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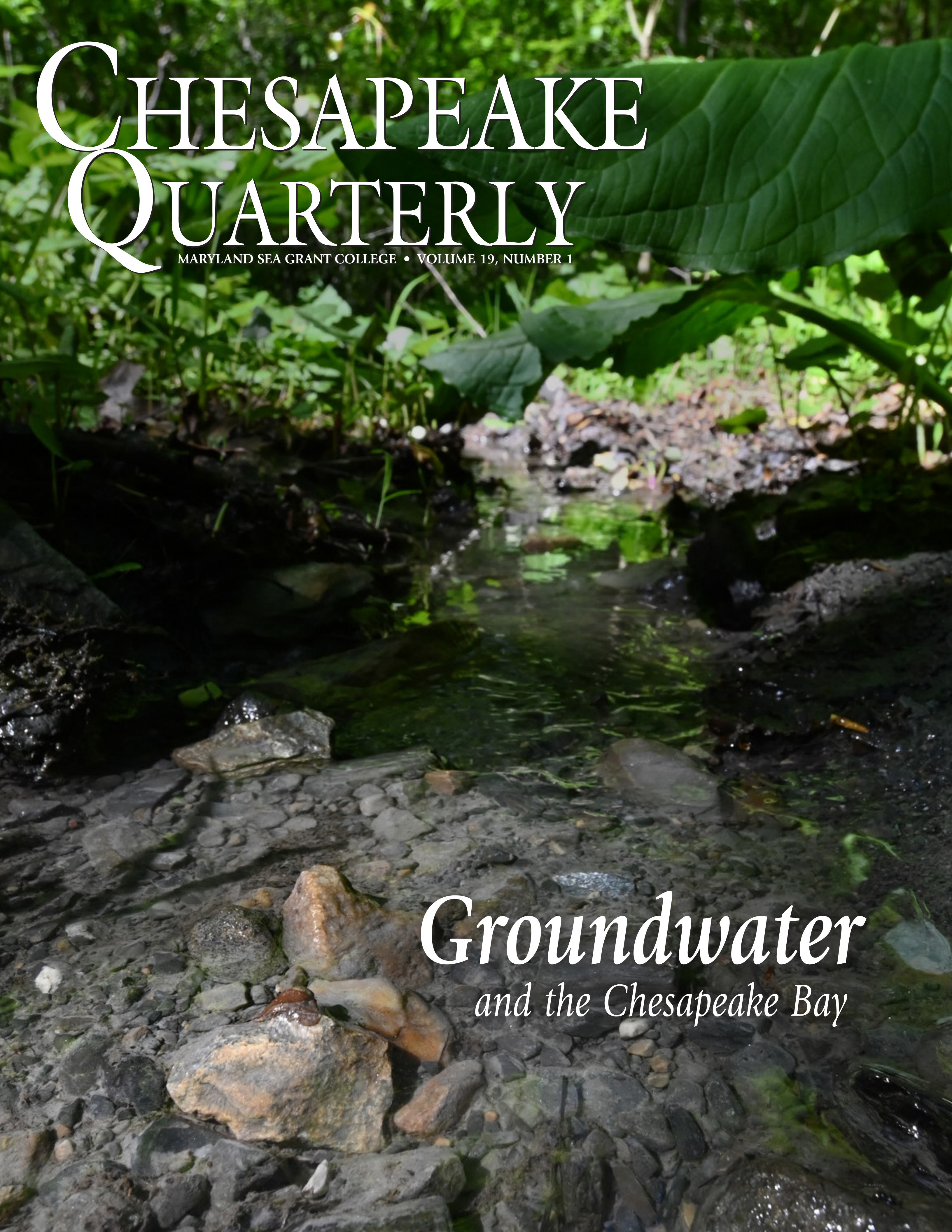

Groundwater
and the Chesapeake Bay

***Chesapeake Quarterly:* Groundwater and the Chesapeake Bay**
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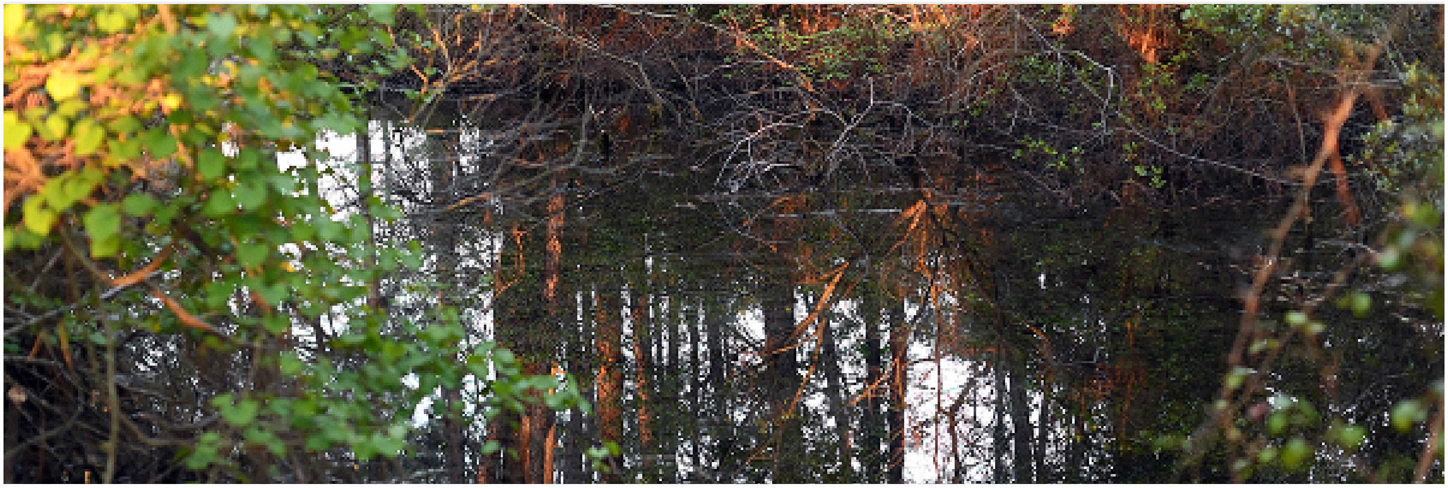
Chesapeake Quarterly explores scientific, environmental, and cultural issues relevant to the Chesapeake Bay and its watershed. The magazine is produced and funded by the Maryland Sea Grant College. The college receives support from the National Oceanic and Atmospheric Administration and the state of Maryland.



Looking Under the Surface

Groundwater and the Chesapeake Bay

Rona Kobell

Most of us don't think about groundwater that much. But maybe we should.

Groundwater—the water beneath Earth's surface—feeds our streams. It feeds us, too. About 30 percent of Marylanders tap into it for their drinking water. But it also contributes significantly to the pollution loads in the Chesapeake Bay.

This issue looks at how groundwater moves through the different geographic regions in Maryland, and at the coming threats to our water supply from legacy industry pollution, saltwater intrusion due to climate change, and growing demand from farmers as they grapple with more extreme weather conditions.

Editor Rona Kobell in the field.
Photo, Nicole Lehming / MDSG

The stories in this issue examine how nitrogen from septic tanks can enter waterways, how researchers have pinpointed its sources, and how they are trying to determine if denitrifying processes have unanticipated harmful side effects. We visit a corn field for a closer look at the nitrogen cycle with doctoral student Jake Hagedorn, who commutes between a farm site on the Eastern Shore and University of Maryland Center for Environmental Science's Appalachian Laboratory in the far western corner of Maryland to run his experiments.

We also visit scientists at the University of Maryland, Eastern Shore, to check in on their on-the-ground research projects that test various ways of reducing nitrogen and phosphorus from fertilizer from entering water supplies, and take a look at the Maryland Department of Planning's efforts to bring together a group of researchers and managers to limit saltwater intrusion in the future as the climate continues to change. Finally, we talk to modelers at the Chesapeake Bay Program who incorporated lag times for groundwater into their model, enabling managers to gauge the effectiveness of best management practices, and how long it would take for those practices to show results. We show how groundwater moves through aquifers and ultimately reaches our seas. We introduce readers to Eric Buehl, a Sea Grant Extension specialist who is working hard to keep the water clean on the Eastern Shore.

There is a lot to look at here, even if we physically can't see the subject so well. We hope you enjoy it, and we'll be back to print for future issues of *Chesapeake Quarterly!*

Header image: Some freshwater ponds on Assateague Island are fed from an unconfined aquifer beneath the island. Photo, Lisa D. Tossey / MDSG

Ground Game

How the Water We Can't See Can Harm the Chesapeake Bay

Rona Kobell

When raindrops fall, where do they go?

Some fall directly into streams, rivers, and the Chesapeake Bay. Some slide down roofs and driveways and flow into storm drains, which often release this runoff, and all it carries, into nearby bodies of water. And some will hit the ground and sink in, where they may be drawn up by the roots of plants or sink deeper to collect in underground reservoirs, called aquifers.

A raindrop that enters the ground in Frederick, Maryland, could make its way through limestone and quartz formations. In Western Maryland, it could travel through shale and steep gorges. On the Eastern Shore, the drop could work its way quickly through sandy, permeable soils and into the underground basins. While raindrops may look alike as they fall from the sky, each has a different impact under the ground. And wherever they fall, raindrops may refill, or recharge, aquifers.

> *"Once it's in there, the problem is you really can't get it out…Eventually all groundwater wants to, and will come back to, a stream–along with the pollutants it carries." –Scott Phillips, U.S. Geological Survey*

This journey is important for all of us—half of the United States' population gets its drinking water from these supplies, which are aptly called groundwater. In the Chesapeake Bay watershed, groundwater supplies nearly one-third of Marylanders, or nearly 1 million people, with their drinking water. Towns, homeowners, farmers, and businesses can drill wells into aquifers and pump out the water, and we often rely on groundwater to irrigate crops that provide the food we eat.

But what's crucial for survival can also be a conduit for excess nutrients. Groundwater feeds streams, and rainwater replenishes the supply to both. In rare instances, streams also feed groundwater. But whichever way the waters flow, they can carry many things with them, including nutrients. Scientists from several universities are assessing the groundwater across the watershed, from central Pennsylvania forests to urbanized streams near Baltimore, to determine how it moves under different geologic formations and the consequences of that flow.

Groundwater in Gambrill State Park, Frederick County, Maryland. *Photo, J. Adam Frederick*

"Once it's in there, the problem is you really can't get it out," Scott Phillips, a hydrologist with the U.S. Geological Survey (USGS) who coordinates the Chesapeake Bay Program's groundwater work, said of the nutrient load in the groundwater. "Eventually all groundwater wants to, and will come back to, a stream—along with the pollutants it carries."

Slightly less than half of the Chesapeake Bay's nitrogen pollution comes from rural-derived sources—mainly manure and conventional fertilizer. Nitrogen, when combined with oxygen, becomes nitrate, which can enter surface water as well as groundwater. When nitrate in the groundwater is too high, it can cause human health problems when ingested, especially in infants, by decreasing hemoglobin's ability to transport oxygen to tissues and contributing to a condition called methemoglobinemia, or blue baby syndrome.

Groundwater quantity and quality go hand in hand. When farmers, municipalities, and industry withdraw groundwater, they deplete aquifers. Less water in an aquifer increases the potential for more saltwater intrusion and less dilution of it or any other contaminants that may enter the system. The Maryland Department of the Environment manages both quantity and quality in conjunction with local jurisdictions; some states have separate managing agencies.

MAPPING THE GROUNDWATER

Groundwater is one of our most valuable resources. But what is it? And how does it work?

https://arcg.is/DG4iy

Confined and unconfined aquifers are also partners in groundwater management. The USGS defines an unconfined aquifer as "an aquifer whose upper water surface (water table) is at atmospheric pressure, and thus is able to rise and fall," while a confined aquifer is "below the land surface that is saturated with water, with layers of impermeable material are both above and below, causing it to be under pressure so that when the aquifer is penetrated by a well, the water will rise above the top of the aquifer." (See “Mapping the Groundwater”). When it rains, water seeps into both the water table and the confined aquifer through fissures in the rock. So, the quality of an area’s groundwater depends on the frequency of rain, the quantity it holds, and the kinds of geographic formations that confine it.

Grounding the Model

It helps to think of groundwater as a delivery mechanism instead of a separate source of nutrients to the Chesapeake Bay, said Gary Shenk, a USGS hydrologist based at the Chesapeake Bay Program. So how do you count it?

It has become tricky for scientists to measure and count groundwater as a contributor to nutrient pollution, in part because it can remain in the water for decades. After the initial Chesapeake Bay Agreement in the 1980s—when leaders of six states and Washington, D.C., agreed to reduce Bay pollution—scientists began modeling pollution-reduction strategies to see how far certain practices would get them. For example, if a town of 10,000 residents upgraded its wastewater treatment plant to reduce nitrogen and phosphorus, the model could provide an idea of how much of a reduction that would be. But groundwater is not straightforward.

“It is so complicated,” said Susan Brantley, Distinguished Professor of Geosciences and director of the Earth and Environmental Systems Institute at Penn State University. “A lot of nitrate goes into the groundwater, and it can be decades before it gets into the rivers.”

It can take decades for nitrogen that enters groundwater to flow through the system and reach the Chesapeake Bay. For example, fertilizer applied during the Reagan Administration could still be working its way through the system, and the model would not have accounted for that lag time of when fertilizer applied in the 1980s might actually enter the Bay. So an effort, or best management practice, a farmer does today to catch or reduce the nitrogen flowing off their fields into the Bay might stop those nutrients today, but not the nitrogen added and trapped in the groundwater decades ago. The slow movement of this "legacy" nitrogen through groundwater and into the Bay is called lag time.

Shenk’s fellow hydrologists at the USGS, Phillips among them, worried that the Bay cleanup model could not accurately predict how much nitrogen best management practices would remove if it did not account for groundwater lag times.

“We can bring nutrients down, but the unanswered question is, how long does it take for the system to respond?” Shenk said. “How long will it take for groundwater to work through the system? It has not been a top priority for the Bay Program, and we haven’t had the model to answer for it until now.”

The latest Chesapeake Bay Program Watershed Model, the sixth such iteration, came out in 2017, and it is the first to factor in the pace at which groundwater moves in different geographic areas. (The Bay Program has models to measure air and sediment also, but those don't look at groundwater.) Having the lag times in the model gives the program greater certainty of when cleanup goals will be met.

MODEL METHODS

Read more about how the latest Chesapeake Bay Program Watershed Model factors in groundwater…

https://arcg.is/0DajKP

The Chesapeake Bay's Total Maximum Daily Load (TMDL) cleanup plan states that all land management practices to reduce pollution in the watershed must be in place by 2025, but Shenk points out that doesn't mean they will produce the desired effect by then. A forest buffer—an area of trees, shrubs, and other vegetation bordering a waterway that helps absorb nutrients before they can enter the water—takes years to grow to full effectiveness. It can also take years to obtain improved water quality by reducing the amount of nitrogen and phosphorus applied to the soil. Because groundwater can move slowly, water that is 20 to 30 years old and full of excess nutrients could just be entering streams now, even as better land management practices are reducing the amount of nutrients being applied today to the land's surface.

