Stormwater Runoff Reduction by Street-Side Water Harvesting Features

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Outline

• Problem and Research Objectives
• Methods, Results, and Conclusions
• Next Steps
Problem

- Rincon Heights Neighborhood
- Flooding streets, stormwater runoff
- Non-point source pollution
  - Neighborhood, High School Wash
- Traffic
  - Vehicles, bicycles, pedestrians
Low Impact Development

• Manages stormwater as close to its source as possible

• Works with conventional flood control measures

• Decentralized, distributed system

• Incorporates natural design

• First flush, first ½-inch of runoff
Objectives

• Assess the potential effects street-side water harvesting basins have on the quantity of stormwater runoff in the Rincon Heights Neighborhood study area
  - Stormwater storage capacity
  - Stormwater runoff generation
Assumptions

1. All basins are functioning as designed.
2. Every basin receives runoff from every rainfall event.
3. Rainfall is uniformly distributed.
4. Rainfall is retained within basins.
5. No other water harvesting features.
Study Area - 33 ha, 78 basins
Mid-Block Basin

Photo: Watershed Management Group
Median Basin
Methods
Methods – Storage Capacity

• 78 basins

• Measured 14 (18%) basins
  - 2 corner basins
  - 12 mid-block basins

• Volume – cross-sectional profiles

• 0.254 meter (10-inch) grid

• Surface Area – 2010 Pictometry orthos
Methods – Storage Capacity

\[ V = \sum [(D) \times (L) \times (W)] \]

where:
- \( V \) = Basin volume (m\(^3\))
- \( D \) = Depth (average depth below baseline, m)
- \( L \) = Length ((# of measurements – 1) \times (0.254 m))
- \( W \) = Width (0.254 m)
Methods – Storage Capacity

Measure Basins

2nd Degree Polynomial Best-Fit Line
\[ y = 0.0005x^2 + 0.0023x \]
\[ R^2 = 0.709 \]
Standard Error = 0.382
Methods – Runoff Generation

- Land Cover
- Unsupervised Classification
- Runoff Calculations
  - Before and after basin installation
Methods – Runoff Generation

• Unsupervised Classification – 6 Bands
  - 2007 NAIP – 1-meter, 4-band imagery
    - Blue, Green, Red, NIR
    - Normalized Difference Vegetation Index (NDVI)
  - 2008 LiDAR
    - Digital Elevation Model (DEM)
    - Digital Surface Model (DSM)
    - Canopy Height Model (CHM)
Methods – Runoff Generation
Methods – Runoff Generation

Diagram:

- NAIP
  - Blue
  - Green
  - Red
  - NIR

- NAIP
  - Red
  - NIR
  - NDVI

- LiDAR
  - DEM
  - DSM
  - CHM

Final output: 6 Bands
Unsupervised Classification
## Unsupervised Classification

<table>
<thead>
<tr>
<th>Classification</th>
<th>Building</th>
<th>Soil/Gravel</th>
<th>Vegetation</th>
<th>Pavement/Concrete</th>
<th>Row Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building</td>
<td>41</td>
<td>2</td>
<td>1</td>
<td>6</td>
<td>50</td>
</tr>
<tr>
<td>Soil/Gravel</td>
<td>5</td>
<td>40</td>
<td>0</td>
<td>5</td>
<td>50</td>
</tr>
<tr>
<td>Vegetation</td>
<td>0</td>
<td>2</td>
<td>48</td>
<td>0</td>
<td>50</td>
</tr>
<tr>
<td>Pavement/Concrete</td>
<td>0</td>
<td>4</td>
<td>0</td>
<td>46</td>
<td>50</td>
</tr>
<tr>
<td>Column Total</td>
<td>46</td>
<td>48</td>
<td>49</td>
<td>57</td>
<td>200</td>
</tr>
</tbody>
</table>

**Overall Accuracy** = 175/200 = 87.5%

- **Producer's Accuracy (omission error)**
  - Building = 41/46 = 89.1%, 10.9% omission error
  - Soil/Gravel = 40/48 = 83.3%, 16.7% omission error
  - Vegetation = 48/49 = 98.0%, 2% omission error
  - Pavement/Concrete = 46/57 = 80.7%, 19.3% omission error

- **User's Accuracy (commission error)**
  - Building = 41/50 = 82.0%, 18% commission error
  - Soil/Gravel = 40/50 = 80%, 20% commission error
  - Vegetation = 48/50 = 96%, 4% commission error
  - Pavement/Concrete = 46/50 = 92%, 8% commission error

**Kappa Coefficient (K)** = 0.83
Methods – Runoff Generation

\[
Runoff = (A) \times (r) \times (c)
\]

where:
- \( Runoff \) = Stormwater runoff (m\(^3\))
- \( A \) = Surface area, land cover polygons (m\(^2\))
- \( r \) = Rainfall depths (m)
- \( c \) = Runoff coefficients
Methods – Runoff Generation

• 60-minute storm (r)
  - 1-year = 0.01969 m
  - 2-year = 0.02537 m
  - 10-year = 0.03988 m
  - 100-year = 0.06147 m

• Runoff coefficients (c)
  - Buildings = 0.9
  - Soil/Gravel = 0.6
  - Vegetation = 0.35
  - Pavement/Concrete = 0.9
Results – Storage Capacity

\[ y = 0.0005x^2 + 0.0023x \]

