Roundtable: Where Urban Forests, Stormwater, and Watersheds Meet

Contributors to this Roundtable explore research, practice, and partnerships at the nexus of urban forestry, stormwater management, and watershed protection. We hear from the following dedicated individuals:

- Urban Forester, Consulting Arborist, and Past President of Western Chapter ISA and American Society of Consulting Arborists *Gordon Mann*
- Texas A&M Stormwater Management Specialist *Dr. Fouad Jaber*
- Missouri University Engineer in Training and Water Quality Graduate Research Assistant *Laura Wiseman*
- Center for Watershed Protection Director of Education and Training *Dr. Neely Law*
- USGS Research Hydrologist *Bill Selbig*
- Friends of the Lower Olentangy Watershed (FLOW) Science Committee Chair *Laura Fay*
- Georgia Southern University Associate Professor in the Department of Geology & Geography and Director of the Applied Coastal Research Laboratory *Dr. John T. Van Stan*
- Vermont Urban & Community Forestry Program Technical Assistance Coordinator *Joanne Garton*

Considerations for Urban Foresters

The urban forest has always been about more than just the trees. As tree managers we have gone from being mostly focused on arboriculture to also promoting the quantifiable benefits of trees to the community. Increasingly, the urban forest is being used strategically to maximize the retention of stormwater and protect the health of our watersheds.

Along with increased attention to the intersection of urban forests and stormwater and watersheds comes new funding for tree planting. However, in this arena as with any tree planting effort, the needs of the trees—for sufficient space above and below ground, adequate water, protection from weed competition, and other maintenance needs—must be considered if the project is to be successful. While many leaders are setting lofty tree-planting goals and encouraging planting trees, please remember that we don't solve much by simply planting trees; the trees have to grow in order to fulfill their purpose.

Previous design efforts for stormwater channeled all the water in pipes away from communities to creeks, rivers, and eventually, to lakes or oceans. Now, we design to guide stormwater back into the ground and aim to manage it on-site versus moving it off-site. Trees can assist stormwater holding areas by pulling water out of the soil to increase the soil's water-holding capacity. Urban natural areas are being retained for stormwater runoff purposes, and increasingly, trees are being considered and preserved in development.

The key to including trees in stormwater and watershed success includes retention of existing tree canopy and restoration of future canopy by planting. In both cases, we have to avoid soil compaction so that water can actually infiltrate the soil and provide ground water recharge. We as arborists and urban foresters must get involved early in development projects to do pre-project site assessment, conduct tree inventories and protected tree evaluations, consult on tree species selection, and make sure the trees are given adequate growing space. We have some leverage, since trees are required for many projects to be accepted by planning commissions and agency councils and boards. We must grow the right tree in the right place for the right purpose, and this takes planning from the earliest stage of development projects—starting with the purpose.

Readers of *City Trees* don't need convincing about the importance of healthy watersheds, but for those who do, a simple way to visualize the serious negative effects that lack of trees has on stormwater runoff and watershed health is to observe the Montecito, California mudslides of 2018 that occurred after wildland fires removed the vegetative soil cover in that area of Santa Barbara County. The unprotected soils slid and along with debris and rocks caused injury and loss of human life, huge loss of property, and ecological damage to five watersheds.

A note about terminology. Personally, I don't like the terms "green infrastructure" and "grey infrastructure." It is all infrastructure and should be considered on equal terms for comparisons of cost, sustainability, and effective design. I encourage us to regard trees and discuss them as an integral part of infrastructure, without the "green" qualifier.

—Gordon Mann, Consulting Arborist and Proprietor, Mann Made Resources

Publication Link:

Accounting for Trees in Stormwater Models

Published in 2018 by the Center for Watershed Protection, this publication is intended to help the stormwater engineering community more easily account for trees in runoff and pollutant load calculations so that they can more readily incorporate them into their stormwater management strategies.

