Green Infrastructure at the Edison Environmental Center - Vegetative

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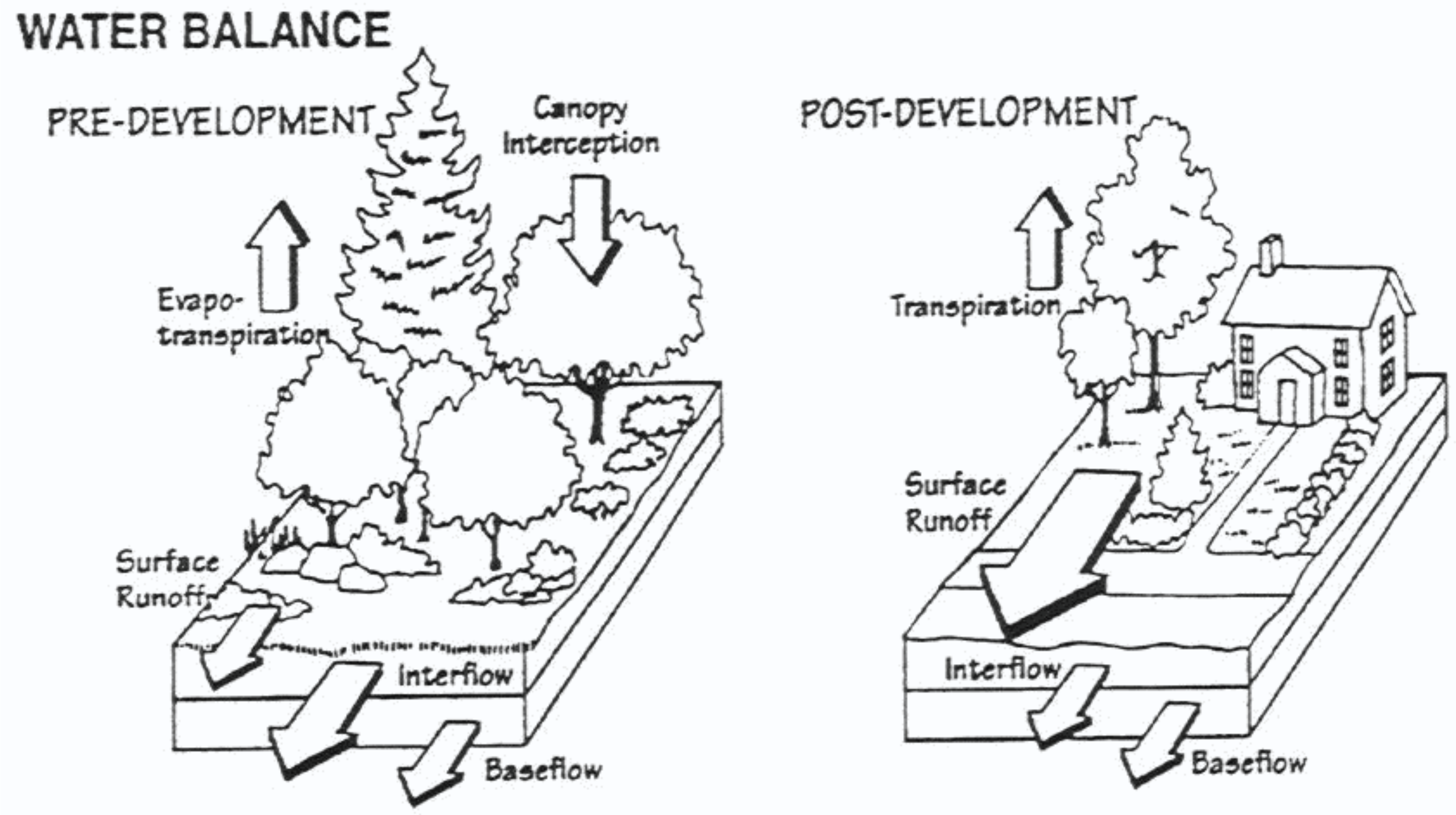
Effect of Development on Water Cycle



EPA (2004)

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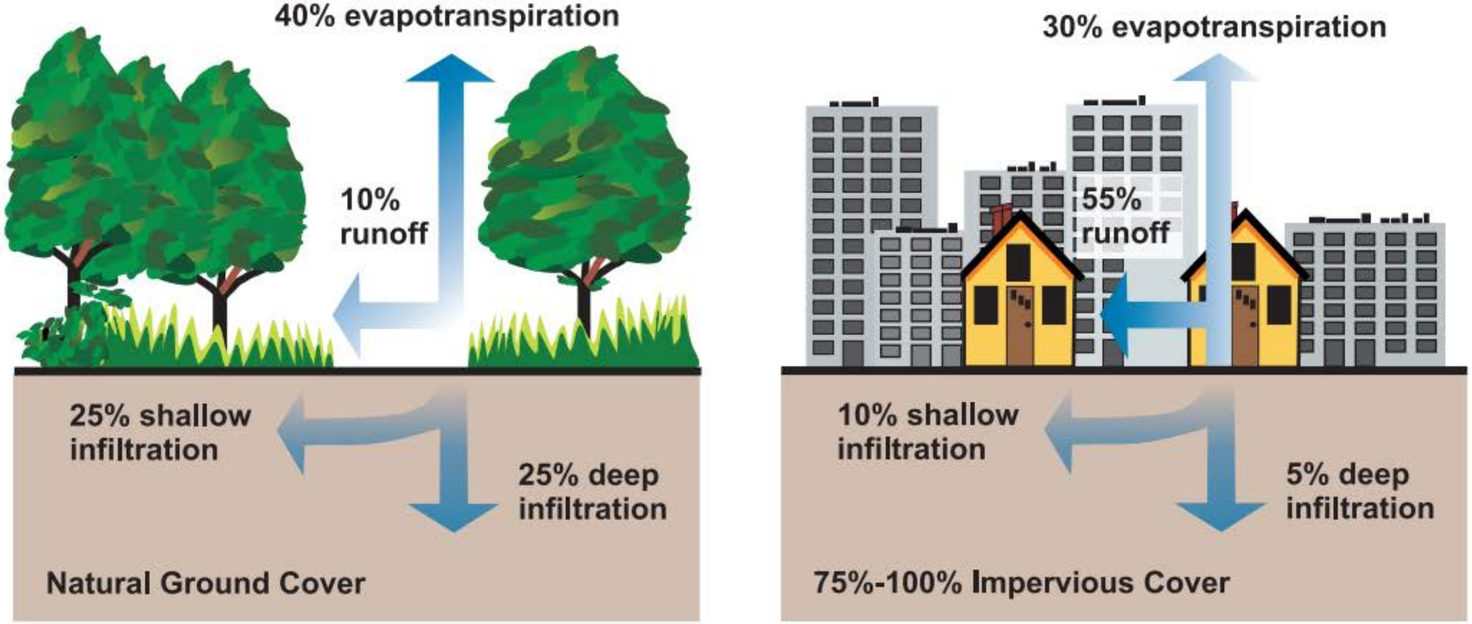
Effect of Urbanization on Water Cycle



EPA 841-F-03-003
http://www.epa.gov/sites/production/files/2015-10/documents/nps_urban-facts_final.pdf

Effect of Development on Stream Flow (Hydrograph)

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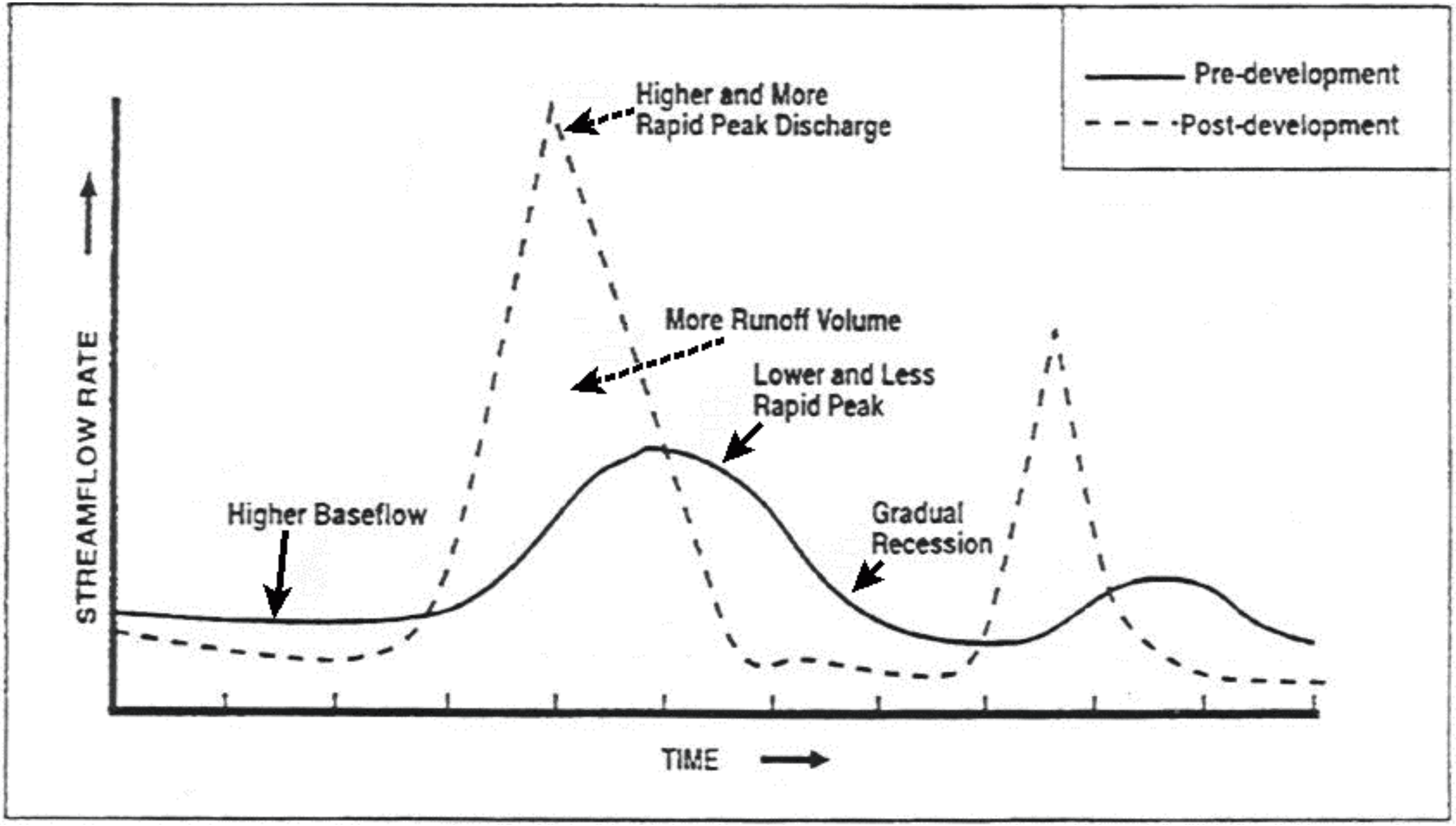


