Rain Gardens – Part of the Solution to Storm Water Problems

Prepared by
Roger Bannerman
WDNR
Increases in Urban Runoff for Lake Mendota from 2000 to 2020

- Amounts of Urban Runoff for 2000:
  - 5,600,000,000 gallons
  - or 17,000 acre-feet

- Amounts of Urban Runoff for 2020:
  - 8,800,000,000 gallons
  - or 27,500 acre-feet

(Increase of 57%)
Impacts of Urbanization on Stream Baseflows

Graph showing the relationship between Baseflow (m³/s/1000km²) and % Connected Imperviousness.
# Impacts of Imperviousness on Surface and Groundwater Quantities

<table>
<thead>
<tr>
<th>Type of Resource</th>
<th>Increase Imperviousness From 2 to 18%</th>
<th>Increase Imperviousness From 2 to 60%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stream Baseflow</td>
<td>-20%</td>
<td>Dry Stream</td>
</tr>
<tr>
<td>Surface Runoff</td>
<td>+ 90%</td>
<td>+485%</td>
</tr>
<tr>
<td>Regional Groundwater Levels</td>
<td>-10%</td>
<td>-55%</td>
</tr>
</tbody>
</table>
# Predicted Temperature Increase

**Lowes Creek, Eau Claire**

<table>
<thead>
<tr>
<th></th>
<th>Mean (°F)</th>
<th>Maximum (°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing</td>
<td>62</td>
<td>71</td>
</tr>
<tr>
<td>Developed</td>
<td>67</td>
<td>82</td>
</tr>
<tr>
<td>(35% Impervious)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Brown Trout Optimum = 66°F*
Number of species

Connected imperviousness (%)

$Y = 10^{\log_{10}(x)(-0.585)+1.775}$ - 1
The Hydrologic Cycle

- Precipitation
- Transpiration
- Direct Runoff
- Infiltration
- Evaporation

Lakes & Oceans
Ground Water
The Runoff Management Rules

Presentation by the Wisconsin Department of Natural Resources
Post-Construction Performance Standards - Peak Runoff

- Reduce peak runoff discharge rates, MEP, as compared to pre-development conditions for the 2-year, 24 hour design storm.
Post Construction Infiltration Performance Standards

By design, infiltrate sufficient runoff volume so that the post-development average annual infiltration volume shall be a portion of pre-development infiltration volume.

**Residential**

90% (1% Cap)

**Non-residential**

60% (2% Cap)
**The Problem: Conventional Site Design**

Collect
Concentrate
Convey
Centralized
Control

**Good Drainage Paradigm**
Conventional Pipe and Pond  Centralized Control

“Efficiency”
Distributed Small-scale Controls

Maintaining Natural Hydrology Functions
Hydrograph Pre/Post Development

Post-Development (Higher Peak, More Volume, and Earlier Peak Time)

Pre-development

Detention
Partnership for Rain Gardens
Maplewood, Minnesota  (near St. Paul)
Rain gardens installed by city as part of street replacement project
<table>
<thead>
<tr>
<th>Box</th>
<th>Cu</th>
<th>Pb</th>
<th>Zn</th>
<th>P</th>
<th>TKN</th>
<th>NH4</th>
<th>NO3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper</td>
<td>90</td>
<td>93</td>
<td>87</td>
<td>0</td>
<td>37</td>
<td>54</td>
<td>-97</td>
</tr>
<tr>
<td>Middle</td>
<td>93</td>
<td>99</td>
<td>98</td>
<td>73</td>
<td>60</td>
<td>86</td>
<td>-194</td>
</tr>
<tr>
<td>Lower</td>
<td>93</td>
<td>99</td>
<td>99</td>
<td>81</td>
<td>68</td>
<td>79</td>
<td>23</td>
</tr>
<tr>
<td>Field</td>
<td>97</td>
<td>96</td>
<td>95</td>
<td>65</td>
<td>52</td>
<td>92</td>
<td>16</td>
</tr>
</tbody>
</table>