Trees: First Line of Defense against Stormwater Runoff

Urbanization is a major cause of increased stormwater runoff and deterioration of water quality in natural systems. Low Impact Development (LID) is an approach to apply nature-based solutions to reduce the impact of impervious areas on stormwater volume and quality. It includes practices such as bioretention, permeable pavement, rainwater harvesting, and green roofs.

One of the practices that does not get mentioned frequently is increasing the tree canopy as an LID practice. In fact, trees are the first line of defense against increased runoff. Trees capture a portion of the rain through interception (that later evaporates directly from the canopy) and they slow down the runoff as throughfall trickles from the leaves, increasing infiltration in the soil (Figure 1). Unfortunately, trees are the first casualties of development and thus not only pervious land is paved, but also a natural defense mechanism is eliminated in the process.

Trees can be effectively used as a stormwater management practice. Trees are commonly planted in sidewalks in cities. The traditional approach of planting trees along a sidewalk is not conducive to reducing runoff and is often unhealthy for the tree (Figure 2).

An improved design, known as tree box filter, can greatly increase stormwater absorption and retention and provide the tree with increased space for root growth. The design consists of suspended pavement and structural cells installed underneath the pavement. The cells are then filled with uncompacted soil and planted with trees (Figure 3).

Other options include a stormwater tree pit, which consists of an opening in the pavement that receives stormwater from the sidewalk or the road and is planted with trees. Bioswales, installed in road medians or parking lots, can also be planted with trees. In addition, trees can be a part of green roofs that double as parks. Klyde Warren Park in downtown Dallas is a great example of a green roof installed on top of an underpass (see photo).

As a stormwater management specialist, I encourage all engineers and landscape architects to consider the integration of trees in any stormwater management project they work on. While trees are usually included in projects for aesthetic, health, and heat island reasons, with the correct design, they can also be an effective nature-based stormwater management structure.

— Fouad Jaber, Ph.D., P.E., Associate Professor and Extension Specialist, Biological and Agricultural Engineering Dept., Texas A&M AgriLife Extension Service

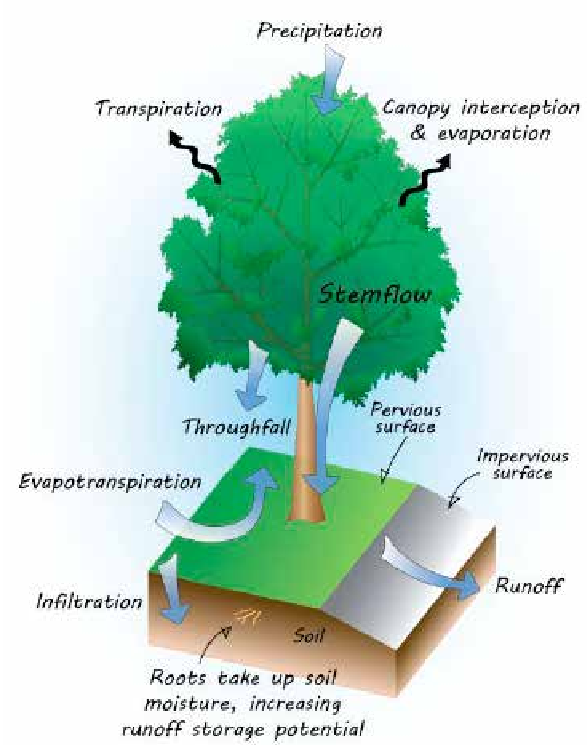

Figure 1. Water processes in a tree. (Figures by Tina McKeand from the 2013 EPA publication *Stormwater to Street Trees: Engineering Urban Forests for Stormwater Management.*)

The popular Klyde Warren Park is a massive green roof atop an underpass in Dallas, Texas. Photo by The Office of James Burnett from the Klyde Warren Park website.

