SWMM5 LID Control for Green Infrastructure Modeling

Ohio Water Environment Association
Collection Systems Workshop
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11:15 AM – 11:45 AM
Introduction

GREEN INFRASTRUCTURE BASICS
Stormwater Management

Green Infrastructure Basics

Flow Rate (Discharge)

Conveyance Only

Volume Control

Undeveloped

Delay

Remove

Convey

The Role of Green Infrastructure

Peak Flow Control

Volume Control and Extended Detention

Rainstorm
What is “Green” Stormwater Infrastructure?

- Vegetated except when it’s not
- “Off the Grid” where feasible
- Decentralized unless regionalized
- Less expensive maybe
- Controls pollution except when discharged to combined systems
- Supports “livable” communities if sustainable
- Not a pond unless it’s a wetland

“An adaptable term used to describe an array of products, technologies, and practices that use natural systems – or engineered systems that mimic natural processes – to enhance overall environmental quality and provide utility services”

U.S. EPA “Managing Wet Weather with Green Infrastructure” Website, glossary of terms
Monitoring Considers Several Design Options

- **Individual BMP**
  - Standard monitoring design for BMPs
  - Inflow versus outflow

- **Watershed or Catchment**
  - Impact of multiple distributed controls
  - Before versus after
  - Paired or test versus control
Monitoring Considerations for “Green” Watersheds

• Sufficient number of BMPs to detect an impact to stormwater
• Sufficient time to establish baseline conditions prior to BMP installation
• Locate matching test and control watersheds
• Sufficient time to compare test and control watersheds prior to BMP implementation
• Controlling changes within watershed during monitoring
MODELING GREEN INFRASTRUCTURE
SWMM LID Controls

- LID added to SWMM5 in 2009
- LID part of “Hydrology” menu
- Five LID Control Types
  - Bio-Retention
  - Infiltration Trench
  - Porous Pavement
  - Rain Barrel
  - Vegetative Swale
- How do the LID Controls work?
SWMM LID Controls

- Large wet-weather flow CSO/SSO programs
- “Green” alternatives
- Quantify “green” benefit
- Predictive modeling
- Need existed to examine and understand the SWMM5 LID Controls
SWMM LID Controls

Bio- Retention Cell

Infiltration Trench

Porous Pavement

Rain Barrel

Vegetative Swale

Modeling Green Infrastructure
Utilizing SWMM LID Controls

1. Choose/define LID type
2. Assign to catchment
3. Define usage
1. Route **impervious** to **pervious** to receiving node
LID Modeling Approaches

2. Create LID catchment as separate catchment – route original catchment to LID catchment to receiving node
   a) LID area extracted from original pervious area
   b) LID area extracted from original impervious area
3. Create LID as part of original catchment – route runoff through LID prior to receiving node
   a) LID area extracted from original pervious area
   b) LID area extracted from original impervious area
Case Study: Study Area

Modeling Green Infrastructure
## Area Devoted to LID

<table>
<thead>
<tr>
<th>Acres</th>
<th>S1</th>
<th>S2</th>
<th>S3</th>
<th>S4</th>
<th>S5</th>
<th>S6*</th>
<th>S7**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original Catchment</td>
<td>4.55</td>
<td>4.74</td>
<td>3.74</td>
<td>6.79</td>
<td>4.79</td>
<td>1.98</td>
<td>2.33</td>
</tr>
<tr>
<td>Bio-Retention</td>
<td>0.20</td>
<td>0.18</td>
<td>0.23</td>
<td>0.34</td>
<td>0.06</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Infiltration Trench</td>
<td>0.20</td>
<td>0.18</td>
<td>0.23</td>
<td>0.34</td>
<td>0.06</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Porous Pavement</td>
<td>0.26</td>
<td>0.30</td>
<td>0.15</td>
<td>0.34</td>
<td>0.42</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Rain Barrel</td>
<td>0.26</td>
<td>0.30</td>
<td>0.15</td>
<td>0.34</td>
<td>0.42</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Vegetative Swale</td>
<td>0.20</td>
<td>0.18</td>
<td>0.23</td>
<td>0.34</td>
<td>0.06</td>
<td>0.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

*Catchment S6 was used as a control catchment

**Catchment S7 was 100% pervious, therefore no LID was modeled in this catchment
Storm Events

• 2-year design storm
  – From SWMM Applications Manual
  – 0.978 inches
  – 2-hour duration

• 3-month design storm
  – Derived from 2-year event
  – 0.499 inches
  – 2-hour duration
Model Evaluation Approach

• Basis of comparison
  – Peak runoff flow rate
  – Total runoff volume

• Expectations
  – LID reduces peak flow rates
  – LID reduces total runoff volume
## Results Summary

<table>
<thead>
<tr>
<th>LID Scenario</th>
<th>3-Month Peak Flow</th>
<th>3-Month Volume</th>
<th>2-Year Peak Flow</th>
<th>2-Year Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bio-Retention</td>
<td>↓</td>
<td>↓</td>
<td>↑</td>
<td>↓</td>
</tr>
<tr>
<td>Infiltration Trench</td>
<td>INCONCLUSIVE (LID MOST LIKELY OVERSIZED)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Porous Pavement</td>
<td>INCONCLUSIVE (LID MOST LIKELY OVERSIZED)</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vegetative Swale</td>
<td>↑</td>
<td>↑</td>
<td>↑</td>
<td></td>
</tr>
<tr>
<td>Impervious to Pervious</td>
<td>↓</td>
<td>↓</td>
<td>↓</td>
<td>↓</td>
</tr>
</tbody>
</table>

