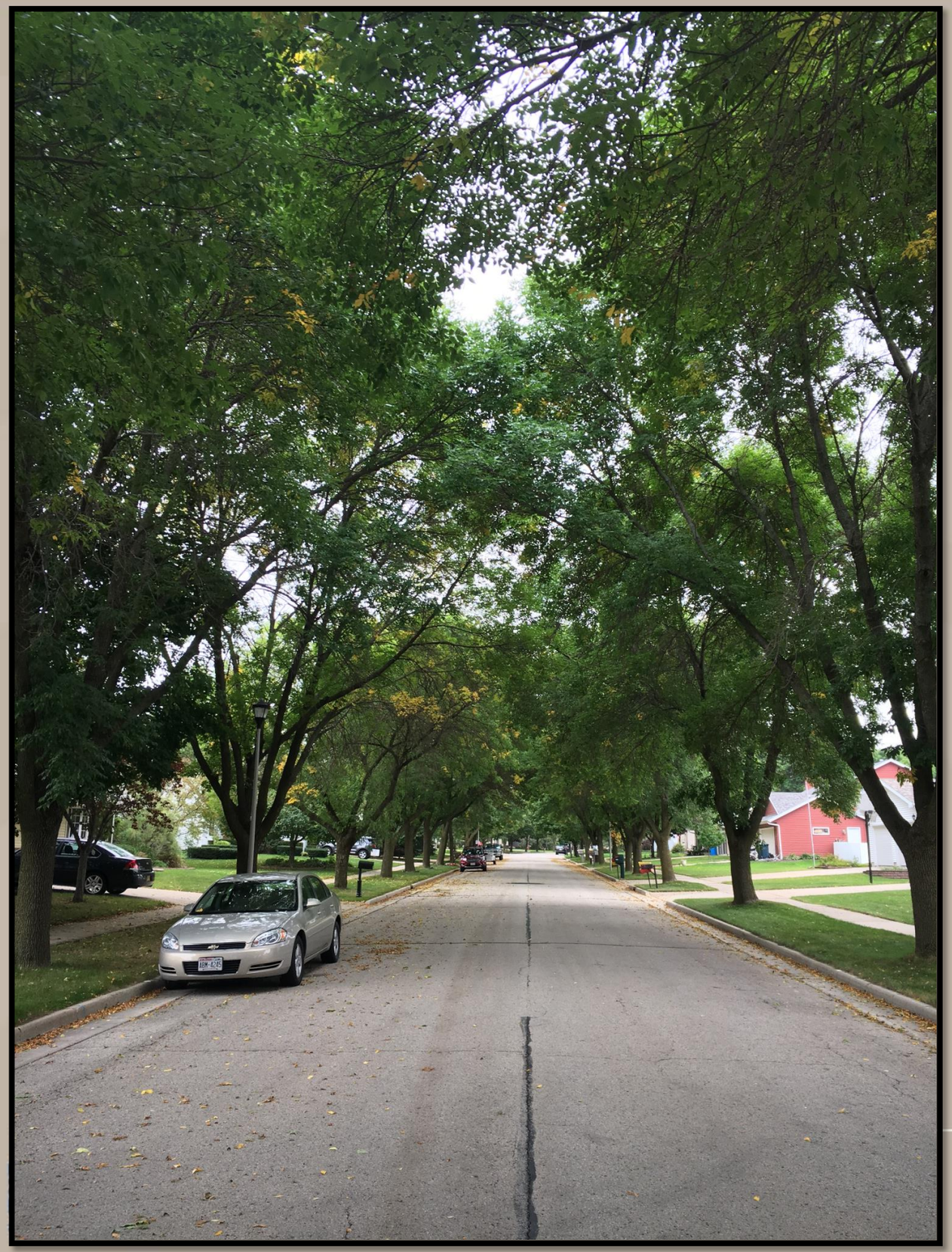
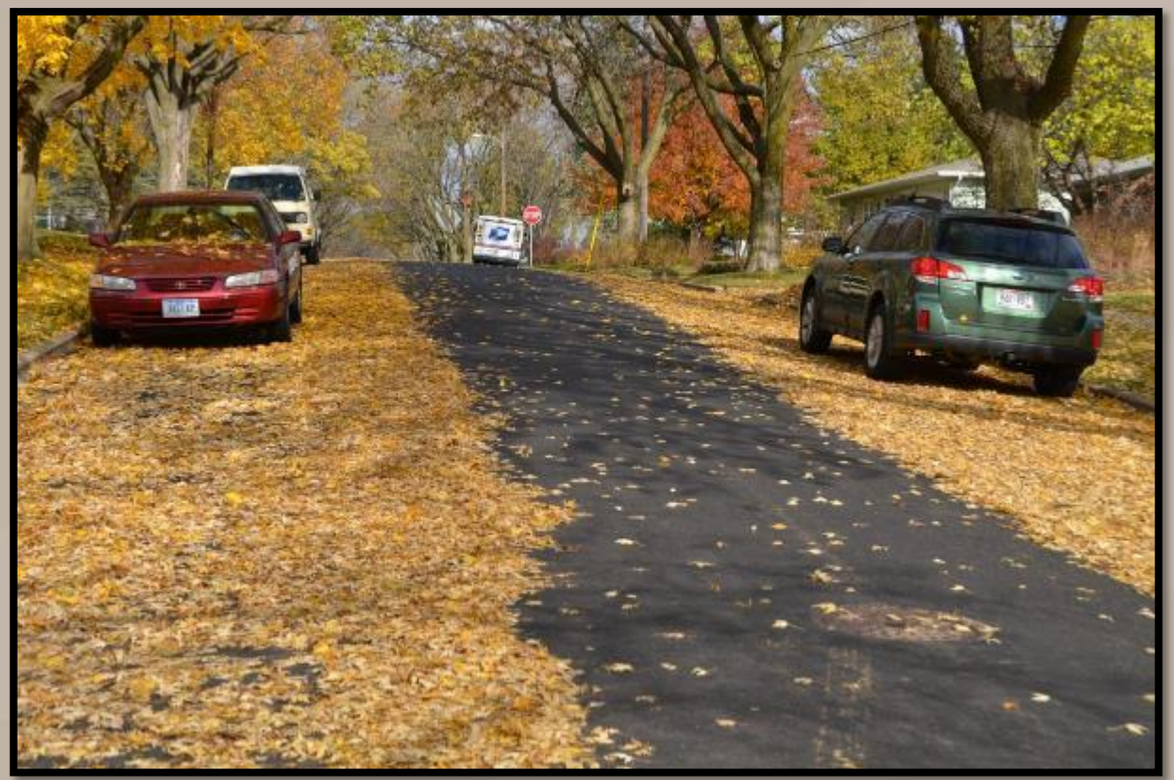
Investigating the Stormwater Quantity and Quality Impacts of Urban Trees





Overview

- Trees and Stormwater Quality
  - Leaf Collection Study, Madison, WI
- Trees and Stormwater Quantity
  - Tree Canopy Study, Fond du Lac, WI

Source: U.S. Forest Service

Why worry about nutrients in urban stormwater?

Source: Madison.com

- Strong public interest to keep lakes fishable and swimmable
  - Beach closures (cyanobacteria)
  - Recreational loss
  - Health concerns
- Federal/State pollutant restrictions
  - TMDL for Total Phosphorus

One of largest recent blue-green algae blooms closes most Madison-area beaches

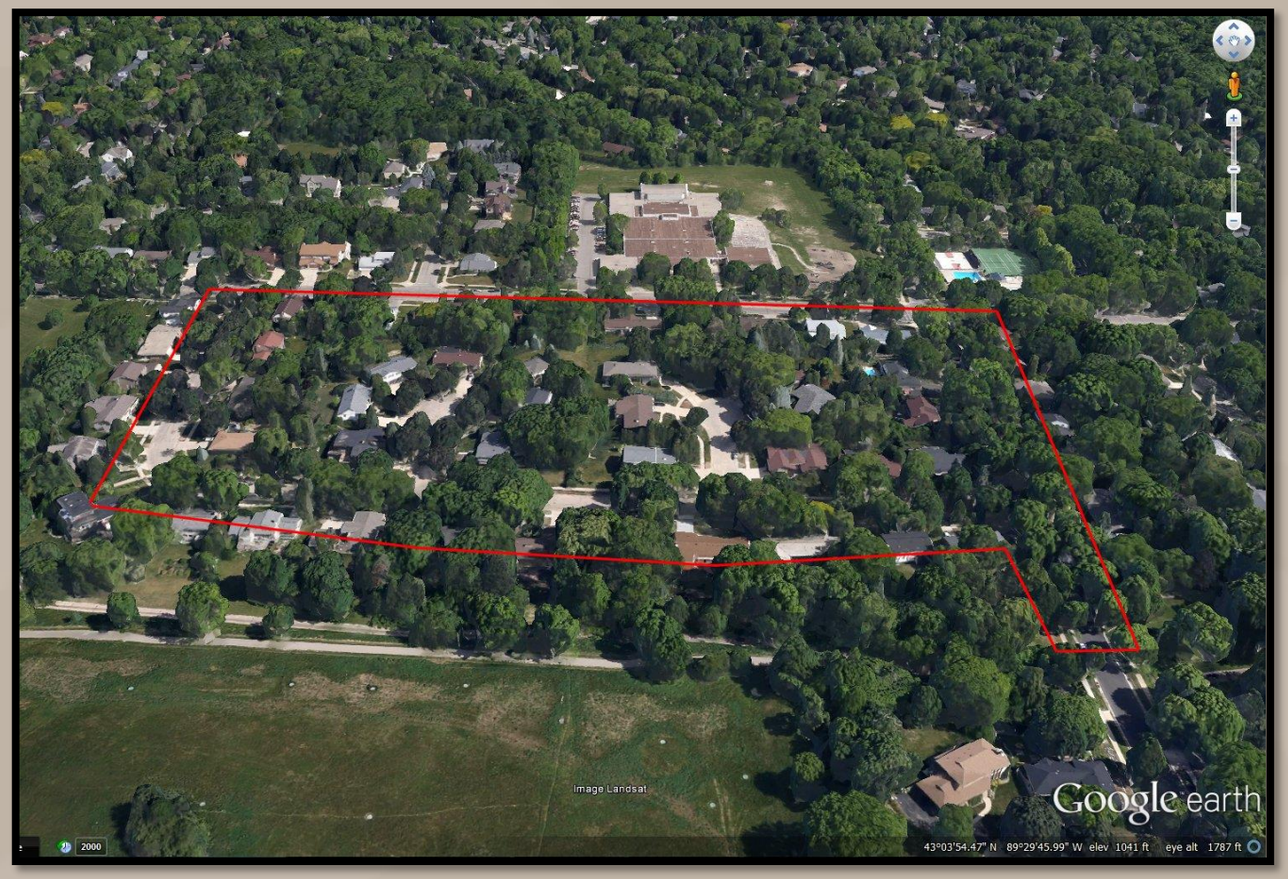
Posted: Jun 28, 2018 11:20 AM CDT Updated: Jun 28, 2018 02:32 PM CDT

Source: Channel3000.com

Source: https://www.limno.com/answering-challenges-habs-information-research/

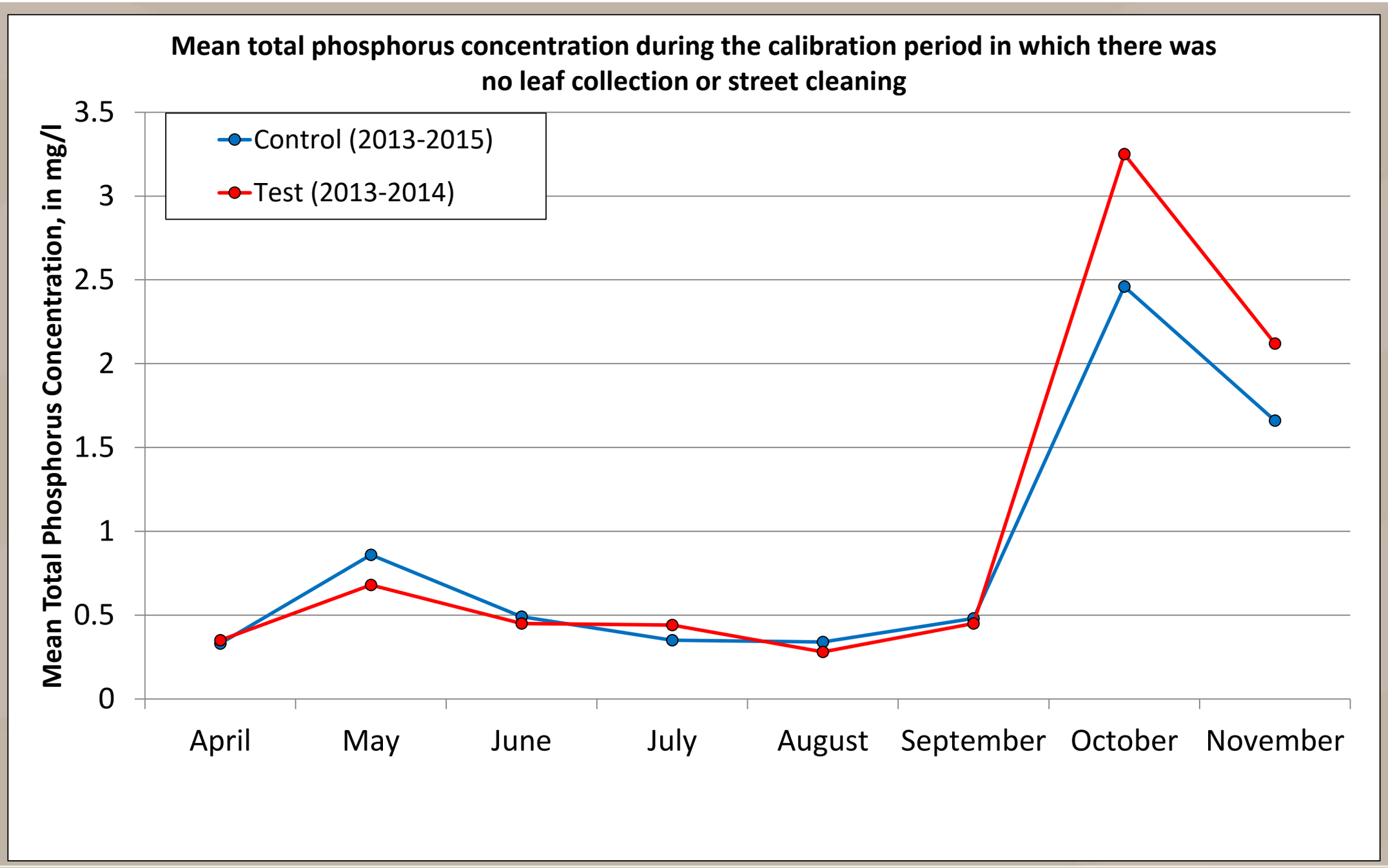
Paired Basin Study Design

Control



Test

Photo Credit: USGS



“Escalated” Leaf Management

In addition to municipal efforts, USGS field crews would clear all organic debris from street surface prior to rain event

