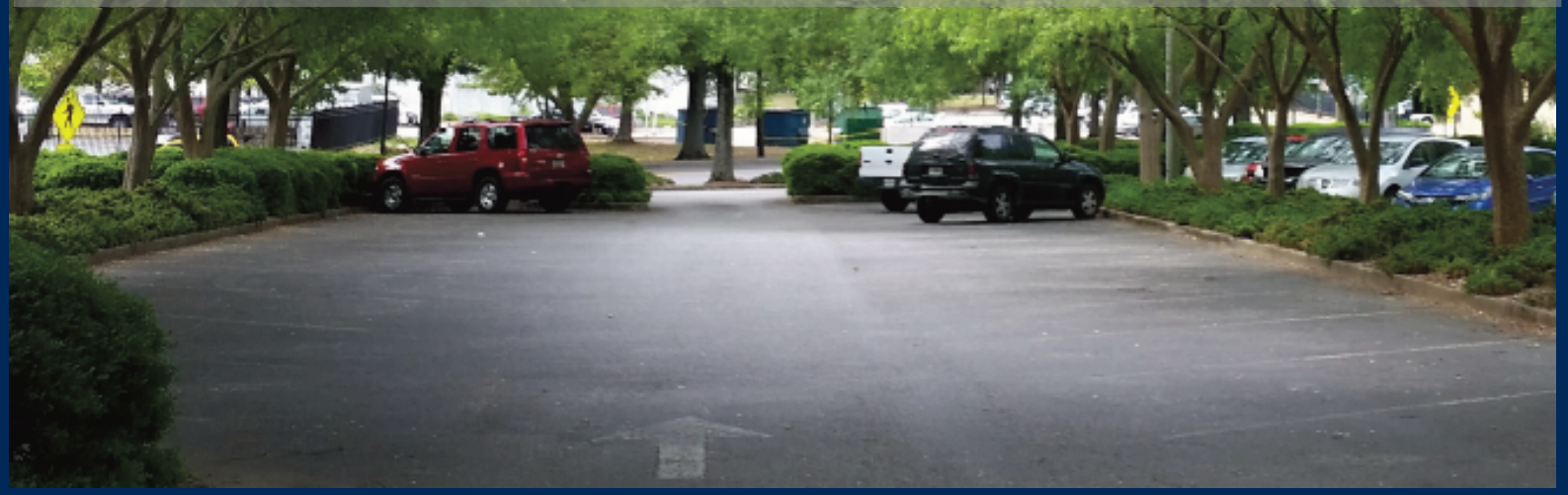
Calculating Stormwater Volume & TSS Reduction under Urban Tree Canopy in Wisconsin using Available Research



