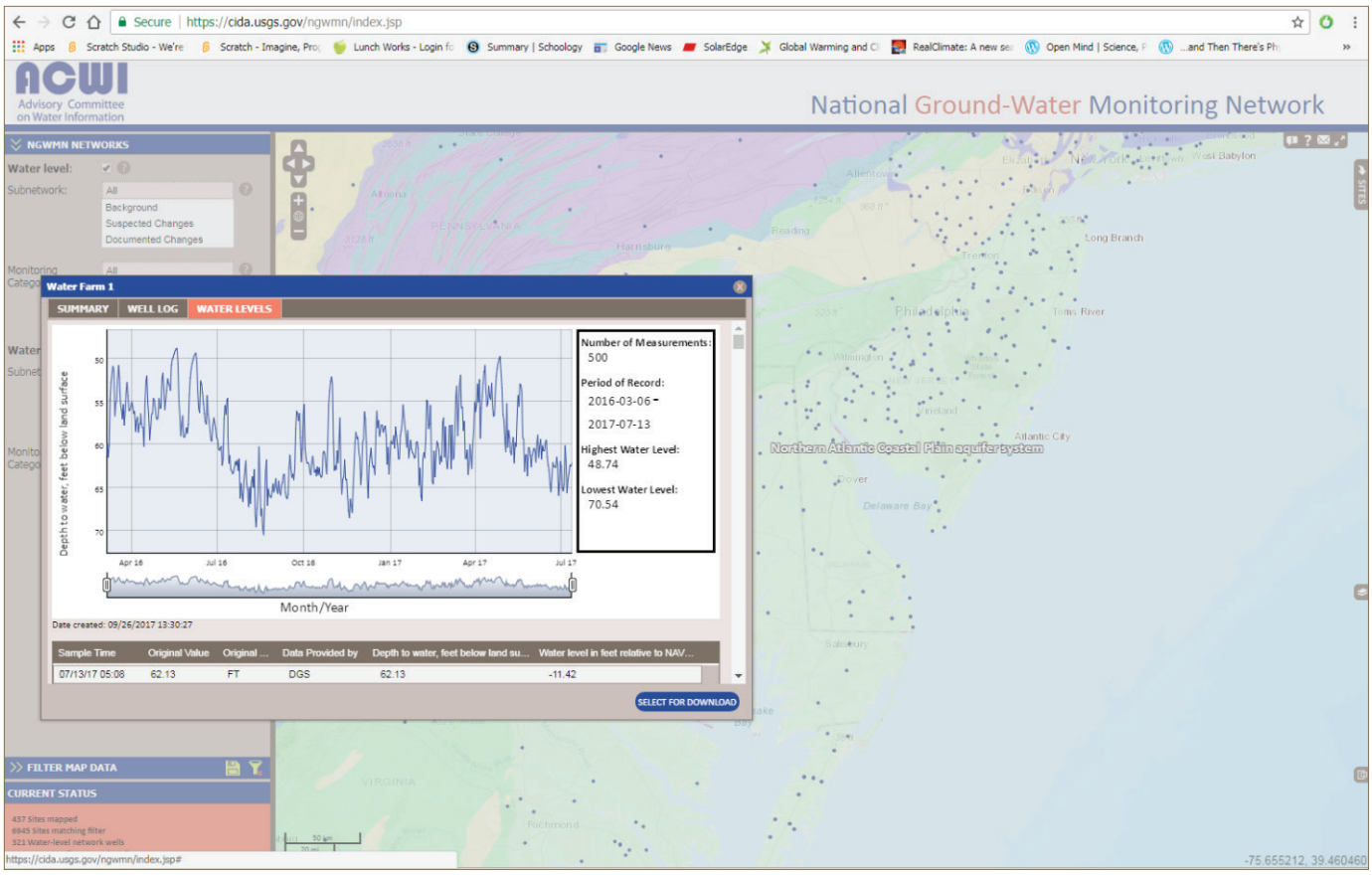
The DGS has recently become involved in multiple large-scale geoscience data networks: the National Groundwater Monitoring Network (NGWMN), a product of the Subcommittee on Ground Water of the Federal Advisory Committee on Water Information (ACWI); the United States Geoscience Information Network (USGIN), which supports the National Geothermal Data System (NGDS);

and the OneGeology initiative, international initiative of the geological surveys of the world.

