Hydrologic Performance of Vegetated Roofs

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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**

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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

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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

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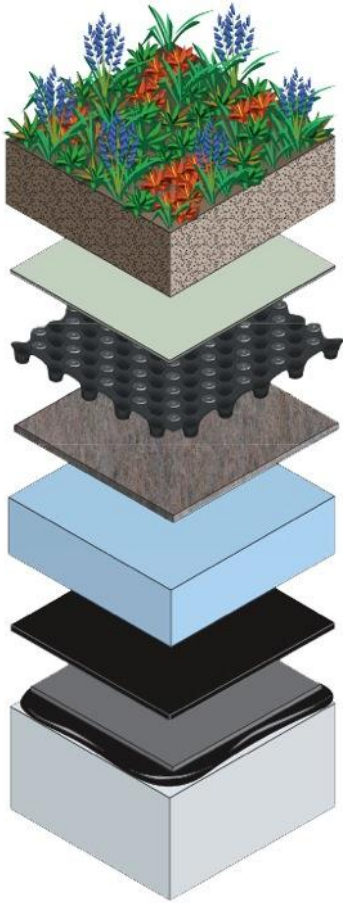
Typical Assembly

- Plants
- Engineered media
- System Filter
- Drainage and Water retention
- Insulation
- Root Barrier
- Waterproofing



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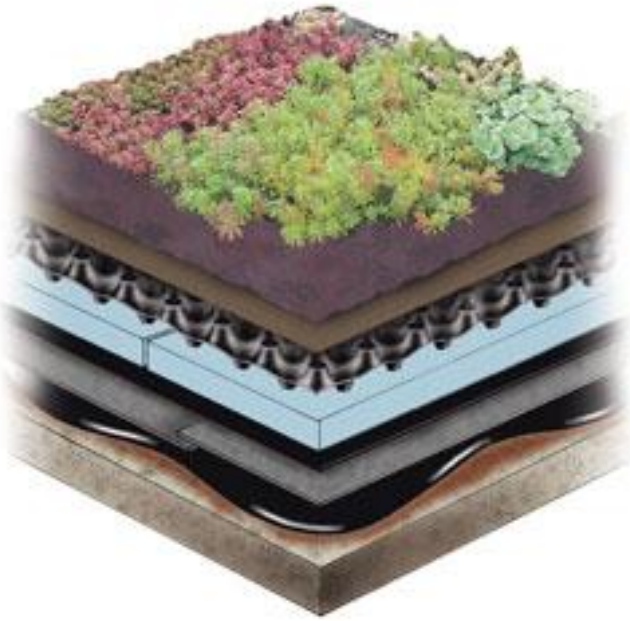
Types of Green Roofs



Extensive

Intensive

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Intensive Roof

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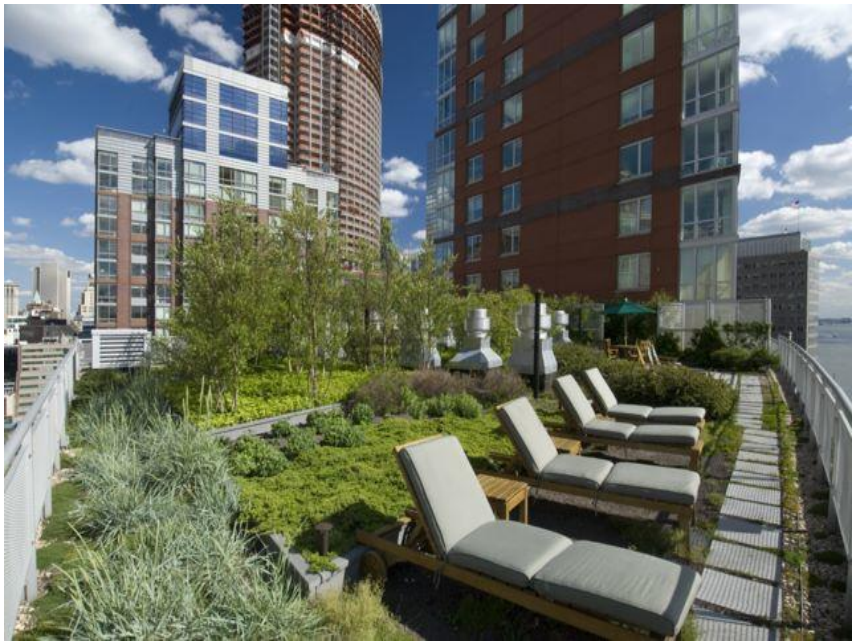
Intensive Roof



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Extensive Green Roofs

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St. Clair Community College
Extensive Roof

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Comparing the Two Roofs

Characteristics	Intensive Green Roof	Extensive Green Roof
Soil	Greater than 6” of soil depth	Less than 6” soil depth
Vegetation	Accommodates large trees, shrubs, and well-maintained gardens	Capable of including many kinds of vegetative ground cover and grasses
Load	Adds 35-300 pounds per square foot	Adds 12-35 pounds per square foot
Access	Regular access accommodated & encouraged	Usually not designed for public accessibility
Maintenance	Significant maintenance required	Low maintenance requirements
Drainage	Includes more robust drainage systems	Simple drainage system