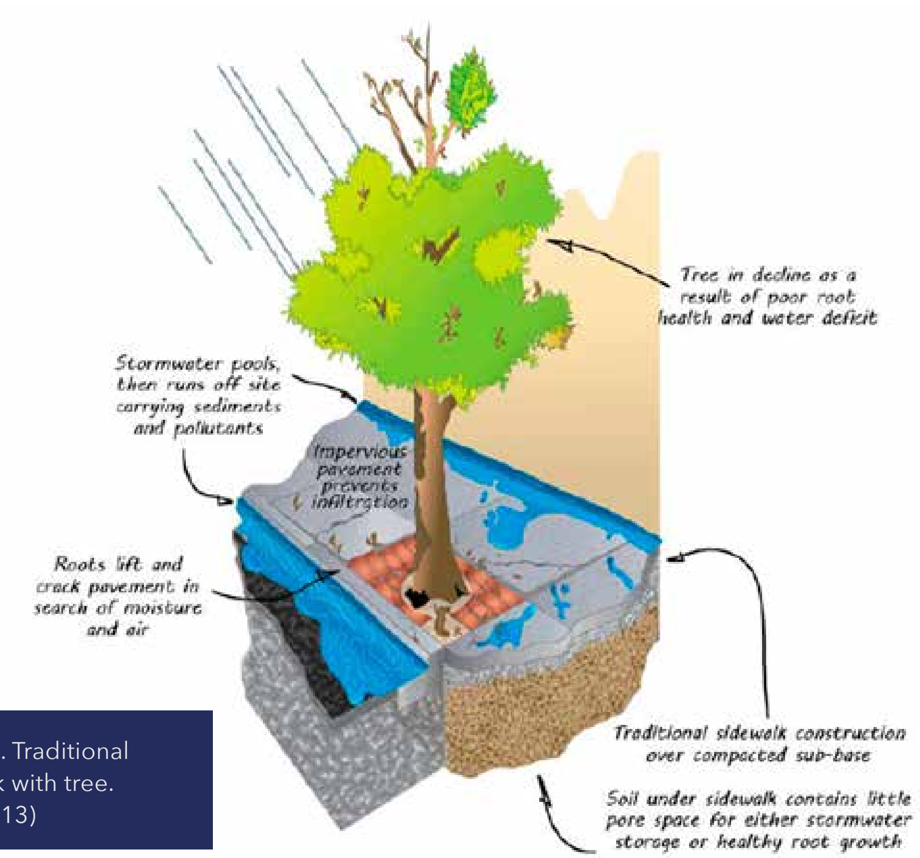

Figure 2. Traditional sidewalk with tree. (EPA, 2013)

