Underwater Soils

Classifying and studying subaqueous soils can provide huge benefits for conservation, restoration, ecosystem services, and infrastructure

by Caroline Schneider

doi:10.2134/csa2015-60-1-1

In the summer of 1992, George Demas could be found wading through water in Sinepuxent Bay, Maryland. He and some colleagues were examining soils in tidal marshes and on small islands in the bay. At times, they had to get out of the boat and push it along. As they walked along the material on the bay bottom, they began to notice differences. In some places, the material was soft or muddy while in other areas, it was sandy. Patches of eelgrass grew here and there.

As a soil scientist, Demas began to wonder why they had only been examining soils in the marshes and on the islands. Why weren't they looking beyond those places into the bay itself? The obvious answer was because that material wasn't soil.

Up to that point, material submerged in shallow water was considered sediment. It wasn't classified or studied as a soil. But the materials Demas and his colleagues were walking on varied like soil and many of them had vegetation growing in them like soils. So why weren't they considered soils?

Intrigued by the question, Demas collected some samples of the materials on the bay bottom and took them back to the lab. As he studied the samples and thought more about the definition of soils at the time, he became more and more convinced that these submerged materials should be studied and classified as soils. But as he began to talk to others about this new idea, he was met with some resistance.

"George wasn't to be dissuaded, though," says SSSA Fellow Martin Rabenhorst, a professor at the University of Maryland who would later be Demas's graduate adviser. "He published a paper in 1993 in *Soil Survey Horizons*, and he mentioned this concept of underwater soils, submerged soils he was calling them."

With his idea published, Demas convinced Rabenhorst that pursuing these submerged soils would make a good doctoral dissertation project. Demas began mapping and sampling the soils of Sinepuxent Bay. In these submerged materials, he was looking for evidence of soil additions, removals, transfers, and transformations—the four components of the theory of soil genesis. He found evidence of all of them. The processes common to the generation of soils on land were also generating the underwater materials in the bay.

It became clear through Demas's work that classifying and studying underwater materials as soil could provide multiple benefits to the environments in which he was working. Restoration plans and efforts to restock these areas with vegetation and shellfish were popular at the time. Demas made a clear case for how understanding the soils would benefit restoration efforts and help conserve valuable resources. The findings of his dissertation work were impressive and far-reaching.

George Demas

"George received the Emil Truog Award, which is the Soil Science Society of America's award for doctoral dissertations," Rabenhorst explains. "His [dissertation] was a great piece of work, and it really launched things from a soil perspective."

The observations Demas made and his continued efforts to rework the definition of soil lead to a modification of the definition in the 1998 edition of *Keys to Soil Taxonomy*. The new definition included soils under shallow water, typically less than 2.5 meters deep. Submerged soils, or subaqueous soils as they are more commonly called now, had a place in the world of soils.

Diving Further into Subaqueous Soils

Sadly, Demas passed away in December of 1999. But with the important groundwork he laid, other soil scientists were quick to enter new areas of research in both estuarine and freshwater subaqueous soils. With this uncharted territory came the need for new techniques to study these

Below: A simple fish-finding unit can provide water depth measurements and location information simultaneously. *Photo courtesy of Flickr/Chesapeake Bay Program.* **Right:** Along with the fish finder, readings from tidal gauges are used to correct for changes in tides. *Photo by Mark Stolt.*

soils that were difficult to see unlike subaerial, or terrestrial, soils.

"That's the big challenge, right? When you're walking along a subaerial landscape, you can see everything," says Rabenhorst, who uses the preferred term "subaerial" for terrestrial soils. "But one of the first major challenges when you move into the subaqueous environment is that what you can see is limited."

The first challenging step in studying subaqueous soils is mapping. Soil scientists want to get a picture of the terrain underneath the water by creating bathymetric maps, just as topographic maps are created for subaerial soils. And while the equipment used to create bathymetric maps has improved, technology was limited in the 1990s. During that time, the Department of Defense was scrambling GPS signals as a security measure. Soil scientists hoping to use GPS to map subaqueous soils had to buy expensive units left over from the army.

"At the beginning of each day, it would take about 20 minutes to upload the descrambling signals from the satellites," Rabenhorst explains. "Once you got that, though, you could collect data that was good within a meter in real time out on the water."

Now, with better technology available, the equipment necessary for creating bathymetric maps is much cheaper. A simple fish-finding unit can provide water depth measurements and location information simultaneously.

"You can basically use a fish finder to measure the distance from the top of the water column to the subaqueous soil interface," says SSSA member Mark Stolt, a professor at the University of Rhode Island. "You just drive the boat, and every 10 seconds or so, it takes a reading."

