Chesapeake Quarterly

MARYLAND SEA GRANT COLLEGE • VOLUME 15, NUMBER 1

Going Green to Manage Urban Stormwater

contents

Volume 15, Number 1

2 Big Greenscaping for a Big City
Washington, D.C., tries new ways to cut stormwater flow and improve Chesapeake Bay water quality.

9 Digging Deep to Improve Water Quality
Machines are building vast tunnels to reduce D.C.'s sewage overflows.

11 Whatever Happened to Watershed 263?
A Baltimore experiment in greening benefitted people and the environment.

15 Maryland's 2016 Knauss Fellows
Four students are working at NOAA.

16 Bernie Fowler Receives Award
Three state legislatures honor a long-time Chesapeake Bay advocate.

CHESAPEAKE QUARTERLY *April 2016*

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 Maryland Sea Grant College program is led by Director Fredrika Moser and receives support from the National Oceanic and Atmospheric Administration and the state of Maryland. Editors, Michael W. Fincham and Jeffrey Brainard; Science Writer, Daniel Pendick; Production Editor and Art Director, Sandy Rodgers. Send items for the magazine to:

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Cover photo:** John Hill crouches over a green roof overlooking the U.S. Capitol. His organization, the United Methodist General Board of Church and Society, installed the 6,800-square-foot vegetated roof in 2014 to reduce stormwater runoff and cut costs for air conditioning.* ***Page 3: *This rain garden on First Street, N.E., in Washington, far from the Chesapeake Bay, plays a small role in its cleanup.* PHOTOGRAPHS: COVER, SKIP BROWN; P. 3, D.C. DEPARTMENT OF ENERGY AND ENVIRONMENT

BIG GREENSCAPING FOR A BIG CITY

Washington, D.C., mixes green techniques, gray engineering to reduce stormwater flows

Jeffrey Brainard

Cliff Notarius was looking closely at the blueprint for a green makeover of his street as city officials explained their plan for installing something called "green infrastructure" in his leafy neighborhood in northwest Washington, D.C. Speaking at the local community center, they were saying their plans offered a new, better way to control the stormwater that runs in sheets during big storms down his street and into a city drain.

The drain is part of a stormwater system that the city started building in the late 1800s to solve a recurring problem: the flooding of downtown streets. But over time, their solution — a big system of underground drainage pipes — created another problem. As stormwater gushes into drains, it carries motor oil and sediment and excess nutrients like nitrogen and phosphorus through the pipes and empties these pollutants into the city's rivers. Those rivers flow into the Chesapeake Bay, where the pollutants lead to poor water quality, low oxygen zones, and disappearing seagrasses.

Notarius learned that green infrastructure in his neighborhood offered a way of handling stormwater that could help reduce water pollution and make his neighborhood look prettier. The city would help homeowners pay the cost of installing native plants on their lawns in "rain gardens" designed to soak up stormwater. Workers would install strips of porous concrete paving along the neighborhood's streets and alleys to capture more water. And along Notarius's block, they would build "bioretention bump-out" boxes — rain gardens that extend out from street curbs into parking lanes. Water running into the gutter would enter through one end of the garden and percolate slowly into the ground.

Each of these techniques could reduce stormwater volume, at least according to scientific studies conducted elsewhere. This project, however, would be one of the first in Washington in which the city measured results from rain gardens and bump-outs installed across an entire neighborhood.

Notarius liked the idea of a greener neighborhood. After all, he considers himself environmentally conscious; he has a sticker in his window announcing that his house's electricity is generated from wind power.

A new solution, however, can create a new problem. Notarius said he was concerned about the pair of 40-foot-long bump-outs planned for his block: in his residential neighborhood they would eliminate parking spaces. "On a typical day, it's wall-to-wall cars here," he said, "and it's hard to find a place to park when you come home." Green infrastructure, it seems, wasn't only about the greenery.

Green and Gray Solutions

A green approach to stormwater management was coming not just to Notarius's

neighborhood but also to other urban locations around the Chesapeake region. Collectively, the plantings and bump-outs represent an ongoing experiment to explore two key questions: What does it take to install a meaningful amount of green infrastructure across a city or suburb? And can this greening reduce stormwater flow enough to help improve water quality in local waterways and the Chesapeake Bay?

For Washington's city leaders, reducing the stormwater flow has been a regulatory imperative for more than decade. Since 2001, the U.S. Environmental Protection Agency (EPA) has issued a series of directives mandating that reduction and requiring other measures to improve local water quality. The EPA set limits to cap the amounts of various contaminants — like nutrients and sediments, but also metals and coliform bacteria — in the Potomac and Anacostia Rivers and Rock Creek. Those caps were intended to advance a requirement under the federal Clean Water Act to make waterways fishable and swimmable. Reaching that goal meant a lot of work — the Anacostia is listed as one of the dirtiest rivers in America.

Then in 2010 the EPA gave Washington additional marching orders that underscored the need for reductions in stormwater flow. The city would have to join surrounding states to reduce excess nutrients and sediments flowing into local waterways and reaching the Chesapeake Bay. These jurisdictions would have to hit a set of pollution limits called the Chesapeake Bay Total Maximum Daily Load or TMDL. Reducing nutrients and sediments was a priority because they fueled summertime bursts of algae that in turn fed the creation of the Bay's dead zones. And the sediments were clouding the estuary's water and cutting out light essential to the growth of the aquatic vegetation that plays a vital role in keeping the waterway healthy.

Using green infrastructure to cut down the flow of stormwater would play an important role in reducing these loads. Not the only role — a large proportion of the nutrients and sediments that Washington was sending to the estuary was being discharged by the regional sewer plant that serves the city, the Blue Plains Advanced Wastewater Treatment Plant.

But urban stormwater emerged as an important priority because it is the fastest-growing source of nutrients and sediments in the Chesapeake's watershed. Overall, stormwater accounts for about 16 percent of the nitrogen, 16 percent of the phosphorus, and 25 percent of the sediment.

In Washington, cutting stormwater flows would also require dealing with problems posed by the city's "gray infrastructure" — two vast networks of underground concrete pipes. One of these networks is called a "combined sewage system" because it carries a mix of stormwater and raw sewage. About one-third of the city's developed land is drained by this network, which carries waste from flushed toilets and stormwater through street drains to the Blue Plains plant. Perched on the east bank of the Potomac River, it is the largest such plant in the world, but during large rainstorms, this combined flow exceeds even this plant's treatment capacity. When that happens, the flow backs up, and the combined-sewage-pipe network is designed to discharge it from 53 outfalls directly into the

Potomac and Anacostia Rivers and Rock Creek.

Washington's water and sewer authority, called DC Water, responded to this problem with a big, gray-infrastructure fix. To settle legal challenges by the EPA and environmental advocacy groups, the water authority agreed in 2005 to build a series of underground tunnels crossing the city to store the backed-up flow during most storms until the Blue Plains plant can treat it. Construction is underway and is to be completed by 2030. (See Digging Deep to Improve Water Quality, p. 9.)

"That vast tunnel will probably be here 500 years from now," says George Hawkins, general manager of DC Water. "This is like the Roman aqueducts, we're building stuff that's going to be here forever."

In 2015, DC Water completed a separate, large improvement to the sewage system designed to further improve water quality. To comply with EPA regulations, DC Water finished a major upgrade to the Blue Plains plant, adding new treatment technology designed to cut its nitrogen discharge by nearly half.

