

DELAWARE GEOLOGICAL SURVEY ANNUAL REPORT OF PROGRAMS & ACTIVITIES



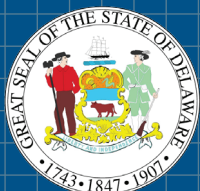
2018-19



This image was created by layering high resolution LiDAR elevation data from the St. Jones River, Delaware at different transparencies. The knob-like shapes along the sides of the river show the historical flow paths, which have changed over time due to human disturbances and natural processes. This image, by Daniel Warner, was chosen for the "Art in Science" exhibit at the University of Delaware.

OUR MISSION

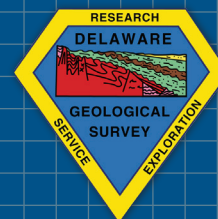
The Delaware Geological Survey's mission is, by statute, geologic and hydrologic research and exploration, and dissemination of information through publication and public service.



Delaware Geological Survey

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Message from the Director



Time flies. This adage was never more evident to me than when I began preparing this column for our Delaware Geological Survey Annual Report. This year's issue marks the fifth year that we will publish the report in its current form, which was birthed from our requirement to report to both the state's Office of Management and Budget, and the General Assembly's Joint Finance Committee during our annual budget request process. Traditionally, we reported the survey's activities in the form of a detailed letter, but five years ago we decided to expand it to a glossy, more appealing document that contains charts and graphics to better present our projects and accomplishments during the previous fiscal year. It's also a great way to give our stakeholders and the general public a clearer snapshot of the important work DGS conducts to benefit the state.

During the past five years, DGS has expanded our geoscience programs, including entering into the Midwest

Regional Carbon Sequestration Partnership (MRCSP), led by Battelle, to work with partner organizations to develop a coherent picture of CO₂ sources and sequestration opportunities in the MRCSP region. This research allowed DGS to obtain a more detailed understanding of the deep geologic framework, both on- and offshore Delaware. We also revitalized a previous research program through cooperative studies with the Bureau of Ocean and Energy Management (BOEM) to characterize sand resources offshore Delaware. This BOEM program was supported by supplemental federal funding following Hurricane Sandy.

Internal to the survey, we have had a few staff retirements in the past five years, but we also hired several new staff who possess youthful enthusiasm for the scientific and technical support work they do. Several senior staff have been inducted into fellowship in scientific organizations and won scientific awards. We have made several infrastructure upgrades, such as enhancing and creating more ergonomic workspaces for offices and labs, enhanced dehumidification and storage in our core repositories, and worked with University of Delaware officials to give our building a facelift by way of landscaping and a new roof.

When I first arrived at DGS, one of the first initiatives we undertook was to conduct a survey of our stakeholders to find out what geoscience data and information they use regularly, how it should be disseminated, and what they perceive as future needs. We used that information to guide a strategic framework for our efforts going forward, and we made

real progress in key areas, including the completion of new 1-foot elevation contours for the entire state, expansion and improvement of our seismic and groundwater monitoring networks and capabilities, preservation of valuable geologic collections, leading a consortium of agency and academic experts in preparing the state's sea-level rise planning report, engaging in 3-D geologic mapping, enhancing information and data access through our website, and many others. As Director, I'm proud of the nimbleness and creativity DGS staff displayed for leveraging resources and adapting to new opportunities in order to meet government and private sector partners' needs for unbiased, high-quality scientific information.

Despite these accomplishments and advances, time does fly. As such, DGS needs to develop a strategic plan for the next five years to prepare and guide our mission for the geoscience information needs and societal challenges ahead, both those that are obvious, and those unseen. So we may be reaching out to you as we develop a plan to optimize our facility and resources, anticipate evolving staff needs, and adapt new technologies to provide information as we forge ahead into a new decade. As always, we appreciate and welcome your feedback.

David R. Wunsch
Director and State Geologist

1. Water Resources



Delaware Groundwater 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 multiple uses by the environmental management, engineering, water supply, and science communities.

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 over 25 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 400,000 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 four grants from the USGS to participate in the National Ground-Water Monitoring Network (NGWMN), 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 NGWMN portal.

This project is partially funded by the Water Supply Section in the Delaware Department of Natural Resources and Environmental Control (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



USGS tide gage on the Christina River at Wilmington, Delaware. Photo courtesy of the USGS.

The USGS, in cooperation with the DGS, has been operating and maintaining continuous-record stream and tide gages throughout Delaware for decades. This year, ten streamgages and seven tide gages were operated for the program. The data are used for water-resource 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 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 and maintenance of real-time streamflow gages for the DNREC

Watershed Assessment Section at Millsboro Pond Outlet at Millsboro, 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 Bow-ers. 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 Land-ing; 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 streams 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.

Stormwater Infiltration BMP Impacts on Groundwater Quality

Project Contacts: Rachel W. McQuiggan and A. Scott Andres

Monitoring groundwater for transport of chlorides during storm events to evaluate the risks of winter de-icing practices on groundwater

In cooperation with the Delaware Department of Transportation (DelDOT), DGS is evaluating best management practices (BMPs) to characterize the fate and transport of chloride in stormwater. Examples of stormwater BMPs include infiltration basins, bioretention swales, and sand filters. The goal is to characterize the potential risks to groundwater quality from de-icing practices at a DelDOT BMP site and a shared-use basin (receiving runoff from roadways, businesses, schools, etc.). This project arose from increasing chloride concentrations observed in a number of groundwater-supplied public water systems in New Castle County. Increased concentrations of radionuclides are observed in some of the impacted water sources.

During the first phase of this project, DGS completed a GIS analysis and field visits to a number of stormwater management facilities. Field visits included limited water-quality sampling. This work led to the selection of two stormwater management sites for site characterization and monitoring. Water sampling combined with sensors installed in each well will help build empirical relationships between inexpensive



DGS staff installing a shallow well at the Summit Bridge site.



Drill cutting containment during monitor well construction in a stormwater infiltration basin. Cuttings were subsequently removed from the basin.

field measurements of electrical conductivity and more time consuming and expensive laboratory-measured chloride concentrations.

A site near Summit Bridge has been selected and is co-located with a pavement runoff and soil amendment project

established by Dr. Paul Imhoff of the University of Delaware Department of Civil and Environmental Engineering. Four shallow monitoring wells and two runoff collectors with automated water level, temperature, and salinity monitoring systems were installed in March 2019 to characterize properties of roadway runoff and salinity of shallow groundwater. A second site near Middletown was selected and includes a stormwater infiltration basin adjacent to the newly constructed Route 301. Twenty-three monitoring wells, and stormwater inlet and outlet monitoring systems have been installed. The monitoring wells were installed in clusters screened at different depths and equipped with automated water level, temperature, and salinity monitoring systems to characterize infiltration and salt movement. Stormwater inlet pipes and the basin outflow weir are equipped with flow and salinity monitoring systems.

The next phase of the project will include an enhanced field monitoring study that includes operation of the automated monitoring systems and sampling of wells and runoff. Data from this work will support development of statistical and simulation tools to evaluate the risks of de-icing practices on groundwater.

DGS Joins Project WiCCED

Project Contacts: A. Scott Andres and Rachel W. McQuiggan

National Science Foundation funds a large joint project between institutions in Delaware

DGS staff members Rachel McQuiggan and Scott Andres are participants in a new National Science Foundation EP-SCoR-funded effort, Water in the Changing Coastal Environment of Delaware (Project WiCCED). Project WiCCED is a consortium of scientists and educators from the University of Delaware (UD), Delaware State University, Wesley College, and Delaware Technical and Community College. Information about Project WiCCED is located at: (projectwicced.org).

