Real-Time Data Helps Philadelphia Improve Green Design

BY: Ben Levine | December 18, 2018

MetroLab Network has partnered with Government Technology *to bring its readers a segment called the MetroLab Innovation of the Month Series, which highlights impactful tech, data, and innovation projects underway between cities and universities. If you'd like to learn more or contact the project leads, please contact MetroLab at info@metrolabnetwork.org for more information.*

In this installment of the Innovation of the Month Series, we continue our exploration of green infrastructure and learn how the city of Philadelphia has partnered with Drexel University to develop the Green Infrastructure Living Laboratory, a collaborative effort focused on collecting real-time data on green infrastructure systems to improve future designs.

MetroLab's Executive Director Ben Levine spoke with Dr. Ziwen Yu, Babak K. Roodsari and Karly Soldner, researchers at Drexel University's Sustainable Water Resource Engineering Lab, as well as Stephen White and Matthew Fritch, engineers at the Philadelphia Water Department, to learn more.

Ben Levine: Could you describe what green infrastructure is and what the Green Infrastructure Living Laboratory project is? Who is involved in this effort?

Matthew Fritch: Green infrastructure describes a range of approaches used to capture stormwater runoff and prevent it from overloading the city's combined sewer system. A rain garden, swale, green roof, pervious pavement, cistern and tree trench are all examples of green infrastructure. Philadelphia's Green City, Clean Waters program is a 25-year plan that includes the wide-scale adoption of green infrastructure as a way to reduce combined sewer overflows into our rivers and streams. In addition to the environmental benefits of healthier streams, green infrastructure can alleviate flooding issues, reduce the urban heat island effect, and create a green workforce to build and maintain these systems.

Karly Soldner: The Green Infrastructure Living Laboratory (GILL) is composed of graduate students and researchers from Drexel University's Sustainable Water Resource Engineering Laboratory and engineers from the Philadelphia Water Department. Our goal is to collect real-time data on green infrastructure systems using low-cost sensors that will eventually inform improvements to green infrastructure design.

Rain garden site located at Drexel University. Courtesy of Karly Soldner, Drexel University.

Levine: Can you describe the activity at GILL?

Fritch: Because green infrastructure is still relatively new, we want to monitor these systems to make sure they are performing well and to inform better designs. The GILL project gives us an avenue to collect data from green infrastructure that's been constructed on private property. Philadelphia's Green City, Clean Waters program can only be successful if investments are made in both public and private property. So the more information we can gather about private systems — in particular, green roofs and cisterns — the better we'll be able to evaluate which projects are working and are most effective in capturing stormwater. It just so happens that Drexel's campus has a variety of green infrastructure project types that make it a good test bed for developing new and more efficient approaches to monitoring and using new technology and networks. We have developed low-cost and low-power sensor networks to collect environmental data from green infrastructure in real time.

Matthew Fritch, an engineer at the Philadelphia Water Department, deploying one of the monitoring devices at a public rain garden site built in a traffic triangle. Courtesy of Karly Soldner, Drexel University.

Levine: How would green infrastructure work in Philadelphia? Are there characteristics unique to the city (e.g., topographical, industrial or land use) that make the use of green infrastructure unique?

Fritch: In general, cities have a lot of impervious surfaces that cause stormwater runoff to be an issue. And like many other cities, much of Philadelphia has a combined sewer system — one sewer pipe that collects sewage from both homes and buildings, as well as stormwater runoff from the street. When it rains, that mixture of stormwater and sewage overwhelms the ability for the treatment plant to handle the volume of water, and it discharges directly into rivers and streams. What's unique about Philadelphia's approach to solving this problem is the scale at which green infrastructure is being implemented — thousands of projects that are changing the way the city's built environment looks and operates. (You can see the number of projects on this map.) Each project is custom designed to fit the streetscape or building and maximize the amount of stormwater that can be diverted from the sewer system.

Levine: How did the city come to work with the university on this issue?

Ziwen Yu: The Sustainable Water Resource Engineering (SWRE) Lab at Drexel University, led by Dr. Franco Montalto, has been researching green stormwater infrastructure in New York City and Philadelphia for many years. The research team has a strong background in green stormwater infrastructure (GSI) site design, hydrologic and hydraulic modeling, real-time monitoring, and data-oriented analysis, which make us a good partner to the Philadelphia Water Department (PWD) on this project.

Stephen White: I worked with Franco and Ziwen in the SWRE lab as a master's student, but I can't take credit for beginning this work. Former PWD Deputy Commissioner Chris Crockett, also a Drexel alumnus, saw members of Franco's group present at a conference. We knew that to implement a program that relied on a paradigm shift we needed resources that would help us adapt and learn. We wanted to make sure PWD took advantage of our local academic resources as we embarked on our ambitious Green City, Clean Waters plan. Chris is no longer working at PWD, but the relationship is still going strong. We hope that Drexel can continue to be a resource for the city.

A smaller on-campus rain garden that receives runoff from the roof of an apartment building and a neighboring parking lot. Courtesy of Karly Soldner, Drexel University.

Levine: What kind of data are you exploring and why? What have been some of your initial findings in your research and is this changing how you view the issue?

