Delaware Geological Survey

ANNUAL REPORT OF PROGRAMS & ACTIVITIES

2022-2023

Above photo: Wireline core drilled by DGS in Smyrna, Delaware, being cleaned prior to describing, photographing, and placing in core box. The abundance of the mineral glauconite gives the core the characteristic green color. The white areas are shell material. Front cover photo: Two split-spoon cores drilled by the DGS in support of the U.S. Geological Survey's STATEMAP-funded project in the area of Kenton, Delaware. Each sample between the wooden blocks represents two feet of drilled core. Credit for both photos: Staff of the Delaware Geological Survey.

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

Collaboration is a popular catchword that is highly touted in the world of modern science. Collaboration with other scientists is now encouraged, and sometimes mandated, in the scientific enterprise. Gone are the days when a scientist worked in near solitude with perhaps a few close colleagues, or subordinate graduate students, with little interaction other than with scientists within their own respective disciplines. Now it is common for many federal grant programs to either award additional scores, or require collaboration with scientists located at external institutions, as well as with specialists in other scientific or social science disciplines. It appears that encouragement to collaborate is in recognition of the ever-complex world we live in and reflects that sponsors of scientific programs have realized that any particular discipline is reliant upon other branches of science, or that outcomes and discoveries in one scientific discipline can have profound effects on other branches of science—as well as on society at large.

DGS geoscientists have a long history of collaboration with scientists from other state and federal agencies, as well as researchers at our host institution, the University of Delaware (UD). And at times, we also collaborate with neighboring state geological surveys in projects that are mutually beneficial. For example, DGS geoscientists in our geology and mapping group are working with the Maryland, New Jersey, and Virginia geological surveys as part of our MAtStrat project, where the partnering surveys, in cooperation with the U.S. Geological Survey, are working to rectify subsurface stratigraphy and nomenclature across state lines. For the unacquainted, a running joke with geologists is that geologic maps often show "boundary faults" which are basically abrupt changes in the geologic nomenclature, descriptions, and extent of formations across state lines. There is no geologic fault present responsible for the abrupt changes. Instead, they are the result of different classifications, descriptions, and naming of geologic formations by the respective authors of the adjoining state maps. Collaboration is essential to rectify the underlying descriptions and continuity of the geology in adjacent states, and successful efforts will ultimately provide a better framework for managing shared resources, such as groundwater.

DGS hydrogeologists are also collaborating with UD researchers to try to understand the effects of rising sea level and its influence on saltwater intrusion into sediments adjoining the Delaware Bay. Saltwater contamination into the fresh groundwater has serious implications for groundwater users along the coast that use it for drinking water supplies and irrigation, as well as coastal ecosystems that are sensitive to changes in salinity. These are just a few examples of many DGS collaborative efforts you will read about within the pages of our Annual Report.

One of the most important collaborations for DGS is working closely with the Delaware Department of Natural Resources and Environmental Control (DNREC). For example, a key part of our mission is characterizing the geology that hosts the many aquifers in our state. We characterize them through scientific studies that include drilling and geologic sample collection, aquifer tests, numerical modeling of groundwater flow, and water quality and quantity monitoring. DNREC relies heavily on the fruits of these endeavors to complete their mission of water resource protection, granting water allocations, and permitting.

In recognition of this important relationship, DGS and DNREC convened their first professional retreat on August 13, 2022. The one-day retreat was an opportunity for scientists and engineers from both agencies to meet in person and share updates on programs and projects they are currently working on that may be of interest to the other partnering agency. This joint retreat has led to more efficient data-sharing opportunities, shared resources that can lead to economic savings, and shared expertise—all of which will lead to more beneficial outcomes for the state. Moreover, the retreat helped to energize our respective staffs. The event, highlighted later in this Annual Report, was so successful that both agencies have agreed to continue convening joint retreats going forward.

Collaboration does lead to better science, better outcomes, and better use of tax dollars for the state. DGS is always willing to collaborate in efforts that provide benefits for our many stakeholders, such as state and local government agencies, non-profit organizations, and the general public.

David R. Wunsch

David R. Wunsch
Director and State Geologist

1. Water Resources

Delaware Groundwater Monitoring Network

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

DGS currently monitors groundwater levels and groundwater quality in a network of wells that support multiple uses by the environmental management, engineering, water supply, and science communities

Groundwater is the backbone of Delaware's water resources, serving the water needs of the public, the economy, and our natural environment. As such, groundwater monitoring is a necessary and resource-intensive program of the DGS. The Delaware Groundwater Monitoring Network is the umbrella program used by DGS to coordinate monitoring activities and leverage institutional resources and staff expertise.

Since the 1960s, the DGS has maintained a network of wells that are used for groundwater-level and groundwater-quality observations. The goals of maintaining this network are to characterize and increase knowledge about the State's groundwater resources, to identify trends and changes in groundwater quality, and to guide the development of best management practices to avoid future groundwater impacts. The network has steadily expanded over the past 10 years. Currently, the network consists of more than 120 wells covering 17 aquifers. Most of these wells are equipped with automatic data loggers that record water levels at 15-minute intervals, while the remaining wells are measured manually four times per year. A small number of wells are equipped with automated conductivity sensors to help track any developing saltwater issues.

In 2021, in response to the challenge of potential degradation of water quality due to ever-growing human activities as well as saltwater intrusion induced by sea-level rise, the DGS added a new water-quality component to the existing Delaware groundwater monitoring network. The groundwater-quality monitoring network consists of 60 wells that were selected from 13 aquifers currently used for water supply. Each well will be sampled every five years and analyzed for basic groundwater geochemical constituents (major ions and select metals) and stable isotopes (^{2}H and ^{18}O). Monitoring methods are adapted from protocols from the U.S. Geological Survey (USGS), the U.S. Environmental Protection Agency (USEPA), programs in other states, and our own experience and

expertise. This project is under contract with the Source Water Protection Program in the Delaware Department of Natural Resources and Environmental Control (DNREC) and is funded through a grant from the USEPA.

As of July 2023, our data resource holds nearly 510,000 records of manually measured water levels and daily average water levels derived from almost 4,800 wells, and 6,063 groundwater samples from 643 wells. We currently manage nearly 38.5 million water-level records collected by automated pressure sensors and are adding over 2.7 million new records to this dataset every year. More than 12.8 million groundwater temperature and 7.6 million salinity records measured by automated sensors are included in our water-quality dataset.

Data that meet QA/QC requirements are stored in an Oracle database and shared with stakeholders and the public through multiple channels. Water-level data, including manual measurements and daily averaged logger data are accessible through the DGS public website (https://www.dgs.udel.edu) and the Delaware Geologic Information Resource (DGIR, http://data.dgs.udel.edu/). More comprehensive digital logger data collected at 15-minute intervals, and water-quality data can be provided electronically per request. In addition, DGS works cooperatively with the Delaware Solid Waste Authority and the Delaware Environmental Observing System (http://www.deos.udel.edu/) to provide telemetered real-time data from four wells. We also provide groundwater-level and groundwater-quality data from more than 50 Delaware wells to the National Ground Water Monitoring Network (www.cida.usgs.gov/ngwmn), a network of over 30 state and regionally operated groundwater monitoring programs.

Stormwater Infiltration BMP Impacts on Groundwater and Infiltration

Project Contacts: Rachel W. McQuiggan and Katherine Buell-Fleming

Evaluating the impacts of winter deicing salt to groundwater, soil chemistry, and infiltration

In cooperation with DelDOT, the DGS has been monitoring groundwater and stormwater at a DelDOT-managed stormwater infiltration basin to characterize the impacts of deicing salt on groundwater. We have been operating and maintaining automated, high-frequency stormwater flow and salinity, as well as groundwater pressure, temperature, and electrical conductivity/salinity systems for over three years. This project was prompted by increasing chloride concentrations in a number of groundwater-supplied public water systems in New Castle County and occurrences of radium in several of the impacted water sources.