Andres is a project co-leader in two research experiments. One, with Dr. Holly Michael and doctoral student Mary Hingst of the UD Department of Geological Sciences is studying salinization of groundwater through direct monitoring and numerical simulation. The focus of this project is on the area east of Dover along Route 9. The second experiment, with a team led by Dr. Bill Ullman of the UD School of Marine Science and Policy and Dr. Deb Jaisi of the UD Department of Plant and Soil Science, is studying impacts of plant nutrients on the Murderkill River and estuary. Both of these experiments build upon the success of previous studies: NEWRNet (<https://www.dgs.udel.edu/>)



Staff of the DGS are installing a monitoring well for the ground-water salinization experiment using the DGS CME-55 drill rig.

projects/newrnet-north-east-water-resources-network) and groundwater flow modeling of east Dover (<https://www.dgs.udel.edu/projects/east-dover-groundwater-flow-model>).

Morphology and Tidal Inundation of Tidal Wetlands in the Delaware Estuary

Project Contacts: Thomas E. McKenna and John A. Callahan

Improving our understanding of Delaware tidal salt marshes with respect to coastal flooding and sea-level rise

An expanse of tidal wetlands fringes the Delaware Estuary and provides Delaware, Pennsylvania, and New Jersey with abundant habitat for indigenous and migrating plants and wildlife, biogeochemical cycling of nutrients, preserving water quality, flood hazard mitigation, and recreational services. However, the tidal wetlands, in particular the saltmarshes, can only survive in a narrow band of elevation relative to the tidal water levels and are continuously degraded due to land use practices, coastal development, waves and inundation from coastal storms, and sea-level rise. The occurrence, timing, and duration of inundation on the marsh is a primary control in many physical, chemical, and biological processes, especially the transport of sediment onto the marsh platform, resulting in vertical accretion and/or horizontal migration. Understanding this dynamic system of marsh hydrology is critical to assessing the current health of the marsh and modeling its behavior under future conditions.

The primary goal of this study is to improve our understanding of the hydrodynamic behavior of the tidal saltmarshes in the Delaware Estuary. The focus is on four estuaries: Black-bird Creek, Leipsic River, St. Jones River, and Murderkill



Watersheds with tidal wetlands where LiDAR elevations are being corrected (yellow fill) and tidal inundation is being calculated (outlined in red).

River. Three sites in each estuary, instrumented with new or existing tide gages, will enable us to quantify the tidal regime. Analyses of tidal harmonics enable the use of simple analytical models to estimate temporal tide heights from the mouth of each estuary to the head of tide. A bathtub model conditioned by the analytical model simulates inundation of the marsh in each estuary.

Marsh platform elevations will be determined by correcting for the positive LiDAR-bias present in the bare-earth Digital Elevation Models (DEMs) of densely vegetated areas, such as saltmarshes. This will be accomplished

through GIS and statistical methods based on GPS real-time kinematic (RTK) data collection across multiple vegetation communities throughout the four marshes. RTK data collection is nearing completion. Using the modeled tidal water surfaces and “corrected” mini-DEMs, we will compute the inundation frequency, extent, and spatial metrics related to the vulnerability of the marsh.

The methodology for identifying and correcting for the LiDAR bias will be applied to all tidal saltmarshes along the Delaware Bay from the City of New Castle to Broadkill Beach. The resulting set of mini-DEMs for each marsh will be available publicly from the DGS website. Modeled water levels, marsh metrics, and GPS RTK data will also be shared with natural resources managers and coastal scientists, particularly at the Delaware National Estuarine Research Reserve (DNERR) and the U.S. Fish and Wildlife agencies. Results from this work will help coastal communities prepare in real-time for upcoming storm events and long-term resiliency planning for sea-level rise.

This project was funded by Delaware Sea Grant and the DGS. Land access graciously provided by Delaware Wild Lands, DNREC Division of Fish and Wildlife, U.S. Fish and Wildlife Service, and Isaac Burrows.

2. Geology & Mapping



Atlantic Outer Continental Shelf Sample and Data

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

NGGDPP funded project preserves valuable cores and data and helps maintain and enhance stakeholder access

The DGS Atlantic Outer Continental Shelf (OCS) Sample and Data Repository is a valuable collection of all the remaining geological samples from the stratigraphic test and exploration wells drilled offshore of the U.S. East Coast between 1977 and 1984. These samples were consolidated in the DGS collection after other repositories deaccessioned their Atlantic OCS sample holdings. Samples include cores, washed and unwashed cuttings, vials containing samples processed for micropaleontology and palynology, thin sections of core and cuttings, and micropaleontology and palynology splits.

The core samples and thin sections from this collection played a major role in the success of the Middle Atlantic Offshore Carbon Storage Resource Assessment Project (MAOCS-RAP), a multi-organizational study that evaluated the carbon dioxide (CO₂) storage potential in nearby offshore areas sponsored by the U.S. Department of Energy. A comprehensive, item-by-item inventory of the repository holdings was conducted during the MAOCSRAP project and revealed that the core sample collection was in poor condition, and in need of preservation. The DGS has worked over the last year to reorganize and preserve these cores, as well as associated sample and data holdings, with support of the National Geological and Geophysical Data Preservation Program (NGGDPP). Two objectives of our work have been: 1) to rescue and preserve irreplaceable core materials; and 2) to complete a collection of digital geophysical log data associated with the wells in the repository. The project prioritized the preservation of core from the Continental Offshore Stratigraphic Test (COST) wells because of their value in representing the most complete stratigraphic records of the subsurface geology of the Atlantic OCS. Archival and sampling sets of cores were created for four COST wells in display ready boxes fitted with custom foam inserts. The resulting preserved collections comprise an archival set of 43 boxes of the most complete core sections and a working set of 19 boxes of ordered and repackaged leftover core slab pieces, slices and chips available for sampling. Additional funding is anticipated from NGGDPP to complete the remaining COST cores in the coming year. The digital preservation of geophysical log data was captured in TIFF format for 48 logs from microfilm records, and from 13 wells; this includes 32 completely new records for four wells with no previous holdings.



Images showing examples of cores before (left) and after (right) preservation.

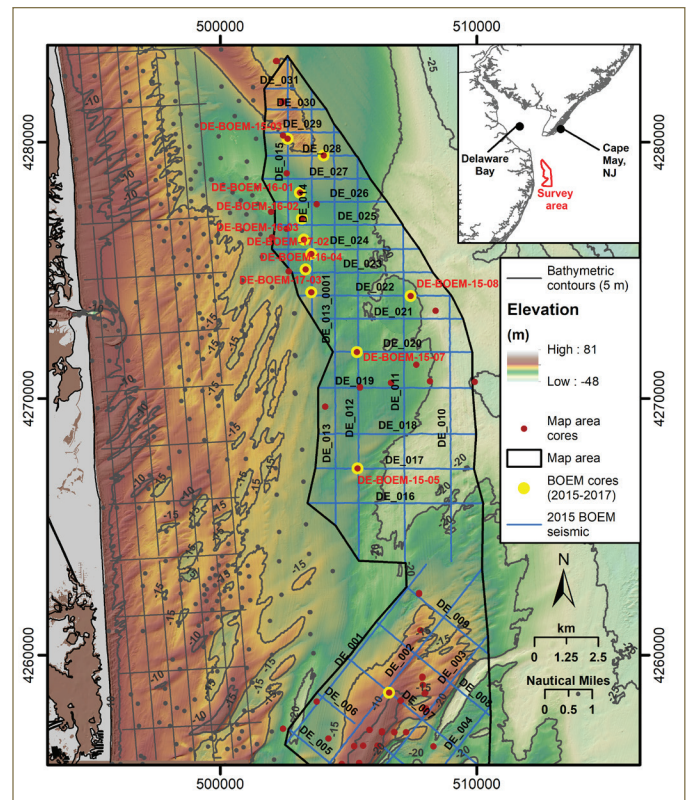
The DGS Atlantic OCS Sample and Data Repository is an important resource for stakeholders from government agencies, universities, consultants, industry and the general public. The repository is used by visiting scientists for examination and sampling for studies directed towards various academic, commercial, and policy applications. The results of these preservation efforts ensure that geologic samples and geophysical data, acquired at a cost of millions of dollars over two decades, have been preserved for the future. This well-curated collection will provide for future geological studies essential for the assessment of geological resources buried deep below the Atlantic OCS.

