Moving towards Dynamic Crediting for Adaptive Stormwater Control Measures

Villanova Stormwater Symposium 2019

Amanda Jean Hess, PhD EIT
OptiRTC, Inc
Villanova University
Outline

- **Goal:** to discuss how credit a dynamic Stormwater Control Measure (SCM) in the current regulatory environment

- In PA, the difference in the 2-year/24-hour storm from pre- to post-construction conditions:
  - Volume
  - Geomorphologic concerns

- Example site in Philadelphia (rain garden):
  - Infiltration
  - Evapotranspiration

- Two real sites (ponds):
  - Dynamic outlet controls (i.e., CMAC logic applied)

- How are other states crediting CMAC designs?
Example site in Philadelphia

- Rain Garden
- 30 years from the Philadelphia international airport
- Green & Ampt equation
- Obtain 2-year/24-hour runoff volumes

<table>
<thead>
<tr>
<th>Description</th>
<th>Postconstruction (impervious)</th>
<th>Preconstruction (pervious meadow)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slope</td>
<td>2%</td>
<td>10%</td>
</tr>
<tr>
<td>Depression storage value</td>
<td>0.05</td>
<td>0.20</td>
</tr>
<tr>
<td>Manning’s n-value</td>
<td>0.01</td>
<td>0.20</td>
</tr>
</tbody>
</table>

Saturated hydraulic conductivity: 0.2 in/h
Soil suction: 5 psi
Example site in Philadelphia – Runoff Volume

Percent exceedance (ranking) vs. runoff volume

- 2 year storm = ½ % chance of exceedance in one year (i.e., 50%)
- Took largest daily runoff volume for every year (i.e., annual exceedance probability)
Percent exceedance (ranking) vs. runoff rate

- 2 year storm = ½ % chance of exceedance in one year (i.e., 50%)
- Took largest daily runoff volume for every year (i.e., annual exceedance probability)
Example site in Philadelphia

- Let’s look at more infiltration rates

<table>
<thead>
<tr>
<th>HSG</th>
<th>Range (NEH 2007, Table 7-2)</th>
<th>Scenario Name</th>
<th>Selected Saturated Hydraulic Conductivity Rate (in/hr)</th>
<th>Selected Soil Suction (psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Greater than 1.42 in/hr</td>
<td>A</td>
<td>1.5</td>
<td>1.9</td>
</tr>
<tr>
<td>B</td>
<td>Between 1.42 and 0.57 in/hr</td>
<td>B</td>
<td>0.6</td>
<td>3.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>C1</td>
<td>0.32</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>C2</td>
<td>0.2</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>C3</td>
<td>0.1</td>
<td>6</td>
</tr>
<tr>
<td>C</td>
<td>Between 0.57 and 0.06 in/hr</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>Less than 0.06 in/hr</td>
<td>D</td>
<td>0.03</td>
<td>8</td>
</tr>
</tbody>
</table>
Example site in Philadelphia

- Let’s look at more infiltration rates
- Already focused on this one

### Table: Infiltration Rates

<table>
<thead>
<tr>
<th>HSG</th>
<th>Range (NEH 2007, Table 7-2)</th>
<th>Scenario Name</th>
<th>Selected Saturated Hydraulic Conductivity Rate (in/hr)</th>
<th>Selected Soil Suction (psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Greater than 1.42 in/hr</td>
<td>A</td>
<td>1.5</td>
<td>1.9</td>
</tr>
<tr>
<td>B</td>
<td>Between 1.42 and 0.57 in/hr</td>
<td>B</td>
<td>0.6</td>
<td>3.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>C1</td>
<td>0.32</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>C2</td>
<td>0.2</td>
<td>5</td>
</tr>
<tr>
<td>C</td>
<td>Between 0.57 and 0.06 in/hr</td>
<td>C3</td>
<td>0.1</td>
<td>6</td>
</tr>
<tr>
<td>D</td>
<td>Less than 0.06 in/hr</td>
<td>D</td>
<td>0.03</td>
<td>8</td>
</tr>
</tbody>
</table>
Example site in Philadelphia

