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

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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

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

Chicago Center for Green Technology
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
Limited Modeling Tools

- US Forest Service (iTree)
  - Urban watershed scale
  - Predicts streamflow & water quality

- CWP credit calculator
  - Curve Number method
  - Annual runoff & loads

- Not site design tools

www.itreetools.org/hydro
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

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

(Xiao et al., 2000)
Modeling Interception

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

\[ y = -0.113 \ln(x) + 0.1647 \]
\[ R^2 = 0.9214 \]
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”
<table>
<thead>
<tr>
<th>Rain Start</th>
<th>Rain Stop</th>
<th>Daily Depth (in)</th>
<th>Interception %</th>
<th>Interception (in)</th>
<th>Seasonal Multiplier</th>
<th>Interception (in)</th>
<th>Adjusted Daily Precip (in)</th>
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</thead>
<tbody>
<tr>
<td>1/1/1981</td>
<td>5:00</td>
<td>1/1/1981 8:00</td>
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<td>1/6/1981 12:00</td>
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<td>48%</td>
<td>0.029</td>
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<tr>
<td>1/7/1981</td>
<td>19:00</td>
<td>1/6/1981 20:00</td>
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<td>69%</td>
<td>0.007</td>
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<tr>
<td>1/15/1981</td>
<td>23:00</td>
<td>1/16/1981 0:00</td>
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<td>69%</td>
<td>0.007</td>
<td>0</td>
<td>0.000</td>
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<tr>
<td>1/31/1981</td>
<td>23:00</td>
<td>2/1/1981 5:00</td>
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<td>41%</td>
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<tr>
<td>2/5/1981</td>
<td>17:00</td>
<td>2/5/1981 23:00</td>
<td>0.05</td>
<td>50%</td>
<td>0.025</td>
<td>0</td>
<td>0.000</td>
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<td>2/7/1981 3:00</td>
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<td>0.000</td>
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<tr>
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</tr>
<tr>
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<td>0</td>
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<td>2/7/1981</td>
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<td>2/7/1981 16:00</td>
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<td>50%</td>
<td>0.025</td>
<td>0</td>
<td>0.000</td>
</tr>
<tr>
<td>3/29/1981</td>
<td>11:00</td>
<td>3/29/1981 13:00</td>
<td>0.06</td>
<td>48%</td>
<td>0.029</td>
<td>0</td>
<td>0.000</td>
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<tr>
<td>3/29/1981</td>
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<td>3/30/1981 5:00</td>
<td>0.07</td>
<td>47%</td>
<td>0.033</td>
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<td>4/3/1981</td>
<td>8:00</td>
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<td>4/8/1981</td>
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<td>0.5</td>
<td>0.050</td>
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<td>4/10/1981</td>
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<td>4/10/1981 23:00</td>
<td>1.06</td>
<td>16%</td>
<td>0.100</td>
<td>0.5</td>
<td>0.050</td>
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<tr>
<td>4/12/1981</td>
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<td>4/12/1981 4:00</td>
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<td>40%</td>
<td>0.051</td>
<td>0.5</td>
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<td>0.007</td>
<td>0.5</td>
<td>0.003</td>
</tr>
</tbody>
</table>
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

<table>
<thead>
<tr>
<th>BIOFILTER DETAILS</th>
<th>Engineered Soil Depth (in)</th>
<th>Native Soil Infiltration Rate (in/hr)</th>
<th>Runoff volume and TSS Reduction Resulting from Tree Canopy Cover</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area (ft²)</td>
<td></td>
<td></td>
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<tr>
<td>500</td>
<td>24</td>
<td>0.13</td>
<td>15.3%</td>
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<td>500</td>
<td>12</td>
<td>0.13</td>
<td>16.4%</td>
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<tr>
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<tr>
<td>500</td>
<td>12</td>
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<td>15.9%</td>
</tr>
<tr>
<td>1,000</td>
<td>12</td>
<td>1.60</td>
<td>15.5%</td>
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<tr>
<td>500</td>
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<td>15.8%</td>
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<tr>
<td>1,000</td>
<td>24</td>
<td>1.60</td>
<td>15.8%</td>
</tr>
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</table>
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/