Dr. Allen Davis, University of Maryland
% Runoff Volume by Landuse for 4 Subwatersheds

- Res.: 42%
- Ind.: 7%
- Comm.: 3%
- Freeway: 1%
- Open: 47%
Bioretention in Residential Right-of-way = 34%
Reduction in Annual Runoff
% Annual Runoff Volumes from Source Areas in 4 Subwatersheds

- Roof: 24%
- Plots: 12%
- Streets: 22%
- Lawns: 7%
- HWY: 7%
- Other: 7%
Rain Gardens on Residential Lawns = 15% Reduction in Annual Runoff
Sources of Annual Runoff Volume in Medium Density Residential

- Lawn: 43%
- Drive: 19%
- Sidewalk: 12%
- Street: 4%
- Roof: 22%
100% Control Lawn and Roof Runoff = 300 sq.ft. of Garden
Plant List for Backyard Rain Gardens

**Shade Garden**
- Jacobs Ladder
- Celandine Poppy
- Short’s Aster
- Zig-Zag Goldenrod

**Middle & Big Garden**
- Blue Flag Iris
- Purple Cone Flower
- Shooting Star
- Sweet Black-eyed Su.
- Smooth Penstemon
- Heartleaf Blue Aster
- Ohio Goldenrod
- Fire Pink
- Silky Wild Rye
- Northern Sea Oats
Value of Using Native Plants

- Deeper roots – absorbs more water
- Uses no fertilizer
- Uses little or no pesticides
- Easy maintenance after first year
- Does not require watering in droughts after establishment
Lake Delton, Wisconsin
St. Francis Addition Plat
Soil Permeability
- Moderate
- Moderately Rapid
- Rapid
- Very Rapid
- Variable
% Annual Runoff Volume by Source Area for St Francis

- Roofs: 16%
- Playground: 4%
- Driveways: 8%
- Sidewalks: 4%
- Street Area: 40%
- Lawns: 5%
- Other Pervious: 12%
- Other Impervious: 6%
Elements of Low Impact Design for St. Francis Development

- Rain Gardens
- Infiltration Trenches in Street Boulevards
- Two Regional Infiltration Basins
- Reduce Street Width from 36 to 32 Feet
- Protection of Riparian Buffer

Steve Apfelbaum: Applied Ecological Services
## Infiltration Goals for Area 4 at St Francis

<table>
<thead>
<tr>
<th>Type of Volume Calculation</th>
<th>Annual Infiltration Volume, inches</th>
<th>Annual Runoff, inches</th>
</tr>
</thead>
<tbody>
<tr>
<td>Predevelopment</td>
<td>28.0</td>
<td>0.8</td>
</tr>
<tr>
<td>90% Goal</td>
<td>25.2</td>
<td>3.6</td>
</tr>
<tr>
<td>No Controls</td>
<td>24.4</td>
<td>4.4</td>
</tr>
<tr>
<td>Volume Change</td>
<td>0.8</td>
<td>0.8 (18% of post annual runoff)</td>
</tr>
<tr>
<td>Type of Practice</td>
<td>Additional Infiltration</td>
<td>Percent of 0.8 inches</td>
</tr>
<tr>
<td>------------------</td>
<td>-------------------------</td>
<td>----------------------</td>
</tr>
<tr>
<td>Rain Garden (1/house)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Infiltration Trenches</td>
<td>3.7</td>
<td>460%</td>
</tr>
<tr>
<td>Infiltration Basin</td>
<td>4.4</td>
<td>550%</td>
</tr>
<tr>
<td>Rain Garden (3/house &amp; 60% of lawn)</td>
<td>0.5</td>
<td>62%</td>
</tr>
</tbody>
</table>
Percent Runoff Volume by Source Area for Cedar Hills

- Roofs: 12%
- Driveways: 11%
- Sidewalks: 12%
- Streets: 60%
- Undeveloped Lawns: 4%
- Other: 1%

Legend:
- Roofs
- Driveways
- Sidewalks
- Streets
- Undeveloped Lawns
Elements of Low Impact Design for Cedar Hills Development

