Innovative Stormwater Research in Western North Carolina

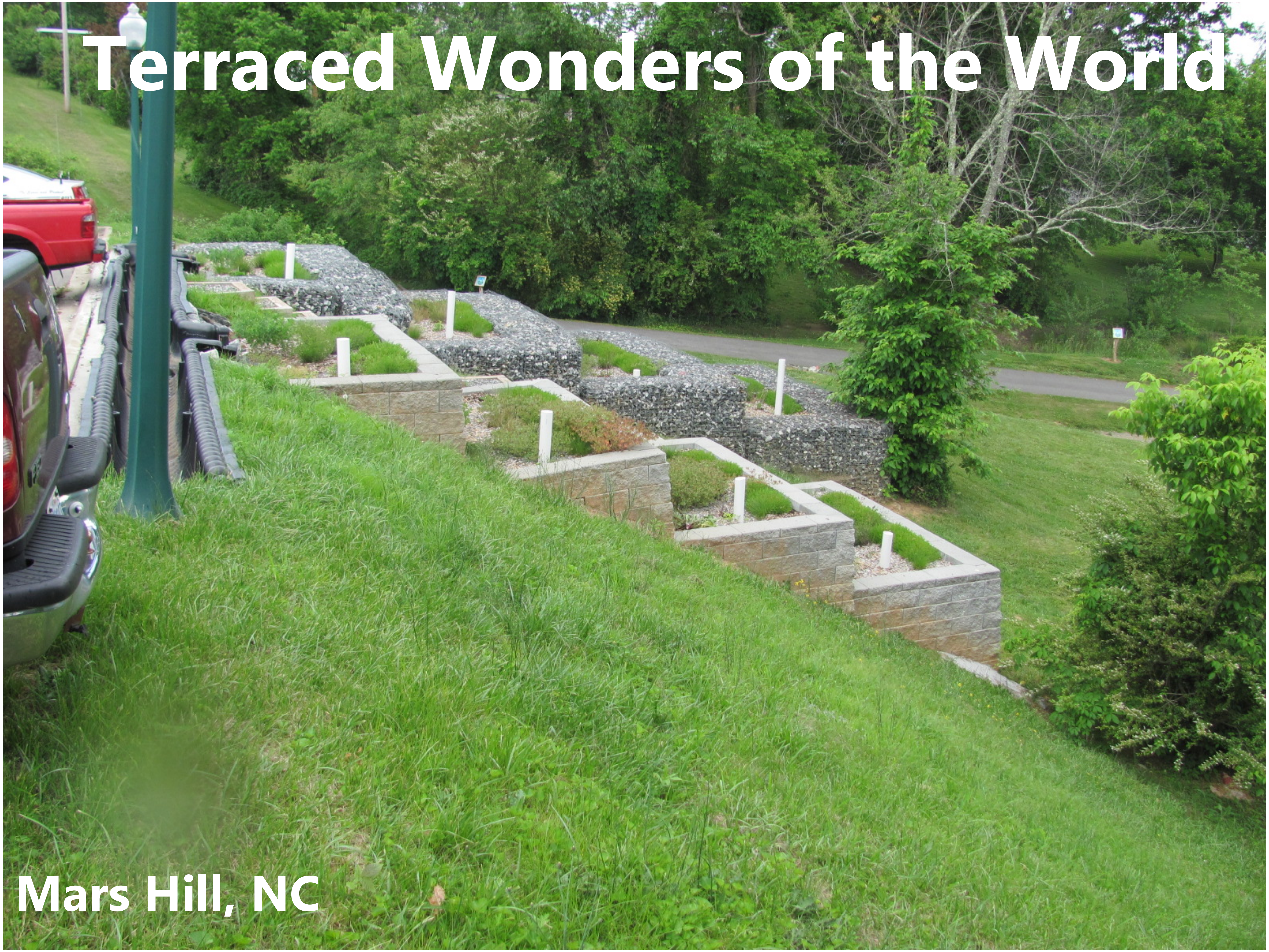
WNC Stormwater Summit
February 22, 2017

Tim Ormond, P.E.
HydroCycle Engineering

Terraced Wonders of the World

Terraced Wonders of the World


Terraced Wonders of the World
Banaue, Philippines
Source: E. Law


Terraced Wonders of the World
Mars Hill, NC

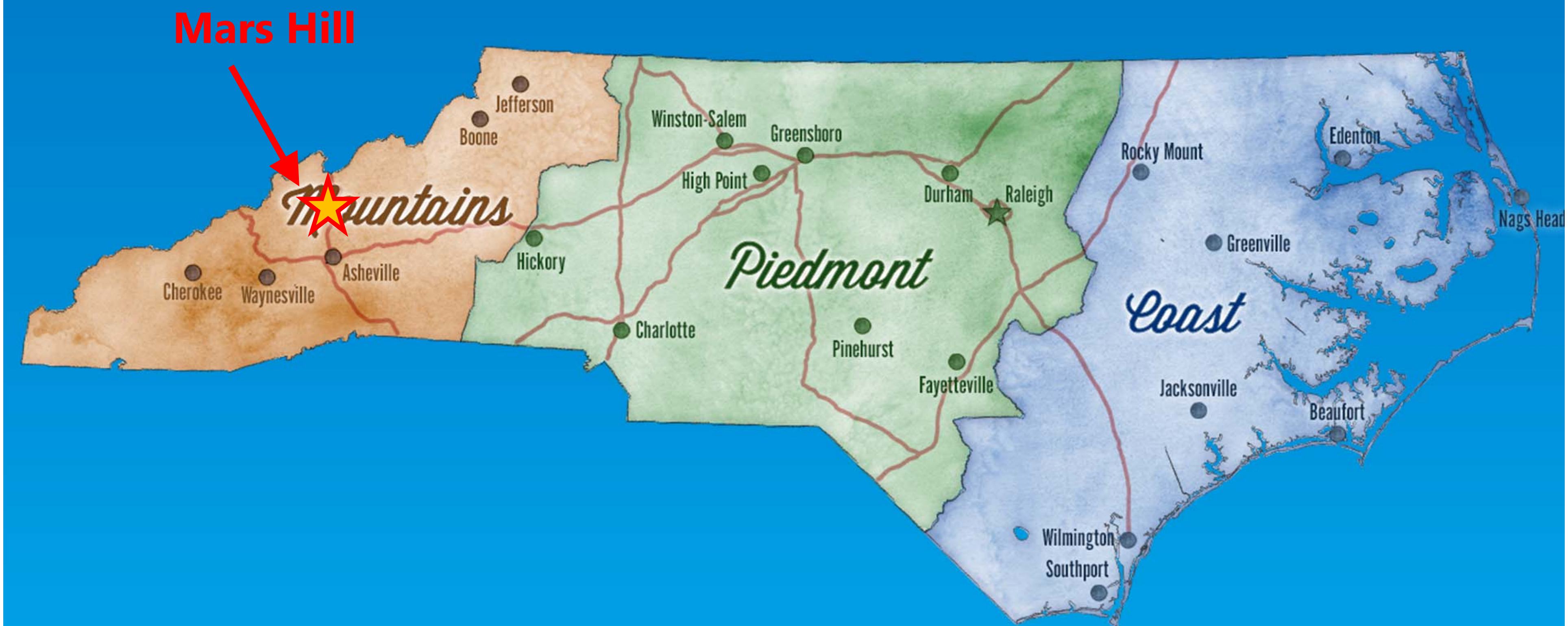
Innovative Stormwater Research

1) Steep Slope Bioretention Pilot Project

2) Stormwater Mycelium Filter Pilot Project

HydroCycle Engineering

Mars Hill, NC



Source: visitnc.com

Summary

Project	Steep Slope Bioretention Pilot	Stormwater Mycelium Filter Pilot
Goal	Test New Technology	Test New Technology
Sponsor	Madison SWCD	Madison SWCD
Grant Source	CWMTF	PRF
Site	Mars Hill Town Hall	Madison Co Dairy Farm
Site Type	Steep Slopes	Agricultural
Stormwater Runoff	Urban	Agricultural
Engineering Research	HydroCycle	HydroCycle
College Research	Mars Hill University	Warren Wilson College/ AB Tech

HydroCycle Engineering, PC

Steep Slope Bioretention Pilot Project

Why This Project?

