Reducing the Impacts of Extreme Precipitation Using Green Infrastructure: What’s the Cost? An Economic Assessment

Hilarie Sorensen
University of Minnesota Sea Grant
Economic Assessment

Setting it up → Estimating flood damages → Choosing green infrastructure options → Estimating green infrastructure costs and benefits
Minnesota: 7 Floods in 7 Years

2007 Late Summer SE MN record 15-inch rain

2008 June MN+IA Cedar River

2009 Spring Snowmelt Red River Basin

2010 Spring Snowmelt Red and MN Rivers

2010 Fall Southern MN 6-10 inches rain

2011 Spring Statewide

2012 June NE MN 6-10 inches rain
June 2012 Flood Event

Preceded by very wet May (one of wettest on record)

6-10 inches of rainfall June 19-20

Severe flash flooding region-wide

Record river flooding for ~2 Weeks

Estimated $80-100 million damages
Hydrographs show differing stream responses

Figure 5. Provisional stage hydrographs at selected U.S. Geological Survey streamgages in northeastern Minnesota for June 10 through July 29, 2012.
Stormwater Challenges

- Large
- Old
- Grade
- Soils C & D
- Bedrock

Slide Courtesy: Chris Kleist, City of Duluth
Reducing Future Damage

- Larger culverts
- Wood and vegetation
- Green Infrastructure

Slide Courtesy: Chris Kleist, City of Duluth
Chester Creek Watershed
Ridge Axis Elevation ~ 1400 feet

Lake Level ~ 590 feet
Damage in Chester Creek from June 2012 Flood

Duluth Research Area

Cost Estimate for Damaged Infrastructure

Miller Creek - $1,596,770
Chester Creek - $1,776,878
1 - $685,000
2 - $2,000
3 - $128,500
4 - $20,000
5 - $941,378
Tischer Creek - $1,298,190

Legend:
- Stream damage
- Trail damage
- Watershed boundary
- 100 year flood zone
- 500 year flood zone
CURRENT LAND COVER

Legend

- Chester Creek Watershed
- Wetlands
- Forest
- Developed, High Intensity
- Developed, Low Intensity
- Developed, Medium Intensity
- Developed, Open Space
- Bare Land
- Cultivated Crops
- Grassland/Herbaceous
- Open Water
- Pasture/Hay
- Scrub/Shrub

Land Cover Source: Coastal Change Analysis Program (C-CAP) 2010
Future Runoff
Runoff Reduction Goal
Runoff Reduction Volumes

Economic Assessment

- Setting it up
- Estimating flood damages
- Choosing green infrastructure options
- Estimating green infrastructure costs and benefits
What Flooding Should We Expect?
## Future Precipitation

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Model</th>
<th>Year</th>
<th>2-yr storm*</th>
<th>10-yr storm</th>
<th>100-yr storm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warm and wet</td>
<td>MRI</td>
<td>2035</td>
<td>8.49%</td>
<td>8.54%</td>
<td>8.77%</td>
</tr>
</tbody>
</table>

* This value is not generated by CREAT and was extrapolated using a log regression trend.
GOAL:
20% Reduction in Peak Discharge
How much storage is needed to reach this target?
### Frequency Increase of Peak Discharges

<table>
<thead>
<tr>
<th>Scenario:</th>
<th>% Chance 2 yr Peak Discharge*</th>
<th>% Chance 10 yr Peak Discharge</th>
<th>% Chance 100 yr Peak Discharge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current Land use &amp; Precipitation</td>
<td>50.00%</td>
<td>10.00%</td>
<td>1.00%</td>
</tr>
<tr>
<td>Future Land Use &amp; Precipitation</td>
<td>74.87%</td>
<td>14.95%</td>
<td>1.84%</td>
</tr>
<tr>
<td>Current Land Use &amp; Precip with Storage**</td>
<td>34.00%</td>
<td>3.95%</td>
<td>0.24%</td>
</tr>
<tr>
<td>Future Land Use &amp; Precip with Storage**</td>
<td>52.49%</td>
<td>7.00%</td>
<td>0.51%</td>
</tr>
</tbody>
</table>

% Chance peak discharge based on current discharge

** Storage assumed to be 20% of flow from current conditions

Final Report, Table 20
GOAL:
20% Reduction in Peak Discharge
How much storage is needed to reach this target?

76 acre-feet
(current conditions)

86 acre-feet
(future conditions)
Damages: What We Estimated

- Damage to Structures (Hazus)
- Loss of Recreational Use
- Post Storm Land Restoration Costs
- Storm Sewer Infrastructure Costs
How We Did It

- Reduce previously calculated peak discharges by 20% (USGS Regression equations)
- Input the new peak discharges into HEC-RAS to obtain flood depth grids
- Re-run Hazus with the new flood depth grids to see how damage changes

The Results

Current Precipitation, Current Land Use, 20% Flood Storage
- 38% fewer buildings damaged
- 27% monetary reduction in building damages

Future Precipitation, Future Land Use, 20% Flood Storage
- 27% fewer buildings damaged
- 16% monetary reduction in building damages
Potential Impacts/ Co-Benefits

- Transportation Infrastructure: roads, bridges, dams, drainage
- Water/wastewater infrastructure: CSOs, SSOs, sewage treatment, drinking water
- Water quality
  - Boating, swimming, fishing
- Recreation - Are there use data?
  - Camping, hiking, birding, xc skiing?
- Increased property values
- Non-Market Values: ecosystem services, wildlife habitat, open space
Economic Assessment

1. Setting up
2. Estimating flood damages
3. Choosing green infrastructure options
4. Estimating green infrastructure costs and benefits
Green Infrastructure/LID
Chester Creek Watershed is 19.2% wetland and 35.1% forest!