Photo Credit: USGS

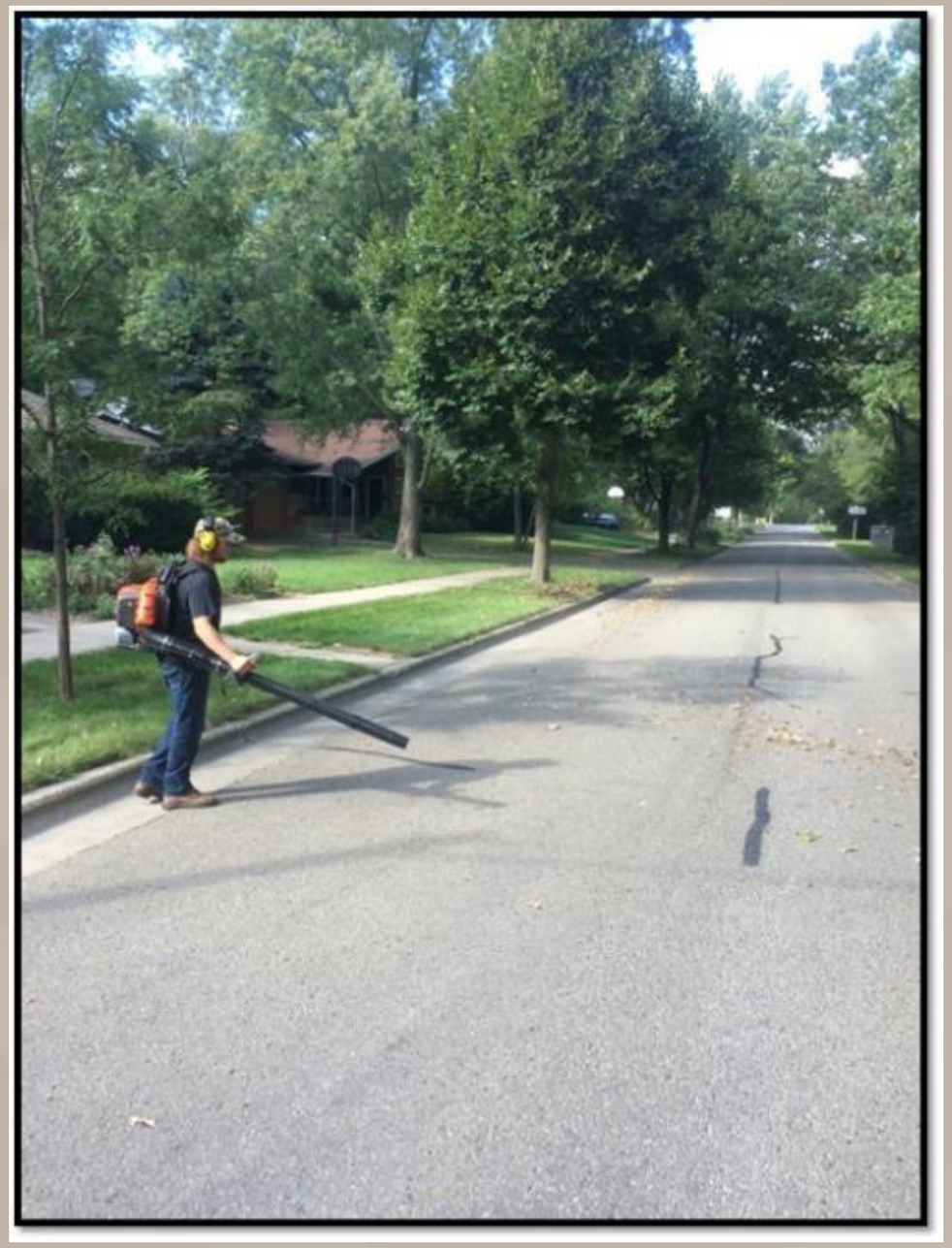
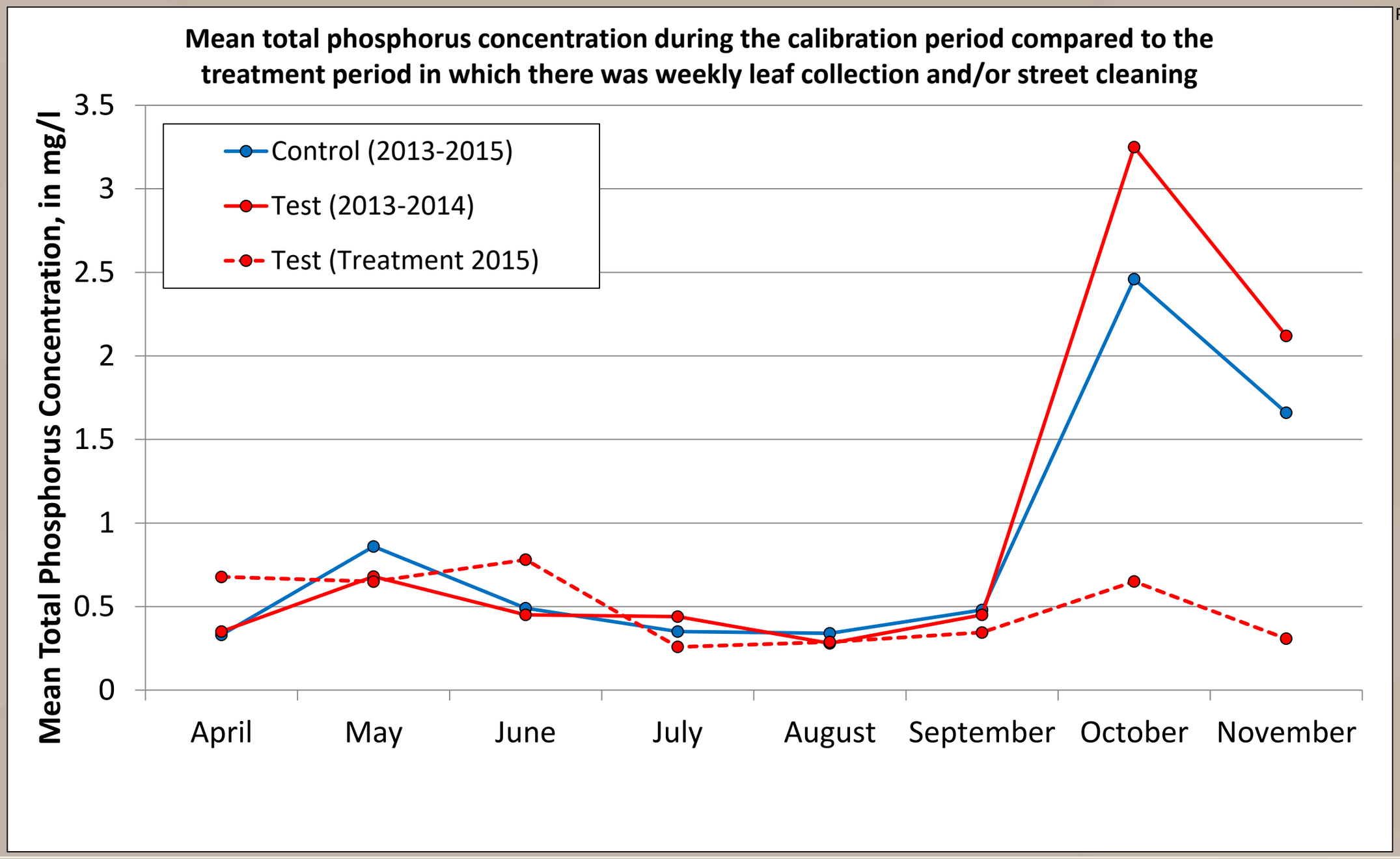


Photo Credit: USGS

Photo Credit: USGS



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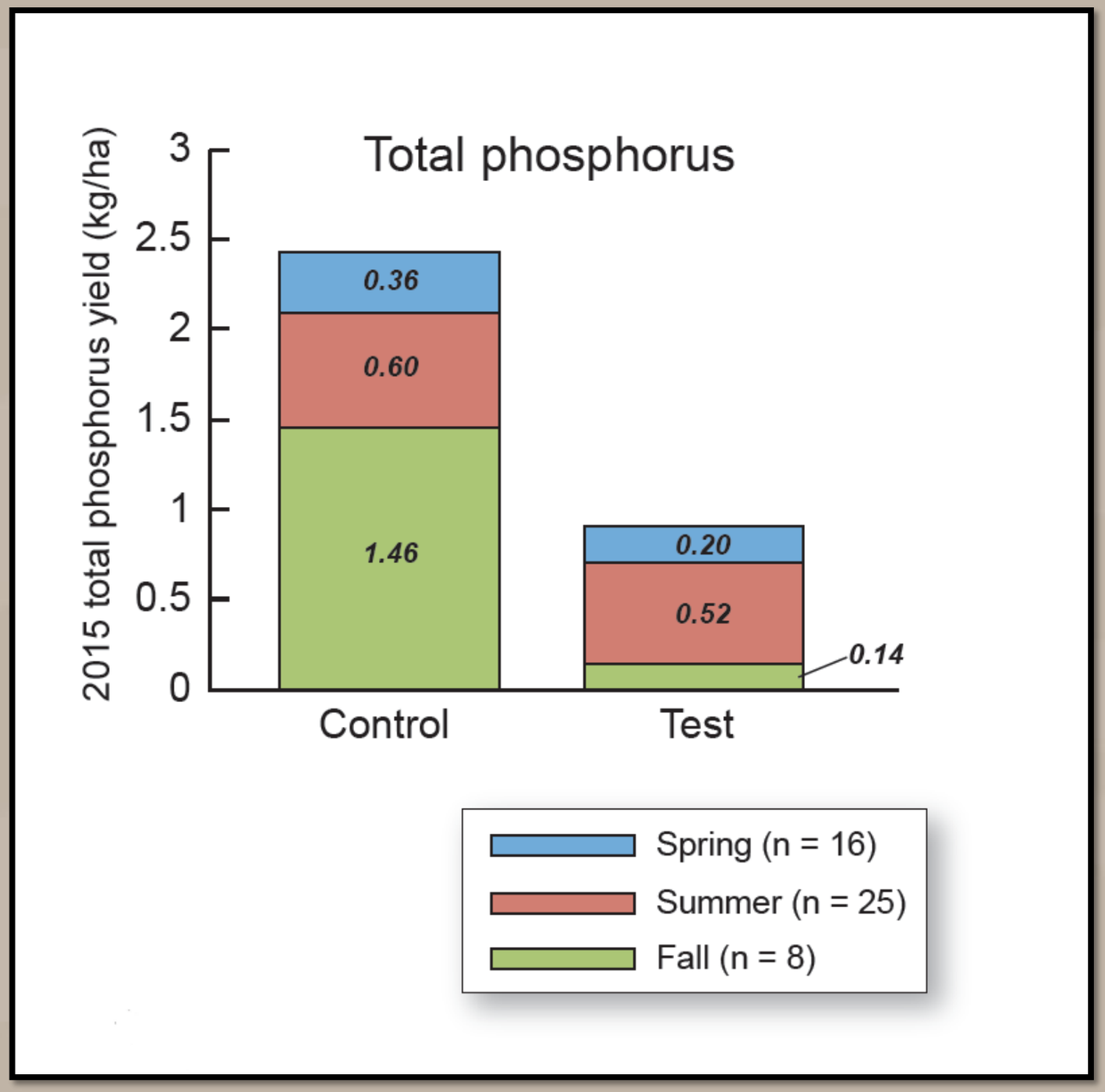
Seasonal Total Phosphorus Yield as a Percent of the 2015 Annual Yield (winter excluded)



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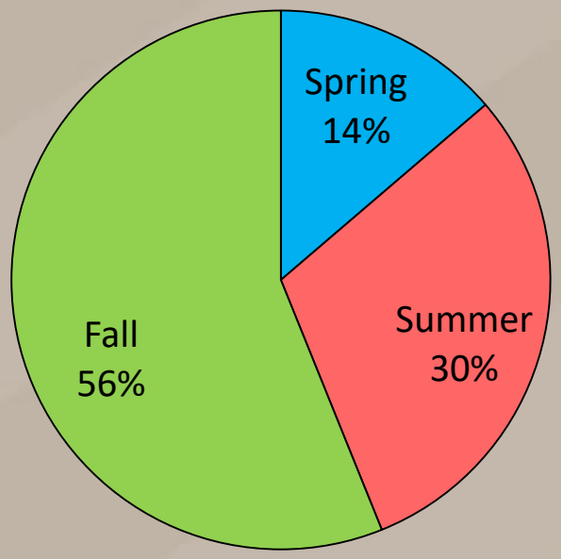

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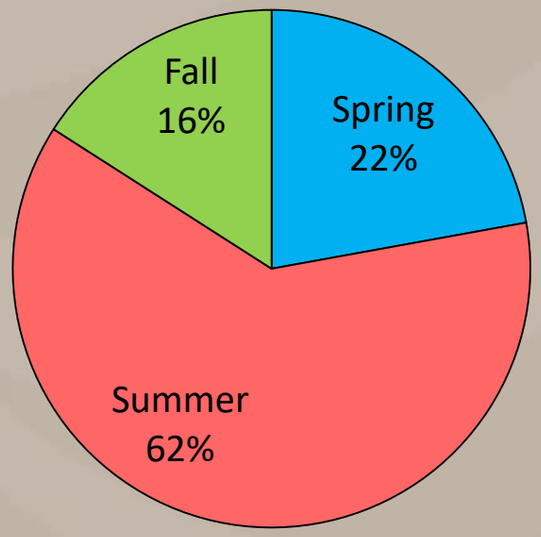

Preliminary Information – Subject to Revision. Not for Citation or Distribution

Leaf Management Practices

Variables that influence EOP nutrient load:

- leaf collection method
- street cleaning technology
- frequency

Photo Credit: USGS

Photo Credit: USGS

Matrix of Leaf Collection and Street Cleaning Practices

HIGH TREE CANOPY				
Leaf Collection		Street Cleaning		
Method	Frequency	Method	Frequency	Year Completed
Transfer	Weekly	Mechanical/blower	Pre-event	2015
Transfer	3-4x	Mechanical	3-4x	2016
Transfer	3-4x	Regenerative Air	Weekly	2017
Vacuum	Weekly	Regenerative Air	Weekly	2017
Transfer	3-4x	None	--	2018
Vacuum	3-4x	Regenerative Air	weekly	2018

MEDIUM TREE CANOPY				
Leaf Collection		Street Cleaning		
Method	Frequency	Method	Frequency	Year Completed
Transfer	3-4x	Mechanical	3-4x	2018
Vacuum	Weekly	Mechanical	Weekly	2019
None	--	Regenerative Air	Weekly	2019