Vegetated Roofs act like a Sponge

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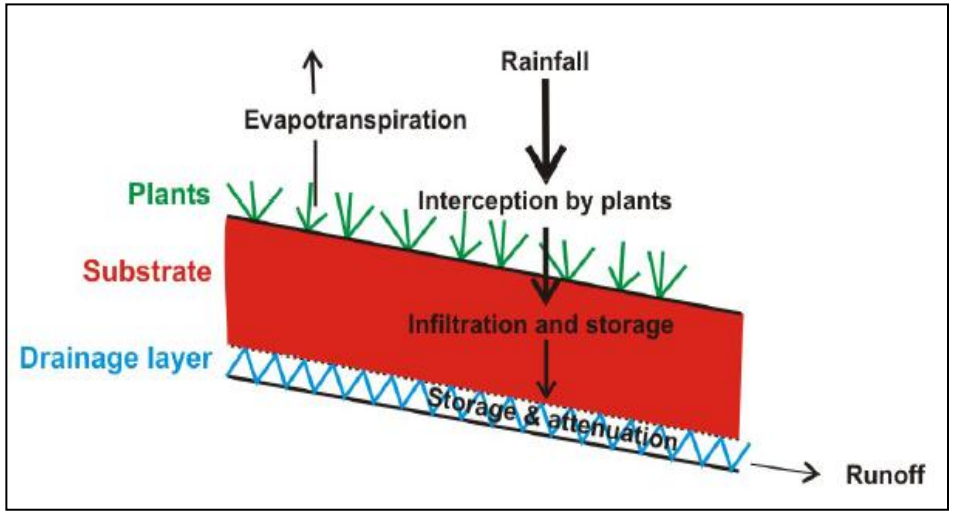
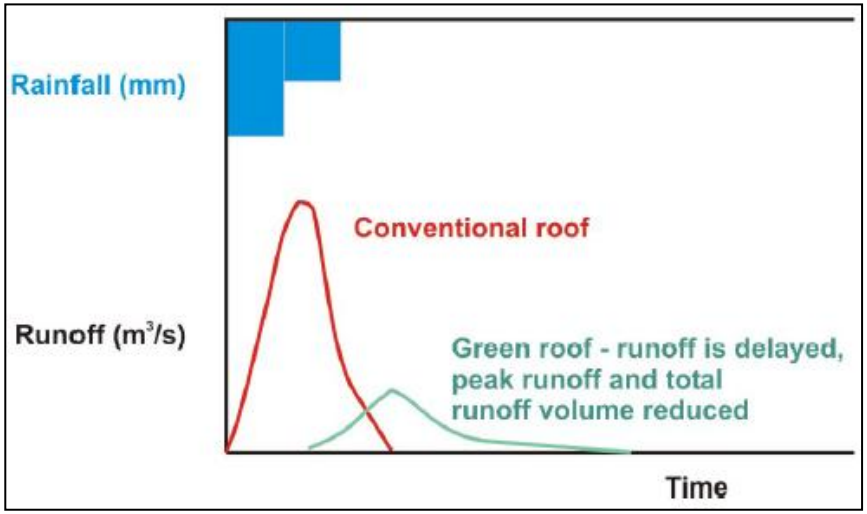
Vegetated Roof Hydrologic Design

- 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





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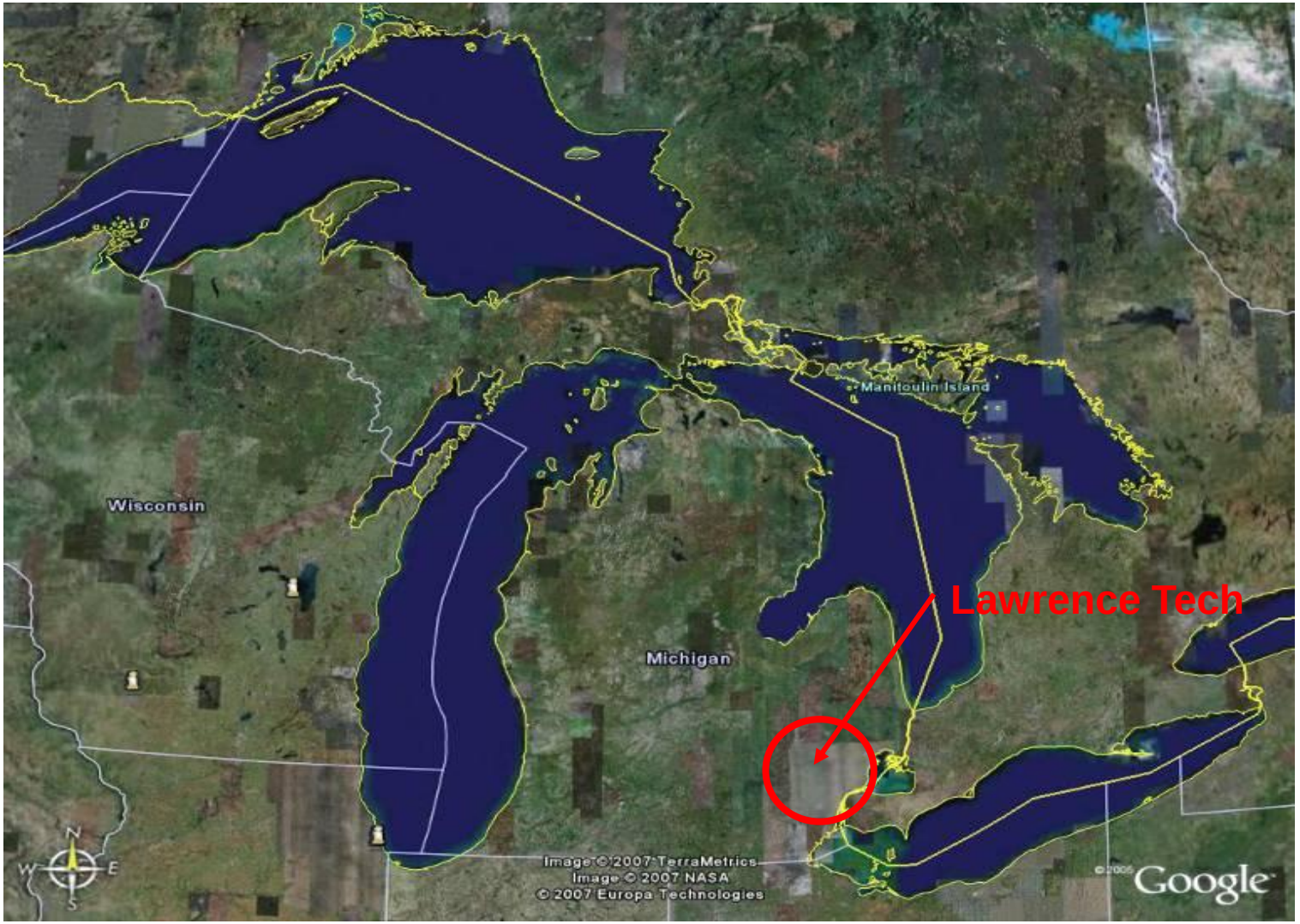