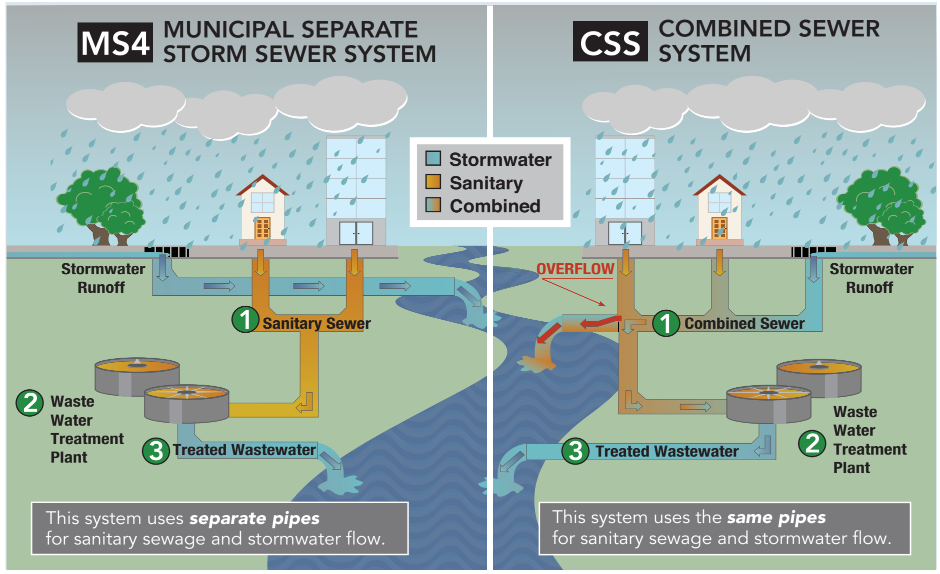
Together, those two projects — the tunnels and the treatment-plant upgrade — are expected to accomplish most of the reduction in nitrogen, phosphorus, and sediment that Washington is responsible for achieving under the EPA's Total Maximum Daily Load to improve water quality in the Chesapeake Bay.

But the city government also faces additional EPA requirements to reduce the volume flowing through yet another network of stormwater-drainage pipes. This one is called the MS4 network, short for the Municipal Separate Storm Sewer System. These pipes carry only stormwater and serve the two-thirds of city land not covered by the combined sewage system. The MS4 network presents its own set of environmental problems. The water in this network does not flow through the city's treatment plant but empties, mostly untreated, from more than 400 outfalls into local rivers.

To reduce that flow and improve water quality, the EPA required the city in 2011 to install green infrastructure, like rain gardens, across the parts of the city drained by the MS4 system. The agency included that condition in the city's five-year permit under the Clean Water Act to operate the MS4 system. City planners and the agency agreed that a key way to reduce stormwater was to convert some of the city's hard, paved surfaces — rooftops, streets, and parking lots — into pockets that function like sponges, soaking up rainwater, instead of acting as chutes leading to storm drains. Reducing the flow of stormwater would also reduce the amount of nutrients and sediment reaching water bodies. And the plants in the new gardens and bump-out boxes would also take up nitrogen.

Green infrastructure would play a role in Washington's plan to meet its Total Maximum Daily Load target for the Bay. The plan calls for taking steps to reduce by 11 percent the amount of nitrogen that the MS4 stormwater pipes send to the Bay. Phosphorus must be reduced by 27 percent and sediment by 26 percent.

Gray infrastructure, green infrastructure — "I think it is a really interesting contrast, two night-and-day approaches to dealing with the same issue," says Glenn Moglen, an expert in urban hydrology at Virginia Tech. The big tunnel approach is expensive but reduces stormwater and nutrient flows by predictable amounts. The green approach can be more cost effective. But because it relies on smaller-scale practices spread more widely over the city, the success of green infrastructure depends on a lot of intangibles, including the performance of the rain gardens, how well they are maintained over time, and how many people choose to install them, Moglen says.



Two Approaches to Reducing Stormwater

Green Infrastructure

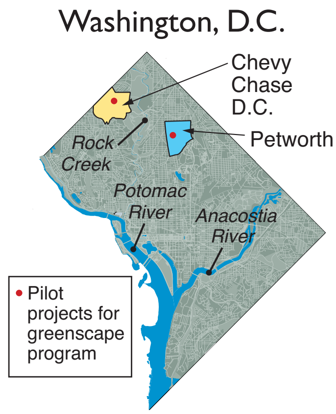
Small-scale engineered structures spread around a city to reduce the flow of stormwater and pollutants.

- Rain gardens
- Bump-out boxes (rain gardens built in street parking lanes)
- Rain barrels (capture stormwater from downspouts)
- Green roofs
- Permeable concrete pavement for streets and sidewalks

Gray Infrastructure

Large-scale engineering projects that reduce stormwater flow and treat pollutants.

- Combined sewage overflow control tunnels
- Improvements to wastewater treatment plant's nitrogen-removal technology



***A network of underground pipes** called the MS4 discharges Washington's stormwater into local waterways with little treatment (graphic, opposite page). In another network, the CSS, the city's stormwater mixes with sewage and can overflow into local rivers. To reduce the flow of stormwater into drains, the city made plans to build a variety of "green infrastructure." City officials met with residents of the Chevy Chase and Petworth neighborhoods (above, top) to show plans for placing features like bioretention bump-outs (above, bottom) in parking lanes.* GRAPHIC (OPPOSITE PAGE) AND PHOTOGRAPH (ABOVE, TOP), D.C. DEPARTMENT OF ENERGY AND ENVIRONMENT; PHOTOGRAPH (ABOVE, BOTTOM), JEFFREY BRAINARD; MAP, ADAPTED BY SANDY RODGERS FROM A DC WATER MAP

"The green infrastructure is aesthetically more appealing, and it has the potential for engaging the community," he says. But "so much depends on human behavior and human investment in these things for the long term."

The Slow Pace of Greening

One of the open questions about green infrastructure is whether enough of it can be built fast enough to really make a dent in the city's stormwater problem.

Under Washington's MS4 stormwater permit, the city is required to ensure that about 400 acres of hard, "impervious" surfaces like streets and rooftops are converted to green infrastructure by 2016. Four hundred acres is a pretty big surface, equivalent to a parking lot slightly larger than the area covered by the entire National Mall. To help meet that requirement, the city changed its stormwater-management rules in 2013 in a way that encourages the construction of green infrastructure.

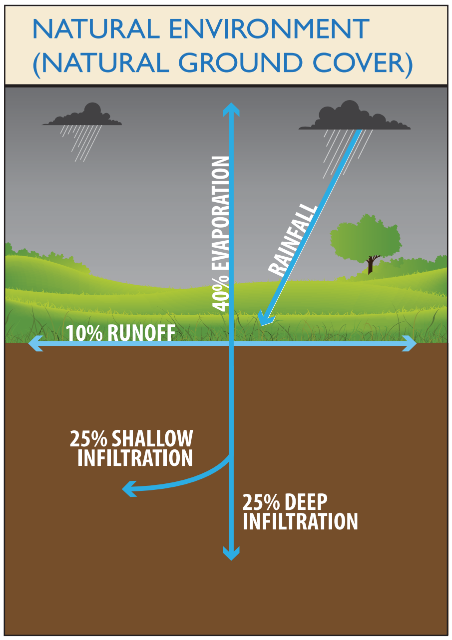
The new rules require new construction projects and renovations over a certain size (5,000 square feet) to include design features that soak in up to 1.2 inches of rain before it can run off-site, away from the building. The figure of 1.2 inches was chosen because 90 percent of all rainstorms in an average year dump that much or less in the Washington region. To comply, developers have to install measures like sidewalk rain gardens or rooftop plantings called green roofs. Some of the water captured by these features seeps into the ground, some evaporates.