- Grass Swales
- Detention Pond
- Infiltration Basin
- Reduce Street Width (From 36 to 33 feet – park one side of street)
Reductions Goals in Runoff Volume for Cedar Hills

<table>
<thead>
<tr>
<th>Type of Volume Calculation</th>
<th>Annual Infiltration Volume, in.</th>
<th>Annual Runoff Volume, in.</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Pre-development</em></td>
<td>28.0</td>
<td>0.8</td>
</tr>
<tr>
<td><em>90% Goal</em></td>
<td>25.2</td>
<td>3.6</td>
</tr>
<tr>
<td><em>No Controls</em></td>
<td>22.5</td>
<td>6.3</td>
</tr>
<tr>
<td><em>Volume Change to Achieve 90%</em></td>
<td>2.7</td>
<td>2.7 (43% of Postdevelop. Runoff)</td>
</tr>
</tbody>
</table>
Volume Reduction Estimates for Practices at Cedar Hills

<table>
<thead>
<tr>
<th>Type of Practice</th>
<th>Additional Infiltration, inches</th>
<th>% of 2.7 inch goal</th>
<th>% Reduction in Annual Postdev. Runoff</th>
</tr>
</thead>
<tbody>
<tr>
<td>33 foot wide streets</td>
<td>0.3</td>
<td>11%</td>
<td>5%</td>
</tr>
<tr>
<td>Grass Swales</td>
<td>0.7</td>
<td>26%</td>
<td>11%</td>
</tr>
<tr>
<td>Infiltration basin – proper size</td>
<td>1.7</td>
<td>63%</td>
<td>27%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>2.7</strong></td>
<td><strong>100%</strong></td>
<td><strong>43%</strong></td>
</tr>
<tr>
<td>Infiltration basin – Actual size</td>
<td>4.6</td>
<td>170%</td>
<td>89% (0.7” runoff)</td>
</tr>
</tbody>
</table>
Infiltration Basin Monitoring

- ISCO refrigerated water-quality sampler
- CS double-bubbler stage sensor
- Tipping-bucket raingage

- H-flume
- Temperature probe

- Marsh-McBirney FLODAR system
  ➢ measures stage, velocity and discharge
Visual Clues to TSS Concentration Variation

May 1999

June 2000

June 2001

November 2001

Blue = KP

Red = Bourbon
### Performance of Low-Impact Design Based on Annual Precipitation

<table>
<thead>
<tr>
<th>Water Year</th>
<th>Construction Phase</th>
<th>Rainfall (inches)</th>
<th>Volume Leaving Basin (inches)</th>
<th>Percent of Volume Retained (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1999</td>
<td>Pre</td>
<td>33.3</td>
<td>0.46</td>
<td>99%</td>
</tr>
<tr>
<td>2000</td>
<td>Active</td>
<td>33.9</td>
<td>4.27</td>
<td>87%</td>
</tr>
<tr>
<td>2001</td>
<td>Active</td>
<td>38.3</td>
<td>3.68</td>
<td>90%</td>
</tr>
<tr>
<td>2002</td>
<td>Active*</td>
<td>29.4</td>
<td>0.96</td>
<td>97%</td>
</tr>
</tbody>
</table>

* Site is approximately 75% built-out
Benefits of Rain Garden

- Help Protect and Restore Natural Hydrology of Your Watershed
- Trap Pollutants
- Attract Birds and Butterflies
- Attractive Addition to Property
- Enhance Beauty of City
How Big to Make the Rain Garden

- How deep to make rain garden?
- What type of soil is at the site?
- What is the area draining to the rain garden?
Rain Garden Size: Any size will provide some benefit – most between 70 and 300 square feet
Rain Garden Depth

Balance Between Depth and Surface Area

- Minimize drain time – less than 1 day.
- Minimize digging.
- Suggest depths between 3 to 8 inches
Selection of Rain Garden Depth – Slope Very Important

- Slope < 4% = 3 to 5 inches deep.
- Slope of 5 to 7 % = 6 to 7 inches deep.
- Slope of 8 to 12 % = about 8 inches deep.
- Slope > 12 % suggest another site.
Importance of Soil Type

Higher the Infiltration Rate the Smaller the Rain Garden Surface Area.