While this process is now fairly straightforward in freshwater areas, there is another variable in estuarine systems—tides. With tides going up and down, the measurements from the top of the water column to the soil underneath can vary at different times of the day. So along with the fish finder, readings from tidal gauges are used to correct for changes in tides. With these data, scientists are able to map the subaqueous terrain and create a picture of the landforms underwater.

The landforms that can be visualized from the bathymetric maps help scientists delineate landscape units. Attributes of the landscape such as slopes and surface shapes help describe the boundaries of landscape units such as flood tidal deltas or washover fans. And once these landscape units are defined, soil samples can be collected to see how the soil types align with the different landforms.

"We can recognize the landscapes, and then we run transects for sampling," Rabenhorst explains. "We cut across the gradient or across the landforms to see how the soils change systematically. This is the way we do it in the uplands too." Adds Stolt, "For the most part, soils will follow those lines, just like they do in subaerial soils."

Actually sampling the soils can be done in multiple ways depending on the characteristics of the soil and how much analysis the scientists want to do. If the soil is soft and fluid, a Macaulay peat sampler can do the trick. This sampler is a fast, efficient way to get 50- or 100-cm increments of the soil profile. With a push and twist in the soil, a half core of soil can be collected. The next increment can be collected simply by pushing the sampler down further. The researchers can then lay out these individual pieces of the profile and look at them immediately.

If the soils to be sampled are dense or sandy, or if researchers plan to do detailed analysis on the sample, a vibracore is often used. The aluminum irrigation pipe used to collect the sample must be long enough to pass through the water and go into the soil profile to the desired depth. The vibracore vibrates the pipe allowing it to be pushed into the soil. By topping off the pipe with water and capping it, a vacuum is created. When the pipe is removed from the soil, the sample stays in the pipe, and the researchers have an intact soil profile.

"You can take the pipes and split them in half with some shears," Stolt says. "And there you've got your profile in front of you just like it is underwater."

Without being able to directly observe them, the mapping, collection, and analysis of subaqueous soils can be time-intensive and difficult. The water creates an extra barrier to the study of such soils compared with subaerial soils. But sometimes an unexpected event allows researchers to actually see the soil under the water. One such event occurred in Rhode Island at Trustom Pond.

In October of 2012, Hurricane Sandy hit the east coast of the United States. Trustom Pond is a coastal freshwater pond with no man-made inlet or outlet. But as Hurricane Sandy hit the coast, Trustom Pond overwashed and breached. The water drained from the pond through the newly made outlet, and water levels dropped 5 to 6 ft.

For Jim Turenne, Rhode Island assistant state soil scientist, the drained pond provided a unique opportunity. Much of the soil that was underwater when he mapped it in 2007 was now exposed, allowing Turenne, an SSSA member and Certified Professional Soil Scientist, to check his maps and directly see the soils.

"It was actually like being able to drain a pond and map it that way," Turenne recalls. "I spent a day out there just walking the pond and getting profile descriptions and good photos of the area. It was an opportunity to dig a hole and not just vibracore to collect some data."

Classification and Interpretations

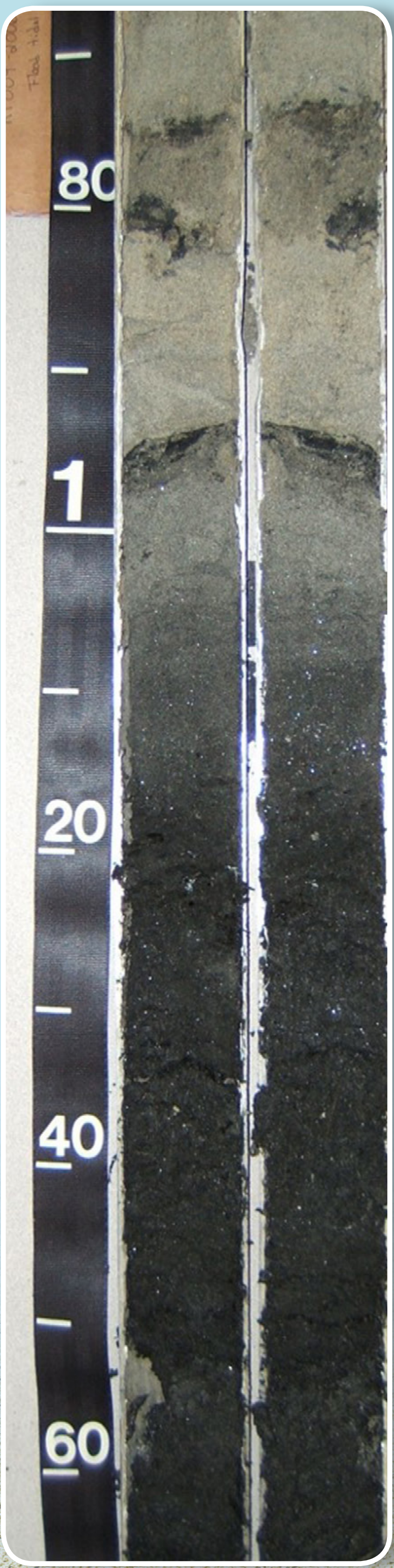
While few scientists will have opportunities to observe subaqueous soils as Turenne did in Trustom Pond, reliable procedures and techniques can now be used to study soils underwater. The processes used to study subaqueous soils are similar to those used for subaerial soils, but what about the soils themselves?