Delaware Offshore Sand Resources

Project Contacts: Kelvin W. Ramsey and C. Robin Mattheus

Identifying sand resources for coastal resiliency and restoration projects

The DGS partnered with the Bureau of Ocean Energy Management (BOEM) in the exploration and identification of offshore sand resources for beach replenishment projects. This endeavor was prompted by the ongoing demand for sand resources and the depletion of resource areas in state waters off Delaware. Targeted areas of exploration funded by BOEM are situated in federal waters. The DGS has taken the lead in identifying which geologic units have the greatest potential for sand suitable for beach replenishment. This research is leading to a new, offshore geologic map, which will utilize sediment-core information and geophysical data to map surface geology across the inner conti-



Data distribution map. The BOEM survey area, which is entirely within federal waters, is outlined in black. There is a noticeable decrease in data density in this area compared to areas closer to shore. Cores collected as part of the Atlantic Sand Assessment Project are highlighted in yellow and labeled by local ID.

mental shelf. Efforts to organize more localized coring activities, designed to fill data gaps and refine sand-volume estimates, are currently underway, with potential collaboration with the U.S.

Army Corps of Engineers (Philadelphia District), the DNREC Division of Watershed Stewardship, and BOEM.

Early Mesozoic Buried Rift Basins in Delaware and Their Carbon Storage Potential

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

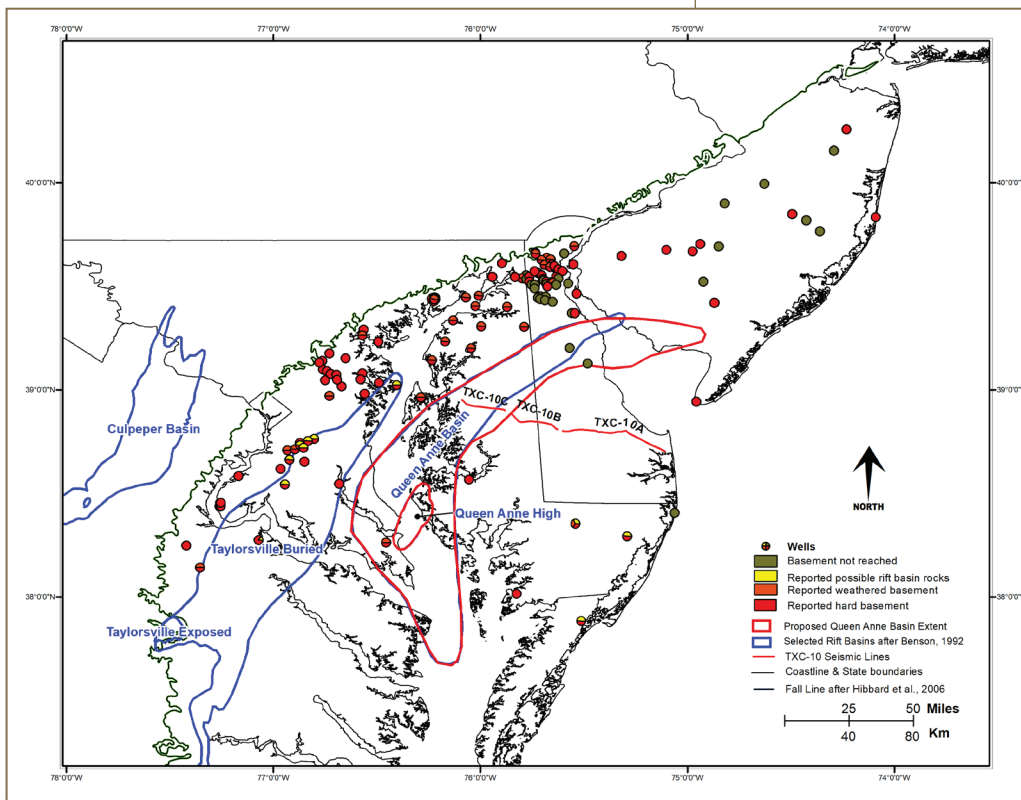
Review and synthesis of available data suggests buried rift basins may occur in Delaware with adequate potential resources for carbon storage

Geophysical surveys of the Middle Atlantic region suggest that Delaware lies along the trend of a series of ancient rift valleys that were formed during the early part of the Mesozoic Era (approximately 140 to 250 million years ago) as North America and north Africa were torn apart by global tectonic forces. These basins would have been characterized by highlands on either side and a valley in the middle filled by lowlands, river systems, and lakes—much like the Great Rift Valley of east Africa today. Some of these paleobasins are exposed at the land surface, such as the Newark Basin of Pennsylvania, New Jersey, and New York; others are buried deep below the earth's surface but are known from deep well drilling, such as the Taylorsville Basin of Virginia and Maryland. Early Mesozoic buried rift basins have been postulated to occur in Delaware in previous work by the DGS and other authors. However, no wells have been drilled to a depth in Delaware to penetrate these basins.

This new study has re-examined the evidence for such buried rift basins under Delaware as part of our work with the Midwest Regional Carbon Sequestration Partnership. Analysis of available geophysical and geological data and comparisons with similar exposed and buried rift basins in Maryland and Virginia suggests that these basins occur as previously postulated. Our review of published interpretations and integration with lithologic, stratigraphic and recent geophysical data resulted in new insights into the extent of the basins, their tectonic evolution, and basin geometries. Recent magnetics and gravity data suggest that a significant rift basin, the Queen Anne Basin, occurs in Kent County and extends into Maryland and southern New Jersey. The new data suggest it may be larger than previously recognized. Our analysis also delineates the two smaller basins that were previously defined, the Greenwood and Bridgeville basins.

Comparison to the geology of other rift basins in the region that are exposed in outcrop or penetrated by wells suggests that the Delaware rift basins may contain reservoir-quality fluvial and lacustrine deposits possibly of Triassic-Jurassic age, that may be of sufficient thickness for carbon storage. The deposits are expected to be fluvial and lacustrine successions consisting of reservoir quality conglomerates, sands and silts interbedded with shales that would serve as local and regional seals. Although the data are limited and insufficient for complete characterization of the basins, this new evaluation supports the idea of well developed deep rift basins under Delaware

and highlights the need for additional data to more fully define the resource potential.



Exposed and inferred buried rift basins and new interpretation of Queen Anne Basin extent shown with wells used in the study.