It matters, too, where the groundwater comes from. Ward Sanford, a research hydrologist with the USGS Water Resources Discipline National Research Program, modeled the groundwater features, and the subsequent lag times in the Potomac River and the Eastern Shore's portion of the Coastal Plain region. The Potomac River, stretching across four Maryland geologic regions, the Piedmont, Blue Ridge, Ridge and Valley, and Appalachian Plateau, represented one data set, while the Coastal Plain represented a second data set. All five regions have distinct rock characteristics and varying groundwater lag times. With these data Shenk said, they had the needed information to effectively model the whole watershed's groundwater inputs accounting for the different features and lag times for nutrient inputs.

Shenk expects the newest model will become more refined, but it’s a start for developing a more accurate picture of when we will see the results of efforts to reduce nutrient pollution.

“This won’t change what we’re asking people to do in terms of their nitrate reductions,” he said, “but it will change how fast we will see the results.”

Too Much Salt

Scientists aren’t sure how climate change will complicate the groundwater picture—only that it will. Already, municipal water supplies are grappling with saltwater intrusion impacting groundwater supplies in coastal areas. If municipalities or industries located in areas near the bay and the ocean pump out too much freshwater, then denser saltwater may move in, infiltrating the wells and making the water too salty for drinking. With the Chesapeake Bay’s sea level rise among the highest in the nation, the frequency and levels of saltwater flooding, as storm surges push saltwater inland and onto cropland, could increase due to climate change. More intense precipitation events from climate change may help replenish aquifers, though aquifer recharge is most effective with a steady, light rainfall, rather than a deluge that sends the water running off the surface. And warmer water temperatures could mean more evapo-transformation—more water entering the air—making less available for groundwater recharge.

John Swaine stands near the road at his Eastern Shore farm. In recent years, he's noticed saltwater intrusion harming his fields. *Photo, Nancy Averett*

For decades, the Swaine family has farmed corn, soybeans, and wheat on 1,200 acres in Royal Oak, near the Oxford–Bellevue Ferry in Talbot County. For almost as long, a Swaine has been watching the weather, including the tides. John Swaine Jr. was one of the state’s 37 certified weather watchers; his son, John Swaine III, took over the tradition when his father died in 2012.

Three to four times a month, the tide is high enough so its saltwater sits on the land and infiltrates the crops. He’s lost about 10 to 12 acres to salt this year. But not far from his mind is Hurricane Isabel, when he lost his well water due to saltwater infiltration. The tide came up enough to submerge the well. Swaine had it pumped out, but he says he would have done things differently to prepare for future saltwater intrusion if he’d known then what he knows now.

“I wish we would have put it in a different location,” he said. “We could have put it on the other side of the house, on higher ground.”

Swaine is not the only farmer watching his wells. Researchers have long noticed that saltwater is ruining some farm fields when tides rise and don't quickly recede. But the saltwater can also come from below the surface. Saltwater is denser than freshwater, and it can seep into groundwater aquifers through cracks in rocks and remain there until it's pumped up. It doesn't take much salt to change a water supply from freshwater to saltwater, and withdrawals can contribute to higher salinity levels. Depleting groundwater creates a cone of depression around wells, which leaves room for increased flow of brackish water into aquifers. That means farmers struggling with the impacts of climate change, such as cycles of heavy rain and drought, will have to rely more on groundwater to irrigate their crops. If salt contaminates that water, it can ruin those crops.

Research from Kate Tully, an assistant professor of agroecology at the University of Maryland, shows that few crops can grow in sustained conditions of salinity more than 2 parts per thousand—far below the salt content in many fields with saltwater intrusion. Tully and her team have worked with many farmers on the Shore, but she said the research is still inconclusive as to how much of the salt is coming from the surface and how much is coming up from shallow aquifers, and whether the saltwater will eventually harm deeper drinking-water wells.

Kate Tully, an assistant professor of agroecology at the University of Maryland, measures the amount of saltwater intrusion on an Eastern Shore farm.

"The creek water that you see is groundwater and it's tidal water—it's already both, it's already mixed," she said. "You're pouring two different cups of water in the same bath—it's hard to determine which one comes from which source."

When rain mixes with the saltwater that has seeped up through the ground, it produces new complications for nutrient-reduction efforts. Saltwater can extract legacy nitrogen and phosphorus from agricultural lands long after they have been abandoned, delivering additional loads of those nutrients to the groundwater and Chesapeake Bay, according to research conducted by Tully and several colleagues, including Keryn Gedan of George Washington University.

Tully and Gedan can see the saltwater is coming, but they can't yet predict where it will go next—in part, said Gedan, because the aquifer maps are "woefully out of date" and ecosystems and connectivity have changed since they were drawn in the 1980s. She and colleagues are monitoring Shore wells to help prepare farmers for a future in which some crops can’t be grown and irrigation water is contaminated with salt.

“I have come to see [saltwater intrusion and groundwater] as a much more important piece of the puzzle,” she said.

Smart Management

The Chesapeake Bay watershed has its groundwater challenges, but also some advantages. Coordination among six watershed states and the District of Columbia ensures that the principals involved in water quality and quantity are talking. Maryland manages its groundwater and surface water jointly, with the state’s Department of the Environment overseeing both and the Maryland Department of Natural Resources weighing in on fish and habitat. Peter Goodwin, president of the University of Maryland Center for Environmental Science and a hydraulic engineering specialist, came to Maryland from the University of Idaho and said he noticed the cooperation almost instantly.

“Maryland is good at that—at coming together with agencies to solve problems collaboratively,” Goodwin said. “Managing groundwater and surface water conjunctively is one example.”

Other states have seen communities, farmers, and water authorities take legal action against each other to protect their groundwater withdrawal rights. Idaho has been a flash point, with a state court recently settling on how much different users could take.

On the quality side, said Goodwin and Phillips, Maryland’s environmental focus and cooperative nature is also helpful. Some areas, like Fort Meade in Anne Arundel County, have issues with groundwater contamination, but expensive mandatory cleanup efforts have lessened the problems, Phillips said. An extensive monitoring project near Phillips' office at the University of Maryland, Baltimore County, is also providing a lot of information about what can pollute groundwater in suburban settings.

The speed at which Maryland officials developed a working group focused on a saltwater intrusion plan is a positive sign as well, Goodwin said. The legislature requested that the Maryland Department of Planning (MDP) lead a study on the saltwater threat, and the agency brought in a diverse group of scientists to do so along with lead writer Jason Dubow, MDP's manager of resource conservation.

It took decades to get stakeholders to pay more attention to what's under their feet. Now that they have become more aware, geologists say, we need to maintain that focus.

"We can't create water, and we can't destroy it," Goodwin said, "so we have to manage what we have got in a much better way."

Header photo: Millbrook Marsh Nature Center in State College, Pennsylvania, is a 62 acre park featuring a two-acre calcareous fen, a rare habitat fed by groundwater seeping through limestone bedrock. Photo, Will Parson / Chesapeake Bay Program

Kate Tully photos by Edwin Remsberg

Model Methods

Rona Kobell

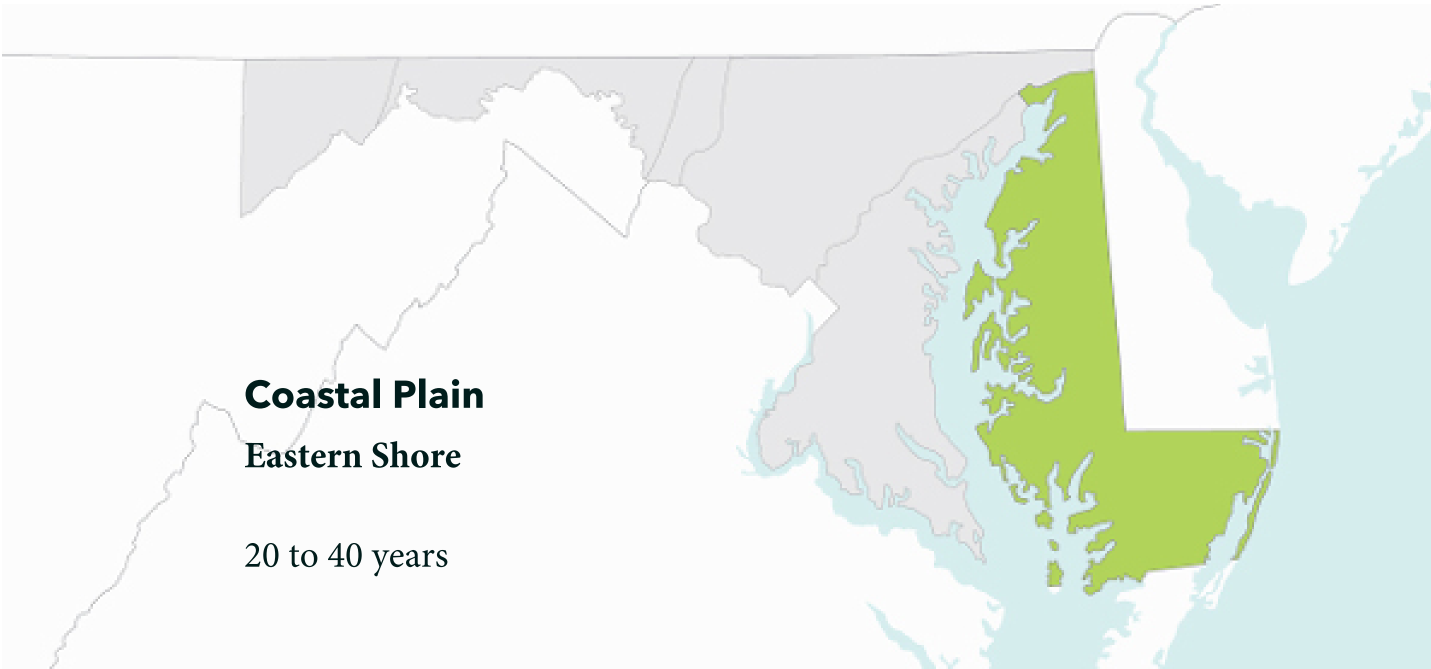
The way in which groundwater moves has raised questions about the pace of Chesapeake Bay cleanup and the adequacy of data to estimate progress.

First, how do we know whether we have reduced nutrient and sediment pollution to the Chesapeake Bay—and second, will we continue to do so? Two gauges are used to measure nutrient reduction in waterways: The states and the federal government look at *conditions,* while the Chesapeake Bay Program Office, which is managed by the Environmental Protection Agency (EPA), uses *models* to evaluate different practices and estimate their effectiveness.

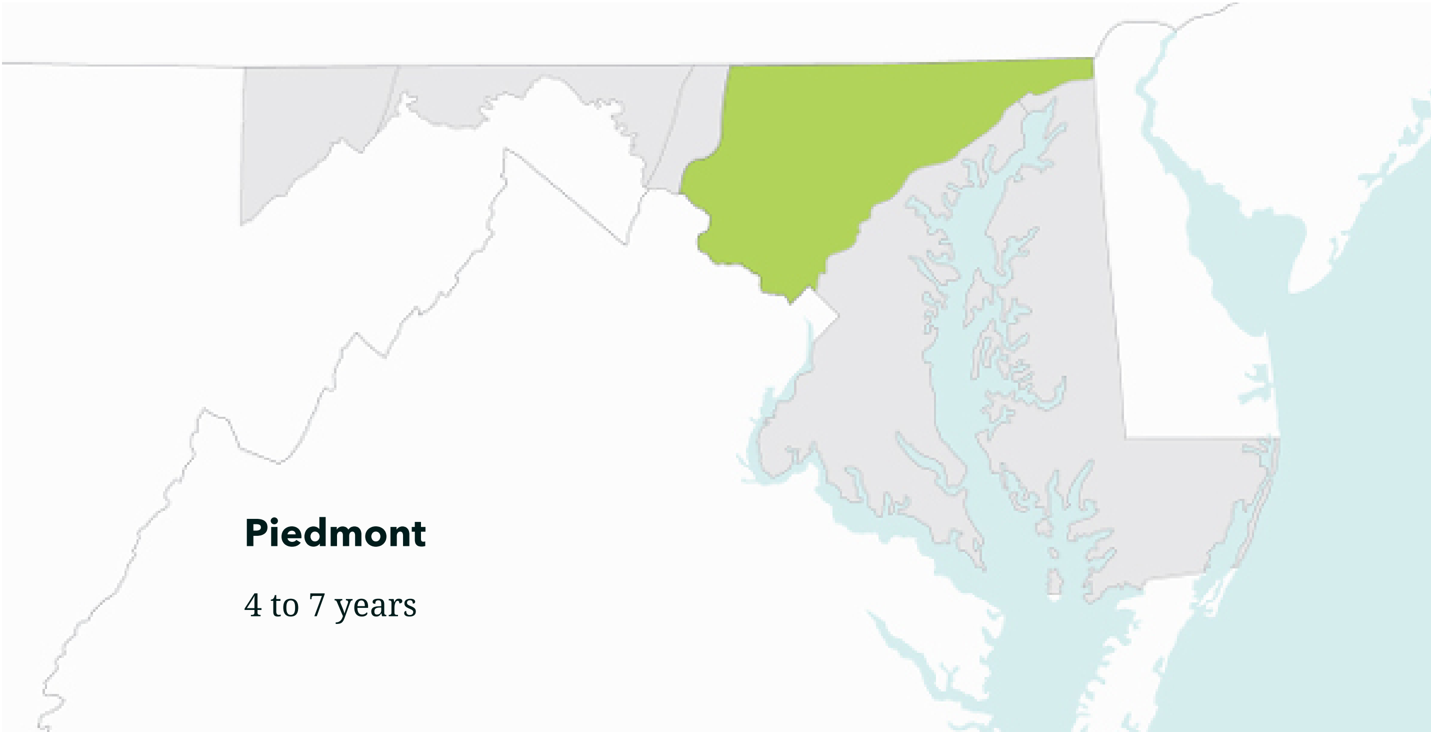
The Chesapeake Bay Program's model of the 64,000-square-mile watershed examines many scenarios to understand water quality. A watershed model may calculate, for example, how much nitrogen and phosphorus will be reduced under different scenarios. So, modelers can enter into their computer calculations one practice that's been used in the past to estimate how long it might take to make a difference in nutrient levels. But until recently, that particular calculation did not factor in the lag time for groundwater—that is, the time from when a practice is put into place to when it starts to take effect.