DGS staff member, Rachel McQuiggan, retrieves a datalogger from a monitoring well.

Extensive use of in-situ measurements of electrical conductivity/salinity made by automated sensors has greatly improved data resolution and our ability to develop and test conceptual models, while reducing the time and money needed for collection and laboratory testing of samples. Empirical relationships between sensor and laboratory-measured data from this study are very well correlated showing that sensors are reliable and cost effective for monitoring movement of salty water. We observed saltwater migrating through

DGS staff member, Katherine Buell-Fleming, downloads data at an infiltration basin.

different layers within the aquifer and found that speed and pathways of saltwater movement depend on hydraulic properties of geologic units.

Groundwater chemistry shows two mixing processes occur beneath the infiltration basin—one that occurs as saline stormwater infiltrates to the water table and moves downgradient from the basin, and the other as dilute stormwater flushes through during late summer and fall. Increasing salt correlated with radium mobilization in groundwater due to competitive cation adsorption. A lag time between chloride and sodium transport to groundwater suggested that sodium was being retained in the vadose zone beneath the basin. Sodium retention from cation exchange is a common occurrence in agricultural fields and is known to decrease surface infiltration by impacting the soil structure.

Infiltration rate is a critical parameter in design and maintenance of stormwater management sites. In general, infiltration rates of newly built facilities will gradually decrease as they age and accumulate fine sediments; however, the role of deicing salt in the process is not quite clear. This past year, we expanded our field monitoring to include soil chemistry and infiltration testing. Our goal was to evaluate soil chemistry over time (before and after winter) and assess whether deicer was negatively impacting basin performance via infiltration. We plan to continue monitoring, testing, and sample collection through next year.

Project WiCCED

Project Contact: Rachel W. McQuiggan

Project leverages other DGS monitoring to investigate groundwater salinization and eutrophication

The five-year National Science Foundation EPSCoR-funded project titled Water in the Changing Coastal Environment of Delaware (Project WiCCED) is nearing an end. DGS staff members Rachel McQuiggan and A. Scott Andres (retired) are participants in the project. 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. Working with Dr. Holly Michael and Dr. Mary Hingst of the UD Department of Earth Sciences, one of the project goals is to investigate the dynamics and drivers of groundwater salinization in the east Dover area through direct monitoring and numerical simulation.

An intensive field study was conducted in ponds, streams, and groundwater-sourced water supplies, and included existing infrastructure that is part of DGS's statewide groundwater monitoring network. Several drivers of salinization were identified, including climate events, such as spring tides and storm surge, as well as conditions that lower the water table, such as over pumping or drought.

DGS has been collaborating with the Delaware Center for the Inland Bays (CIB) in the funding, siting, design, and installation of stations, development of a data management system and SOP/QAPP, and annual data review for a continuous water-quality monitoring network in the Delaware Inland Bays. Six stations measure tide height, temperature, salinity, dissolved oxygen, turbidity, pH, and plant pigments chlorophyll a and phycoerythrin every 30 minutes. Over the past three years, CIB staff have operated the network, which has collected over 130,000 measurements. The work has allowed the team to quantify the frequency and duration of hypoxic events and their relationships to other water-quality, climate, and flow variables. The measurements provide critical data for Delaware's Clean Water Act programs, and the CIB's prioritizing and targeting of management and mitigation practices.

More information can be accessed on the project website: www.projectwicced.org.

Delaware Stream and Tide Gage Program

Project Contacts: Stefanie J. Baxter and Kelvin W. Ramsey

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, 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 Assesment 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 Bowers. Also included in the DGS-USGS cooperative program is the operation and maintenance of water-quality monitoring stations for the DNREC Watershed Assesment 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; and a continued five-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.

The Coastal Critical Zone

Project Contact: Rachel W. McQuiggan

Studying coastal processes to understand critical feedbacks related to climate change

The critical zone includes all Earth processes from the tree canopy down to bedrock. In Delaware, coastal marshes play an important role in the critical zone by storing carbon, nutrients, and other contaminants. Sea-level rise is expanding the marshes, but also salinizing soil and shallow groundwater, which can damage adjacent forests and farm crop fields.

DGS staff member, Rachel McQuiggan, joined a NSF-funded project investigating the hydrological, biogeochemical, ecological, and geomorphological processes in the coastal Mid-Atlantic region. UD's Department of Earth Sciences professor, Dr. Holly Michael, is the lead primary investigator (PI) for the research cluster called The Coastal Critical Zone: Processes that transform landscapes and fluxes between land and sea. The group of additional researchers includes other UD staff and faculty as co-PIs, as well as collaborators at Wesley College, University of Maryland, George Washington University, Virginia Institute of Marine Science, and Boston University. McQuiggan is the data manager for the coastal group, assisting with processing, management, storage, and dissemination of field and experimental data.

Six project study sites have been instrumented with long-term water, soil, air, vegetation, and land surveying monitoring equipment. Study sites are located in Delaware, Maryland, and Virginia, and focus on the transition zones between marsh, forest, and agriculture. Changes in hydrology and salinity in the coastal transition zone are driven by both fast events, such as tides and storms, and slow events, such as sea-level rise, changes in water use, march accretion/compaction, and climate change. These process, in turn, drive positive and negative feedbacks to the complex biogeochemical, ecological, and geomorphological system.

Research is being supported by an intensive field sampling program and by the deployment of hundreds of automated sensors, collecting over 20 million records to date. Data for this project is being stored and shared via several online data repositories including HydroShare and the Environmental Data Initiative.

DGS Welcomes Katherine (Katie) Buell-Fleming

Katie Buell-Fleming joined the Delaware Geological Survey research staff in February 2023. Ms. Buell-Fleming is a recent graduate of the University of Delaware obtaining a degree with distinction in Environmental Science, with concentrations in Ecoscience and Marine Science. As a Research Associate I, Katie primarily works on projects centered around Delaware's hydrogeology and is working on evaluating the impacts of winter deicing salt on groundwater and taking water-level measurements as a part of the DGS groundwater monitoring network.

Delaware Water Tracker

Project Contacts: Changming He and Stefanie J. Baxter

Climate change is expected to lead to increases in extreme weather events, which will exacerbate water-quantity issues across Delaware

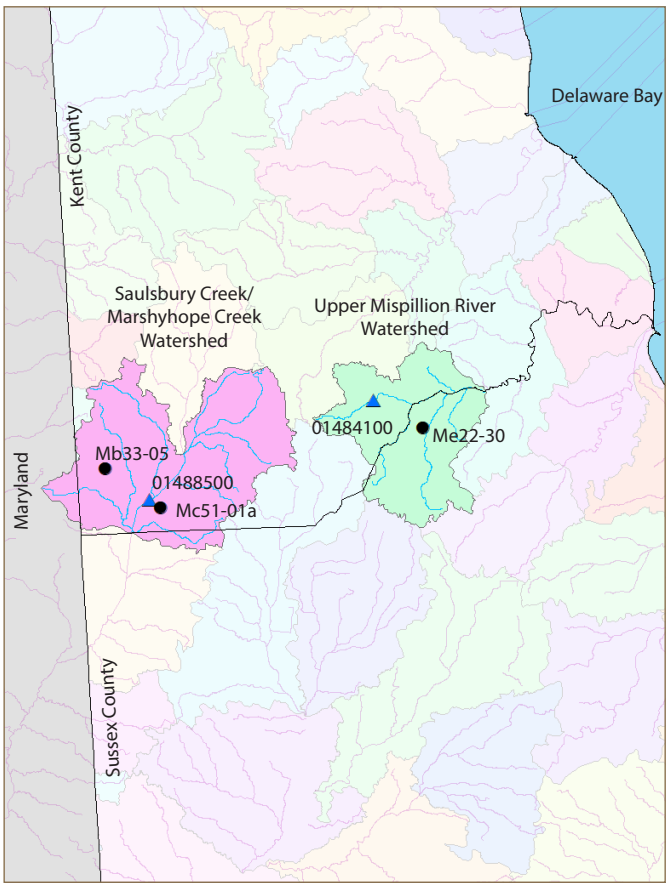
In general, Delaware is rich in water resources; however, climate change is expected to lead to increases in extreme weather events such as droughts and floods, which will exacerbate water-quantity issues across the state. Kent and Sussex Counties, where the agriculture industry plays an important role in the economy, will likely see the most severe impacts from a changing hydrologic cycle. The ability to assess water quantity in southern Delaware is of great importance in managing this critical natural resource.