- Let’s look at more infiltration rates
- Already focused on this one

<table>
<thead>
<tr>
<th>HSG</th>
<th>Range (NEH 2007, Table 7-2)</th>
<th>Scenario Name</th>
<th>Selected Saturated Hydraulic Conductivity Rate (in/hr)</th>
<th>Selected Soil Suction (psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Greater than 1.42 in/hr</td>
<td>A</td>
<td>1.5</td>
<td>1.9</td>
</tr>
<tr>
<td>B</td>
<td>Between 1.42 and 0.57 in/hr</td>
<td>B</td>
<td>0.6</td>
<td>3.5</td>
</tr>
<tr>
<td>C</td>
<td>Between 0.57 and 0.06 in/hr</td>
<td>C1</td>
<td>0.32</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>C2</td>
<td>0.2</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>C3</td>
<td>0.1</td>
<td>6</td>
</tr>
<tr>
<td>D</td>
<td>Less than 0.06 in/hr</td>
<td>D</td>
<td>0.03</td>
<td>8</td>
</tr>
</tbody>
</table>

HSG C soil was broken down into 3 different infiltration rates.
Example site in Philadelphia – Runoff Volume

Percent exceedance (ranking) vs. runoff volume
• Same as before
Example site in Philadelphia – Runoff Volume

Percent exceedance (ranking) vs. runoff volume

• Same as before

<table>
<thead>
<tr>
<th>Scenario</th>
<th>2-yr/24-hr volume</th>
<th>Difference (cf)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre (cf)</td>
<td>Post (cf)</td>
</tr>
<tr>
<td>A</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>B</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>C1</td>
<td>1368</td>
<td>1260</td>
</tr>
<tr>
<td>C2</td>
<td>2952</td>
<td>2232</td>
</tr>
<tr>
<td>C3</td>
<td>5148</td>
<td>4680</td>
</tr>
<tr>
<td>D</td>
<td>7776</td>
<td>7488</td>
</tr>
</tbody>
</table>
Example site in Philadelphia – Flow Duration

• Number of hours for each flow rate leaving the SCM
• Important for geomorphological concerns
  • 2-year/24-hr preconstruction peak flow is not exceeded in postconstruction
  • Duration of all flows <2-year/24-hr peak
  • All C & D reduced
  • A&B flow rate insignificant

• 2-year/24-hour preconstruction peak flows

Flow Duration (hr)
Flow (cfs)
Example site in Philadelphia – Flow Duration

- Flow-duration curves for 30 years
- Number of hours that flow rate was produced
- 2-year/24-hr preconstruction peak flow is not exceeded in postconstruction
- Duration of all flows <2-year/24-hr peak
  - C1,2,3 & D reduced
  - A&B flowrate insignificant

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Duration of 2-yr/24-hr peak flow</th>
<th>Difference (hrs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre (hrs)</td>
<td>Post (hrs)</td>
<td></td>
</tr>
<tr>
<td>C1</td>
<td>41</td>
<td>34</td>
</tr>
<tr>
<td>C2</td>
<td>37</td>
<td>22</td>
</tr>
<tr>
<td>C3</td>
<td>36</td>
<td>25</td>
</tr>
<tr>
<td>D</td>
<td>39</td>
<td>32</td>
</tr>
</tbody>
</table>
Example site in Philadelphia – Ponding

• SCM sizing primarily based on 2-year/24-hour storm
• Also considered meeting a 72 hour ponding time
  • 90% of the time ponding is under 72 hours
  • Only needed to adjust footprints for C3 and D soils
Continuous Approach – Comparison to Static

- Footprint SCM size compared to Continuous Simulation approach vs. static design storm approach sizing

- Static Storage
  - Used CN & NOAA rainfall depth
  - PA DEP Manual currently allows for 6” ponding depth
  - Modeled with 18” depth
Continuous Monitoring and Adaptive Control (CMAC)
Continuous Monitoring and Adaptive Control (CMAC)
CMAC Example logic

Storm Size
- Clear Skies
- Preparing For Rain
- Rain Imminent
- In Rain Event
- Has Rained Recently

24 hours ahead of the storm
6 hours ahead of the storm

Can't capture fully; drain to minimize discharge during wet weather.