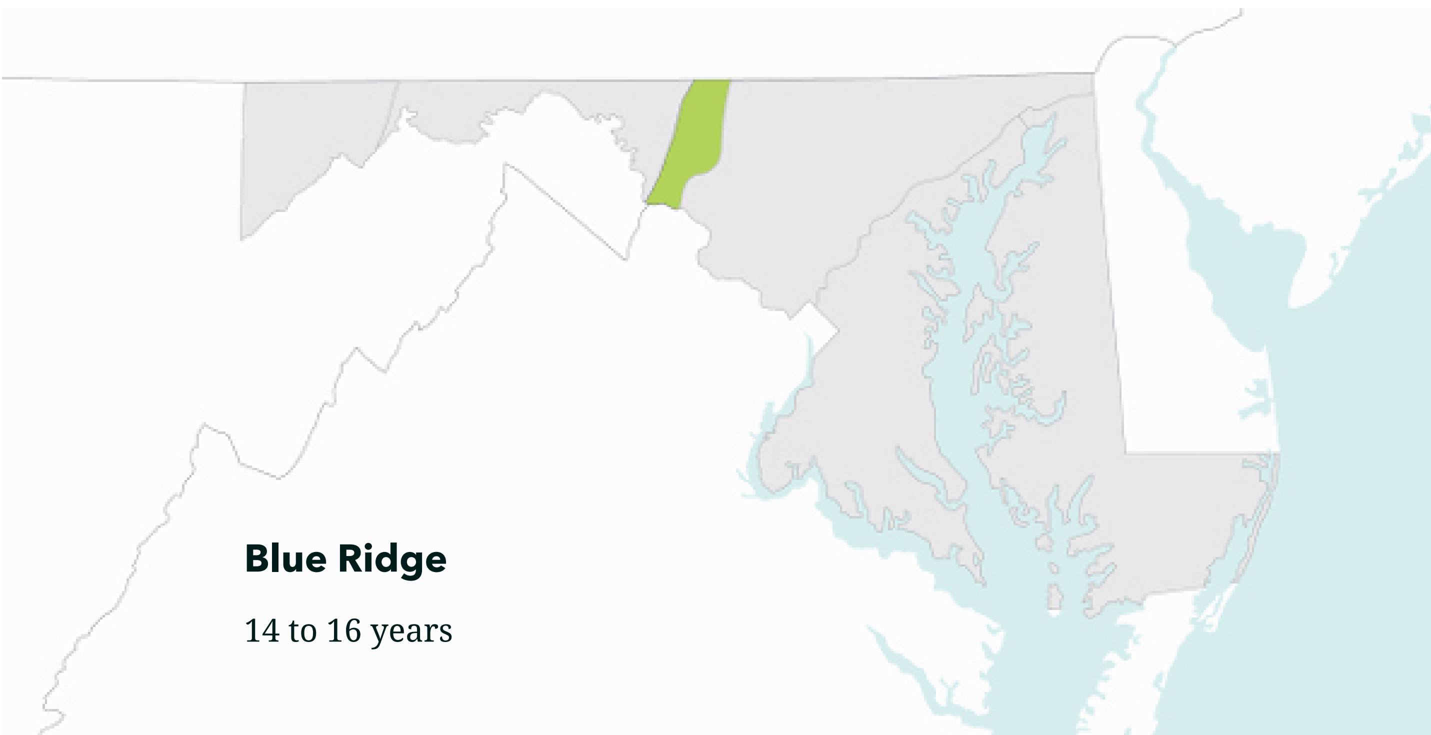
The median time for nitrogen on the land to reach streams can be 20 to 40 years, according to a U.S. Geological Survey (USGS) study; this means that fertilizer applied during the Reagan Administration could still be working its way through the Eastern Shore's rivers. Compare that to other practices, such as an upgrade to a treatment plant, where the impact is immediate: new pollution-capturing technology is installed, and the resulting discharge water is less nutrient laden.

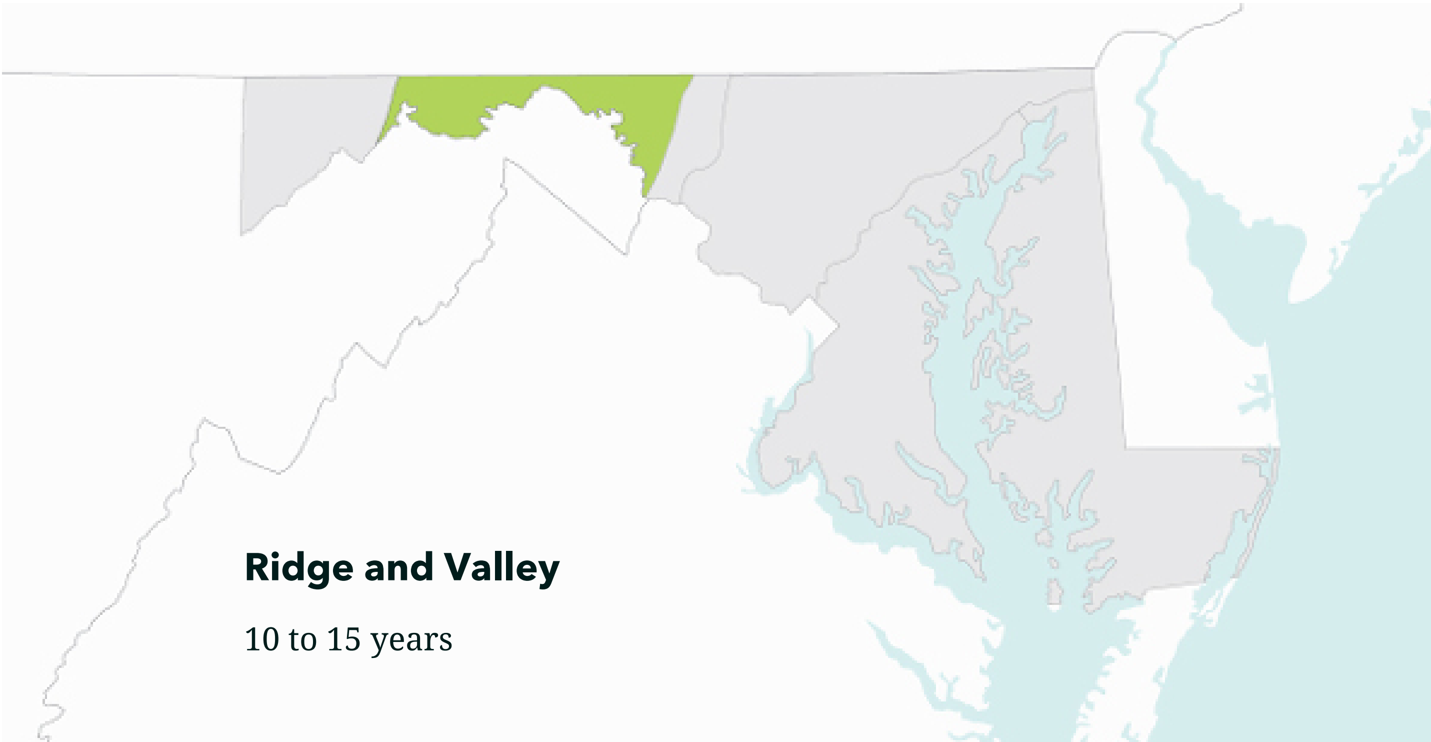
The challenge with the model lies in trying to estimate how long it takes for nitrogen to go through groundwater and into the streams and then the Bay. USGS officials worked with Bay modelers to factor in the lag times for groundwater to enter Chesapeake Bay. They recognize that groundwater moves much more slowly through the system; in addition, the path that groundwater takes is not always understood, which makes response times hard to predict. But geologists and modelers have tried, and here are their estimated lag times for Maryland's diverse geographic regions:

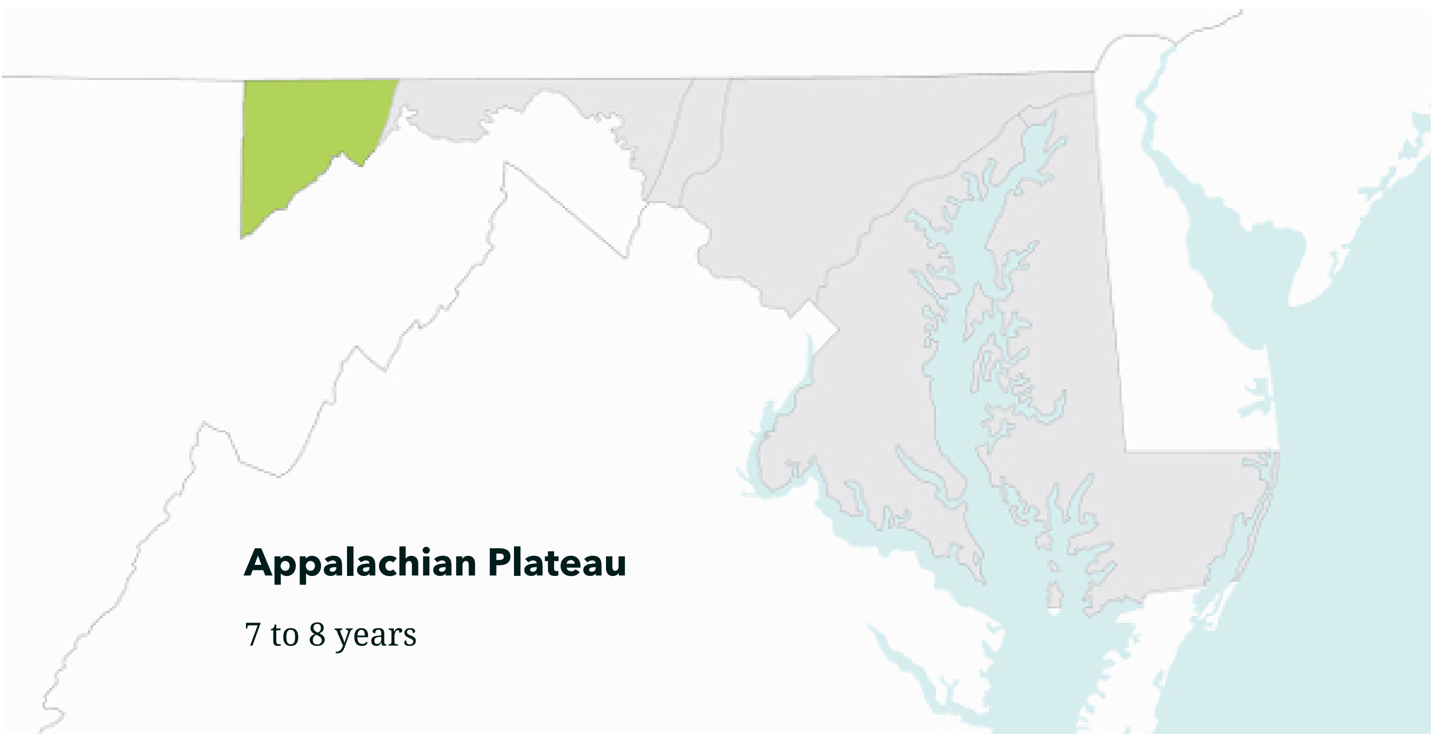

Coastal Plain
Eastern Shore
20 to 40 years


Coastal Plain
Western Shore (includes parts of Baltimore and Southern Maryland)
8 to 10 years


Piedmont
4 to 7 years


Blue Ridge
14 to 16 years


Ridge and Valley
10 to 15 years


Appalachian Plateau
7 to 8 years

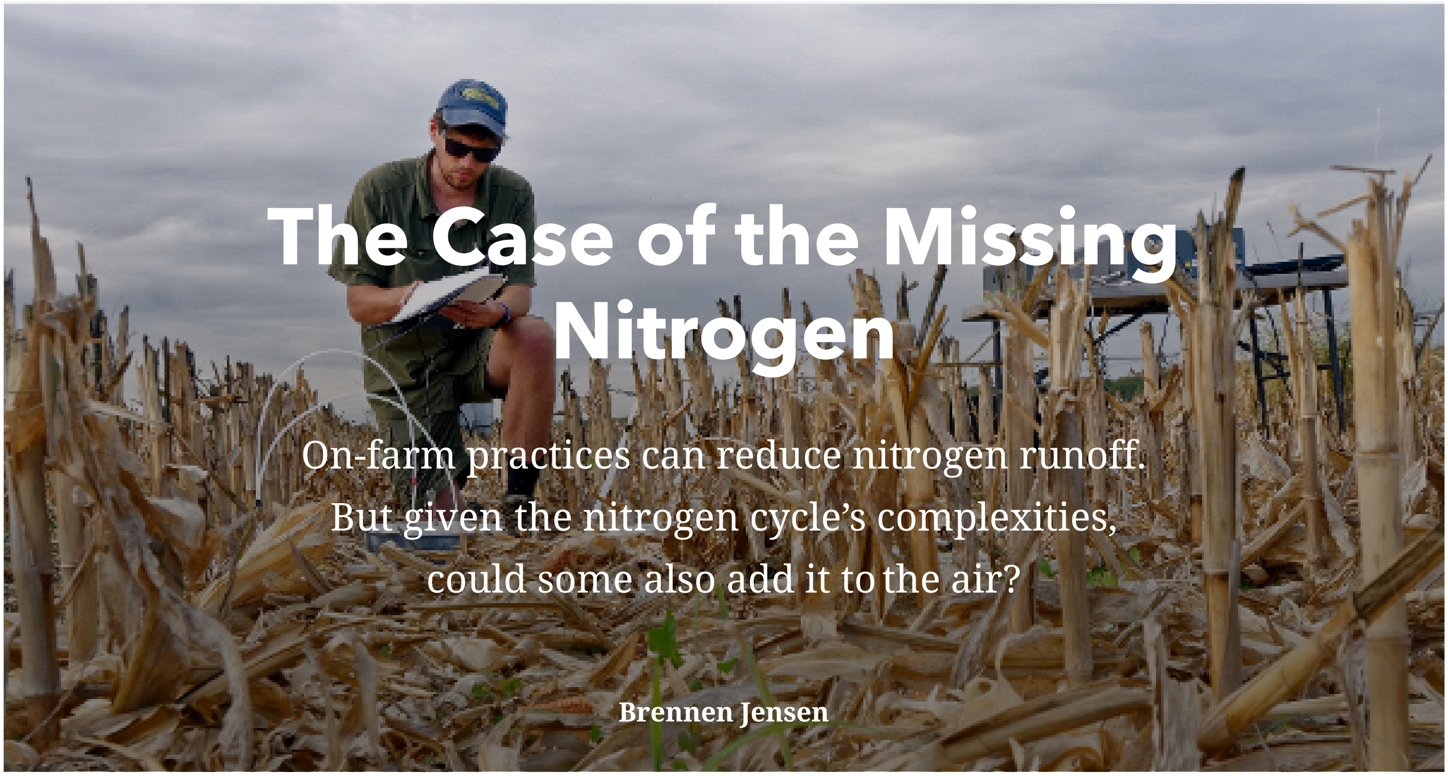
MARYLAND'S GEOLOGIC REGIONS

Take a closer look at the unique geology of the state's five distinct regions.

https://arcg.is/TDfKu

Header image: Aerial image of the Chesapeake Bay taken on September 13, 2011. Photo credit, NASA

Graphic by Nicole Lehming / MDSG, redrawn from USGS graphic



The Case of the Missing Nitrogen

On-farm practices can reduce nitrogen runoff. But given the nitrogen cycle's complexities, could some also add it to the air?