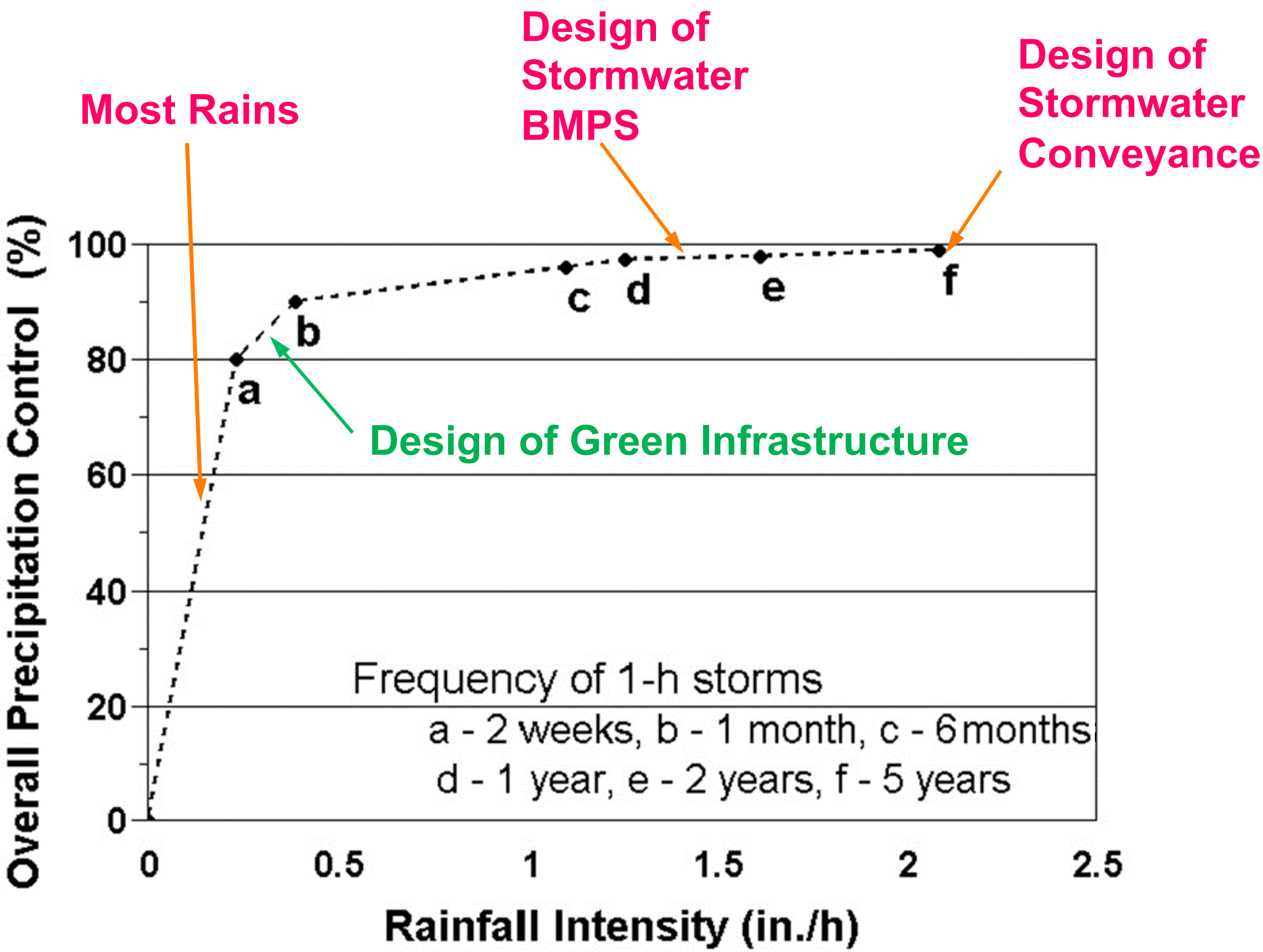
EPA (2004)

“Surface Depression Storage”

“Even with carefully graded lawns there are still many depressions that must be filled before surface runoff begins. Where blocks contain vacant lots, some, or all, of the lots may be depressed below the sidewalks, thus creating large pools of depression storage. For storm sewer design, however, it will be generally assumed that these larger areas will be filled and graded at some later date” (Tholin and Keifer, 1959).

Green Infrastructure is Surface Depression Storage and other technical approaches.

Overall Percent Precipitation Control vs. Rainfall Intensity (Data - Atlanta, GA, 1948 - 1972) (EPA-600/2-77-064b, NTIS PB 266 005)

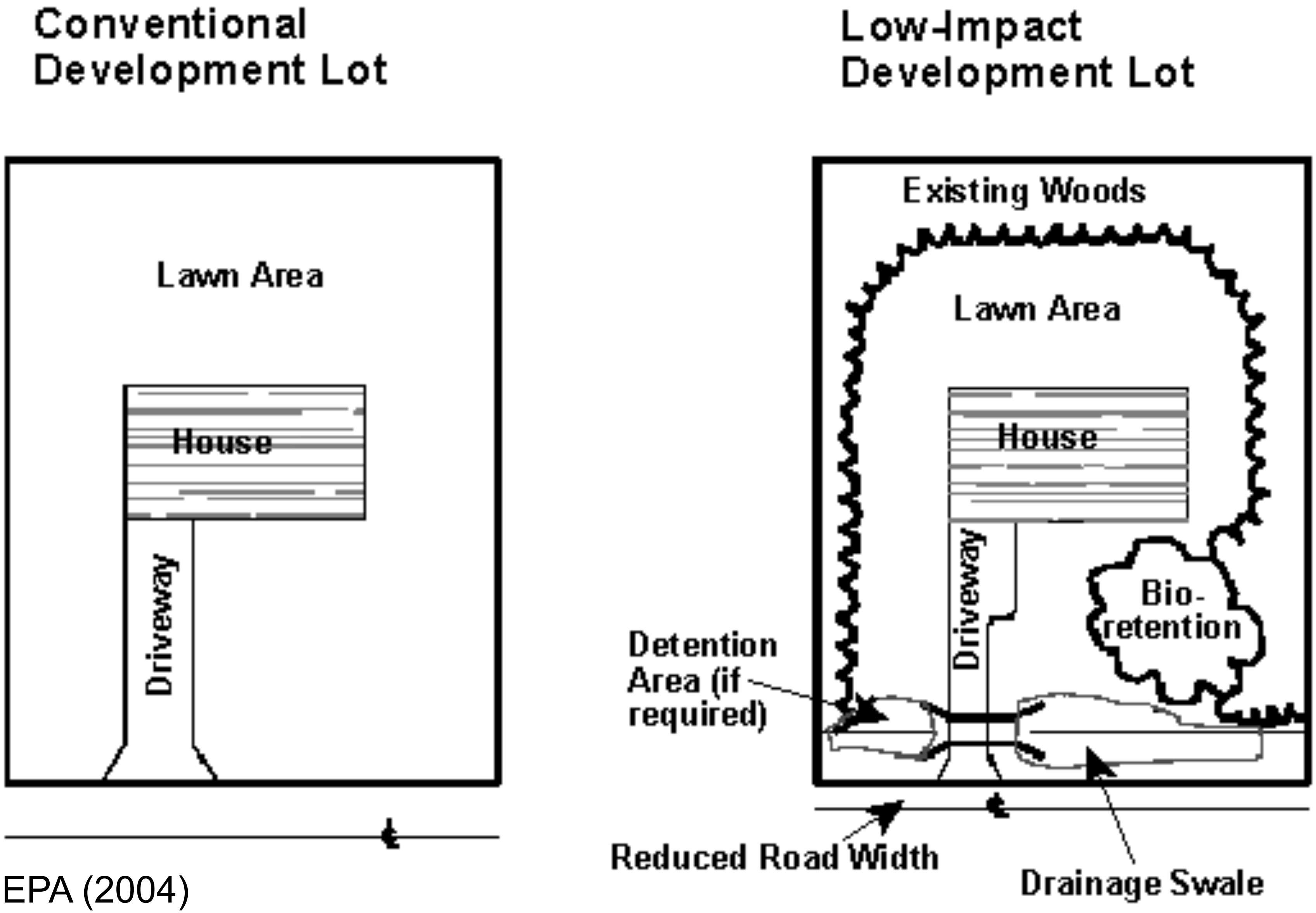


Flood Control Basins (1960s)

- Typically large basins
- Downstream property protection
- New construction and development

Flood control detention basin (concrete lined)
Rutgers Campus Piscataway, NJ

Single Lot Low Impact Development (LID) Principles



EPA (2004)

EPA United States Environmental Protection Agency

Green Infrastructure

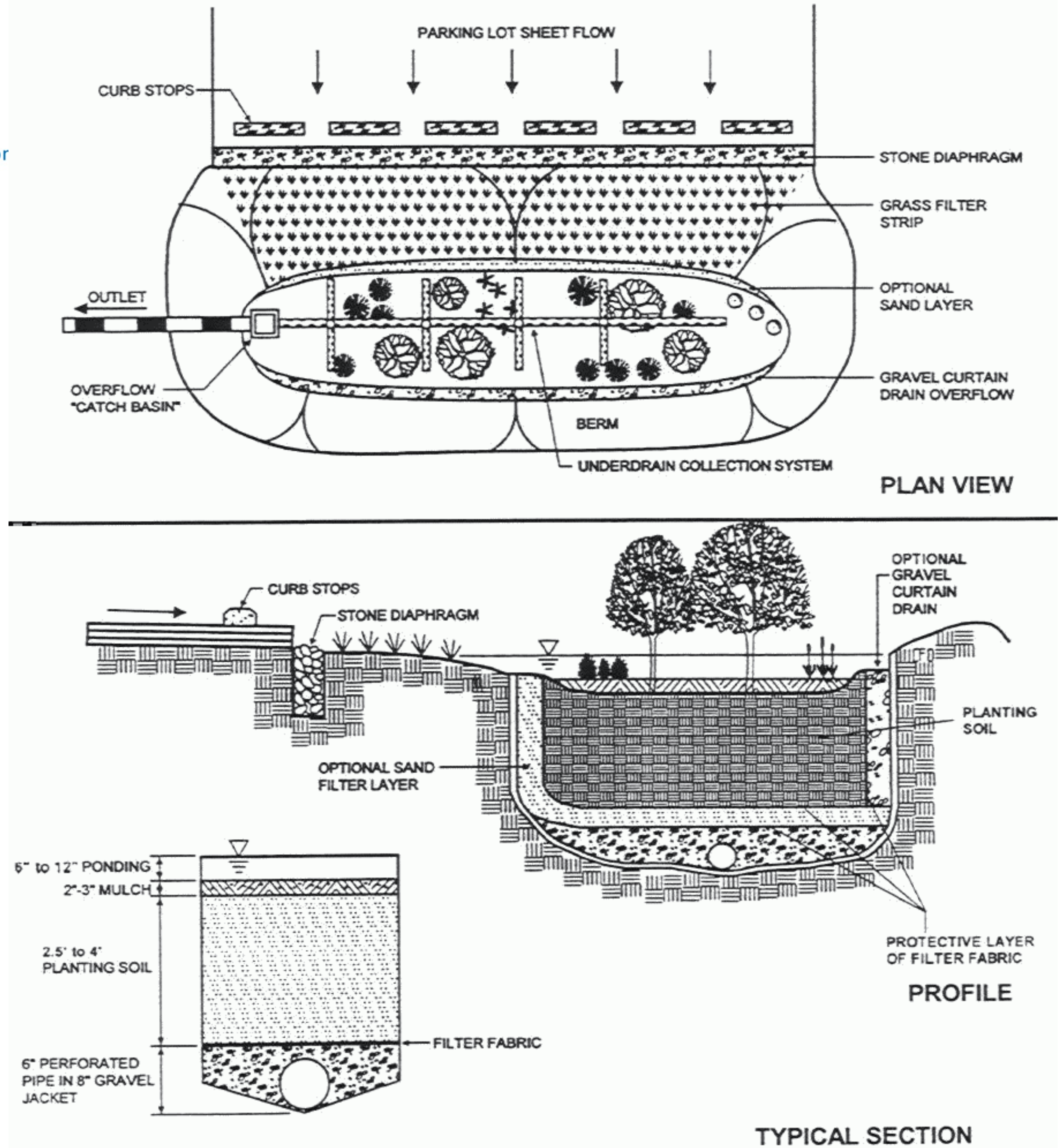
- Green Infrastructure (GI) (circa 2010)
  - Incentives to property owners to capture runoff
  - Municipal rights-of-way (ROW) for storm capture
  - Small scale - same techniques as LID - but on larger drainage area scale
  - New and existing (**retrofit**) infrastructure and buildings
  - Supplements existing grey infrastructure, i.e., sewers