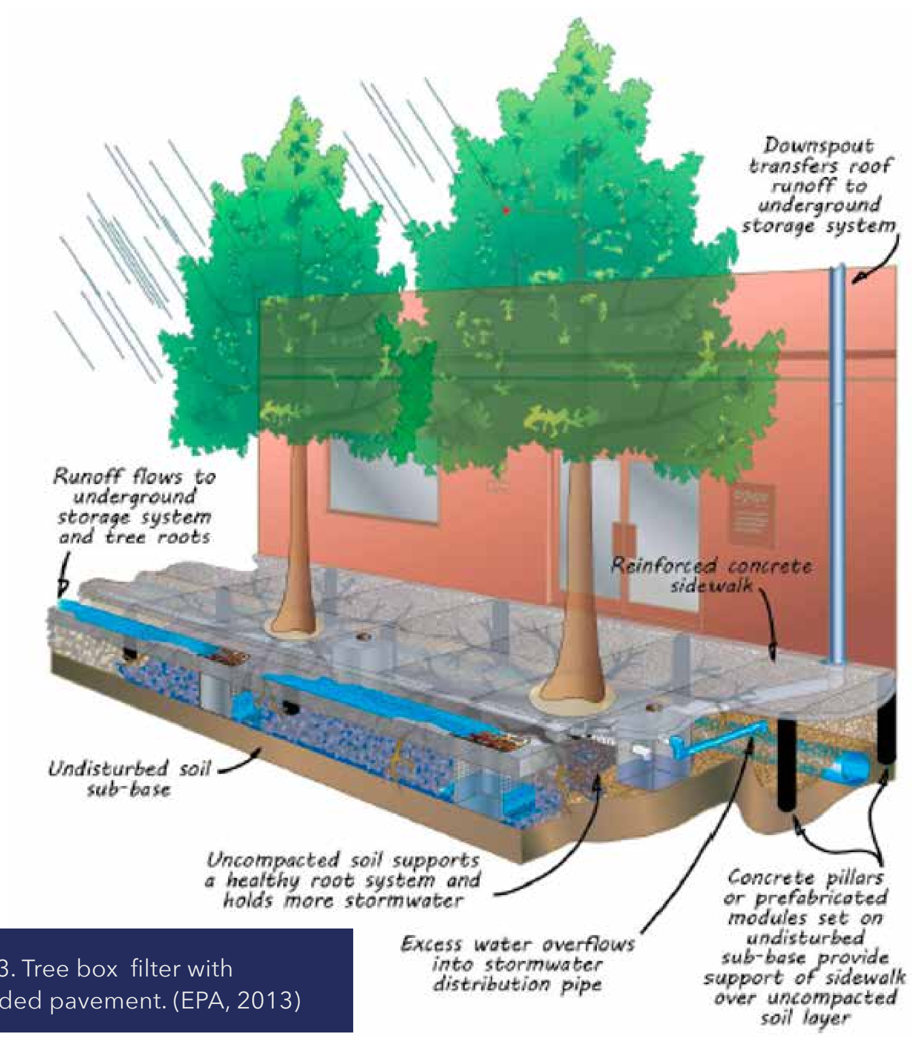

Figure 3. Tree box filter with suspended pavement. (EPA, 2013)

Level Spreader at Hinkson Creek: Implementing a Stormwater BMP

A level spreader is a stormwater best management practice that transitions concentrated stormflows from a stream or culvert into sheet flow over the ground surface. It can be useful to attenuate peak flows from small developed or impervious areas. An added benefit of a level spreader is increased infiltration of stormwater and uptake by plants as the water is distributed over a larger surface area.

A level spreader works best in conjunction with a well vegetated and very mildly sloped area downstream. An ideal location for this type of BMP is just upstream of a vegetated or riparian buffer strip. The level spreader will facilitate infiltration while also decreasing the stormwater that directly enters the water body. Increased infiltration can help trees and grasses in the buffer to be successful, and in turn, well-established vegetation prevents soil erosion from water overtopping the level spreader and flowing over the ground.

The City of Columbia built a level spreader in a city park to divert water from a small stream back into a reforested floodplain of Hinkson Creek. This level spreader is composed of a vegetated swale, a basin to still and pond the water, and a concrete level lip to distribute the water evenly over the floodplain.

A study is taking place to determine the effectiveness of the level spreader as a stormwater BMP. Initial results indicate that the level spreader works to attenuate stormflows differently during small and large rain events. During smaller storms, all the water is held inside the level spreader basin and slowly infiltrates into the soil in this area—similar to a retention basin. In larger storms, the level lip is active, and water is distributed onto the floodplain. Whether the level lip is overtopped during a storm or not, the level spreader is effective at attenuating peak flows in the small stream by infiltration and evapotranspiration. Two consecutive years of technical reports on the project can be found here.

—Laura Wiseman, EIT, Graduate Research Assistant-Water Quality, Missouri University Civil/Environmental Engineering

Ground view of Hinkson Creek level spreader. Photo by Laura Wiseman

Level spreader aerial view. Courtesy City of Columbia, Missouri

The Center for Watershed Protection Advises City of Raleigh on Tree Protection

The City of Raleigh is one of the fastest growing urban areas in North Carolina with goals to develop with environmental protections to improve and protect air and water quality. The City recognized the importance of the urban forest as an integral strategy to achieve these goals. In 2019, the City secured the services of the Center for Watershed Protection to determine and recommend how the conservation and/or expansion of forest and tree canopy during development can help to improve water and air quality. This work is intended to address the following goal identified in the Growth and Natural Resources Focus Area of the City's Strategic Plan: "Encourage a diverse, vibrant built environment that preserves and protects the community's natural resources while encouraging sustainable growth that complements existing development."