To better assess water quantity across Delaware, the DGS in partnership with the Center for Environmental Monitoring and Analysis at the University of Delaware, will initiate a multi-phase project that will result in estimating the relative abundance of available water across all USGS-defined HUC-12 stream basins in Delaware. To accomplish this goal, observed, estimated, and modeled data will be utilized. Observations from the Delaware Environmental Observing System,discharge data from USGS streamgages, public and industrial water-use data from DNREC, and instrumented groundwater levels in the unconfined aquifer will be employed to meet the goals of the project. The data, estimates, and model output will be integrated to provide a relative water-quantity index for each HUC-12 stream basin.

The objective of Phase 1 is to validate the methodology using two watersheds—the Saulsbury Creek/ Marshyhope Creek and the Upper Mispillion River. Using these two pilot watersheds, we will study the feasiblity of estimating daily water use and availability of water in the surficial aquifer from real-time monitoring data and develop a plan to implement the methodology statewide. Data will be collected and analyses will be performed to better understand the relationship between meteorlogical variables (precipitation, evaportranspiration, etc) and hydrological variables (stream discharge, water levels, soil moisture). In addition, an inventory of statewide hydrological data will be conducted to better understand the need for potential new monitoring sites to be used in later phases of the project.

Building on Phase 1, Phase 2 will expand the project from two pilot stream basins to statewide data collection and analysis. Analytical results from the comparison of hydroclimatic parameters in the pilot watersheds will be used to develop a prototype framework for determining the groundwater resource status of each pilot watershed. Output from the prototype will be compared to future well observations within the watershed to validate its accuracy.

This project is being funded by a grant from the Delaware Coastal Management Program within the DNREC Division of Climate, Coastal and Energy.



Two HUC-12 watersheds chosen as pilot areas for the Water Tracker project. Black circles are shallow groundwater wells identified with DGS well names and blue triangles are USGS stream gages.

2. Geology & Mapping

DGS Drills a Deep Exploratory Corehole at Sandtown, Delaware

Project Contacts: Peter P. McLaughlin and Kelvin W. Ramsey

Analyses of stratigraphy, ages, and environments are expected to provide insights into the imprint of global climate change on the Middle Atlantic stratigraphic record

The Delaware Geological Survey successfully drilled a deep exploratory borehole at Sandtown, Delaware, during the summer 2023 field season. The drilling operation took place from May 30 to June 13, 2023, and achieved the deepest, continuously cored hole ever drilled in Delaware by the DGS, reaching a depth of 766 ft with a remarkable 85% core recovery. As a result, we obtained a nearly continuous core record of Paleogene and Neogene formations and aquifers that lie below the site, substantially improving our understanding of the geology of central Delaware and nearby areas of Maryland. The core samples were obtained using a technique called wireline coring, a type of drilling that is used for detailed analyses of the nature of buried geological formations. Wireline coring uses specialized drilling equipment to recover a tube of sample of the underground geology in good condition with minimal disturbance. The operation requires careful attention to the performance of the drilling equipment and nature of the formations, especially at greater depths as borehole conditions become more difficult to manage. The DGS is fortunate to have a highly skilled, experienced well driller, Steve McCreary, who adjusts procedures and modifies equipment during the operation in ways necessary to ensure recovery of core from most of the footage drilled.

The success of the drilling operation has resulted in a large volume of new sample material and data for DGS scientists and our collaborators. Detailed on-site lithologic descriptions, core photographs, geophysical logs, and spot samples for biostratigraphy allow for a preliminary interpretation of the nature of the subsurface geological formations and of the aquifers that provide groundwater in the area. This site is especially valuable because it fills a gap in regional core coverage. In-progress analyses of stratigraphy, ages, and environments are expected to enhance understanding of interstate stratigraphic equivalency and provide insights into the imprint of global climate change on the Middle Atlantic stratigraphic record.

DGS drill rig and field equipement set up at the Sandtown drill site.

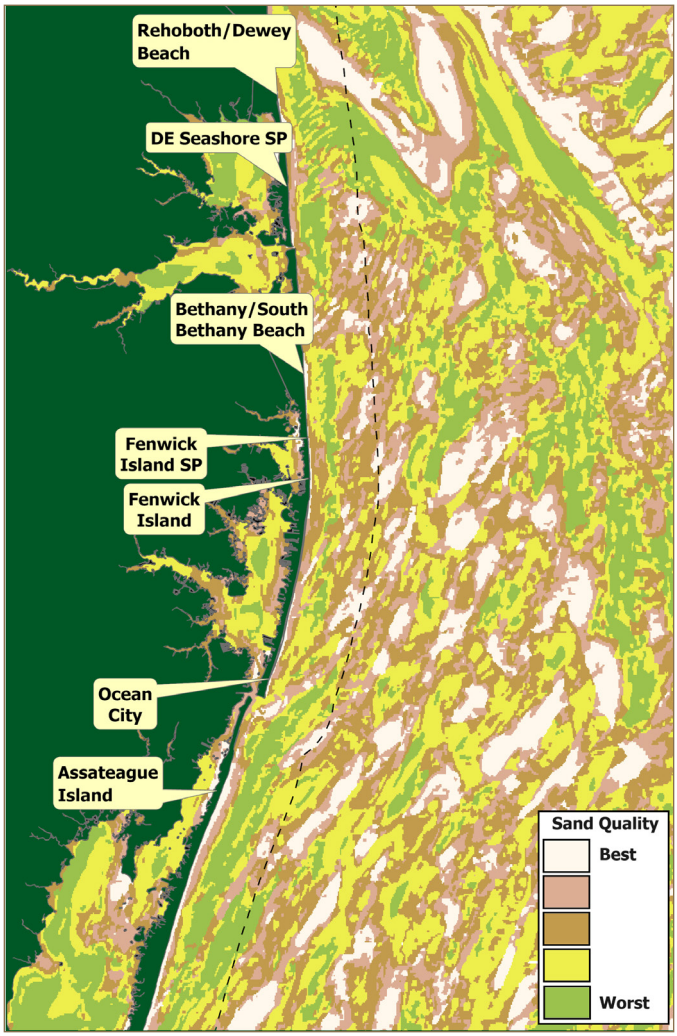
This research allows us to address several important geologic questions. In the upper 300 ft of the hole, the lower Miocene Calvert Formation was encountered. This formation is important because it contains a series of shallow marine sands, that provide groundwater resources to communities, households, and agriculture in central Delmarva. The connectivity of these sands in the subsurface of this area can be better understood through analysis of the stratigraphy and lithofacies. The poor development of some of the confining beds between the aquifer sands impacts the groundwater hydrology of the Miocene aquifer system, especially towards Maryland, and makes correlation of individual aquifers a challenge. In the middle depths of the hole, between 300 and 500 ft, the middle Eocene Piney Point Formation is present. The salt-and-pepper shelly sands of this formation function as a critical and heavily used source of high-quality groundwater in Delaware, Maryland, and New Jersey. The cores from this borehole can help us better understand an observed trend towards slightly muddier, poorer quality aquifer sands northward in Kent County. An interesting discovery was the occurrence of a muddy formation called the Marlboro Clay near the bottom of the borehole. The Marlboro Clay is of great interest to geological researchers because it provides a sedimentary record of an extreme and rapid global warming event that affected the planet 55 million years ago, a period called the Paleocene/Eocene Thermal Maximum. Geologists study events like this to understand the processes related to global warming in the past and how they might provide insights into global warming in the modern world.

