How water and sediment move through and around urban areas?

[City of Richmond, VA 2018]

Drainage from I-95
Philadelphia, PA, 2018

[Albright, 2018 Dissertation]

[Mora Jerez et al., 2019]
Population Density
How water and sediment move?

1. Flow routing?

2. Capture?

3. Budget?

[Jahangiri et al, 2019; Vaughn et al, in prep]
Flow Routing?

Basin Analysis

- Delineate subbasins (Flow routing directions) [Jahangiri et al., 2019]
- Tested with a range of DEM resolution [Vaughn et al., 2019]
Flow Routing?

Basin Analysis

- DEM preprocessing
  - Fill sinks
  - Sink GSIs and stormwater inlets
  - Raise buildings

- Watershed delineation
  - Generating flow lines
  - Inlets’ subbasin delineation
Flow Routing?

Runoff Analysis

- Design storm
  - NRCS 10-year, 24-hour storm for Philadelphia

<table>
<thead>
<tr>
<th>Duration</th>
<th>10-year Precipitation (mm)</th>
<th>Intensity (mm/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 min</td>
<td>14.7</td>
<td>176.8</td>
</tr>
<tr>
<td>10 min</td>
<td>22.9</td>
<td>137.2</td>
</tr>
<tr>
<td>15 min</td>
<td>28.2</td>
<td>112.3</td>
</tr>
<tr>
<td>30 min</td>
<td>39.6</td>
<td>79.2</td>
</tr>
<tr>
<td>1 hrs</td>
<td>51.6</td>
<td>51.6</td>
</tr>
<tr>
<td>2 hrs</td>
<td>62.5</td>
<td>31.2</td>
</tr>
<tr>
<td>3 hrs</td>
<td>68.8</td>
<td>22.9</td>
</tr>
<tr>
<td>6 hrs</td>
<td>86.4</td>
<td>14.4</td>
</tr>
<tr>
<td>12 hrs</td>
<td>106.7</td>
<td>8.9</td>
</tr>
<tr>
<td>24 hrs</td>
<td>125.7</td>
<td>5.2</td>
</tr>
</tbody>
</table>
Flow Routing?

Runoff Analysis

- Runoff estimate
  - NRCS (depth)
    \[ S = \frac{1000}{C_{N_{Avg}}} - 10 \]  
    Initial Abstraction- Land cover land use

\[
H \ (\text{in}) = \frac{(P - 0.2S)^2}{(P + 0.8S)} \quad \text{Runoff Depth}
\]

- Modified rational (discharge)
  \[
  Q_p \ (cfs) = \left[ (0.95 \times A_{imp}) + (0.35 \times A_{per}) \right] \times i \quad \text{Maximum Discharge}
  \]

\[ V = Q_p \ D \quad \text{Volume} \]

\[
H = \frac{V}{\text{Area}} \quad \text{Runoff Depth}
\]
Runoff model results

NRCS

[Map showing runoff model results with color-coded areas indicating different levels of inundation (cm) for the NRCS method.]

Legend:
- Philadelphia Municipal Boundary
- Rivers, Lakes, and Streams
- Inundation (cm): NRCS Method
  - ≤3.7
  - ≤8.0
  - ≤9.8
  - ≤11
  - ≤12

Note: The map illustrates the coverage of the study area and the extent of potential flooding based on the NRCS model.
Runoff model results

Modified rational
Runoff model results

NRCS vs Modified rational

- A: 5 min
- B: 30 min
- C: 3 hours
- D: 24 hours
Results integration

- Probability index

<table>
<thead>
<tr>
<th>Condition</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>((H_{Ri}&gt;Thr) \text{ AND } (H_{NRCS}&gt;Thr))</td>
<td>100</td>
</tr>
<tr>
<td>((H_{Ri}) \text{ OR } (H_{NRCS}&lt;Thr))</td>
<td>50</td>
</tr>
<tr>
<td>((H_{Ri}&lt;Thr) \text{ AND } (H_{NRCS}&lt;Thr))</td>
<td>0</td>
</tr>
</tbody>
</table>
Results integration

• Impact index (maximum runoff)
Results integration

• Risk index (average runoff)
Future Work

Include social and demographic data to find vulnerable areas in city.
Future Work

Sediment coming off the landscape?

Sediment Impact on Downstream Waterways

[SCHEMATIC SEQUENCE: LAND USE, SEDIMENT YIELD]

AND CHANNEL RESPONSE

FROM A FIXED AREA

Land Use
- Forest
- Cropping
- Woods
- Grazing
- Urban

Channel Condition
- Stable
- Aggradation
- Scour
- Stable Scour
- Bank Erosion
- Aggradation

[Wolman 1967]
Future Work

- Water and sediment budget
- **Link** flow and sediment routing to stormwater **outfalls**
- Analysis impact on **instream** response
2019 Stormwater Management Symposium

Building Resilience into Stormwater

Partners

AECOM  
Philadelphia Water Department  
Opti

CONTECH
ENGINNEERED SOLUTIONS

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ARCADIS  
RK&K  
NTM Engineering

FRIENDS

Jacobs  
Gannett Fleming Geosyntec  
Michael Baker  
Sci-Tek Consultants  
Princeton Hydro  
T&M Associates