Narrow Street **Reduces** Impervious Cover

Sea Streets, Seattle, WA

Bioretention to Manage Stormwater Runoff

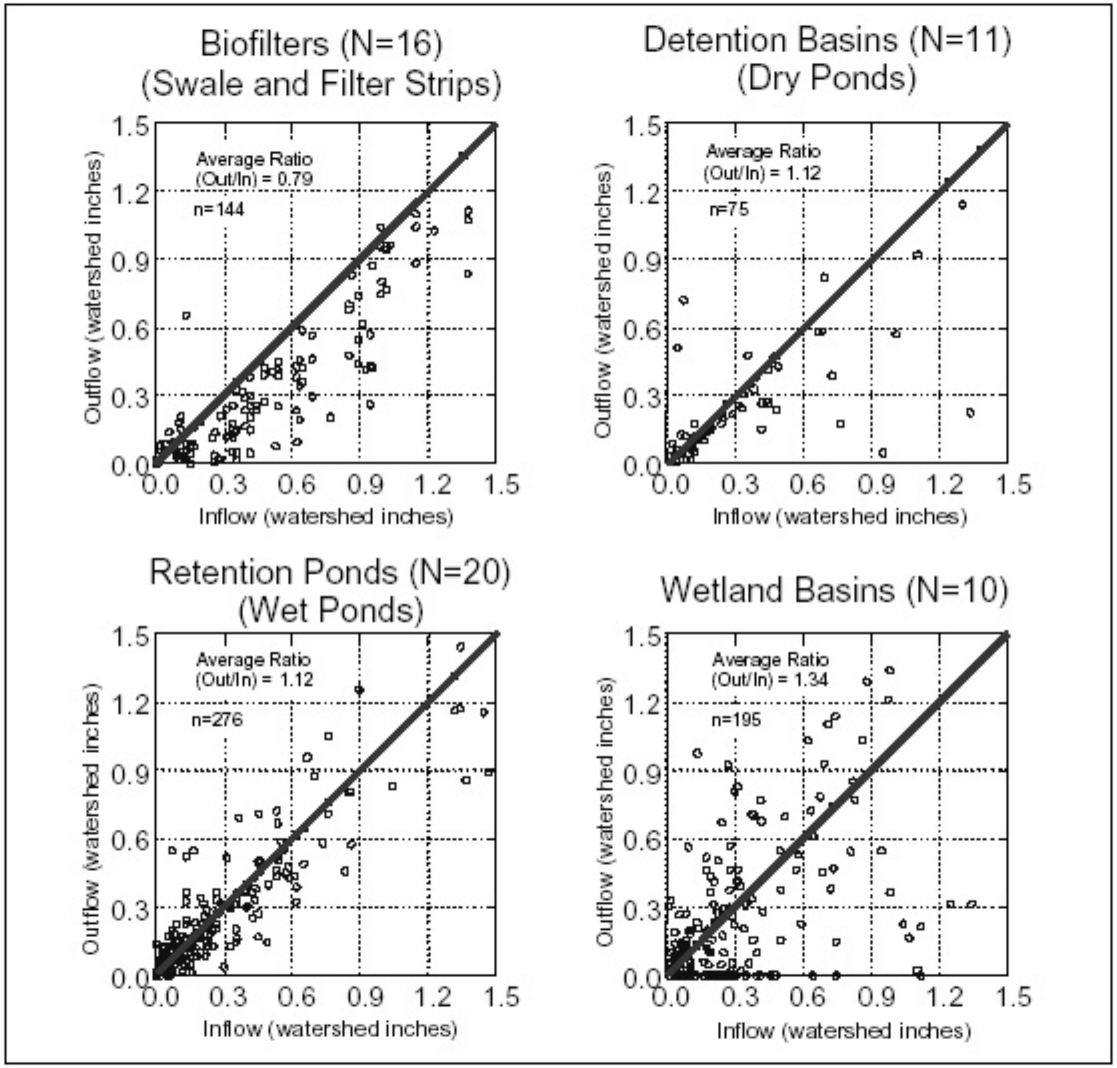
Typical Municipal ROW Bioretention Design – Example for Parking Lot



EPA (2004)

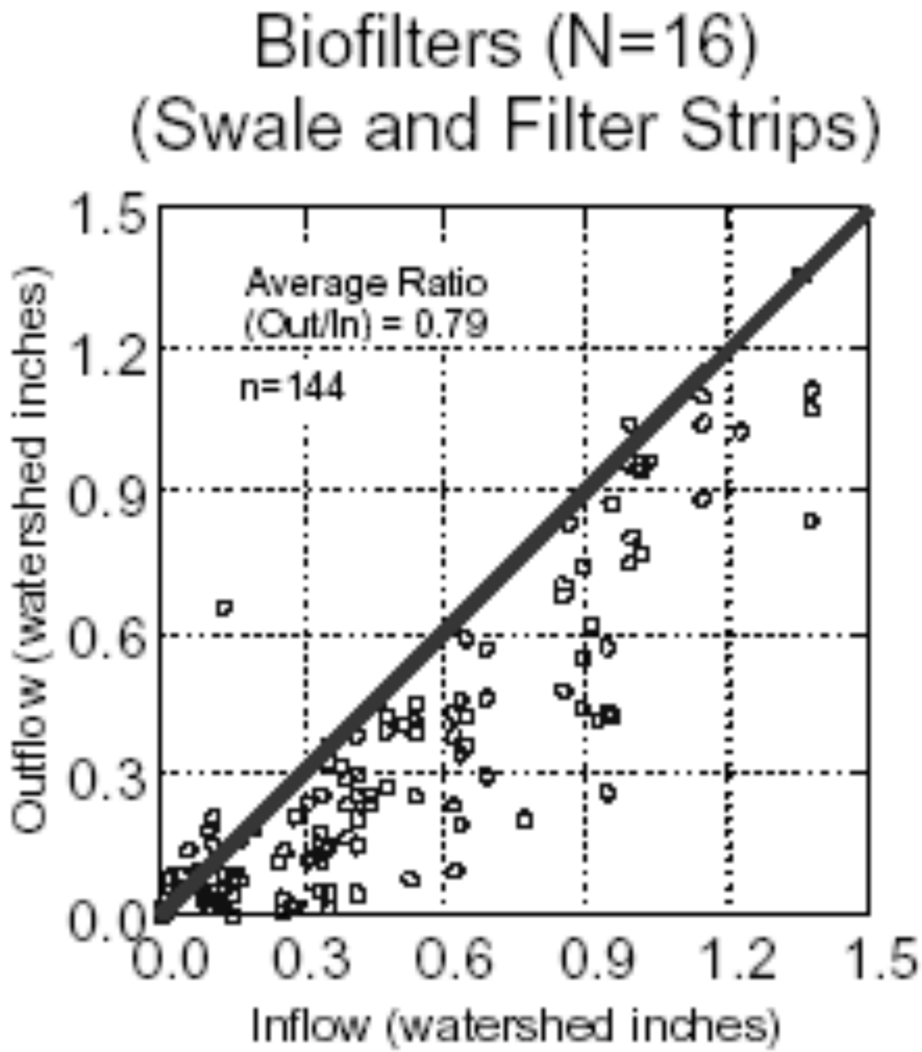
Runoff Volume Control

Early results of ASCE BMP Database shows ratio of outflow to inflow < 1 for Biofilters, 0.79.



From presentation “ASCE BMP Database Update”
by E. Strecker to EPA Washington on February 10, 2003

Biofilter Runoff Volume Control



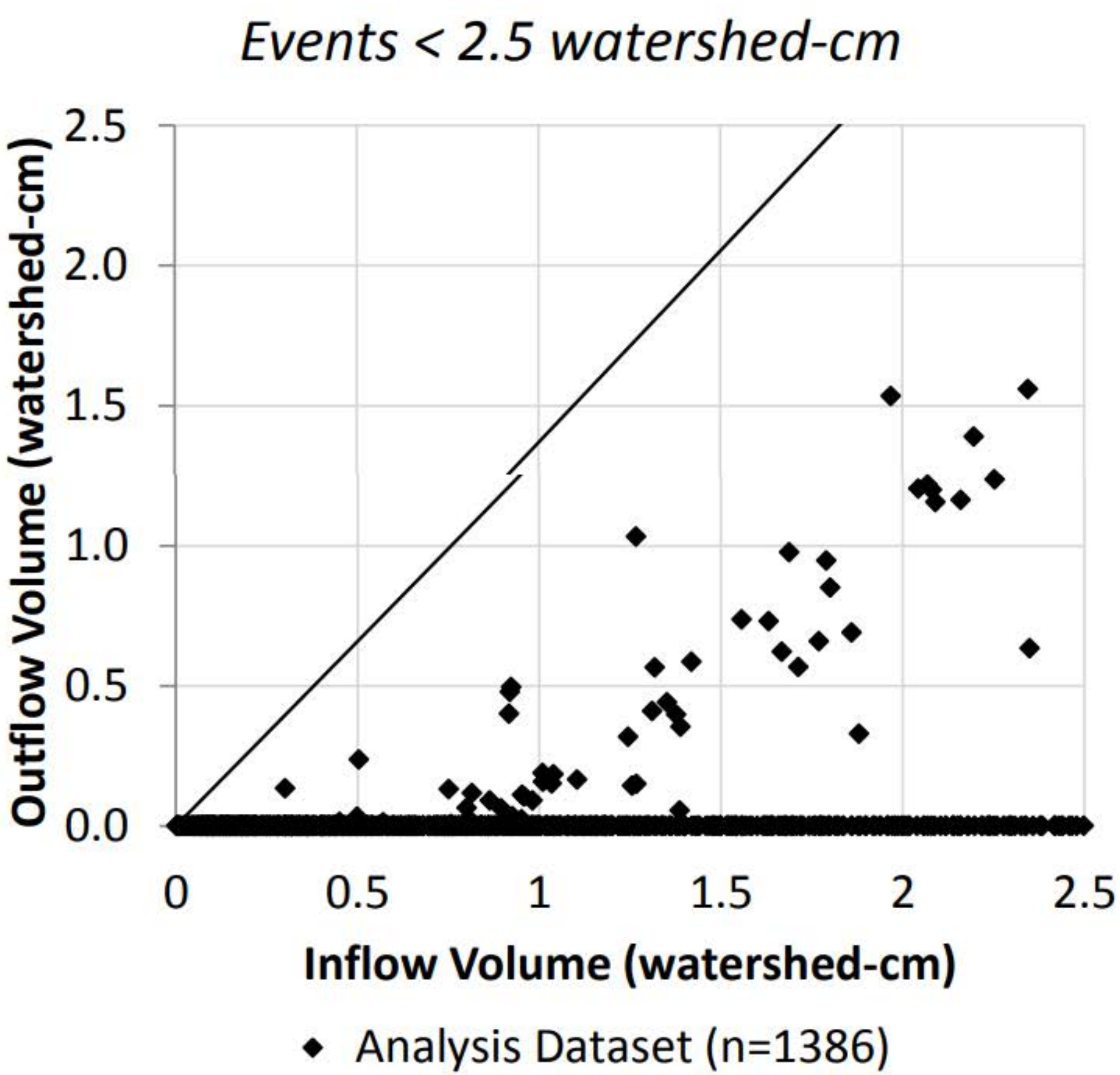
Early results of ASCE BMP Database shows ratio of outflow to inflow < 1 for Biofilters, <u>0.79</u>.