WAFSCM 2018 Annual Conference

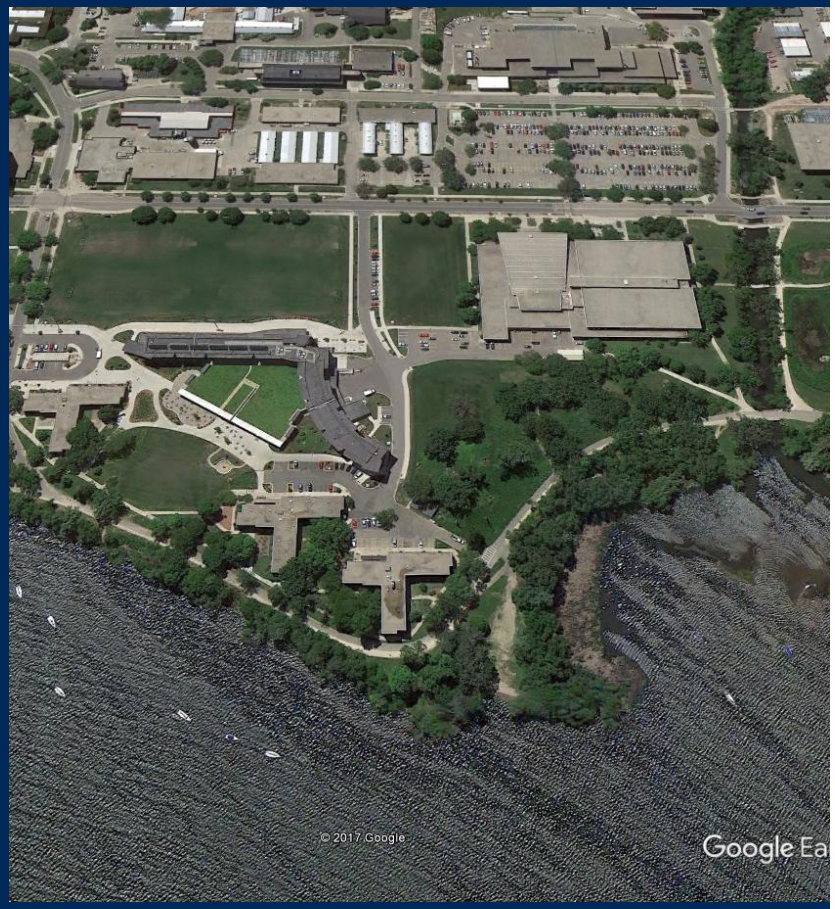
November 8, 2018

Steve Gaffield & Dane Wudel

www.ma-rs.org

Project Overview

- UW-Madison redevelopment stormwater study
- Lake flooding concern
- Ambitious stormwater volume control goal
  - Maintain native vegetation runoff
- TSS control driven by MS4 permit & TMDL



