TURNING STORMWATER GREEN

Green infrastructure can help reduce polluting runoff during severe storms, but questions about costs give some localities pause

BY HAILEY PHELPS

On Aug. 25, 2017, Hurricane Harvey hit the coast of Texas. Over the next four days, the storm dumped about one trillion gallons of rainwater onto Houston. At its peak on Sept. 1, 2017, one-third of Houston was underwater. The total cost of the destruction was $125 billion, which included damage to over 300,000 structures (more than 200,000 homes) and one million vehicles. Nearly any city would be overwhelmed by more than 4 feet of rain, but Houston is unique in its regular massive floods. Its sewer system was designed to only clear out 12 to 13 inches of rain per 24-hour period, so it quickly overflows and floods during large storms. Another issue is urban sprawl and urbanization, which limits the city's natural drainage capacity and makes cities like Houston more susceptible to flooding.

More than half of the world's population lives in cities. Before the pandemic, experts predicted that this share was likely to grow to two-thirds by 2050. While the trajectory of cities might be on a different course today (see "Has the Pandemic Changed Cities Forever?" p. 4), urbanization remains at a high level by historical standards. Urbanization typically means expanded areas of hard, impermeable surfaces such as roofs, sidewalks, and streets. This — together with predictions that weather events will continue to become more severe due to changes in the Earth's climate — has contributed to concerns about pollution from stormwater runoff. When it rains in urban areas, stormwater flows across the streets and sidewalks at faster speeds and picks up harmful pollutants, carrying a greater amount of them into storm drains and rivers. The increased runoff also limits the amount of precipitation that can soak into the soil and replenish groundwater reservoirs.

Most urban stormwater and sewer systems in the United States were built following World War II, and cities have historically set aside little money for infrastructure operations, maintenance, and renewal. The threat of increased flood events has brought together local government officials, policymakers, climate scientists, and civil engineers to consider solutions beyond traditional flood control infrastructure to increase resiliency.

IMAGE: WILL PARSON/CHESAPEAKE BAY PROGRAM

A rain garden at Long Wharf Park captures and filters stormwater pollution before it reaches the Choptank River in Dorchester County, Md.

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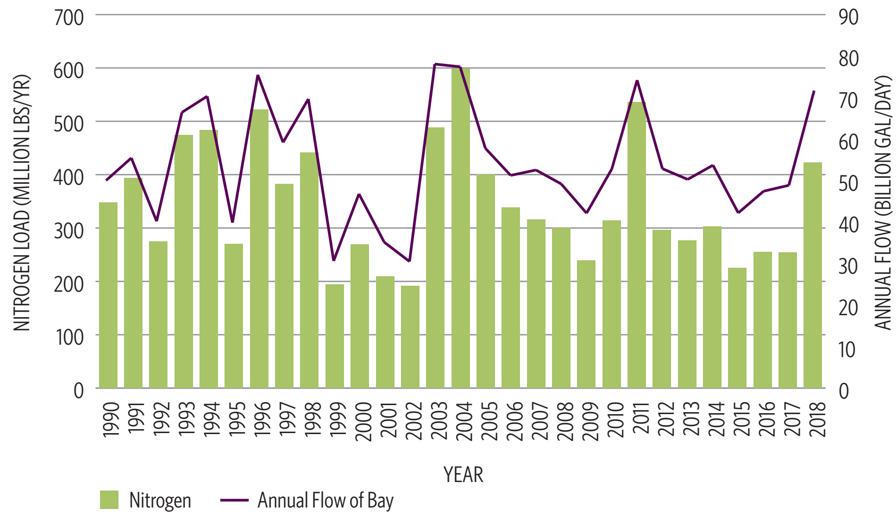
Within the Fifth District, stormwater runoff is the fastest-growing source of pollution to the Chesapeake Bay, the watershed that encompasses parts of Maryland, Virginia, West Virginia, and the District of Columbia. When the watershed receives more rain and river flows increase, the water usually carries more pollution in the form of nitrogen, phosphorus, and sediment. According to data from the Chesapeake Bay Program's Watershed Model, between October 2017 and September 2018, nearly 423 million pounds of nitrogen reached the bay, a 66 percent increase from the previous year. (See chart.) Over the same period, about 42.1 million pounds of phosphorus and 15 billion tons of sediment reached the bay — a 181 percent increase and a 262 percent increase, respectively.