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

The DGS is responsible for maintaining an understanding of the geology of the lands of the U.S. Outer Continental Shelf (OCS) adjacent to our state, providing information that can become the basis for our state government's input on federal government plans and activities in these offshore areas. This year marked the final phase of our participation in the Middle Atlantic Offshore Carbon Storage Resource Assessment Project, a three-year collaborative study of the geology below the sea bottom offshore of the U.S. Middle Atlantic region. This project, led by Battelle Memorial Institute, was supported by a grant from the U.S. Department of Energy and undertaken in cooperation with the Maryland Geological Survey, the Pennsylvania Geological Survey, Columbia University, and Rutgers University. DGS staff led the analysis of hydraulic properties from the sites of offshore oil and gas exploration wells drilled between 1977 and 1984 to support estimates of CO₂ storage potential in formations deep below the seabed. The analysis depended heavily on the DGS OCS Sample and Data Repository, which holds the only remaining geologic samples from the 51 oil and gas wells that have been drilled off the east coast. The new analyses filled gaps and/or verified older analyses previously documented in well reports 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. The integration of well and geophysical data allowed a re-interpretation of regional stratigraphy, helped to identify and map potential CO₂ storage zones, and make regional

assessments of offshore carbon storage resources. Results of the project suggest that the formations of this region have the potential to store decades of CO₂ from nearby industrial sources and provide a foundation for future study of storage development opportunities.

Delaware Geologic Mapping Program

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

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

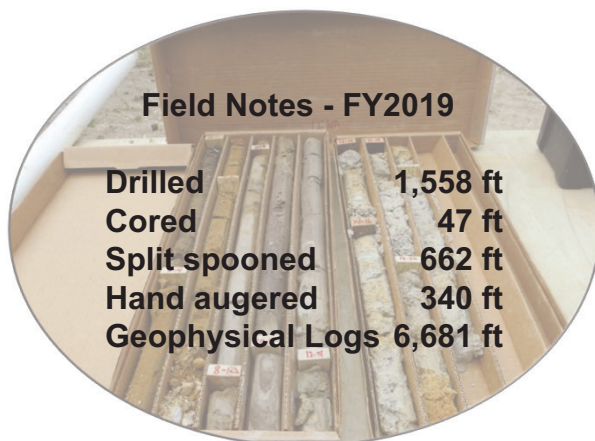


DGS staff member, Jaime Tomlinson, uses a hand auger to extract shallow, subsurface sediments as part of a STATEMAP project.

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 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 located in Little Creek and Bombay Hook Quadrangles. Fieldwork for this project began in July 2019 and will be completed in June 2020. Geologic Map Number 26, Cecilton and Middletown Quadrangles, is in review.



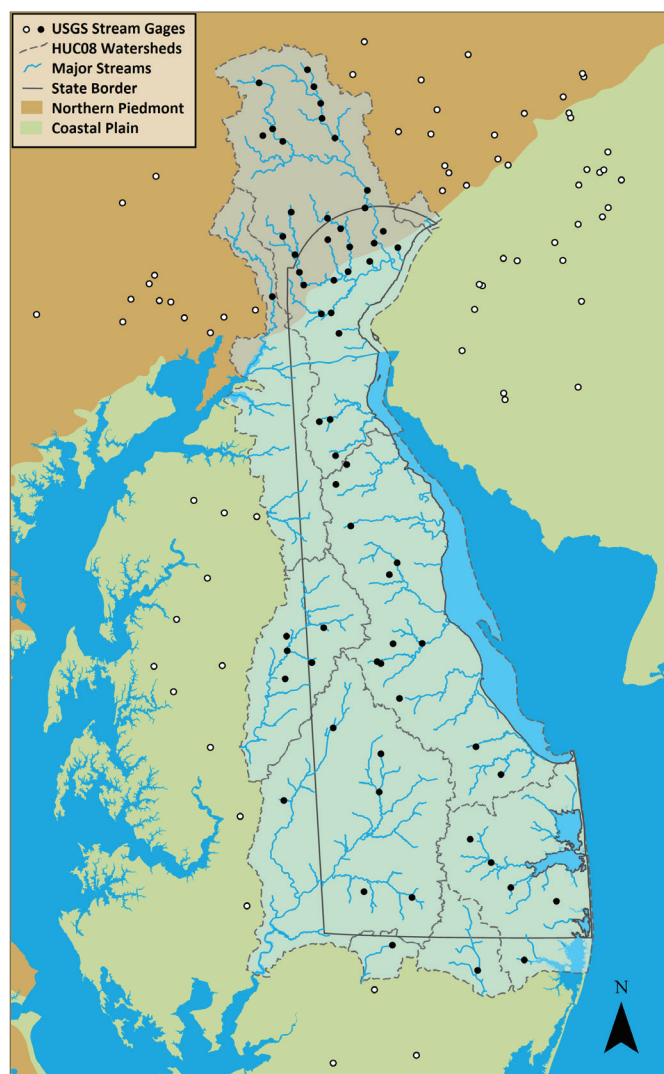
3. Natural Hazards

Delaware StreamStats

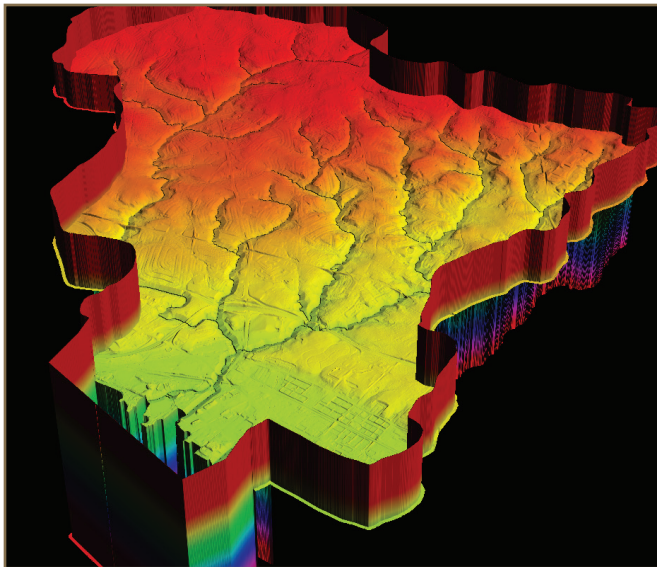
Project Contacts: John A. Callahan, Daniel L. Warner, and David R. Wunsch

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

The USGS StreamStats program is a web-based platform allowing users to delineate their own local watersheds and estimate peak flood levels at gaged and ungaged sections of stream networks across the United States. Peak flood statistics are extrapolated from empirical regression equations fit to observed peak flow curves at USGS stream gages using a set of basin characteristics as predictors, derived from



Map of major streams in DGS study area and USGS gage stations inside (black circles) and outside (white circles) this area. HUC08 watershed boundaries are depicted in gray dashed lines. The Northern Piedmont and Coastal Plain physiographic regions are separated in the USGS regression analysis due to their distinctive differences in hydrology.



A DEM that has been clipped to its HUC08 boundary and hydrologically conditioned. During conditioning, streams are burned into the elevation surface with a sloped buffer zone on either side, while outer walls are built at the watershed boundary to ensure all flow exits through a single point downstream.

soil, terrain, meteorological, census, and land use data sets. StreamStats provides critical information for transportation engineers by predicting peak flood conditions at proposed roads, bridges, and railways, and is used by water quality modelers and urban planners to map potential inundation patterns across the landscape.

Because hydrologic patterns change over time with changes in land use and climate, it is important to periodically update these regression equations and basin characteristic datasets. The existing version of Delaware StreamStats was released in 2006, and numerous high-flood events from coastal storms as well as changes in land use and land cover have occurred in the state since that time. Supported by DelDOT, the DGS and USGS are jointly updating the data behind Delaware StreamStats.