Subaqueous soils are similar to soils found in marshes or some flood plains, Rabenhorst says. From a geological timeframe, subaqueous soils are young and weakly developed. The soils may be only 100 or 200 years old, or sometimes up to 2,000 years old, still young from a soils standpoint. Because these soils are young, they rarely have significant B horizons, which develop over time.

"You have A horizons that form, and in certain circumstances, you might see some weak B horizons, but then they go into mostly C horizons," Rabenhorst explains. "But the horizons are distinct and distinguishable."

Stolt led an effort to develop new taxa to classify these soils, and the 11th edition of the *Keys to Soil Taxon-*

Left: Vibracore soil sample. *Photo by Martin Rabenhorst.* **Above:** An area of bouldery Napatree soils exposed following the breach of Trustom Pond in South Kingstown, RI. *Photo by Jim Turenne.*



Subaqueous soil profile. *Photo by Mark Stolt.*

omy, published in 2010, included two new suborders. These are Wassents and Wassists, which correspond with subaqueous Entisols and Histosols. Below these suborders are great groups and subgroups into which Wassents and Wassists are further divided based on characteristics of the soils. The presence of sulfides, the texture of the soils, and varied horizons within the soil all help scientists classify these subaqueous soils as they have done for years with subaerial soils. And in more fully classifying the soils, both researchers and practitioners can better tie soil type to possible soil uses.

Subaqueous soil uses, or interpretations as they are called by soil surveyors, can include conservation projects, restoration efforts, basic ecosystem services, and infrastructure support. A better classification system for subaqueous soils helps us all understand the importance of these soils and the services they can provide. In fact, NOAA now recommends the subaqueous soils approach when interpreting the use and management of shallow subtidal soils.

"We can do a soil survey like we do on all the upland landscapes," Rabenhorst says, "and then we can figure out all the marvelous interpretations we can make once we get that soils information."

The tie between soil classification and use was clear to Demas back in the 1990s. And it only becomes increasingly important as more people move to the coasts and as our coastal waters become even more valuable resources. For example, knowing the characteristics of the subaqueous soils used to support docks and other structures people build along the coasts is crucial when determining if those structures will be secure.

Another example of how classification can help manage these soils is seen with dredging. Dredging of subaqueous soils is commonly done to deepen waterways and replenish beaches. However, sulfides, which can accumulate in these soils, can cause problems. When sulfide-containing soils are dredged and placed on subaerial soils, the sulfides oxidize and lower the pH of surrounding soils. These soils then become uninhabitable for both plants and animals. Such problems can be avoided if sulfide-containing soils are mapped and characterized.

A somewhat unseen, but increasingly important, service provided by subaqueous soils is carbon sequestration. As climate change concerns and atmospheric carbon dioxide increase, scientists have become more and more interested in sinks and sources of carbon. Stolt recently published a paper in which he and his co-authors found that different subaqueous soils sequestered carbon at different rates among various landscape units. Average rates were equivalent to those seen in subaerial forest soils. "Clearly one of the services these soils provide would be carbon sequestration," Stolt states.

One of the more obvious benefits of understanding subaqueous soils, and one that Demas championed from the beginning, is their role in estuarine restoration. Estuarine managers are charged with restoring the health of these aquatic environments, and while water quality has often been considered and addressed, the underlying soils have been overlooked.

"Re-establishing submerged aquatic vegetation in these areas is a very expensive process," Rabenhorst says. "You're talking about maybe $50,000 per acre to plant these. If you put them in soils that aren't well suited for their growth, that's a waste of a lot of money."

Re-establishment of vegetation, such as eelgrass, on appropriate soils can go far to benefit the aquatic ecosystem and restore that environment. With eelgrass come many other organisms that depend on the grass, and therefore, on the soils.