One way to slow the total amount and frequency of pollution entering watersheds such as the Chesapeake Bay is green infrastructure, a relatively new type of infrastructure that has gained momentum in local government planning.

Nitrogen Pollution in the Chesapeake Bay



SOURCE: United States Geological Survey

WHAT IS GREEN INFRASTRUCTURE?

As the name implies, green infrastructure relies, roughly speaking, on utilizing soil and plants in place of concrete. The U.S. Environmental Protection Agency (EPA) defines green infrastructure as an installation that "uses vegetation, soils, and other elements and practices to restore some of the natural processes required to manage water and create healthier urban environments."

Two of the most common types of green infrastructure are green roofs and rain gardens. Creating a green roof involves planting vegetation or hosting a community garden on rooftops. Green roofs provide benefits such as improving aesthetics, reducing stormwater runoff, and lowering rooftop temperatures, decreasing the heat island effect that contributes to higher temperatures in urban areas. Rain gardens consist of native shrubs and flowers planted in a small depression formed on a natural slope. They temporarily hold and absorb stormwater runoff that flows from roofs, driveways, and lawns. Both green roofs and rain gardens are relatively simple green infrastructure projects within the reach of individuals and small groups.

Local governments can create green infrastructure on a larger scale by funding projects such as bioswales and permeable pavement. Bioswales function similarly to rain gardens, but they are typically larger. These vegetated ditches allow for the collection, filtration, and permeation of stormwater. Parking lot islands, road shoulders, and medians are ideal sites for bioswale construction. Another way to mitigate flooding and stormwater runoff is by using alternatives to traditional pavement when paving roads. Permeable — that is, porous — pavement allows surface runoff to penetrate to underlying layers of dirt and gravel and slowly infiltrate into the soil below or discharge into a sewer system.

In addition to green infrastructure, civil engineers and urban planners refer to "grey" or "blue" infrastructure. Grey, or general, infrastructure is what people most often think of when they hear the word "infrastructure"; it includes systems like highways, local roads, sidewalks, power lines, sewer systems, water lines, and structures like buildings and seawalls. Blue infrastructure refers to water elements, like rivers, canals, ponds, wetlands, and floodplains.

Organizations like the Green Infrastructure Center (GIC), a nonprofit formed in 2006, help communities and developers in the United States evaluate their green infrastructure assets from natural resources such as forests and wetlands to constructed green infrastructure such as bioswales and green roofs. "We focus on helping local governments and communities make plans to conserve as much of their natural resource assets as possible and then build in the least impactful manner," says Karen Firehock, the executive director and co-founder of the GIC.

In 2009, the GIC developed a map of green infrastructure assets for the Richmond, Va., region to identify opportunities to connect a network of green infrastructure across jurisdictional boundaries. The following year, the project was expanded to create a "greenprint," a blueprint of how the postindustrial city can develop its over 9,000 underutilized or vacant parcels of land in environmentally conscious ways, including stormwater runoff control.

The GIC followed up its plan in 2012 with a demonstration pilot project using Upper Goode's Creek, a small watershed in the southern part of Richmond, Va. The organization and its partners created a new two-acre park and walkable access to Oak Grove-Bellemeade Elementary School to show how restoration activities can be targeted within neighborhoods to reduce stormwater runoff. In 2013, the GIC partnered with the James River Association, the Alliance for the Chesapeake Bay, and the City of Richmond to clean up Upper Goode's Creek. Through this collaboration, they were able to restore the streambanks, install a forested buffer, and create a bioswale, which helped reduce pollutant loads into the creek and provide outdoor recreation and learning opportunities.