- Infiltration Rate of Sandy Soils: 2.5 in/hr
- Infiltration Rate of Silty Soils: 0.5 in/hr
- Infiltration Rate of Clayey Soils: 0.3 in/hr
Determination of Soil Type

- Best method is to have soil analyzed.
- Use soil map – not too dependable because of possible disturbed soils in construction area.
- Use feel of soil.
- Do perk test – six inches deep
Size of Drainage Area

Question: Is the rain garden treating rooftop and lawn or just rooftop runoff?
Calculation of Drainage Area

Example Calculation

- Length = 100 feet
- Width = 20 feet
- \( L \times W = 2000 \text{ sq feet} \)
- \( 2000 \text{ sq. ft.} / 4 = 500 \text{ square feet} \)
## Size Factors for Rain Gardens Less Than 30 feet from Downspout – 100% Control

<table>
<thead>
<tr>
<th>Type of Soil</th>
<th>3 to 5 Inches Deep</th>
<th>6 to 7 Inches Deep</th>
<th>8 Inches Deep</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sandy</td>
<td>0.19</td>
<td>0.15</td>
<td>0.08</td>
</tr>
<tr>
<td>Silty</td>
<td>0.34</td>
<td>0.25</td>
<td>0.16</td>
</tr>
<tr>
<td>Clayey</td>
<td>0.43</td>
<td>0.32</td>
<td>0.20</td>
</tr>
</tbody>
</table>
Garden Size Calculation for Silty Soils and 4 Inch Depth

Size of Rooftop Draining to Garden X Size Factor = Size of Garden

\[ 500 \text{ square feet} \times 0.34 = 170 \text{ square feet} \]

Shape = 10 feet X 17 feet
## Size Factors for Rain Gardens More Than 30 Feet from Downspout – 100% Control

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>All Depths Between 3 and 8 inches</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sandy</td>
<td>0.03</td>
</tr>
<tr>
<td>Silty</td>
<td>0.06</td>
</tr>
<tr>
<td>Clayey</td>
<td>0.10</td>
</tr>
</tbody>
</table>
Variation in Rain Garden Size with Percent Reduction in Annual Runoff

Size for >30 feet from Downspout and Silty Soils
Size of Bannerman Rain Garden

- Size = 180 square feet or 30% of roof area.
- Depth is about 3.5 inches.
- Volume of Garden is about 55 cubic feet or it holds about 400 gallons of water.
- Volume is equal to the runoff from a 1 inch rainfall. Controls 60% of annual roof runoff.
- Infiltration rate is about 2 inches/hour
downhill stake

string

5% slope

start digging here

uphill stake

10'

6"
List of Plants in Bannerman Rain Garden

- Blue False Indigo
- Red Milkweed
- Nodding Pink Onion
- Prairie Blazing Star
- Sq. Stemmed Sticky Monkey
- Sweet Black-Eyed Susan
- Ohio Goldenrod
- Prairie Dropseed

- Early summer
- Summer
- Summer
- Summer
- Summer
- Fall
- Fall
- All
Deep Tilling
Maintenance of Rain Gardens

- First year requires vigilant weeding.
- Some watering at first, especially plants on berm.
- Dead plant debris should be removed in the spring.
Cost of Rain Gardens

Cost of Landscape Contract in Dane County is about $12 to $15 per Square Foot. Includes Design, Construction, Plants, and Planting.
This project is funded in part by the CT DEP through the US EPA Nonpoint Source grant under § 319 of the Clean Water Act.
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Bioretention – Lodi, WI; WDOT (John Voorhees)
Bioretention Design

Growing Media

Aggregate for Water Storage

Underdrain Pipe

Infiltration
Partnership for Rain Gardens
Partnership for Rain Gardens
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