Opportunity
Bioretention
Proven Technology

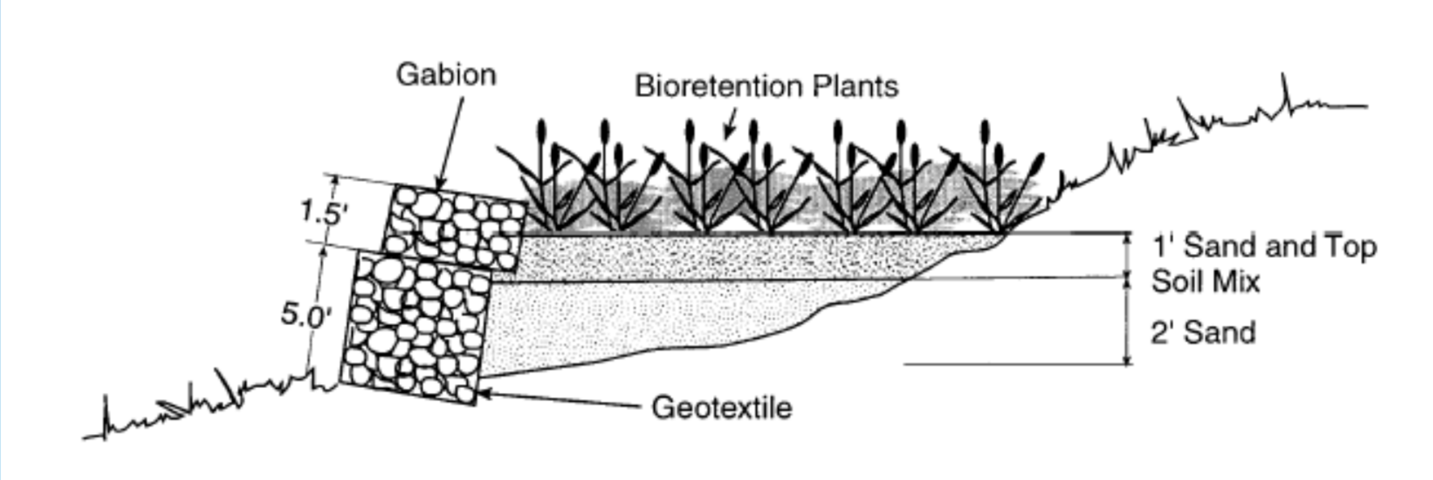
+

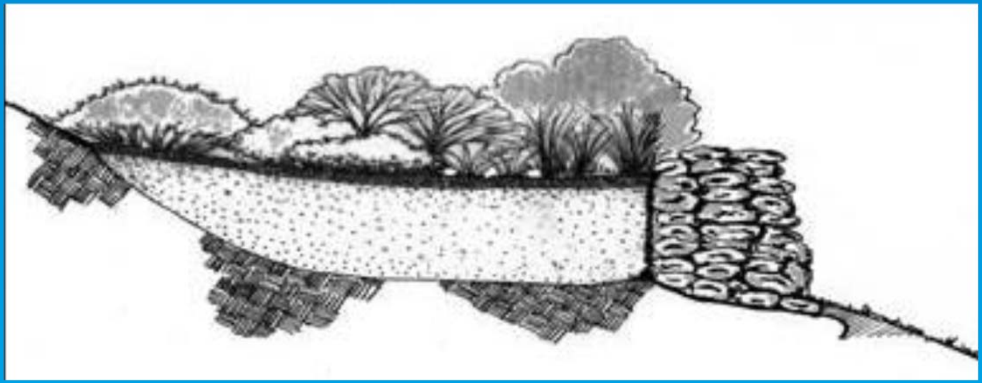
Need
Stormwater Mgmt for Steep Slopes

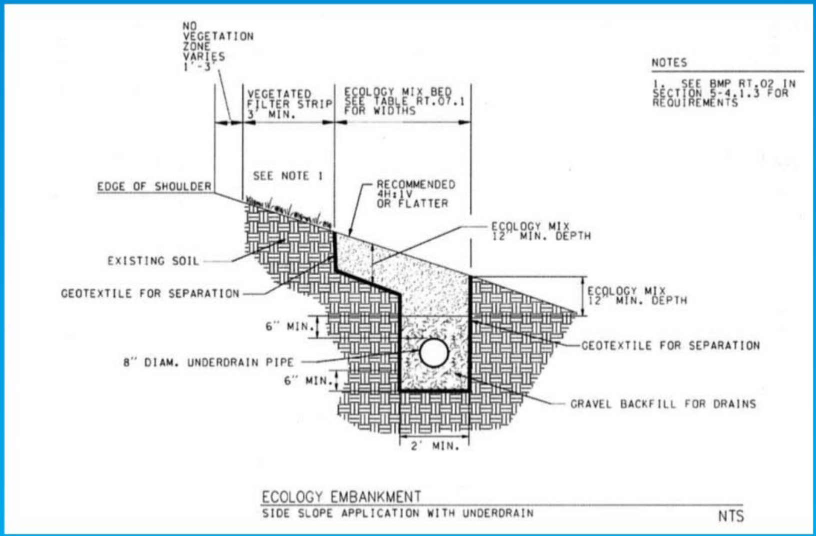

Photo: landofsky.org

Research

Current Practice







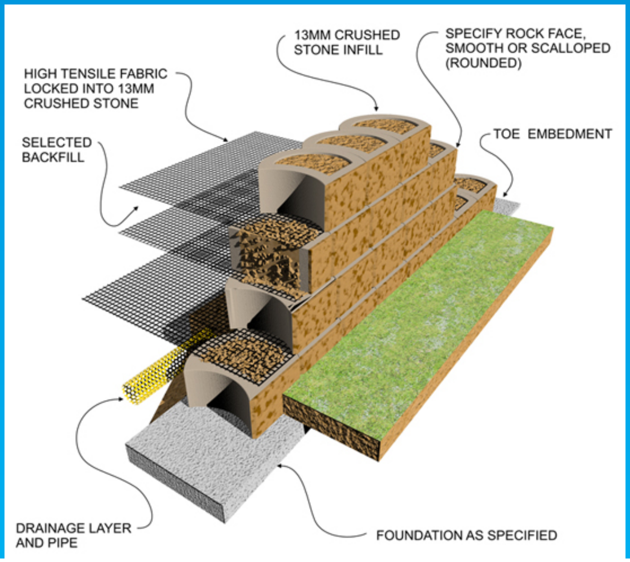
- >20 Criteria Manuals
- Not for slopes above 20%