In addition to the GIC, there are many groups active in restoring and preserving the Chesapeake Bay. One such group is the Chesapeake Stormwater Network, a network of nearly 11,000 stormwater professionals from within the Chesapeake Bay watershed who work on stormwater control practices across the Chesapeake Bay region. "We are working with researchers who are developing projected precipitation volumes and intensities for the Chesapeake Bay watershed and thinking about how to change future design standards to better withstand those conditions," says David Wood, the stormwater coordinator of the organization.

ENVIRONMENTAL BENEFITS OF GOING GREEN

Investing in green infrastructure can both absorb and slow runoff, improve water quality, reduce flooding, and aid in the supply of fresh, reusable water. "Green infrastructure is the meat and potatoes of stormwater management from a water quality standpoint and increasingly from a flood control and prevention standpoint," says Wood.

In July 2018, the GIC finished a two-year project to map and evaluate green infrastructure in Norfolk, Va., and help Norfolk's government create strategies to make the city more resilient to sea level rise due to climate change. Using imagery from the National Aerial Imagery Project, the GIC created a land cover map of green spaces and impervious surfaces and used that map to develop "plaNorfolk 2030," a comprehensive green infrastructure plan. The organization found that community planning and individual actions can have a large effect in mitigating stormwater runoff. Their data revealed that there are approximately 47,500 single-family home parcels in Norfolk, Va. — 31,000 of which have room to plant at least one tree. If each household planted just one tree, over 62 million gallons of rainwater would be intercepted each year, enough to fill 1.5 million bathtubs.

Green infrastructure strategies such as tree planting and rainwater harvesting, a method of collecting and storing rainwater, increase the efficiency of the water supply system. Rainwater collected on rooftops and in barrels can be used for outdoor irrigation and can reduce indoor municipal water use. The water infiltrated into the soil through rain gardens and bioswales can increase the supply of ground water, an important source of freshwater in the United States. Additionally, presence of trees in a community can decrease the amount of stormwater runoff and pollutants that reach local waters. Tree roots and leaf litter create soil conditions that help rainwater infiltrate into the soil. "We can certainly build more stormwater ponds, but they waste valuable land. It's a lot cheaper and easier to put more trees in a city," says Firehock.

ECONOMIC BENEFITS

Adding green infrastructure for stormwater management systems often results in lower capital costs. According to the EPA, green infrastructure can also reduce a community's infrastructure costs, promote economic growth, and create construction and maintenance jobs. A survey of members of the American Society of Landscape Architects revealed that many stormwater professionals select green infrastructure over grey because green options were less costly and that long-term operation and maintenance expenses cost less. The savings result primarily from lower costs for site grading, paving, and landscaping.

But the economics can be ambiguous. On one hand, green infrastructure design standards are often more context-specific than grey infrastructure design standards because green infrastructure projects are designed and built to suit the soil, terrain, and water conditions of each individual site. On the other hand, some green infrastructure projects allow elimination or reduction of expensive material components, such as curbs, drains, stormwater conveyance pipes, and tanks. Others, such as green roofs, may be initially more expensive than traditional counterparts but have lower long-term maintenance costs, which make them less expensive over time. Although some green infrastructure materials are more expensive than conventional grey solutions, they reduce overall stormwater management needs, possibly reducing total costs.

One example of a cost-saving green infrastructure project is the quadrangle of Episcopal High School in Baton Rouge, La. For years, the school suffered from flooding in the courtyard because of an old and inadequate drainage system. The cost to fix the quadrangle using conventional grey infrastructure was approximately $500,000. Instead, the school hired Brown+Danos Landdesign to design bioswales and a rain garden for the space to capture rainfall and limit the amount of stormwater flowing into the existing drainage system. The cost of implementing the green infrastructure facilities cost $110,000, nearly 80 percent less than the conventional solution cost.