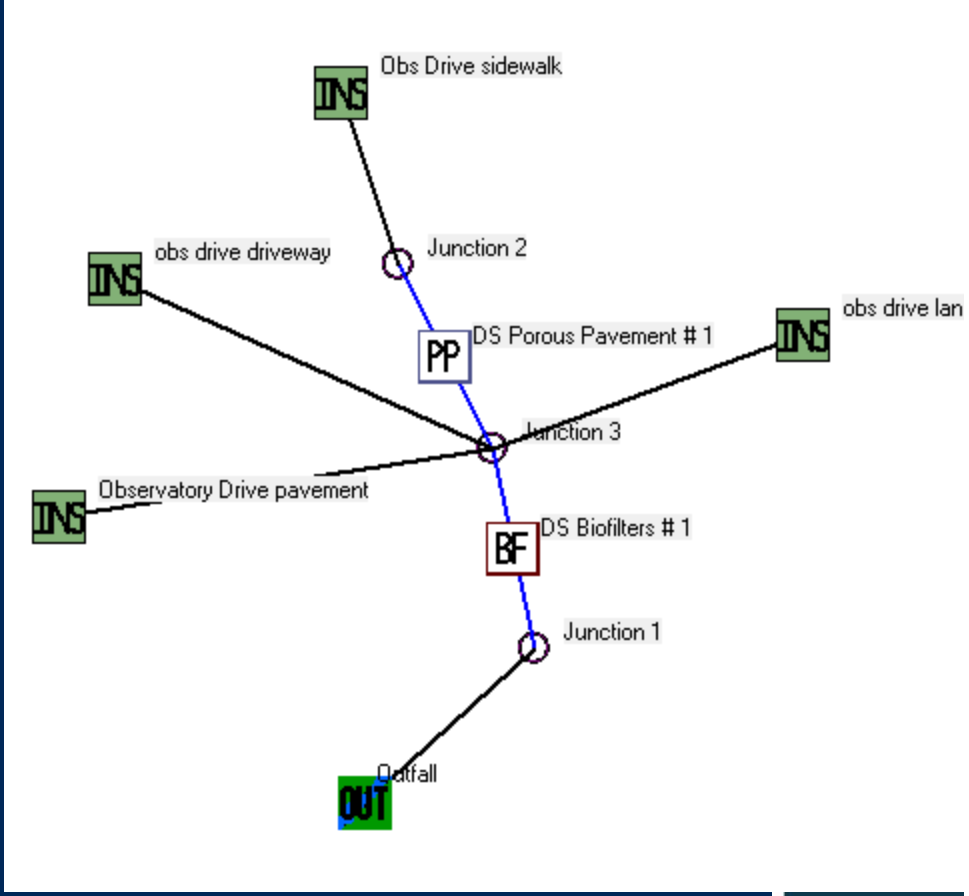
Green Infrastructure Approach

Chicago Center for Green Technology

- Bioretention
- Permeable pavement
- Green roofs
- Underground storage
- Rainfall harvesting & reuse
- Native landscaping
- Trees?

WinSLAMM Model

- Requested by UW
- Compatible with other campus work
- Rainfall-runoff-pollutant loading model
- Widespread use & regulatory acceptance in Wisconsin
- Doesn't model trees



Tree Canopy Interception

- Throughfall: hits ground below canopy
- Stemflow: flows down branches & trunks
- Interception: retained on leaves, branches & trunks

- Also: roots affect soil infiltration

National Interest in Urban Trees

- CWP & American Forests proposed stormwater credits
- USGS Wisconsin work on phosphorus export
- USGS & UW monitoring in Fond du Lac
- University research