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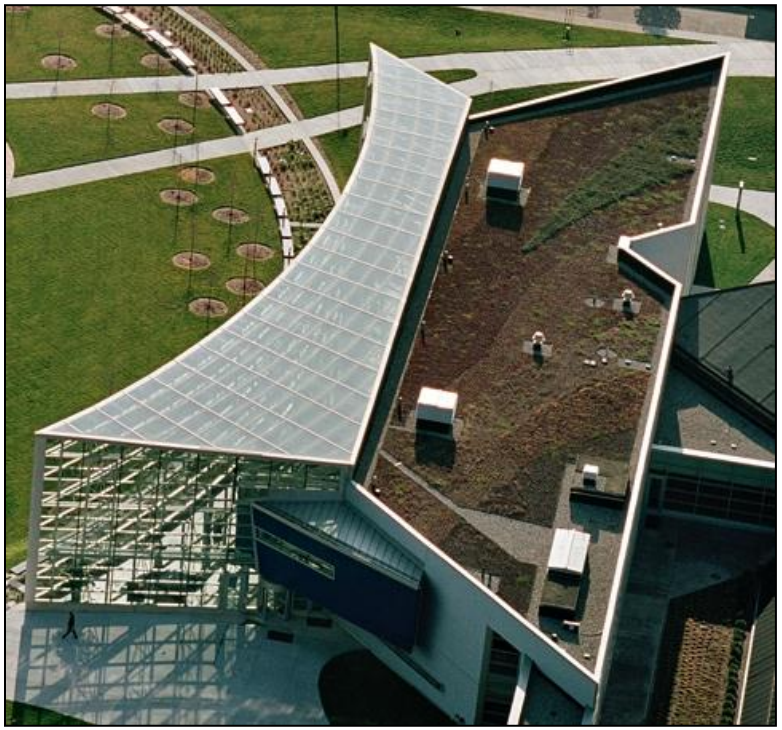
Lawrence Tech Vegetated Roof



- 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)

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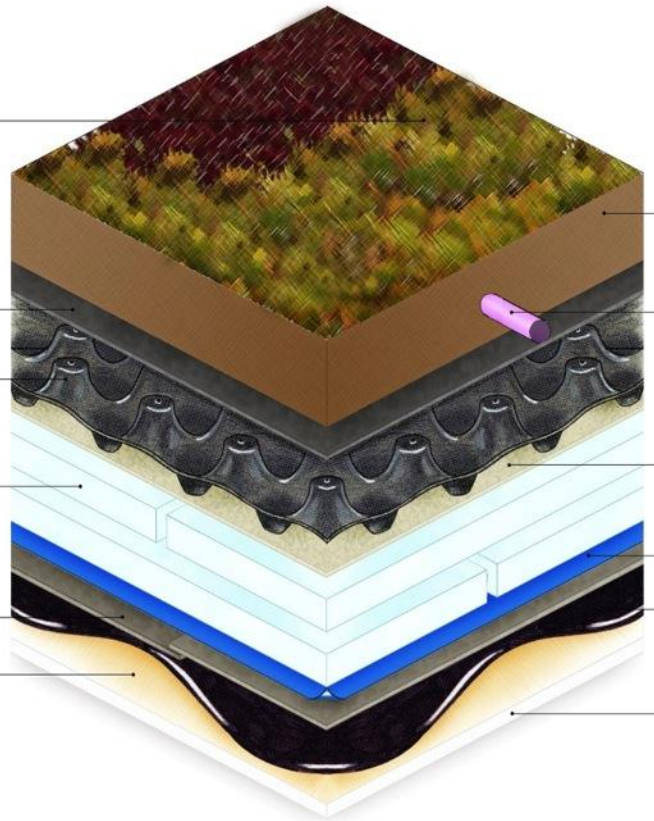
LTU Vegetated Roof Cross-Section



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

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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)

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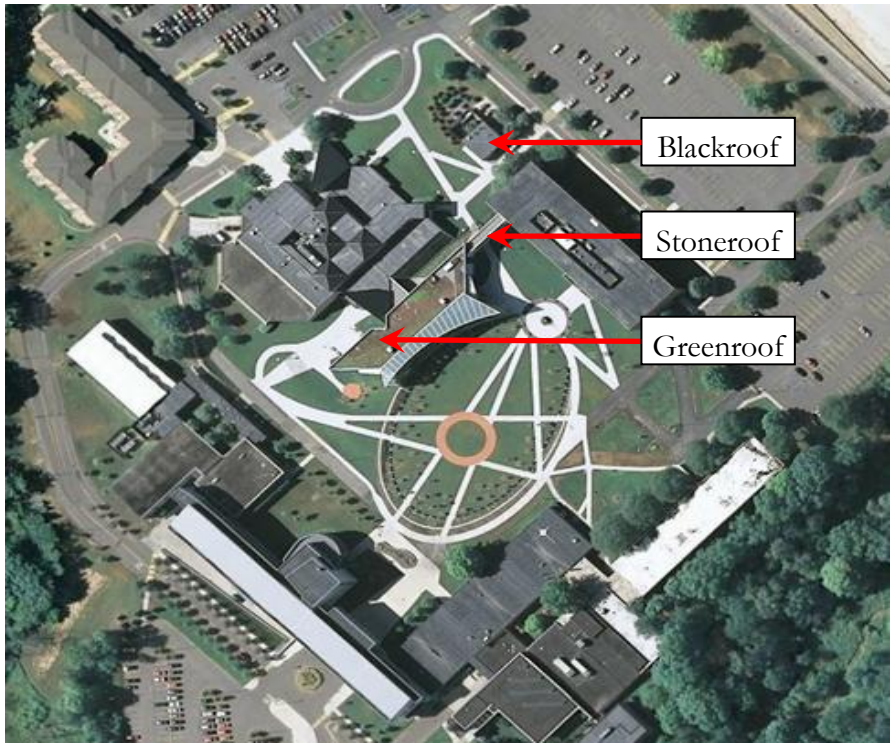
Experimental Set-Up

- 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)



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Monitoring Equipment

- Teledyne ISCO Avalanche Samplers
- Teledyne ISCO 730 Bubbler Flowmeter
- Teledyne ISCO 674 Rain Gauge
- 4" Palmer-Bowlus Flumes
- Microdaq USB Temperature sensors