PROTECT EXISTING FORESTS AND WETLANDS

CREATE NEW NATURAL AREAS TO ABSORB FLOOD WATERS

- Rain Barrels and Cisterns
- Retention Ponds
- Green and Blue Roofs
- Extended Detention Wetlands
- Permeable Pavement
- Underground Storage
- Stormwater Tree Trenches
- Bioswales and Rain Gardens
Committed communities
Economic Assessment

Setting it up → Estimating flood damages → Choosing green infrastructure options → Estimating green infrastructure costs and benefits
What would it cost to get 76 Acre-feet using GI?

Factors influencing cost:

- Site Hydrology
- Available open space
- Community preference
- Presence of underground obstructions
- Presence of natural features

<table>
<thead>
<tr>
<th>GI Practice</th>
<th>Capital Cost / Cubic foot storage</th>
<th>Annual O&amp;M / cubic foot storage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bioswale</td>
<td>21.2</td>
<td>1.3</td>
</tr>
<tr>
<td>Blue Roof</td>
<td>6.0</td>
<td>0.2</td>
</tr>
<tr>
<td>Permeable Pavement</td>
<td>16.8</td>
<td>N/A</td>
</tr>
<tr>
<td>Underground Storage</td>
<td>41.3</td>
<td>1.3</td>
</tr>
<tr>
<td>Retention Pond</td>
<td>2.9</td>
<td>0.0</td>
</tr>
<tr>
<td>Detention Wetland</td>
<td>1.3</td>
<td>N/A</td>
</tr>
</tbody>
</table>
If you implemented 76 acre-feet of extended detention wetlands at $1.30/CF your total cost would be $4,303,728.

If you implemented 76 acre-feet of underground storage at $41.30/CF your total cost would be $136,726,128.

**What’s the answer?**

<table>
<thead>
<tr>
<th>Most Expensive $$$$$</th>
<th>Underground Storage</th>
</tr>
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<tbody>
<tr>
<td>Bioretention</td>
<td>Permeable Pavement</td>
</tr>
<tr>
<td>Blue Roof</td>
<td>Retention Pond</td>
</tr>
<tr>
<td>Least Expensive $</td>
<td>Extended Detention Wetland</td>
</tr>
</tbody>
</table>
Co-Benefits of Green Infrastructure

- Recreational, educational, and other use
- Increased property values
- Ecological Benefits
- Improved water and air quality
- Improved neighborhood aesthetics
- Reduced damages to public infrastructure
  - Roads, bridges, sidewalks
  - Water and sewage treatment facilities
What can this mean for Duluth?

Duluth has science-based information to support planning, decisions, and future funding opportunities.

- Increased property values
- Pilot projects
- Increased water quality
- Reduced risk
- Able to use park
- Reduced O&M costs
Duluth receives U.S. EPA’s first Great Lakes Shoreline Cities Green Infrastructure Grant

Table 50.18.1.E-4: Discharge Rate Limits

<table>
<thead>
<tr>
<th>Location</th>
<th>Post-Development Peak Flow Rates at Each Discharge Point Shall Not Exceed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone A -- Above Bluff Line</td>
<td>Zone B -- Below Bluff Line</td>
</tr>
<tr>
<td>Type of Activity</td>
<td></td>
</tr>
<tr>
<td>New Development</td>
<td>75% of predevelopment peak flow rates for 10 and 100 year events; and 90% of predevelopment peak flow rate for 2 year event</td>
</tr>
<tr>
<td>Redevelopment</td>
<td>Predevelopment peak flow rates for all storm events</td>
</tr>
</tbody>
</table>

“I’m pleased to announce these projects and the new funding to support them,” said U.S. EPA Region 5 Administrator Bob Persily. “This marks the first time EPA is providing this type of grant to Great Lakes cities and is another example of the federal government partnering with localities to protect Great Lakes water quality. Duluth’s projects will provide important benefits to the city and surrounding communities. These include reduced stormwater runoff, improved water quality and increased public access to Lake Superior.”
Major Project Components

- **Climate Prediction**: How much precipitation in 2035 and 2060? ERG/HW (EPA’s CREAT Model)
- **Hydrology and Hydraulics**: What is the resulting flood elevation and associated impacts for the biggest storms? Army Corps of Engineers
- **Flood Damage Estimate**: What is the cost of the damage caused? ASFPM (HAZUS)
- **Planning Options**: What can be done to minimize damages (i.e., adapt)? ERG/HW (Land Use Planning and Gray/Green Infrastructure)
- **Economic Analysis**: What are the costs and benefits of such adaptations? ERG/HW
Questions?

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