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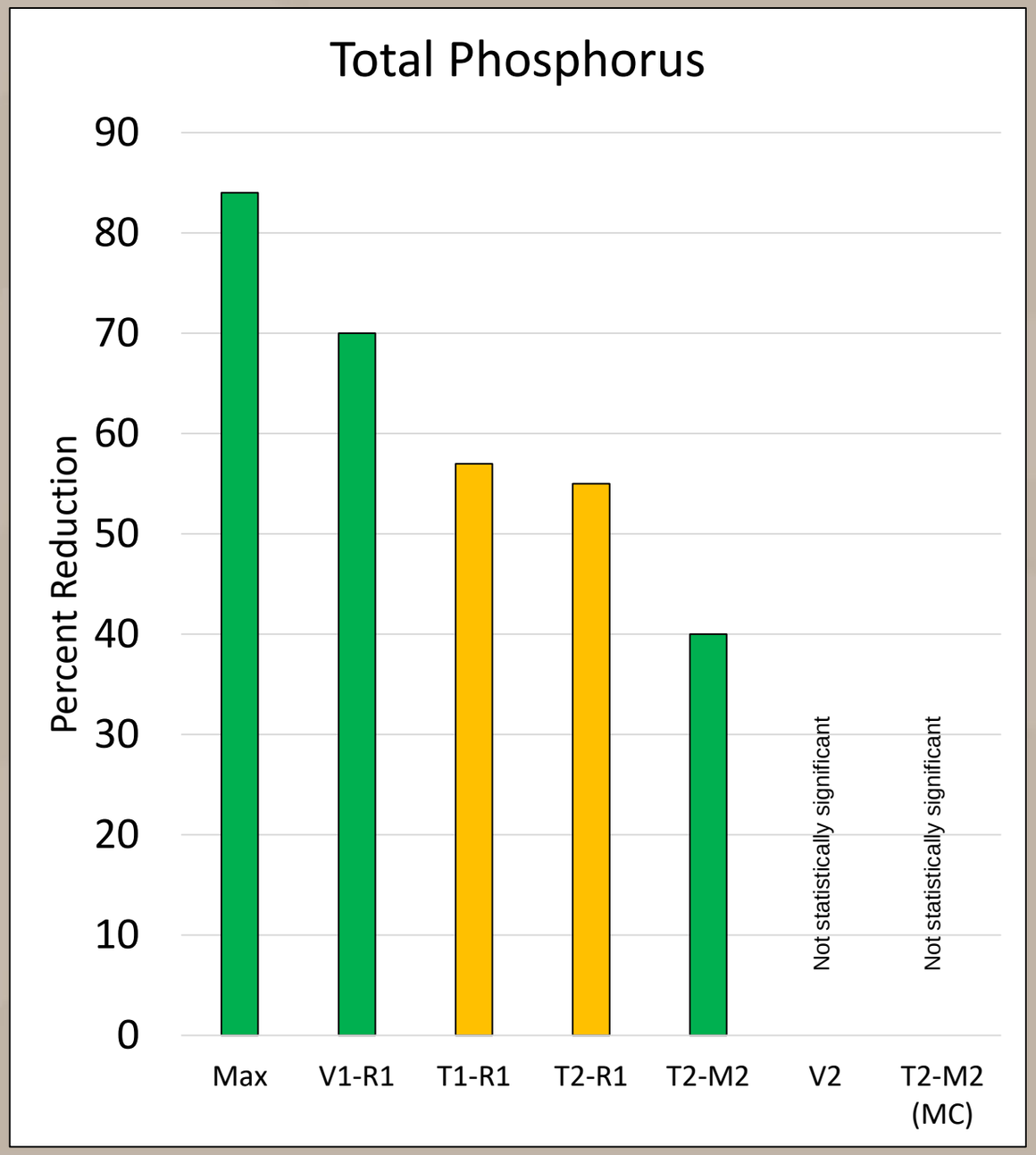
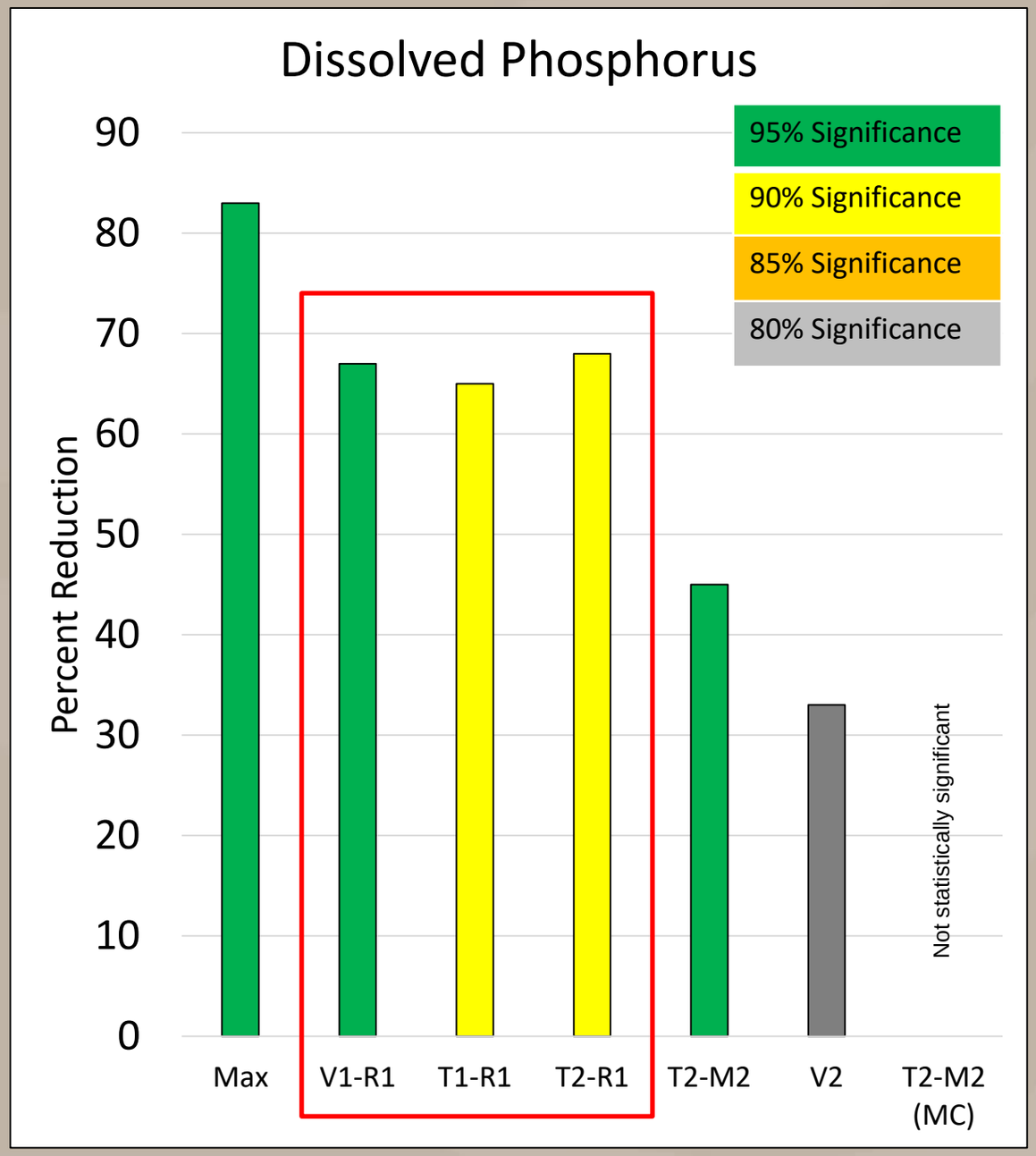
Change in Phosphorus Load





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Phosphorus Reduction Credits

Madison SOP = 3-4 times/season

WISCONSIN
DEPT. OF NATURAL RESOURCES

BUREAU OF WATERSHED MANAGEMENT
PROGRAM GUIDANCE

RUNOFF MANAGEMENT POLICY AND MANAGEMENT TEAM
Storm Water Management Program

Wisconsin Department of Natural Resources
101 S. Webster Street, P.O. Box 7921
Madison, WI 53707-7921

Interim Municipal Phosphorus Reduction Credit for Leaf Management Programs

DRAFT 10-05-17
EGAD Number: 3800-2017-08

Notice: This document is intended solely as guidance, and does not contain any mandatory requirements except where requirements found in statute or administrative rule are referenced. This guidance does not establish or affect legal rights or obligations, and is not finally determinative of any of the issues addressed. This guidance does not create any rights enforceable by any party in litigation with the State of Wisconsin or the Department of Natural Resources. Any regulatory decisions made by the Department of Natural Resources in any matter addressed by this guidance will be made by applying the governing statutes and administrative rules to the relevant facts.

APPROVED:

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Next Steps…

- Develop algorithms to predict phosphorus in stormwater
  - WinSLAMM
  - i-Tree

Photo Credit: USGS

Assessing Stormwater Volume Reduction by Urban Trees

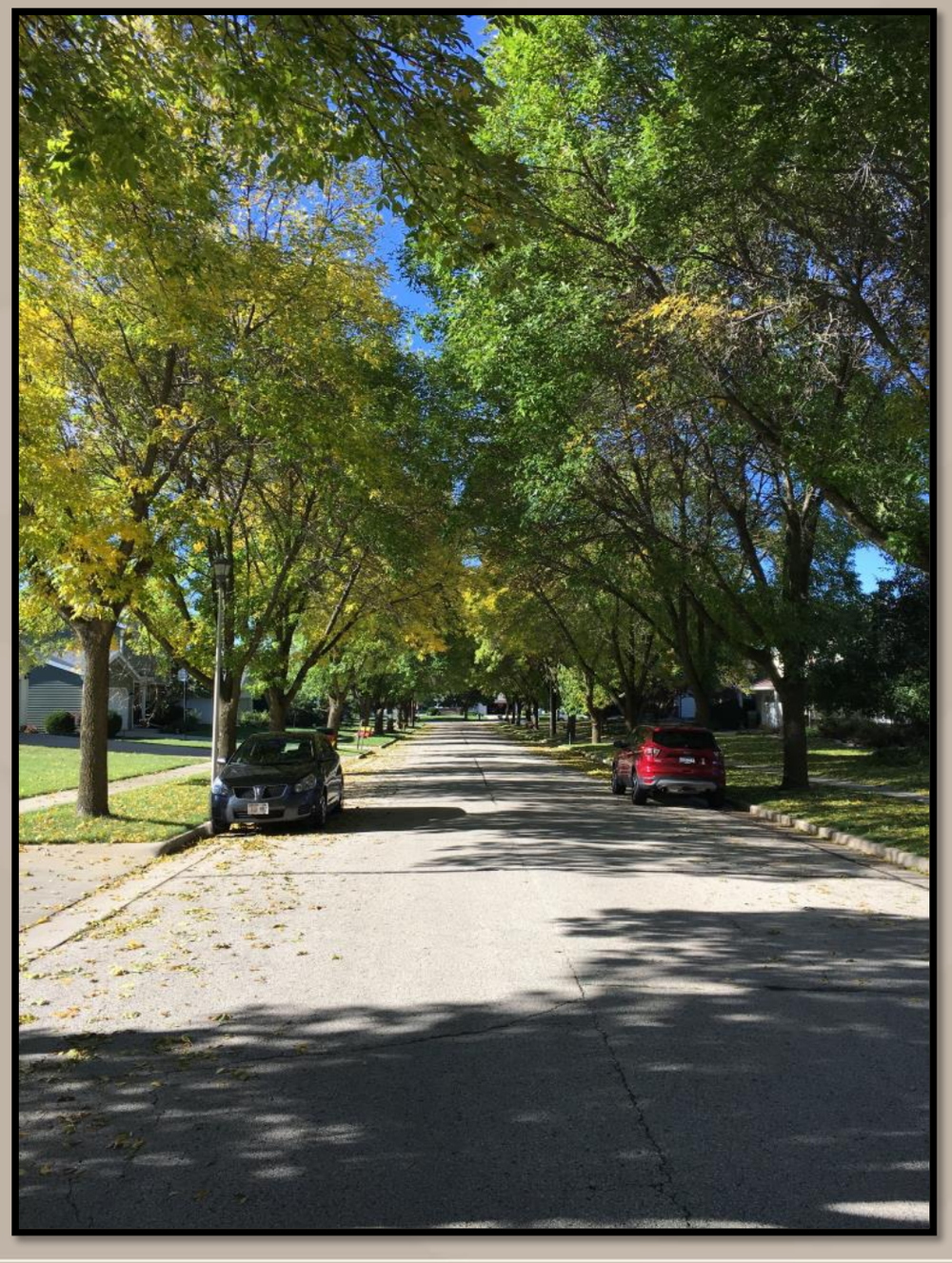
Funded through the Great Lakes Restoration Initiative

Runoff Reduction by Trees: Highly Variable and Difficult to Measure

Great Lakes RESTORATION

"The standard conversion factor of 59 gallons per tree per year and 18 gallons per tree seedling and shrub established will be used for purposes of review"