Less water discharging (overflowing) LID or GI.

From presentation “ASCE BMP Database Update” by E. Strecker to EPA Washington on February 10, 2003.

Addendum 1 to Volume Reduction Technical Summary (January 2011)
Expanded Analysis of Volume Reduction in Bioretention BMPs (May 2012)

Bioretention without underdrains.



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EPA Bioinfiltration Research and Demonstration Controls

- Adjacent to Permeable Pavement Research and Demonstration site
- Receives parking lot and roof runoff
- Instrumented with water content reflectometers based on time domain reflectometer technology
- Media primarily sand – choice after extensive testing
- Plants: drought and inundation tolerant, salt tolerant
- Six side-by-side units – three surface area in duplicate
- Plastic sheeting separates units and surrounding area
- Middle units 11:1 watershed area to surface area (close to NJDEP guidance) with smaller ½ surface area and larger twice surface area

Rain Garden Demonstration Site

This site demonstrates and allows EPA to document the capabilities of rain gardens to allow stormwater to seep, or infiltrate, into underlying soil where it will eventually recharge groundwater and nearby streams. Infiltration of stormwater in rain gardens serves to reduce stormwater runoff volumes, improve water quality through removal of stormwater contaminants, and enhance the physical and biological integrity of streams.

Research

Stormwater runoff from Building 205 and the adjacent parking lot is directed through a pipe and curb cuts into the rain garden. The rain garden has six cells of different sizes separated by walls, allowing researchers to study how size affects the ability of rain gardens to infiltrate stormwater runoff created by a wide range of storm sizes. Instruments buried in the media and underlying soil measure how quickly runoff infiltrates through the rain garden profile into the underlying soil.

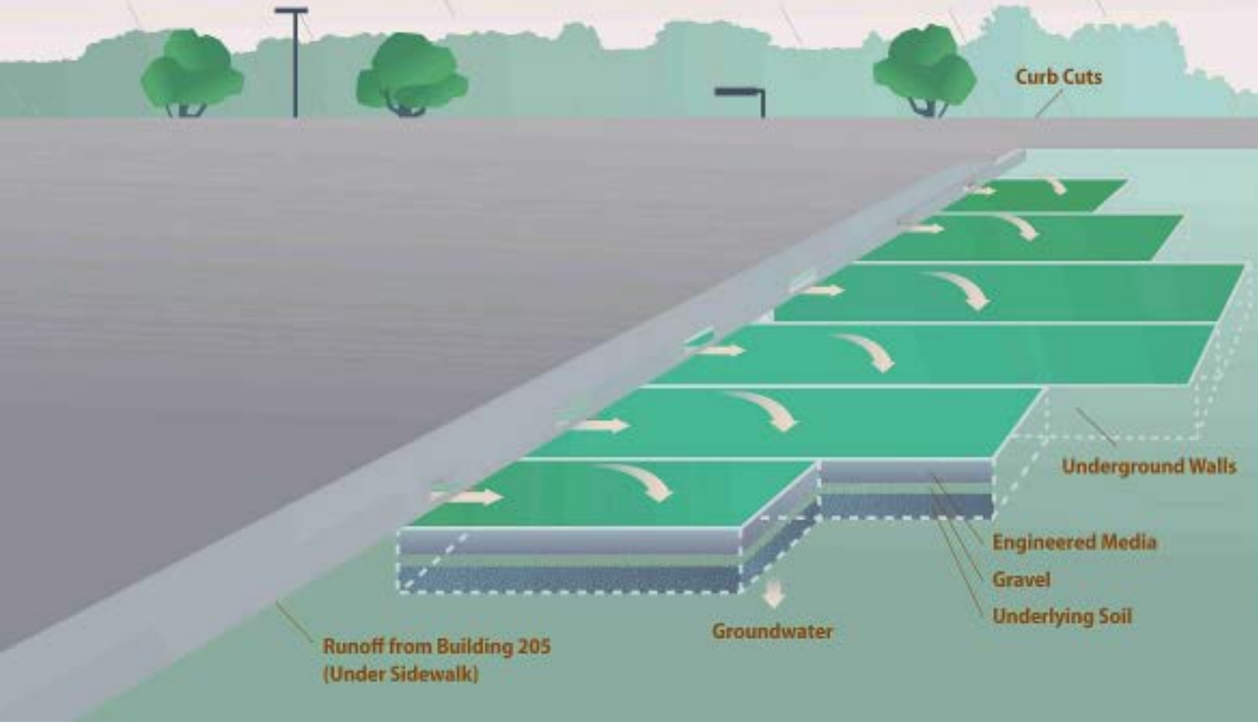
Results

The rain garden will help EPA study:

- How rain gardens mimic natural drainage processes and reduce stormwater runoff volume to the conventional storm sewer system.
- The effects of surface area on drainage properties of rain gardens.

Acknowledgements

This project is a joint research effort between EPA's Office of Administration and Resources Management, Region 2, and the Office of Research and Development.



Native Plants for Mid-Atlantic Rain Gardens

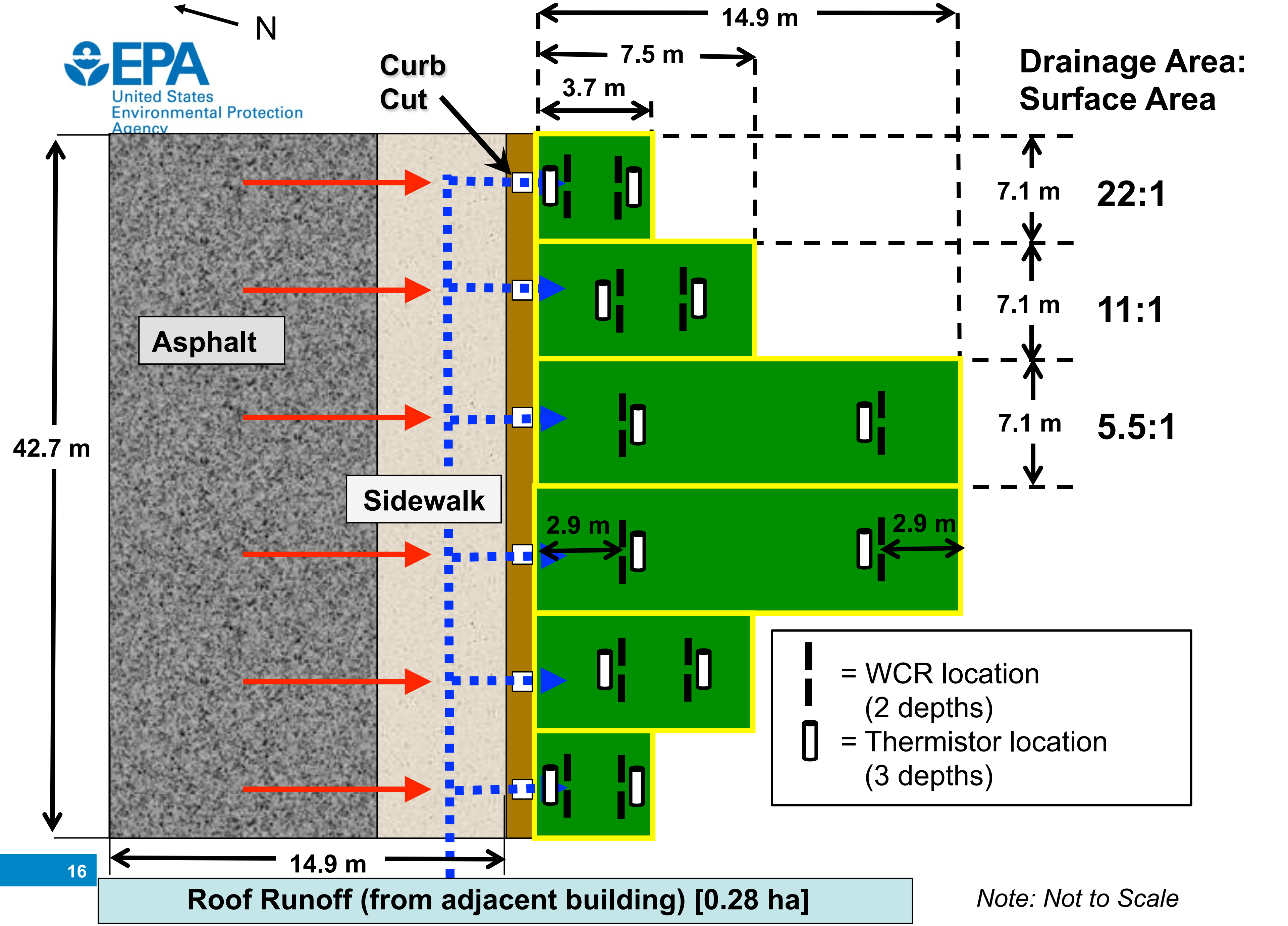
Trees
Red Maple
Redosier
Dogwood

Grasses/Rushes
Switchgrass
Indian Grass
Big Bluestem
Common Rush

Shrubs
Highbush Blueberry
Beach Plum
Winterberry
Black Chokeberry
Groundsel Tree

Herbs
Seaside Goldenrod
Blue Flag
Sunflower
Golden Zizia

https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P100BXHW.txt


N
EPA
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Curb Cut
14.9 m
7.5 m
3.7 m
Drainage Area: Surface Area
7.1 m
22:1
7.1 m
11:1
7.1 m
5.5:1
42.7 m
Asphalt
Sidewalk
2.9 m
2.9 m
= WCR location (2 depths)
= Thermistor location (3 depths)
14.9 m
Roof Runoff (from adjacent building) [0.28 ha]
Note: Not to Scale