- **↓** LID as separate catchment
- **↓** LID as part of existing catchment
Findings/Observations

- Peak runoff flow rates
  - Increase or decrease depending on precipitation depth
  - Vary per catchment for specific LID Control type

- Total runoff volume
  - More consistent trends than peak flow
  - Decrease or constant depending on precipitation depth
  - Select catchments decreased for 2-year but not 3-month event

- Routing impervious to pervious to receiving node provided most consistent, reliable, and reasonable results

- Use SWMM LID Controls with caution
CDM Smith Example

MODELING GREEN INFRASTRUCTURE
SWMM LID Controls Study

• Model LID with Observed Field Data
  – Madison, Wisconsin
  – United States Geological Survey (USGS)
  – University of Wisconsin

• SWMM LID Control
  – Bio-Retention Cell

Prepared in cooperation with the City of Madison and Wisconsin Department of Natural Resources


Scientific Investigations Report 2010–5077

U.S. Department of the Interior
U.S. Geological Survey
Observed Field Data

- Data gathered 2004-2008
- Rain gardens
  - Turf-sand
  - Prairie-sand
  - Turf-clay
  - Prairie-clay
- Used observed data from 2004-2007
  - Field set-up changed in 2008
  - Doubled tributary area to some rain gardens
Field Set-up
Clay Rain Gardens

Courtesy of Bill Selbig, USGS
Field Set-up
Sand Rain Gardens

Courtesy of Bill Selbig, USGS
Modeling Objective

• Challenge:
  – To recreate observed results using SWMM LID Controls

• Goals:
  – To verify simulation results for a single-event (May 23, 2004)
  – To verify results for a long-term simulation (2004 – 2007)
Field vs. Model Parameters

• 18 unique input parameters for SWMM Bio-Retention Cell
  – 12 values directly from field data
  – 6 “text-book” values

• Field work
  – Performed for different goals
  – Unaware of SWMM
  – Limitations to accuracy
Single Event Results – Field Measured Depth in Turf- and Prairie- Sand Rain Gardens

![Graph showing water depth and cumulative precipitation over time.]

- **Depth of water, turf-sand garden**
- **Depth of water, prairie-sand garden**
- **Cumulative precipitation**

**Average infiltration rate:**
- 1.2 inches in 0.65 hours = 1.85 inches/hour

**Peak infiltration rates:**
- 3.1 inches/hour
- 3.0 inches/hour
Single Event Results – Modeled in SWMM
Depth in Turf- and Prairie- Sand Rain Gardens

CDM Smith GI Modeling Example
Single Event Verification Results
Strengths and Weaknesses

- Peak values match well
- Timing of peak generally good
- Prairie-sand missing the return to zero value
- Receding limbs deviate from timing and slope
  - Receding limb performance is important for modeling green infrastructure, not just peaks and overall volumes
  - Are SWMM LID Controls simulating the processes correctly
  - Can something be done to improve it
Long-Term Model Results (2004-2007)
Sand Rain Gardens

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Measured Value</th>
<th>Modeled Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precipitation (in)</td>
<td>147</td>
<td>137</td>
</tr>
<tr>
<td>Influent Turf (in)</td>
<td>500</td>
<td>691</td>
</tr>
<tr>
<td>Influent Prairie (in)</td>
<td>464</td>
<td>691</td>
</tr>
<tr>
<td>Effluent Turf (in)</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Effluent Prairie (in)</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Evapotranspiration Turf (in)</td>
<td>96</td>
<td>84</td>
</tr>
<tr>
<td>Evapotranspiration Prairie(in)</td>
<td>51-70</td>
<td>91</td>
</tr>
<tr>
<td>Recharge Turf (in)</td>
<td>550</td>
<td>749</td>
</tr>
<tr>
<td>Recharge Prairie (in)</td>
<td>540-560</td>
<td>745</td>
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</tbody>
</table>
Long-Term Model Results (2004-2007)  
Clay Rain Gardens

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Measured Value</th>
<th>Modeled Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precipitation (in)</td>
<td>145</td>
<td>140</td>
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<tr>
<td>Influent Turf (in)</td>
<td>603</td>
<td>566</td>
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<tr>
<td>Influent Prairie (in)</td>
<td>485</td>
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<tr>
<td>Effluent Turf (in)</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>Effluent Prairie (in)</td>
<td>0</td>
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<tr>
<td>Evapotranspiration Turf (in)</td>
<td>93</td>
<td>87</td>
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<tr>
<td>Evapotranspiration Prairie(in)</td>
<td>19-47</td>
<td>55</td>
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<tr>
<td>Recharge Turf (in)</td>
<td>637</td>
<td>611</td>
</tr>
<tr>
<td>Recharge Prairie (in)</td>
<td>584-613</td>
<td>584</td>
</tr>
</tbody>
</table>
Findings/Observations

• The Bio-Retention Cell LID Control was found to simulate published results reasonably well for a single event as well as over a long-term period
• SWMM 5.0.022 LID Controls perform well when compared to measured data
• Possible explanations for differences
  – Single-event vs. long-term parameters differed slightly
  – Field measurement uncertainty
  – Used “text book” values for some parameters
  – Model representation of physical process is limited
Future Use of SWMM LID Controls

- More extensive monitoring is needed
  - Expand existing database of performance data
  - Detailed seasonal- and regional-specific soil parameters
  - Client specific data

- Better monitoring leads to better modeling
  - Compare the model with measured data
  - Use the model for predictive performance with more confidence
  - Improved modeling with better representation of physical processes
THANK YOU

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Questions