- Special techniques needed

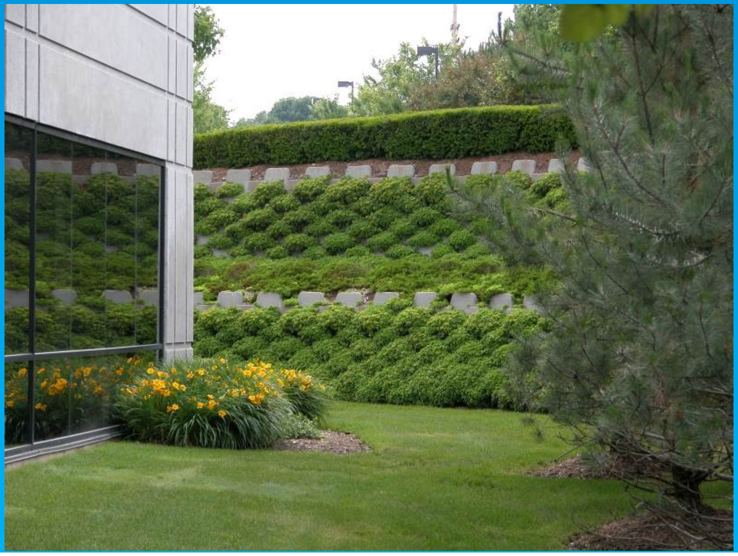
Ancient Terraced Systems

Wall Types

Wall Types

Wall Types


13MM CRUSHED
STONE INFILL
SPECIFY ROCK FACE,
SMOOTH OR SCALLOPED
(ROUNDED)
HIGH TENSILE FABRIC
LOCKED INTO 13MM
CRUSHED STONE
SELECTED
BACKFILL
TOE EMBEDMENT
DRAINAGE LAYER
AND PIPE
FOUNDATION AS SPECIFIED