The Center partnered with Brown and Caldwell to complete several research tasks. These included:

- Evaluating the City of Raleigh's existing regulations and programs impacting tree conservation and planting against established benchmarks, using the Center's *Forest-Friendly Code and Ordinance Worksheet* (COW).
- Summarizing the extent to which the City of Raleigh is utilizing the North Carolina Statute enabling legislation to protect urban tree canopy during development/redevelopment.
- Synthesizing the current state-of-the-science on the relationship between urban forests and their water and air quality benefits.
- Reviewing models that can be used to quantify the water and air quality benefits of the urban forest.

The results of the *Forest-Friendly COW* find that the City has a strong program in place for tree conservation and to expand its urban forest, while identifying areas to improve or strengthen its tree conservation efforts, thus increasing the ability to improve local air and water quality. Further, the Center's team made recommendations for the City on development of a modeling framework to quantify the effects of the urban forest on air quality and water quality and quantity, and how future land use changes may impact these benefits.

These recommendations provide the City with a path forward that includes next steps, a timeline, and costs that can be scaled to the City's available resources in subsequent phases. A Technical Advisory Committee comprised of six subject matter experts in hydrology, modeling, and forestry provided review and input on all aspects of this project.

The City is in the process of discussing the results of the regulatory review with its multi-departmental strategic planning group with an eye to advance recommendations from this project. The City is also exploring a possible nexus with its Communitywide Climate Action Plan.

—Neely Law, Ph.D., Center for Watershed Protection Director of Education and Training

Removal of Fallen Leaves Can Improve Urban Water Quality

The timely removal of leaf litter can reduce harmful phosphorus concentrations in stormwater by over 80 percent in Madison, Wisconsin, according to our recent U.S. Geological Survey study.

Autumn leaf litter contributes a significant amount of phosphorus to urban stormwater, which then runs off into waterways and lakes. Excessive amounts of nutrients like phosphorus and nitrogen can cause eutrophication, or the depletion of oxygen in water, resulting in death of aquatic animals like fish. The USGS-led study found that without removal, leaf litter and other organic detritus in the fall of 2015 contributed 56 percent of the annual total phosphorus load in urban stormwater compared to only 16 percent when streets were cleared of leaves prior to a rain event.

Our study found that leaf removal is one of the few treatment options available to environmental managers for reducing the amount of dissolved nutrients in stormwater. These findings are applicable to any city that is required to reduce phosphorus loads from urban areas.

The USGS Madison, Wisconsin study found that stormwater nutrient levels were highest during the fall months when the amount of organic debris on streets was at its peak. Photo by Bill Selbig

We compared concentrations of phosphorus and nitrogen in stormwater from two residential catchments in western Madison that had similar tree cover. The City applied a leaf litter removal program from late September through mid-November at one site but not the other. We found significantly lower amounts of phosphorus and nitrogen at the site where leaves were removed.

The study also found that stormwater nutrient levels were highest during the fall months when the amount of organic debris on streets was at its peak. This finding suggests that leaf removal programs are most effective during fall in Madison, and that sources other than leaves, such as street dirt and grass clippings, were likely the primary contributors of phosphorus and other nutrients during spring and summer. The efficiency, frequency, and timing of leaf removal and street cleaning are the primary factors to consider when developing a leaf management program.