Bioinfiltration units during construction

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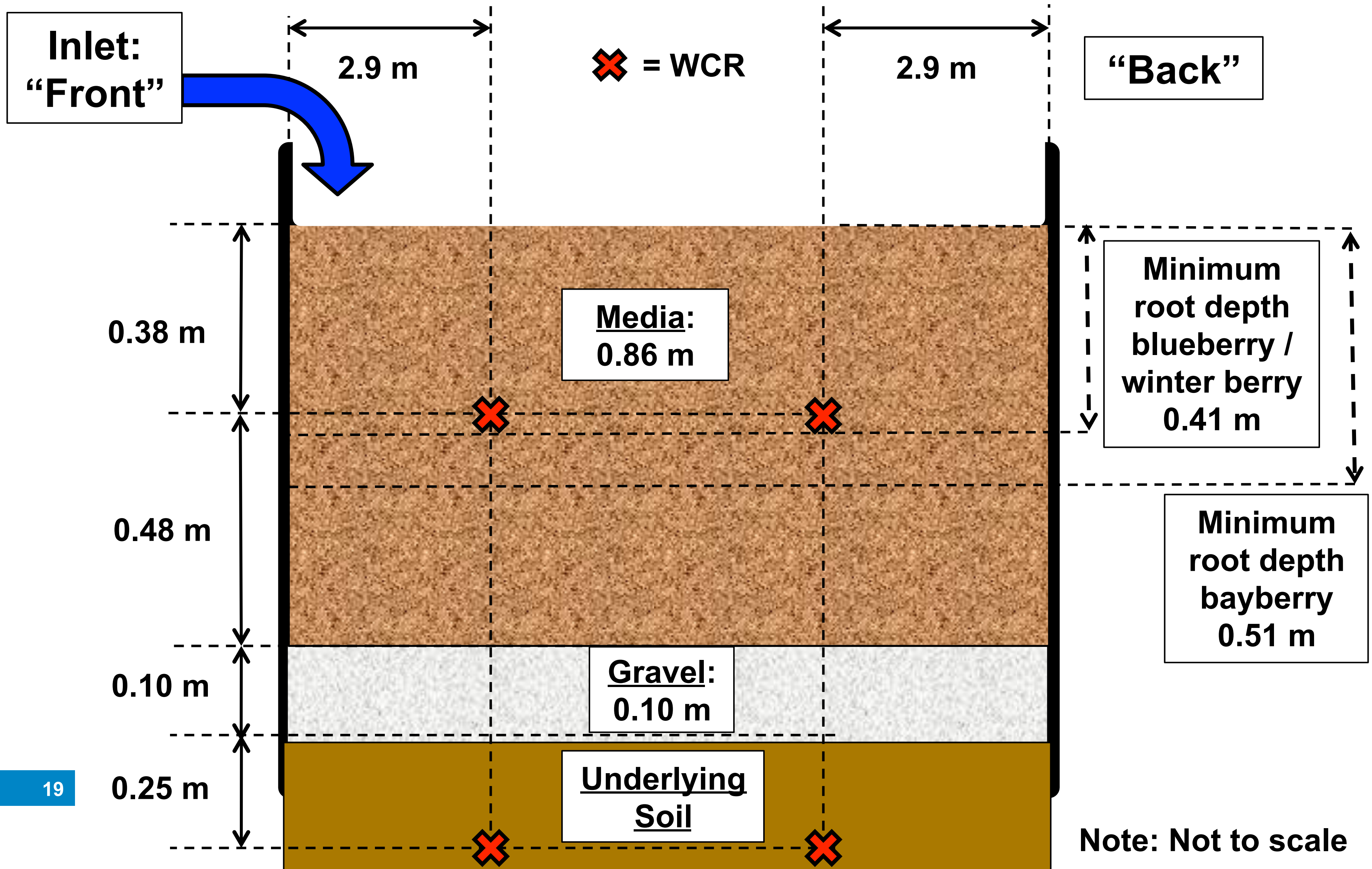
Bioinfiltration units over time

Media 90% sand (United States Golf Association concrete sand) and 10% sphagnum peat moss by volume; organic content 1.1% test lost on ignition.



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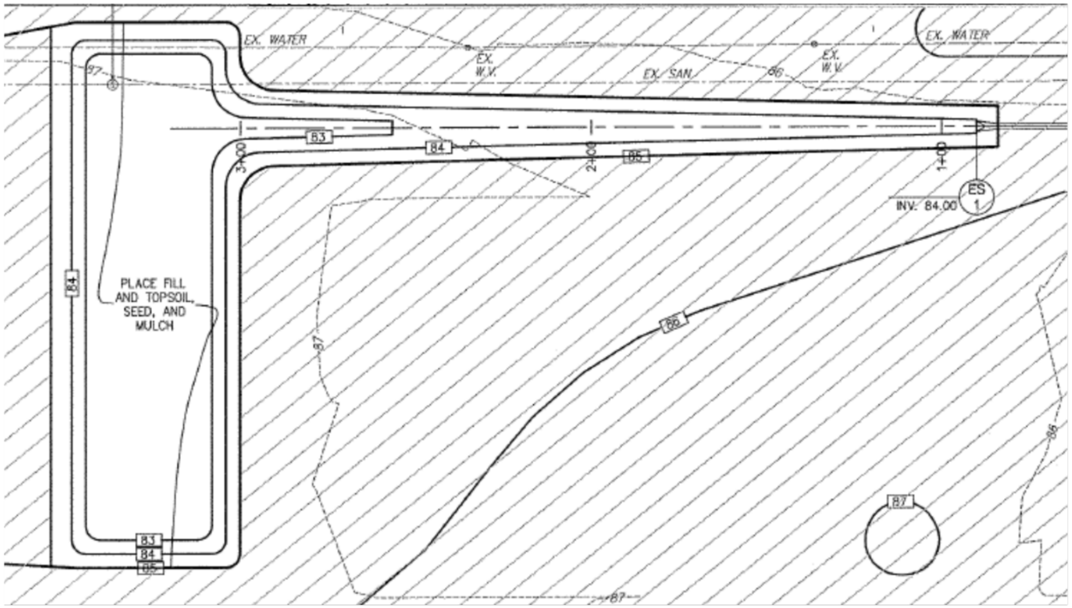
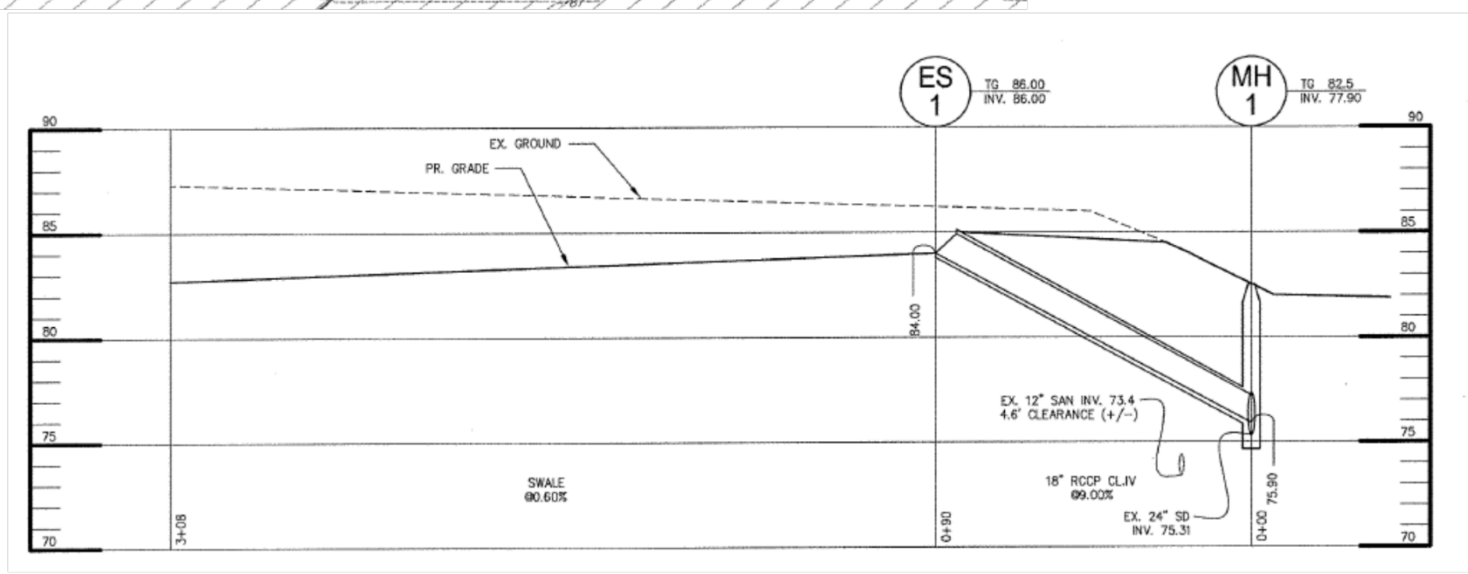
Swale to Storm Drainage Pipe





Swale to Storm Drainage Pipe

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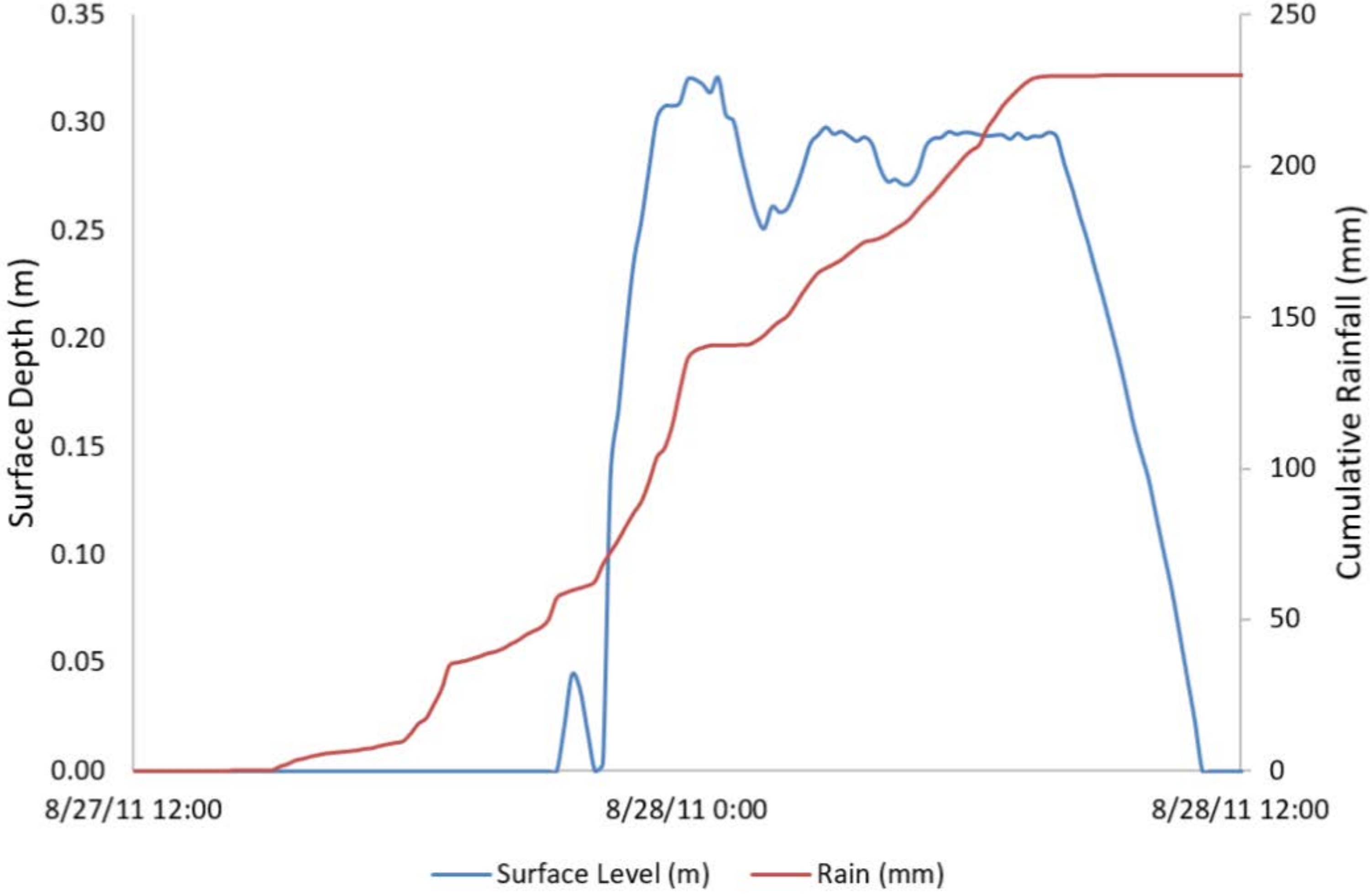
Hurricane Irene Response