Updates to StreamStats began with generating a hydrologically conditioned elevation surface to allow for accurate delineations of basins. The DGS team assembled a 3-meter resolution DEM (compared to the 30-meter resolution DEM used in 2006) primarily from high-resolution LiDAR data collected in 2014, which was merged with DEMs from bordering states. The stream network was built using a 'hybrid' approach that harmonized the National Hydrographic Dataset (NHD) and stream networks predicted based on flow routing across the DEM surface. This allowed the DGS team to identify potential additions and modifications to the NHD, which were

then validated based on aerial photographs and field surveys. This stream network was edited to create dendritic stream flow lines (all flow routed through a single outlet with no internal loops) and a hydrologically conditioned DEM for each major HUC08 watershed within the study area. Watersheds for each USGS streamgage were delineated and corresponding basin characteristics of population, soil, elevation, precipitation, and land use were extracted for use by USGS to develop new peak flow regression equations.

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 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.

Sea-Level Rise Report Wins John C. Frye Memorial Award

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

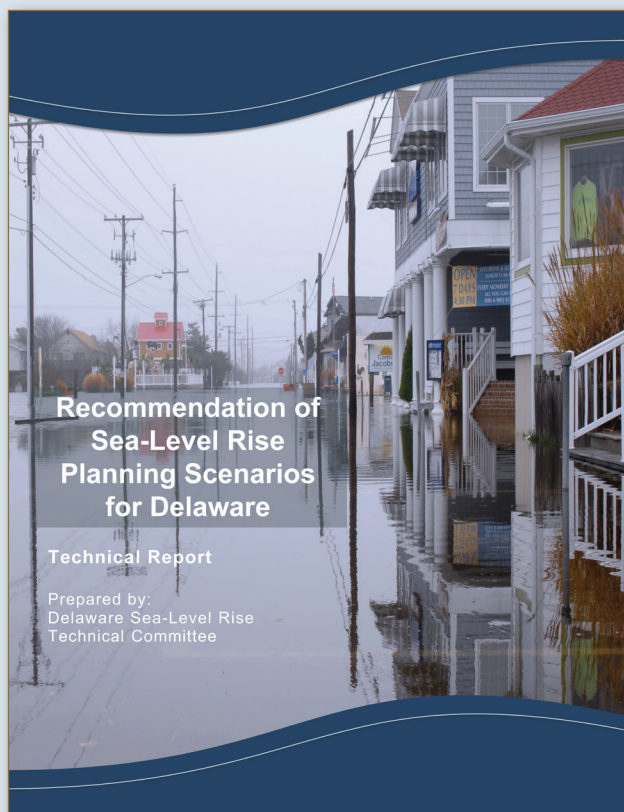
Report on sea-level rise scenarios wins prestigious award

The report *Recommendation of Sea-Level Rise Planning Scenarios for Delaware: Technical Report* was selected as the winner of the 2019 John C. Frye Memorial Award. Supported by DNREC Delaware Coastal Programs, the report summarizes work performed by the Sea-Level Rise (SLR) Technical Committee and was released at the Delaware Resilient And Sustainable Communities League (RASCL) Environmental Summit in November 2017. The SLR Technical Committee was composed of regional and state scientific experts, planners, and resource managers. Staff at the Delaware Geological Survey played significant roles in this effort: John Callahan was lead author and chair of the committee, Thomas McKenna was a co-author and a member of the committee, and David Wunsch was a member of the committee.

Information on future projections of sea-level rise in Delaware to the year 2100 as well as information on past sea level estimates from proxy records and current observations from tide gages and satellites are detailed in the report. It also provides some basic guidelines on how best to use these projections in state planning activities, information that is currently being used and making an impact at several layers of government.

The John C. Frye Memorial Award is co-sponsored by the Geological Society of America (GSA) and the Association of American State Geologists (AASG), and is given to the best paper on environmental geology published by either GSA or by a state geological survey during the past three years. The SLR Report met the criteria for the award, which include that the report clearly establishes an environmental problem or need, provides substantive information on the geologic and climatic processes pertinent to the problem, provides recommendations for appropriate land use considerations, and presents the information in a manner that is understandable and directly usable by planners, engineers, policy makers, and the educated general public.

More details on the project and a PDF version of the report can be found on the DGS website at dgs.udel.edu.



The Delaware Coastal Flood Monitoring System

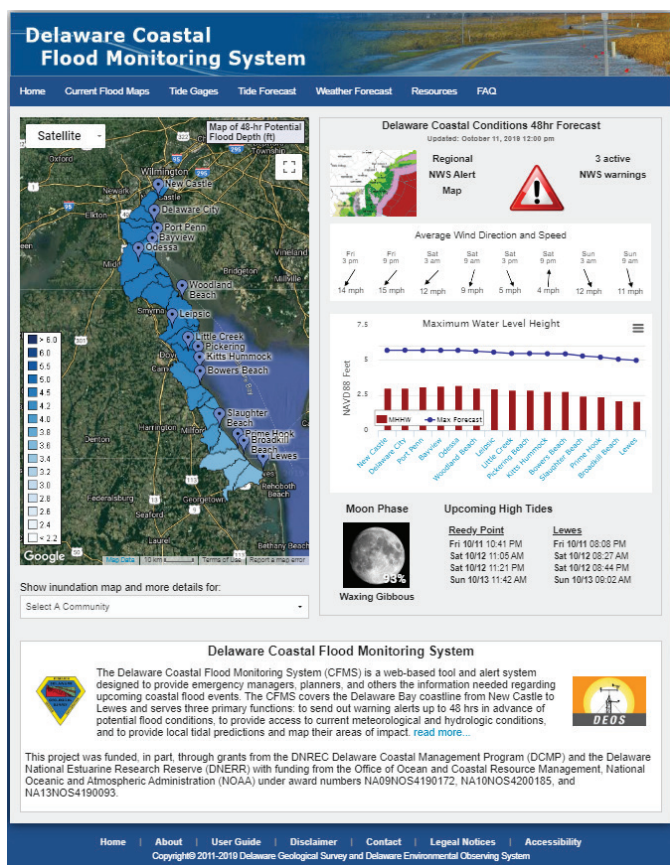
Project Contact: John A. Callahan

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

The Delaware Coastal Flood Monitoring System (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. The storm left at least one person dead and many people homeless, causing evacuations in many communities within Kent County along the Delaware Bay. 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



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.

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.

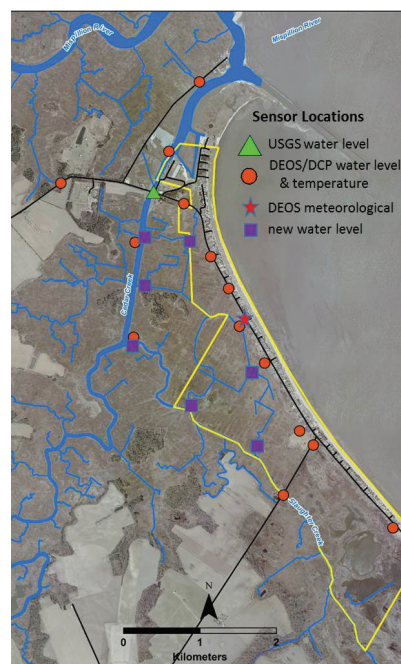
In the last two decades, large tropical storms such as Hurricanes Katrina, Sandy, and Harvey, as well as numerous strong nor'easters along the mid-Atlantic coast, have resulted in significant loss of life, injuries, and property damage in the United States. Much of the damage was the result of severe coastal flooding. Sea-level rise, land subsidence, flat open coastal terrain, and significant coastal development 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.

Determining Flow Paths for Flooding and Draining in Slaughter Beach, Delaware

Project Contact: Thomas E. McKenna

Providing hydrologic information to develop and implement strategies for a bayside community



Locations of existing and proposed monitoring stations. Town boundary shown by yellow line.