Delaware Offshore Sand Resources

Project Contacts: Daniel L. Warner, Kelvin W. Ramsey, and David R. Wunsch

Modeling 21st Century Beach Sand Supply and Demand on Delaware and Maryland's Atlantic Coastlines

Over the past 60 years, coastal communities in Delaware and Maryland have used periodic beach nourishments as a strategy to preserve the economic and ecological value of their coastal infrastructure and beaches. This approach was chosen over alternatives of hard construction and coastal retreat due to its relative costs and benefits, but it requires frequent dredging of offshore sand resources to maintain the structure of dunes and beaches. Working with the Bureau of Ocean Energy Management, the DGS is investigating past trends in beach nourishment and



Map of major historical beach nourishment areas with model classifications of offshore sand resource quality quality. Dark green areas are onshore and barrier spit (Fenwick Island) and barrier island (Assateague Island).

forecasting future sand needs and supply. The goal of this work is to assess past and future sand resource needs in the region relative to existing supply and to identify potential offshore sand deposits to prioritize for further investigation. This work aims to support long-term, sustainable coastal and offshore management strategies in the face of climate change and competing interests in the offshore environment.

Sand demand was forecast from 2021 to 2100 under several different future scenarios ranging from a baseline extension of current nourishment trends to scenarios incorporating worst-case increases in erosive storm surge events due to sea-level rise and changes in storm frequency. We estimate that between 46 and 110 million cubic yards of sand will be needed to meet sand demands in the study area, depending on scenario parameters. The estimated volume of sand available in current sand sources may be able to meet demand until the mid-century, but there is still uncertainty regarding how much material these sources will be able to realistically supply. We used existing sediment core data and modeled potential additional sand resource areas based on bathymetric characteristics of the seafloor. Our model suggested that there are potentially abundant sand resources on the outer continental shelf, but we currently lack confirmatory survey data and sufficient understanding of the potential ecological impacts of dredging activities in these areas. Mapping potential high-value sand resource areas may allow managers to preclude them from being leased for other offshore activities until additional surveying can be done.

Middle Atlantic Coastal Plain Stratigraphic Reconciliation Initiative

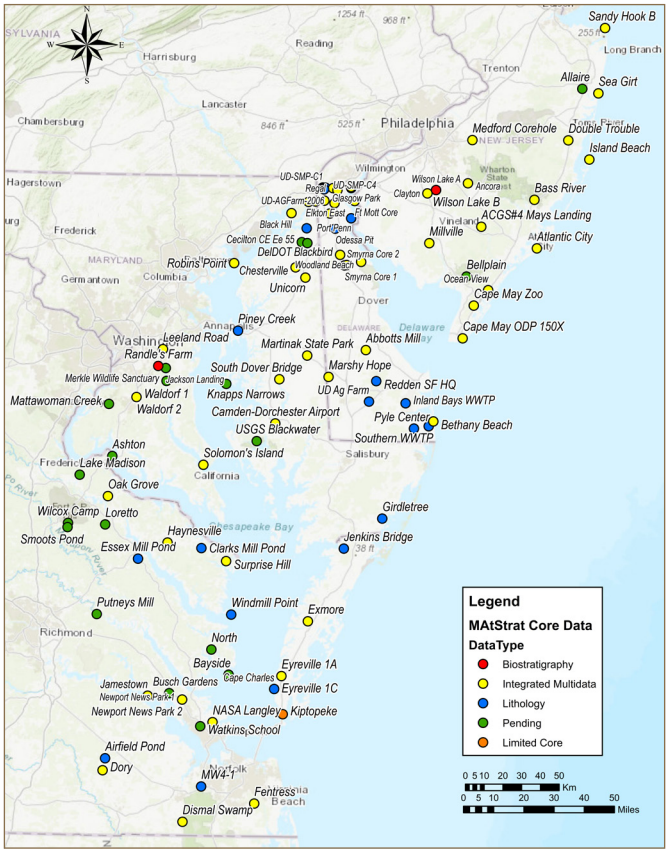
Project Contacts: Peter P. McLaughlin and Kelvin W. Ramsey

USGS-funded multistate initiative to establish equivalency of geologic units

The DGS has continued its multi-year effort leading a cooperative research project named the Middle Atlantic Coastal Plain Stratigraphic Reconciliation Initiative or "MAtStrat." The purpose of this project is to improve understanding and provide documentation of the equivalencies of formation names in the Middle Atlantic Coastal Plain province across state lines of four states: Virginia, Maryland, Delaware, and New Jersey. A key to the success of this project has been the collaboration of experts on the geology of the region across numerous participating organizations, including state geological surveys, water resource agencies, universities, and the USGS.

The MAtStrat Project was funded by the USGS's National Geologic Map Database Project (NGMDB) as the first of a handful of regional stratigraphic equivalency initiatives across the nation. The results of the project are helping to clarify the definition of geological formations in the four states, which will impact geological understanding in areas ranging from surficial geological mapping to management of groundwater resources. Mapping projects benefit from resolution of longstanding issues of formation name equivalencies at state boundaries where surficial geological maps created by different systems can appear to conflict. Groundwater management benefits from clarification of the equivalency of naming systems for groundwater-bearing formations, improving understanding of the connectivity of aquifer systems in the region.

The work effort has resulted in the compilation of a very large volume of data that documents regional stratigraphy. Most notable is the compilation of detailed multidisciplinary stratigraphic data (descriptive logs, geophysical logs, core photos, age/chronostratigraphy) from more than 100 wireline coreholes.



Map showing locations of cores used with the MAtStrat project.

Middle Atlantic Coastal Plain Stratigraphy Reconciliation Initiative, Part II

Led by the DGS, the state geological surveys of the Mid-Atlantic (Virginia, Maryland, Delaware, New Jersey) have partnered with the USGS to examine the Coastal Plain stratigraphic nomenclature of each state in order to update the USGS Geolex stratigraphic names database as a part of the Mid-Atlantic Stratigraphic Reconciliation Project (MAtStrat). As an outgrowth of the MAtStrat Project, MAtStrat II was funded to focus on the late Miocene to early Pleistocene section. These strata are associated with aquifers that are used by agriculture, industry, and consumers from southeastern Virginia to Cape May, New Jersey including the major Atlantic Coastal towns in Maryland and Delaware. The goal of MAtStrat II is to examine in detail all available core and sample material (especially wireline core) in the area of interest to develop a regional stratigraphic framework of the units. This goal will be accomplished by: 1) collection of all available stratigraphic data both published and unpublished, 2) identification of available core material and by use of state survey geologists and students serving internships for the project describing in detail the cores, 3) construction of regional cross-sections of the strata, 4) initiation of a multi-state workshop to refine the cross sections and correlations, and 5) identification of additional work that is needed. The project had 5 student interns for the summer of 2022 who obtained hands-on experience with cores. Especially important is the interstate cooperation and conversation between the states regarding the geology of the Delmarva Peninsula and the understanding of the aquifers that are the source of the important groundwater resources for the region.