In addition to the direct effect on stormwater, green infrastructure may have other benefits to area residents — a characteristic economists call externalities. One research project sought to determine how much value people put on green infrastructure's benefits. In a recent study published in the *Journal of Environmental Economics and Management*, researchers at University of Illinois Urbana-Champaign, Reed College, and the EPA conducted a survey in two major U.S. cities, Chicago, Ill., and Portland, Ore., to estimate the benefits of stormwater management improvement in terms of people's stated willingness to pay money and volunteer their time. They found that people placed positive values on improvements in aquatic habitat, water quality, and flood reduction, and that the monetary value of such improvements in urban areas can be quite large. Participants stated they would be willing to pay as much as $294 per household per year in Chicago and $277 per household per year in Portland to fund a hypothetical project to improve an aquatic habitat from fair to excellent and water quality from boatable to swimmable. The results also indicate that people may be willing to volunteer nontrivial amounts of time to participate in a project to improve the environment in urban areas. An average respondent might be willing to volunteer 50 hours a year for the same hypothetical project to restore an aquatic habitat and improve water quality.

CHALLENGES OF GREEN INFRASTRUCTURE

Despite growing enthusiasm for their benefits, green infrastructure projects have limitations and drawbacks as well. Green roofs, for example, can function only on roofs with slopes less than 20 degrees and may also require additional support to bear the added weight of the vegetation. Also, during dry periods, green roofs need to be irrigated and maintained by hand. Similarly, rain gardens and bioswales cannot absorb stormwater if they are constructed on steep slopes. Bioswales also require more maintenance than traditional curb and gutter systems. Lastly, the use of permeable pavement is limited to paved areas with low traffic volumes and decreased speeds and with slopes less than 5 percent. Although many sites fit within these constraints, many others do not.

Another challenge of integrating green infrastructure into stormwater programs is that green infrastructure performance and its benefits are context and location specific, yet fixed design standards often imply a one-size-fits-all approach. Some cities are working to address this challenge through partnerships among public, private, nonprofit, and academic research organizations. In the United States, the EPA offers several tools that assist designers and planners seeking to incorporate green infrastructure into a project. The integration of green infrastructure within existing certification schemes can be a useful way of introducing green infrastructure to local or national design practitioner communities.

Mainstreaming green infrastructure also faces the challenge of finding a suitable regulatory environment. Unlike fire or land protection, few jurisdictions have clear rules for regulating green infrastructure. In the United States, there are federal regulations that mandate green infrastructure in certain vulnerable areas like coastal regions, but there is no such regulation for less vulnerable urban areas. Property rights of landowners also make it challenging to impose top-down green infrastructure initiatives in cities. For these reasons, most green infrastructure projects seek voluntary participation.

A fourth type of barrier is financial — lack of funding to implement projects and uncertainty about costs and cost-effectiveness. At the federal level, there is no single source of dedicated funding to design and implement green infrastructure. Without federal assistance, the most frequently used tool is issuance of municipal bonds, a type of bond issued by states, cities, counties, or other government entities to fund day-to-day obligations or finance projects. Another way to raise money for green infrastructure projects has been to increase stormwater fees, the charges imposed on real estate owners for pollution from stormwater drainage and impervious surface runoff. Other communities have found success by encouraging homeowners and developers to incorporate green infrastructure practices by offering incentives in the form of stormwater fee discounts or credits. Unfortunately, many communities do not have the funds to offer such incentives, and others are unwilling to do so.

Proponents of green infrastructure argue that the biggest deterrent to investing in green infrastructure is the belief that green infrastructure is too expensive and not worth the cost. "People are often told that they can't do green infrastructure projects because they cost more than conventional stormwater management projects," says Firehock. "Oftentimes, green infrastructure costs less, but a lot of people are not familiar with how to do it." But outside of surveys, it is difficult to estimate the costs and benefits of green infrastructure technology in a particular situation and how to translate these cost/benefit calculations into financial models to fund capital and labor expenditures. Moreover, because green infrastructure projects are not always cheaper up front than grey infrastructure projects, policymakers may be hesitant to pursue them due to uncertainties regarding the cost of long-term maintenance and cost savings.

CONCLUSION

The history of urban drainage and stormwater management in the United States has been written in miles of underground grey infrastructure such as pipes, sewers, and tunnels that carry stormwater out of sight and out of mind. Supporters of green infrastructure believe a transition to green infrastructure will be a worthwhile transition in the long run, leading to safer and less flood-prone communities. **EF**

READINGS

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