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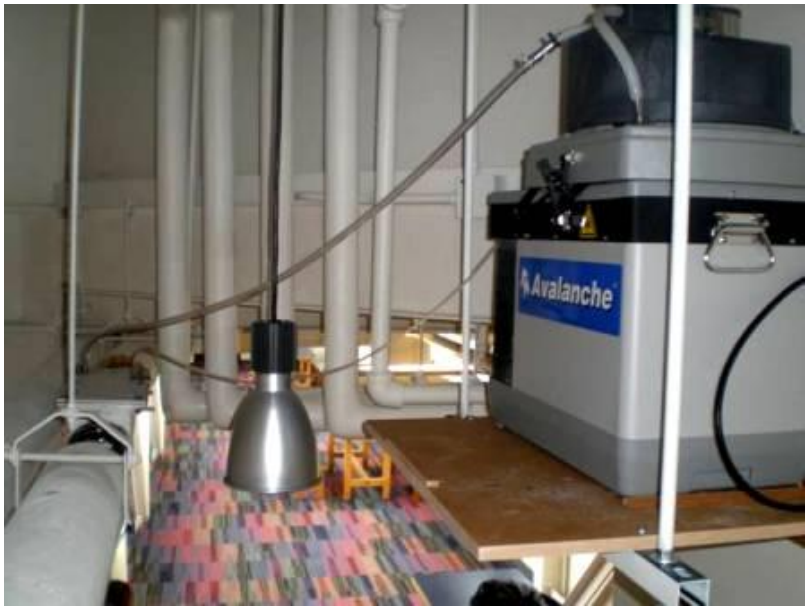
Flow Monitoring Equipment



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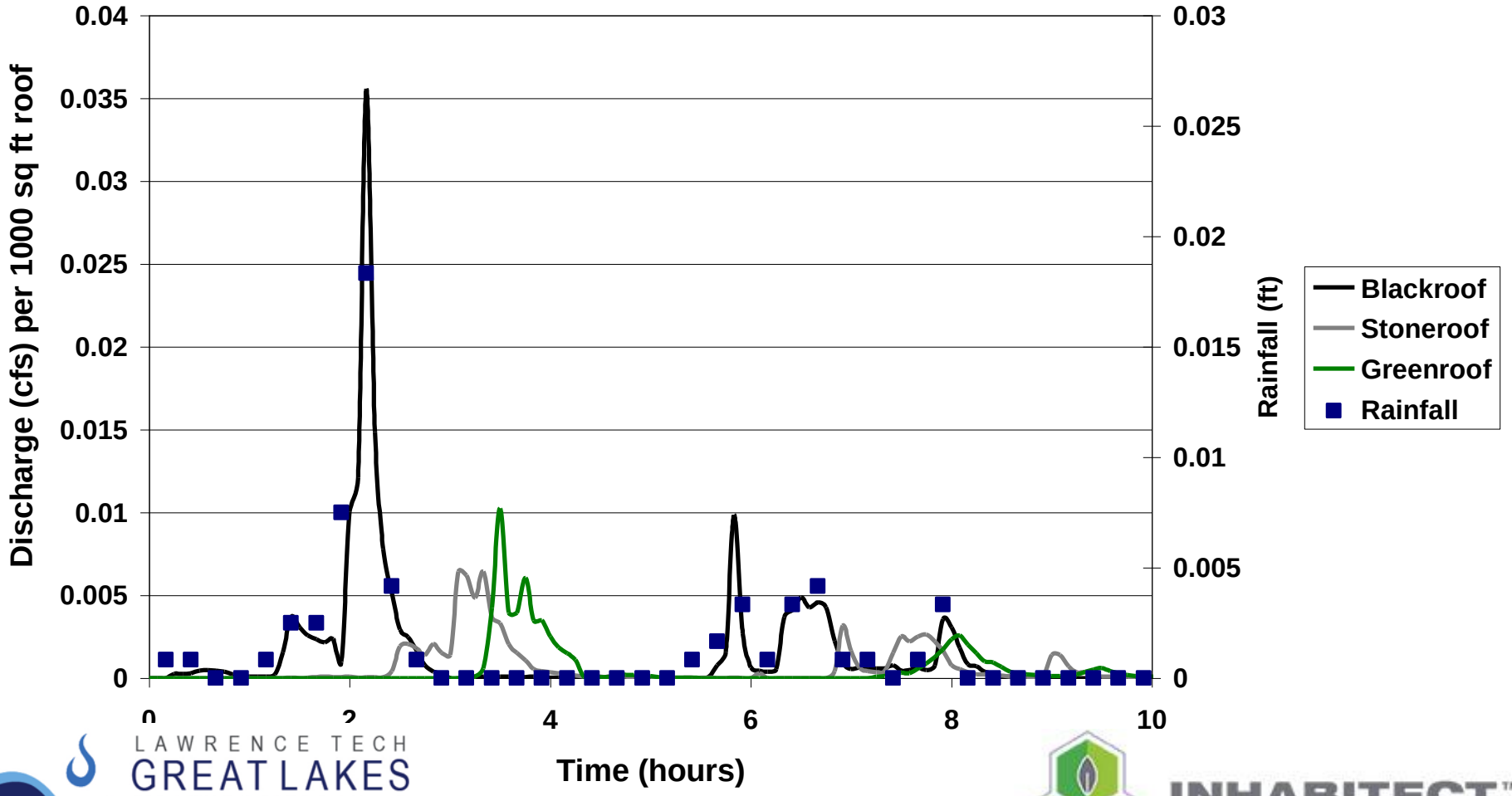
Normalized Hydrographs - June 10, 2008