While examining the corehole data for the MAtStrat II project for the Delmarva Peninsula, a gap in coreholes was identified between Ocean City Maryland, and the southern Delmarva of Maryland. With the cooperation of the Maryland Geological Survey, a 470-foot deep continuous wireline corehole was drilled in 2022 with the DGS drill rig at the Maryland State Highway Administration site north of Rt. 50 East of Berlin, Maryland. In 2023, two additional split-spoon cores were drilled at the Rt. 13 Welcome Center at the Maryland-Virginia border and at the Maryland State Highway Administration yard in Snow Hill, Maryland. Other participants in the core drilling included geologists from the Virginia Department of Environmental Quality, Groundwater Characterization Program. The results of the project have resolved some of the interstate stratigraphic correlation issues related to the major aquifers for coastal Delaware from Rehoboth Beach to Fenwick and into Ocean City, Maryland, that will aid in water resource management for these important sources of drinking water.

MAtStrat II core drilling at the Rt 13 Welcome Center in Maryland. Participants included geologists from the DGS, Maryland Geological Survey, and the Virginia Department of Environmental Quality.

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

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 the Kenton Quadrangle. This quadrangle was chosen, in part, with the guidance of the Delaware Geologic Mapping Advisory Committee (DGMAC). The DGMAC is comprised

In Memory of
Dr. Richard N. Benson

The DGS would like to remember longtime Senior Scientist Dr. Richard N. (Dick) Benson who passed away on August 22, 2023. Dr. Benson retired from the Delaware Geological Survey in February 2006 following more than 30 years of service to the DGS, University of Delaware, and the State of Delaware. He had a joint appointment as associate professor in the Department of Geology at the University of Delaware and was a Delaware licensed geologist. Dr. Benson's contributions to our understanding of the geology of Delaware cannot be overstated. His research brought groundbreaking new insights into the stratigraphy of the sediments under Delaware's Coastal Plain, the deep rift-basins that make up the foundation of our basement geology, and the petroleum potential offshore of Delaware's coast.

Dr. Benson earned a bachelor of arts degree in geology from Augustana College and a Ph.D in geology from the University of Minnesota. He joined the DGS in 1975 following six years of employment as an assistant professor of geology at Augustana College and four years as a geologist with Humble Oil and Refining Company. While employed at Humble Oil, he conducted research in regional stratigraphy and well-site paleontology and developed petroleum prospects in the Louisiana Gulf Coast. The broad base of knowledge and experience gained in industry and academia enabled him to contribute significantly to our understanding not only of the geology and hydrology of Delaware, but also that beneath the Outer Continental Shelf offshore Delaware. Dr. Benson was involved in research related to development of the subsurface geologic framework and geologic history of the Delaware Coastal Plain and the petroleum resource potential of the U.S. Atlantic Continental Margin. His scientific contributions are significant and invaluable in that they enabled the DGS to more fully understand the relationship between geologic formations and associated major aquifers that are used for public, industrial, commercial, water supply, and throughout the Coastal Plain of New Castle, Kent, and Sussex Counties. He also served as DGS editor for many years. The results of his work are contained in more than 42 publications and reports related to the geology and hydrology of Delaware and the Atlantic Outer Continental Shelf. In addition, he has served on numerous state, federal, and university graduate student committees, taught several courses, presented numerous lectures, and supported his profession through active participation and service in professional societies. Dr. Benson was a very fine scientist and educator but, more importantly, was a kind, thoughtful, congenial colleague held in the highest respect by his peers. The legacy of his career accomplishments will continue to benefit future geological researchers.

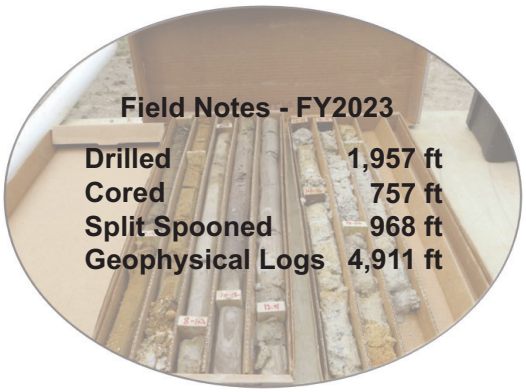
DGS Welcomes Christopher (Chris) Myers

Chris Myers joined the Delaware Geological Survey research staff in November 2022. Chris is a 2014 graduate of the University of Delaware obtaining a degree in Geological Sciences. Prior to joining the DGS staff, Chris worked as an environmental geologist at EHS Support. As a Research Associate II, Chris works on projects centered around Delaware's geology and is a part of the STATEMAP team.

DGS Welcomes Madeline Belknap

Madeline Belknap joined Delaware Geological Survey as a Research Associate I in April 2023. Madeline graduated from the University of Colorado Denver with a degree in Geography specializing in Environmental Science. She previously worked as an environmental analyst in Colorado and Maryland. Ms. Belknap is currently working on the data preservation project.

of stakeholders from diverse backgrounds including federal, state, and county government, environmental consulting, academia, and the non-profit sector. The committee prioritized this area over two other possible project locations because it is an emerging area of concern for water-yield issues for the State. This quadrangle is also adjacent to two previously mapped quadrangles (Clayton and Dover). Fieldwork for this project will be completed in June 2024.

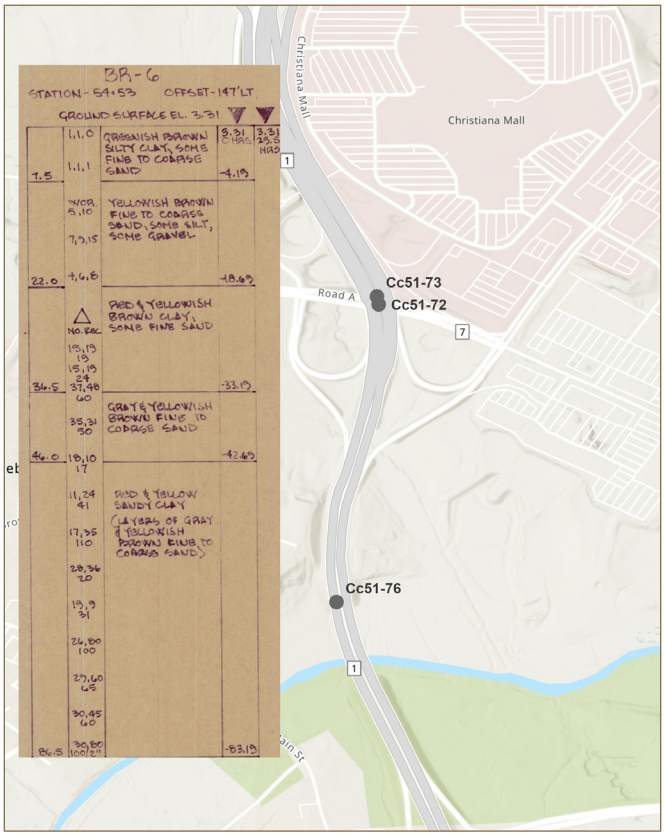


Borehole Log Data Preservation Project

Project Contacts: Project Contact: Peter P. McLaughlin

NGGDPP-funded project preserves borehole lithology logs for future studies

The DGS has continued to make advances in the capture of previously uncatalogued borehole data as part of our effort to preserve and improve public access to geological and geophysical data. Borehole lithology descriptions are fundamental to DGS geologic and hydrologic research and so must be permanently and securely preserved and retrievable for use by our researchers and stakeholders. The DGS has been able to dedicate a substantial effort to this objective with the support of the National Geological and Geophysical Data Preservation Program (NGGDPP), a federal program administered by the USGS that provides assistance to



1988 borehole log and location map preserved through the Data Preservation Program. Borehole BR-6 is DGSID Cc51-76.

