Hydrologic Performance of Vegetated Roofs

Donald Carpenter, Ph.D., PE, LEED AP
Lawrence Technological University

Nathan Griswold, ASLA, GRP
Inhabitect, LLC
Session Overview

- Brief Introduction to Vegetated Roofs
- Hydrologic Performance
- Monitoring
- Modeling
- Hydrologic Design Parameters
Stormwater Management

• Every drop of stormwater that hits a jobsite must be accounted for and managed in some form or fashion

• Vegetated roofs are capable and have the ability to managing a high percentage of this rain on our rooftops

• Filter the runoff to improve water quality
Vegetated Roofs

- Vegetated roofs, also known as green roofs, eco-roofs or living roofs, are engineered systems that are installed over a watertight, man-made, structure.

- Green roofs offer a wide range of economic, ecological, and social benefits in both the public and private sector.
Public Benefits of Green Roofs

• Create “Green Collar” jobs
• Improve stormwater management (quality and quantity)
• Improve air quality
• Increase biodiversity
• Decrease municipal infrastructure costs
• Increase tax revenue
• Reduce the urban heat island effect and peak load energy demand
• Improve community health and well being
• Facilitate new recreational opportunities
• Reduce greenhouse gas emissions
Private Benefits of Green Roofs

- Aesthetic improvements
- Energy savings
- Increase property values
- Increase employee productivity
- Reduce employee absenteeism
- Improve solar panel efficiency
- Improve roof membrane durability
- Meet stormwater and green space regulations
- Improve marketability
- Urban agriculture revenue potential
Typical Assembly

- Plants
- Engineered media
- System Filter
- Drainage and Water retention
- Insulation
- Root Barrier
- Waterproofing
Types of Green Roofs

Extensive

Intensive
Intensive Roof
Intensive Roof
Extensive Green Roofs
St. Clair Community College
Extensive Roof
Comparing the Two Roofs

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Intensive Green Roof</th>
<th>Extensive Green Roof</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil</td>
<td>Greater than 6” of soil depth</td>
<td>Less than 6” soil depth</td>
</tr>
<tr>
<td>Vegetation</td>
<td>Accommodates large trees, shrubs, and well-maintained gardens</td>
<td>Capable of including many kinds of vegetative ground cover and grasses</td>
</tr>
<tr>
<td>Load</td>
<td>Adds 35-300 pounds per square foot</td>
<td>Adds 12-35 pounds per square foot</td>
</tr>
<tr>
<td>Access</td>
<td>Regular access accommodated &amp; encouraged</td>
<td>Usually not designed for public accessibility</td>
</tr>
<tr>
<td>Maintenance</td>
<td>Significant maintenance required</td>
<td>Low maintenance requirements</td>
</tr>
<tr>
<td>Drainage</td>
<td>Includes more robust drainage systems</td>
<td>Simple drainage system</td>
</tr>
</tbody>
</table>
Vegetated Roofs act like a Sponge
Vegetated Roof Hydrologic Design

• Hydrologic response is dependent on roof type and rainfall characteristics
• Most companies report annual retention values – not helpful for site design
• CN and C will vary for each storm – need site specific information or modeling
Hydrologic Performance

- Response is diverse due to:
  - variation in the physical properties of the media
  - layered structure of the various proprietary systems
  - local climatic conditions
Lawrence Tech Vegetated Roof

- 10,000 sq ft: Hydrotech Garden Roof Assembly
- Research project to determine the long term effectiveness with regards to water quality and quantity (USEPA and LTU COE)
LTU Vegetated Roof Cross-Section

- Drought Tolerant Plants Including Sedum Varieties & Dianthus
- Filter Fabric
- Floradrain FD25
- 2 Layers of 1 1/2” Polystyrene Insulation
- Roof Protection Course
- Primer
- 4” Expanded Shale Blend Planting Medium
- Drip Irrigation Tubing Used During Initial 2 Seasons of Plant Establishment
- Water Retention Layer
- Root Barrier
- Waterproof Roof Membrane
- Roof Deck
  - Fire Rated Gypsum Deck Board
  - Metal Deck
LTU Vegetated Roof Performance Evaluation Goals

• Establish long-term monitoring station capable of determining the temporal performance of the green roof
• Determine the overall percent of precipitation retained and detained by the green roof (water quantity)
• Determine the nutrient loading capabilities of the green roof (water quality)
• Determine the reduction in ambient temperature associated with the green roof (air quality)
Experimental Set-Up

- Performance monitoring equipment was set up on three full scale roof systems on campus
  - 3496 sq ft Garden Roof (greenroof)
  - 912 sq ft new rock ballast roof (stoneroof)
  - 1647 sq ft existing asphalt roof (blackroof)
Monitoring Equipment