- Final report will use i-Tree or National Tree Benefit Calculator



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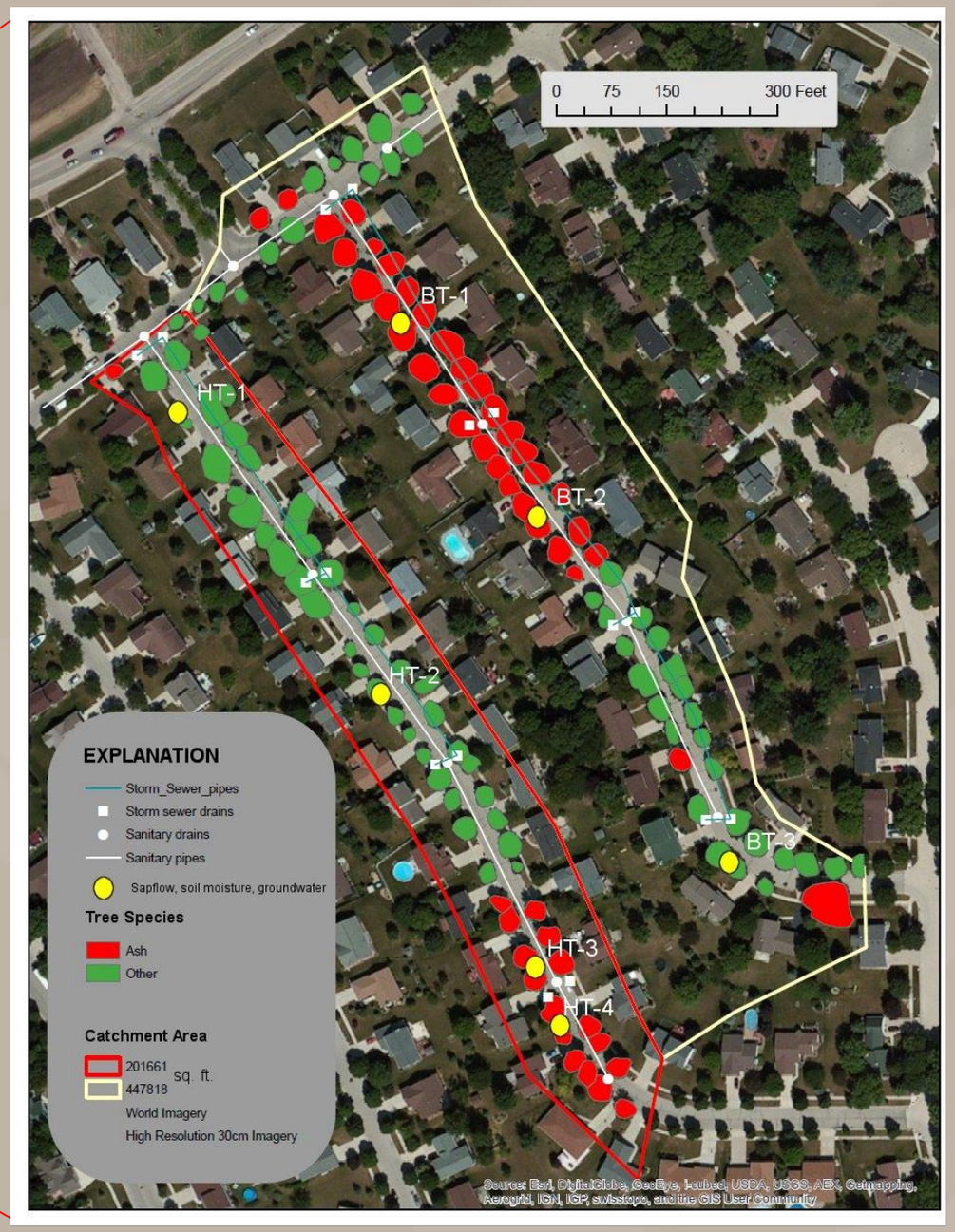
Great Lakes Restoration Initiative - Lake Michigan Drainage Basin

Fond du Lac, WI



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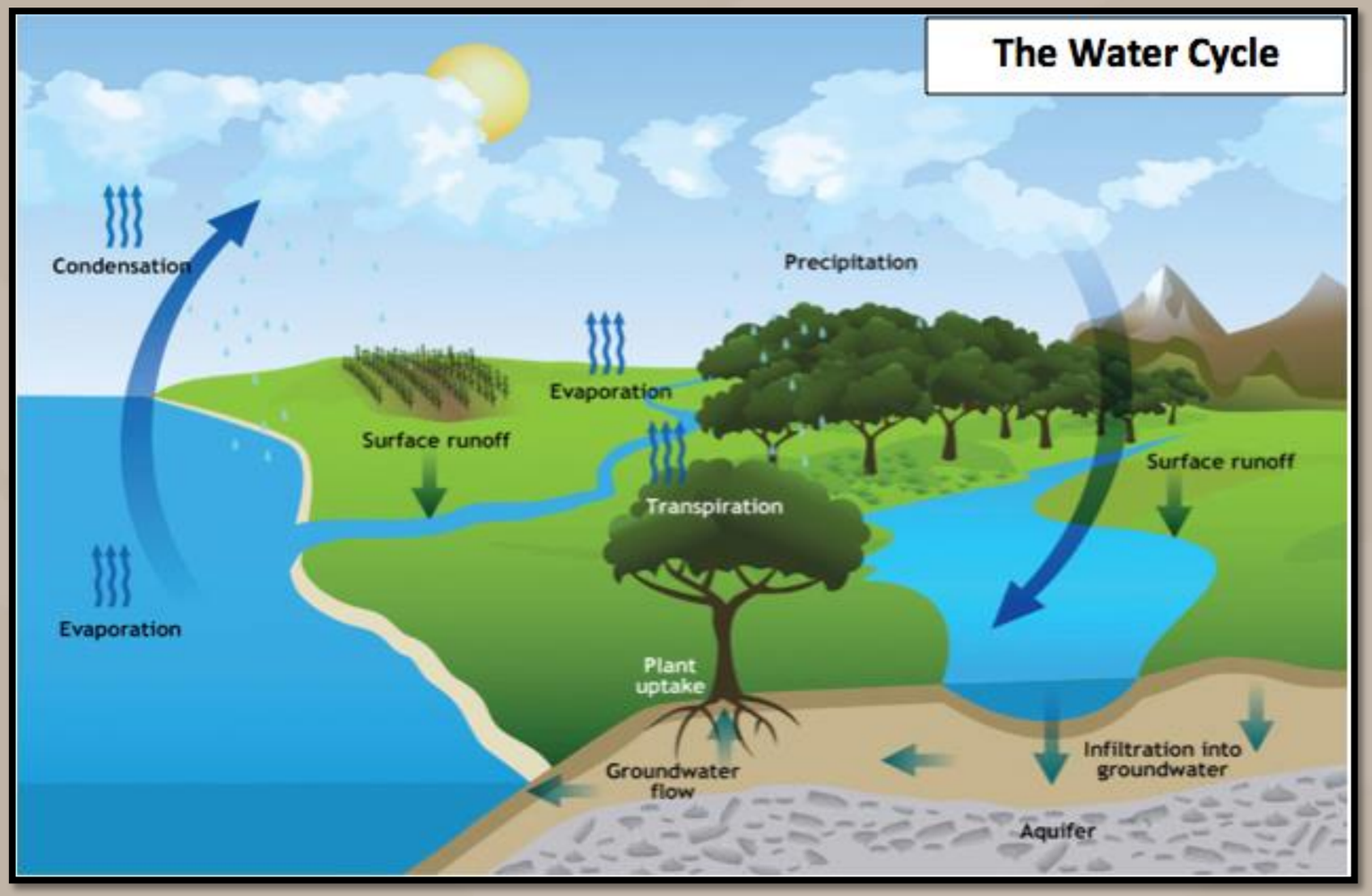
Study Design

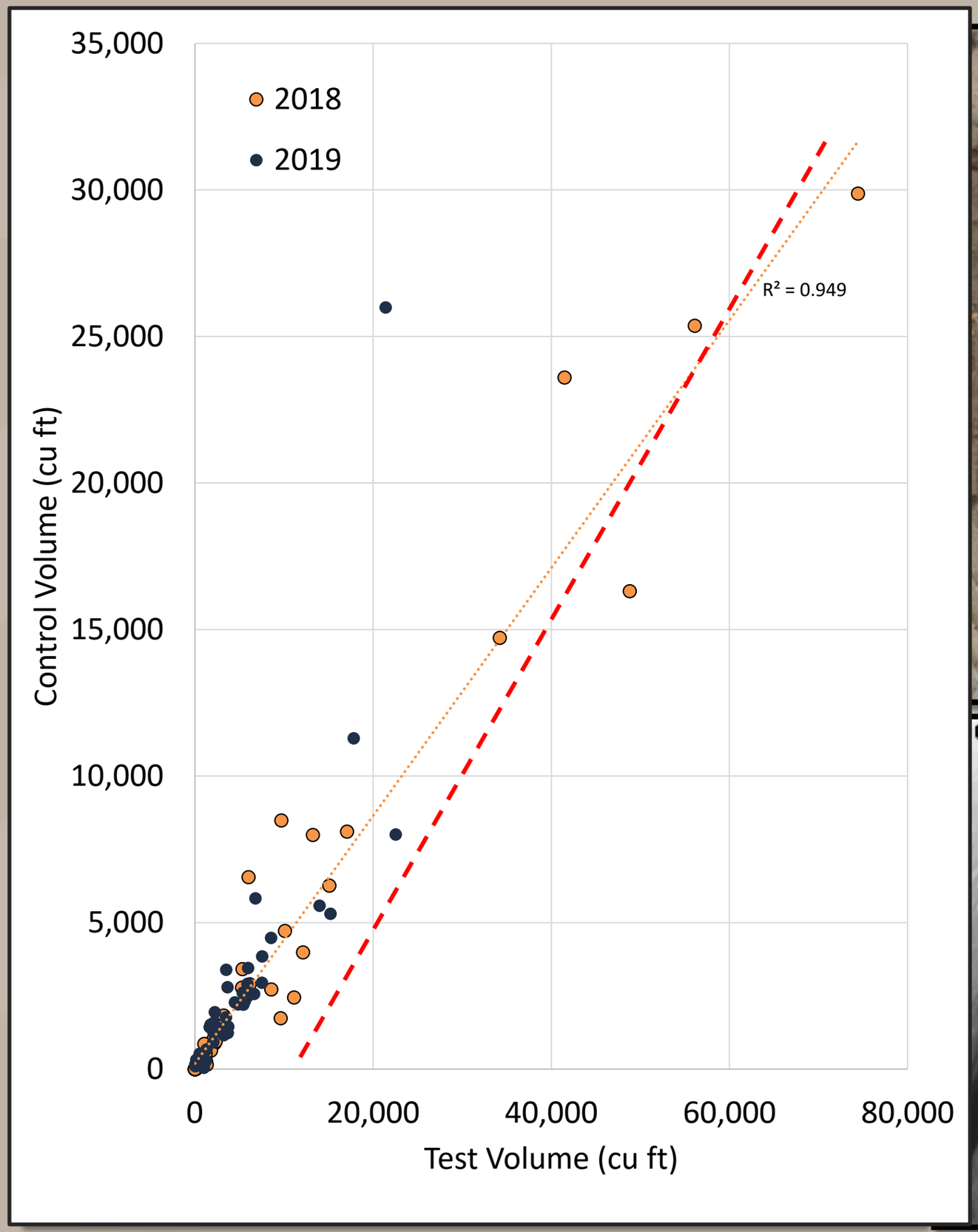
- Measure
  - **R**unoff
  - **P**recipitation
  - **E**vapotranspiration
  - **I**nfiltration
  - **S**torage