DGS and DNREC Hold a Professional Retreat

The Water Division of the Delaware Department of Natural Resources and Environmental Control (DNREC) relies heavily on the geological and hydrogeological information that DGS collects as part of our mission. These data play a significant role in providing DNREC the subsurface information to accurately characterize the state's aquifers, thus allowing them to make responsible allocations of groundwater through the state's groundwater withdrawal and permitting process. In addition, the DGS geology and mapping program provides critical analysis and characterization of the geologic framework of the state's aquifers, which is important for determining their areal extent, productivity, recharge potential, and hydraulic characteristics that can be used to determine safe well yields. In addition, DGS routinely provides scientific and technical support for guiding monitoring and research projects on behalf of DNREC.

"Meeting with the professional staff from DNREC provided valuable feedback for DGS scientists to help guide our research programs in order to provide optimal benefits for DNREC personnel that use our data and expertise on a regular basis" remarked DGS Director David Wunsch.

To foment the exchange of information between both agencies, the leadership from DGS and DNREC convened their first annual joint agency retreat at the state's Buena Vista Conference Center on August 16, 2022. The retreat provided an opportunity for the staff of both agencies to meet and become acquainted in person and create opportunities for DGS staff to learn about DNREC's immediate data and information needs. The retreat was a successful and valuable event for both agencies, with plans to continue the retreats annually. Staff from both DGS and DNREC look forward to continuing their great working relationship for the benefit of the state of Delaware.

"DNREC and DGS have had an excellent long-standing relationship that has enabled us to better understand and manage the natural resources of our State. The sharing of information between our programs and the collaboration of our collective staff greatly strengthens both organizations. The recently established DGS/DNREC retreat provide us with the opportunity to continue these efforts and strengthen those relationships, particularly as both agencies bring on new staff" noted Steve Smailer, Director of the DNREC Division of Water.

state geological surveys for the preservation of geologic and geophysical data, maps, and samples.

Over the last year, the project identified, catalogued, and digitized borehole lithology log data from nearly 1,000 sites that will benefit DGS geological mapping projects, aquifer studies, and stakeholders who use data for environmental and engineering studies. A large portion of the project effort was focused on the capture of historical records of boreholes drilled for older highway construction projects. Additionally, we were able to preserve images of very high-quality DGS geologist logs and digitize the associated lithologic data in a standard format with quality assurance checks. These data are now captured as high-quality PDF-format images of lithologic logs and digitized through transcription of thousands lithology entries in the DGS in-house WATSYS relational database system. These newest data will soon be available to the public via DGS map-based internet interfaces.

In the coming year, data preservation efforts will shift from borehole lithology logs to wireline electrical/geophysical logs, a data type that contributes to the understanding of both subsurface geology and groundwater systems. The preservation of that additional category of data will be of great value to DGS stakeholders and to our own geological and hydrological studies.

Proposed Delaware Subsidence Monitoring Network

Project Contacts: Thomas E. McKenna, Changming He, Daniel L. Warner, and David R. Wunsch

Quantifying and mapping land subsidence along Delaware Bay

Delaware's land is subsiding (decreasing in elevation) while global sea level is rising. This increases the risk of flooding in coastal communities. The rise in the global sea level is relatively well known but the land subsidence component is still poorly understood. Relative sea-level rise along the coastlines of the northern Delmarva Peninsula (Delaware and Chesapeake Bays) is about two times higher than the global rise of 1.7 mm/year over the last century. DGS conducted a study to map land subsidence in the Delmarva region by analyzing National Geodetic Survey (NGS) historical high-accuracy geodetic-leveling data and NOAA long-term tide-gage data. Results suggest that the subsidence rates are 1 to 4 mm/year with subsidence increasing from north to south. DGS also began annual GPS monitoring of subsidence

GPS pole deployed on a survey mark to determine how much the land is subsiding. A survey is conducted annually.

at eight locations in 2019 in cooperation with a regional evaluation focused on greater Chesapeake Bay. The effort was jump-started by a year of funding from DNREC Coastal Programs.

Preliminary results for Delaware indicate subsidence is occurring at most of the locations, but it is not statistically significant because the amount of subsidence is not much more than the margin of error that GPS can measure. Results should be significant after 5-10 years. With the regional project winding down in its fifth year, DGS is proposing to create a permanent Delaware Subsidence Monitoring Network. This will enable Delaware's government agencies and communities to optimize actions to mitigate increased flooding due to sea-level rise and land subsidence. DGS is currently developing a monitoring strategy and seeking funding to implement a permanent monitoring network.

The DGS Support Team

Behind every program and activity is a fantastic support team

June A. Hazewski

Research Technician

June joined the DGS in 2021. One of her major laboratory responsibilities is the processing of sediment samples to isolate fossil pollen and other microscopic fossils. June also performs other standard laboratory operations including sediment analysis and helps manage DGS sample collections. She supports DGS field operations for collection of water levels in monitoring wells and obtaining geophysical logs from recently drilled wells.

Denise T. Heldorfer

Business Administrator

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 acquiring 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 taking 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.

3. Natural Hazards

DGS Natural Hazards Emergency Response Program

Project Contacts: Stefanie J. Baxter, Kelvin W. Ramsey, 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 and property. Our Natural Hazards program includes scientific initiatives as well as event-driven advisement to emergency management agencies. 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. The DGS 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, 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.

Assessing transportation impacts of nuisance and major coastal flooding in central Kent County, Delaware

Project Contact: Daniel L. Warner

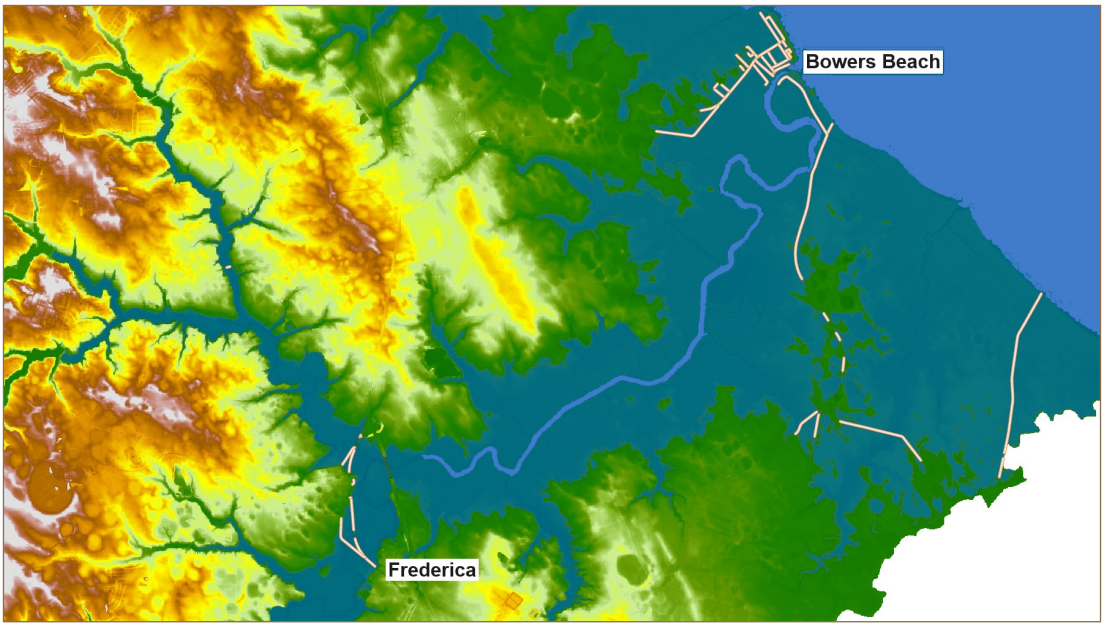
Modeling potential impacts of coastal flooding on road networks in Kent County to inform long-term planning decisions

Coastal communities in Delaware, such as Bowers Beach, Kitts Hummock, and Woodland Beach, are impacted by frequent, low-intensity flooding called "nuisance" flooding

An example of "nuisance flooding" of a coastal community's access road. Such flooding can occur multiple times per week, impacting transit to and from a community and potentially damaging the roadway.

on their primary (or only) access roads. While nuisance flooding may impact day-to-day traffic activities, major storm surges can have cascading impacts on traffic patterns that spread much further inland. Both types of flooding may affect the access to critical emergency services, and quantifying the impacts of these floods is important for long term strategic planning by the Delaware Department of Transportation (DelDOT).