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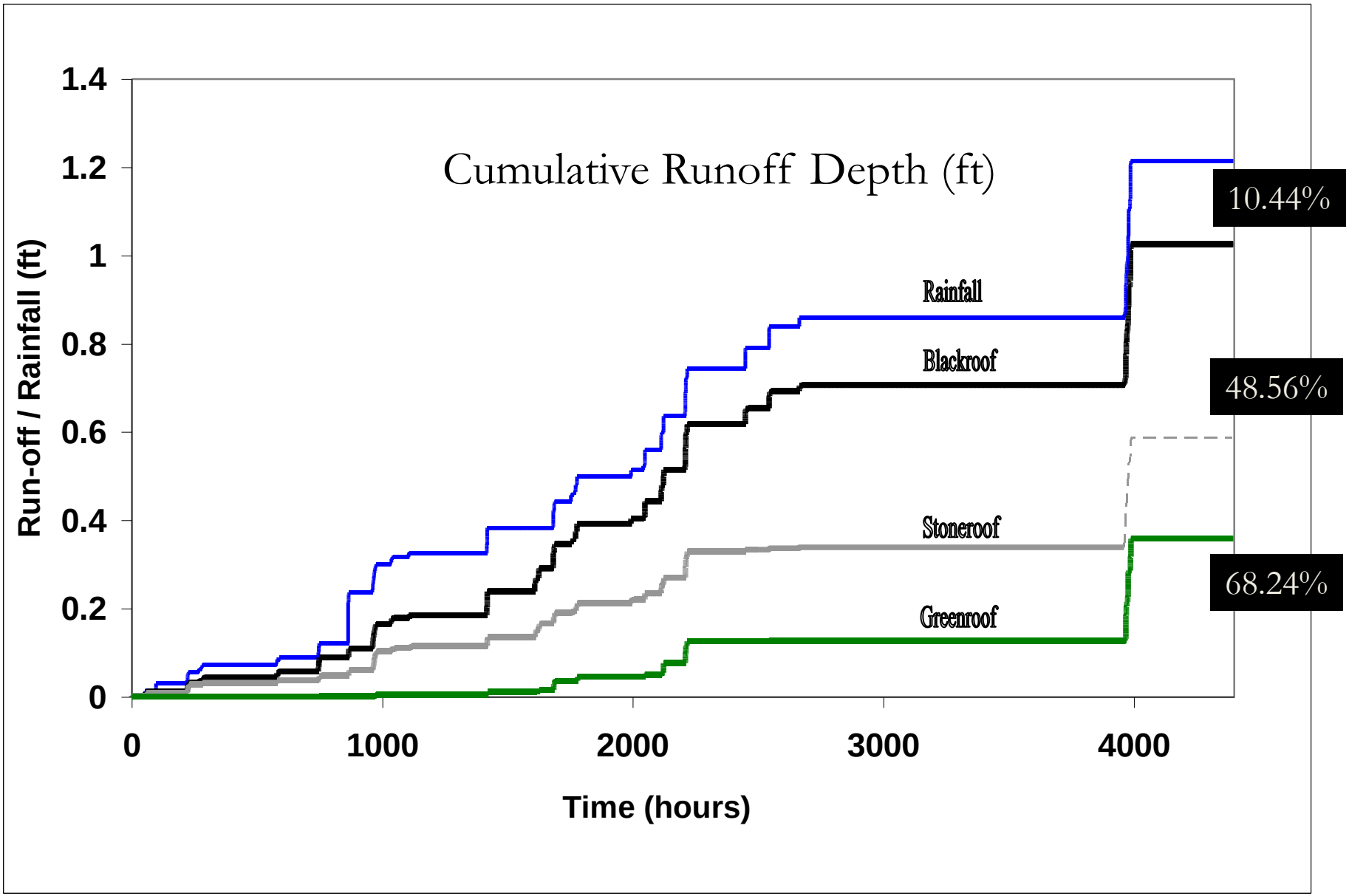