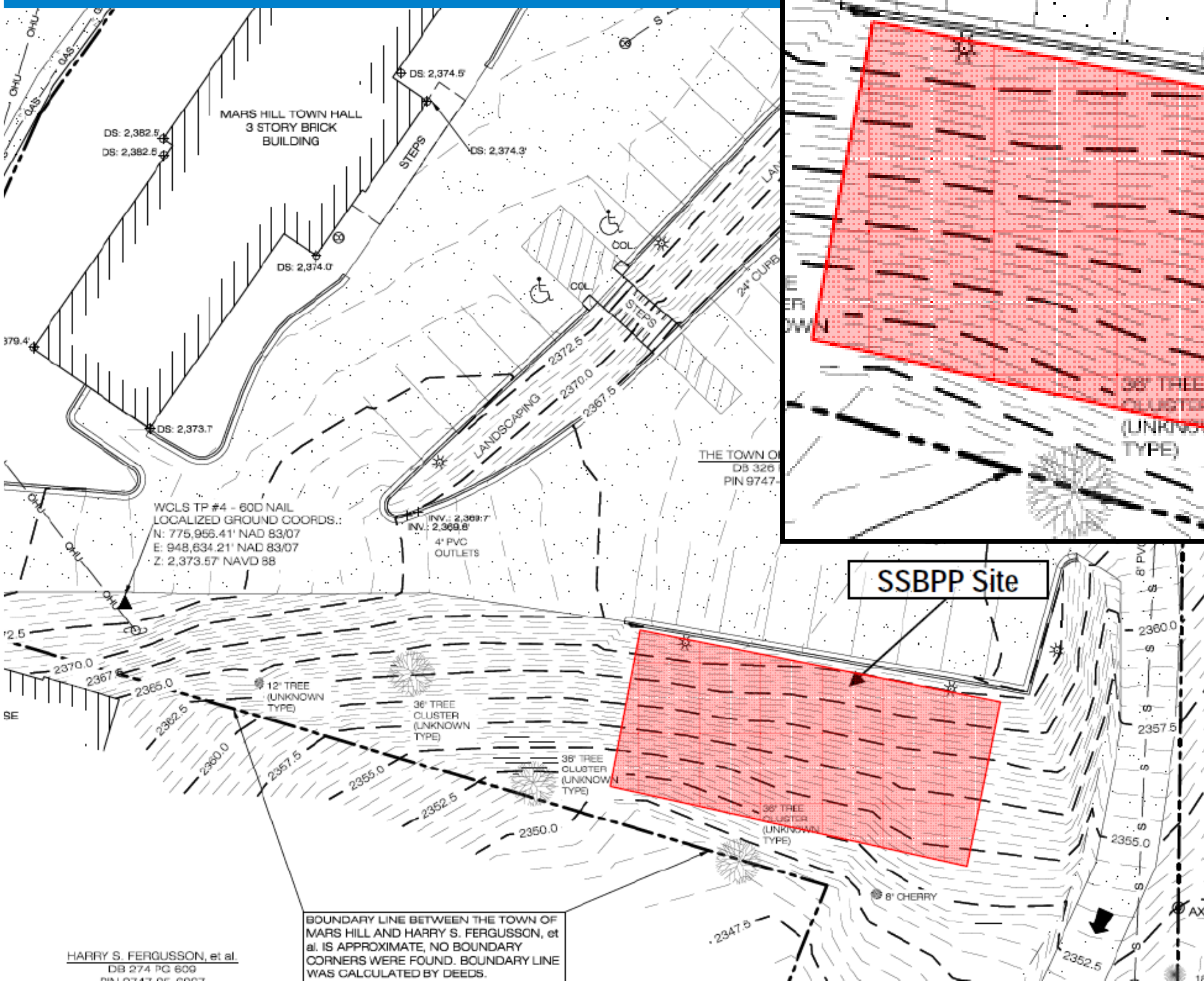
Comparison of Wall Types

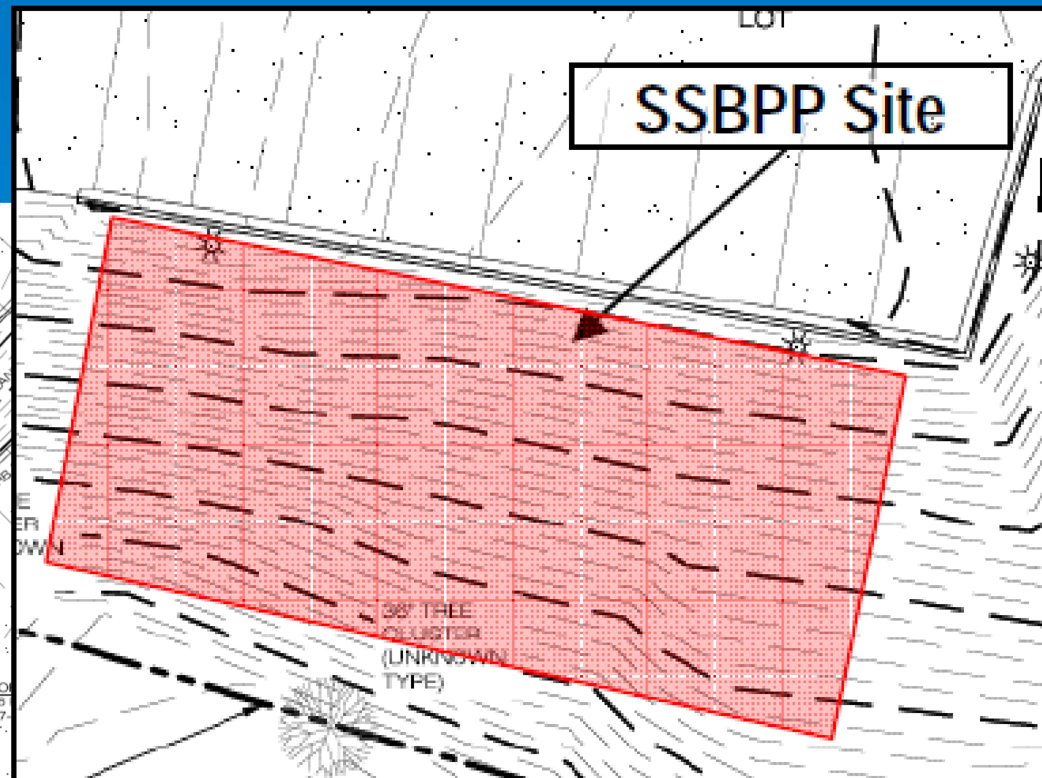
Wall Type	Advantages	Disadvantages
Timber/ Wood	• Low Cost • Aesthetics • Ease of construction	• Durability
Gabion	• Cost • Permeable • Ease of construction	• Aesthetics
Sheet Pile	• Small size/width • Maximize bioretention area	• Cost for construction • Impermeable • Difficulty of installation for terraces
Segmental Block	• Aesthetics • Ease of construction • Semi-permeable • Includes vegetated blocks	• "Unnatural" appearance • Need for geosynthetic reinforcement
Poured concrete	• Ease of construction • Smaller width	• Impermeable • Aesthetics (unless decorative)