Brennen Jensen

As Jake Hagedorn concentrates on setting up monitoring equipment to measure nitrogen in the atmosphere, part of his mind focuses on something else: *Don't trip on the corn!* Hagedorn, a doctoral student at the University of Maryland Center for Environmental Science's Appalachian Laboratory, works with lab director Eric Davidson. Once a month for nearly three years now, he leaves the lab's Frostburg facilities for his Eastern Shore field office. In this case, that's *field* in the literal sense.

He's there on a sunny October afternoon, on a farm some two miles west of Marydel in Caroline County, standing before a laptop and other equipment set up on a folding table amid rows of corn stover. "They're like knives," he said of the long rows of desiccated stalks at his feet. He added that he's also been out here at the height of the growing season when the corn towers over his head, which he equated to working in a shadowy maze. Such are the challenges of fieldwork.

Hagedorn employs a flux chamber measurement system, which uses a series of metal rings embedded in the soil, each about a foot in diameter. Moving from one ring to another, he temporarily connects a chamber—roughly the size and shape of a large inverted mixing bowl—to each ring. Hoses connect each chamber to gas-measuring equipment on the table. While he practices agricultural soil science and will earn a degree in environmental science, in his fieldwork he applies a rule borrowed from the medical profession: First, do no harm.

Jake Hagedorn, a doctoral student at the University of Maryland Center for Environmental Science's Appalachian Laboratory, employs a system to measure nitrogen gases that may be released as an unintended consequence of denitrifying practices. *Photo, Brennen Jensen*

He is testing the effectiveness of a potential best management practice for farming that could decrease the amount of nitrogen fertilizer leaching from fields and ending up in the Chesapeake Bay, where it can cause harmful algal blooms.

As is typical of Eastern Shore farmland, the fields where Hagedorn works are flanked by drainage ditches, some of which have flow-control devices that can be manually manipulated to reduce the outflow and keep more water in the fields they serve. That enables the farmer to control how much water stays on the field, and for how long. As a potential best management practice, the theory is that this approach will alter soil chemistry dynamics and reduce water pollution from the farm field.

But there's a potential catch: The process might also create nitrous oxide (N_2O), a greenhouse gas that's 300 times more potent than carbon dioxide (CO_2). If conditions get too wet and become anaerobic—a condition in which no oxygen is present—bacteria can start to produce methane (CH_4), another greenhouse gas.

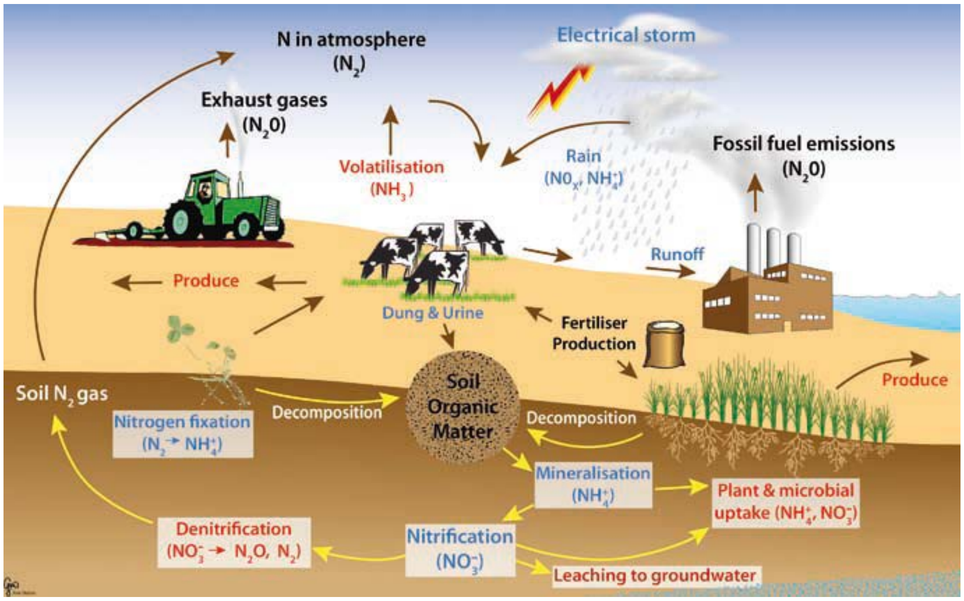
To test the method and its potential downside, Hagedorn set up a treatment field, installing flow-control devices on about half of the 40 acres he's investigating; the other half of his acreage was left untouched as a control area.

"If we get too much nitrous oxide coming out, are we just trading one form of pollution for another?" Hagedorn wondered. "That's the question we're investigating for this best management practice."

A Complex Cycle

Phosphorus and nitrogen are the two most problematic fertilizers when it comes to polluting the Bay. Of the two, phosphorous is easier to track and measure after farmers apply it to crops and it cycles through the environment, because of what scientists call its "sticky" characteristics. After farmers apply phosphorus to fields, the crop absorbs a certain amount at harvest time. The soil holds on to some, plant residue retains some, and some enters the watershed. Because of its stickiness, scientists can balance it—that is, they can determine quantitatively, with a certain degree of confidence, where each pound of phosphorus ends up after application.

Nitrogen, on the other hand, seems conditioned to "run," assuming gaseous forms. In a process called denitrification, naturally occurring soil bacteria convert nitrogen fertilizer into atmospheric nitrogen (N_2), the harmless gas that makes up more than 78 percent of the air we breathe. But certain forms of denitrification can also create the potent nitrous oxide (N_2O).



The nitrogen cycle illustrates the complexity of measuring the element in its gaseous form. Farmers are putting lots of practices on the ground, but scientists are trying to figure out if denitrification unintentionally releases nitrogen into the air. The above graphic shows the principle components of the terrestrial nitrogen cycle. *Graphic, Louis A. Schipper and Max Oulton, The University of Waikato*

"We don't know where all the nitrogen goes," said Tom Fisher, professor emeritus at the University of Maryland's Horn Point Laboratory. He said that accounting for the missing nitrogen is one of the pivotal challenges in the emerging field of nitrogen biochemistry.

"There's a bunch of it somewhere," Fisher explained. "So the issue is, [is] it being stored in the soil or groundwater, or is it being converted into nitrogen gas and leaving into the atmosphere? There's lots of denitrification going on, but it's difficult to measure. One of the big problems is that nitrogen is just so prevalent, and trying to measure some small flux into this big pool of nitrogen in the air is analytically difficult."

In other words, it's easier to detect and measure anomalies in the air, such as trace amounts of nitrous oxide, than to measure minute changes in the amount of nitrogen, which is already abundant. (Fisher noted that he and some students at Horn Point Laboratory have developed a promising technique to measure nitrogen denitrification that detects changes in the ratio of argon gas to atmospheric nitrogen.)

What *is* understood is that the soil bacteria responsible for denitrification prefer anoxic environments, where there is very little dissolved oxygen—conditions found commonly in wetlands.

And that brings us back to Hagedorn's cornfield and the notion of manually slowing the water outflow and creating wetter soil conditions. Researchers also are concerned that artificially created soil conditions might facilitate chemical reactions that could increase the amount of phosphorus entering the watershed. That could happen if yet another type of bacteria converts a stable form of iron commonly found in soil to a water-soluble version, chemically freeing up excess phosphorus to enter groundwater as well.

"Cautiously Optimistic"

It all goes back to the "do no harm" concept—but so far, so good. "We're cautiously optimistic, as my measurements have not detected a significant difference in nitrous oxide production between the treatment and control fields," Hagedorn said. Methane production has not been an issue either.

And the situation in the ditches appears positive so far as well. "Our data shows there is about three times less nitrogen being exported from the treatment ditches than the control ditches," said Anne Gustafson, a Horn Point senior faculty research assistant involved with the water analysis. "This is based on two years of data and is still being monitored and analyzed."

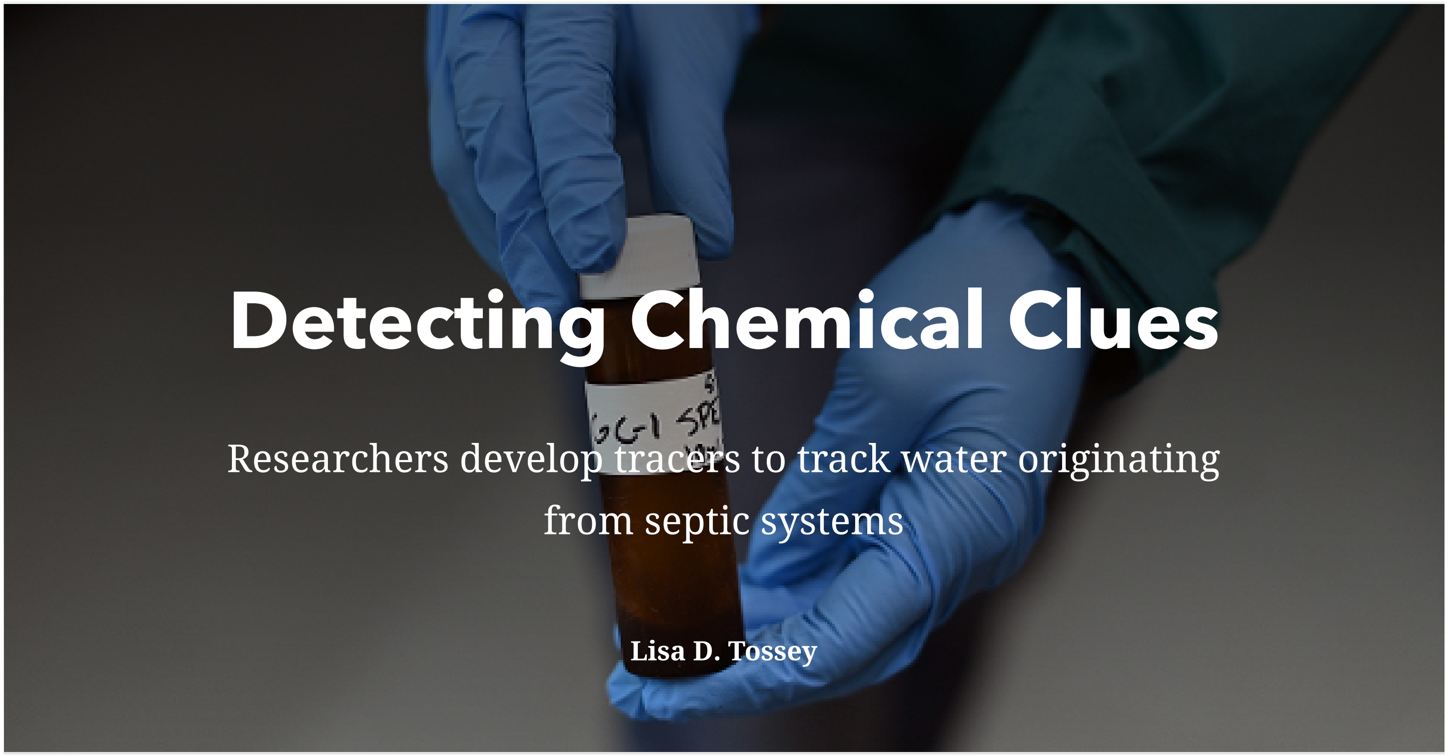
Phosphorus leaching did increase some in the treatment field, but by a much smaller amount when compared to the sizable reductions in nitrogen. Still, the researchers say, it only underscores the complexity of soil chemistry and the need for thorough monitoring.

The chamber method records only a snapshot of gas emissions in the area directly under the chamber, and emissions can vary based on temperature, humidity, and other atmospheric conditions. To make up for some of the shortcomings of the chamber system's nitrous oxide measurements, Hagedorn shares his field with an automated system for measuring gas emissions. It features four apparatus-festooned towers, each about four feet tall, that collect data on nitrous oxide and methane emissions around the clock over a wide area.

Davidson—a PhD in forestry who focuses on biochemistry and greenhouse gas exchanges among groundwater, soil, plants, and the atmosphere—said the tower measurements aren't as sensitive as the chambers. But using both enables researchers to go both a mile wide and a few inches deep, so to speak. And so far, the high-tech towers back up what Hagedorn has discovered manually.

"We are probably stimulating nitrous oxide a little bit, but not enough for us to be able to conclude a statistically significant difference from the control site," Davidson said. "And so if that result holds, that's good news in terms of this best practice being something that can really be used to reduce nitrate runoff."

Header photo: Jake Hagedorn, a doctoral student at the University of Maryland Center for Environmental Science's Appalachian Laboratory, records nitrogen data on an Eastern Shore farm. Photo, Brennen Jensen



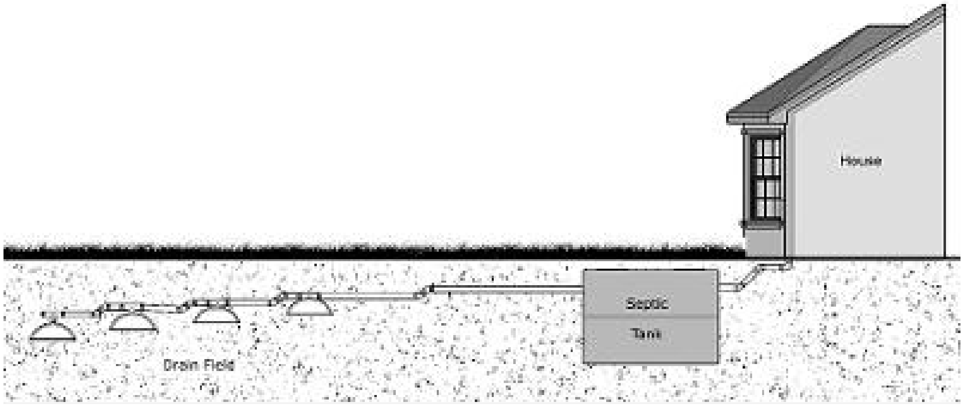
Detecting Chemical Clues

Researchers develop tracers to track water originating from septic systems

Lisa D. Tossey

Flushing a toilet is part of our daily routine. We pull a handle, or push a button, or an infrared sensor does the work automatically as we exit a bathroom stall. Water is released and the contents swirl away, carrying waste through the plumbing network to a place where it is treated. In urban areas, it is connected to a municipal sewer that drains to a wastewater treatment plant. In older suburban or rural areas, it likely connects to a septic system—a small, self-contained underground wastewater treatment system.