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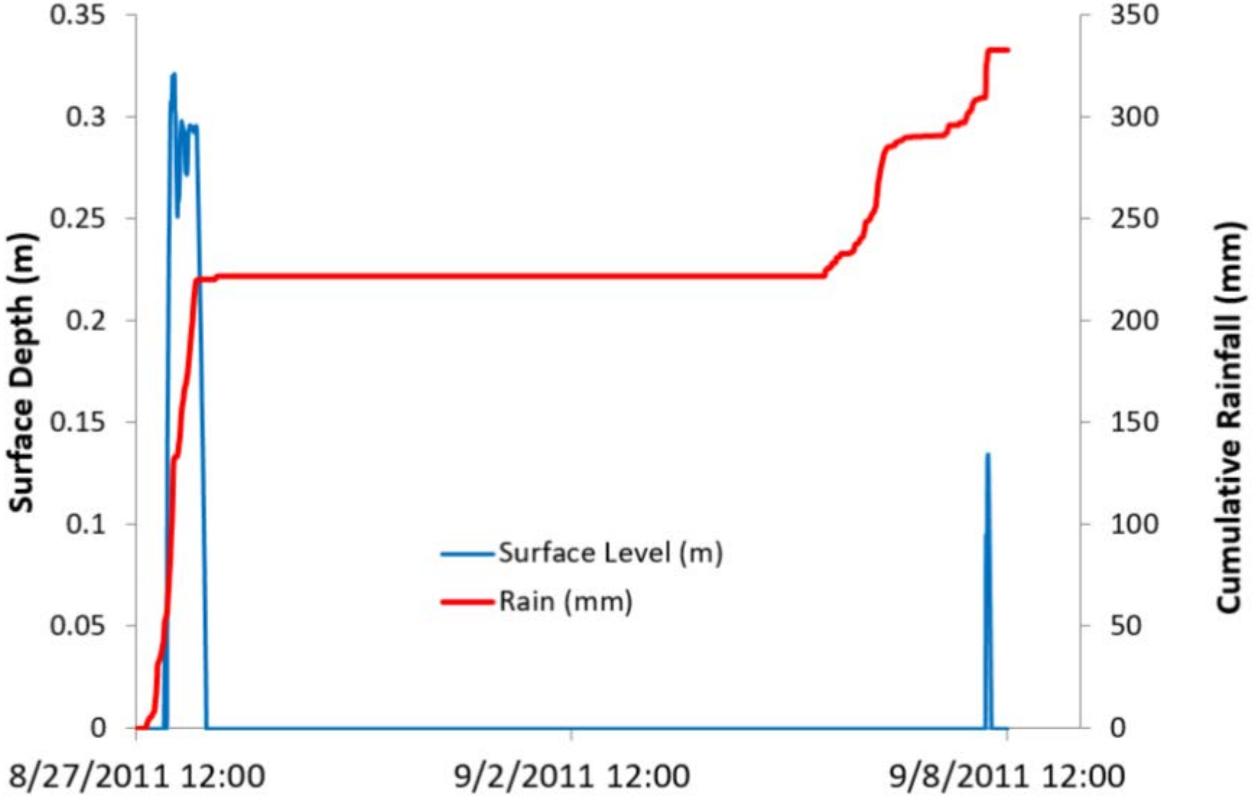
Hurricane Irene Totals and Intensity

- Peak hourly rainfall intensity was 44.4 mm/hr (1.75 in/hr)
- Discharge to storm drainage pipe first occurred after 95.7 mm (3.77 in) of rain had fallen
- 95th percentile rainfall event (EPA 2009; directive federal facilities) only calls for capture of first 43.2 mm
- Point precipitation estimates by National Oceanic and Atmospheric Administration (Bonnin et al., 2004)
  - total rainfall, 221.8 mm (8.73 in), within the 90% bounds for the 100-yr storm
  - initial 82.4 mm (3.24 in) in 6 hr exceeded 82.4 mm (3.24 in) mean with recurrence interval of 1 in 5 years
  - 1 yr recurrence interval 24 hr storm 77.2 mm (3.05 in)
  - 2 yr 93.7 mm (3.69 in)

O'Connor and Amin (2015)

September 8, 2011 Flooding of Bioinfiltration Units

Comparison of Hurricane Irene to September 8, 2011



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Annual reduction in roof discharge to existing EEC storm sewer system

- Mean annual rainfall for New Jersey is 1,100 mm (45 in) (Robinson, 2013)
- For typical year, approximately 2.9 x 10^6 L (7.6 x 10^5 gal) infiltrate through biofiltration units from roof of adjacent building
- Rainwater harvesting effort yields 5.3 x 10^5 L (1.4 x 10^5 gal)
- Combined runoff diversion from both bioinfiltration units and rainwater harvesting annually prevents 3.4 x 10^6 L (9.0 x 10^5 gal) from entering the stormwater conveyance system

O'Connor and Amin (2015)

United States Environmental Protection Agency

Number of shrubs per bioinfiltration unit (BU) – some plants do not survive

BU Number	BU Size	Location	Number Measured (Planted -2010)		
			Bayberry	Blueberry	Winter-berry
1	Small	West	1 (1)	1 (1)	2 (2)
2	Medium	West	3 (3)	3 (3)	6 (6)
3	Large	West	9 (11)	9 (11)	6 (7)
4	Large	East	9 (11)	11 (11)	6 (7)
5	Medium	East	3 (3)	1 (3)	5 (6)
6	Small	East	1 (1)	1 (1)	2 (2)

Brown et al. 2015

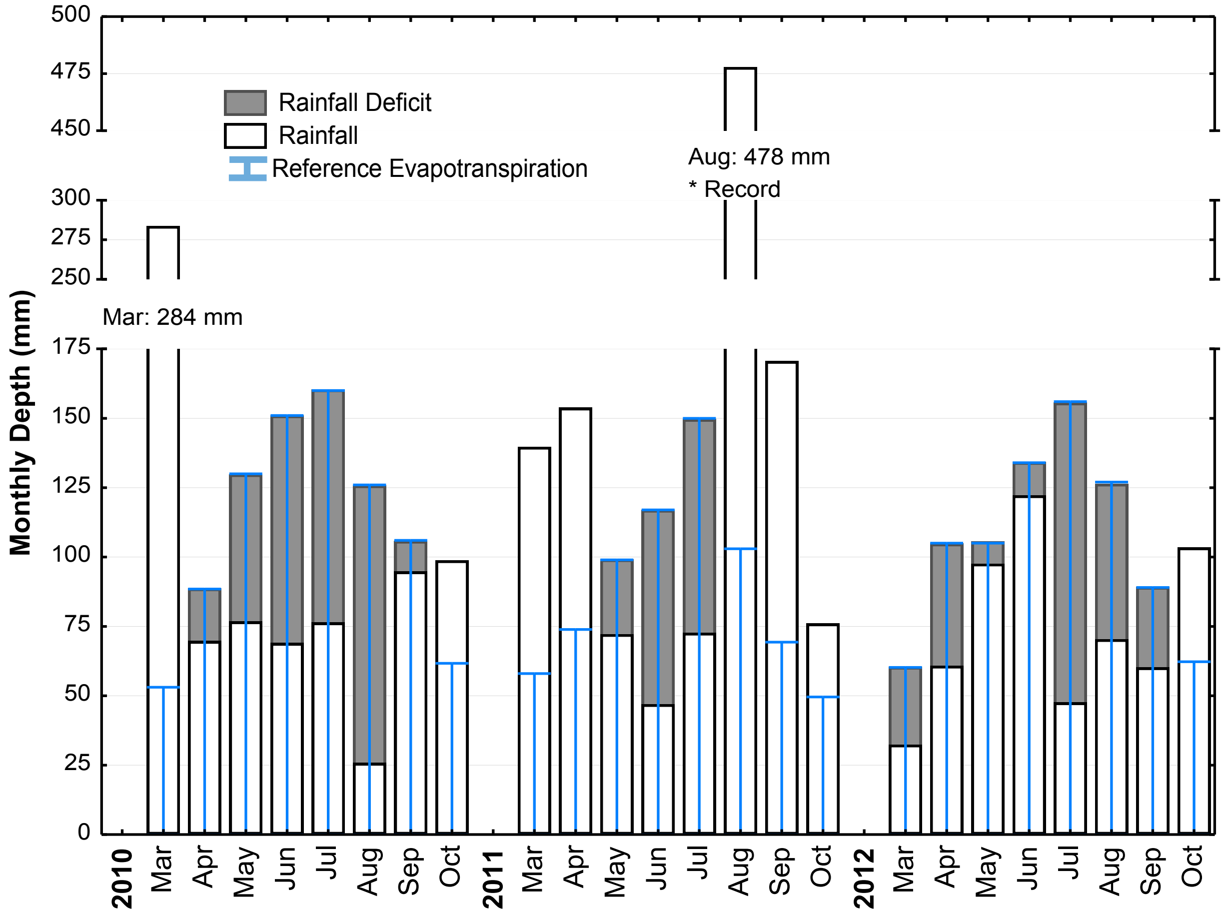
United States Environmental Protection Agency

Plant growth assessment of shrubs

- Document survivability
- Review rainfall statistics
- Calculate reference crop evapotranspiration
- Soil moisture
- Measure trunk diameter for modified Basal area
- Measure height
- Assess shading

Brown et al. 2015

Rainfall and reference crop evapotranspiration



Brown et al. 2015

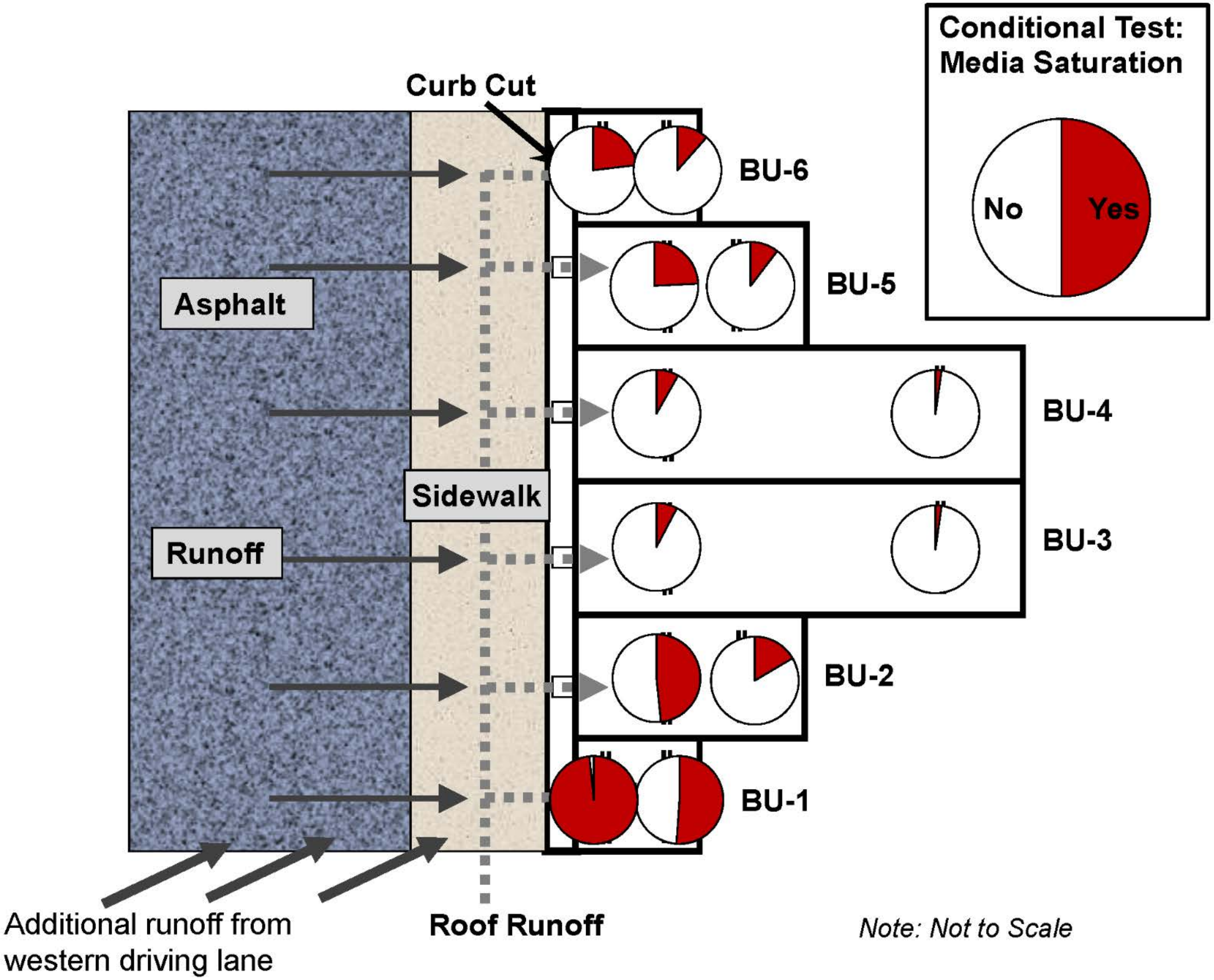
WCR monitoring locations media saturation

Total of 91 events analyzed with complete data from all WCR locations.