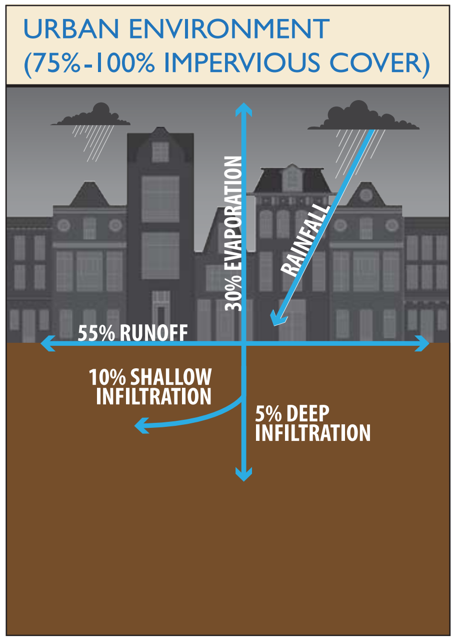
Making plans is one thing. But as of 2015, Washington was behind in its progress toward turning 400 acres of hard, impervious surfaces into greenscaped land. From 2011 to 2015, the city recorded only about 100 acres (about four million square feet) in this category. The slower-than-anticipated pace reflects that this part of the city's green infrastructure plan relies heavily on the construction and renovation of commercial buildings. These large projects trigger the city's stormwater rule about controlling the first 1.2 inches of rainfall. But economic factors slowed the speed of construction for several years after the 2008 recession, says Steve Saari, a city official who helps to lead the green infrastructure efforts for the District Department of Energy and Environment.

Saari and his colleagues expect that pace will pick up. The city's plans depend on it — the city estimates that these large projects will provide most of the reduction in stormwater volumes in the MS4 permit area, as developers work to comply with the city's rule.

On other fronts, the city has made more progress. Another regulatory requirement in D.C.'s MS4 permit is to install 350,000 square feet of green roofs. Grasses and plants are grown in beds of soil atop buildings with flat roofs. Rainwater soaks into the soil and the plants take up the water for growth and return water to the atmosphere through a biological process called transpiration.

To encourage homeowners and developers to build green roofs, the city funds a program that subsidizes construction at a rate of up to $15 per square foot. Between 2011 and 2015 owners installed nearly 900,000 square feet of green roofs on more than 150 buildings in the District. And in 2014 alone, more green roofs were built in Washington than in any other American city.





***Strips of permeable paving** were installed by the city in this Washington residential neighborhood (above) to let rainwater soak into the ground. In urban areas, more stormwater runs off paving and roofs into storm drains than in less developed, unpaved areas (graphic, left), where more rainwater seeps slowly or "infiltrates" into the ground and can also be taken up by plants. The new headquarters of the U.S. Coast Guard in Washington (opposite page) has a green roof of 557,000 square feet, one of the largest in the world.*

PHOTOGRAPHS, JEFFREY BRAINARD (ABOVE, LEFT AND CENTER); D.C. DEPARTMENT OF ENERGY AND ENVIRONMENT (ABOVE, RIGHT); TAYLOR LEDNUM, GENERAL SERVICES ADMINISTRATION (OPPOSITE PAGE); GRAPHIC (LEFT), D.C. WATER

Bonuses of Greening

While Washington city officials are required to reduce stormwater, they have also embraced the effort and the green projects needed to achieve it, arguing that the changes make the city more environmentally sustainable and a more attractive place to live. For example, in 2006 the city revised its building code to require construction of energy-efficient buildings known as LEED certified. The code promotes the construction of green roofs because, besides diverting water from the sewer system, they can help cool down buildings, lowering air-conditioning costs.

In addition to energy savings, green infrastructure offers other benefits. A study in Portland, Oregon, for example, found that property values increased after the city carried out an extensive green infrastructure plan and built more than 700 bioretention features. And a green infrastructure project in one section of Baltimore measured increased satisfaction among city residents who live in greened areas (see Whatever Happened to Watershed 263? on p. 11).

The visible, social benefits of green infrastructure are among the reasons that George Hawkins, the general manager of DC Water, pushed to include a green-infrastructure component in the mostly gray-infrastructure plan for building the big tunnels to solve Washington's problem of combined sewage overflow. The 2005 settlement that resulted in the tunnel-construction plan was amended in 2015 to include construction of green infrastructure within 500 acres of city street right of way and public land.

"Green infrastructure works all the time and gray infrastructure only works when the storm is big enough to cause the overflow," Hawkins says. "All the rest of the time it's under there, empty, doing nothing."

Does Green Infrastructure Work?

How many pollutants green infrastructure removes and under what conditions are questions that water scientists and engineers have studied for years.

Allen P. Davis at the University of Maryland, College Park has spent 20 years researching the long-term performance of rain gardens and similar bioretention stormwater control measures. A professor of civil and environmental engineering, he has been a pioneer in running field and laboratory experiments to test their performance. His research has focused on experimental rain gardens on the university campus and at locations in the surrounding Prince George's County. He helped the county develop one of the first manuals on maintaining green infrastructure so that it continues to work as designed over time.

"Ten years ago, we were just trying to see what these things did — bioretention rain gardens were holes in the ground," he says. "And now I think we're beyond that. The science has evolved where they're not just black boxes. Now we have a pretty good fundamental understanding where we can say, if we want to get a lot of water removal, a lot of nitrogen removal, you design it this way."

The promising news is that his studies — and others by researchers at institutions like North Carolina State University, the University of New Hampshire, and Villanova University — have documented that properly designed bioretention cells can reduce both the volume of stormwater and the amount of excess nutrients that harm water quality. Davis says that the evidence indicates that, under ideal conditions, bioretention cells can remove up to 60 percent of total nitrogen in the stormwater they capture and up to 75 percent of the phosphorus.

Other scientists have found a similarly broad range of performance in green roofs. The amount of research on this topic has picked up in recent years, and studies are finding that green roofs can reduce stormwater runoff by amounts ranging from 30 to 86 percent, according to a review published in 2014 by Roger Babcock at the University of Hawaii. Green roofs also reduced peak flows, when stormwater gushes fastest.

But performance was uneven, varying with factors like the species of plants grown, the depth of the soil laid on roofs, and the amount of rainfall in each storm. As rainfall increased and the green roof's soil became saturated, the volume of stormwater retained decreased. More research is needed to predict consistently how much stormwater green roofs can reduce and under what conditions, Babcock wrote.

Washington's plans for spreading green infrastructure across the city is based on extrapolating from scientific studies like these to hit targets for reducing stormwater volume and nutrients. But plenty of challenges remain both for researchers and for the city managers who would try to apply the scientific findings in practice. The limited number

of field studies of rain gardens done to date may not apply consistently in other locations with somewhat different soil types, say Davis and other researchers.