Center for Watershed Protection

December 2017

CENTER FOR WATERSHED PROTECTION

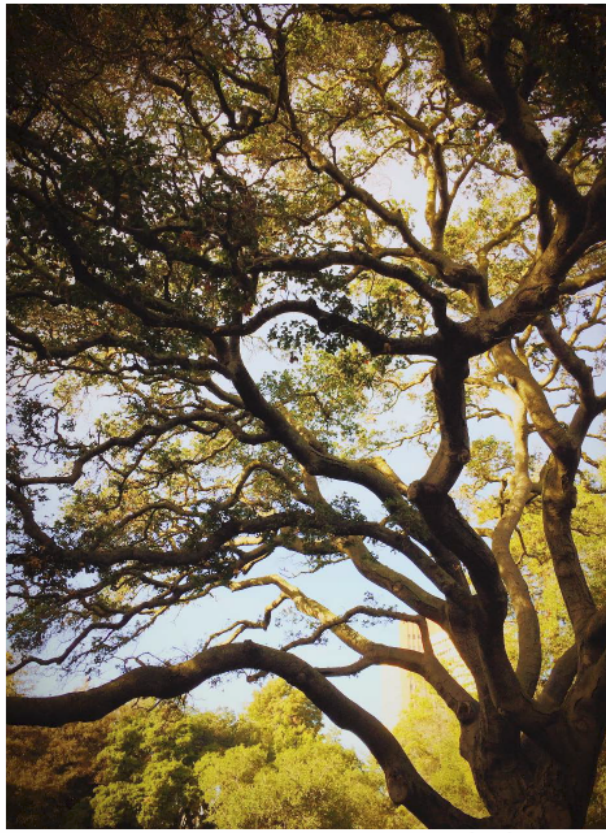


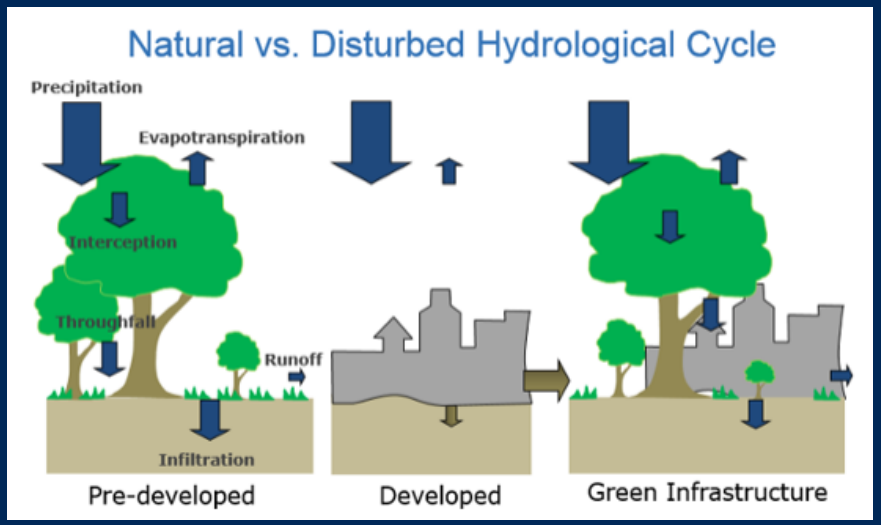
Photo by Victor Zam

CREDITING FRAMEWORK PRODUCT #1:

Literature Review

Limited Modeling Tools

www.itreetools.org/hydro



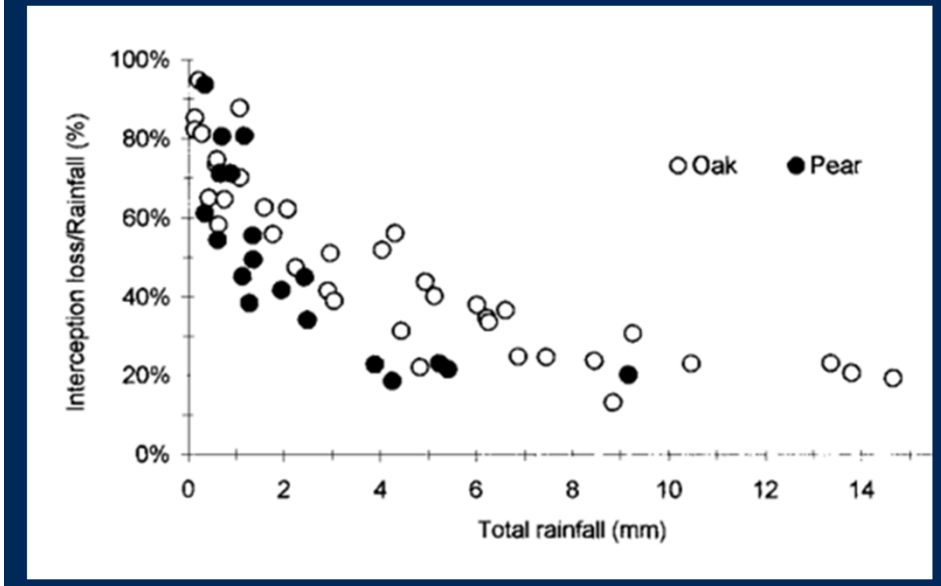
- US Forest Service (iTree)
  - Urban watershed scale
  - Predicts streamflow & water quality
- CWP credit calculator
  - Curve Number method
  - Annual runoff & loads
- Not site design tools

Tree Modeling Approach

- Proof-of-concept
- Integrate with SLAMM
- Modify rainfall input to simulate canopy interception
- Change in soil & runoff generation not simulated

(USEPA, 2016)