The Town of Slaughter Beach is a bayside community impacted by the effects of climate change, particularly sea-level rise. Nuisance flooding and flooding from storms can inundate streets and property in the area. Flooding is primarily on the roads entering Slaughter Beach and in the back-barrier area. This project will provide hydrologic information needed to develop and implement strategies for flood mitigation. The project is a direct follow up to

a Resilient Community Partnership project by the DNREC Coastal Program. Results of this study will identify the flow paths for flooding and draining in Slaughter Beach, focusing on the back-barrier area, to mitigate flooding. This project will seek to confirm and/or identify the locations prone to flooding using both existing data and field-based hydrological evaluations. DGS will apply in-situ methods that use temperature as a tracer of tidal water flow, including remotely-controlled thermal infrared and visual cameras mounted on a small inflatable drone. This allows for observing the marsh over extended periods to capture both spatial and temporal dynamics. In addition, a distributed temperature system will be deployed in the marsh to measure temperature along several kilometers of fiber-optic cable.

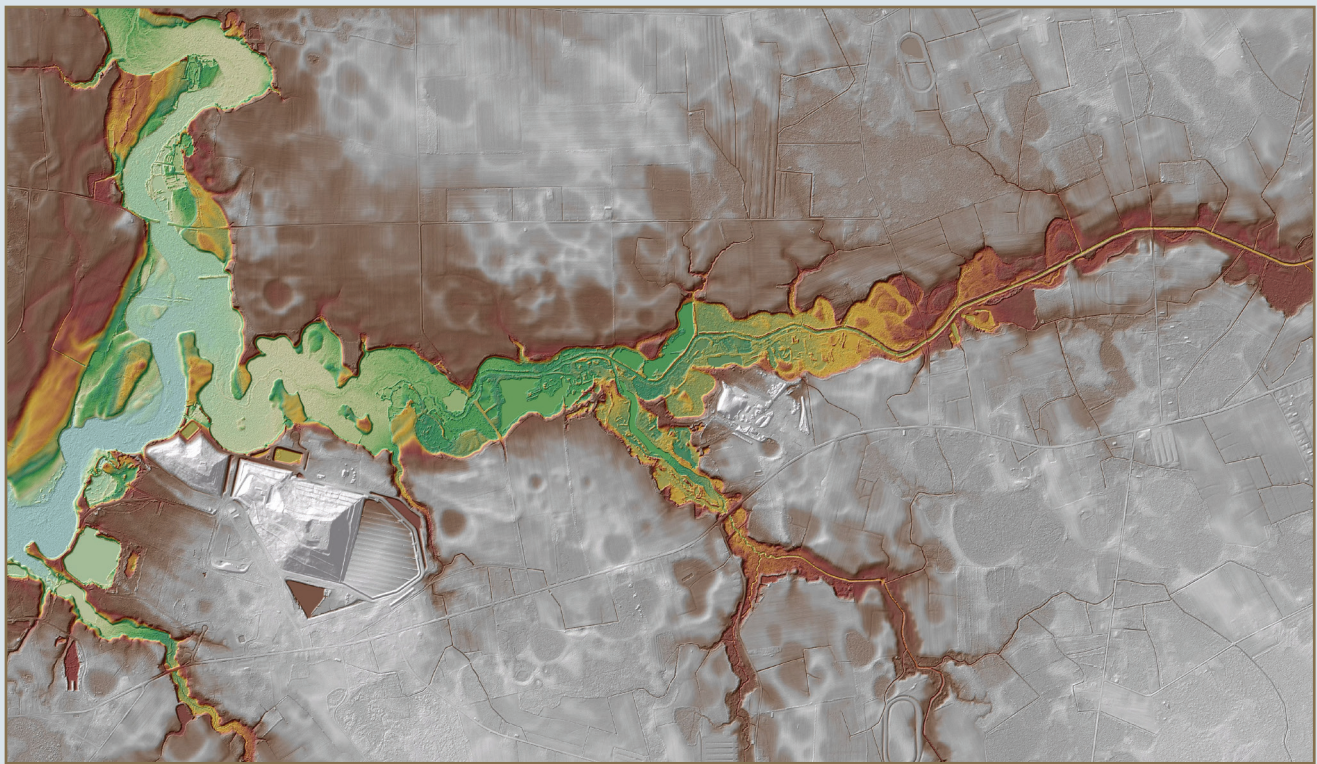
This project is funded by DEMA, DNREC, and DGS. Land access graciously provided by Delaware Nature Society, DNREC Division of Fish and Wildlife, and the Town Council of Slaughter Beach.

Images by DGS Staff Selected for Display in UD's Art in Science

Portions of the following text are excerpted from UD's College of Engineering website

Art in Science, sponsored by the National Science Foundation and UD's College of Engineering, College of Arts and Sciences, and Department of Biomedical Engineering highlights cutting-edge research across disciplines—engineering, biological sciences, chemistry, art preservation and more—at the University of Delaware. The aim of the competition is to engage and educate the local community about the research taking place at the University of Delaware and its potential impact on local, national, and international communities. Students from local schools are included as well to spark interest in STEM education, especially among underrepresented student populations.

This year, entries submitted by John A. Callahan and Daniel L. Warner from the DGS were selected for display in the 2019 Art in Science exhibition. Entries made by William S. Schenck, also from the DGS, were selected for display in previous competitions and were featured on the inside covers of the 2015-2016 and 2017-2018 Annual Report of Programs & Activities.



Digital Elevation Model obtained from high resolution LiDAR flown in early 2014 of Cow Marsh Creek in western Kent County. Green Creek is seen at the top of this image; Mahon River is on the right. North is oriented up. Blue and green colored areas represent lower elevations; red to white colored areas represent higher elevations. Image is draped over a hillshade representation of the topography. Notice the remnants of the creek meanders and the circular Carolina Bay depressions.

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.

Online XML and Mapping Applications

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

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

The DGS participates in the National Groundwater Monitoring Network (NGWMN), a product of the Subcommittee on Ground Water of the Federal Advisory Committee on Water Information (ACWI). The NGWMN is 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 (<https://cida.usgs.gov/ngwmn>). Data are continuously evaluated for consistency and quality, converted to the national standard formats, and distributed through XML web data services. Existing wells and supporting infrastructure are regularly maintained and new wells are evaluated for possible inclusion in the network. Participation in the network allows users to view Delaware's current status and trends in groundwater quality and availability in a local, regional or national context.

Additionally, DGS distributes many types of data through the Delaware Geologic Information Resource (DGIR), an online application (<http://maps.dgs.udel.edu/dgir/draft/>) designed

