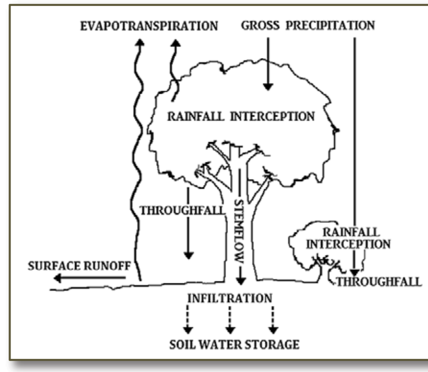
Resource or Hazard? Stemflow from Urban Trees

How is rainwater modified volumetrically as it passes through tree canopies? The few studies done in urban environments suggest that hydrological processes in **isolated deciduous trees**, such as those in streets or parking lots, differ from better-researched dynamics in forests. However, many models and calculations of stormwater-related benefits assume that the processes and quantities are similar. Growing investment in green infrastructure has intensified the need for studies specific to urban trees. **We aimed to test the assumption that forest trees and urban trees perform similarly for one specific component of understory precipitation, *stemflow*, in a manicured urban park.**

What is Stemflow?

Of the total rain that falls on a tree canopy:

- ***Stemflow*** is the portion that is funneled to and concentrated at the base of the trunk—in deciduous forests, this typically represents < 3 % of the total, but may not be negligible for isolated urban trees!
- ***Throughfall*** is the portion that reaches the ground diffusely, passing through gaps in the canopy, or drips from leaves, twigs, and branches comprising the canopy.
- ***Interception loss*** is the portion of rain stored in the canopy to be evaporated, never reaching the ground.



Source: Inkiläinen et al., 2013 adapted from Levia and Frost 2006

To reduce flooding caused by stormwater, urban foresters, landscape architects, and stormwater engineers have typically aimed to maximize interception loss, but haven't focused on throughfall or stemflow.

- *What if stemflow is not negligible for some commonly planted trees?*
- *Could informed tree selection and planting allow us to manage stemflow as a resource (e.g., irrigation)?*
- *Could designs for stemflow infiltration also accommodate integrated stormwater management practices?*

Methods

Our study site was an intensively managed urban park in semi-arid Kamloops, BC. Stemflow and weather data were collected over 17 months using the following methods:

- Stemflow collected by a system of collars and reservoirs
- 37 isolated deciduous trees representing 21 commonly used cultivated species (e.g., ash, maple, beech)
- Diameter-at-breast-height ranged from 10–69 cm; single- and multi-leader trees were analyzed separately
- 86 rain events, > 80% of which were < 5 mm in depth

Highlights of our Findings

Stemflow in isolated deciduous trees in our study was associated with:

- High branch angles
- Smooth bark, particularly for multi-leader trees
- Linearly furrowed bark for single-leader trees
- Plentiful leaders converging at the base of the canopy
- High wood cover % (stemflow-conducting infrastructure)

Record Holders

Two trees had the highest stemflow percent (relative to total rain falling on a canopy):

- A single-leader Columnar English Oak funnelled 22.8% of rain from a 25.6 mm event, and had an impressive 11.8 ± 9.1% average over the study period. Why was this the case? This tree had the highest branch angles and canopy height-to-width ratio in the study, and very dense wood cover within its canopy.

- A multi-leader American Beech funnelled 18.7% from an 8.8 mm event, and had a relatively high study average of 9.9 ± 1.4%. Why? This tree had many leaders, high upper-branch angles and wood cover, and smooth bark (possibly hydrophobic, which would increase the flow of water even more).

What are the Implications of our Results?

Most importantly, we showed that stemflow is *not necessarily negligible*, as had previously been assumed, particularly for certain tree species, forms, and sizes.

Existing Streetscapes: If soils are highly compacted and/or paving dominates the site, it is unlikely that either stemflow or other stormwater is infiltrating at the base of the tree. The risk of concentrated stemflow contributing to runoff quantity and quality issues depends on the rainfall regime, airborne pollutant conditions, size and traits of existing trees, and consequences of mismanagement (e.g., sensitive ecosystems). Runoff may be controlled through diversion to various best management practices (e.g., raingardens or rock pits/trenches) in this situation.

Proposed Streetscapes: Ideally, designs will ensure infiltration capacity by specifying appropriate soils and generous soil volumes. If stemflow can infiltrate into either grass or permeable soil at the base of the tree (such as into a suspended pavement system, open planter, or raingarden) for the majority of a location's anticipated storm events, then species may be chosen that promote stemflow. The benefits of infiltrating stemflow can be significant, and include: **1)** reduction of runoff from water quantity and quality perspectives; **2)** self-irrigation, with the need for supplementation depending on the species and climate; **3)** self-nourishment with nutrient-rich stemflow; **4)** biofiltration of pollutants washed from the canopy into soils via stemflow; and **5)** groundwater recharge.

If infiltration into surrounding soil is limited or undesirable (e.g., soil instability), then trees may be selected for non-conducive traits. However, reducing stemflow may increase throughfall, which is more difficult than concentrated stemflow to manage as it typically falls diffusely on pavement beneath the canopy.

Conclusion

While more systematic urban-tree studies are needed in various climates, we have confirmed the importance of high branch angles, bark relief, and wood cover for stemflow. Novel findings of our research included the stemflow-promoting role of linearly furrowed bark in single-leader trees' stemflow rates and the association of stemflow production with different traits for single- vs. multi-leader canopy structures. Further study is needed on these topics as well as on urban conifers and stemflow chemistry, but the key take-home messages from this study are:

1) Recognize urban trees as part of the hydrological cycle. Stemflow can be a valuable input (or problematic in excess), so tree selection, siting, and planting design should reflect a tree's anticipated contribution to site hydrology over its lifespan.
2) Provide sufficient quality and quantity of soils to absorb and biofilter stemflow (as well as throughfall and runoff) and support growth of trees to maturity.
3) Integrate trees with broader "green infrastructure" in a system designed to manage rainwater at the source.

About the Researchers

Julie Taylor Schooling*, MScES, MBCSLA, is a Landscape Architect with McElhanney Consulting Services Ltd. who has long had an interest in the integration of stormwater management and landscape features.* ***Darryl Carlyle-Moses****, PhD, is Associate Professor and Chair in the Department of Geography & Environmental Studies at Thompson Rivers University in Kamloops, BC. His forest hydrology expertise and Julie's passion for urban trees helped to frame and answer this study's research questions.*

More Information: jschooling@mcelhanney.com | dcarlyle@tru.ca | www.kamloops.ca/stormwatertrees (for MScES Thesis)

Kamloops Naturalist Club | Thompson Rivers University | Kamloops – Canada's Tournament Capital | University of Victoria | Kamloops Foundation | Golder Associates | TD Friends of the Environment Foundation | NSERC CRSNG | Urban Systems | real estate foundation British Columbia | the partnership for water sustainability in bc – Convening for Action in British Columbia