Tree Canopy Interception

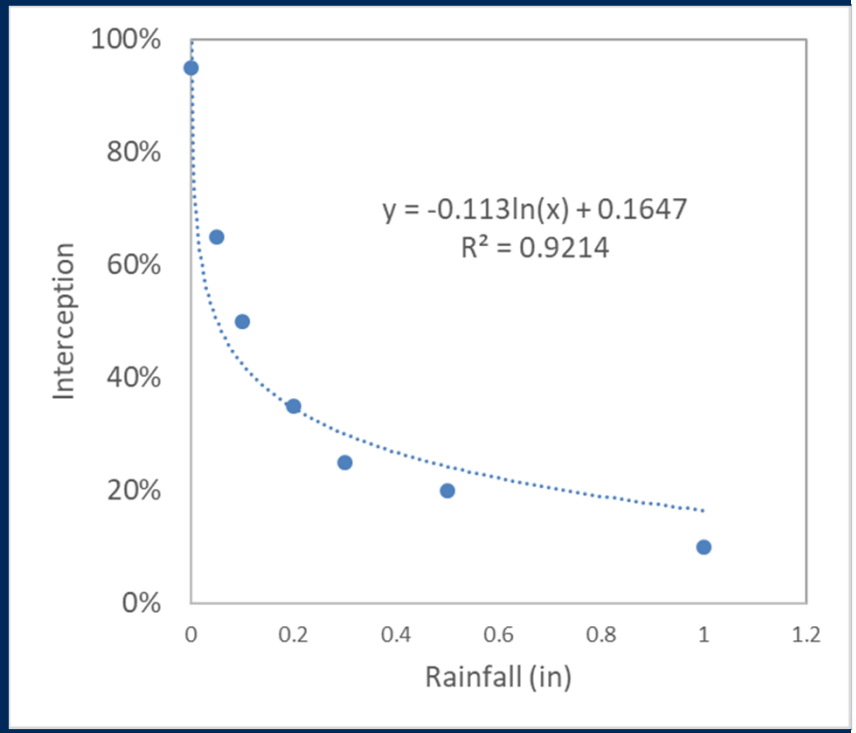


(Xiao et al., 2000)

- Monitoring data from California study
- No Wisconsin data
- Literature indicates interception increases with rainfall

Modeling Interception

- Regression based on Xiao data
- Similar relationship in Belgian study (Staelens et al. 2007)
- Seasonal weighting for leaf growth