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Help Spread the Message of Soils during the International Year of Soils

Soil scientists all around the world are joining forces to educate the public about the importance of healthy soils this year, which has been named the International Year of Soils by the United Nations (UN). The Soil Science Society of America (SSSA) is coordinating with the UN's Global Soil Partnership and other organizations around the world to celebrate the 2015 International Year of Soils and raise awareness and promote the sustainability of our limited soil resources. We all have a valuable role in communicating vital information on soils, a life-sustaining natural resource. Therefore, SSSA wants to provide everyone with resources to learn about soils and help us tell the story of soils! Help us promote #IYS on social media by sharing our posts from Facebook and Twitter!

Soil Science Society of America

To date, 12 monthly themes and three to five messages per theme have been developed by SSSA for the International Year of Soils (see www.soils.org/IYS). Members of SSSA are serving as monthly leaders, leading the efforts to create activities surrounding the monthly messages. Further, a series of videos are in production, narrated by Jim Toomey, describing the themes and concepts. The first video is ready to view at www.soils.org/iys/monthly-videos.

In addition, SSSA will be sending out monthly news releases, writing Soils Matter blog posts (https://soilsmatter.wordpress.com/), and covering the monthly topics in our member magazines. Know a K-12 teacher? Have them sign up to receive monthly emails with links to that month's activities.

SSSA members: Watch for a special edition of *News Flash* at the beginning of the year (and then monthly), to keep you up-to-date on the available activities for you to use (or tailor for your own message) throughout 2015. This is our opportunity to bring soils to the forefront of the public's mind, and to help all to understand that soil is necessary for life as we know it!

Visit www.soils.org/IYS

In the meantime, here are some other ways that you can celebrate and support the International Year of Soils:

- Make a Cake! Use soils-related dessert recipes (www.soils.org/iys/desserts) that members have shared (and feel free to contribute your own),
- Order I "heart" Soil clothing and merchandise from Lands' End (http://ocs.landsend.com/cd/frontdoor?store_name=SSSA&store_type=3),
- Share what's happening on your own Facebook and SSSA's Facebook pages and Twitter feed #IYS—post pictures of any celebrations you may do,
- Make a donation (www.soils.org/membership/donate/IYSGIFT) to help us offset the development of our International Year of Soils materials, and
- Get Excited about the International Year of Soils! We'll need you to be our hands and feet, going out into the public with targeted messages that help everyone see how soils relate to our daily life, health, and quality of life.

Left: Former University of Rhode Island graduate student Chrissy Pruett preparing some eelgrass restoration test frames. In the upper right of the photo, you can see eelgrass hanging down from the elevated frame. *Photo by Mark Stolt.* **Below:** In many areas, the quality of the aquaculture and the number of shellfish that can be supported are greatly affected by the soils. *Photo by Graham Siener/Flickr.*

"Eelgrass is important for harboring lots of aquatic animals," Stolt explains. "Finfish, crabs, scallops, and so forth come into these systems and live in the eelgrass meadows. The soil is supporting the aquatic plants, and the plants are harboring very important parts of the estuarine ecosystem."

In addition to vegetation restoration, shellfish aquaculture and leasing are environmental and financial resources in many areas. The quality of the aquaculture and the number of shellfish that can be supported are greatly affected by the soils that are there. In addition to harvesting the shellfish for profit, the presence of oysters, clams, or scallops can benefit water quality. They filter a lot of water, removing nutrients and other compounds that come into the estuarine systems. Knowing which soils will best support those organisms is vital to their success.

"These types of questions may be typically asked in subaerial areas. Do we grow this crop or that one? Do we manage it this way or that way? These are not questions that had been asked from a soils perspective in aquaculture," Stolt says.

That soils perspective is what Rabenhorst hopes soil scientists can continue to bring to studies of estuarine ecology. And he is quick to recognize the extensive work that benthic ecologists have done in this area of study. Rabenhorst has developed collaborations with benthic ecologists and encourages other soil scientists to work in interdisciplinary teams. He hopes that enhanced dialog among soil scientists, ecologists, and marine geologists will provide a more complete picture of what's happening in these subaqueous systems.

"There's nothing comparable to a comprehensive soil survey," Rabenhorst says. "I think that is the main contribution we're bringing into this system—a pedological perspective."

Stolt agrees that soil scientists can, and should, approach these environments from their distinct angle. It's an angle that has been used for years in subaerial environments and the angle that Demas took as he brought the definition of soil underwater.

"We have a unique approach as soil scientists to mapping out our resources and using those maps to help manage," Stolt says. "How can we best manage these estuaries, lakes, or ponds but also conserve what's there? We're trying to classify the resource that's out there so we can do a better job of both managing and conserving it. It's really not different than what is done in a subaerial system."

C. Schneider, Science Communications Coordinator for ASA, CSSA, and SSSA