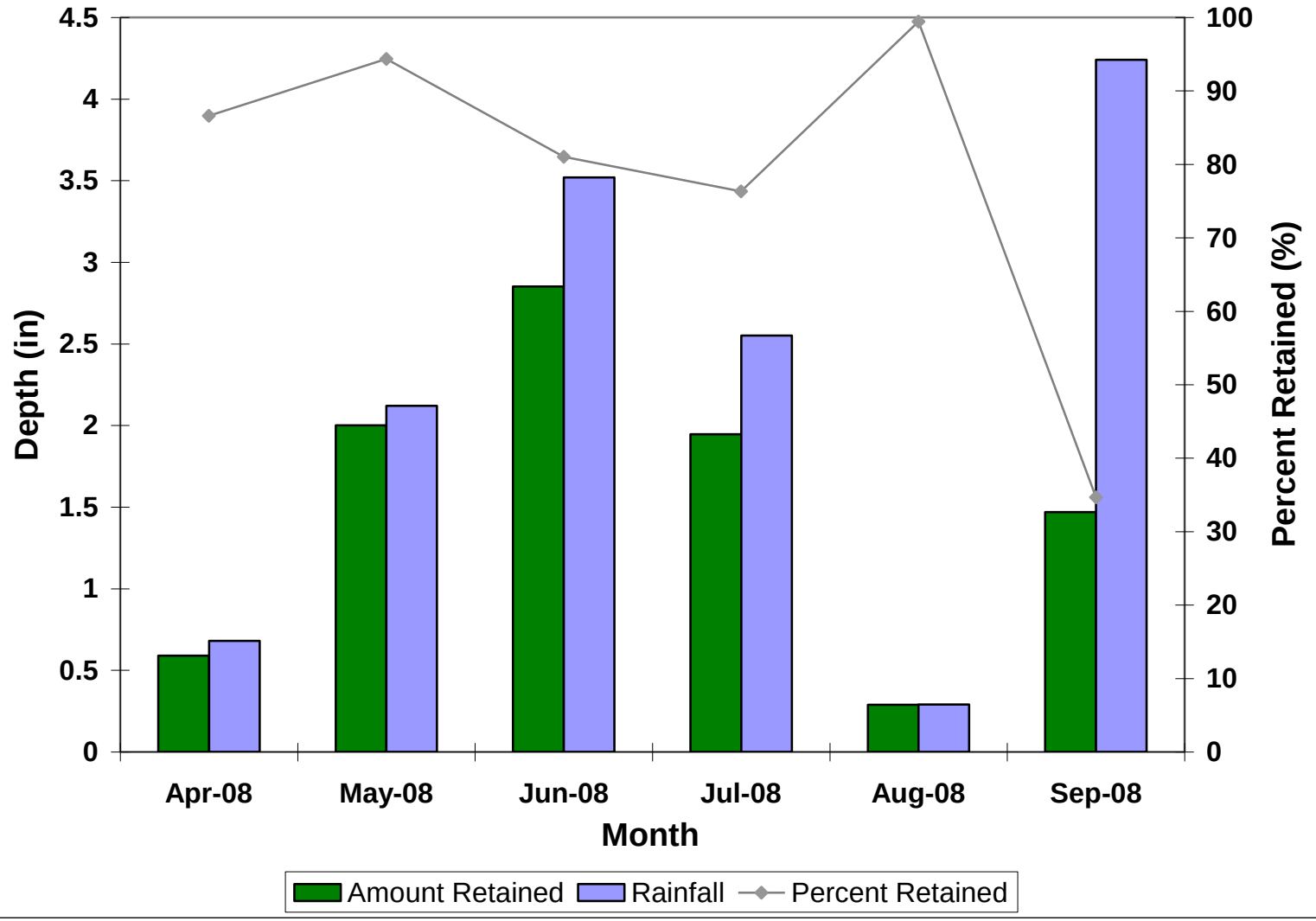
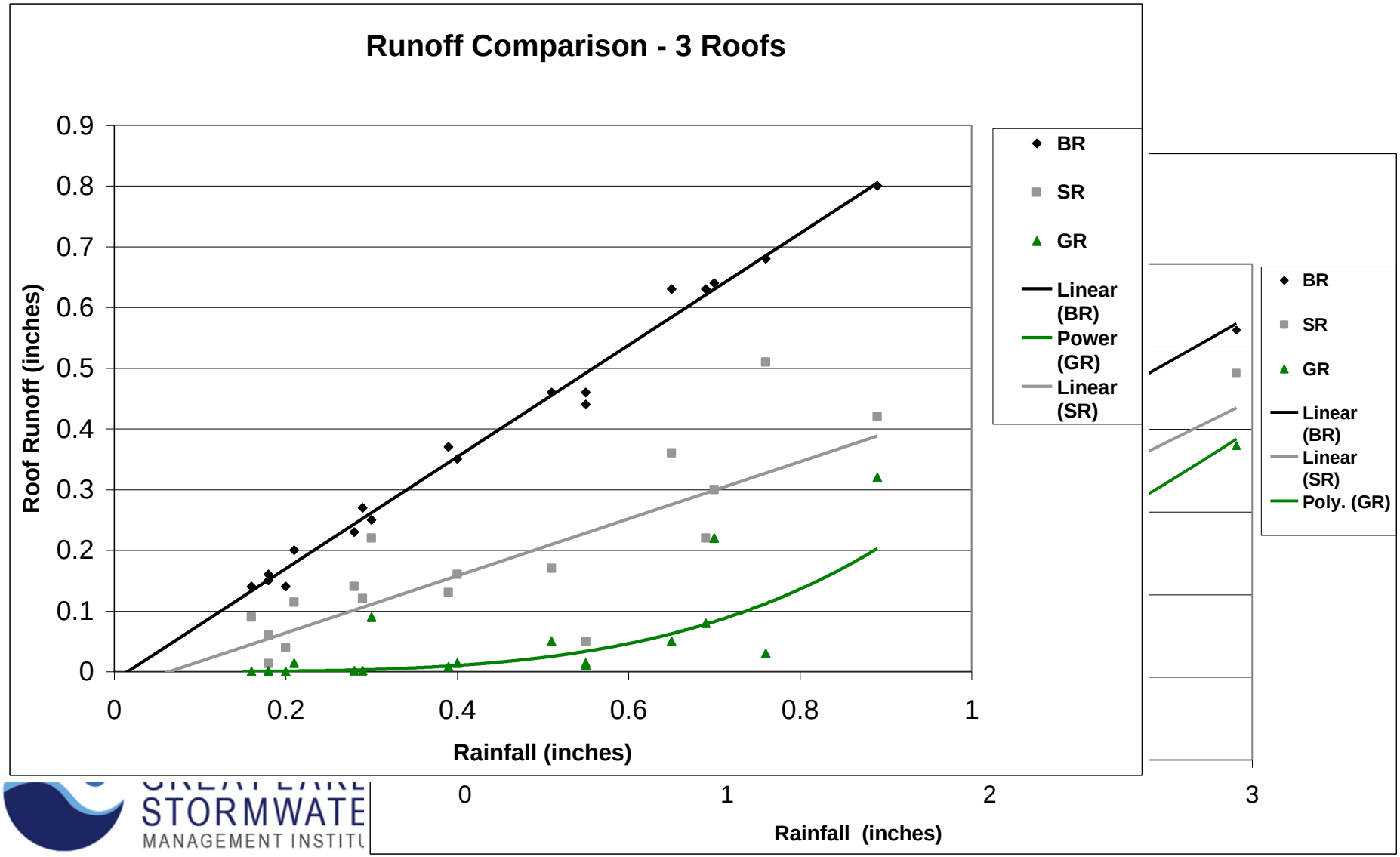