During 2013 through 2015, the City of Madison used municipal leaf collection and street cleaning to remove leaf litter from residential areas, and it asked residents to pile their leaves adjacent to the street to limit excess debris. Leaf collection and street cleaning occurred about every seven days from late September through mid-November. Additionally, leaf blowers were used to clean debris off streets prior to storm event. Results showed more than an 80 percent reduction in phosphorus load compared to no cleaning. Since then, the USGS continued to evaluate other municipal leaf collection and street cleaning programs that vary in both method, frequency, and amount of overhead tree canopy. Results of that portion of the study should be available by the end of 2020.

The USGS collaborated with the City of Madison, City of Oshkosh, City of Fond du Lac, League of Wisconsin Municipalities, the Clean Lakes Alliance, Yahara WINS, the Fund for Lake Michigan, and the Wisconsin Department of Natural Resources on the study.

—Bill Selbig, Research Hydrologist, USGS – Upper Midwest Water Science Center, Middleton, Wisconsin

Three generations of tree planters at FLOW's Earth Day 2019 event. Photo Courtesy FLOW

FLOW volunteers get instructions before Earth Day 2019 planting. Photo Courtesy FLOW

Partners in the Lower Olentangy Watershed

Based in Columbus, Ohio, the Friends of the Lower Olentangy Watershed (FLOW) have two exciting projects at the intersection of urban forestry and watersheds. We are lucky enough to have great partners in our watershed like the Cities of Upper Arlington and Worthington, Ohio.

FLOW started working with Worthington in 2018, offering to clear invasive bush honeysuckle in parks. Our partnership has resulted in clearing both the east and west banks of Potter's Creek in Perry/Snouffer Road Parks and replanting native seedling and containerized trees and shrubs along the cleared riparian corridor. We also seeded and planted two pollinator gardens in the vicinity. The project benefitted the municipality by getting rid of the monoculture of understory honeysuckle to increase safety, visibility, and heterogeneity of vegetation for park users. The advantage to the watershed was in increasing the habitat along the stream corridor, which will eventually improve the stream biota.

Worthington also gave us a great piece of land to create an urban tree nursery. FLOW is growing more than 750 trees to give away to residents to increase the canopy on their property or for us to use in stream restoration projects. We'll be back in Worthington in 2020 to celebrate the 50th Anniversary of Earth Day by planting more native trees.

Another great example of opportunity at the urban forest-watershed intersection is in Upper Arlington (UA) along Slyh Run. The Friends of UA Parks has been clearing invasive bush honeysuckle and replanting in the headwaters in Smith Nature Park, while FLOW has been working 1,500 feet (0.45 km) downstream removing invasive bush honeysuckle at Cranbrook Elementary School.

After replanting the cleared corridor with native trees, FLOW also created a 0.1 acre (.04 ha) seeded pollinator habitat to provide a land lab opportunity for students and neighbors. FLOW has been monitoring the macroinvertebrates in Slyh Run since 2015 and although it has one of the lowest tributary diversities in the watershed, we are continuing to monitor the stream to document its improvement. FLOW also sent out stream report cards to landowners to tell them how they could help improve the stream water quality.

FLOW suggests that all municipalities reach out to their local watershed groups for help in keeping the urban canopy healthy. Watershed volunteers love removing invasive plants and planting everything from seedling trees to B&B stock. It could be a great partnership, especially if the watershed group has funding to pay for trees.

—Laura Fay, Science Committee Chair, Friends of the Lower Olentangy Watershed (FLOW)

For Urban Forests, Watershed Management Starts at the Treetop

Key Terms

Canopy water storage capacity: Maximum amount of precipitation water that can be stored on the surfaces of leaves, bark, and any (epiphytic and parasitic) plants living within the canopy.

Net precipitation: Total amount of precipitation that reaches the soil surface beneath plant canopies. This is the sum of throughfall and stemflow. As the surface in forests can have a litter layer, this term differs from "effective precipitation" which describes the amount of net precipitation that actually enters into the soil.

Precipitation interception: Storage and evaporation of precipitation by plant canopies. This process reduces the amount of precipitation that reaches the surface and is typically just called "interception" in the hydrology community.