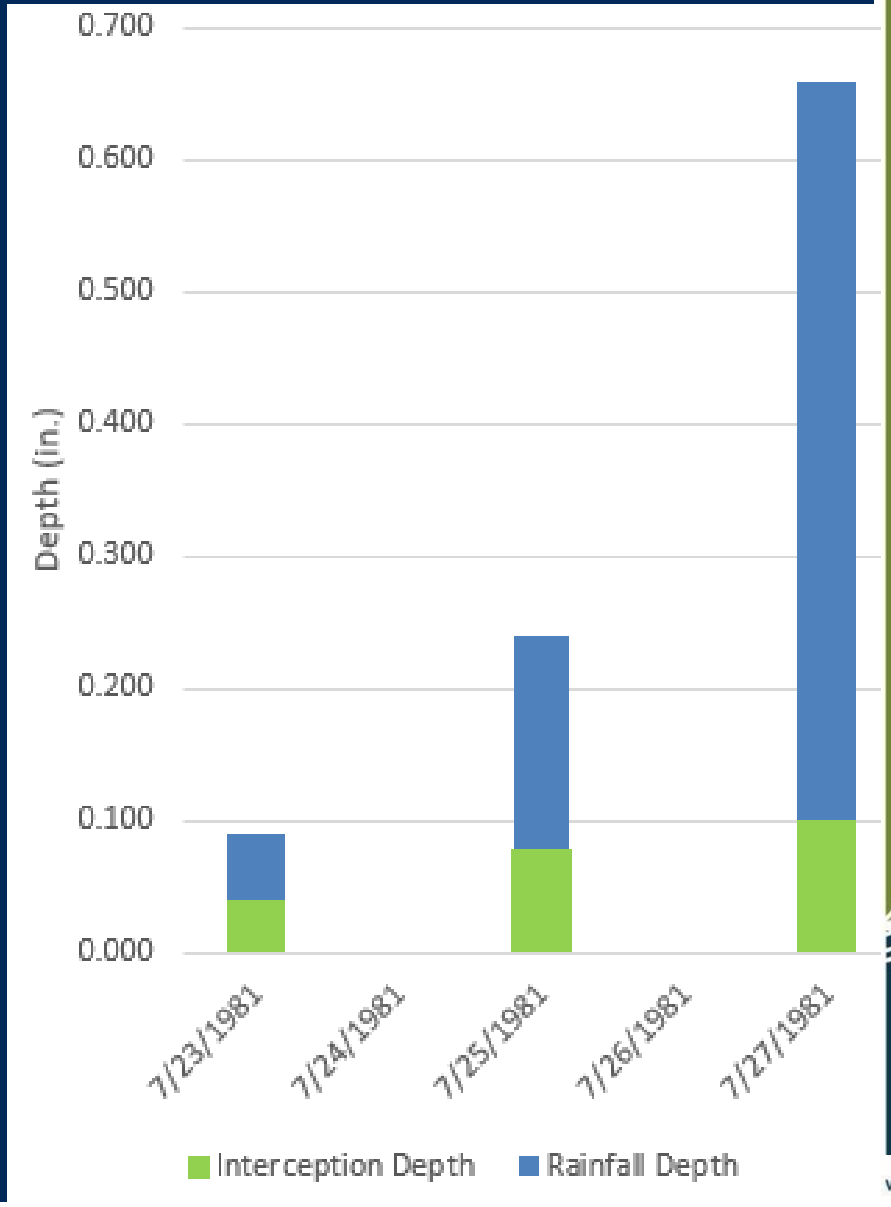


Some Limitations

- Based on limited data (but could easily refine with more / local data)
- Only considers areas with full canopy coverage
- Does not consider antecedent moisture in the canopy

Interception Simulation

- Applied regression to 1981 rainfall series
- Conservatively assumed 0.1” maximum interception depth
- Reduced rainfall accordingly
- Interception volume approx. 12% of annual rainfall



Interception Simulation

April 12, 1981 example

Rainfall depth from 1981 series: 0.13”

% Interception = -0.113 ln(0.13”)+0.1647 = 39.5%

Leaf growth adjustment for April = 0.5

Interception depth = (0.13”)(39.5%)(0.5) = 0.026”

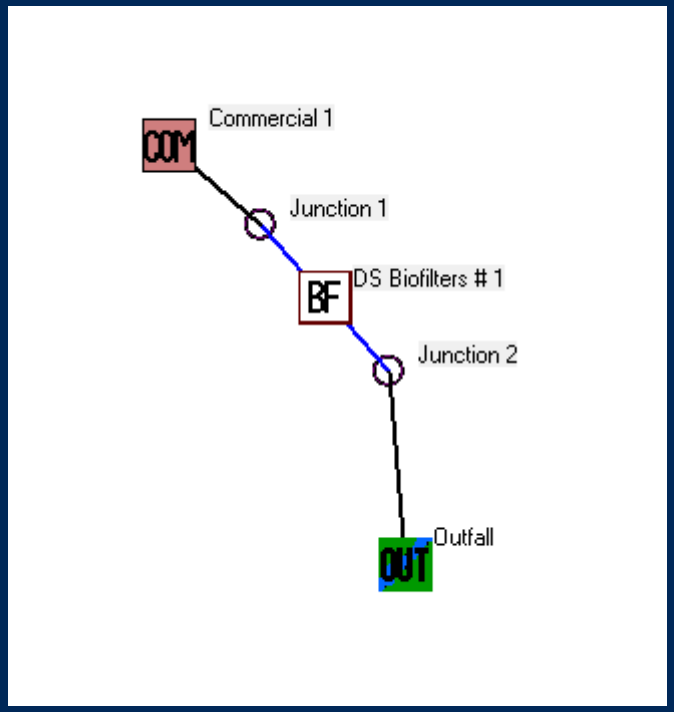
Adjusted precipitation = 0.13” – 0.026” = 0.10”