Cumulative Runoff Depth (ft)
Run-off / Rainfall (ft)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
1000
2000
3000
4000
Time (hours)
Rainfall
Blackroof
Stoneroof
Greenroof
10.44%
48.56%
68.24%

Greenroof Retention (April - September 2008)



Runoff Volume Coefficient



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

Size Category	Storm Size	Number of Observations	Greenroof	Blackroof	Stoneroof
Small	0.1 -0.5 (in)	9	0.037	0.88	0.44
Medium	0.5 – 1 (in)	8	0.13	0.91	0.36
Large	> 1 (in)	3	0.55	0.92	***0.62***

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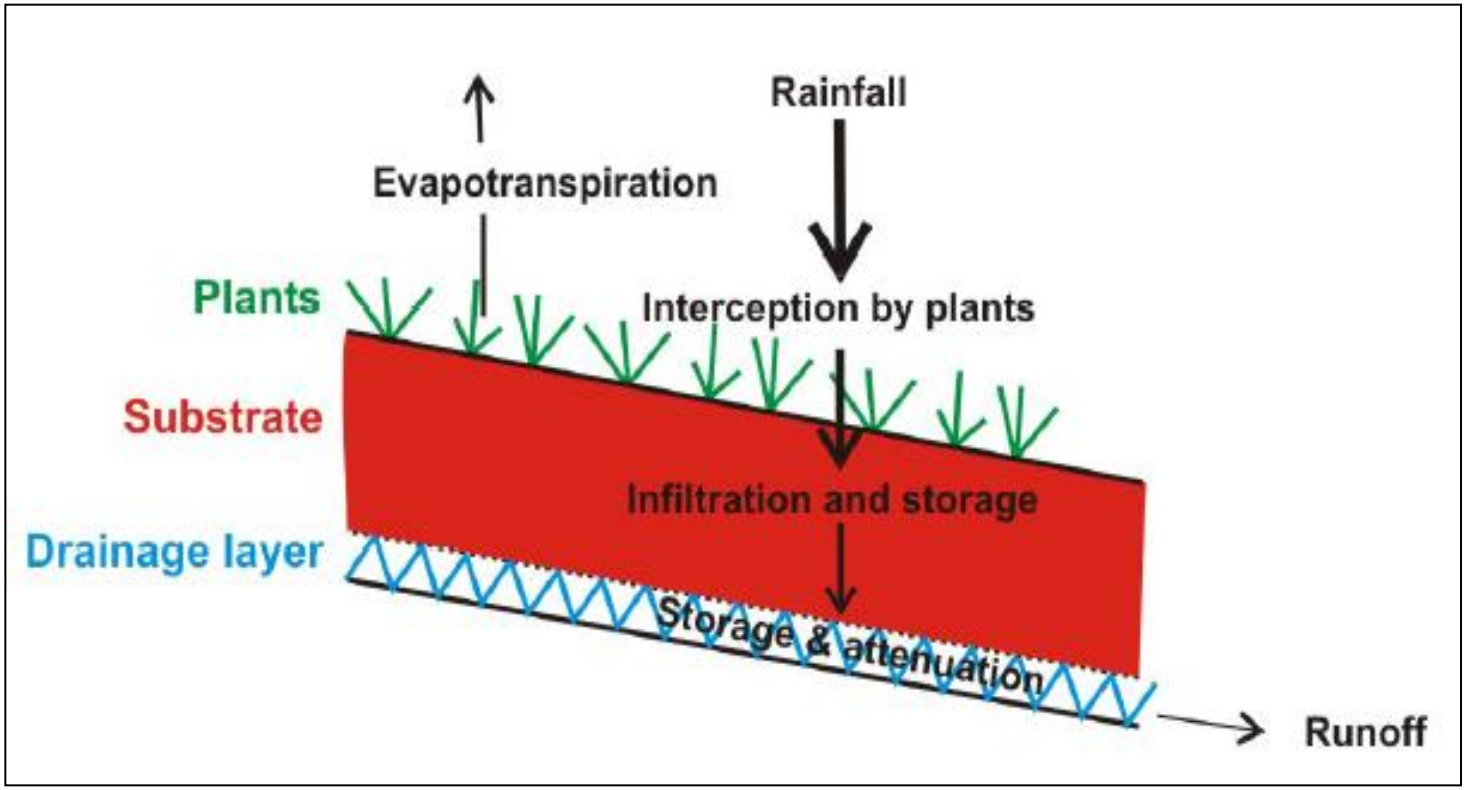
Hydrologic Modeling



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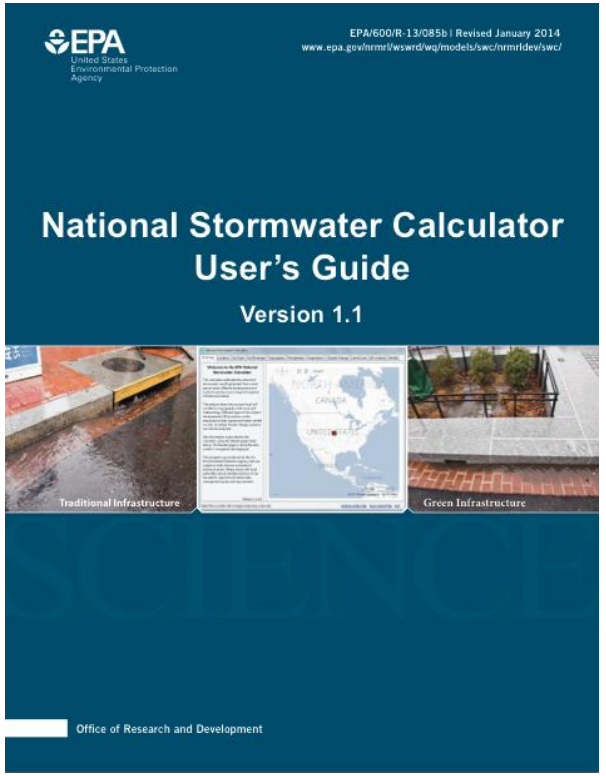
What is the market asking for?

- 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



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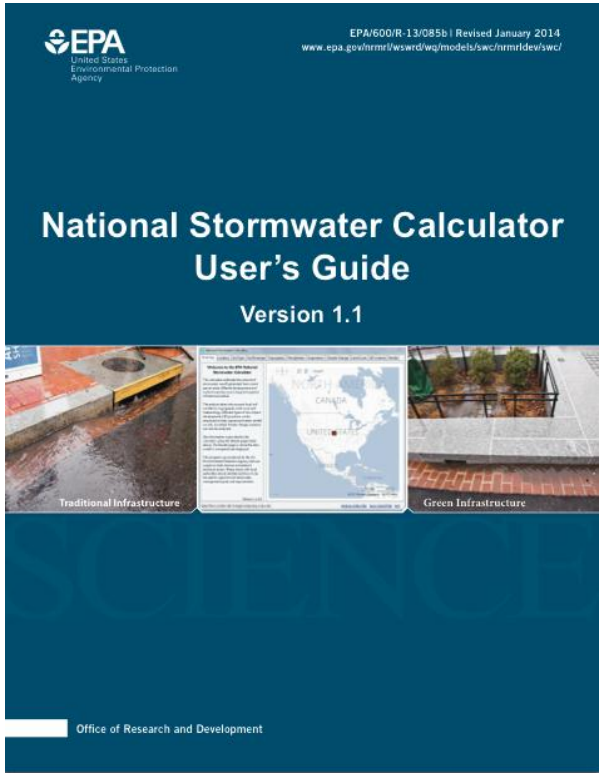
National Stormwater Calculator (SWC)