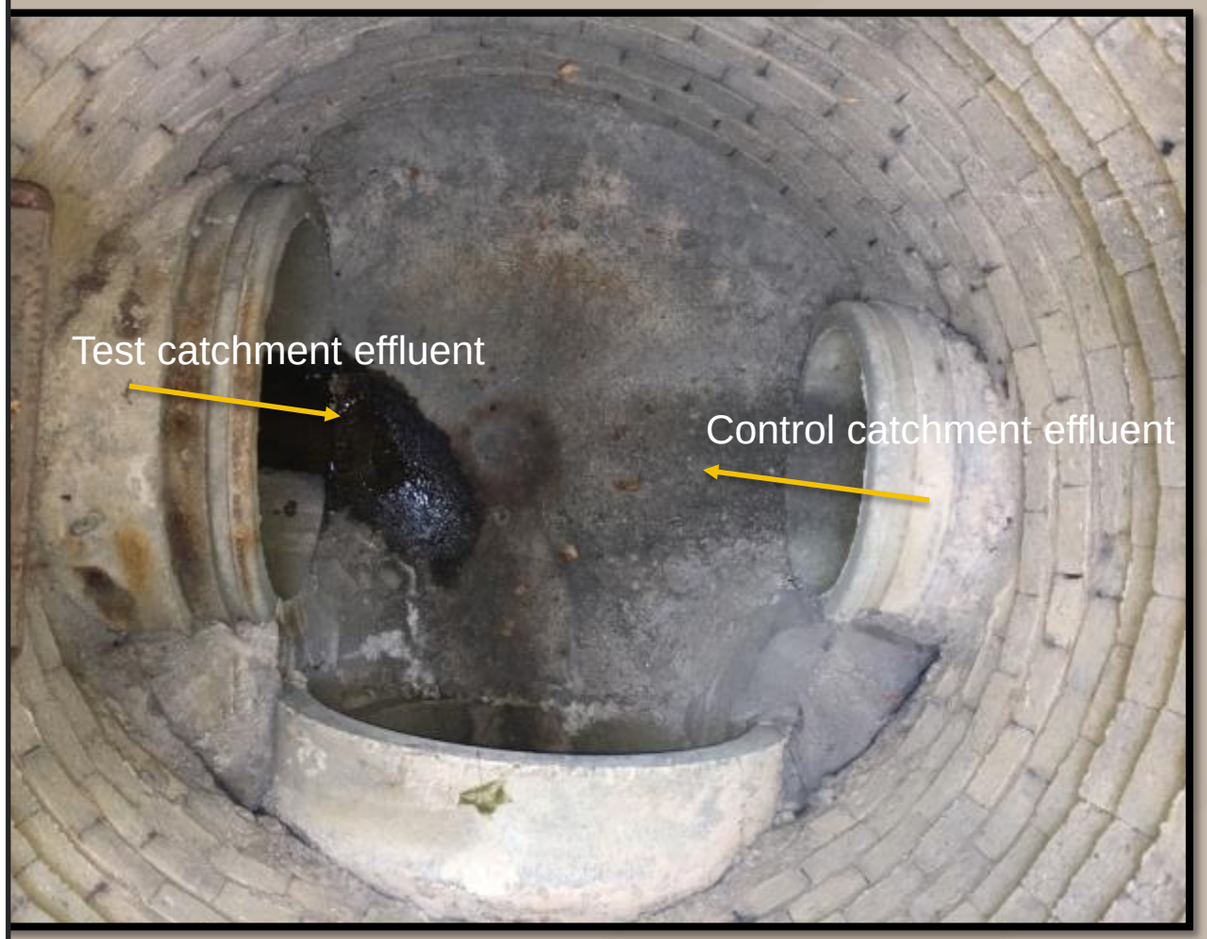


https://www.treesmatter.org/STBlog/3250197

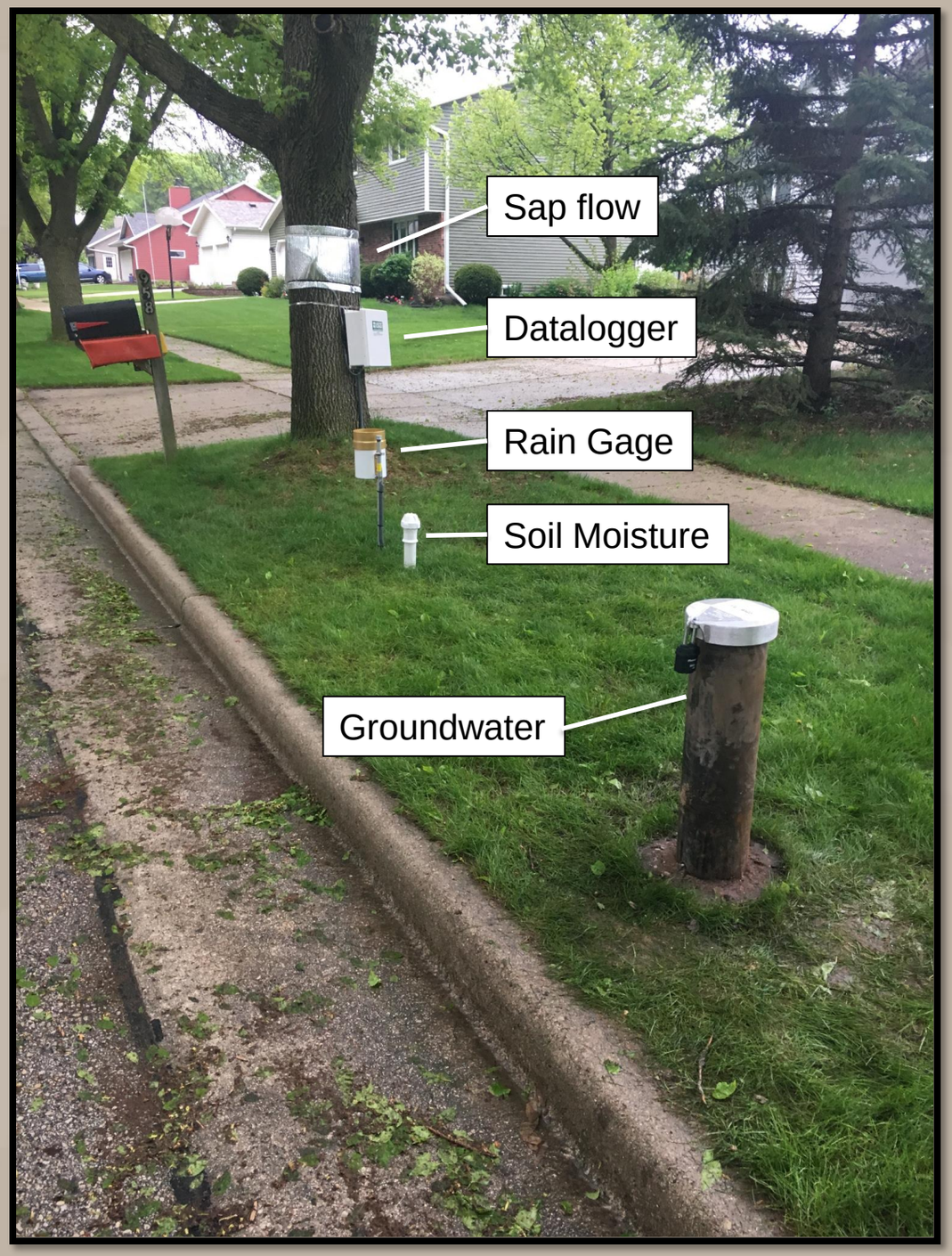
- Model
  - i-Tree Hydro

Surface Runoff

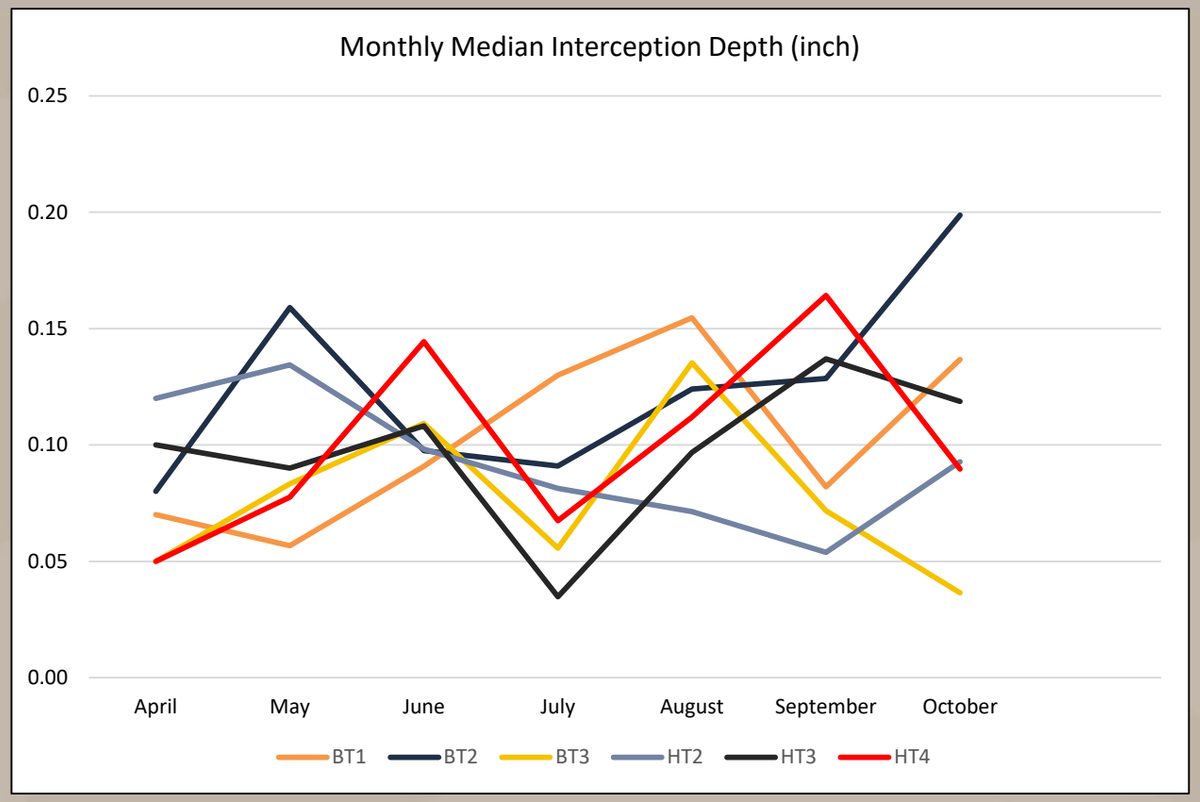


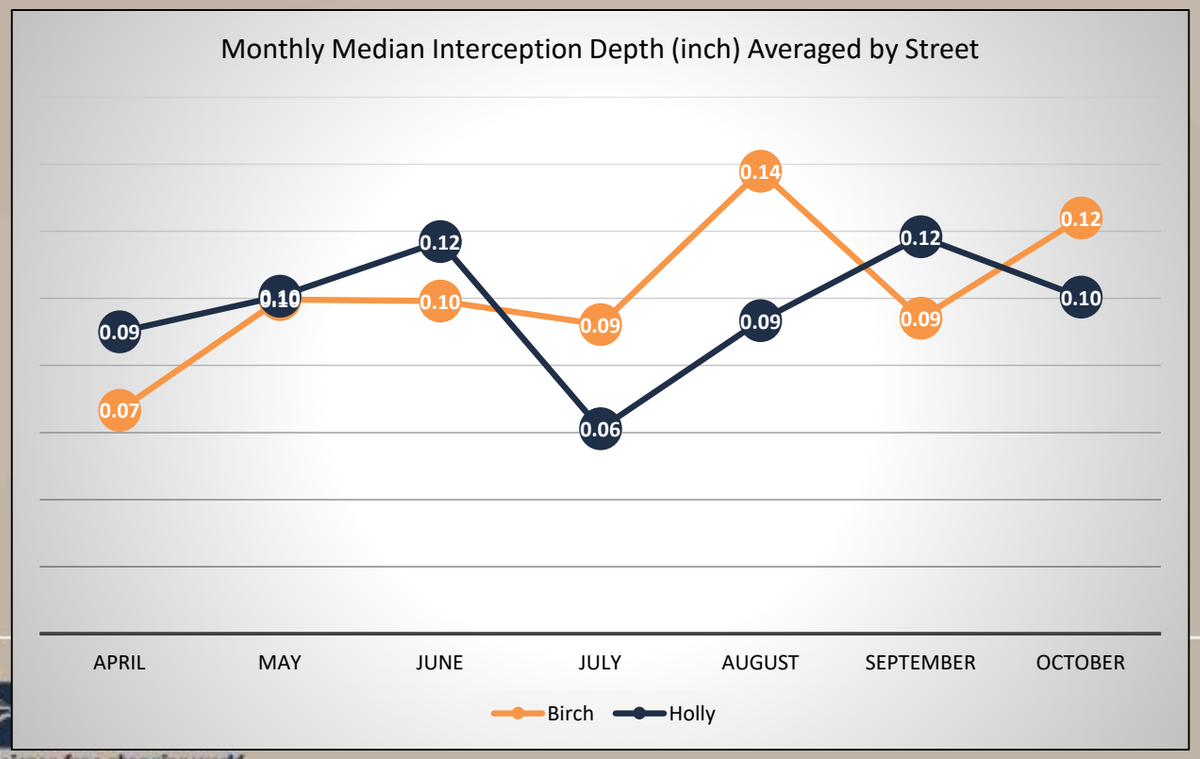


Aboricultural Hydrologic Parameters



Canopy Interception





Total Canopy Interception (inch)

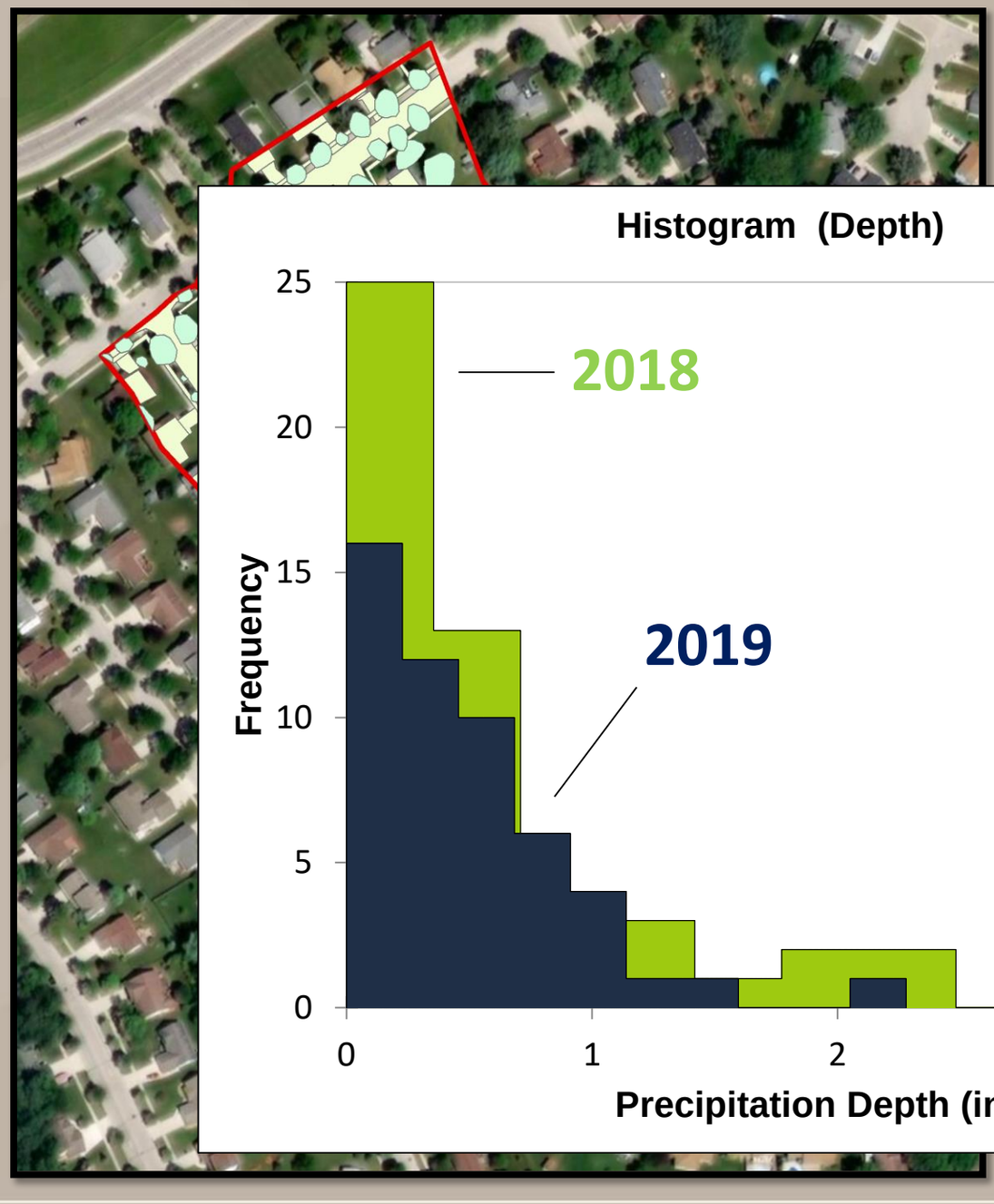
(averaged by catchment)

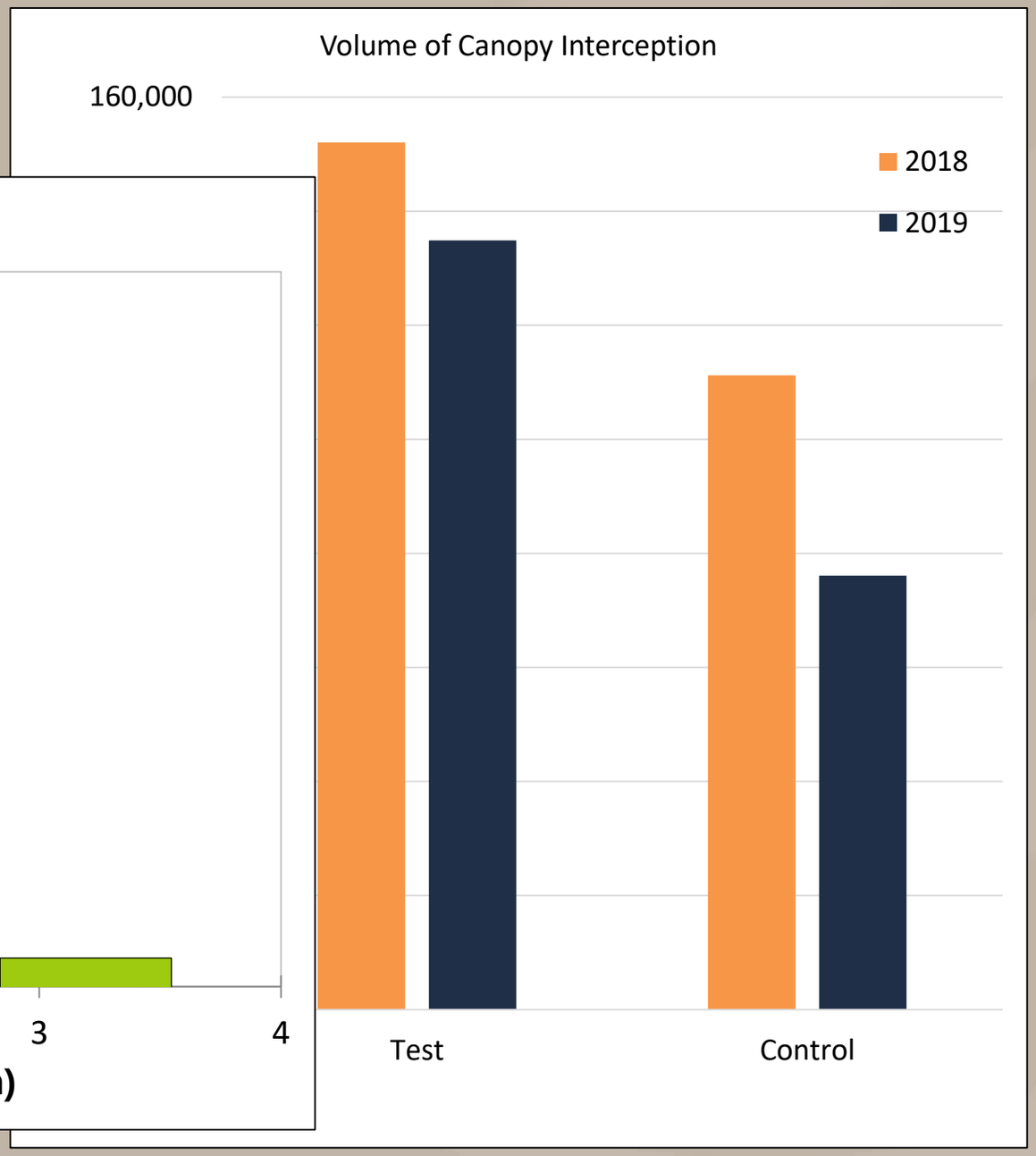
Year	Test	Control
2018 (May – Nov)	6.2	7.6
2019 (April – Sept)	5.5	5.2

