Improving Rainfall Runoff Modelling with Microtopography

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Abstract
The impact of topographic resolution on rainfall-runoff models was assessed in a stormwater runoff study of 'Lot 10,' located at the corner of 12th and Diamond Streets on the Temple University Campus in Philadelphia, PA. Lot 10 was modeled twice using the U.S. EPA's Stormwater Management Model (SWMM). In the first model, existing 2-ft coarse topographic contours developed from airborne LiDAR were used to delineate 10 subcatchments. In the second model, ArcGIS was used to delineate 36 subcatchments based on a high-resolution, 0.25-ft microtopographic digital elevation model (DEM, developed from ground-based LIDAR data. Both SWMM simulations included the same hydraulic features and outfall point so that differences in simulation outcomes could be attributed solely to differences in topographic resolution. Based on model results, use of microtopography (0.25-ft) resulted in a 3.3% reduction in peak runoff rate and a 4.3% reduction in total runoff volume for the 2 yr-24 hr and the 100-yr-24 hr storm events. In addition, continuous modeling using locally observed rainfall collected between October 2011 and June 2013 showed that the microtopography model produced longer runoff periods and better agreement with measured water depth, with mean square error (MSE) values 1.33% to 32.0% lower than the MSE for the coarse topography model.

Methods I: Coarse Topography

Figure 3. Subcatchments (outlined in black) were delineated within SWMM based on coarse topography (2-ft contours) obtained from the PA Geospatial Data Clearinghouse (PASDA). The contours were developed from airborne LiDAR which is typically more precise than what might often be used (eg USGS topographic maps). This more precise data supported just 10 subcatchments.

Results (cont’d)

<table>
<thead>
<tr>
<th>Storm Event</th>
<th>Model</th>
<th>Runoff volume (ft³)</th>
<th>Peak flow (cfs)</th>
<th>Lag Time (hr)</th>
<th>Runoff time (hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-Yr</td>
<td>0.25-ft</td>
<td>15970</td>
<td>1.78</td>
<td>0.95</td>
<td>54.3</td>
</tr>
<tr>
<td></td>
<td>2-ft</td>
<td>16650</td>
<td>1.83</td>
<td>0.92</td>
<td>43.3</td>
</tr>
<tr>
<td>100-Yr</td>
<td>0.25-ft</td>
<td>39030</td>
<td>3.52</td>
<td>0.65</td>
<td>57.1</td>
</tr>
<tr>
<td></td>
<td>2-ft</td>
<td>40700</td>
<td>3.64</td>
<td>0.60</td>
<td>47.3</td>
</tr>
</tbody>
</table>

Table 2. For design storms, the microtopography models result in slightly reduced runoff volumes, reduced peak flows and significantly longer runoff periods.

Methods II: Microtopography

Figure 4. Microtopography data were collected using ground-based LiDAR, and processed to a 0.25-ft resolution DEM. Using the ArcHydro tools within ArcGIS 10.1, 36 subcatchments (outlined in green) and drainage paths (in turquoise) were delineated and incorporated into SWMM (shown in black). Because the bioswale was not uniquely delineated in ArcGIS, its characteristics were manually incorporated into SWMM. The Subcatchments ultimately drain to an outlet north of Lot 10. Water elevation data were collected at the numbered and circled inlets.

Results

Figure 5. Runoff hydrographs for the 2-yr and 100-yr design storms. While differences between the models are slight, microtopography produces statistically significant lower mean flow (~3.3%, p<0.01) and total runoff volume (~4.1%, p<0.01).

Conclusions
Continuous modeling using microtopography provided better results at the storm inlets monitored at Lot 10. The microtopography also tended to increase runoff time and reduce runoff volume, likely due to increased sheet flow travel time and increased opportunity for infiltration. Preliminary results suggest that microtopographic data can improve rainfall runoff modelling and future microtopographic studies should focus on more topographically complex parcels with more heterogeneous land cover.

Acknowledgments
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References

Table 3. SWMM was run using continuous rainfall data (10/1/11-6/28/13). Model output at Inlets 1, 2 and 3 (Figure 4) was compared to measured water depth at these locations. Mean Square Error (MSE) is the mean of the squares of the difference between the measured water depth and the respective model output at each time step. Runoff duration is the total time SWMM-estimated runoff occurred. The microtopography model had lower MSE and longer runoff duration than the coarse model at all measurement locations. In addition, the microtopography model produced 3.5% less total runoff volume at the Lot 10 outlet.

Figure 2. Cross-section of corrugated metal pipe draining the bioswale. Pipe is perforated to increase infiltration and only excess stormwater will be drained to Philadelphia City storm sewer system.

Figure 1. Lot 10 (indicated by red star) is located at the corner of 12th St. and Diamond St. on the Temple University campus in Philadelphia, PA.

Table 1. Physical characteristics of Lot 10 and its bioswale

<table>
<thead>
<tr>
<th>Number</th>
<th>MSE (m)</th>
<th>Runoff Duration (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.25-ft</td>
<td>2-ft</td>
<td>% Difference</td>
</tr>
<tr>
<td>1</td>
<td>4.70E-2</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>1.03E-2</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>1.71E-3</td>
<td>2</td>
</tr>
</tbody>
</table>

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