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



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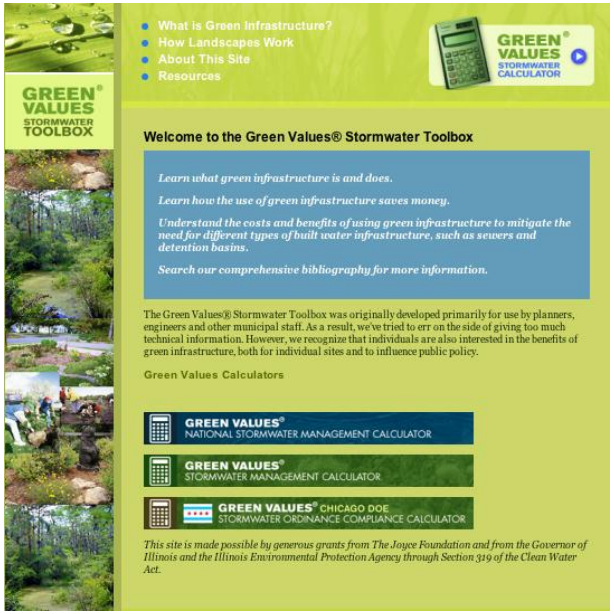
Green Values Stormwater Toolbox

- Developed by the 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

CNT Sustainable Communities Attainable Results



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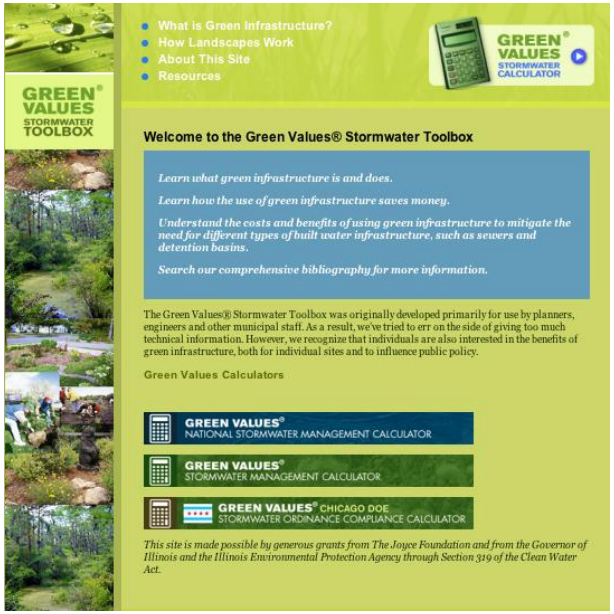
Green Values Stormwater Toolbox

- 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

CNT Sustainable Communities Attainable Results



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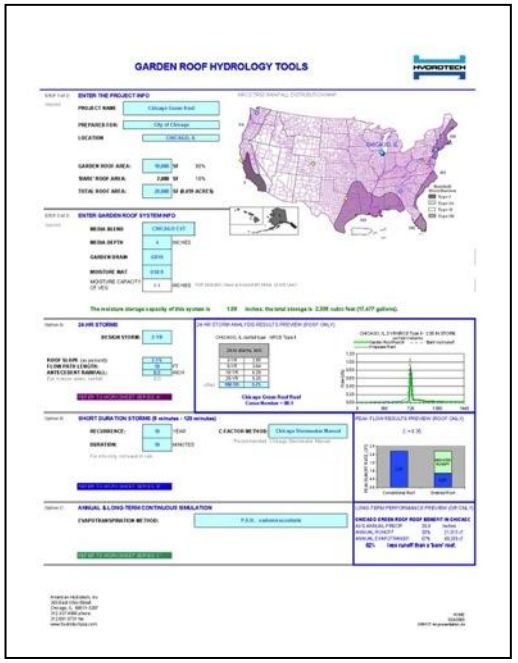
Hydrotech Hydrology Tool (HHT)

- 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



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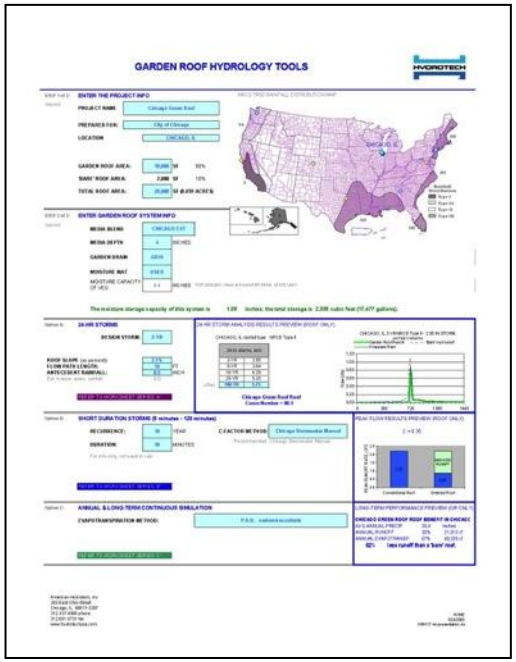
Hydrotech Hydrology Tool (HHT)

- 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



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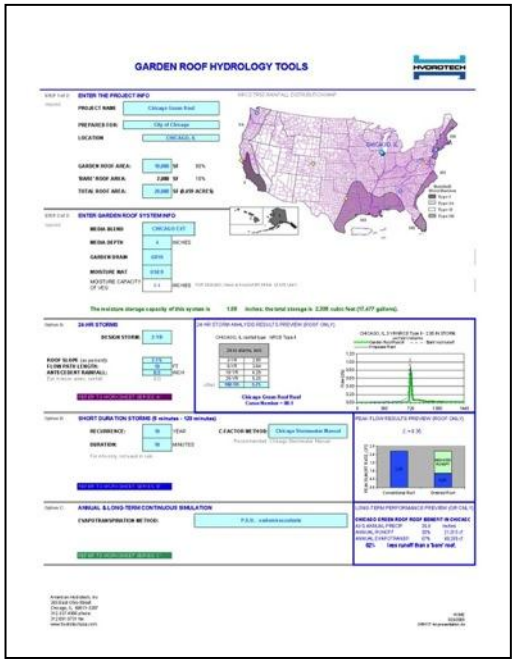
Hydrotech Hydrology Tool (HHT)

- **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



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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

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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

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Questions?

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