What's more, without proper design, rain gardens can temporarily release more phosphorus than they retain because of the relatively high phosphorus content in some of the soil types used as the plant bed. And the top layer of soil in rain gardens can become clogged with sediments, requiring maintenance to restore their ability to soak up water. In sum, there's little information about the performance of bioretention areas over time, Davis says.

And there is another source of unpredictability about the long-term performance — estimates that changing climate will bring more intense storms that dump more rain over longer periods on city streets and rain gardens. "Ideally, if you get a nice gentle rain once a week, these things will work perfectly," Davis says. But as bioretention areas become saturated, he says, their performance drops off.

Determining the value of green infrastructure for reducing stormwater volume and nutrient loads will require scientists to go beyond controlled laboratory studies and collect data about the effects of green infrastructure installed across a large swath of an urban area, Davis says. "I'm not sure anyone has been able to do that yet because we haven't yet been able to green up a large-enough area to make an impact," he says. "Somewhere along the line, we have to see [reductions in nutrients] show up in the streams and the rivers and, ultimately, the Bay."

One Neighborhood's Results

Steve Saari and his colleagues in Washington's government also wanted evidence that the city's green-infrastructure measures were reducing stormwater flows. So they tried a test of green infrastructure on a relatively small scale, two neighborhoods in northwest Washington called Chevy Chase, D.C., and Petworth. The areas measured only 14 and 13 acres, respectively. But they were chosen in part because each neighborhood study area drained into a single stormwater drain. That would allow the city to install green infrastructure and then measure the effects on stormwater flows.

Starting in 2012, both neighborhoods received a mix of green infrastructure funded by the city as part of an existing city-wide program called RiverSmart Washington. Workers installed strips of permeable paving and bioretention bump-outs along city streets. The city dug more than 60 test holes to ensure that these installations along public streets would be located in areas where the soil would drain quickly enough to make a difference.

The city also gave individual homeowners incentives of up to $5,000 each to subsidize the cost of installing green infrastructure on their private property — measures like planting rain gardens and trees. By the time the work ended in

Continued on p. 16

Greening One House at a Time

The flyer came in the mail with a plea. Washington, D.C., was looking for homeowners in my neighborhood who would agree to add a whole lot of "green infrastructure" on their properties — special plantings like rain gardens to soak up stormwater. Would we come to a meeting to consider signing up?

My neighborhood, Chevy Chase, D.C., in the city's northwestern part, had been chosen back in 2011 for an experiment. The city had teamed up with the nonprofit Rock Creek Conservancy to answer a question: if all of the homeowners in a single stormwater drainage area acted together, could they reduce the amount of rainwater flowing off their properties and into their common stormwater drain? The city was looking to monitor and reduce this flow because the water was washing pollutants like road dirt and motor oil into a drainage system where they would end up in local waterways and eventually the Chesapeake Bay.

I didn't know much about rain gardens or stormwater management. But I was about to get a crash course. As the grandson of a florist, I was interested; I had something of a green thumb and liked to putter in my backyard. I attended a public meeting at the community center and then a cocktail party around the corner at which project sponsors talked up the idea. It felt like my neighbors and I were in this together — the more of us who signed up, the better the odds that the project would result in reduced stormwater flow.

Plus, there was cash on the table. The city was offering up to $5,000 for the green-infrastructure costs at each participating home. We could use this money to pay for one or more greening options. They included rain gardens — native vegetation planted in bowls of soil landscaped to hold stormwater so it can slowly percolate into the ground. Another option was "Bayscaping," creating gardens of native plants without the bowl. We could plant trees. And install rain barrels to catch rain coming out of our gutter downspouts. Or remove paved surfaces such as the concrete pathway and patio slabs in our backyard.

My Bayscaped garden *contains native plants, like orange milkweed and northern highbush blueberry. Compared with a grass lawn, plants like these do a better job of retaining stormwater and reducing soil erosion.* PHOTOGRAPH, JEFFREY BRAINARD

My wife and I opted for the full menu. Then we found out that all of this would cost double the $5,000 budget from the city. This business of greenscaping wasn't exactly cheap, not with professional landscapers doing the work.

We narrowed our project's scope, opting for one rain garden instead of two. It would take up 40 square feet in our front yard. We paid some of our own money over and above the $5,000 to remove an unsightly concrete sidewalk that ran straight down the middle of our backyard to our detached garage. New grass and a Bayscaping garden, measuring 100 square feet, would replace it.

Overall I'm pleased with the result. The orange milkweed (*Asclepias tuberosa*) attracts butterflies. The northern highbush blueberry (*Vaccinium corymbosum*) is lovely. Our backyard seems more of an oasis than it was. And somewhat less rainwater pools there after big storms — the plants seem to be sucking up moisture as expected.

City officials liked the result, too. Stormwater flows in the neighborhood have decreased. And after the vegetation was installed, project leaders brought about 15 people through my backyard one weekend afternoon on an inspection tour. They included students and volunteers interested in learning more about greenscaping. They joked with me about wanting to stay — if only I would fire up my grill and cook for them.

In my neighborhood, 33 of the 61 other homeowners joined me in signing up for the greening. So did 30 homeowners in the Petworth area of northwest D.C., another neighborhood chosen for the same project to monitor and reduce stormwater.

The city is continuing to fund a group of programs to carry out greening work like this across Washington. One of them, RiverSmart Homes, began in 2007 and in 2014 funded the installation of Bayscaped gardens at 130 properties. Any home in Washington is eligible. (Learn more at http://doee.dc.gov/service/riversmart-homes-overview or phone 202-535-2252.)

But there's a key difference between RiverSmart Homes and the program that subsidized work at my house. RiverSmart Homes caps its subsidy at $1,200, a lot less than the $5,000 I received. City officials have said the higher payments in my program, which the city no longer offers, were necessary to encourage enough participants to make it possible to monitor the effectiveness of greenscaping. (The project for the 60 homes in both neighborhoods cost a total of $3.5 million.)

I consider myself fortunate to have received the financial support. There are many detached homes and row houses in Washington — the city has more than 100,000 — where green infrastructure could make a difference in addressing the city's stormwater-management problem. Greenscaping a lot more of them will be no small or inexpensive feat. But as my own experience showed, there's a lot to be said for the result.

— *Jeffrey Brainard*

Digging Deep to Improve Water Quality

Jeffrey Brainard

It's the biggest public-works project in Washington, D.C., since the construction of the Metro system. It is also the single most expensive project aimed at improving water quality in the Chesapeake Bay. But to many people, it's invisible and little known.

It's the $2.6-billion project in which DC Water, the city's water-and-sewer authority, is building 18 miles of tunnels under the nation's capital. They are designed to address a water-quality problem known as combined sewage overflows. A giant machine began digging the first section of tunnel starting in 2013, and the work will continue one section at a time through 2030.