Design

Before Conditions

Site Topography

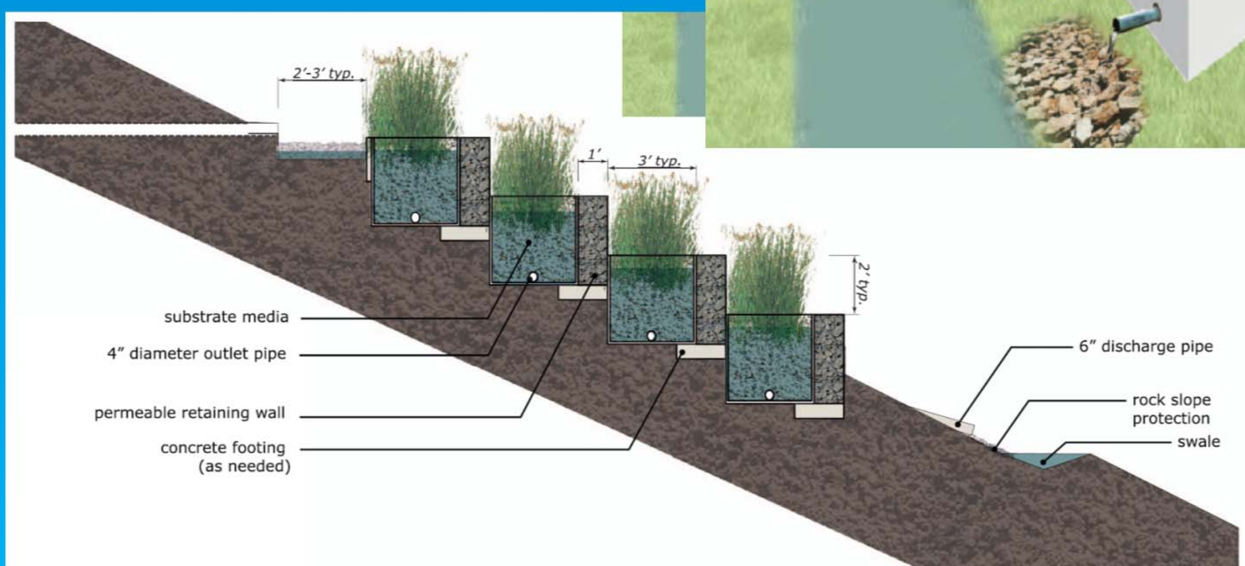




Fill Slope

Slope: 30-55%

Conceptual Design

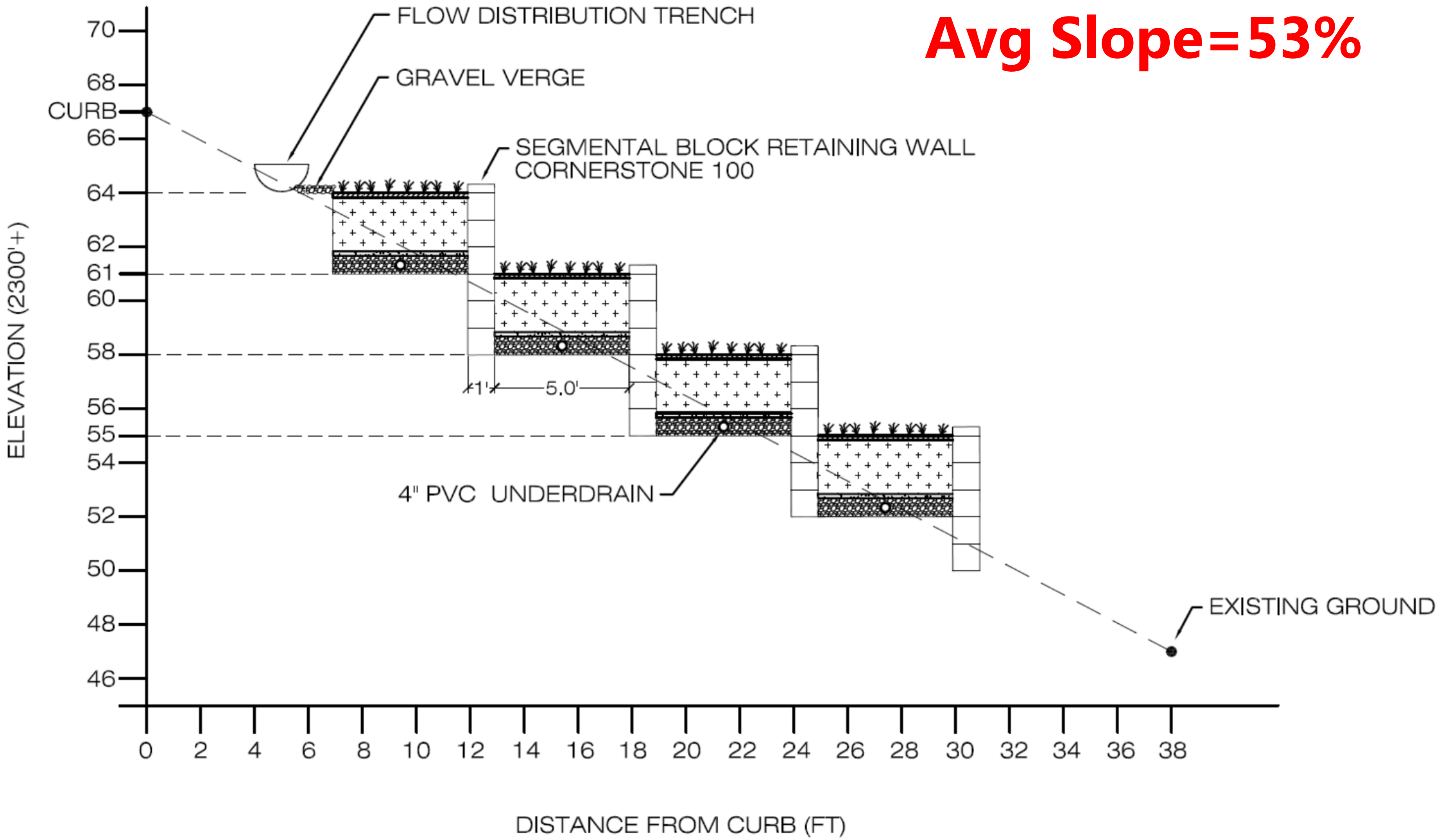


Site Hydrology

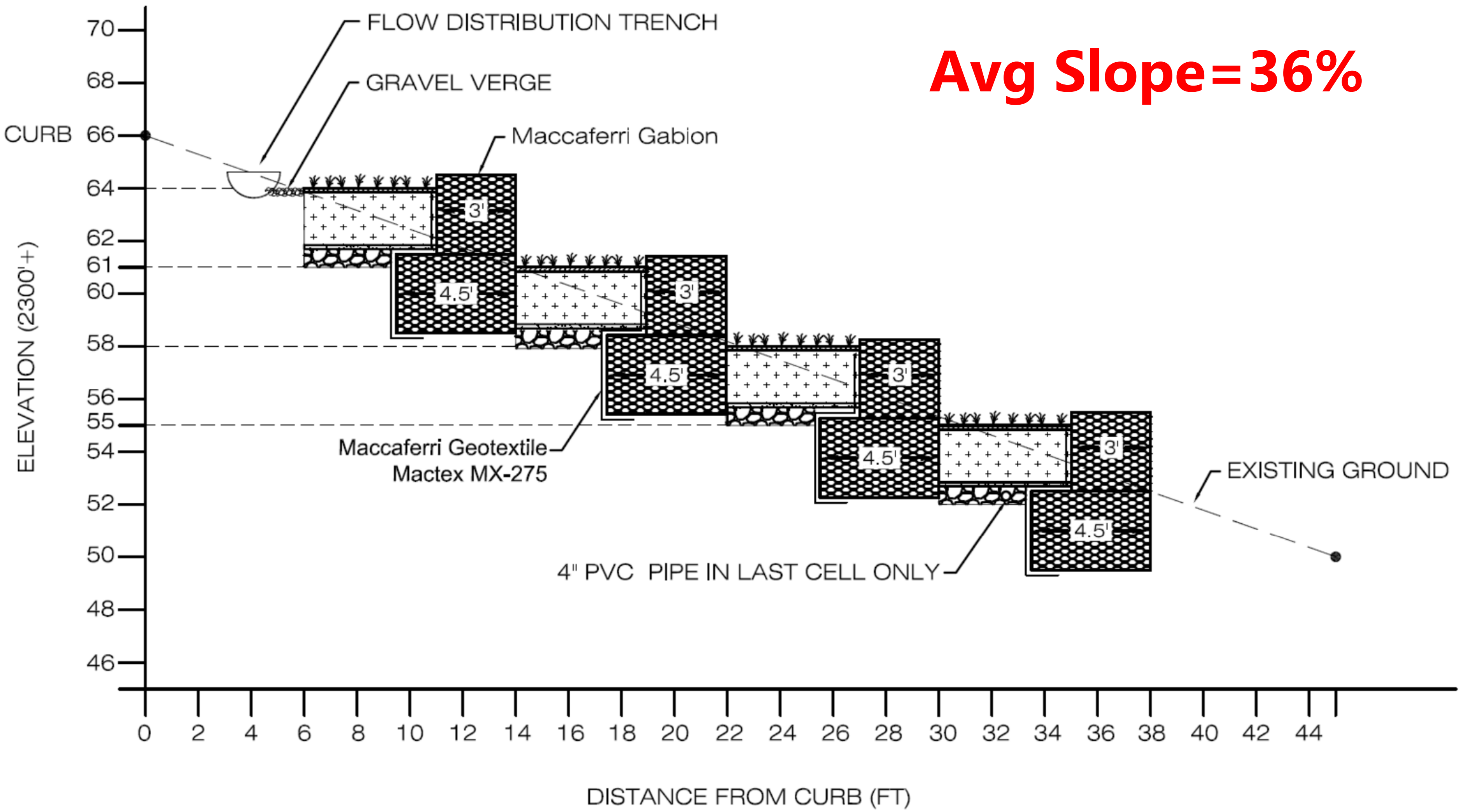
Comparison of Systems

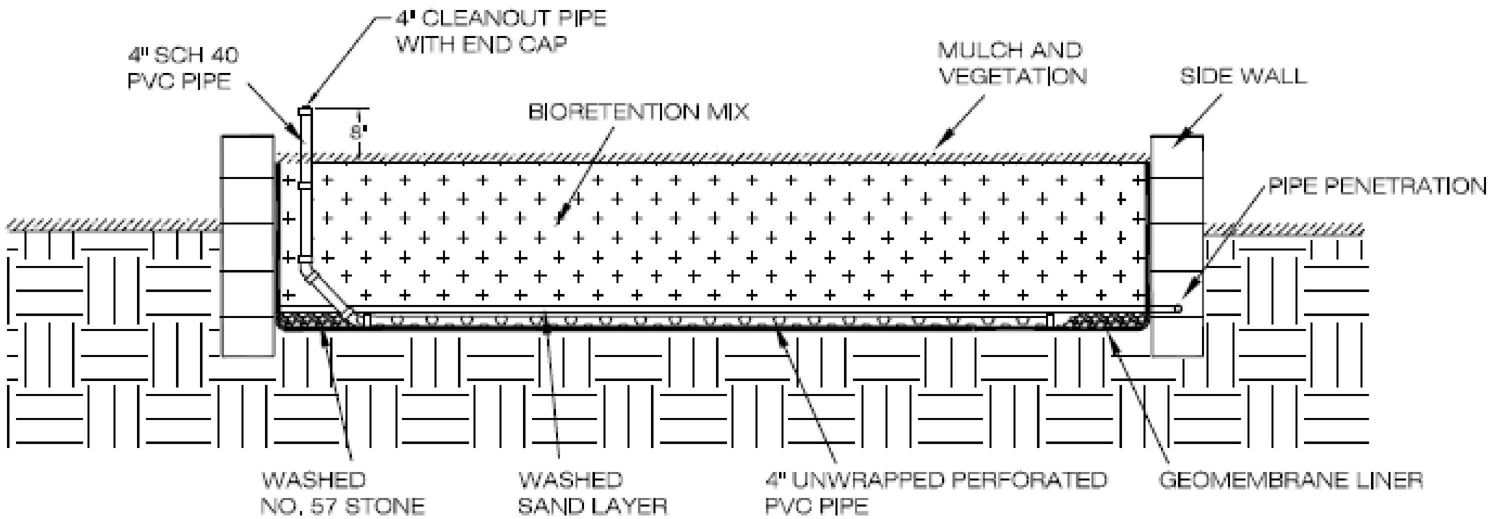
Characteristic	Segmental Block Wall	Gabion Weep Wall
Retaining Wall Product	Cornerstone 100	Maccaferri Gabion
Average Site Slope	53%	36%
Depth of wall (ft)	1.0	3.0 (4.5 ft at base)
Number of Bioretention Terraces	4	4
Length of Bioretention Terraces (ft)	12	12
Width of Bioretention Terraces (ft)	5	5
Total Surface Area (ft^2)	240	240
Media Material	Stalite PermaTill	Stalite PermaTill
Media Depth (in)	24	24
Gravel Underdrain Layer Depth (in)	8	8
Intermediate Sand Layer Depth (in)	2	2
Mulch Layer Depth (in)	2	2
Total Filter Depth (in)	36	36
Average Ponding Depth (in)	4	4
Underdrain Pipe Diameter (in)	4	4
Geomembrane Liner	4 side walls and bottom	3 side walls and bottom