Spreadsheet Model

Standard WinSLAMM rain file					Modification for tree interception				
Rain Start		Rain Stop		Daily Depth (in)	Interception % No seasonal adjustment	Interception (in) No seasonal adjustment	Seasonal Multiplier	Interception (in)	Adjusted Daily Precip (in)
1/1/1981	5:00	1/1/1981	8:00	0.03	56%	0.017	0	0.000	0.030
1/6/1981	4:00	1/6/1981	12:00	0.06	48%	0.029	0	0.000	0.060
1/6/1981	19:00	1/6/1981	20:00	0.01	69%	0.007	0	0.000	0.010
1/15/1981	23:00	1/16/1981	0:00	0.01	69%	0.007	0	0.000	0.010
1/31/1981	23:00	2/1/1981	5:00	0.11	41%	0.046	0	0.000	0.110
2/5/1981	17:00	2/5/1981	23:00	0.05	50%	0.025	0	0.000	0.050
2/6/1981	22:00	2/7/1981	3:00	0.06	48%	0.029	0	0.000	0.060
2/8/1981	3:00	2/8/1981	4:00	0.01	69%	0.007	0	0.000	0.010
2/9/1981	5:00	2/9/1981	6:00	0.01	69%	0.007	0	0.000	0.010
2/10/1981	2:00	2/10/1981	22:00	0.38	27%	0.100	0	0.000	0.380
2/21/1981	22:00	2/22/1981	17:00	1.58	11%	0.100	0	0.000	1.580
2/23/1981	4:00	2/23/1981	19:00	0.06	48%	0.029	0	0.000	0.060
2/27/1981	3:00	2/27/1981	16:00	0.24	33%	0.078	0	0.000	0.240
3/10/1981	19:00	3/10/1981	21:00	0.08	45%	0.036	0	0.000	0.080
3/25/1981	21:00	3/26/1981	1:00	0.07	47%	0.033	0	0.000	0.070
3/29/1981	2:00	3/29/1981	5:00	0.05	50%	0.025	0	0.000	0.050
3/29/1981	11:00	3/29/1981	13:00	0.06	48%	0.029	0	0.000	0.060
3/29/1981	20:00	3/30/1981	5:00	0.07	47%	0.033	0	0.000	0.070
4/3/1981	8:00	4/3/1981	9:00	0.02	61%	0.012	0.5	0.006	0.014
4/3/1981	23:00	4/4/1981	3:00	0.26	32%	0.082	0.5	0.041	0.219
4/7/1981	20:00	4/8/1981	8:00	0.71	20%	0.100	0.5	0.050	0.660
4/8/1981	15:00	4/8/1981	21:00	0.41	27%	0.100	0.5	0.050	0.360
4/10/1981	20:00	4/10/1981	23:00	1.06	16%	0.100	0.5	0.050	1.010
4/12/1981	3:00	4/12/1981	4:00	0.13	40%	0.051	0.5	0.026	0.104
4/13/1981	19:00	4/14/1981	1:00	0.32	29%	0.094	0.5	0.047	0.273
4/16/1981	14:00	4/16/1981	15:00	0.01	69%	0.007	0.5	0.003	0.007

Runoff Simulation

- Used edited rain file in WinSLAMM
- Source area annual runoff volume & TSS load reduced by 11% with tree cover
- Significantly improved “downstream” biofiltration performance



Biofilter Performance Simulation

- Analysis to simulate retrofit
- Large contributing area relative to BMP size
- Evaluated runoff from 1 acre of parking lot under tree canopy (modified rainfall input)
- Varied the following:
  - Biofilter area
  - Depth of engineered soil
  - Native soil infiltration rate

Biofilter Performance Results

- Volume and TSS reduction increased by 15-18% as compared to the same scenario without tree canopy cover

BIOFILTER DETAILS			Runoff volume and TSS Reduction Resulting from Tree Canopy Cover
Area (ft^2)	Engineered Soil Depth (in)	Native Soil Infiltration Rate (in/hr)	
500	24	0.13	15.3%
1,000	24	0.13	17.0%
500	12	0.13	16.4%
1,000	12	0.13	15.9%
500	12	1.60	15.9%
1,000	12	1.60	15.5%
500	24	1.60	15.8%
1,000	24	1.60	15.8%

Lessons Learned

- Analyzing the effect of trees on urban stormwater management is a complex field
- Simple proof-of-concept analysis points to significant impacts provided by interception

Next Steps?