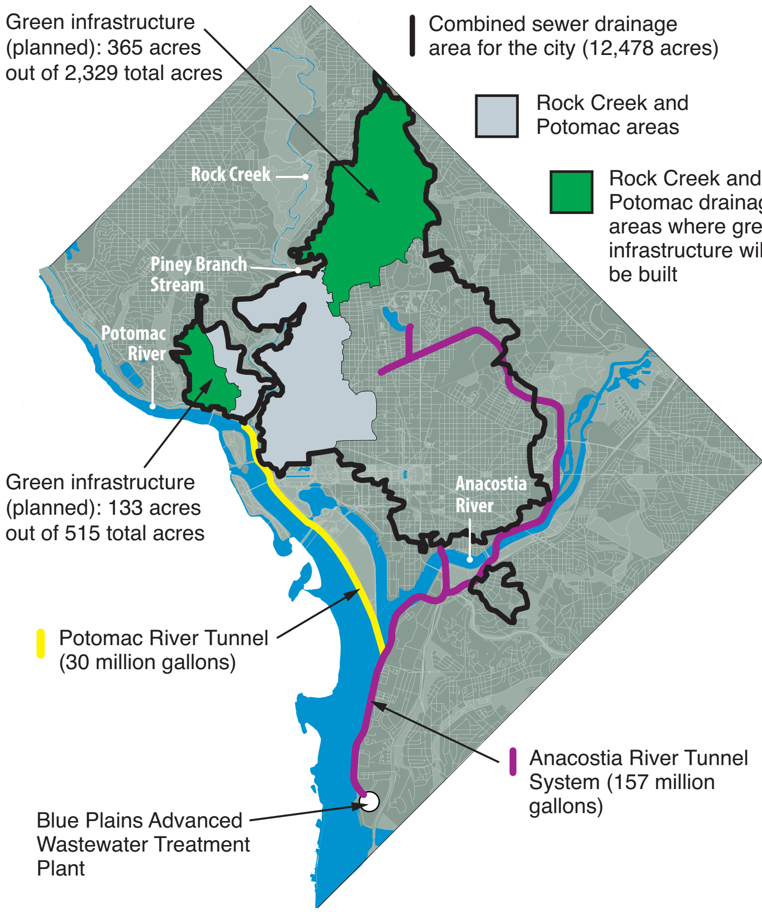
These underground tunnels are a large part of DC Water's plan to correct a big above-ground problem: in about one-third of Washington, untreated sewage empties into the same pipe network that carries stormwater, and during big rains, the mix overflows directly into local waterways. The "combined sewer system" of pipes sends the mixed flow to the Blue Plains sewage treatment plant that DC Water operates in the city's southwest corner, along the Potomac River. The flaw in the system: even during a rainstorm as small as one-tenth of an inch, the flow can exceed the system's capacity. When that occurs, the pipes are designed to let the untreated overflow run directly into the Potomac and Anacostia Rivers and into Rock Creek. In an average year, nearly three billion gallons are released.

The water authority began this massive subterranean project after the Environmental Protection Agency and environmental organizations filed legal challenges against DC Water in the early 2000s for violating the Clean Water Act. In 2005 the water authority agreed to settle the case by building a network of three tunnels to fix the problem — one each for the Anacostia and Potomac Rivers and Rock Creek. For all but the largest rainstorms, tunnels will store the backed-up mix of sewage and stormwater until it can be pumped or flow by gravity to the Blue Plains plant for treatment.

***Workers sink a shaft** at street level in a dense neighborhood at 1st and V Streets, N.W., in Washington (right) as part of a tunnel-building project below. Pieces of a giant tunnel-boring machine are lowered (above) and assembled underground. The machine bores space for a tunnel 23 feet wide to store a mix of stormwater runoff and sewage to improve water quality.*
PHOTOGRAPHS, DC WATER

The tunnels are being built in sections to spread out the cost and to address the Anacostia River's pollution problems first. Two-thirds of the city's total combined sewage overflow now

Washington, D.C., Stormwater Planning



Washington's water-and-sewer authority *is building 18 miles of tunnels to store a mix of stormwater and sewage and keep the city's "combined sewage system" (CSS) from overflowing into local waterways. The black line shows the CSS boundary. DC Water will build "green infrastructure" within a fraction of this area (shown in green) to help reduce stormwater flowing into the CSS pipe network.* GRAPHIC, ADAPTED BY SANDY RODGERS FROM A DC WATER IMAGE.

enters the Anacostia. The first tunnel section, completed in 2015, stretches four-and-a-half miles north from the Blue Plains plant, crosses the Anacostia River, and ends near Nationals Stadium. Also in 2015, construction began on the next section, stretching southwest two-and-a-half miles from Robert F. Kennedy Stadium to link up with the first tunnel section. That work is to be finished by 2018.

The project's vast scale recalls the Chunnel rail tunnel built under the English Channel during the 1980s. The Washington tunnels are cylinders 23 feet in diameter — big enough to fit a Metro rail car — and located more than 100 feet deep. That depth will allow the tunnels to run below other utilities and Metro tunnels.

The machines that build the tunnels share a similarly grand scale. The one that built the first tunnel section weighed 1,300 tons and measured 442 feet, longer than a football field. To get this massive digger in place, workers built a vertical shaft, lowered the various parts to the bottom, and assembled the machine underground.

During 2015, DC Water used two of these boring machines at once to dig the tunnel sections then under construction. The water authority tried to give the mechanical behemoths a personal face by naming them: The machine that built the first section was called Lady Bird after the wife of President Lyndon Johnson who was famous for her campaign to beautify public spaces in America. Nannie, the machine that attached the next section, was named for Nannie Helen Burroughs, an educator and civil-rights activist from Washington.

While digging, the tunnel-boring machines creep along 24 hours a day, six days a week, at a speed of about 100 feet per day. Machines are boring the Anacostia tunnel through clay and silt, avoiding bedrock, but constructing the Potomac tunnel will require boring through rock. The machines chew through this material using a spinning face studded with scrapers made of tungsten carbide. As a machine moves forward, workers assemble pre-fabricated concrete rings in its wake to extend the tunnel. Each ring — six feet in width and weighing 40 tons — is lowered into the tunnel, placed on a rail car, and rolled out on tracks to the boring machine. There workers use a mechanical arm to lift the ring sections into place.

The Anacostia tunnel sections are scheduled to be completed by 2022; construction of the Potomac tunnel would begin that year and run through 2030. When all is done, the net result is expected to be a big reduction — a 96-percent drop — in the total volume of overflow from the combined sewer system. The remaining four percent represents the runoff from the biggest storms, which can exceed even the capacity of the tunnel storage system.

Other cities, including Chicago, Cleveland, and Milwaukee, have also built or are building tunnels to reduce overflows, but the Washington tunnel will achieve one of the country's largest reductions in terms of percentage for a combined sewage system.

The result will be a lot of underground, concrete gray infrastructure, but DC Water also plans a green infrastructure component visible above ground in parts of the city. The authority will build 500 acres of bump-out boxes and other measures to reduce the amount of stormwater flowing into the tunnel system.

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***Baltimore resident Christopher Redwood** stands at the entrance gate to one of four formerly vacant lots in West Baltimore turned into green public space by a partnership of three neighborhood associations.* PHOTOGRAPH, MICHAEL W. FINCHAM

Whatever Happened to Watershed 263?

An innovative experiment in ultra-urban greening brings potential benefits to Baltimore neighborhoods

Daniel Pendick

On a chilly midmorning in West Baltimore, Christopher Redwood and I ponder an empty 32-ounce beer can that an anonymous passerby had lobbed into a small park. Once a vacant lot, the park is located near Redwood's house on West Lombard Street in the historic Hollins Market neighborhood, and he has worked on a project to beautify it. "What can you do?" Redwood says, a verbal shrug tinged with the stubborn optimism of an advocate for community-based greening in hardscrabble West Baltimore.