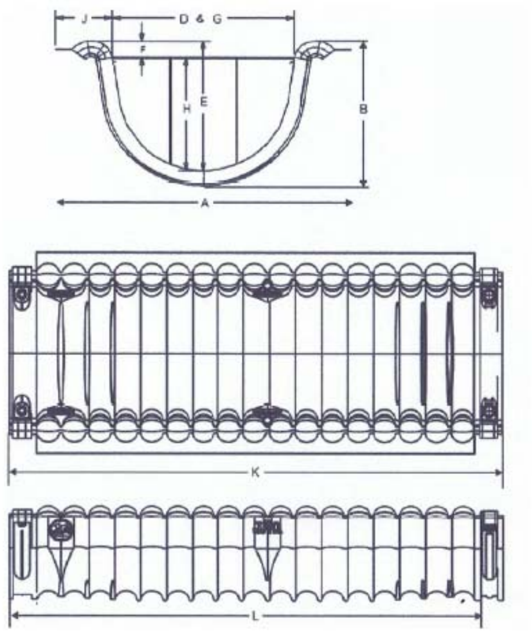
Segmental Block Wall

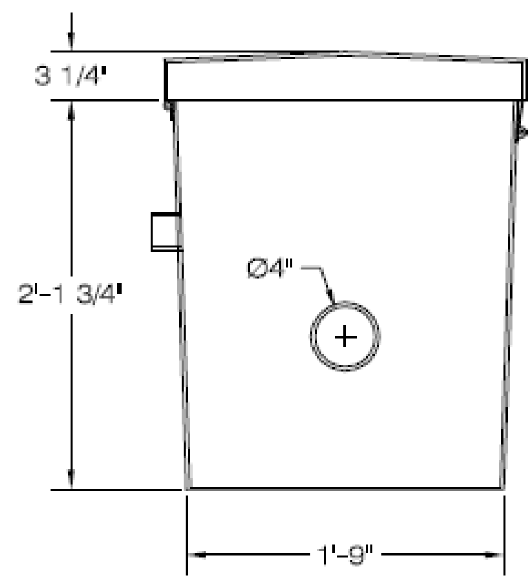


Gabion Weep Wall




4" CLEANOUT PIPE
WITH END CAP
4" SCH 40
PVC PIPE
MULCH AND
VEGETATION
SIDE WALL
BIORETENTION MIX
8"
PIPE PENETRATION
WASHED
NO. 57 STONE
WASHED
SAND LAYER
4" UNWRAPPED PERFORATED
PVC PIPE
GEOMEMBRANE LINER




3 1/4"
2'-1 3/4"
Ø4"
1'-9"

Construction





CAT







Planting Plan

ID	Scientific Name	Common Name	Height	Spread	Spacing	Bloom Time	Qty/ Cell	Total Qty
A	*Asclepias tuberosa*	Butterflyweed	10-24"	12-18"	15"	July	3	24
B	*Baptisia australis*	False Blue Indigo	36-48"	36-48"	36"	May - June	1	8
C	*Coreopsis lanceolata*	Lanceleaf Tickseed	12-24"	12-18"	15"	April - June	3	24
D	*Phlox subulata*	Moss Pinks	6"	6-24"	12"	April	6	48
E	*Rudbeckia fulgida*	Rudbeckia	24-36"	24-30"	24"	Aug - Oct	2	16
F	*Sporobolus heterolepis*	Prairie Dropseed	24-36"	24-36"	30"	Aug - Oct	6	48

Educational Signage

Monitoring

Monitoring Plan

Number of sampling events	12
Number of events per month (avg)	2
Minimum rainfall depth for event	~1 inch
Process for sampling storm event	Monitor weather forecast and mobilize when runoff begins. Begin sampling when flow begins through system. Capture “first flush” into system as well as later samples (>15 min into storm event and every subsequent hour). Take effluent sample upon discharge.
Number of sampling points on site	4 (2 influent and 2 effluent samples)
Duplicate samples	Duplicate samples will be taken at all sampling points
Flowrate measurement	Measure and record depth of flow above weirs, both influent and effluent weirs
Rate for system flow-through	Record time at which inflow into system begins and time at which outflow from system begins to compute system flow-through rate.
Primary parameters to test	TSS, nitrate, phosphate, temperature
Secondary parameters to test	Biochemical oxygen demand (BOD), electrical conductivity
Total sample bottles per event	12 (1.0 L each) [2 influent + 2 duplicates @ first flush + 2 influent + 2 duplicates @ mid storm + 2 effluent + 2 duplicates upon discharge from system] = 12
Total Sample Bottles for 12 events	144
Sample transport and storage	Use standard protocols
Documentation and Reporting	Maintain log book with sample dates, times, weather conditions, temperature, rainfall depth, influent and effluent flow depths and flow rates, time at which inflow begins, time at which outflow begins, lab methods, photographic documentation, observations of water flow paths and function, and results.
Lab Analysis Protocols*	
TSS	Standard Methods for the Examination of Water and Wastewater (APHA, 2005)
Nitrate	Standard Methods for the Examination of Water and Wastewater (APHA, 2005)
Phosphate	Standard Methods for the Examination of Water and Wastewater (APHA, 2005)
BOD	Standard Methods for the Examination of Water and Wastewater (APHA, 2005)
Conductivity	Meter


POLICE

Results & Conclusions

Rank	Date	Max Temp (F)	Min Temp (F)	Max Wind Speed (mi/hr)	Precipitation (Inches)
1	12/22/2013	65	56	21	2.80
2	11/26/2013	44	30	17	2.59
3	9/21/2013	69	61	24	1.39
4	1/11/2014	56	42	23	1.38
5	10/7/2013	65	53	24	1.12
6	9/25/2013	63	59	8	1.11
7	12/14/2013	41	35	8	0.85
8	2/12/2014	29	22	9	0.78
9	12/29/2013	53	37	22	0.77
10	2/21/2014	63	39	25	0.69
11	12/21/2013	65	52	21	0.65
12	2/3/2014	58	37	26	0.64
13	12/6/2013	70	50	25	0.58
14	12/9/2013	53	34	17	0.54
15	1/10/2014	50	34	9	0.52
16	3/16/2014	48	39	14	0.50
Data from Asheville Regional Airport rainfall gauge. Data does not include cumulative totals for consecutive days.					