Period of analysis: 2010-2012 growing seasons (April to October).

When saturation not frequent, the change in soil moisture was attributed to direct rainfall.

Brown et al. 2015



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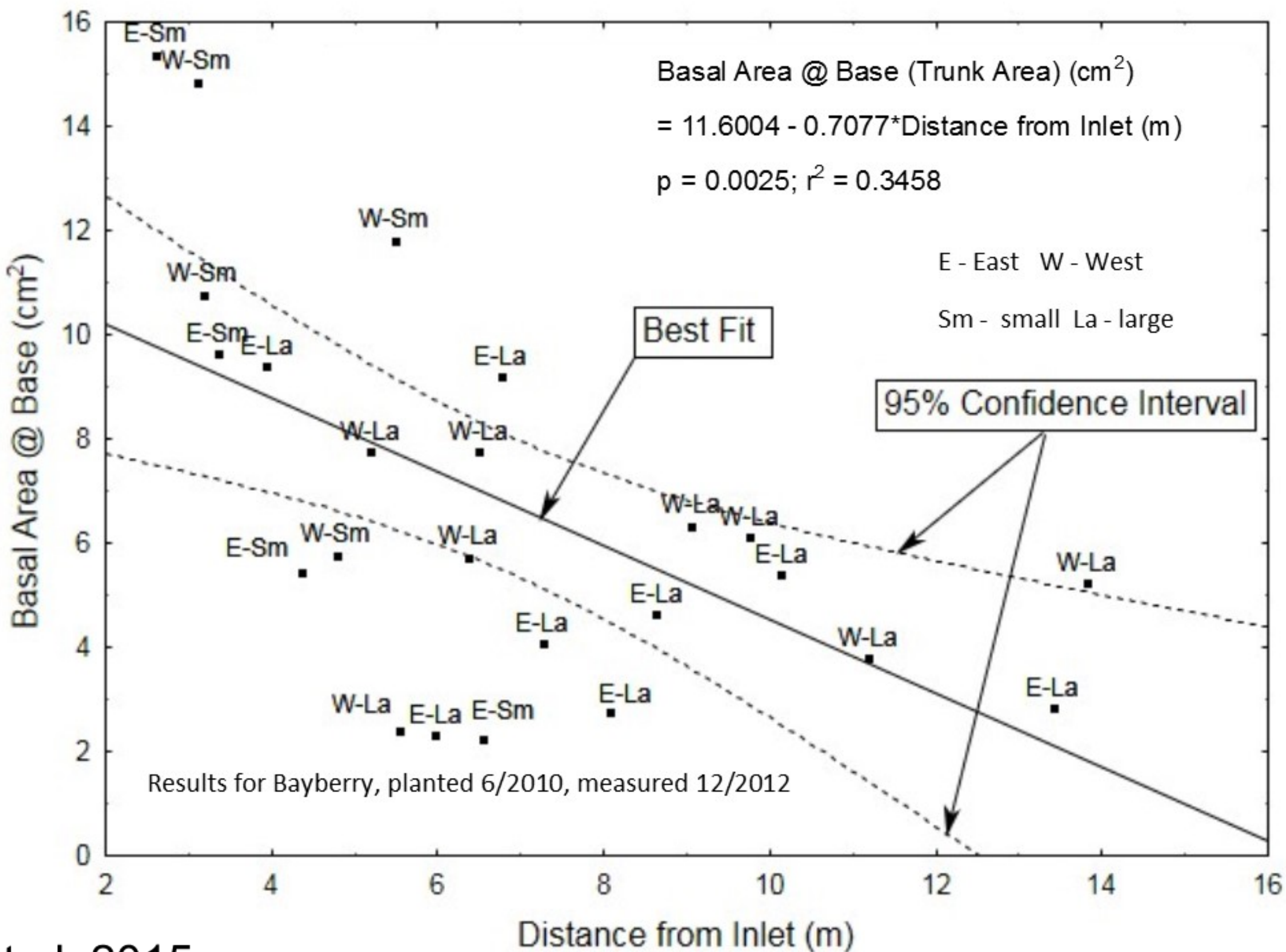
Bayberry growth closer to inlet and in smaller bioinfiltration units better than in large units



Brown et al. 2015

Winterberry height closer to inlet and in smaller bioinfiltration units taller than in large units

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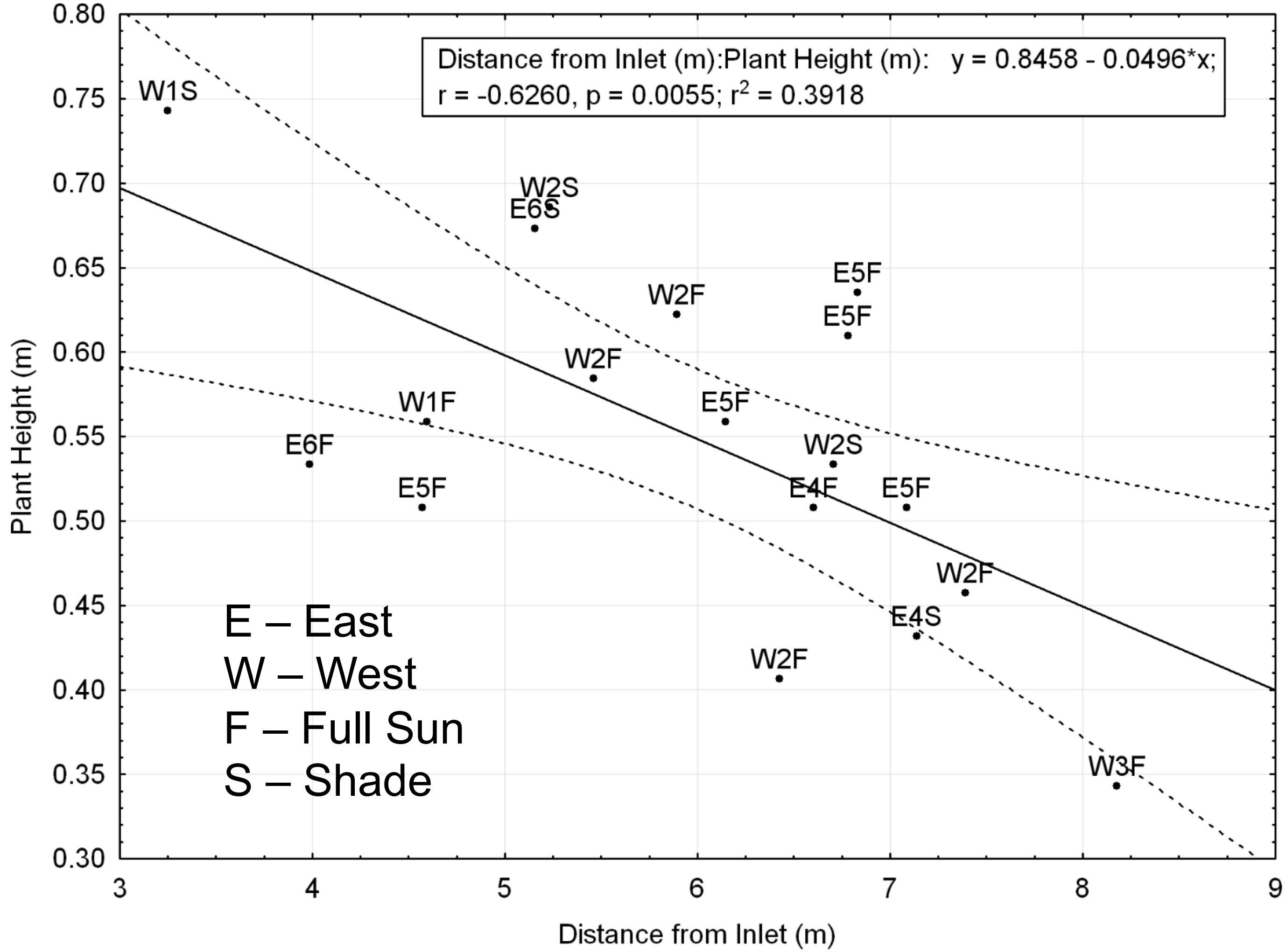
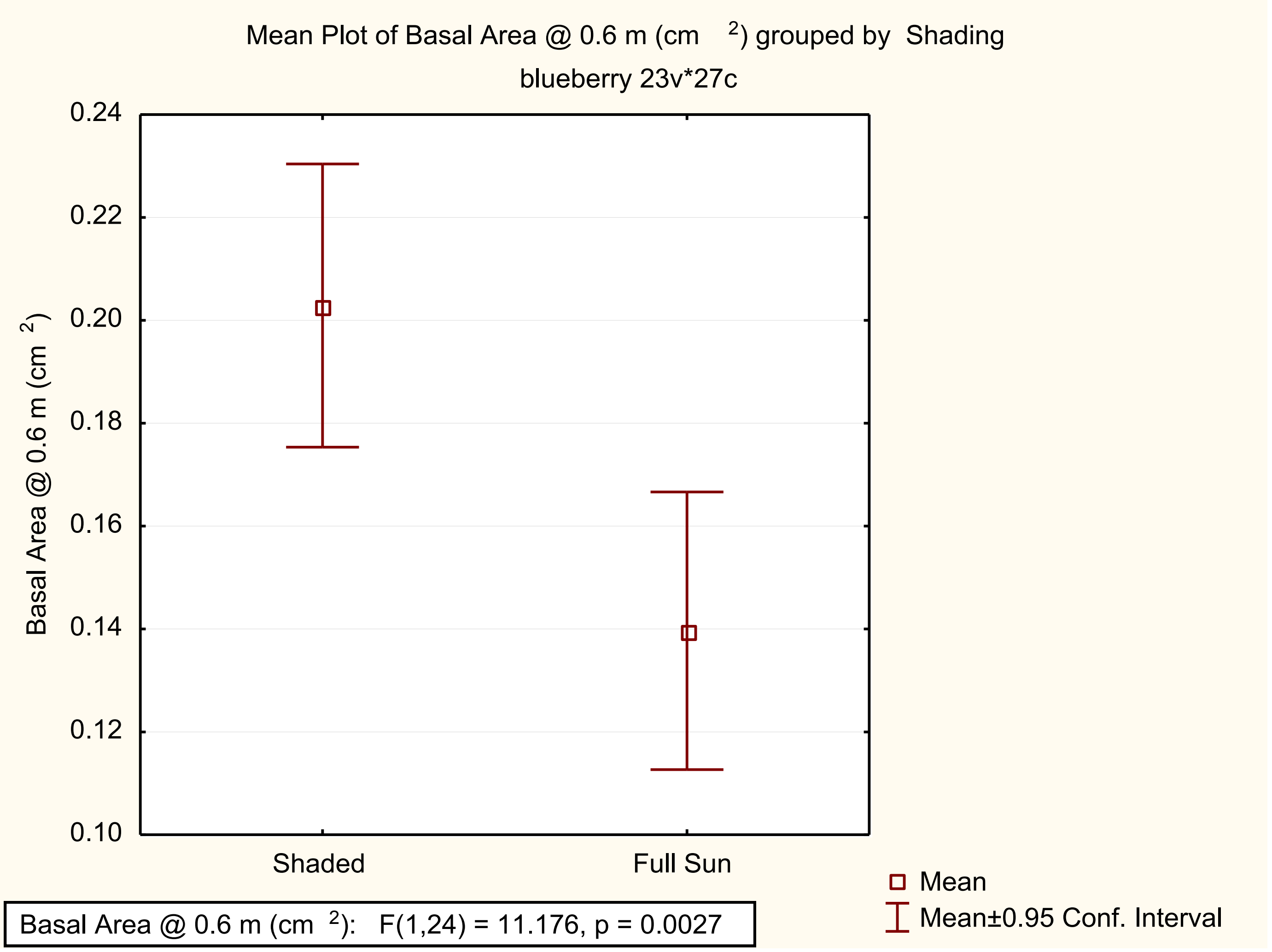
Also effect of shading