Maybe it's just one cast-off beer can, but it testifies to a chronic problem: once you convert a weedy, vacant lot into an urban oasis, someone has to keep it free of litter.

Hollins Market is one of 12 neighborhoods (plus Carroll Park) that make up Watershed 263, a densely urbanized area of the city where stormwater is channeled through a common drainage system. Each heavy rain flushes fine sediment and a film of pollutants from the roadway into the storm drains gurgling below. These eventually empty into Baltimore Harbor and into the Chesapeake Bay beyond.

On the map, Watershed 263 stretches from Presstman Street in the Sandtown-Winchester neighborhood in the north to Russell Street in the Carroll-Camden Industrial Area in the south. Below the ground, water quietly flows downslope toward the harbor through Baltimore's vast masonry and concrete "gray infrastructure."

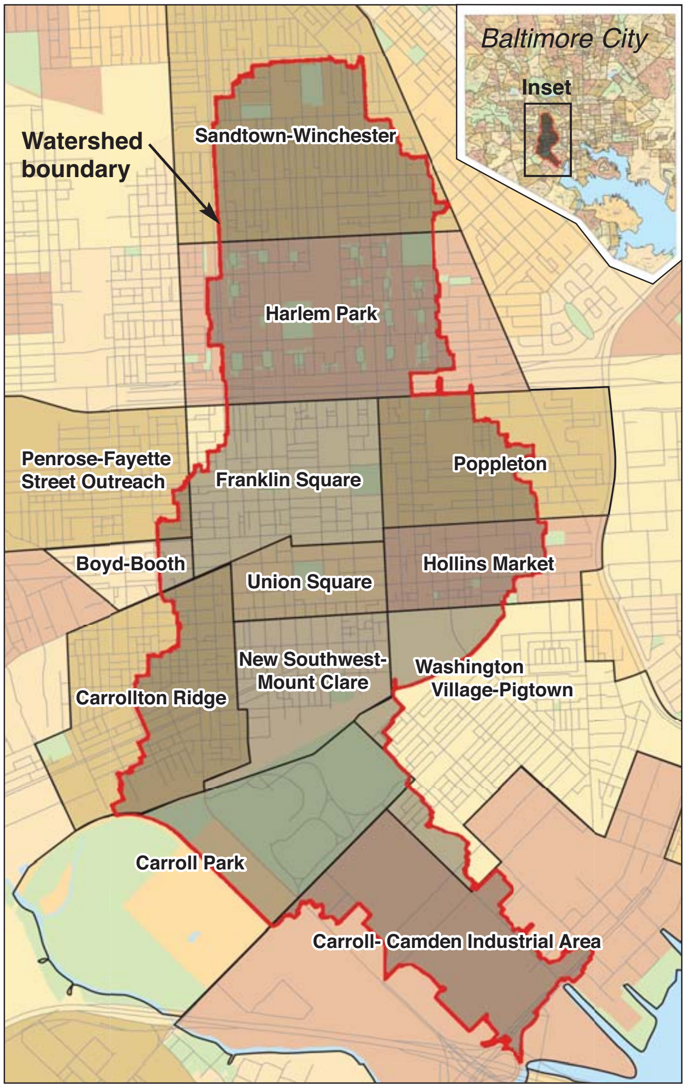
This system of drains and pipes has entirely replaced the surface streams that once drained old West Baltimore. The watershed's 930 acres include 355 stormwater drains and 43 miles of pipes. At its southernmost edge on Russell Street, the network pinches to a single 25-foot-wide stonework mouth, named Pipe 263, which disgorges its contents into the brackish backwater where the

Middle Branch of the Patapsco River empties into the harbor. Those contents include trash, oil, heavy metals, and lots of nitrogen and phosphorus, whose reduction is central to the cleanup of the Bay.

Starting in 2004, Watershed 263 was the target of an experiment to see if urban greening strategies like planting trees, converting vacant lots into parks, and landscaping formerly paved-over schoolyards could improve both water quality and quality of life for the residents. In addition to soaking up stormwater and removing pollutants, the parks and plantings provide places to walk and socialize. Researchers wanted to find evidence — still hard to come by — for those subtle social benefits, which buried drains and pipes cannot offer.

Greening isn't always cheaper or even as effective as gray infrastructure, but demonstrating that it transforms neighborhoods could lead to changes in how cities manage their stormwater. "We need to be able to provide advice about how to spend public money to make these environments better for people where they live, and at the same time achieve those stormwater goals for which the city government is accountable," says Morgan Grove, a social scientist with the U.S. Forest Service who worked on the Watershed 263 project.

Baltimore's Watershed 263



The network of storm drains and buried pipes *in Watershed 263 discharges stormwater runoff from all or part of 12 neighborhoods, plus Carroll Park, in West Baltimore. The runoff, bearing sediment and a mix of pollutants, drains into Baltimore Harbor at the southernmost end of the watershed and into the Chesapeake Bay beyond.* MAP, ADAPTED BY SANDY ROGERS USING A BASE MAP FROM THE CITY OF BALTIMORE DEPARTMENT OF PLANNING

Bill Stack's Big Idea

In 2002, Bill Stack, then-chief of stormwater pollution control for the Baltimore Department of Public Works (DPW), looked at Watershed 263 and saw an opportunity where others may have seen only urban blight: the area was peppered with some 2,000 empty lots, left behind after burned-out or decrepit buildings were torn down. "There was a tremendous number of vacant properties that would lend themselves to greening," he recalls.

To start, greening the lots would allow water to soak more slowly into the soil rather than pouring into storm drains. Watershed 263 is heavily paved — about 75 percent of its surface area is impervious to water. That means the stormwater flowing over all those streets, sidewalks, roofs, and parking lots carries pollutants into the Bay.

Stack also knew about a program in Boston that had stripped the asphalt from city schoolyards and replaced it with trees and gardens. Why couldn't the paved-over playgrounds in West Baltimore also be removed to create new porous surfaces to intercept stormwater runoff?

The most critical piece of the project was already in place: the Parks and People Foundation of Baltimore, a nonprofit that promotes community-based green projects and environmental education and already had deep roots in West Baltimore. "I talked to Parks and People and they said, great, sign us up," Stack says.

In 2004, project workers started greening the neighborhood. They turned vacant lots into parks. They planted trees along the streets. They installed specially engineered plantings, or "green infrastructure," such as curb "bump-outs" filled with native plants. These extend a few feet into the street, allowing them to capture and soak up street-level runoff before it can gush, unfiltered and at full force, into the storm drains.

Stack also teamed up with scientists to design a study to find out if the newly greened surfaces do more than just clean stormwater. Would people living near them feel better about their neighborhoods and want to stay? Would others feel good enough about the improved neighborhoods to buy one of the scores of unoccupied row houses in Watershed 263, thus helping to revitalize the community?

The evidence that greening fuels social change has often been limited to subjective opinions and impressions. The Watershed 263 project tried to go beyond anecdotes and collect hard data about the project's benefits on the neighborhood level. "That's a huge big deal," says Peter Groffman, a hydrologist with the Cary Institute of Ecosystem Studies in New York state who assisted in the water quality research on Watershed 263. Nationally, there have been relatively few scientific studies of how community greening affects how people think, feel, and behave.