Volume Reduction from Canopy Interception

	Test	Control
Canopy over impervious (ft^2)	39,340	23,475

	2018	2019
Total Rain (inches)	35	26
Interception (inches)	6-8	5-6





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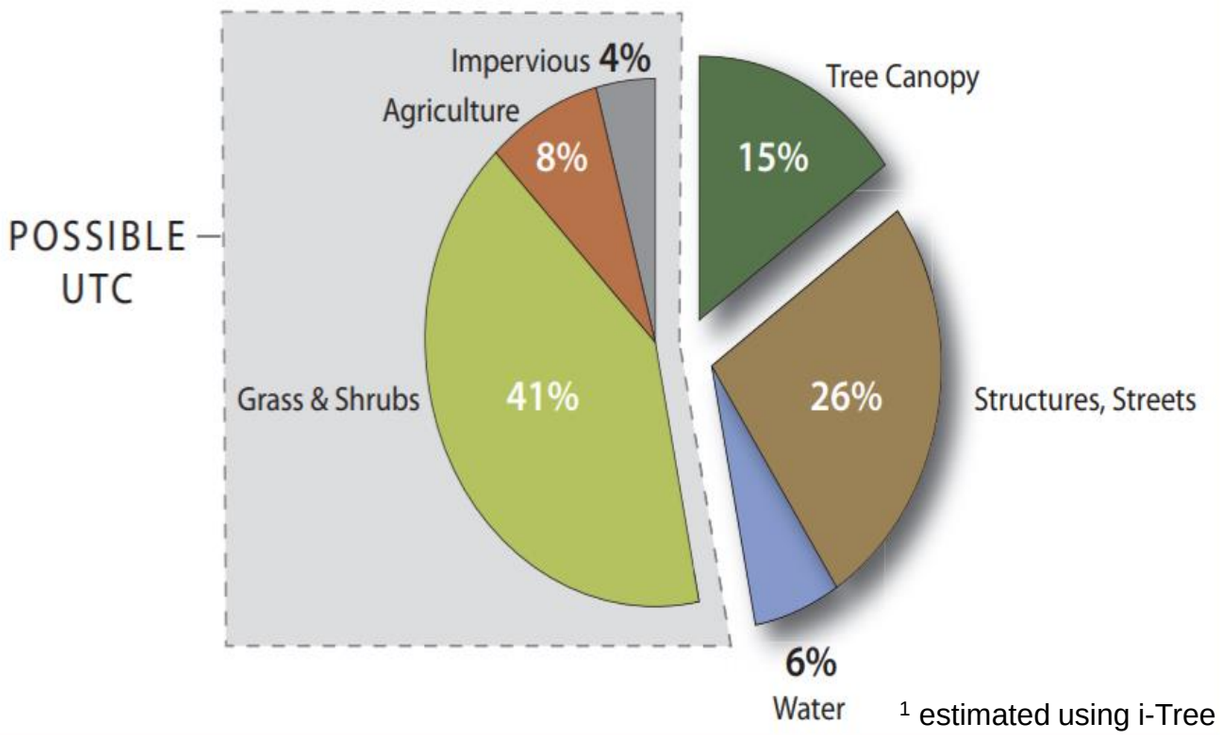
UTC analysis for Fond du Lac shows[1]:

- An existing tree canopy of 15% (1,991 acres)
- Trees could potentially cover an additional 53% (6,780 acres) of the city's land surface. These "Possible UTC" areas include grass, agriculture land, and impervious surfaces (e.g., parking lots, paved playgrounds & ROW).
- The remaining 32% (4,154 acres) of the city 's area is buildings, streets, water and other permanent features and is generally unsuited to UTC improvement.



[1] estimated using i-Tree

https://www.itreetools.org/resources/reports/WDNR_Fond_du_Lac_reports.pdf

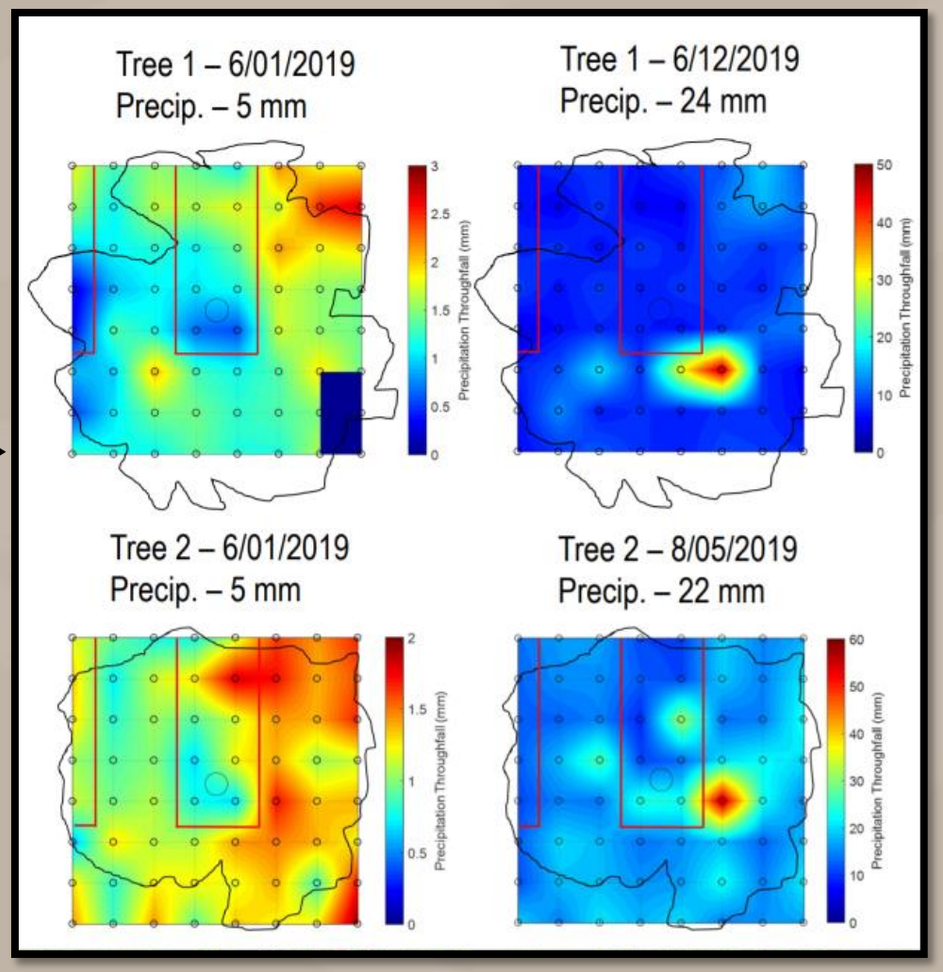
- Acres of tree canopy = 1,991
- Interception = 5 to 8 inches

270 to 435 million gallons

Canopy Interception and Throughfall (continued)

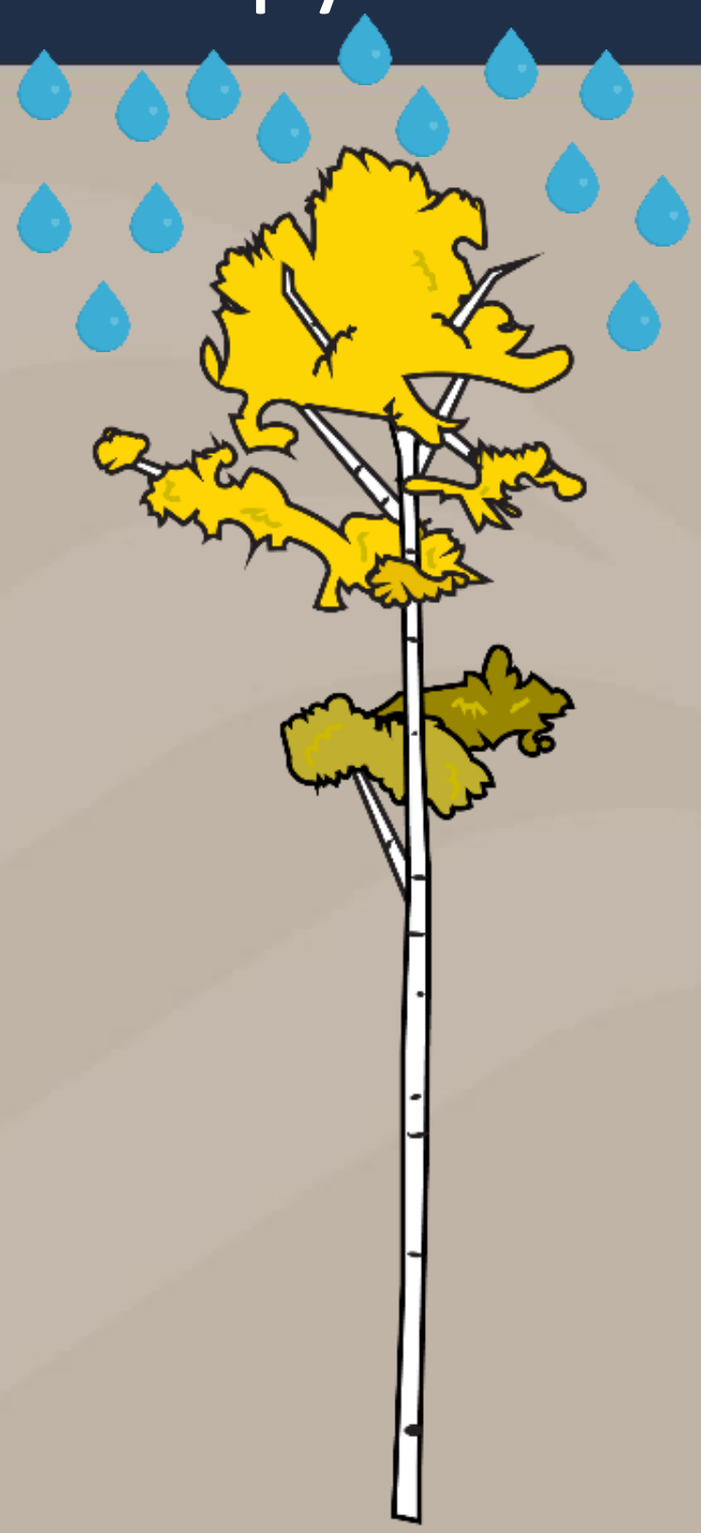
To explore how precipitation throughfall is distributed beneath the tree canopy, an experiment involving a grid of buckets is underway.

The intent is to see how canopy architecture is related to spatial heterogeneity of throughfall. This will be related to metrics of leaf density such as Leaf Area Index or Plant Area Index.



Source: William Avery, University of Wisconsin -Madison

Canopy Interception and Throughfall (continued)

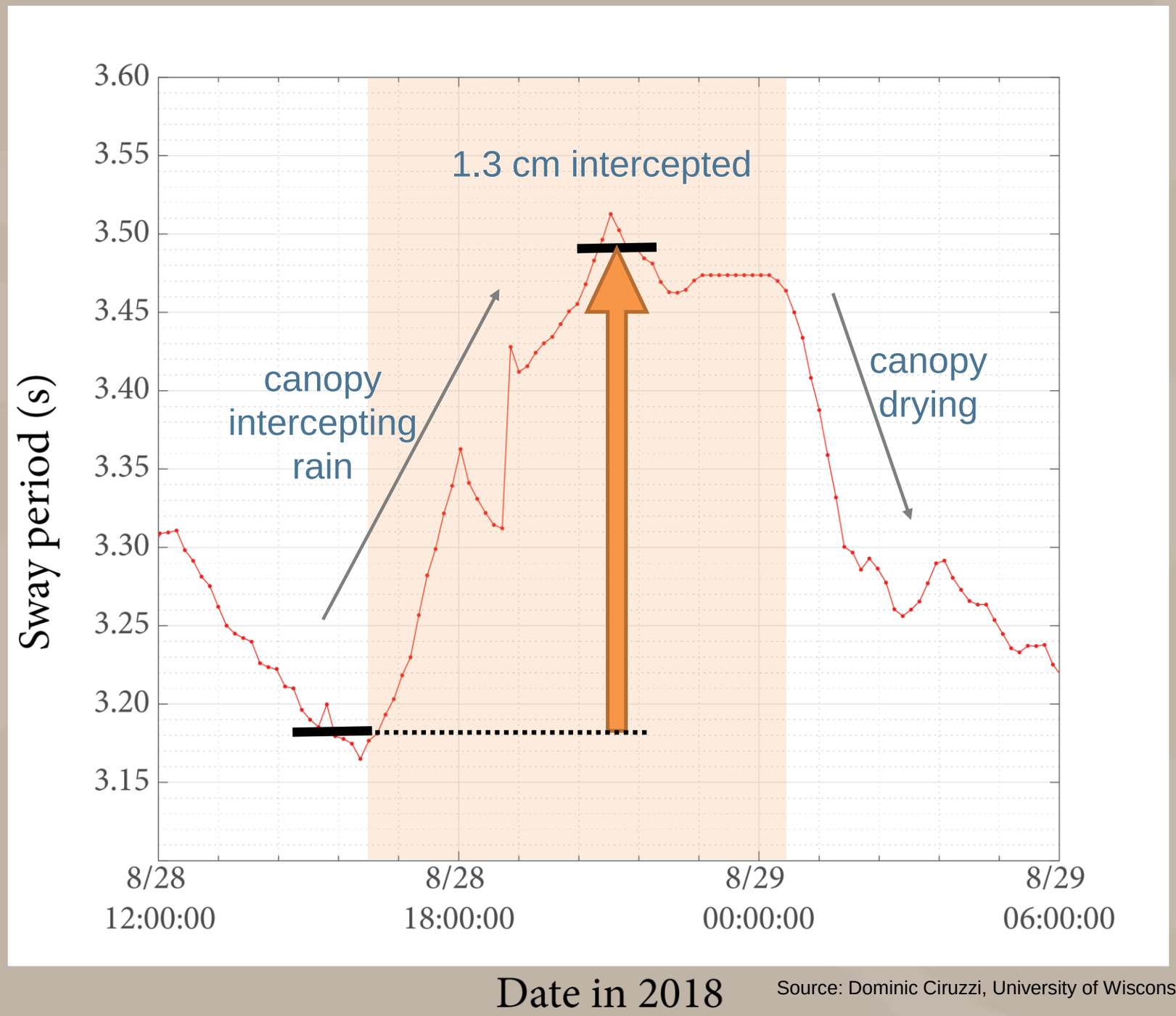


Canopy interception will **increase overall tree mass** and **increase the sway period**

$$\frac{M}{K} \propto T$$

Source: Dominic Ciruzzi, University of Wisconsin -Madison

Canopy Interception and Throughfall (continued)