Brown et al. 2015



Blueberry growth in shade better than full sun



Brown et al. 2015

Conclusion and discussion for shrub study

- Be mindful of rain fall deficit
- May not have uniform surface infiltration
- Smaller controls may provide better function than oversized control
  – greater plant survivability and robustness
  – continue to infiltrate even when flooded

Brown et al. 2015

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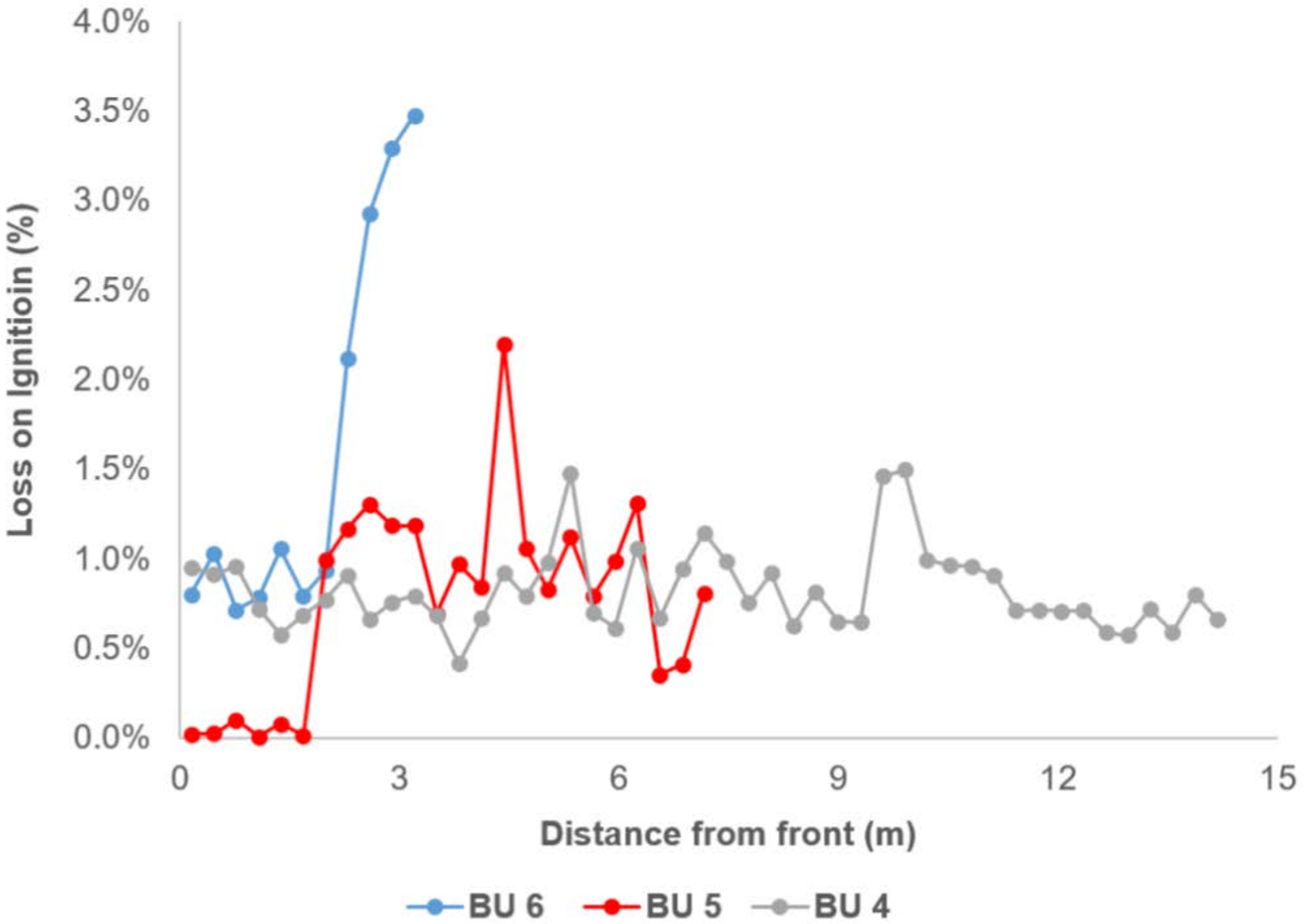
Recent measurements of organic content in bioinfiltration units

- Organic content of bioinfiltration soils measured by loss on ignition (LOI) – burn off organic material
- Sampling plan
  - at set intervals from curb – 0.3 m (1 ft)
  - at 0.15 m (0.5 ft) below surface
  - along center line of bioinfiltration units (BU) 4, 5 and 6
- Sampling and analysis in 2017

Loss on Ignition: All Results



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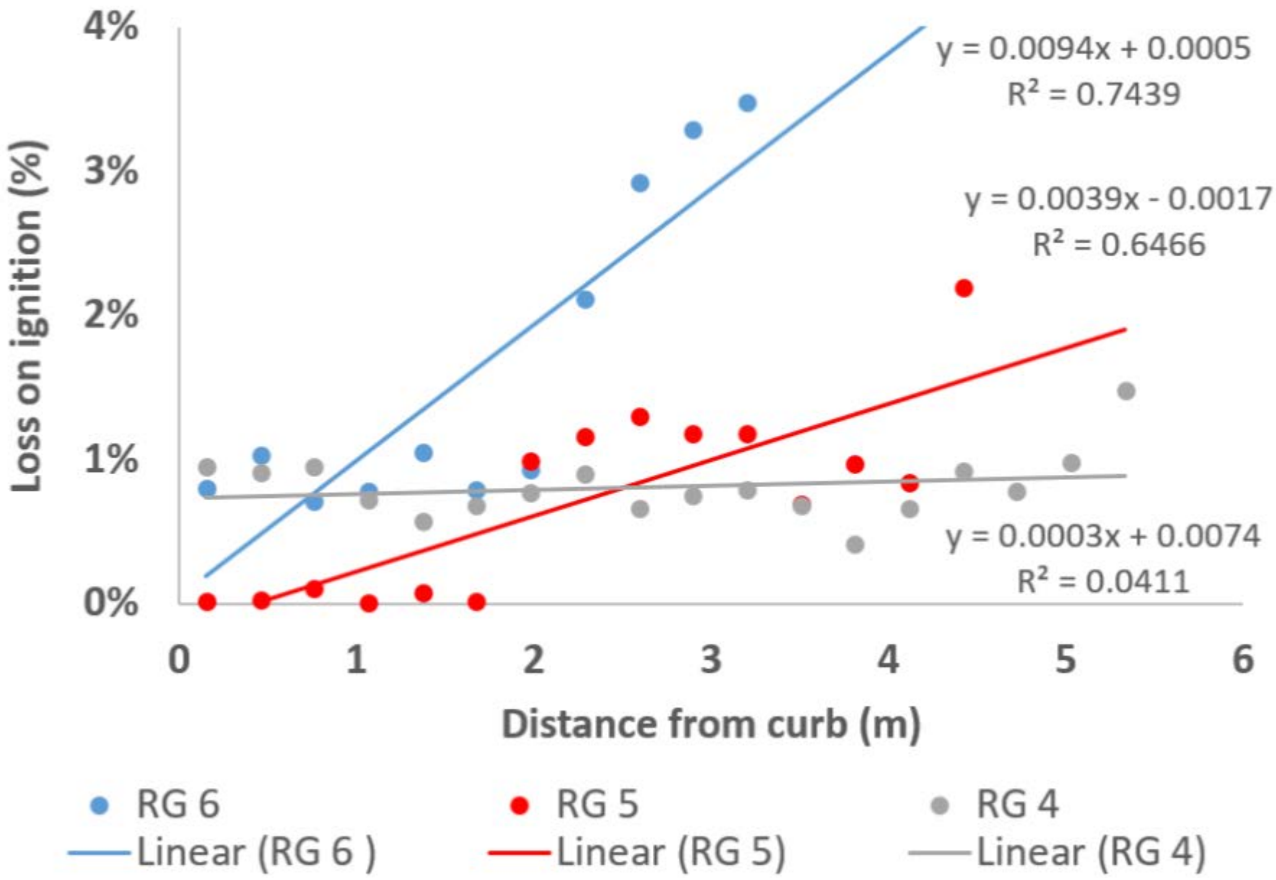
Loss on Ignition: Rise to Peak Analysis



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Statistical Results for LOI Study

- One-way analysis of variance (ANOVA) of LOI indicated significant difference ($p<0.05$), but limited: BU 6 ≠ BU 4 or BU 5, but BU 4 = BU 5
- General Linear Model (GLM) of LOI in BUs and distance – similar result to ANOVA of LOI, distance not a significant factor ($p>0.05$)
- Analyzing Rise to Peak, BU 6 strong correlation (R^2 = 0.74) and high slope with distance from curb. BU 5 has lower correlation (R^2 = 0.65) and a third of the slope of BU 6 (0.0039/0.0094). BU4 no correlation (R^2 = 0.04) for distance and slope flat.
- GLM for Rise to Peak – similar results to previous GLM, but distance is a significant factor ($p<0.05$).

Evidence of Washout in BU5

Sand exposed in front of BU5 by inlet.

Inlet for BU5 along centerline while other two inlets slightly offset with less washout along centerline.

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Implications of LOI Study

- Greater build up of organic material in smaller units
- Implies greater biological activity
- Supports results of previous study (Brown et al. 2015)
- Requires additional sampling and analysis
  - other bioretention units
  - varying depths

Reference Journal Articles

- R. Brown, T. P. O'Connor and M. Borst (2015). "Divergent Vegetation Growth Patterns Relative to Bioinfiltration Unit Size and Plant Placement" ASCE's Journal of Sustainable Water in the Built Environment (JSWBE), Vol. 1, No. 3. (http://ascelibrary.org/doi/abs/10.1061/JSWBAY.0000796)
- T. P. O'Connor and M. Amin (2015). "Rainwater Collection and Management from Roofs at the Edison Environmental Center" ASCE's JSWBE, Vol. 1, No. 1. (http://ascelibrary.org/doi/abs/10.1061/JSWBAY.0000792)

EPA Reports and Publications

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- Stormwater Best Management Design Guide
  - (EPA/600/R-04/121) (http://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=901X0A00.txt)
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- EPA Green infrastructure (GI) page (http://water.epa.gov/infrastructure/greeninfrastructure/)
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Other Resources

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- Robinson, D. A. (2013). "The Climate of New Jersey" Office of the New Jersey State Climatologist, Department of Geography, Rutgers University, http://climate.rutgers.edu/stateclim/?section=uscp&target=NJCoverview

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Questions?