Getting Hard Numbers On Greening

DPW workers and project scientists began climbing down manholes to draw water samples from stormwater pipes once or twice a week to measure pollutants. They also set instruments in place to monitor flow during storms. Monitoring would continue from 2004 to 2011.

The scientists wanted to find out if they could link the new green projects to improvements in water quality. To test their hypothesis, they measured and compared water quality and storm flow in two smaller areas of Watershed 263's sprawling 930-acre footprint. Each of these so-called subwatersheds drained only 37 acres (about ten city blocks each), but together they could provide a snapshot of water-quality changes across the larger watershed. It was like studying drainage from an entire high-rise apartment building by tapping into drainpipes from only two of its floors.

A variety of community-managed greening efforts *are underway in West Baltimore. In the Penrose-Fayette Street Outreach neighborhood, summer camp participants from Positive Youth Expressions, Inc. Educational Institute helped tend a community garden at the corner of Pulaski and Vine Streets. In 2015, a coalition of community groups won city funding to beautify additional locations in the area.* PHOTOGRAPH, TIMOTHY BRIDGES

The manhole for one subwatershed was on Baltimore Street; the other, north of Baltimore Street, was on Lanvale Street. There had been a lot of greening in the Baltimore Street sample area, but none in the Lanvale Street subwatershed. If greenscaping had any effect on water quality, it should show up at Baltimore Street but not at Lanvale Street.

In 2013, scientists with the project reported their results in the journal *Frontiers in Ecology and the Environment*. They summarized the greenscaping that workers had carried out across Watershed 263 during the study period from 2004 to 2009: 1,000 trees planted, more than 200 lots greened, and four acres of schoolyard asphalt ripped up and replaced by trees, gardens, and grass. The project also installed 12 new pieces of green infrastructure to soak up rainwater runoff — the curb bump-outs, for example.

Did all this improvement have an effect on water quality? The preliminary answer is yes, though the details were unclear. In the Baltimore Street subwatershed, nitrogen and phosphorus declined by 50 percent. (The Lanvale Street area showed no such change.) However, the amount of greening completed by 2009 in the Baltimore Street area could not account for all of the improvement in water quality observed there. "There was a significant decline in nutrients," says Guy Hager, a recently retired senior greenscaper with Parks and People who was deeply involved in the Watershed 263 project. "The problem is that the decline was so large nobody believes it was just from our projects. That part is still up in the air."

Other causes might have contributed — like street sweeping, which removes surface pollutants before they can wash into the storm drains. Another possibility was that the city had repaired or rerouted a sewer line in the Baltimore Street sample area, preventing sewage from trickling into the stormwater network. (Sewer and stormwater pipes share the city's subterranean spaces, and cross-contamination happens.) But the team was unable to pin the decline in pollutants on either street sweeping or sewerage repairs. The evidence that greening helped to reduce surges of rainwater into the system during storms was also inconclusive.

Greening Hearts and Minds?

What the team could be sure of was that greening had changed the landscape in Watershed 263's neighborhoods. But did the new parks, trees, and rain gardens have a measurable impact on people's behavior and attitudes? If so, that could be a real selling point for people who advocate for a bigger role for trees, parks, and plantings in Baltimore's stormwater management strategy.

To assess the social effects of the Watershed 263 project, the team drew on data from community surveys by scientists with the Baltimore Ecosystem Study (BES), a long-term, city-wide research project that began in 1998. The BES had surveyed approximately 3,000 Baltimore residents by phone in 2003 and 2006, including 100 people within the boundaries of Watershed 263.

Their survey showed that people in Watershed 263 were more likely to engage in outdoor recreation, such as walking and bicycling, compared with those in other areas of Baltimore. People said they were satisfied with their neighborhoods and were more likely to stay than to move out. What is more, a study conducted at elementary and middle schools in Watershed 263 indicated that students' understanding of environmental science concepts improved after schoolyard asphalt was replaced by a garden "reading circle."

These kinds of social benefits persist

today as neighborhood groups continue to push for greening in Watershed 263. But with the benefits have also come concerns from some residents about certain aspects of these projects.

Maintenance, for example, is a continuing challenge because open spaces like parks can be magnets for trash. "The greening is beautiful," says Romina Campbell, who lives just over the western border of Watershed 263. "Personally I love it, but when they get those grants, they need to ask for more money for upkeep."

Stack, now with the nonprofit Center for Watershed Protection in Ellicott City, recalls that during the project, some residents "didn't understand why the money spent on planting green space couldn't be used to address more immediate needs, say creating jobs or addressing crime and drugs."

Leaders can help to address such concerns by talking to residents in neighborhoods targeted for greening, door to door or at public meetings, says Inez Robb, who has represented the Sandtown-Winchester neighborhood on the Watershed 263 Stakeholder Community Council. "If you put in a curb bump-out with this green stuff and nobody knows what it is, who put it there, and what it's for," Robb says, "then nobody cares."

Fresh produce grows year-round inside *plastic-covered greenhouses located on the 1800 block of Lorman Street in West Baltimore. Operated by Strength to Love II, a grass-roots community organization, the one-and-a-half-acre farm provides produce for farmers markets and restaurants as well as jobs to help men transition out of correctional facilities. In the future, Baltimore's Growing Green Initiative hopes to foster more urban agriculture like this.* PHOTOGRAPH, WENDALL HOLMES, STRENGTH TO LOVE II

Lessons Learned

Watershed 263's experiment also left an impression beyond West Baltimore, according to Mark Cameron, a city planner with Baltimore DPW. He says that the Watershed 263 project "provided multiple lessons learned regarding green infrastructure and community greening in Baltimore." In addition to the educational benefits and community engagement, partnerships between citizens and organizations like Parks and People make it possible to launch new greening projects in Baltimore neighborhoods using outside funding from nonprofits and federal and state agencies.

But, says Cameron, the project also highlighted some of the challenges that would-be urban greenscapers face, like managing costs, avoiding conflicts with city utility infrastructure, and winning neighborhood acceptance of greening projects.

The lessons learned may come in handy as Baltimore pursues its city-wide Growing Green Initiative, managed by the city's Office of Sustainability. Its goal is to turn city-owned vacant land into green space that delivers a variety of benefits. Some of these efforts will reduce stormwater runoff, but the city also wants to nurture other drivers of sustainability like urban agriculture.

Knowing the benefits of greening also matters as the DPW strives to meet part of its federal stormwater requirements. Out of the roughly $21.3 million that the Baltimore Department of Public Works spent in 2015 on stormwater-related activities, about $2 million went to watershed restoration construction projects, and among them were many greening and green infrastructure improvements. Most of DPW's stormwater-related expenditures went to other priorities like maintaining the city's stormwater plumbing system.

Although green infrastructure makes up a relatively small percentage of the city's stormwater management, Cameron says it plays an important and beneficial role. Street sweeping helps keep pollutants out of the Bay, but it doesn't offer the social or economic benefits that greening does. "That's why we looked at it as a suite of options," Cameron says. "We can't just do one thing. We need to do a number of different practices."

Lots of Art

Today, the greening of Watershed 263 continues. Christopher Redwood and other members of a coalition of three neighborhood associations in Watershed 263 are still working to beautify the small park back in his Hollins Market neighborhood. In 2014, the project, called "Lots of Art," won a city-sponsored Growing Green Design competition that provided $13,010 to green the corner lot at West Lombard.