These on-site septic systems use natural processes to treat the wastewater, which travels slowly through a tank and into a drainfield, where it eventually percolates through layers of gravel and soil. These layers act as biological filters for the water as it seeps through before entering groundwater reserves below. While greases, oils, and solids settle out of the wastewater in the septic tank, some compounds remain throughout its journey to the groundwater, where they may ultimately end up in nearby streams and waterways.



A basic schematic showing a traditional septic system—waste drains from a home into a septic tank, where greases, oils, and solids settle out before wastewater slowly travels out into a drainfield. The size and configuration of these systems vary based on the use and square footage of the dwelling and the geology of the site. *Graphic, Matthew Amey*

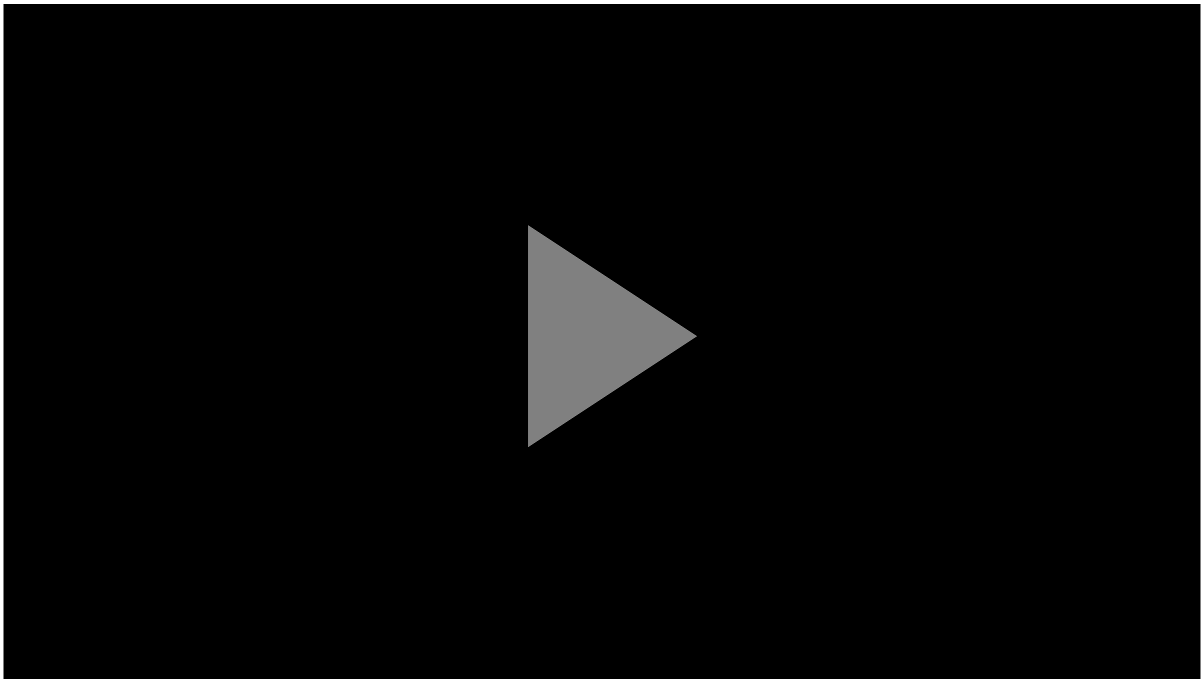
These chemical fingerprints are clues chemists can use to try to determine where water may have originated. Michael Gonsior is one of these chemists. He, along with a team of researchers at University of Maryland Center for Environmental Science's Chesapeake Biological Laboratory (UMCES-CBL), has been working to develop organic tracers to track water coming from septic systems using a combination of traditional nutrient measurements, chemical signatures, and sophisticated new analytical techniques. Identification of these tracers will help determine if discharge from septic tank systems has affected neighboring or adjacent watersheds.

As Gonsior, an analytical and environmental chemist, states, "It's a simple question that is not so easy to answer: Are these streams impacted by septic water?"

Seeking Sources of Nitrogen

Why is this important to determine? Wastewater can contain ammonium and other forms of organic nitrogen from human waste, garbage disposal waste, and cleaning products. As this septic system discharge, or effluent, passes through the system and into the drainfield, bacteria can convert the ammonium to nitrate, a process called nitrification. From there the nitrate may be taken up and used by plants in the immediate area or filtered out by the soil, depending on a number of factors including the rate of effluent release, the quality of the soil, and the size and depth of the drainfield. But those removal methods vary widely in effectiveness, and much of the nitrogen percolates down into groundwater, largely in the form of nitrate.

For this reason, septic systems are a potential nonpoint source of nitrogen pollution; in other words, they are one of many disconnected sources of pollutants that can be hard to trace back to the source. By the time these nutrients enter a waterway, it is difficult to determine their origin. Nitrogen in a creek or stream can come from a variety of sources—in addition to soaking through the ground from septic drainfields into groundwater, it can flow off the land as runoff from fertilizer applications or animal waste, or be deposited from the air as a result of the burning of fossil fuels. And once it is in a waterway, it can cause problems. Excess nitrogen can lead to an explosion of algae that form toxic algal blooms, and decaying algae can rob the water of oxygen, creating oxygen-free uninhabitable dead zones.



Small creeks like this one in Calvert County can be impacted by a variety of sources, including nutrients and chemicals from urban and agricultural runoff and surrounding septic systems. Take in a 180-degree view as co-principal investigator Andrew Heyes and graduate student Katie Martin collect a water sample.

As a result, lowering nitrogen input to the Chesapeake Bay watershed has been an ongoing effort in Maryland, and with approximately 420,000 septic systems in the state, part of that effort has focused on determining their impact. Development of a chemical fingerprint to detect nitrogen pollution from septic systems would enable scientists to calculate their contribution to the total nitrogen load in local waterways that feed into the Bay. It could also help measure the efficacy of new septic system designs that use advanced technologies to remove nitrogen from water.

According to the Maryland Department of the Environment, conventional septic systems remove just 10 to 20 percent of the nitrogen in wastewater and deliver approximately 23.2 pounds of nitrogen to groundwater per year. In comparison, new systems equipped with nitrogen-removing Best Available Technology (BAT) units can reduce nitrogen load by 50 to 75 percent. The state offers financial incentives, through its Bay Restoration Fund, to encourage BAT septic system upgrades, particularly for residents in Critical Areas—those defined by the state as land within 1,000 feet of tidal waters and wetlands. Therefore, developing a way to understand and measure the effectiveness of these advanced systems is important.

“I think that local planners can use this information to prioritize investments from the Bay Restoration Fund into septic system upgrades—that would be a great use,” said Lora Harris, an estuarine ecologist at UMCES-CBL and co-principal investigator on the septic tracer project. “Eventually, I would hope it could also help to identify nitrogen hotspots in the landscape and help folks understand what the sources might be. In combination with isotopic tracers, this could help differentiate wastewater from agricultural sources, which would be useful.”

Finding a Chemical Fingerprint

The UMCES-CBL project team—Harris, Gonsior, co-principal investigator Andrew Heyes, and graduate student Katie Martin—began by collecting water samples in Calvert County each month for a year as part of a Maryland Sea Grant-funded project. The majority of the county’s approximately 90,000 residents are served by traditional septic systems.

In the Field

Co-principal investigator Andrew Heyes and graduate student Katie Martin collect water samples at a creek in Calvert County that the team used as a reference site.

The team targeted nine streams in the county, choosing six that had potentially been impacted by septic systems and three that were in wooded sections further removed from developed areas, which they identified as reference sites. They also collected water samples directly from the tanks of septic systems in each area. They filtered all samples to extract and concentrate the dissolved organic components, and then performed chemical analyses to identify the complex mixture of compounds. The analysis provided the chemical fingerprint of each organic sample, revealing compounds that occur naturally in forests and streams—and also those that do not, including chemicals that pass through the body or are washed down the drain, such as soaps, cleaners, medications, and artificial sweeteners. These were the tracers that the researchers were looking for to develop methods to quantify chemicals that indicate the presence of wastewater, and the latter proved to be key.

Sample analysis showed high levels of sucralose in some of the streams. An artificial sweetener sold under the brand name Splenda, sucralose is found in soft drinks, chewing gum, candy, and various other products. Marketed as a calorie-free sugar substitute, it mostly passes through the body rather than being broken down and absorbed during digestion. Its stability makes it a good wastewater tracer.

Graduate student Katie Martin filters creek water samples to extract and concentrate the dissolved organic components from them at University of Maryland Center for Environmental Science's Chesapeake Biological Laboratory.

The researchers compared concentrations of sucralose in samples taken at adjacent septic tanks in an effort to make a direct connection to the specific systems and calculate how much water originated from each.

"The idea was, this is mostly a quantification of known wastewater tracers, which hasn't been applied in Calvert County," Gonsior said. "So we were really first looking at this in the streams. Artificial sweeteners like sucralose, which is a very stable molecule, are not degrading effectively in the environment, so it's what we call a conservative tracer."

The team used a multi-tracer approach, said Gonsior, to confirm the presence of other wastewater tracers, such as surfactants from soaps and detergents, caffeine, and ibuprofen. Using sucralose as the stable conservative tracer, they could then look at the rate at which these other compounds were degrading in wastewater in relation to the sucralose. This information allowed the researchers to measure how much processing potentially had happened at any point in the sampling, providing an idea of how "aged" that signal is.

“Let’s take caffeine, for example, or acetaminophen or ibuprofen. For a time they would degrade, but at different rates,” Gonsior said. “So relating the different rates of degradation to sucralose itself, a very stable compound, gives us an idea about how important this signature we’re seeing is, in terms of relating it again back to the nitrogen loading. This data correlates quite well with the nitrogen loading, so we have indirect correlation that the nitrogen we see is likely to be coming from the septic systems.”

Water samples are pulled through filters, providing dissolved organic material to analyze.

The team measured dissolved nitrogen in the streams and found higher levels in those with more septic systems in their catchment areas: the higher the density of septic systems, the higher the total nitrogen loading. They also looked at the stable isotopes of nitrogen with a collaborator at the UMCES Appalachian Laboratory. Stable isotopes are a form of an element that do not decay, and therefore their abundance stays the same over time; in this case, the team found that it aligned well with the wastewater signature they had observed in other tracer work. This allowed them to distinguish it from nitrogen that originated from atmospheric deposition or fertilizers, which have different distinctive isotopic signatures.

“So the effect is interesting, in this case, that actually the nitrogen load you’re seeing in those streams are quite well correlated with our tracers—for septic systems specifically,” Gonsior said.

By knowing the tracer concentrations in both the septic tank and the adjacent stream, the researchers can calculate how much water in the stream originates from the system. It’s still impossible, however, to identify how much nitrogen the septic system alone is delivering to the stream, because there are other contributing sources of nitrogen. Gonsior said they can infer that the systems are a source, but they are doing more analytical work using isotope ratios to identify exactly how much of the nitrogen load comes directly from septic wastewater.

Take a look around the laboratory that graduate student Katie Martin uses to run advanced chemical analysis of the samples her team collects.

The forensic tools being developed in Maryland will have application nationwide, said Harris, especially in older, high-density residential communities with a legacy of septic systems not connected to public wastewater treatment plants.

Their work will also be an important tool for implementing and measuring the impacts of restoration efforts.

“As an ecologist, I am also always curious about the source of nitrogen that a particular water body experiences, because it tells me about the restoration potential for that system—what is realistic,” Harris said. “If the source is something local, like septic systems, there is the potential to motivate policy, investment in septic upgrades, et cetera. As someone who does a lot of advising, and monitoring, and research around poor water quality issues, we are asked all the time for advice on restoration. Knowing whether septic or wastewater is the source can be a big help in those conversations.”

Header photo: Graduate student Katie Martin prepares a sample for chemical analysis in the laboratory.

Photos and videos by Lisa D. Tossey / MDSG

Maryland’s Geologic Regions

America in Miniature

Rona Kobell

One of Maryland’s nicknames is “America in Miniature” due to the wide variety of terrain within its 10,460 square miles. To drive across the state is to witness dramatic changes—from the flat salt marshes of the Eastern Shore, to the urbanized landscapes of Baltimore, to the towering forests of Western Maryland. But what drivers can’t see are the equally dramatic differences beneath these landscapes and how they filter, hold, and release groundwater stored there.

Here’s a look at the state’s five distinct geologic regions:

COASTAL PLAIN

Size

Covers 50 percent of the state, approximately 5,000 square miles

Characteristics

- Flat, with loosely arranged sediments of gravel, silt, and clay, it is the youngest geological formation in the state at about 144 million years old.
- The Chesapeake Bay bisects it, creating one groundwater region separated by America's largest estuary.
- Sediment layers become thicker moving east from the Baltimore region toward Ocean City.
- Soils on the Eastern Shore are sandy and permeable, and the landscape is flat. Drainage is poor because of the high water table and shallow stream incision.

Groundwater concerns

Most residents of the Coastal Plain get their drinking water from groundwater. Saltwater intrusion is a threat and may require some residents to drill deeper into the ground to find fresh water.

Some farmers are also withdrawing more water to irrigate fields because of inconsistent weather patterns, causing scientists to worry about quantity.

PIEDMONT

Size

Covers 25 percent of the state, or approximately 2,500 square miles

Characteristics

- The Piedmont consists of more solid rock than the sandy and more permeable Coastal Plain sediments.
- Groundwater aquifers occur within fractures in the Piedmont rocks.

- There is an abrupt change in elevation between the Coastal Plain and Piedmont region, which has steeper topography.
- The Piedmont region's elevation ranges from an average of 350 feet in the Frederick Valley to more than 1,200 feet at Sugarloaf Mountain.
- Many Piedmont residents rely on reservoirs for water supply. Farmers, however, use both groundwater and surface water sources for irrigation because groundwater supplies alone are not sufficient.

Groundwater concerns

The Piedmont relies on rainfall to replenish its surface waters and its aquifers, and precipitation has been inconsistent over the last several years, causing cycles of drought. In Frederick County, Maryland, as in other areas facing urbanization, rapid growth can result in streams being channeled into pipes or paved over with concrete and asphalt. Such changes can limit the ability of streamwater to soak into the ground and recharge groundwater, according to Andrew Elmore, an ecologist at the University of Maryland Center for Environmental Science.

BLUE RIDGE

Size

Covers about 5 percent of the state, approximately 500 square miles

Characteristics

- The Blue Ridge is a small part of Maryland, but it underlays many other states, including Pennsylvania.
- Rock here, much of it hardened sedimentary and metamorphic, is more resistant to erosion than other formations in Maryland.
- The area includes three mountain ridges—Catoctin Mountain, South Mountain, and Elk Ridge—all composed of quartzite, a very resistant rock.