This multidisciplinary project involves researchers from several groups, including the DGS, Delaware Center for Environmental Monitoring and Analysis, UD Water Resources Center, National Oceanic and Atmospheric Administration (NOAA), and the UD Center for Applied Demography and Survey Research. Working together we aim to develop a flexible framework for forecasting nuisance flooding under different sea-level rise projections and hindcasting major historical storm surges to assess their respective impacts on local traffic patterns and accessibility to critical services. The role of the DGS in this work is to develop scripts for automating GIS analyses of impacted roadways and their characteristics under different flooding scenarios. While this study is focusing on communities in central Kent County, Delaware, its approach is intentionally flexible. This will allow the methods we develop to be rapidly applied in other coastal areas around the state or under different hypothetical flooding conditions. This work supports DelDOT's ongoing efforts to address coastal hazards on the state transportation network in a changing climate.



Example output of road flooding estimates. DGS is developing a flexible, automated GIS analysis for identifying roads that would be flooded under different coastal inundation scenarios. Elevation characteristics of the affected road segments are automatically extracted to estimate flooding depth and probable points that will flood first. The affected roadway segments are fed into traffic analysis models to predict the impacts that a storm event may have on transportation and access to critical services. Warmer colors denote higher elevations.

DGS Education Outreach and Community Engagement

The DGS provides opportunities to enhance STEM (Science, Technology, Engineering, and Mathematics) education programs in the state. We also participate in forums where we can engage with members of the public to answer questions and make educational as well as other earth science materials available.

DGS Coast Day display showing how different natural environments move through geologic time.

UD's College of the Earth, Ocean, and Environment (CEOE) hosts their annual Coast Day at the Lewes Campus in southern Delaware each fall. The DGS has engaged the coastal community at Coast Day for over 20 years. Visitors interact with the DGS staff, prompted by poster displays, rocks, cores, and hands-on activities for children. New and rotating exhibits are displayed. Our exhibits focus on geologic and water resources and natural hazards. Activities for children have included searching for fossils, painting with natural clay minerals, and a Pet Rock Petting Zoo. Visitors are provided with samples of the state mineral

DGS display featuring the bedrock geologic map of the Delaware Piedmont with samples of the bedrock units.

DGS participates annually in UD's CEOE Environment, Climate and Ocean (ECO) Camp for students entering grades 7 through 12 with a keen interest in marine science. This year, DGS Director, David Wunsch, introduced the students to the DGS and what the functions are of a state survey. He went on to give a "tour" of the DGS drill rig, explaining split-spoon and wireline coring.

Following the drill-rig demonstration, Jaime Tomlinson took the students to the core lab where she gave a short talk on how geologists determine formations using color, grain size, mineralogy, silt matrix, and distinctive fossils.. This discussion was followed by a hands-on exercise where teams of 2-3 students described their cores and tried to match what they saw with standard formation descriptions.

4. Information and Data Dissemination

Online Open Data Access

Project Contact: 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 Delaware First Map (https://firstmap.delaware.gov) as web map services or 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. Map products are available as Adobe PDF files with source data downloadable separately in GIS format. Published map products in recent years are available as interactive PDFs, allowing the user to switch on/off each map layer embedded in the document. The variety of data sharing methods employed by DGS provides easy access for state agencies, academic research groups, industry, and the public.

Online XML and Mapping Applications

Project Contacts: Changming He and Daniel L. Warner

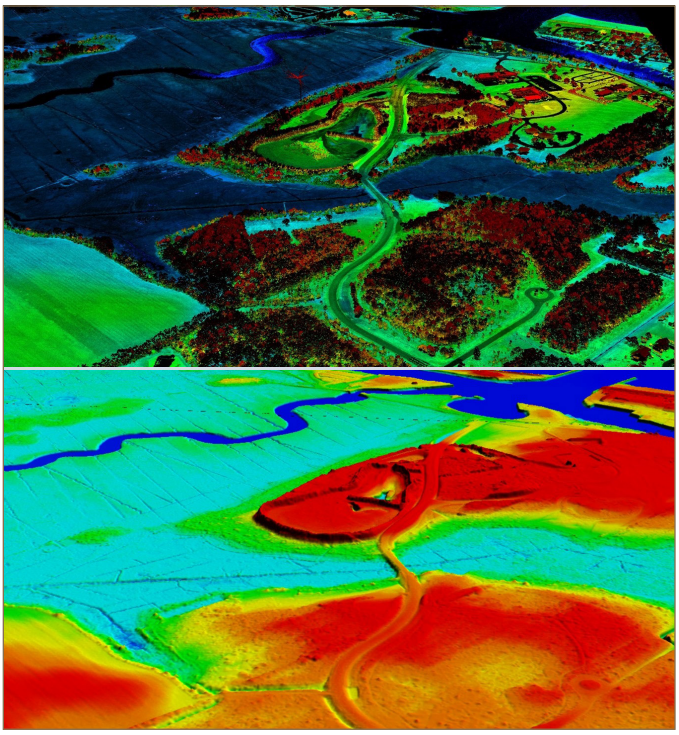
Delivering DGS data to state agencies and the public using web-based technologies

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. 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 geologic and 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.



Example of a LiDAR point cloud (top) that captures ground, vegetation, structures, boats, and even birds. The point cloud is filtered and interpolated to produce a digital elevation model (bottom) that provides a smooth surface of local topography. Note that these data are vertically exaggerated 5x to make it easier to distinguish major features.

Statewide LiDAR Program for Delaware - 2023 Update

Contact: Daniel L. Warner

New LiDAR product offers higher resolution for Delaware

Airborne Light Detection and Ranging (LiDAR) is used for measuring the structure of buildings, vegetation, and bare ground using millions of laser pulses emitted from low flying aircraft. These pulses are processed to produce data products like digital elevation models, vegetation structural models, and 3-dimensional representations of buildings and infrastructure, which are critical for supporting analyses in environmental, engineering, and agricultural sectors.

Airborne LiDAR was used to measure the elevation of the ground surface for the entire state of Delaware in 2013 as part of a multi-agency state and federal effort (including the DelDOT, DNREC, USGS, and NOAA) in the wake of Hurricane Sandy. However, areas of the state have undergone substantial changes in land use and development since then. The DGS, with funding from the Delaware Department of Technology and Information (DTI), have entered a joint funding agreement with the USGS to collect an updated LiDAR dataset for the state. The new dataset will meet USGS quality level-1 standards that far exceed the 2013 dataset. With a minimum point density of 8 pulses per square meter, the new dataset will provide elevation maps with 0.5-meter resolution. The new dataset is also tide-coordinated, meaning that coastal areas were only surveyed at low tide. This will give an unprecedented representation of the structure of Delaware's extensive tidal wetland networks and support coastal flooding and conservation projects. Ultimately, the new LiDAR dataset will support ongoing state and federal research, development, and management activities for years to come.

PUBLICATIONS

DGS PUBLICATIONS COMPLETED

BULLETINS

B 22 Aquifers and Groundwater Withdrawals, Kent and Sussex Counties, Delaware, **McLaughlin, P.P., Tomlinson, J.L.,** and Lawson, A.K., 2023, 105 p.

REPORT OF INVESTIGATIONS

RI 83 Evaluating Impacts of Sea-Level Rise on Groundwater Resources in the Delaware Coastal Plain, **He, C.,** and **McKenna, T.E.,** 2023, 15 p.