Source: Dominic Ciruzzi, University of Wisconsin -Madison

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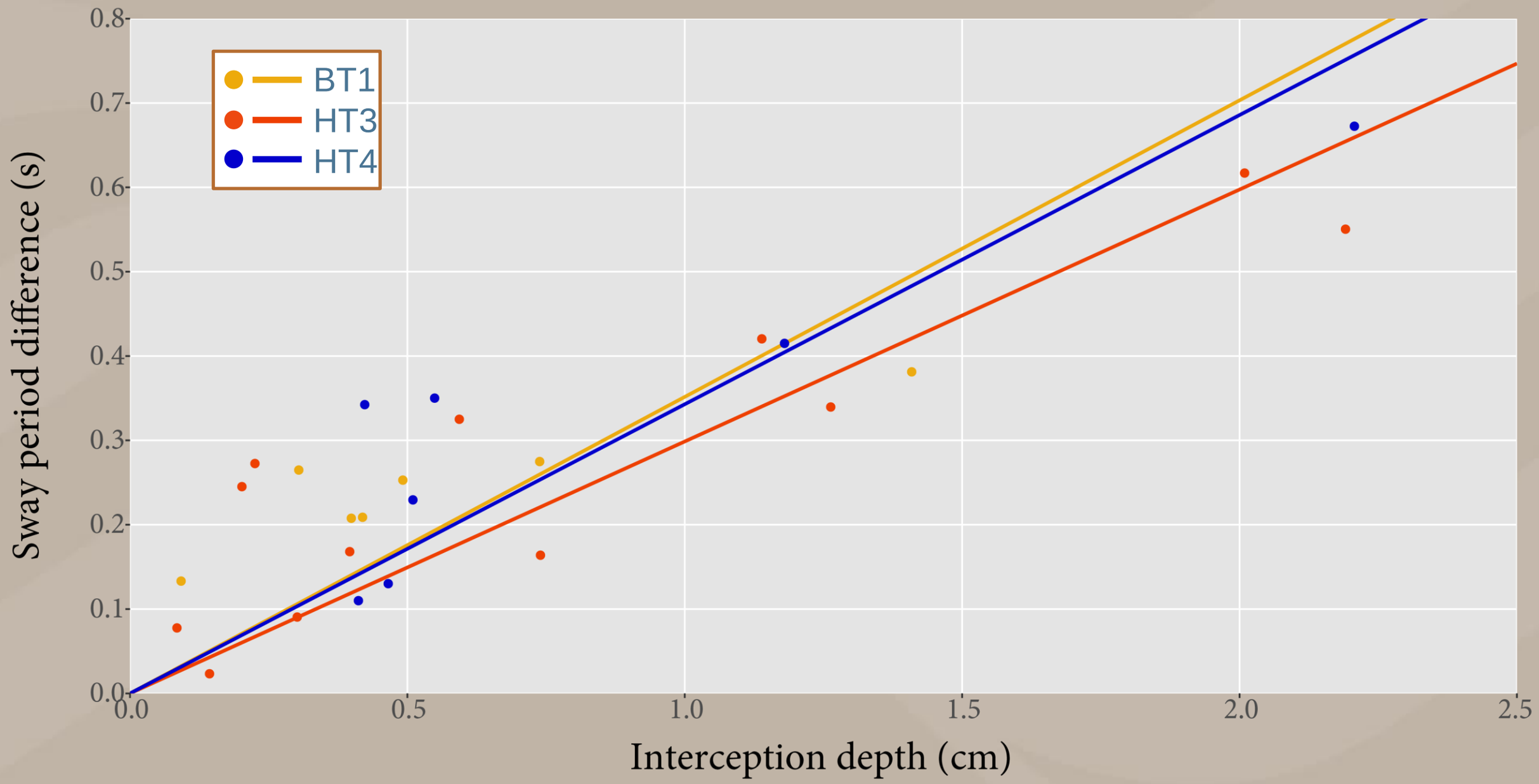
Canopy Interception and Throughfall (continued)