- 78 basins
- Volume = 75.41 m³
Results – Runoff Generation

- 78 basins = 3,042 m² (0.87%)

<table>
<thead>
<tr>
<th>Grid Code</th>
<th>Land Cover Class</th>
<th>Area (square meters)</th>
<th>Percent of Total Area</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Before</td>
<td>After</td>
</tr>
<tr>
<td>1</td>
<td>Building</td>
<td>62,046</td>
<td>61,998</td>
</tr>
<tr>
<td>2</td>
<td>Soil/Gravel</td>
<td>117,671</td>
<td>116,804</td>
</tr>
<tr>
<td>3</td>
<td>Vegetation</td>
<td>70,796</td>
<td>70,316</td>
</tr>
<tr>
<td>4</td>
<td>Pavement/Concrete</td>
<td>100,531</td>
<td>98,884</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>351,044</td>
<td>348,002</td>
</tr>
</tbody>
</table>
## Results – Runoff Generation

<table>
<thead>
<tr>
<th>Grid Code</th>
<th>Land Cover Class</th>
<th>1-Year (0.01969 m)</th>
<th>2-Year (0.02537 m)</th>
<th>10-Year (0.03988 m)</th>
<th>100-Year (0.06147 m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Building</td>
<td>1,099.24</td>
<td>1,416.95</td>
<td>2,226.84</td>
<td>3,432.46</td>
</tr>
<tr>
<td>2</td>
<td>Soil/Gravel</td>
<td>1,389.81</td>
<td>1,791.51</td>
<td>2,815.49</td>
<td>4,339.80</td>
</tr>
<tr>
<td>3</td>
<td>Vegetation</td>
<td>487.77</td>
<td>628.75</td>
<td>988.12</td>
<td>1,523.09</td>
</tr>
<tr>
<td>4</td>
<td>Pavement/Concrete</td>
<td>1,781.06</td>
<td>2,295.84</td>
<td>3,608.08</td>
<td>5,561.50</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>4,757.87</td>
<td>6,133.05</td>
<td>9,638.53</td>
<td>14,856.85</td>
</tr>
</tbody>
</table>

<table>
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<tr>
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<th>1-Year (0.01969 m)</th>
<th>2-Year (0.02537 m)</th>
<th>10-Year (0.03988 m)</th>
<th>100-Year (0.06147 m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Building</td>
<td>1,098.39</td>
<td>1,415.86</td>
<td>2,225.12</td>
<td>3,429.80</td>
</tr>
<tr>
<td>2</td>
<td>Soil/Gravel</td>
<td>1,379.57</td>
<td>1,778.31</td>
<td>2,794.75</td>
<td>4,307.82</td>
</tr>
<tr>
<td>3</td>
<td>Vegetation</td>
<td>484.46</td>
<td>624.48</td>
<td>981.42</td>
<td>1,512.76</td>
</tr>
<tr>
<td>4</td>
<td>Pavement/Concrete</td>
<td>1,751.88</td>
<td>2,258.23</td>
<td>3,548.97</td>
<td>5,470.38</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>4,714.30</td>
<td>6,076.88</td>
<td>9,550.25</td>
<td>14,720.77</td>
</tr>
</tbody>
</table>
## Results – Runoff Generation

<table>
<thead>
<tr>
<th></th>
<th>1-Year</th>
<th>2-Year</th>
<th>10-Year</th>
<th>100-Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduction in Stormwater Runoff Generation (cubic meters)</td>
<td>43.58</td>
<td>56.17</td>
<td>88.28</td>
<td>136.07</td>
</tr>
<tr>
<td></td>
<td>(0.92%)</td>
<td>(0.92%)</td>
<td>(0.92%)</td>
<td>(0.92%)</td>
</tr>
</tbody>
</table>
## Results – Total Potential Reduction in Stormwater Runoff

<table>
<thead>
<tr>
<th></th>
<th>1-Year</th>
<th>2-Year</th>
<th>10-Year</th>
<th>100-Year</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Storage Capacity</strong></td>
<td>75.41</td>
<td>75.41</td>
<td>75.41</td>
<td>75.41</td>
</tr>
<tr>
<td><strong>Runoff Generation</strong></td>
<td>43.58</td>
<td>56.17</td>
<td>88.28</td>
<td>136.07</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>118.99</td>
<td>131.58</td>
<td>163.69</td>
<td>211.48</td>
</tr>
<tr>
<td><strong>(cubic meters)</strong></td>
<td>(2.50%)</td>
<td>(2.15%)</td>
<td>(1.70%)</td>
<td>(1.42%)</td>
</tr>
</tbody>
</table>
Conclusions
Conclusions

- 78 basins = 3,042 m² (0.87%)
- Storage capacity increased - 75.41 m³
- Runoff generation reduced - 0.92%
- Smaller storms – storage capacity, first flush, LID
- Larger storms – runoff generation
Next Steps
Next Steps

• Storage capacity – dynamic storage, infiltration rates, change over time
• Rainfall volumes/intensities
• Curve Number
• Additional studies
  - Dunbar Springs, Menlo Park, and Northwest Neighborhoods
Acknowledgments

• Field Data Collection
  - Eric Herman, Amy Dillon, Mary & Bill Willmon

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  - Camiliano Juarez, Pima County Neighborhood Reinvestment Program
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  - Helen Wilson

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Thank You

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