The park includes a small wooden deck for performances or just a barbecue. It's a place to read a book, have a relaxing sit-down, or chat with neighbors — or so the builders hope. Grass-roots action is nothing new for Redwood. "In the family I come from, we see problems but don't just complain about it," he says. "We go out and do things."

Parks and People also continues to help community groups to remove asphalt and plant trees in other parts of the city. Christina Bradley, the group's director of capital improvements, says, "If it can work in West Baltimore, it can work anywhere."

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Maryland's 2016 Knauss Fellows

Four graduate students supported by Maryland Sea Grant have begun their terms as 2016 Knauss Marine Policy Fellows. They are working for one year for the National Oceanic and Atmospheric Administration (NOAA) on habitat conservation, environmental policy international affairs, and fishery ecosystem science.

Alexandra Atkinson will be working with NOAA's Habitat Conservation Department as a habitat focus area program specialist. She will help NOAA coordinate and implement their Habitat Focus Area project, in which 10 sites across the country will be restored to create healthy, sustainable habitats for fish and wildlife.

Her past research has involved studying a variety of marine species, including mysids (small shrimps), Atlantic menhaden, and gray whales. Atkinson also worked to restore local wetlands in Illinois, her home state.

Atkinson completed a B.S. in ecology and evolutionary biology at the University of Rochester and an M.S. in fisheries science at the Chesapeake Biological Laboratory, part of University of Maryland Center for Environmental Science (UMCES). While working on her master's, she was president of the student subunit of the American Fisheries Society's Tidewater Chapter. Atkinson hopes that working with NOAA will allow her to gain an appreciation for the inner workings of the agency.

Shanie Gal-Edd is joining NOAA's Oceanic and Atmospheric Research (OAR) Office of Policy, Planning, and Evaluation as a research planning and policy analyst.

Her past research involved studying the genetics and greenhouse competition of a species of submerged seagrass (*Vallisneria americana*). She also worked with the USDA Agricultural Research Station in Beltsville studying the invasive brown marmorated stink bug (*Halyomorpha halys*). Gal-Edd was also a fellow with the U.S. Fish and Wildlife Service, where she performed population and habitat assessment of migratory birds.

Gal-Edd received a B.A in psychology and a B.S. in biology and ecology. She is currently pursuing an M.S. in conservation and restoration ecology of the Chesapeake Bay at the University of Maryland, College Park.

Efeturi Oghenekaro will be working in the NOAA Research Office of International Affairs. She will contribute to NOAA's research in the Arctic and support the agency's efforts with the Transatlantic Ocean Research Alliance, a cooperative effort between the U.S., Canada, and the European Union.

Oghenekaro completed her undergraduate degree in fisheries science at the University of Benin, in Nigeria. She earned her doctoral degree from University of Maryland, Eastern Shore in marine, estuarine, and environmental sciences. Her doctoral research documented spatial and seasonal patterns of abundance in mesozooplankton. She also documented five species of marine cladocerans, which are small crustaceans.

Oghenekaro, who is enthusiastic about international affairs, hopes that this fellowship will introduce her to the process of planning and implementing international collaborative research in ocean science. She also enjoys participating in outreach activities, where she can help educate people about environmental science, conservation, and sustainability.

Wencheng Slater will be working as a fishery ecosystem science and management specialist in the NOAA National Marine Fisheries Service's Office of Science and Technology. She will be applying her experience in food-web dynamics and zooplankton ecology to ecosystem-based fisheries management.

Slater is a doctoral student in biological oceanography at the University of Maryland, College Park. She is working at UMCES' Horn Point Laboratory, studying predator-prey interactions between marine species in low-oxygen ecosystems in Chesapeake Bay. Slater has a M.S. in marine science from National Sun Yat-sen University in Taiwan, where she is from.

Slater's previous research included studying climate change and jellyfish blooms in Taiwan. She also worked with the Office of International and Tribal Affairs in the U.S. Environmental Protection Agency, assisting the International Environmental Partnership between the U.S. and Taiwan. Slater has a passion for public outreach and communication involving environmental science.

The Knauss Marine Policy Fellowship, begun in 1979, is designed to let outstanding graduate students spend a year working on science policy in Washington, D.C. The program, coordinated by the National Sea Grant Office, places fellows in legislative or executive branch offices in the federal government that work on ocean, coastal, and Great Lakes policy issues. Fellowships run from February 1 to January 31 and pay a yearly stipend plus an allowance for health insurance, moving, and travel. Students can apply through the Sea Grant program in their state. For more information, visit:

Maryland Sea Grant Program, Knauss Fellowships:
www.mdsg.umd.edu/education/knauss

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Big Greenscaping, from p. 7

2014, city officials obtained what they considered to be a high participation rate among the residents there — about half of the property owners in both neighborhoods installed at least one of these features. That gave Saari and his colleagues confidence that they should see measurable results.

In 2015, city officials presented some preliminary findings. Their monitoring showed a significant decline in the volume of stormwater in Chevy Chase. Further analysis will quantify exactly how much. Monitoring work in Petworth is not yet complete. The results so far were a useful and welcome confirmation that the collective efforts are making a difference, Saari says.

Not that every step of these projects was easy. Residents of the Chevy Chase neighborhood were upset when they were told that they couldn't drive on the permeable pavement installed along streets and alleys because the new concrete took several weeks to cure completely. Still, Saari says, an important lesson from the project was figuring out what kinds of permeable paving are practical and cost-effective to install in neighborhood alleys.

Another important lesson concerned parking — often a sensitive topic in D.C. and other cities. At public hearings, Chevy Chase residents complained that the bump-outs would take up parking in the neighborhood or be placed directly in front of some houses. Complaints like that weren't always predictable. The project managers received more complaints from the Chevy Chase neighbors about losing parking spaces than they did from those in Petworth — even though Chevy Chase had more available parking spaces, about 180 spaces for 120 cars, by the city's count.

Saari says that the original blueprint for the Chevy Chase project located the bioretention bump-outs where they would collect the most stormwater. But to address the neighbors' concerns, city planners decided in the end to remove the bump-outs from Notarius's block. They relocated others away from the fronts of houses and closer to street corners.

"We sited our bump-outs in areas where people don't park as much," Saari says. "That's kind of common sense, but it was a lesson we needed to learn." As Washington pushes for more green infrastructure to manage stormwater, it will probably need to balance engineering practicalities with social realities like these. Success may depend on how people feel about how green infrastructure actually looks and how it works in their neighborhoods.

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State Legislatures Honor Bernie Fowler


Sky Swanson

Bernie Fowler entered politics 46 years ago with $152 in campaign funds and a promise to fight for a cleanup of his beloved Patuxent River and Chesapeake Bay. This February the legislatures of Maryland, Virginia, and Pennsylvania passed resolutions honoring him for his political and moral leadership in the long battle to restore these waterways. His lawsuits helped force reductions in wastewater discharges. His Patuxent crusade became a model for the three-state campaign to restore the Chesapeake. And his annual wade-in events in the Patuxent River are keeping politicians and the public focused on the cause. Elected as County Commissioner and then Maryland State Senator, he also served as a member of the Chesapeake Bay Commission for 32 years. To learn more go to: http://www.chesapeakequarterly.net/V14N2/main2

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