The USGIN initiative is the product of a partnership between the AASG and the USGS that was created to facilitate the discovery of, and access to, geoscience information provided by U.S. state and federal geological surveys. DGS received funding to partner with the Arizona Geological Survey to establish a clearinghouse node on the USGIN for Delaware geoscience information, and to standardize distribution formats and protocols. Mapping services and metadata hosted on the Delaware node can be searched through the DGS website or other USGIN nodes, and contains data descriptions, contact information, and direct links to downloadable data and other information. All surface geologic maps published by the DGS since 1993 as well as datasets related to geothermal properties of Delaware are available through USGIN/NGDS.

OneGeology (http://www.onegeology.org/) is an international effort to make available digital geologic map data from around the world. Each country, state, or province that participates in OneGeology will store its own data and serve its own public services, but the effort has a special focus on developing a common infrastructure and set of open and interoperable web mapping service protocols. DGS manages and has submitted statewide web mapping services of 1:100,000-scale surficial geologic units and 1:100,000-scale surficial geologic contacts. Currently, DGS maintains a Four Star web service accreditation rating and is one of only a few states in the U.S. that participates in OneGeology.

During this past year, DGS has joined the NGWMN, a consortium of state and local agencies and the USGS that was established in 2013 to create a single point of access for scientists, engineers, policy makers, and the public to view and acquire important physical and chemical data on the nation's groundwater resources. DGS contributes groundwater levels, lithologic data, and water quality information from a selected set of wells to the national portal though XML web data services (https://cida.usgs.gov/ngwmn).



Screenshot of the NGWMN Data Portal displaying a hydrograph of groundwater for a well in Delaware.

PUBLICATIONS

DGS PUBLICATIONS COMPLETED

REPORT OF INVESTIGATIONS

RI 81 Characterization of Tidal Wetland Inundation in the Murderkill Estuary

RI 82 Southern New Castle - Northern Kent Counties Groundwater Monitoring Project: Results of Subsurface Exploration and Hydrogeological Studies

OPEN FILE REPORTS

OFR 51 Groundwater Monitoring Procedures Part 1: Equipment and Procedures for Manual and Automated Field Measurement of Groundwater Levels in Dedicated Monitoring Wells

OFR 52 Results of Groundwater Flow Simulations in the East Dover Area, Delaware

GEOLOGIC MAPS

GM 24 Geologic Map of the Millington, Clayton, and Smyrna Quadrangles, Delaware

DGS PUBLICATIONS IN PROGRESS

REPORT OF INVESTIGATIONS

RI 83 Aquifers and Groundwater Withdrawals, Kent and Sussex Counties, Delaware

RI 84 Evaluating Impacts of Sea-Level Rise on Groundwater Resources in the Delaware Coastal Plain

RI 85 Results of Physical Hydrogeologic Investigations of the Columbia, Rancocas, and Mt. Laurel Aquifers, and Magothy Formation, Southern New Castle and Northern Kent Counties, Delaware

RI 86 Results of Groundwater Quality Investigations of the Columbia, Rancocas, and Mt. Laurel Aquifers, and Magothy Formation, Southern New Castle and Northern Kent Counties, Delaware

RI 87 The Potomac Formation in Five Core Sites in New Castle County, Delaware

RI 88 Stratigraphic Geometry and Facies Characteristics of the Potomac Formation near the Chesapeake and Delaware Canal, Delaware, on the basis of a Reflection Seismic Survey and Well Data

GM 25 Geologic Map of the Cecilton and Middletown Quadrangles, Delaware

EXTERNAL PUBLICATIONS BY DGS STAFF

Vaughan, M.C.H., Bowden, W.B., Shanley, J.B., Bermilyea, A., Sleeper, R., Gold, A.N., S. Pradhanang, Inamdar, S.P., Levia, D.F., **Andres, A.S.,** Birgand, F., Schroth, A.W., 2017, High-resolution dissolved organic carbon and nitrate measurements reveal differences in storm hysteresis and loading in relation to land cover and seasonality: Water Resources Research, v. 53, doi:10.1002/2017WR020491.

Photo credit: Mike Ciosek, photographer for the Wilmington and Western Railroad.

PUBLICATIONS

Vidon, P., Karwan, D.L., **Andres, A.S.,** Inamdar, S., Kaushal, S., Mullaney, J.M., Ross, D.S., Schroth, A.W., Shanley, J.B., B. Yoon, 2018, In the path of the Hurricane: impact of Hurricane Irene and Tropical Storm Lee on watershed hydrology and biogeochemistry from North Carolina to Maine, USA: Biogeochemistry, https://doi.org/10.1007/s10533-018-0423-4.