Stemflow: Precipitation which drains down leaves and branches until reaching the trunk, whereafter this water continues to drain in rivulets until reaching the surface near the trunk.

Throughfall: Precipitation that passes through gaps or drains along leaves and branches until reaching a point where it drips to the surface. This can create (a) dry spots where precipitation was diverted away to another location and (b) concentrated drip points.

Because we live on the land surface, the effects of urbanization on stormwater runoff are literally right beneath our noses. As a result, much is known about runoff processes and watershed management options exist to control runoff (and its associated nutrients and pollutants). We rarely look upward during a storm and, therefore, it comes as no surprise that the processes in urban forest canopies that precede runoff are much less researched and hardly considered in watershed management. I say "hardly considered" because one role of urban trees is somewhat included in water budgeting: the interception of precipitation by canopies. Given the right canopy conditions, interception can reduce precipitation by 25% in large storms, and >90% in small storms! Broad, and sometimes problematic, assumptions are often made to estimate interception for an entire urban forest.

For example, it may be assumed that all trees with one kind of canopy (i.e., needle-leaves) can store x amounts of precipitation, while all trees with another kind of canopy (i.e., broadleaves) can store y amounts of precipitation. Of course, as arborists are no doubt aware, canopy structure (and therefore the amount of precipitation that can be stored on a canopy) can vary dramatically between individual trees of the same species in different urban settings—and even more so between species with similar leaf types. Thus, broad assumptions about the urban forest's canopy water storage capacity can result in erroneous estimates of interception.

This is important as errors in interception are carried through all subsequent water budget calculations, including runoff and infiltration. With this in mind, something as simple as sharing tree age and canopy structural information (e.g., whether branches or deadwood were pruned) with watershed managers may help improve not only interception estimates, but reduce uncertainty for other more common hydrological processes of interest.

Now, what about the precipitation that reaches the surface beneath canopies—the net precipitation? One may think, since net precipitation is what's left over after interception, that with an interception estimate you can begin making hydrological calculations and predictions at the surface … but, the story is a little more complicated than that. The pattern of gaps, leaves, and branches (all at different angles) force net precipitation into a pattern of wet and dry spots at the surface.

After a heavy rain event in Asheville, NC, stemflow-induced runoff was so large that it washed away the leaf litter from around its stem, exposing bare soils.

A stemflow pathway has begun on the trunk of a *Lagerstroemia indica* tree in Statesboro, GA. As the storm progressed, this stemflow pathway grew into a highway capable of transporting nearly 100 liters (26 gallons) of water to the soil at the base of the stem in a single rain event. Photo by John Van Stan

Throughfall drip points and their branchflow pathways, frozen in time during a rain-to-ice storm in Statesboro, GA. Photo by John Van Stan

Most net precipitation drips from the canopy or through its gaps as "throughfall." Still, throughfall can concentrate large amounts of water at drip points, where the surface can receive up to 10x more water than precipitation in the open. The location where throughfall drip points occur may be meaningful for an area. For example, do throughfall drip points direct most net precipitation to impervious or permeable surfaces?

Trees have another trick up their trunk for re-directing large amounts of precipitation to tiny spots at the surface: stemflow. If a tree's canopy has enough branches, inclined at the right angles, and with the right bark (not so rough, flaky, or spongey), hydrologists have observed stemflow waters at the surface that are 100x greater than open precipitation! Although stemflow is one of the least understood pathways for precipitation through tree canopies, it has often been reported to supply >10x more water per unit area to near-stem soils than open precipitation.

Depending on the surface and subsurface soil properties, stemflow rates can be so high that they overflow urban tree planters and become runoff, or preferentially infiltrate deep into the subsurface. Because of this, it is arguably worthwhile knowing the stemflow patterns in an urban forested watershed. Importantly, since stemflow and throughfall drip points bathe the most canopy surfaces, they can be loaded with as much nutrients as runoff.