Groundwater concerns

Due to mountainous terrain, there is not much worry concerning growth and groundwater shortages, as the region accounts for only one percent of the state's groundwater use.

RIDGE AND VALLEY

Size

Covers about 10 percent of the land, approximately 1,000 square miles

Characteristics

- The region is composed of erosion-resistant shale and sandstone (ridges), and broad, flat valleys of weaker layers of limestone.
- As with the Blue Ridge, this region comprises a small part of Maryland, but its parallel ridges and intervening valleys extend through parts of several other states.
- Due to the area's limestone deposits, the region includes soils, known as the Hagerstown series, that the U.S. Department of Agriculture declared among the best in the nation for growing certain crops.

Groundwater concerns

Groundwater wells are most commonly drilled into the limestone rock aquifers of the region. However, because these rocks commonly have small, naturally occurring channels, these aquifers can be more vulnerable to contaminants such as fertilizers introduced at the land surface. They also can have sinkholes, which can foster even faster movement of contaminants through the near-surface aquifer. Groundwater used for public water supply typically come from aquifers that can be over 250 feet beneath the surface and are less susceptible to activity on the land's surface.

APPALACHIAN PLATEAUS

Size

Covers about 10 percent of the land, approximately 1,000 square miles

Characteristics

- This region is Maryland’s coal country, consisting of hardened shale, siltstone, and sandstone, with layers of coal preserved in this formation.
- Groundwater occurs in fractured rock similar to the other formations in Maryland, with the exception of the Coastal Plain.
- Public water supplies usually come from both surface and groundwater sources, Most rural areas use private wells for water supply.
- This area, only partially situated in the Chesapeake Bay watershed, is home to Deep Creek Lake, Maryland’s largest freshwater lake.

Groundwater concerns

Arsenic was detected in a small percentage of wells at levels exceeding the U.S. Environmental Protection Agency's drinking water standard for maximum contaminant levels.

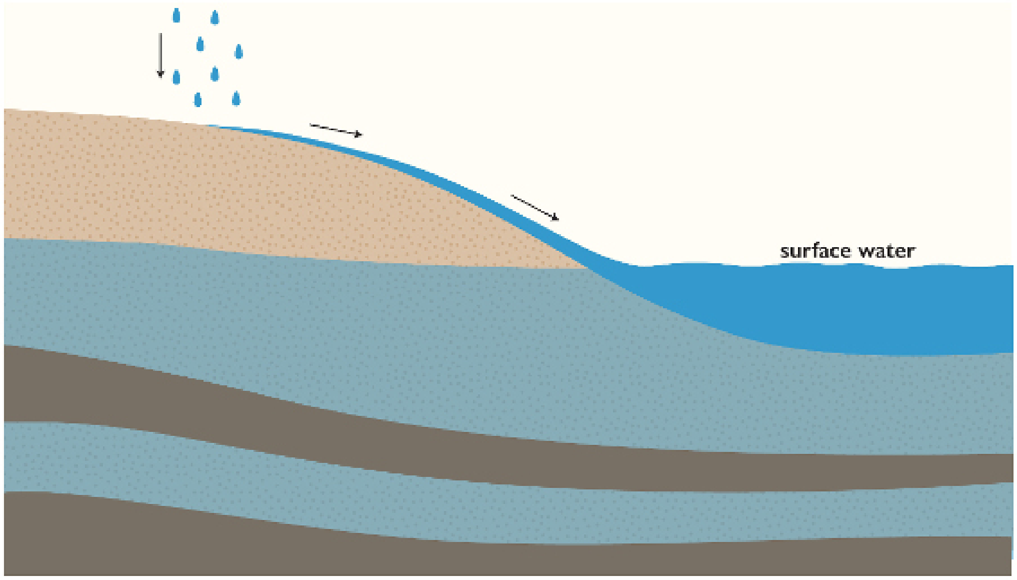
Graphics by Lisa D. Tossey / MDSG, redrawn from USGS graphic

Mapping the Groundwater

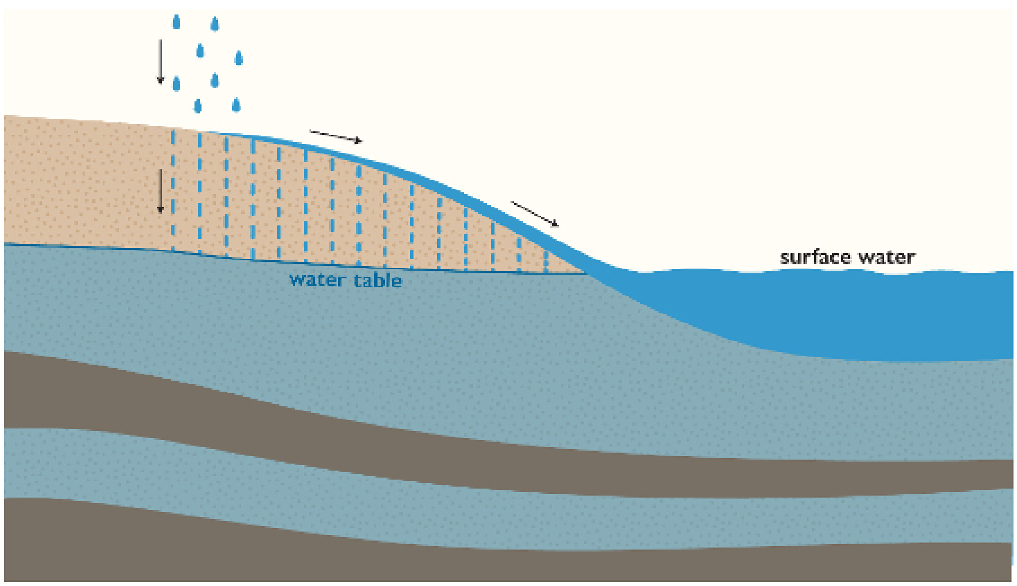
Rona Kobell

Groundwater is one of our most valuable resources. Half of this country's population gets drinking water from supplies under the ground. And many more rely on it to irrigate crops that provide the food we eat.

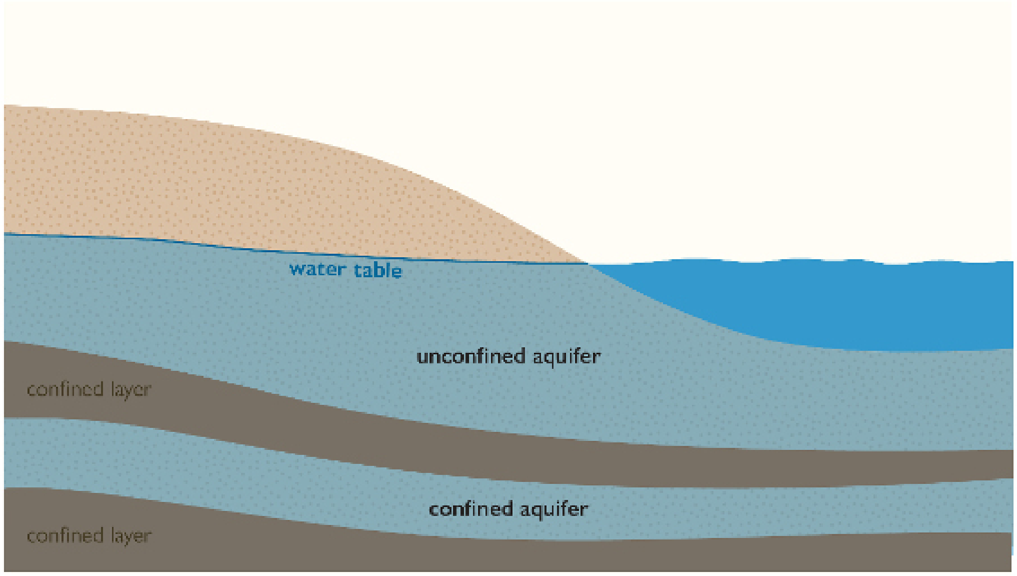
How does groundwater work?



When it rains, much of the water runs off the land and into streams. This is called **surface water**—it's all the water we see.



But some of the water hits the ground and seeps through the soil. That which is not taken up by plants sinks deeper, through porous sediments or cracks in rocks, to reach the **water table**—the top of a zone in which these openings are saturated with water, which started as raindrops.



Groundwater can accumulate in aquifers—underground layers of water-bearing permeable rock, rock fractures, or unconsolidated materials such as gravel, sand, or silt—that receive water from rain falling on the ground above.

It may sit in an aquifer for decades before it eventually flows out into surface water. Or, the water may be pumped from a well drilled by a town, homeowner, farmer, or business.

The upper surface of an **unconfined** aquifer, also called the water table, remains at atmospheric pressure, allowing it to rise and fall. A **confined** aquifer is an area below the land surface, with a layer of impermeable material both above and below it that places the water within it under pressure.

Groundwater issues

Concerns about groundwater relate to both quality and quantity: In an unconfined aquifer, groundwater can be more susceptible to contamination from fertilizers, septic tanks, and pharmaceuticals. In that case, communities may be forced to drill deeper wells into confined aquifers where contaminants are less likely to penetrate.

Increased demands due to population growth and farm irrigation puts pressure on water resources by extracting more water from aquifers than rainwater can naturally replace. In addition, saltwater intrusion from rising sea levels contaminates aquifers, making it more difficult to secure fresh water for drinking or irrigation.

Header image: Groundwater seep in Gambrill State Park on Catoctin Mountain in Frederick County, Maryland. Photo, J. Adam Frederick / MDSG

Graphics: Jenna Clark / MDSG

Best Practices

Rona Kobell

For nearly two decades, researchers at the University of Maryland Eastern Shore (UMES) have been partnering with scientists from the U.S. Department of Agriculture's Agricultural Research Service to determine best practices for reducing nutrient pollution that's already in the soil. They have worked to intercept it before it reaches rivers, streams, and groundwater in this low-lying region of the state.

The UMES campus, located on Maryland's lower Eastern Shore, contains land along the Manokin River where a poultry business once operated. The soil here is rich in phosphorus and nitrogen from application of poultry litter over the years, making it an excellent location for graduate students and scientists to monitor the effectiveness of pollution-reduction practices in soils. (Soil is defined as the area between the surface, where rain falls, and the layer of dirt below the soil that is saturated with water—the water table and unconfined aquifer.)

UMES Associate Research Professor Amy Collick is working with her UMES colleague, Professor Arthur Allen, and Ray Bryant of the UDSA's Agricultural Research Service. They have installed monitoring wells around the site of the former poultry operation to measure groundwater and the effectiveness of different experimental land-management practices. On their research and teaching farm, they are testing different practices to reduce soil-based nitrogen and phosphorus from leaching down to the aquifer or into the river. If a particular pollution reduction method succeeds, UMES researchers will assist willing local farmers to adopt the practice on their own properties. Researchers will monitor those farms for up to five years to gauge the efficacy of the method over time.

Below is a sampling of practices that Collick, Allen, Bryant, and their colleagues are testing:

FORESTED BUFFERS

Where to put them

Between an agricultural field and a surface water source

How they work

Plant roots absorb water running off the surface before it gets to the waterway or river; more nutrients taken up by plants means fewer nutrients reach the water.

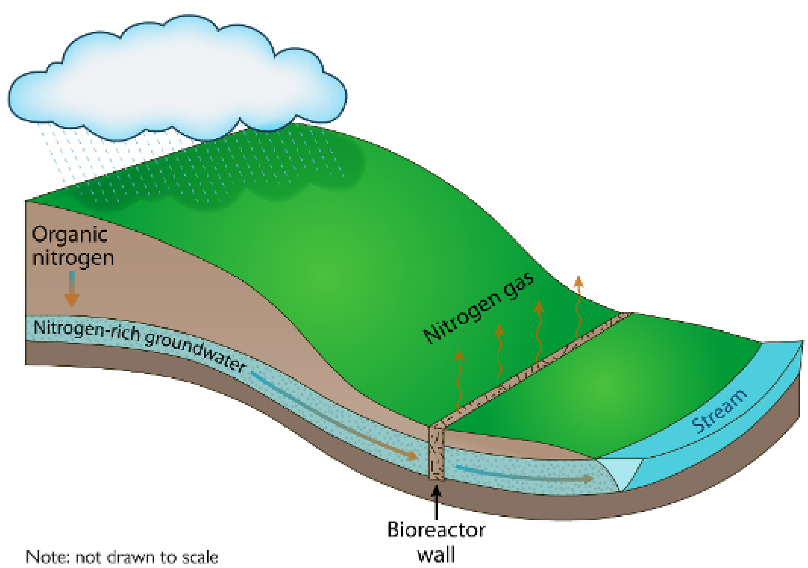
Where they are

Farmers throughout the Coastal Bays and Chesapeake Bay watersheds have been planting forested buffers, often with federal assistance, for decades.

Effectiveness

Reductions of 30 to 50 percent for phosphorus, and about 50 percent for nitrates on the UMES research site.*

**Collick noted that land slope at the research site may also contribute to nutrient reduction, beyond what plants remove, accounting for higher reductions than seen elsewhere in Maryland.*



BIOREACTORS

Where to put them

At the edge of an agricultural field

How they work

A bioreactor is a buried trench with a carbon source—usually wood chips or sawdust mixed with soil at an equal ratio—that intercepts nitrogen-rich groundwater and converts its nitrogen into nitrogen gas. This process, called denitrification, prevents the nitrogen from flowing into a stream. At the UMES farm, Collick said, the trench is dug about five feet deep, parallel to the river, on the site of the former poultry operation. That positioning helps determine its effectiveness at keeping runoff out of a stream on a farm.

Where they are

Approved as a conservation practice in 2015, they are more common in Iowa and South Dakota; however, bioreactors are starting to get some traction on the Eastern Shore, with local contractors helping farmers secure funds to install them.

Effectiveness

An expert panel convened by the Chesapeake Bay Program conservatively estimated that bioreactors remove 20 percent of total nitrogen in water from the area they treat; UMES research is achieving closer to 35 percent. Collick said the forested buffer and the bioreactor together make a powerful combination for pollution reductions.

GYPSUM CURTAINS

Where to put them

Across a drainage area

How they work

U.S. Department of Agriculture (USDA) research has shown that 90 percent of dissolved phosphorus entering farm drainage ditches comes from groundwater, not surface runoff. The “curtains” are actually gypsum dust that is applied to the sides of a drainage ditch. It forms a curtain-like barrier between the soil on either side of a ditch. This nutrient reduction practice removes dissolved phosphorous. It works because soluble calcium in gypsum chemically joins with the phosphorus and forms calcium phosphate precipitate, which remains in the curtain and doesn’t enter the ditch water. Once installed, they resemble drapes on a window, which is how they got their name.