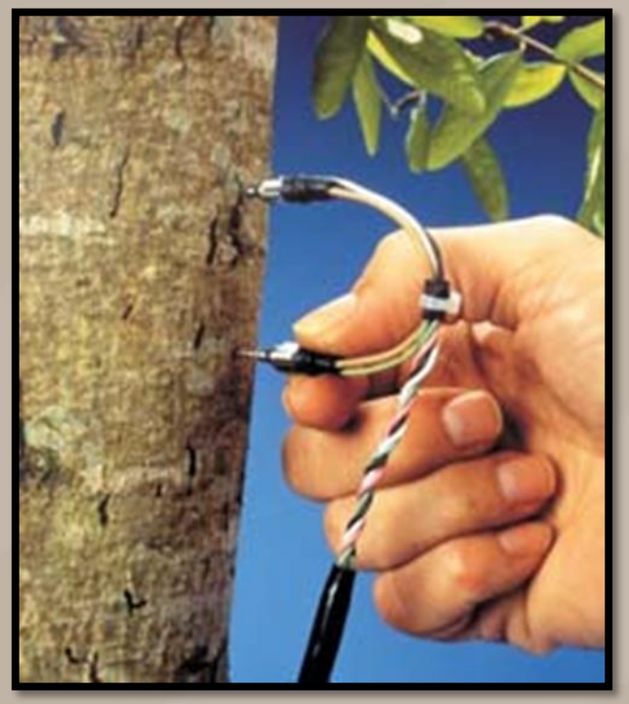


Source: Dominic Ciruzzi, University of Wisconsin -Madison

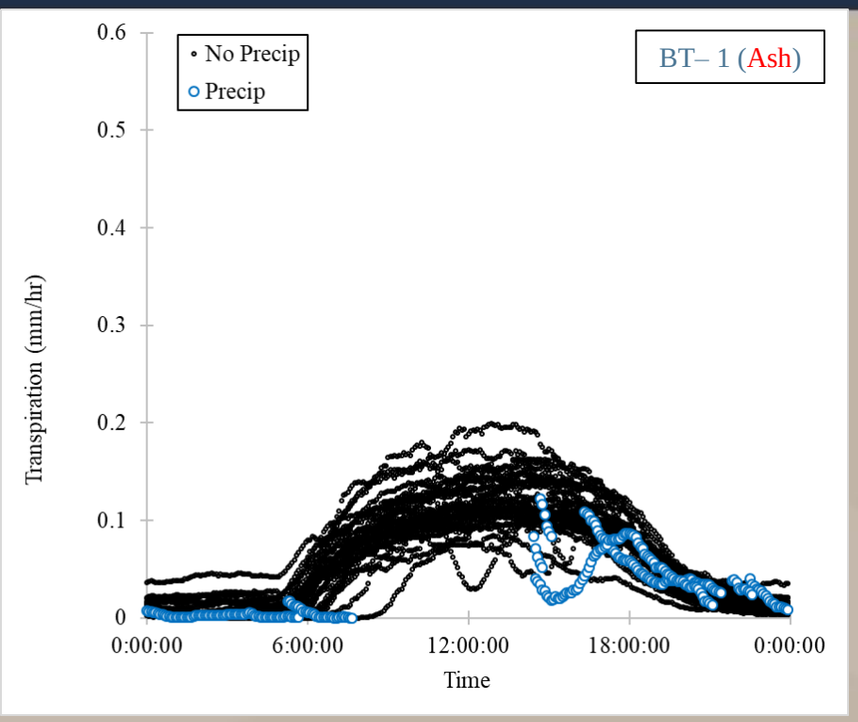
Source: Dominic Ciruzzi

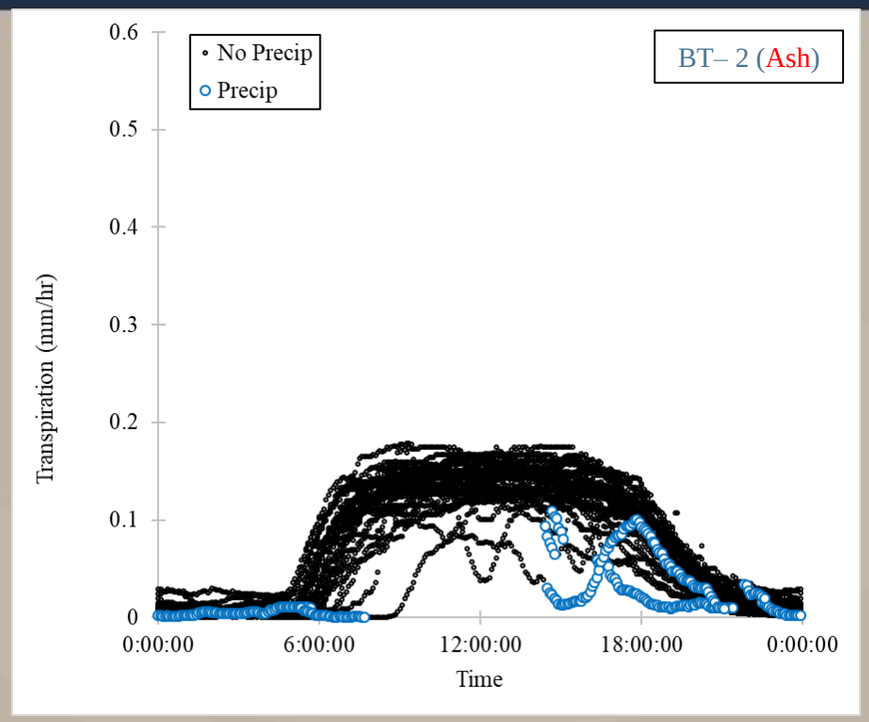
Aboricultural Water Consumption

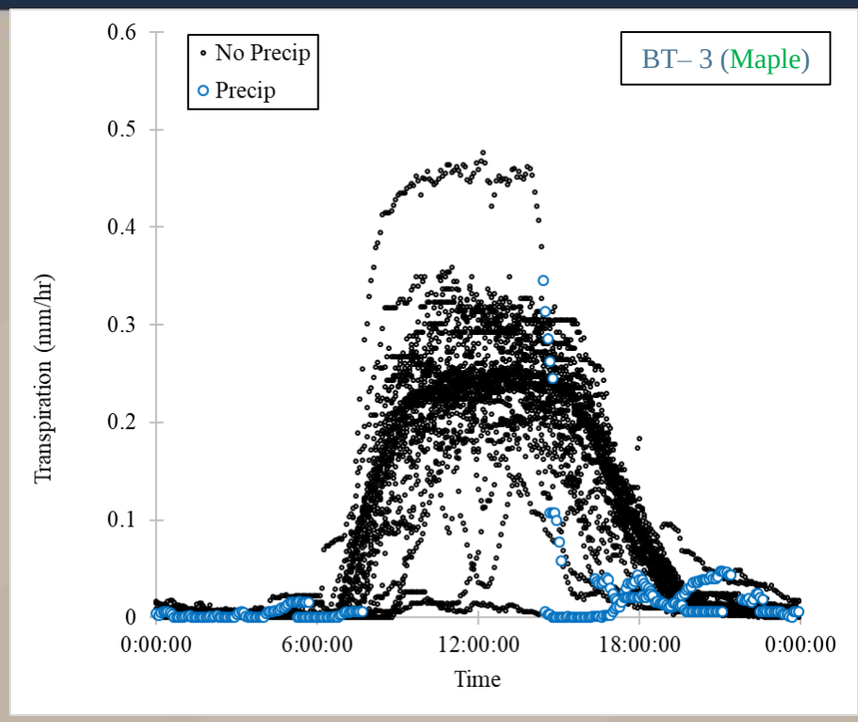
Sap flow sensors

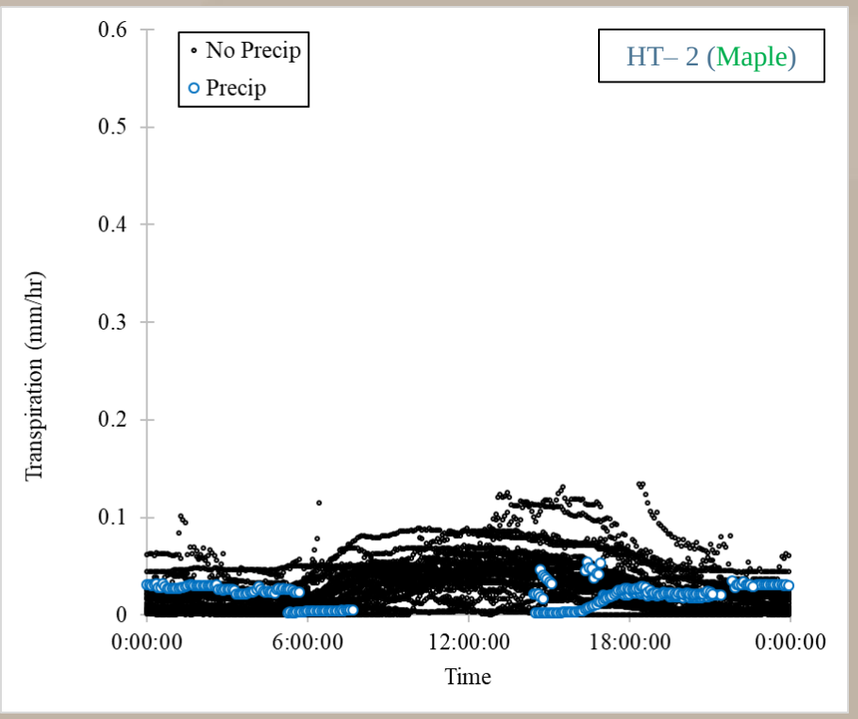


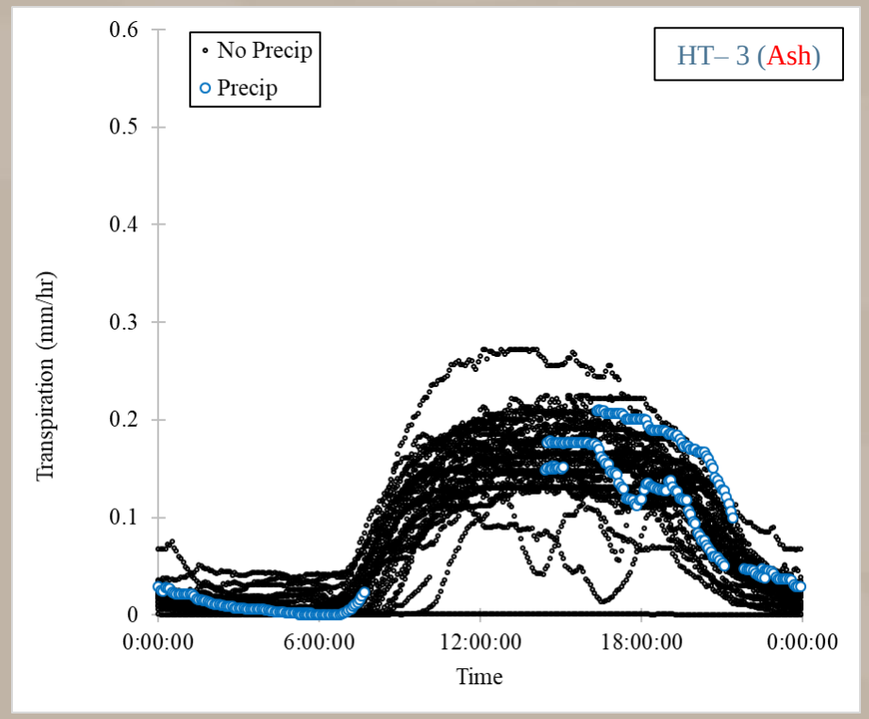
By measuring the ratio of heat transported between two symmetrically placed temperature sensors, the magnitude and direction of water flux can be calculated

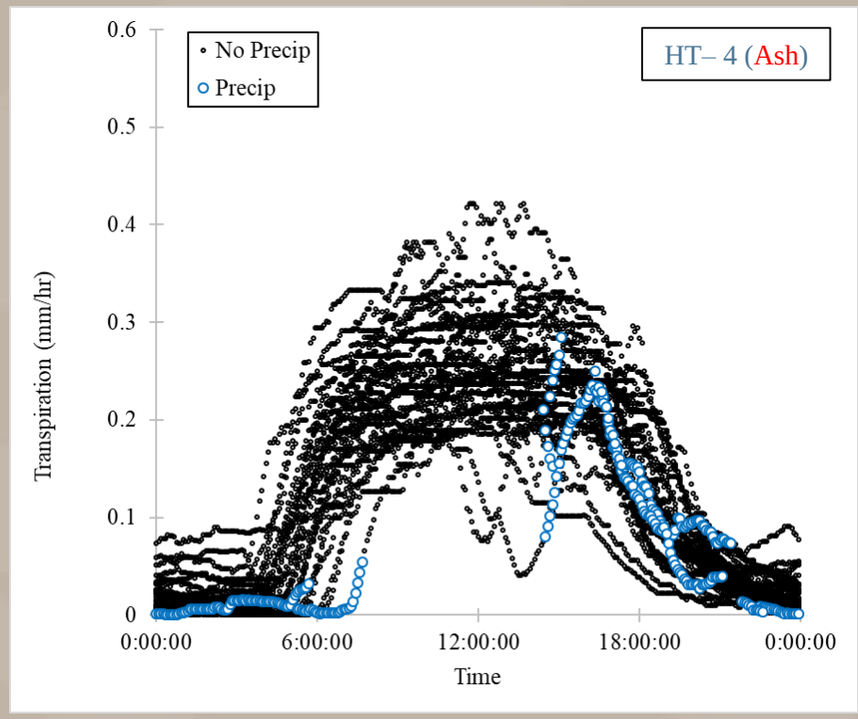












Source: William Avery

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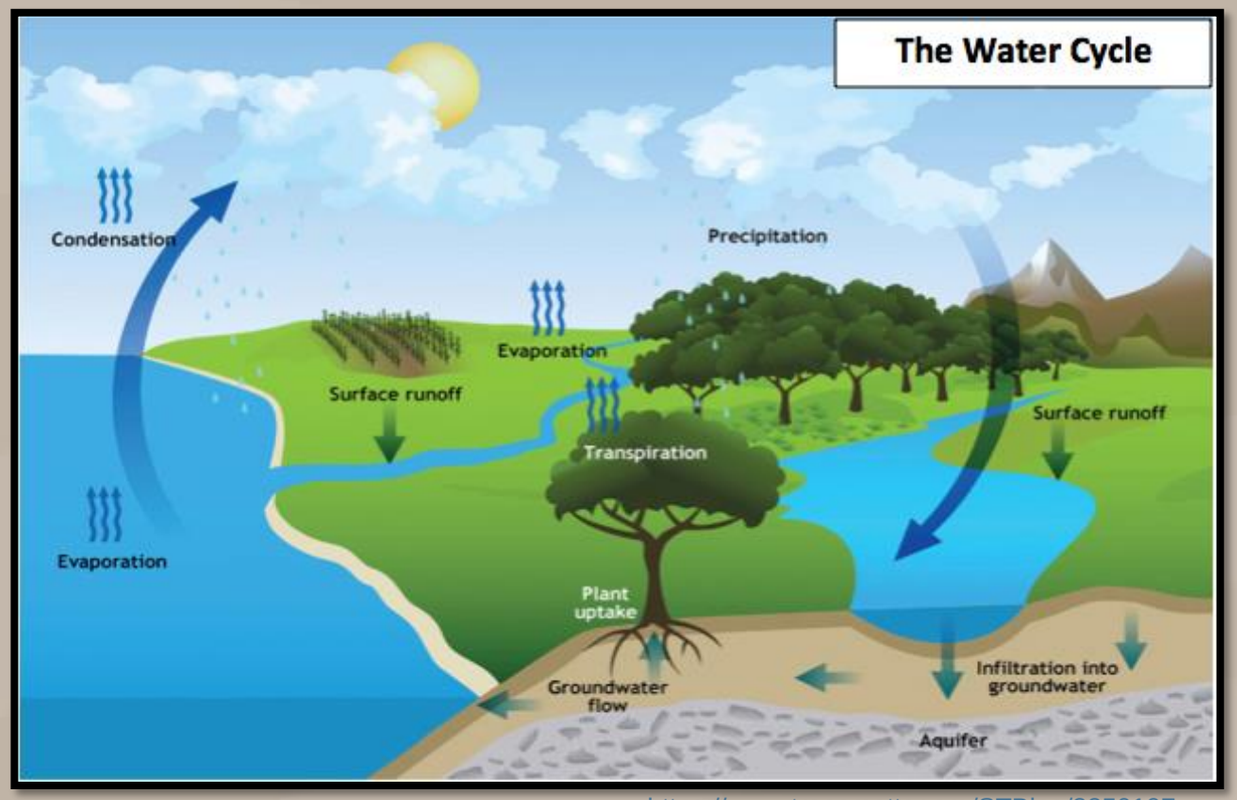
Estimated Water Balance



https://www.treesmatter.org/STBlog/3250197

Preliminary estimates of the water balance show canopy similarities between the Control and Test catchments. This relation is anticipated to change once Green Ash trees are removed from the Test catchment in 2020.

2018

Variable (May – Nov, 2018)	CONTROL (ft^3)	% of Total	TEST (ft^3)	% of Total
Precip.	659,183		1,378,046	
Runoff	204,429	31%	438,964	32%
$Storage_{Canopy}$	34,420	5%	66,945	5%
ET_{open}	161,810	25%	426,484	31%
ET_{shaded}	92,595	14%	244,053	18%
Infilt. + $Storage_{other}$	165,929	25%	201,600	14%

2019

Variable (April – Sept., 2019)	CONTROL (ft^3)	% of Total	TEST (ft^3)	% of Total
Precip.	473,970		990,852	
Runoff	98,338	21%	200,283	20%
$Storage_{Canopy}$	23,582	5%	59,193	6%
ET_{open}	137,004	29%	361,103	36%
ET_{shaded}	39,150	8%	113,173	11%
Infilt. + $Storage_{other}$	175,896	37%	257,100	27%

U.S. Forest Service: i-Tree Modeling

- Calibrate i-Tree Hydro using hyperlocal weather and discharge data
- Simulate discharge with and without tree cover
- Validate model predictions with post-tree removal discharge observations
- Assess performance and identify necessary improvements to i-Tree

Figure 1. GIS assessment of land cover

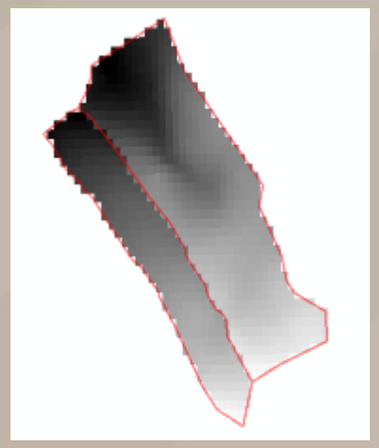


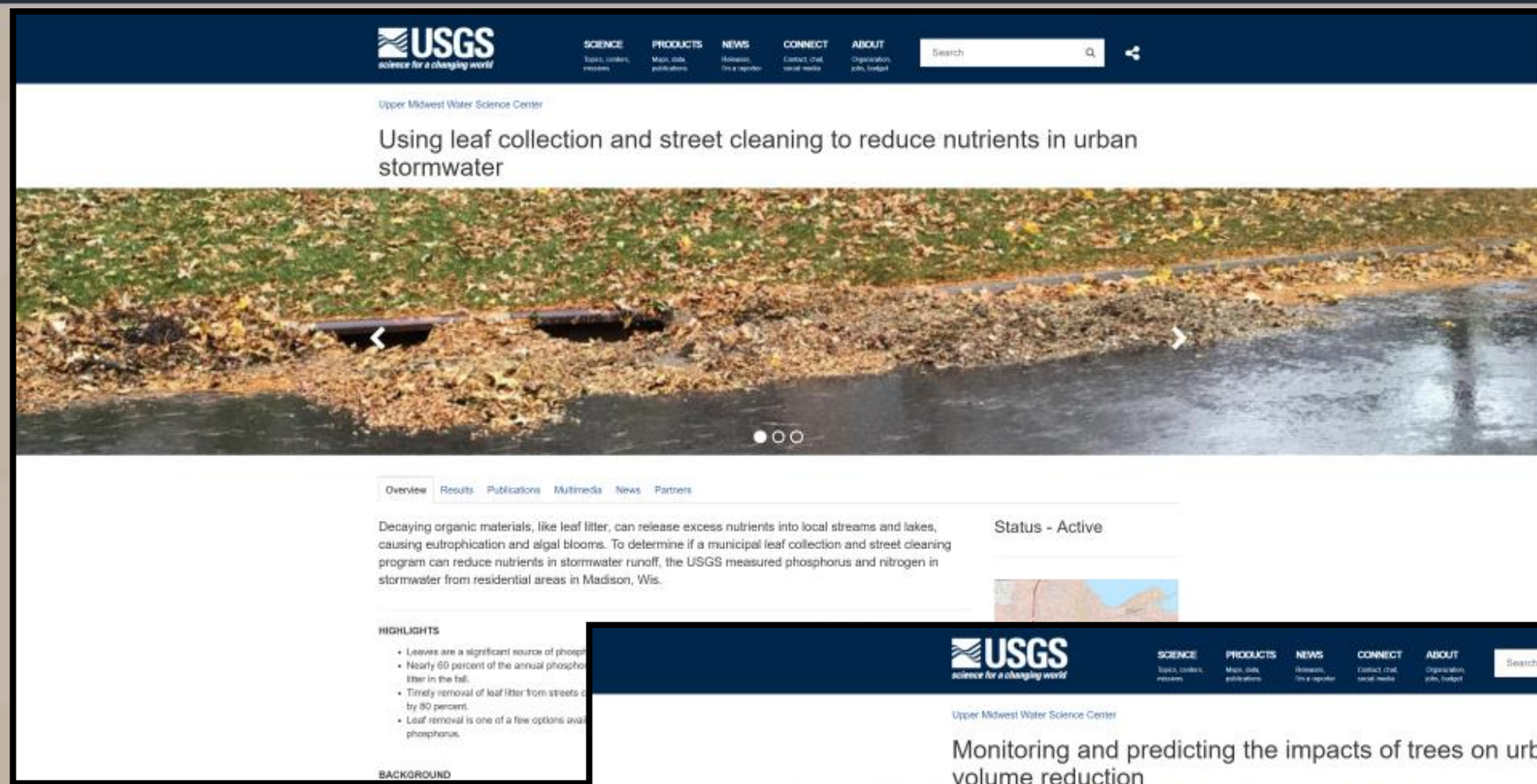
Figure 2. GIS assessment of topography

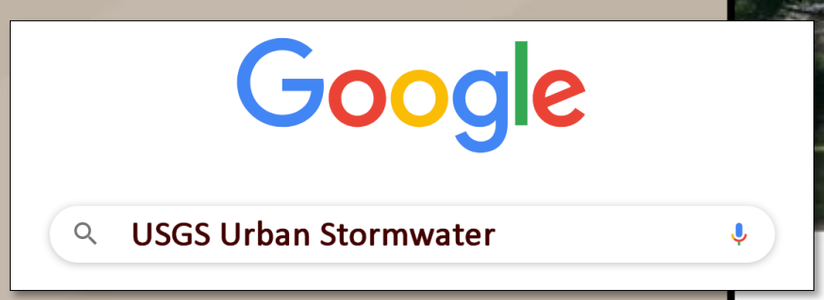
Table 1. Preliminary estimate of change in surface runoff with loss of trees

Basin Name	Preliminary Estimate of Change in Runoff if All Trees are Removed [a]
Holly Tree lane Basin	+93.5 m^3 (+1.32% of base case surface runoff)
Birch Tree Lane Basin	+186.7 m^3 (+1.36% of base case surface runoff)

[a] Difference in surface runoff if current tree canopy % in each area is converted to the land cover that was beneath that canopy, either herbaceous or impervious cover.

For more information: wrselbig@usgs.gov





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