6 hours after the previous storm and at least 6 hours before the next
CMAC Example logic

- **Storm Size**
  - Clear Skies
  - Preparing For Rain
  - Rain Imminent
  - In Rain Event
  - Has Rained Recently

- Can't capture fully; drain to minimize discharge during wet weather.
- Can capture fully; do not drain.

- 24 hours ahead of the storm
- 6 hours ahead of the storm
- 6 hours after the previous storm and at least 6 hours before the next
CMAC Example Performance

- Delayed release of real time controlled (CMAC) systems leads to:
  - Reduction in wet weather flows
  - Flow duration curve augmentation
  - Longer settling times
CMAC Site 1

- Real flow duration curves from wet pond with CMAC
- Probability of exceedance (normalized to duration)
- Passive vs active regimes (not preconstruction)
  - Maximum flow rate reduced
  - Lower flows do not enter the downstream system as often
CMAC Site 1

- Real flow duration curves from wet pond with CMAC
- Probability of exceedance (normalized to duration)
- Passive vs active regimes (not preconstruction)
  - Maximum flow rate reduced
  - Lower flows do not enter the downstream system as often
CMAC Site 1

- Real flow duration curves from wet pond with CMAC
- Probability of exceedance (normalized to duration)
- Passive vs active regimes (not preconstruction)
  - Maximum flow rate reduced
  - Lower flows do not enter the downstream system as often
CMAC Site 2

- Real flow duration curves from an in-stream wet pond with CMAC
- Desired:
  - Reduction of high flows for detention
  - Increase in baseflow for the frogs
CMAC Site 2

- Real flow duration curves from an in stream wet pond with CMAC
- Desired:
  - Reduction of high flows for detention
  - Increase in baseflow for the frogs

![Flow Duration Curves with CMAC and Passive Comparisons](image.png)

- Critical Erosive Flow Range to Avoid
- CMAC
- Passive

`Flow Rate (cfs)`

`Probability of Exceedance (%)`
CMAC Site 2

• Real flow duration curves from an in stream wet pond with CMAC

• Desired:
  • Reduction of high flows for detention
  • Increase in baseflow for the frogs
How dynamic are other states?
PA it is possible to adopt of **continuous simulation** to meet 2-yr/24-hr requirement.
Washington state is one of the states that has already adapted a form of continuous simulation for ponds. 10% difference in flow durations is considered as well.
West Virginia and Ohio have adopted flow based TMDLs.
Maryland CMAC is on its way to regulatory approval crediting controllable volume towards water quality credits.
Minnesota CMAC rainwater harvesting systems can credit **higher water quality** through reuse and treatment.
Southern California allows 3 days of a storm event that is forecasted to have a 50% or greater probability of providing precipitation (using forecast from the National Weather Service Forecast)
North Eastern Ohio allows rainwater harvesting to be drained within 3 days to permit the capture of a consecutive rain event.
Summary

• Dynamic loss mechanism and flow control mechanisms provide multiple benefits that are not fully realized in the current regulatory environment
  • Infiltration & ET based systems can be sized to be more resilience in face of climate change
  • Dynamic outlet controls can provide system with a more ideal flow regime
• Generally, forward movement seems to be in this direction
Questions?

Amanda Jean Hess, PhD EIT
OptiRTC, Inc (Ahess@optirtc.com)
Villanova University (Amanda.hess@villanova.edu)