Andres, A.S., Ballestero, T.P., and Musick, M.L., 2018, Stormwater management: when is green not so green?: Groundwater, v. 56, No.3, https://doi.org/10.1111/gwat.12653.

Callahan, J.A., Horton, B.P., Nikitina, D.L., Sommerfield, C.K., **McKenna, T.E.,** and Swallow, D., 2017, Recommendation of Sea-Level Rise Planning Scenarios for Delaware: Technical Report, prepared for Delaware Department of Natural Resources and Environmental Control (DNREC) Delaware Coastal Programs. 114 p.

Callahan, J.A., McKenna, T.E., and Medlock, C.L., 2018, Lidar Vertical Error Estimation and DEM Correction in a Tidal Salt Marsh. Annual Meeting of the American Association of State Geologists, Rehoboth Beach, DE, p. 19, Abstract.

KunleDare, M.A., and **McLaughlin, P.P.,** 2018, Leveraging a Legacy Sample and Data Collection for Carbon Storage Resource Assessment: 2018 AAPG Annual Convention and Exhibition, Salt Lake City, Utah, AAPG Datapages/Search and Discovery Article #90323 (Abstract)/#42240 (Presentation).

Mattheus, C.R., 2018. The shallow stratigraphic framework of the inner continental shelf of Delaware mapped from high-resolution seismic and core data. Geological Society of America Abstracts with Programs 50 (2).

Medlock, C., Bates, N.S., **McKenna, T.E., and Callahan, J.A.,** 2018, Fieldwork and Dataset Preparation to Create an Improved Digital Elevation Model for St. Jones and Blackbird Creek Reserves 2018, Delaware Wetlands Conference, Wilmington, DE.

McKenna, T.E., Keyser, T.A., Asreen, R.C., and Cargill, J.G., 2017, Environmental Thermography Determines Transport Pathways and Groundwater Sampling Locations During Site Investigations in Delaware, USA. Geological Society of America Abstracts with Programs. Vol. 49, No. 6, Seattle, WA.

McKenna, T.E., 2017, Jack Sharp's Meinzer and Missouri Years (1974-1982) and the Advent of Sedimentary Basin Modeling. Geological Society of America Abstracts with Programs. Vol. 49, No. 6, Seattle, WA.

Miller, K.G., Sugarman, P.J., Stanford, S.D., Browning, J.V., Baldwin, K., Buttari, B., Dunham, B., Farazaneh, M., Filo, R., Gagliano, M.P., Horton, B., Gallegos, G., Graham, S., Johnson, C.S., Khan, N., Kulhanek, D.K., Lombardi, C.J., Malerba, N., McKoy, K., **McLaughlin, P.P., Jr.,** Monteverde, D.H., Stanley, J.N., and Woodard, S., 2018, Sandy Hook sites: In Miller, K.G., Sugarman, P.J., Browning, J.V., et al., Proceedings of the Ocean Drilling Program, Initial Reports, 174AX (Suppl.): College Station, TX (Ocean Drilling Program), https://doi.org/10.2973/odp.proc.174AXS.112.2018.

Duke, H.J., Thompson, C.M., Simonds, M.H.K., Lockwood, R., and **Ramsey, K.W.,** 2018, Geographic and substrate distribution of Holocene mollusks in Mid-Atlantic offshore deposits: Geological Society of America Abstracts with Programs, v. 50, Abstract no. 36-2.

Worthington, E.N., **Ramsey, K.W.,** Berquist, C.R., Jr., and Owens, B.E., 2018, Evaluation of heavy mineral sands offshore of southern Delaware: Geological Society of America Abstracts with Programs, v. 50, Abstract no. 34-5.

Thompson, C.M., Lockwood, R., and **Ramsey, K.W.,** 2017, Molluscan paleoecology and substrate affinities on the Mid-Atlantic Continental Shelf: Geological Society of America Abstracts with Programs, v. 49, Abstract no. 190-6.

Wehmiller, J.F., **Ramsey, K.W.,** and Thieler, E.R., 2017, Paired racemization and radiocarbon analysis of Pleistocene and Holocene shells, U.S. Atlantic Coastal Plain; implications for shell geochronology, Pleistocene sea level history, and paleoclimate: Geological Society of America Abstracts with Programs, v. 29, Abstract no. 19-5.