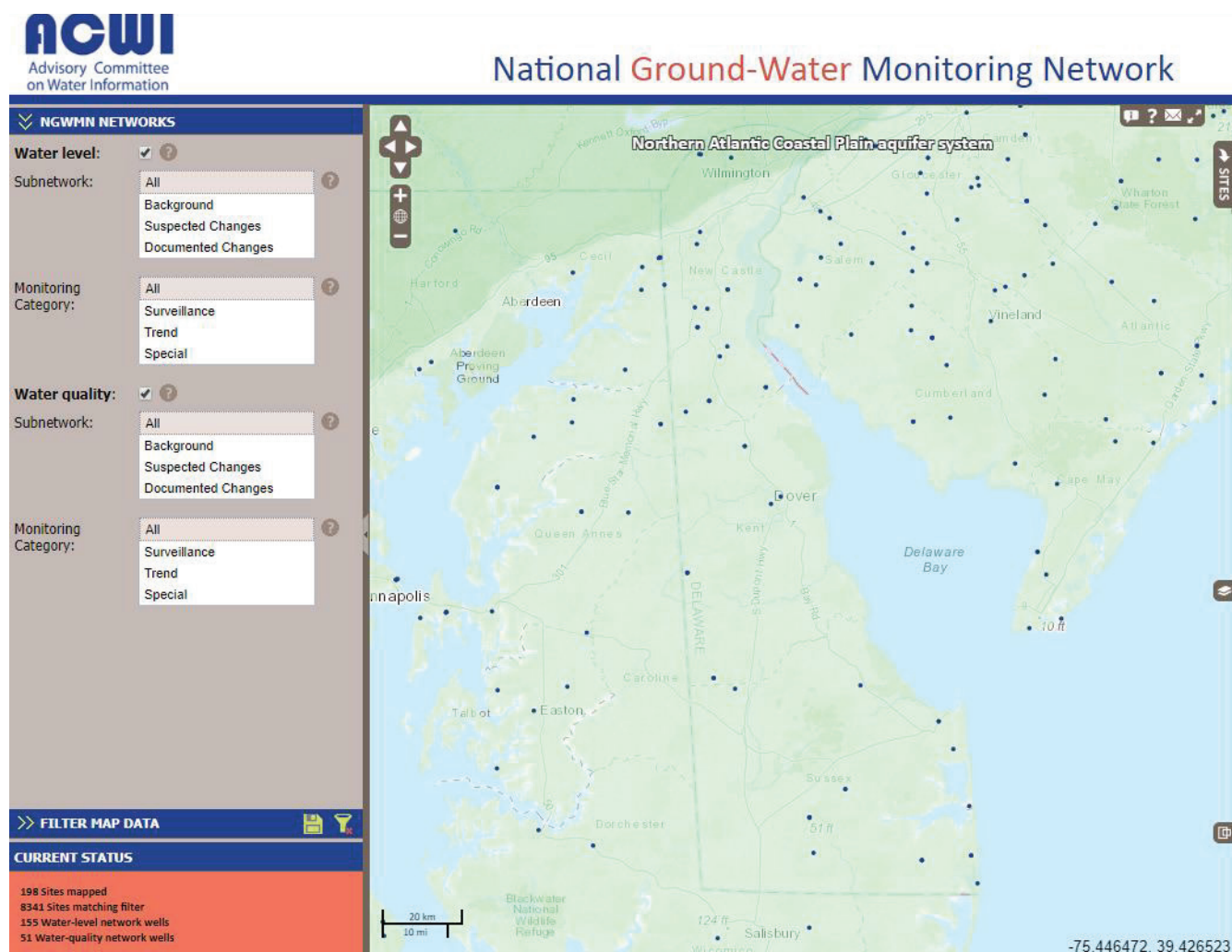
to deliver the most commonly available and requested geologic and hydrologic information. The application provides an intuitive and comprehensive toolset for locating, quickly viewing, and downloading hydrogeologic information. DGIR includes a rich variety of DGS data and products, including point data 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.

Statewide LiDAR Program for Delaware

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

Distribution of topographic contours and LiDAR products for Delaware

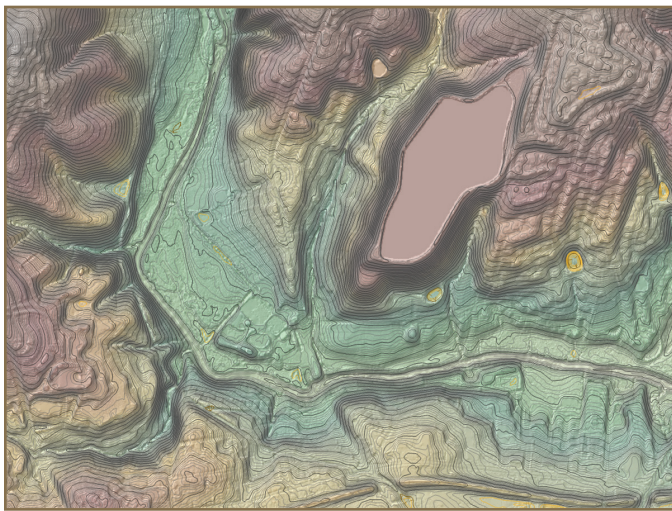
LiDAR is an active remote sensing method that utilizes a pulsed laser to measure distances at high resolution. Airborne LiDAR was used to measure the elevation of the ground surface for the entire state of Delaware in 2014 as part of a multi-agency state and federal effort (including the DelDOT, DNREC, USGS, and NOAA) and funded by the Hurricane Sandy Relief appropriation. Acquisition of the 2014 LiDAR data met Quality Level 2 technical specifications with a sampling density of greater than 2 points per square meter and an open terrain accuracy of 6.3 cm. Data collected include a classified LiDAR point dataset, hydrographic breaklines, LiDAR intensity data, and a hydro-flattened 1-meter Digital Elevation Model (DEM).



Screenshot of the NGWMN Data Portal displaying wells in Delaware and surrounding area in the NGWMN database.

The DGS analyzed the 2014 LiDAR datasets to generate topographic elevation contours (i.e., lines of equal elevation that form the basis of many topographic maps) for the entire state of Delaware at one-foot intervals. Contours were developed through the combination of an automated algorithm developed by the USGS as well as subsequent computer processing and manual quality control by DGS staff. The new contour data were designed to spatially align with existing datasets of water bodies (e.g., lakes, ponds, streams) already in use in Delaware and detail important information on Delaware's low-elevation landscape.

The DGS stores and makes available all of these LiDAR data products as well as provide expertise for Delaware state and local agencies and its citizens. Additionally, these LiDAR data are being integrated into several DGS studies including modeling coastal inundation scenarios, geologic mapping, salt marsh elevation studies, examination of potential bacterial and nutrient source areas, and habitat analysis, among others.



Topographic map showing new 1-foot elevation contours draped on a 3-D elevation model for the Newark Reservoir and surrounding area.

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.

PUBLICATIONS

DGS PUBLICATIONS COMPLETED

OPEN FILE REPORTS

OFR 53 Kent County Groundwater Monitoring Project: Results of Subsurface Exploration

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 Mapping Evapotranspiration for 2016 Growing Season Using Landsat 8 Images and Metric Model, Sussex County, Delaware

RI 86 The Potomac Formation in Five Core Sites in New Castle County, Delaware

RI 87 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

GEOLOGIC MAPS

GM 25 Geologic Map of Offshore Delaware

GM 26 Geologic Map of the Cecilton and Middletown Quadrangles, Delaware



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

EXTERNAL PUBLICATIONS BY DGS STAFF

Andres, A.S., Main, C.R., Pettay, D.T., and Ullman, W.J., 2018, Hydrophysical and hydrochemical controls of cyanobacterial blooms in Coursey Pond, Delaware (USA): *Journal of Environmental Quality*, vol. 48, no. 1. doi: 10.2134/jeq2018.03.0108.

Andres, A.S., Main, C.R., Pettay, D.T., and Ullman, W.J., 2018, Biogeochemical responses of a Coastal Plain pond to hydrologic and nutrient loading variability – implications for long-term management and mitigation: Abstract H53N-1779 presented at 2018 American Geophysical Union Fall Meeting, Washington, D.C., 10-14 Dec.

Brothers, L., Foster, D.S., Pendleton, E.A., Baldwin, W.E., **Ramsey, K.W.**, Wehmiller, J., and **Mattheus, C.R.**, 2019, Late Quaternary evolution of the continental shelf and coastal system of the Delmarva Peninsula: *Geological Society of America Abstracts with Programs*, vol. 51, no. 3, abstract 35-6, presented at the Southeastern Section Meeting, Charleston, South Carolina, 28-29 Mar.

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, Delaware.