Where they are

Mostly on the UMES research farm, although a few Somerset County farmers are experimenting with them, and the power industry has run some pilot projects with Ohio farmers.

Effectiveness

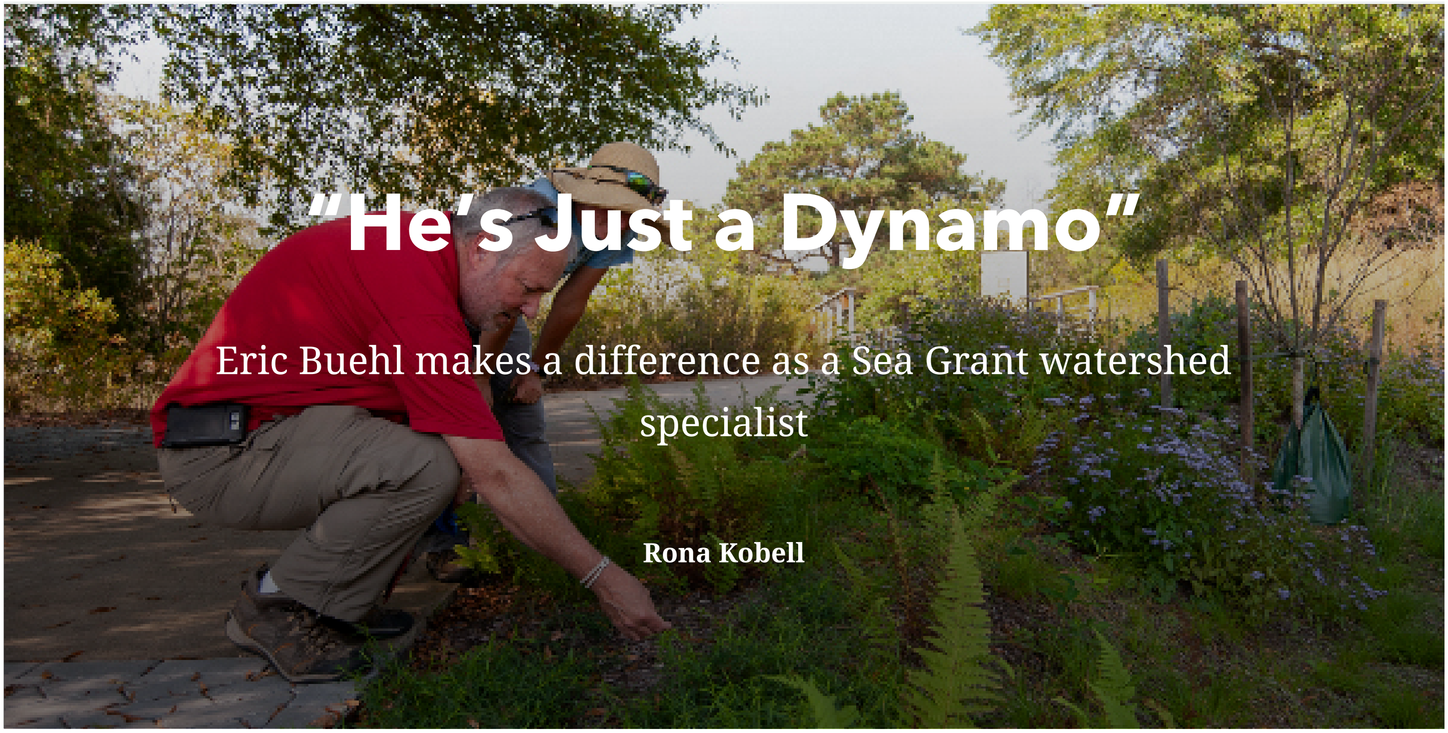
UMES work and UDSA research have shown that the gypsum reduces soluble phosphorus by 75 to 90 percent. But animals, such as muskrats, can disrupt the curtains when they burrow into the ditches, creating openings that diminish effectiveness.

Header photo: USDA-ARS soil scientist Ray Bryant (left) and Arthur Allen, a professor in the Department of Agriculture, Food and Resource Sciences at UMES, collect groundwater samples before and after they are filtered through a "curtain" of gypsum. Photo, Stephen Ausmus

Forest buffer photo: Courtesy of Ben Longstaff / IAN

Bioreactor graphic: Nicole Lehming / MDSG, redrawn from graphic by Louis A. Schipper / The University of Waikato

Gypsium curtain photo: Gypsum curtain installation at a private farm on the Eastern Shore. Photo, USDA/ARS



"He's Just a Dynamo"

Eric Buehl makes a difference as a Sea Grant watershed specialist

Rona Kobell

Sea Grant Extension watershed specialists sometimes refer to themselves as the grease that gets the wheels to move. Trained in water quality restoration techniques, their job is to bring people together and help them find the money and the technical assistance to put stormwater management projects in the ground to improve water quality. Those projects might include rain gardens at municipal buildings, or median strips filled with green plants and pervious pavers to take up stormwater. They are helping clean the Chesapeake Bay by keeping excess nutrients out of it, and they are especially important to cash-strapped and small communities that don't have their own staff to accomplish their clean-water goals.

Five years into his tenure, Eric Buehl's projects are growing. Buehl works in five counties north of the Choptank River: Kent, Cecil, Queen Anne's, Talbot, and Caroline. He has helped county planners and environmental staff in those jurisdictions secure grants and find contractors for various projects that reduce the amount of runoff entering the Chesapeake Bay.

Maryland Sea Grant Extension Specialist Eric Buehl stands with Leslie Grunden, Caroline County's assistant director of planning, at Choptank River Park. They worked together on water quality projects that also make the park more pleasing to visitors.

"He's just a dynamo," said Leslie Grunden, the assistant director of planning in Caroline County, who partners with Buehl and others on many of the projects he champions. "His momentum really carries so much of what we do."

A Shore resident since 1989, Buehl had worked on similar projects for more than a decade as the restoration coordinator for the Delaware Center for the Inland Bays in Rehoboth Beach, Delaware. A veteran of the U.S. Navy, where he worked as an air traffic controller, Buehl graduated with an environmental science degree from Wesley College in Dover, Delaware. He is one of five watershed specialists at Maryland Sea Grant. (*Chesapeake Quarterly* has profiled his colleagues Kelsey Brooks and Jennifer Dindinger, who work in other parts of the state.)

On a recent tour, Buehl said that three years ago, most of his projects were still just dreams. Now, he can see the fruits—and flowers—of his labor.

A rain garden that Maryland Sea Grant Extension Specialist Eric Buehl helped plant at the Greensboro Volunteer Fire Company. The grounds are along a main highway and are a gathering spot for community events.

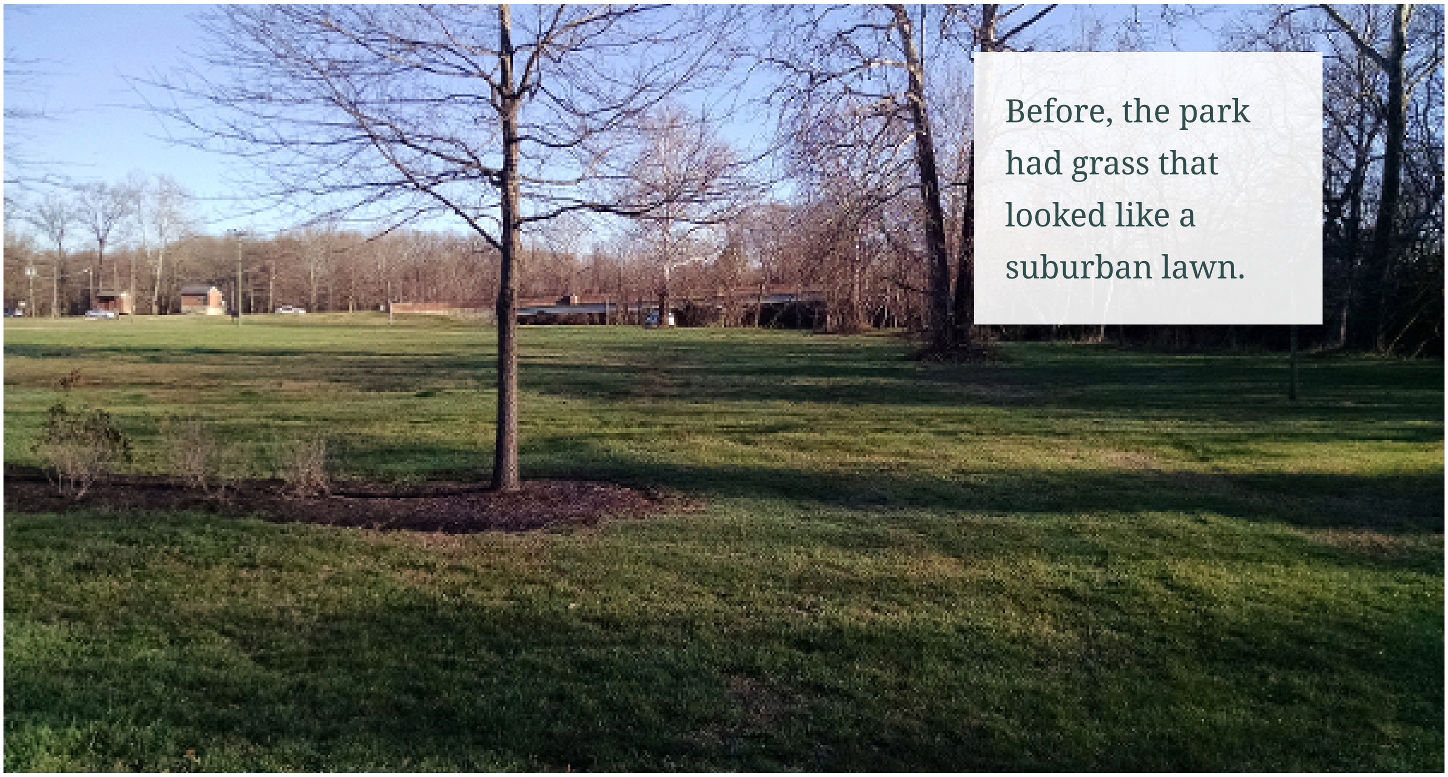
"His momentum really carries so much of what we do."–Leslie Grunden, assistant director of planning in Caroline County

Buehl helped the fire station on the outskirts of Greensboro design and install a rain garden. He also helped the fire company design and fund a stormwater management project to keep runoff out of the Choptank River. At Choptank River Park, he helped design a trail with native plantings and a meadow along the trail to absorb stormwater runoff. A lot of these towns have requirements to reduce their runoff, Buehl said, but they don’t have the funding or the technical expertise to design programs that will accomplish that goal. He can help; often, he has applied for grants on similar projects, and he knows where to turn for assistance.

Choptank River Park was a prime candidate for some restoration, as it sits along the river and is a large, public spot.

Before, the park's meadow looked a little bare.

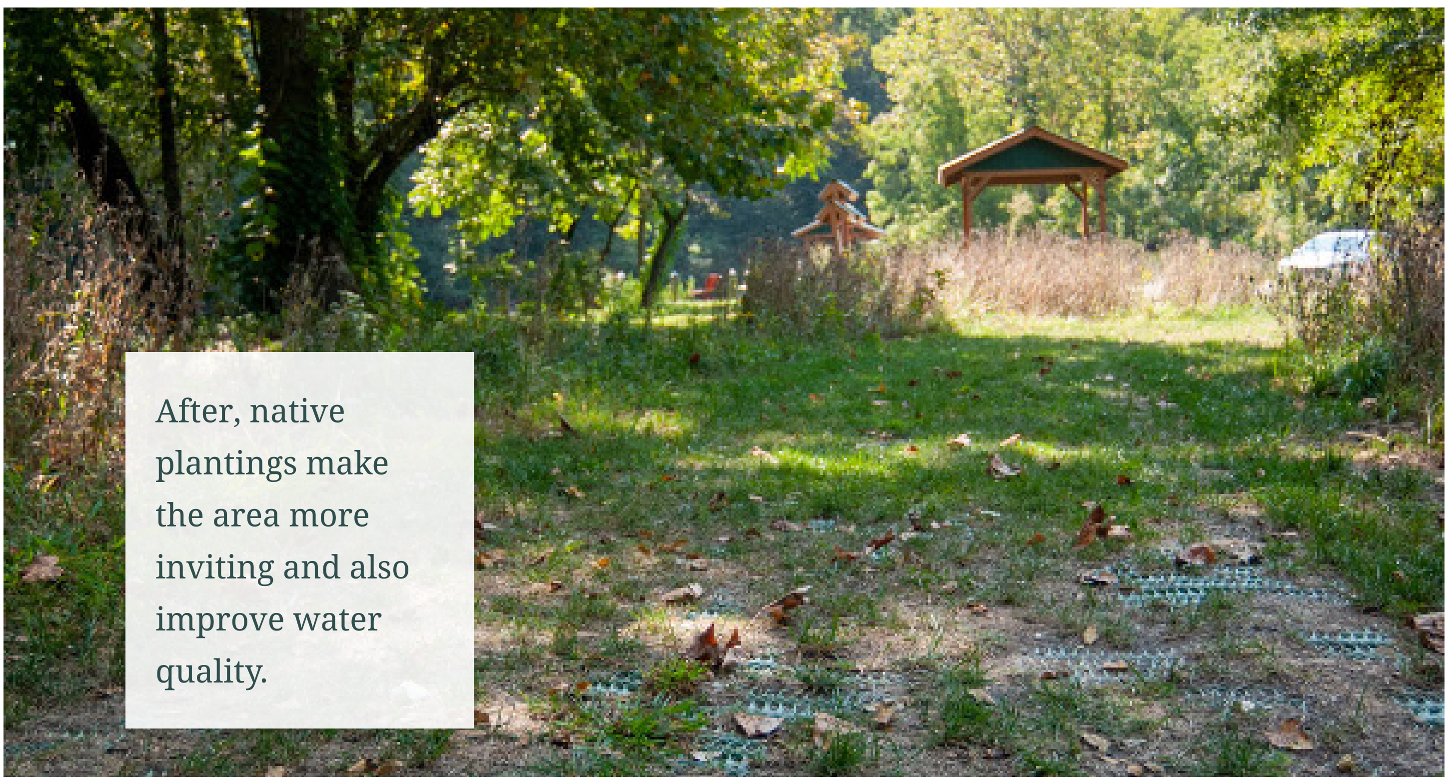
After, native grasses and a new fence give the meadow a more inviting look that also helps absorb runoff before it arrives at the river.



Before, the park had grass that looked like a suburban lawn.

After, a meadow with wildflowers is more inviting for visitors and more beneficial for the river, as it absorbs runoff and rains.

Before, water tended to pool in the grass.