RI 84 Mapping Evapotranspiration for 2016 Growing Season Using Landsat 8 Images and Metric Model, Sussex County, Delaware, **He, C**., **Andres, A.S.**, Brinson, K.R., and DeLiberty, T.L., 2023, 10 p.

RI 85 Kent County Groundwater Monitoring Project: Results of Subsurface Exploration and Hydrogeological Studies, **Andres, A.S., McQuiggan, R.W., He, C.,** and **McKenna, T.E.**, 2023, 75 p.

DGS PUBLICATIONS IN PROGRESS

REPORT OF INVESTIGATIONS

RI 86 Kent County Groundwater Monitoring Project: Hydrogeology and Salinization Dynamics of Eastern Kent County *(in press)*.

OPEN FILE REPORTS

OFR 56 Early Mesozoic Rift Basins in Delaware: A Review of their Occurrence and an Assessment of their Carbon Potential ***(in press).***

OFR 57 Groundwater Monitoring Procedures Part 2: Equipment and Procedures for Collection of Water-Quality Samples from Monitoring Wells *(in press)*.

GEOLOGIC MAPS

GM 28 Geologic Map of the Newark West, Newark East, and Wilmington South Quadrangles.

EXTERNAL PUBLICATIONS BY DGS STAFF

Dorsey, A., Kaste, J.M., Lockwood, R. and **Ramsey, K.W.,** 2023, Stratigraphic Distribution and Source of Radon in the Yorktown Formation (Virginia), *Geological Society of America Joint Southeastern and Northeastern Section Meeting Abstracts with Programs,* v. 55, no.2.

Hingst, M.C., **McQuiggan, R.W.,** Peters, C.N., **He, C.,** Andres, A.S., and Michael, H.A., 2022, Surface Water-Groundwater Connections as Pathways for Inland Salinization of Coastal Aquifers, *Groundwater*, v. 61, no. 5, https://doi.org/10.1111/gwat.13274.

McLaughlin, P.P., Vincett, W., Gardner, K.F., and Self-Trail, J., 2022, Paleogene Chronostratigraphy, Facies Changes, and the Enigmatic PETM in Central Delaware, *Geological Society of America Abstracts with Programs,* v. 54, no. 5, doi: 10.1130/abs/2022AM-383740.

McQuiggan, R., Andres, A.S., Roros, A., and Sturchio, N.C., 2022, Stormwater Drives Seasonal Geochemical Processes Beneath an Infiltration Basin, *Journal of Environmental Quality,* v. 51, no. 6, https://doi.org/10.1002/jeq2.20416.

Norville, R.C., and **McLaughlin, P.P.,** 2022, The Stratigraphy of the Magothy Formation in the Northern Delmarva Peninsula: New Data from the Bohemia River Corehole, *Geological Society of America Abstracts with Programs,* v. 54, no. 3, doi: 10.1130/abs/2022NE-375103.

Warner, D. L., Callahan, J. A., **McKenna, T. E.,** and Medlock, C., 2023, Reducing Vertical Bias and Error in Tidal Marsh Digital Elevation Models with Machine Learning and LiDAR Derivatives, *Estuarine, Coastal and Shelf Science,* v. 291, 108442, https://doi.org/10.1016/j.ecss.2023.108442.

Wunsch, D.R., and Keane, C., The AGI Fisher Congressional Fellows Program: A Sustained and Successful Intersection of Geoscience and Congress, *Geological Society of America Abstracts with Programs,* v. 54, no. 5, doi: 10.1130/abs/2022AM-379122.

DGS PRESENTATIONS

Schreiber, R., Musick, M., **Wunsch, D.,** The Development and Implementation of the National Groundwater Monitoring Network (NGWMN) – A Shining Example of Cooperation and Data-Sharing, 13th National Monitoring Conference, Virginia Beach, Virginia, April 24-28, 2023.

Wang, L.T., The Hunt for Delaware Boundary Monuments, North American Cartographic Information Society (NACIS) Conference, Minneapolis, Minnesota, October 18-22, 2022.

Warner, D.L., Ramsey, K.W., and **Wunsch, D.R.,** Assessing Offshore Sand Resource Needs Along the Delaware and Maryland Atlantic Coast to Support Coastal Resilience Efforts, American Geophysical Union Fall Meeting, Chicago, Illinois, December 12-16, 2022.

Warner D.L., Callahan J.A., **McKenna T.E.,** and Medlock C., Reducing Vertical Bias of LiDAR Elevation Data in Tidal Marshes: Implications for Estimates of Marsh Inundation Frequency and Extent, American Geophysical Union Fall Meeting, Chicago, Illinois, December 12-16, 2022.

Warner D.L., Callahan J.A., **McKenna T.E.,** and Medlock C., Reducing Vertical Bias of LiDAR Elevation Data in Tidal Marshes: Implications for Estimates of Marsh Inundation Frequency and Extent, Delaware Geospatial Data Committee Fall Meeting, Dover, Delaware, August 11, 2022.

Warner D.L., Callahan J.A., **McKenna T.E.,** Mapping and Modeling Blue Carbon Storage in Delaware Coastal Wetlands, Mid-Atlantic Committee on the Ocean Forum, Virtual, May 5, 2022.

DGS Service to Professional Societies, Boards, and Committees

American Association of Petroleum Geologists Committee on Preservation of Geoscience Data

American Geophysical Union

American Geosciences Institute, Executive Committee

Association of American State Geologists

Association of American State Geologists Foundation

Center for the Inland Bays, Board of Directors

Center for the Inland Bays, Hydrodynamic/Water Quality Model Workgroup

Chesapeake Bay Vertical Land Motion Workgroup

Center for the Inland Bays Scientific and Technical Advisory Committee

Cushman Foundation for Foraminiferal Research, Board of Directors

Cushman Foundation for Foraminiferal Research, Chairperson for Student Awards Committee

Delaware Department of Natural Resources Source Water Protection Program Citizen and Technical Advisory Committee

Delaware Emergency Management Agency State Hazard Mitigation Council

Delaware Emergency Management Agency Technical Assessment Center Group

Delaware Geographic Data Committee

Delaware Geologic Mapping Advisory Committee

Delaware Leaking Underground Storage Tank Committee

Delaware River Basin Commission Regulated Flow Advisory Committee

Delaware State Board of Geologists

Delaware State Names Authority

Delaware Water Infrastructure Advisory Council, Wastewater Subcommittee

Delaware Water Resources Advisory Committee

Delaware Water Supply Coordinating Council

Delaware Water Well Licensing Board

Directory of Public Repositories of Geological Materials Working Group

Federal Geologic Mapping Advisory Committee

Geological Society of America, Academic and Applied Geoscience Relations Committee

Geological Society of America, Hydrogeology Division, Liaison to AGI

International Continental Scientific Drilling Program

Murderkill River Monitoring and Modeling Workgroup

National Association of State Boards of Geology

National Association of State Boards of Geology Council of Examiners

National Geologic Map Database, Geologic Map Schema Working Group

National Ground Water Association, Water Management Subcommittee

National Index of Borehole Information Working Group

National Petroleum Council

New Castle County Resource Protection Area Technical Advisory Committee

New Jersey-Delaware Tidal Marsh Working Group

River Master Advisory Committee

River Master Decree Party Workgroup

Sussex County Source Water Protection Technical Advisory Committee

University of Delaware Engagement Council of Public Engagement

University of Delaware Ph.D. and M.S. Student Committees

University of Delaware Department of Earth Sciences Chairperson Search Committee

University of Delaware Water Resources Center Advisory Panel

NOTES

ANNUAL REPORT OF PROGRAMS AND ACTIVITIES | 2022-2023

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