Childs, B.D., Balascio, N.L., and **Ramsey, K.W.**, 2019, Late Quaternary paleoenvironmental analysis of the Cypress Swamp Formation, Delaware: *Geological Society of America Abstracts with Programs*, vol. 51, no. 3, abstract 31-17, presented at the Southeastern Section Meeting, Charleston, South Carolina, 28-29 Mar.

Cumming, L., Fukai, I., Burchwell, A., Sminchak, J., **McLaughlin, P.P.**, **KunleDare, M.A.**, and Gupta, N., 2018, Performing carbon storage resource assessments for offshore Mid-Atlantic United States: 14th International Conference on Greenhouse Gas Control Technologies, Melbourne, Australia.

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Kim, W., Gold, M., Ramsay, J., Meltzer, A., **Wunsch, D.**, **Baxter, S.**, Lekic, V., Pearson, K., Wagner, L., Roman, D., Golden, S., and Pratt, T., 2018, Mw 4.2 Delaware Earthquake of 30 November 2017: *Seismological Research Letters*, doi: 10.1785/0220180124.

Mattheus, C.R., **Ramsey, K.W.**, and Santoro, J.A., in press, Evaluating continental shelf seabed-elevation changes from archived sediment-core records: issues with vertical positioning and implications for integration with subsurface geophysics: *Journal of Coastal Research*, (in press).

Mattheus, C.R., **Ramsey, K.W.**, and **Tomlinson, J.L.**, 2019, Sedimentary dynamics of the inner continental shelf of Delaware: Do offshore vibracore records provide insight into shelf geomorphology?: *Geological Society of America Abstracts with Programs*, vol. 51, no. 3, abstract 35-5, presented at the Southeastern Section Meeting, Charleston, South Carolina, 28-29 Mar.

McKenna, T.E., **Callahan, J.A.**, Brinson, K., Huntley, D., and Slawik, D., 2019, Determining flow paths for flooding and draining in Slaughter Beach, Delaware: Delaware Estuary Science and Environmental Summit, Cape May, New Jersey.

McKenna, T.E., **Medlock, C.L.**, and **Callahan, J.A.**, 2019, Towards a hydrological characterization of Delaware Bay tidal wetlands – elevation and tidal channels: Delaware Applied Coastal Research Symposium, Newark, Delaware.

McQuiggan, R.W., and **Andres, A.S.**, 2018, Groundwater level decline in the Piney Point aquifer of Delmarva and New Jersey: Proceedings of the Maryland Groundwater Symposium, Baltimore, Maryland.

Medlock, C.L., 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, Delaware.

Medlock, C.L., **McKenna, T.E.**, and **Callahan, J.A.**, 2018, LiDAR vertical bias assessment and digital elevation model correction in Delaware's tidal salt marshes: Abstract EP23C-2340 presented at 2018 American Geophysical Union Fall Meeting, Washington, D.C., 10-14 Dec.

Schaefer, R.B., Lerner, M.J., Puleo, J.A., and **McKenna, T.E.**, 2018, Morphological impacts and vegetation-induced attenuation of wind and vessel generated waves: Abstract

OS23G-1712 presented at 2018 American Geophysical Union Fall Meeting, Washington, D.C., 10-14 Dec.

Smith, M.T., Hinnov, L.A., and **McLaughlin, P.P.**, 2019, Preliminary examination of the Paleocene-Eocene record of a Mid-Atlantic shallow-marine section: The Woodland Beach Core, Delaware: *Geological Society of America Abstracts with Programs*, vol. 51, no. 3, doi: 10.1130/abs/2019SE-327545, presented at the Southeastern Section Meeting, Charleston, South Carolina, 28-29 Mar.

Thompson, C.M., Lockwood, R., Worthington, E.N. and **Ramsey, K.W.**, 2018, Taxon diversity and community structure of fossil molluscan assemblages from the mid-Atlantic continental shelf (USA): *Geological Society of America Abstracts with Programs*, vol. 50, no. 6., abstract 38-9.

Warner, D.L., O'Hara, B., and **Callahan, J.A.**, 2019, A hybrid approach for incorporating high-resolution LiDAR DEMs into USGS StreamStats at the state level: poster presented at American Association of Geographers Annual Meeting, April 2019, Washington, D.C.

Wehmiller, J.F., Brothers, L., Foster, D.S., and **Ramsey, K.W.**, 2019, Southern Delmarva barrier island beaches: linking onshore and offshore units using racemization geochronology to infer sediment sources during shoreline migration: *Geological Society of America Abstracts with Programs*, vol. 51, no. 3, abstract 39-1, presented at the Southeastern Section Meeting, Charleston, South Carolina, 28-29 Mar.

Wehmiller, J.F., **Ramsey, K.W.**, Howard, S., **Mattheus, C.R.**, and Harris, M.S., 2019, New perspectives on US Atlantic Coastal Plain aminostratigraphy gleaned from extensive analyses of shell specimens from inner continental shelf vibracores: *Geological Society of America Abstracts with Programs*, vol. 51, no. 3, abstract 39-1, presented at the Southeastern Section Meeting, Charleston, South Carolina, 28-29 Mar.

Worthington, E.N., **Ramsey, K.W.**, and Berquist Jr., C.R., 2018, Evaluation of terrestrial and offshore heavy mineral assemblages in Delaware formations: *Geological Society of America Abstracts with Programs*, vol. 50, no. 6, abstract 266-8.

Wunsch, D.R., 2018, Book review: Timefulness – How thinking like a geologist can help save the world, 290 p., Bjornerud, M., Princeton University Press. *Science*, vol. 361, issue 6406.

DGS Service to Professional Societies, Boards, and Committees

American Association of Petroleum Geologists Committee on Preservation of Geoscience Data	Delaware Water Resources Center Advisory Panel
American Association of Stratigraphic Palynologists	Delaware Water Supply Coordinating Council
American Geophysical Union	Delaware Water Well Licensing Board
American Geosciences Institute, Executive Committee	Federal Advisory Committee on Water Information
Association of American State Geologists	Federal Geologic Mapping Advisory Committee
Association of American State Geologists Foundation	Federal Subcommittee on Groundwater
Center for the Inland Bays Board of Directors	Geological Society of America, Academic and Applied Geoscience Relations Committee
Center for the Inland Bays Scientific and Technical Advisory Committee	Murderkill River Monitoring and Modeling Workgroup
Delaware Department of Natural Resources Source Water Protection Program Citizen and Technical Advisory Committee	National Association of State Boards of Geology
Delaware Emergency Management Agency State Hazard Mitigation Council	National Association of State Boards of Geology Council of Examiners
Delaware Emergency Management Agency Technical Assessment Center Group	National Geologic Map Database, Geologic Map Schema Working Group
Delaware Geographic Data Committee	National Ground Water Association, Water Management Subcommittee
Delaware Geologic Mapping Advisory Committee	New Castle County Resource Protection Area Technical Advisory Committee
Delaware Leaking Underground Storage Tank Committee	Ph.D. and M.S. Student Committees (University of Delaware)
Delaware Resilient and Sustainable Communities League	Regulated Flow Advisory Committee of the Delaware River Basin Commission
Delaware Sea Level Rise Technical Workgroup	River Master Advisory Committee
Delaware State Board of Geologists	River Master Decree Party Workgroup
Delaware State Names Authority	Sussex County Source Water Protection Technical Advisory Committee
DelawareView (Delaware Chapter of AmericaView)	University of Delaware Council of Public Engagement
Delaware Water Infrastructure Advisory Council, Wastewater Subcommittee	



ANNUAL REPORT OF PROGRAMS AND ACTIVITIES | 2018-19



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