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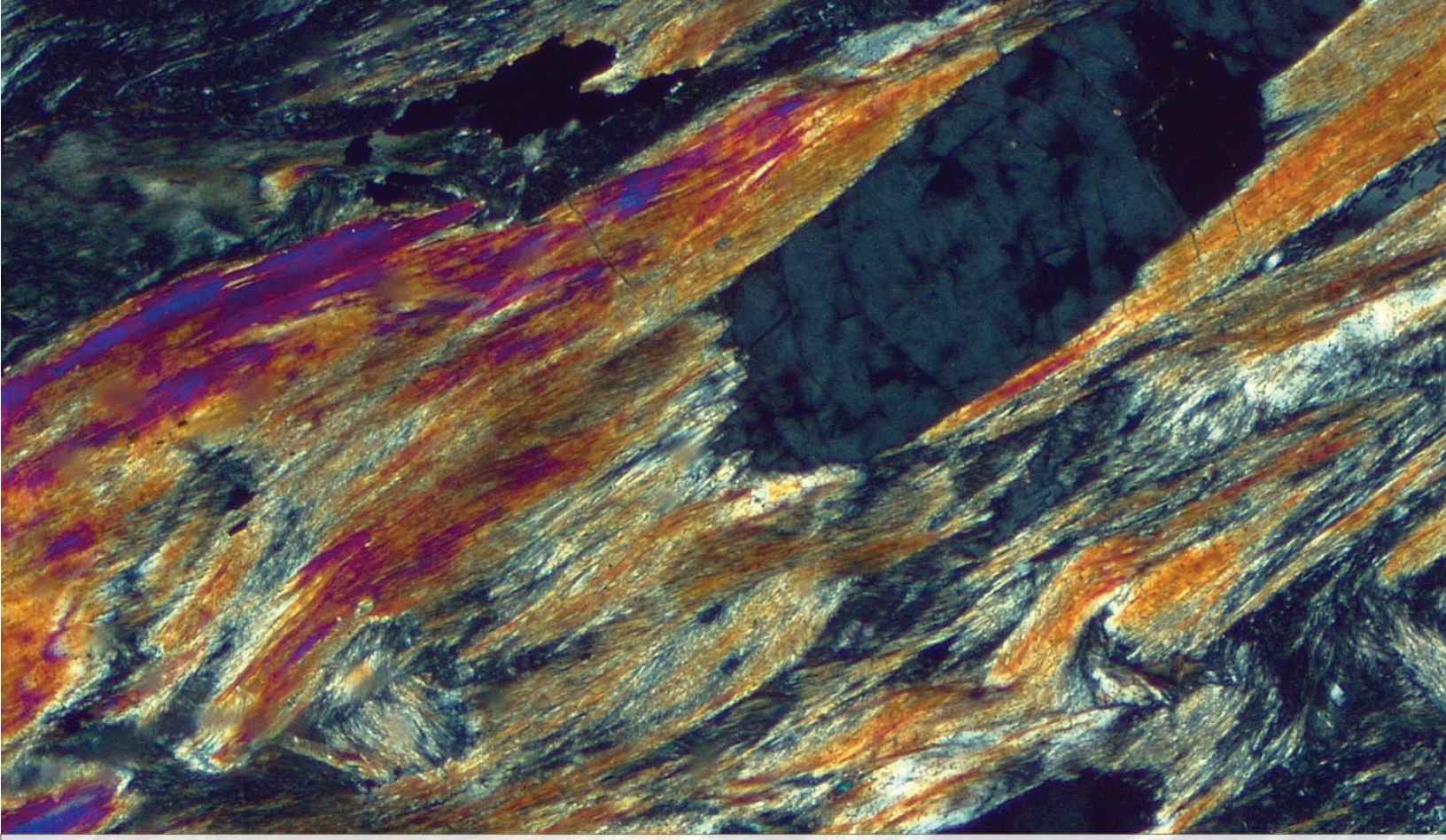

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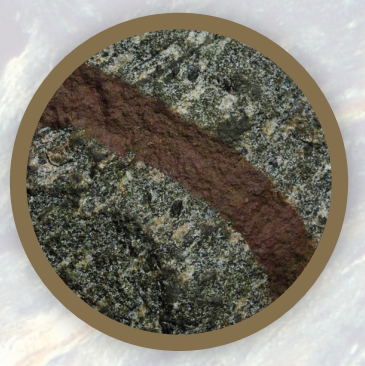

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