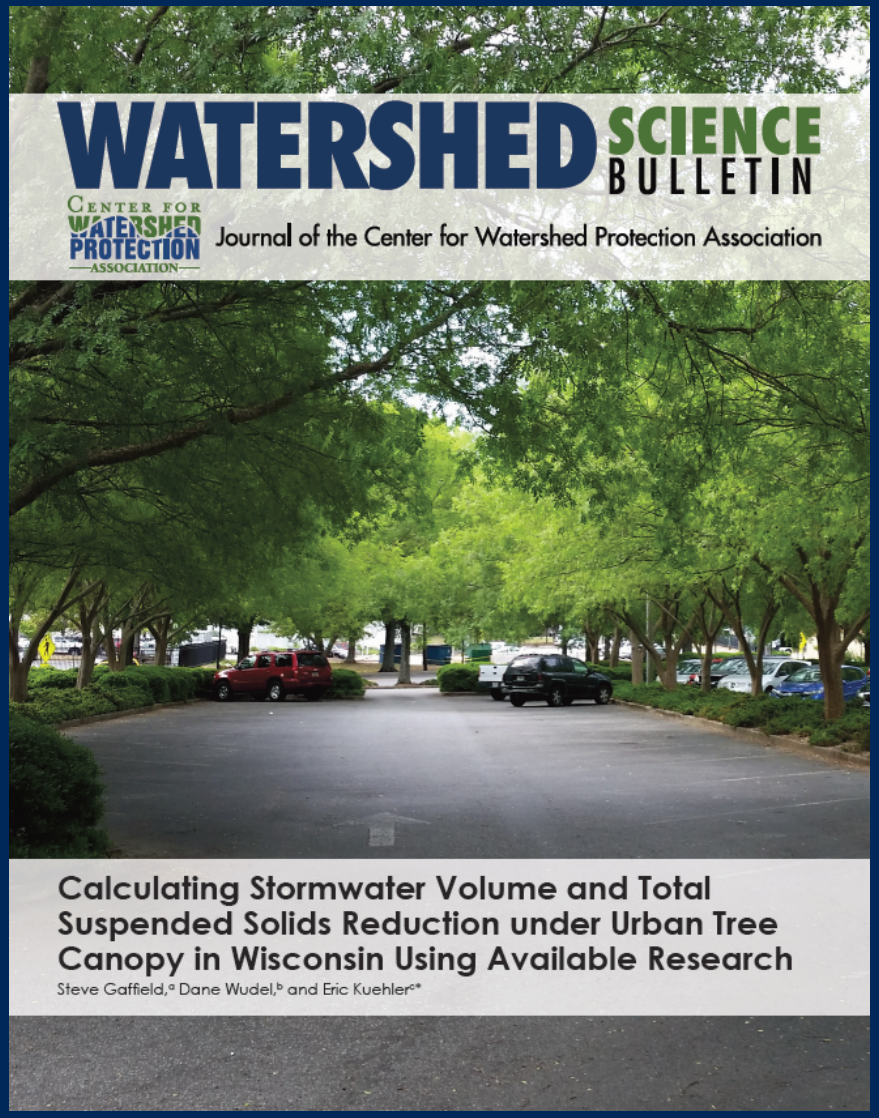
Research

- More local data
  - Runoff volume
  - Runoff peak discharge
  - Water quality
- Model refinement
  - Partial canopy coverage
  - Different trees & ages
  - Infiltration effects
  - Nutrient loading

Application

- Urban retrofits
- Apply interception calculation to other models
- Future policy development?

For More Details



https://www.cwp.org/watershed-science-bulletin-past-issues/

www.ma-rs.org