So, let's start looking upward during storms—or at least, let's start thinking about how precipitation may interact with the trees we plant and with our modifications to the existing canopy. Although these interactions have not been very systematically researched compared to other processes, we can improve interception estimates and make a few generalizations about throughfall and stemflow.

Anecdotally, tree species with steep branches and smooth bark have been observed to generate more stemflow, while species with multiple branch bends or confluences (which may also be due to pruning) may create throughfall drip points. If trees are selected or pruned in such a way as to favor stemflow, one should ensure that the near-trunk soils are capable of infiltrating high water supply rates. Given how little these processes have been considered to date, perhaps their consideration in future watershed management will yield surprising new advances.

—John T. Van Stan, II, Ph.D., Director of the Applied Coastal Research Laboratory, Georgia Southern University, Savannah, GA and Associate Professor, Dept of Geology & Geography, Georgia Southern University, Statesboro, GA

Vermont's Local Leaders for Green Streets and Watershed Health

As Vermont's urban centers grow and rural areas become home offices or bedroom communities, more residents are reckoning with the power of local decision-making to affect both healthy tree canopy and clean water in the state. The Resilient Right-of-Ways project, first envisioned as an information-sharing initiative intended to guide both rural and urban Vermont communities in roadside community tree care, has blossomed into a larger effort to document the challenges that communities face to balance right-of-way vegetation with local bylaws, state statutes, water quality mandates, and road safety. The Vermont Urban & Community Forestry Program (VT UCF) plays an important role in supporting local leaders volunteering as tree wardens and on conservation commissions, connecting them with the network of professionals managing roadside trees for beauty, safety, and watershed health.

Vermont's few municipal arborists and many volunteer tree wardens advocate for public trees while weighing the best interests of the community's landscape, budget, and risk tolerance. They may team with town road foremen, conservation commissions, or tree boards to promote tree canopy, remove risk trees, or resolve disputes between the town and private landowners. While tree wardens must follow the Vermont Tree Warden Statutes and the direction of their town's selectboard, they must also interpret the intent of the self-governing document of their town, the Town Plan.

Local tree wardens and conservation commissions in Vermont examine the best ways to protect roadside water bodies such as this one in Marshfield, Vermont. Photo Courtesy VT UCF Program

Updated every five to eight years, the Town Plan should reflect the vision of their town's financial, ecological, and social landscape. Some towns are able to protect forested areas (in fact, a new State act requires towns to include forest block connectivity as an element of their updated Town Plans) but most are challenged to include tree planting or strategic reforestation as necessary tools to protect water quality.

In the last three years, VT UCF has partnered with 20 towns to create room for thoughtful roadside vegetation management in both urban and rural settings. Ten Vermont cities and towns examined their municipal bylaws to encourage green stormwater infrastructure in targeted downtown areas. Steered by the new Vermont Green Streets Guide, other downtown districts can now also follow suit in these practices as they apply to cold-weather climates. Additionally, ten rural towns formed Resilient Right-of-Ways committees to review recommendations specific to their backroad vegetation, addressing everything from rural roadside ash populations to forestry practices that identify and promote the healthiest trees in these challenging roadside environments.

Throughout the process, VT UCF has elevated the role of the town tree wardens, encouraging road crews and selectboards to follow guidance from these local leaders dedicated to creating healthy and resilient tree canopy in their communities. For the tree wardens themselves, VT UCF hosted its first tree warden summit, designed to share experiences, address local concerns, and provide feedback on proposed updates to modernize the Vermont Tree Warden Statutes.

Through support of local tree wardens, technical assistance for roadside vegetation management, grant funding for community tree planting, and resources dedicated to forest health and integrity, VT UCF continues to support the on-the-ground work communities do to plan and care for public trees that line their roads, parks, and backyards. With local partnerships and shared statewide resources, Vermont cities and towns are using trees to take responsibility for flood resilience and watershed health in their own backyards.

—Joanne Garton, Technical Assistance Coordinator, Vermont Urban & Community Forestry Program