- Teledyne ISCO Avalanche Samplers
- Teledyne ISCO 730 Bubbler Flowmeter
- Teledyne ISCO 674 Rain Gauge
- 4" Palmer-Bowlus Flumes
- Microdaq USB Temperature sensors
Flow Monitoring Equipment
Greenroof Retention (April - September 2008)

- **Depth (in):** 0, 0.5, 1, 1.5, 2, 2.5, 3, 3.5, 4
- **Percent Retained (%):** 0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100
- **Month:** Apr-08, May-08, Jun-08, Jul-08, Aug-08, Sep-08

The chart shows the amount retained during different months of 2008, with depth increasing and percent retained decreasing as the summer progresses.
Runoff Volume Coefficient

Runoff Comparison - 3 Roofs

- BR
- SR
- GR
- Linear (BR)
- Power (GR)
- Linear (SR)

Rainfall (inches)

Roof Runoff (inches)
LTU Water Quantity Summary

- Volume Retention
  - Rain = 13.4”  Black = 12.0”  Stone = 6.88”  Green = 4.25”
- Peak discharge reduction of 54.23% to 99.94%
- Run-off volume coefficient varies with event magnitude

<table>
<thead>
<tr>
<th>Size Category</th>
<th>Storm Size</th>
<th>Number of Observations</th>
<th>Greenroof</th>
<th>Blackroof</th>
<th>Stoneroof</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small</td>
<td>0.1 - 0.5 (in)</td>
<td>9</td>
<td>0.037</td>
<td>0.88</td>
<td>0.44</td>
</tr>
<tr>
<td>Medium</td>
<td>0.5 – 1 (in)</td>
<td>8</td>
<td>0.13</td>
<td>0.91</td>
<td>0.36</td>
</tr>
<tr>
<td>Large</td>
<td>&gt; 1 (in)</td>
<td>3</td>
<td>0.55</td>
<td>0.92</td>
<td><strong>0.62</strong></td>
</tr>
</tbody>
</table>
Hydrologic Modeling
What is the market asking for?

• Proof of green roof performance
• Specific stormwater management data
• Proof of compliance with local and federal code requirements
• Stormwater quantification data
  • For use in measurable drainage computations by design professionals
National Stormwater Calculator (SWC)

• Developed by the EPA
• A desktop tool that helps users control runoff to promote natural movement of water and to protect and restore the environmental integrity of our waterways
• Clean water is essential to keeping our families and the environment healthy
National Stormwater Calculator (SWC)

- Location
- Soil Type
- Soil Drainage
- Topography
- Precipitation
- Evaporation
- Climate Change
- Land Cover
- Low Impact Development (LID) Controls
- Runoff
Green Values Stormwater Toolbox

- Developed by the Center for Neighborhood Technology (CNT)
- Primarily for planners, engineers, and other municipal staff
- Calculates the benefits of green infrastructure for individual sites and to influence public policy
Green Values Stormwater Toolbox

• Learn what green infrastructure is and what it offers
• Learn how green infrastructure can help you save money
• Understand the costs and benefits of using green infrastructure to mitigate the need for different types of built water infrastructure, such as sewers and detention basins
Hydrotech Hydrology Tool (HHT)

- Manufacture specific calculation
- Calculations offered free of charge
- Utilizes known performance of specific green roof materials
  - Lawrence Tech was one of many monitoring programs used to calibrate the HHT
Hydrotech Hydrology Tool (HHT)

- Can address site specific stormwater requirements
- Provide proof of the Hydrotech Garden Roof Assembly’s performance
- Stormwater quantification data for use in accurate and measurable drainage computations
Hydrotech Hydrology Tool (HHT)

- **24 hour storm event evaluations**
  - How much water is retained within the Garden Roof Assembly

- **Short duration storms events (Rational Method)**
  - How fast water is leaving the Garden Roof

- **Long term storm evaluations**
  - Predicts average performance of the Garden Roof

- **Establish LEED compliance**
  - Does the Garden Roof help the projects LEED goals
Extensive Vegetated Roof Design Parameters

- Recommend Modeling for Performance BUT…
- Curve Numbers
  - $CN = 65$ for rain events 3 x’s depth of media (MI LID Manual)
  - $CN = 85$ for events greater than moisture holding capacity (ASCE Green Roof TC)
- Runoff Volume Coefficient
  - $0 < C_v < 0.8$
- Time to Peak
  - At least one hour
Smarter Design

- Vegetated roofs are a value added piece of the larger, longer term, infrastructure puzzle
- Vegetated roof systems must be designed according to local climatic conditions
- Performance expectations must be based on vegetated roof system and the climatic conditions
- Important to understand performance in the region of application and preferably from full-scale monitoring or modeling results
Questions?

carpenter@ltu.edu
nate@inhabitect.com