Yu: The climate data we collect includes temperature, precipitation, relative humidity and air pressure. We also collect on-site hydrology data to observe fluctuations in soil moisture, water level or unit weight. In addition, we collect information on the monitoring devices themselves, such as their battery levels and connectivity strengths. This information is used to assess the performance of the site as a stormwater tool and as a living system.

Soldner: We've been focusing on two important green stormwater infrastructure types: cisterns and rain gardens. These are both popular on privately owned property, and they both exist on the Drexel campus. Rain gardens are engineered depressions that capture water during rain events, before soaking it slowly into the ground. Different compositions and textures of the soil allow water to infiltrate into the ground at different rates and also support different types of plants, which are also sensitive to soil moisture levels. These dynamic environmental interactions contribute to a rain garden's success as a stormwater tool and as a living garden. Tracking changes in soil moisture in relation to rain events allows us to better understand the volume of water stored in the system, the rates at which that water enters and exits the system, and how the changing amounts of water affect the plant life.

Babak K. Roodsari: Cisterns are perhaps the most common green infrastructure tool for collecting surface runoff from rooftops of residential or public buildings. Water stored in cisterns is often used for nonpotable applications such as toilet flushing, pavement washing and landscape irrigation. One of the goals of the GILL project is to understand how cisterns perform during rainstorms. We also aim to investigate potential ways of optimizing the available water storage in the cistern and decreasing overflows to the sewer system. For this purpose, we have been monitoring water levels inside one of the largest cisterns in Philadelphia, located at Drexel University's recreation center. Our findings indicate that the recreation center cistern efficiently collects the rooftop runoff and provides the toilet flush water needed at the recreation center gym throughout the year.

Levine: How will the findings developed in this project impact future activities and approaches by the Philadelphia Water Department?

White: Through our partnership, the city can weigh in on experimental designs and offer perspective about key needs. We can take the outcomes of experiments and monitoring and plug them into design guidance and policy. Monitoring data collected by the GILL team from a water reuse cistern at Drexel is a great example. We will use that case study as guidance for designers at PWD. It also demonstrates that there is a capacity for water reuse that can meet our design requirements for stormwater management. We've even used observations from GILL to offer guidance to Drexel's facilities management on an underperforming site. We caught the flaw before significant performance loss occurred, hopefully saving Drexel time and money. You can bet the city's stormwater credits team will be checking in soon to make sure the suggested changes were made!

One of the monitoring devices in the field, taken in a rain garden at a public playground. Courtesy of Karly Soldner, Drexel University.

Levine: What was the most surprising thing you learned during this process?

Roodsari: We learned that the benefits of green infrastructure systems, such as rainwater harvesting cisterns, have not been well quantified in the past. Our one-year monitoring results from the 8,000-cubic-foot rainwater-harvesting cistern at Drexel University's recreation center indicated that this system provides enough water to flush toilets for over 500 visitors per day without falling below 30,000 gallons in storage. It's interesting that the system performs at this level despite only receiving runoff from three medium-size rooftops with a total area of around 1.2 acres. Furthermore, our monitoring results indicate that the leakage rate from the cistern is nearly equal to the toilet flush use at the center. This means that the available storage could serve two or three times the number of visitors if the leaks were repaired. If property owners in Philadelphia were to add rainwater harvesting cisterns to their businesses and residential buildings, we could potentially have many cost-saving systems that both manage stormwater and provide nonpotable water.

White: While bureaucratic processes can often appear to be slow-moving and cumbersome machines, once you have the right people working together things can move very quickly. I think the image of an ivory tower researcher can be the result of siloed activities by researchers and practitioners. We've learned that if you're willing to spend a little effort, the outcomes from research can be more effective.

A city-owned site that receives runoff from a bordering street. Courtesy of Karly Soldner, Drexel University.

Levine: Where will this project go from here?

Soldner: Because our monitoring technologies are scalable, modifiable and low-cost, we can always expand to more sites as the project grows. It would be great to add a green roof site since they are typically difficult to access and monitor. The most rewarding aspect of our research on existing private green stormwater infrastructure tools is that it will be used to optimize designs and monitoring opportunities for future systems in Philadelphia and other cities.

Yu: Since GSI sites are decentralized, it can be challenging for the city to efficiently maintain them. GILL will continue to explore low-cost data collection opportunities, predict performance and risks of sites based on external data sets, and increase maintenance efficiency of existing sites.

Fritch: Because smart city technologies and approaches are evolving so quickly, hopefully GILL will stay on top of those developments and always have something new to work with from the technical side. We are still evaluating LoRaWAN networks, for example, and deploying new sensors to test accuracy and durability. So in that sense we're in a constant state of research and development. From the analysis side, it will be interesting to have long-term data from green infrastructure to see how our different sites perform over time. The data collected by GILL can serve as a constant feedback loop to the Water Department's green stormwater infrastructure design team.

White: Philadelphia's green infrastructure implementation plan is a 25-year program, but it doesn't end there. We're making a big commitment to change how our stormwater is managed. GSI designs will evolve as we respond to challenges in implementation. As Karly mentioned, those changes will need to be evaluated. Working with our peers at Drexel will be a big part of that.

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