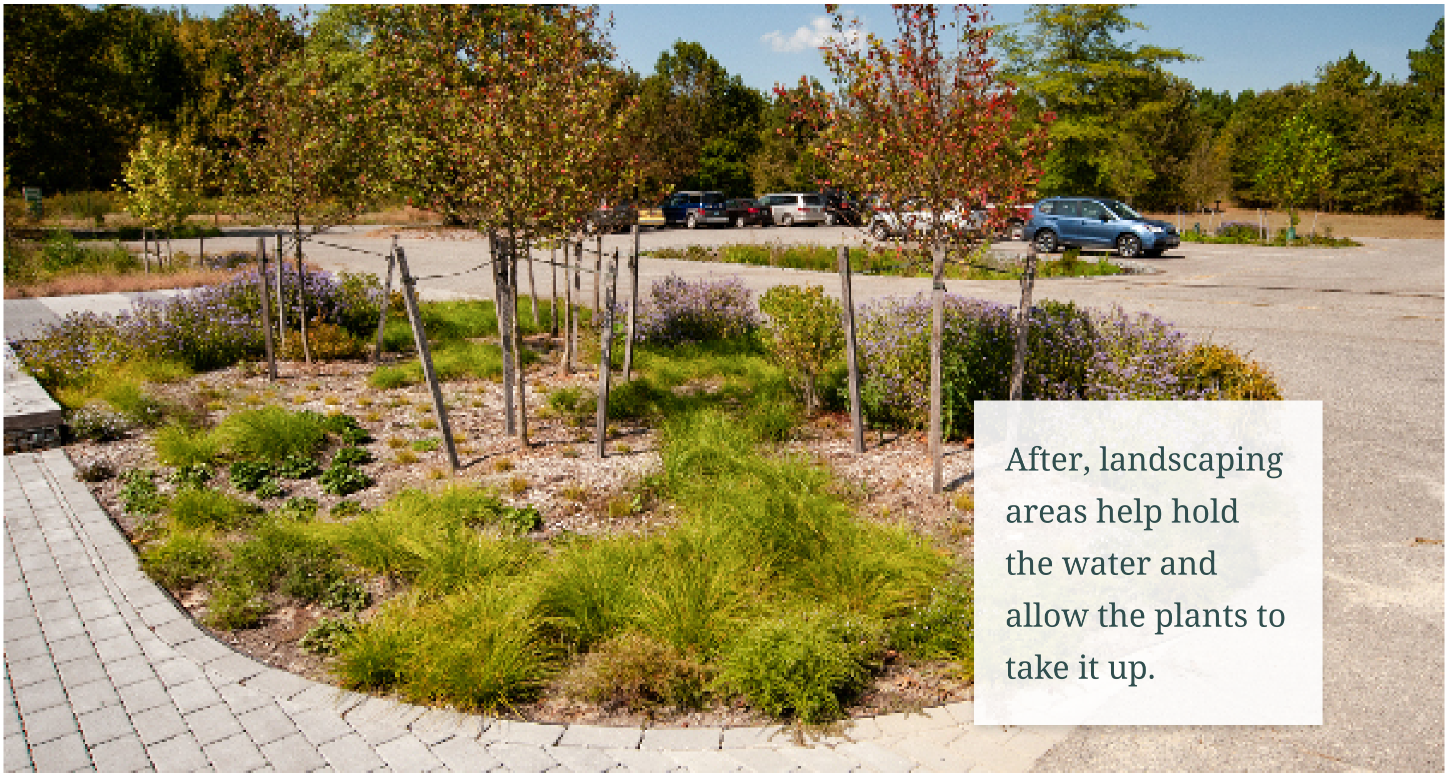
After, native plantings make the area more inviting and also improve water quality.

“The satisfaction in this job comes when we help somebody get to the point that now problems can start getting solved,” Buehl said.

He’s especially proud of the Adkins Arboretum’s Parking Lot Alive! retrofit project in Caroline County. Buehl helped connect the arboretum with $328,750 from the Chesapeake Bay Trust and the Maryland Department of Natural Resources to transform a flat parking lot into gardens focused on stormwater retention. “He really helped us pull it together,” said arboretum director Ginna Tiernan.

The Parking Lot Alive! project revitalized an asphalt area that was uninviting and harmful to the waterways near it.

Before, when it rained, water would pool in the lot and run off into Blockston Branch, a tributary of Tuckahoe Creek.



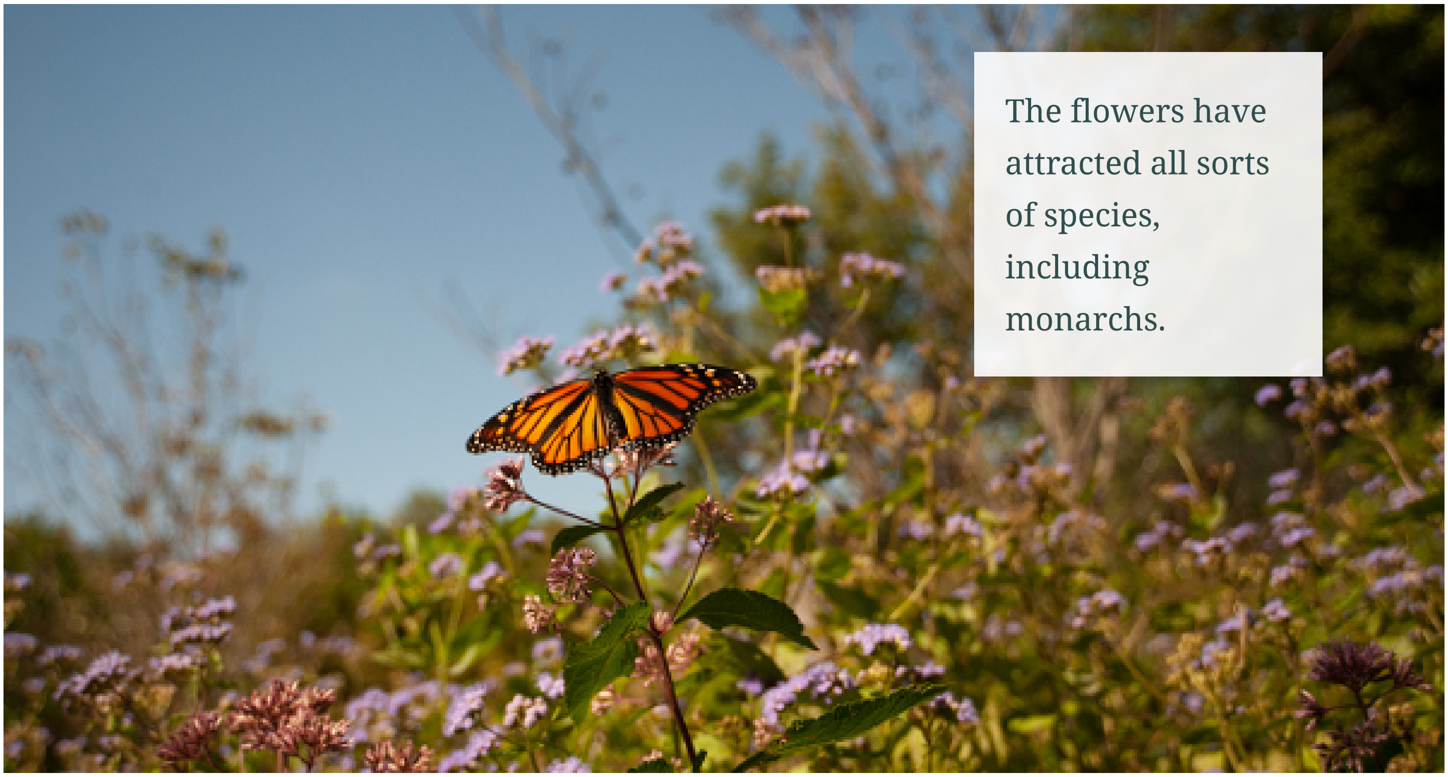
After, landscaping areas help hold the water and allow the plants to take it up.

Before, the drains that removed the water from the lot sometimes became overwhelmed.

After, bioretention areas designed specifically for the arboretum help to hold the water so that it doesn't run off the land. The project removed 4,987 square feet of asphalt, according to the arboretum.

The previous lot's landscaping was convex mulch islands with native plants that broke up the pavement, but the new plantings are concave and help the plants retain the water.

Native flowers bloom in the spring at Parking Lot Alive!



The flowers have attracted all sorts of species, including monarchs.

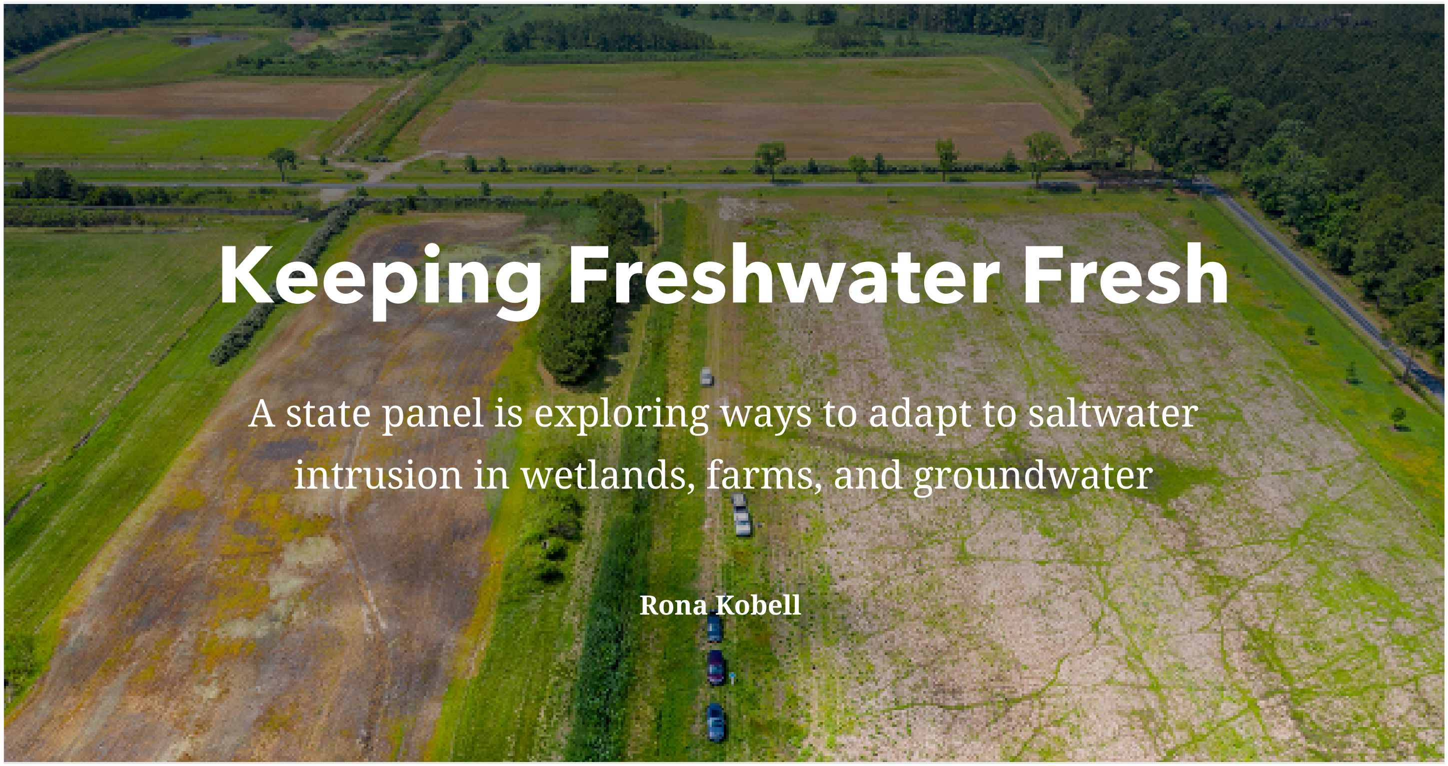
Buehl said his colleagues were correct when they warned him that the first year would be about understanding how the position worked, the second would be about building relationships, and the third and fourth would be about getting projects ready to put in the ground.

“I look at the minor successes as being nice—when we get an email that a grant was approved, when someone calls me back, when people return and ask for my assistance on a different project,” he said. “It’s been several years, and several iterations, but you go back and you look at the feedback, and you think, yeah, we made it.”

Header image: Maryland Sea Grant Extension Specialist Eric Buehl examines new growth near the parking lot of Adkins Arboretum with Kathy Thornton, the arboretum’s land steward.

Photos by Nicole Lehming / MDSG

Before photos of the arboretum and park by Eric Buehl



Keeping Freshwater Fresh

A state panel is exploring ways to adapt to saltwater intrusion in wetlands, farms, and groundwater

Rona Kobell

Maryland regulators and scientists are working on a plan to respond to saltwater intrusion in the state's aquifers, surface waters, farmland, wetlands, coastal forests, and infrastructure.

The Maryland General Assembly requested the plan last year, when it asked the Maryland Department of Planning to establish a strategy for adapting to saltwater intrusion in consultation with the Department of Agriculture, Department of Environment, and Department of Natural Resources.

Regulators worry that saltwater will enter coastal aquifers, requiring those who get their water from wells to dig deeper ones. The more water that is withdrawn, the more likely that saltwater intrusion could occur. Though the state has a regulation prohibiting withdrawals from areas where saltwater can intrude, regulators need updated maps and real-time information to pinpoint where those areas are.

The State Agency Saltwater Intrusion Workgroup includes scientists from Maryland Sea Grant, Maryland Department of the Environment, University of Maryland Center for Environmental Science, Maryland Geological Survey, and University of Maryland Harry R. Hughes Center for Agro-Ecology on the Eastern Shore. The plan maps the areas at risk for inundation and possible saltwater intrusion, which include much of Dorchester and Somerset counties but also parts of Worcester County and slivers of southern Maryland. It divides the preparation tasks into near-term ones, such as developing study plans and addressing aquifer vulnerabilities, to longer-term ones, such as developing forecast models. These models can identify possible future changes in the risk of saltwater intrusion into the state's drinking water aquifer supplies, giving regulators time to plan.

"Maryland seems to be lucky in that we don't appear to have many issues with saltwater intrusion in our drinking water—in part because we have a variety of aquifers. The more immediate threat is to coastal farmland, wetlands, and forests," said workgroup coordinator Jason Dubow, Maryland Department of Planning's manager for resource conservation. "But we need to remain vigilant. We know there's a big ecological change happening in Maryland. . . . It's not going to be stopped; it's just a matter of how much we are expecting."

The plan is available on the Maryland Department of Planning's website.

Header image: On the Eastern Shore, some farm fields are becoming brown patches where many crops can't grow. Saltwater intrusion is often the culprit. Photo, Edwin Remsberg