Construction Performance

Segmental Block Wall

Gabion Performance

Cost Comparison

Component	Segmental Block Wall System	Gabion Weep Wall System	Other
Bioretention Components	$4,710	$4,880	
Retaining Wall Structure Components	$10,420	$13,060	
Total	$15,130	$17,940	
Bioretention Area (sf)	240	240	
Unit Cost for Bioretention Only ($/SF)	$20/SF	$20/SF	
Unit Cost with Retaining Structures ($/SF)	$63/SF	$75/SF	
Monitoring Related Components			$8,590
Education Signage			$1,000
Total			**$42,660**

Conclusions

1) Bioretention feasible on steep slopes (tested up to 53%)
2) Both designs valid
3) Earth retention structure cost is significant (~70% total)
4) Segmental block wall more flexible/cost-effective
5) Gabion wall cost about 25% higher
6) Incorporate plantings for aesthetics
7) Geotechnical analysis required
8) Proper water management through system is critical (use underdrains, media with adequate infiltration rate, impermeable liners, and proper wall design)
9) Most applicable sites:
   - Space is extremely limited for other SCMs
   - Retaining wall already planned
   - Shorter slopes
   - Compare costs to other ultra-urban SCMs (underground storage, bioretention planters, etc.)

Stormwater Mycelium Filter Pilot Project

Why This Project?

Opportunity
Technique used in Pacific Northwest

+

Need
Simple Practices for Agricultural Runoff

Project Goals

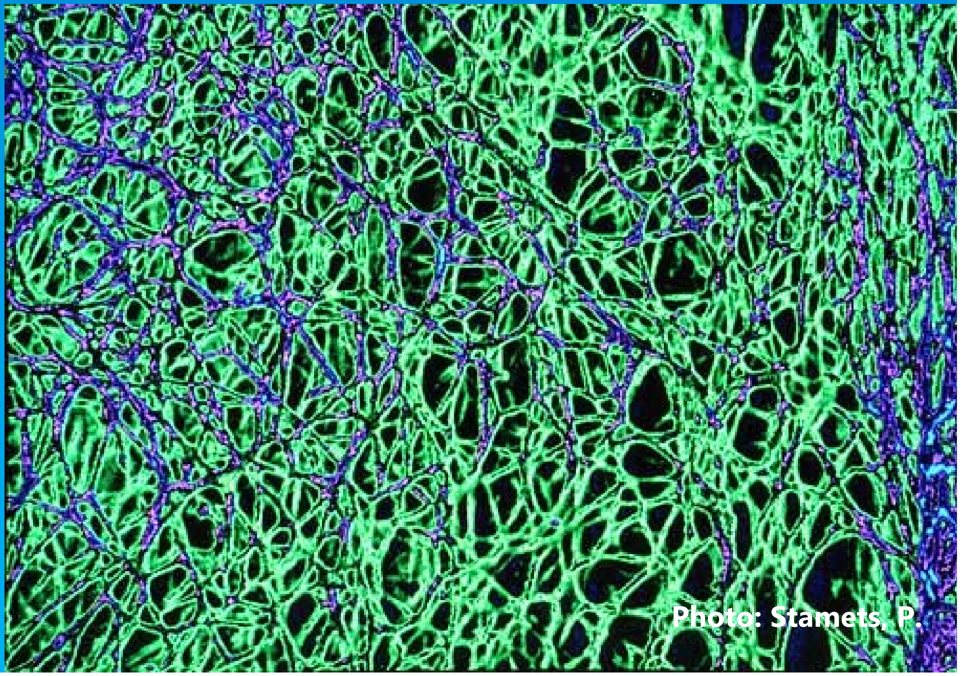
1) Test the effectiveness of mycelium filters for removing common water-quality pollutants from agricultural stormwater runoff.

2) Provide monitoring results to potentially facilitate widespread adoption as a stormwater BMP.

Research

Mycelium

"vegetative part of a fungus, consisting of a mass of branching, thread-like hyphae."



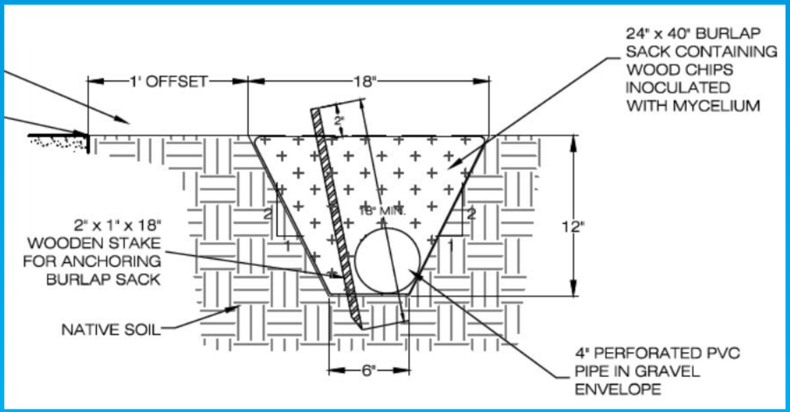
Mycoremediation

- Using fungi to degrade or sequester pollutants
- Fungal *mycelium* for filtering stormwater
- *Mycofiltration* coined by Paul Stamets
- Pilot testing in Washington State

Mycelium shown to remove:

- Pathogens (protozoa, bacteria, viruses)
- Silt and sediment
- Chemical toxins (including hydrocarbons)

Mushroom Mycelium Filter



- **Oyster Mushroom**
- **Petroleum Hydrocarbons from 20,000 PPM to 200 PPM in 8 Weeks**

Source: P. Stamets

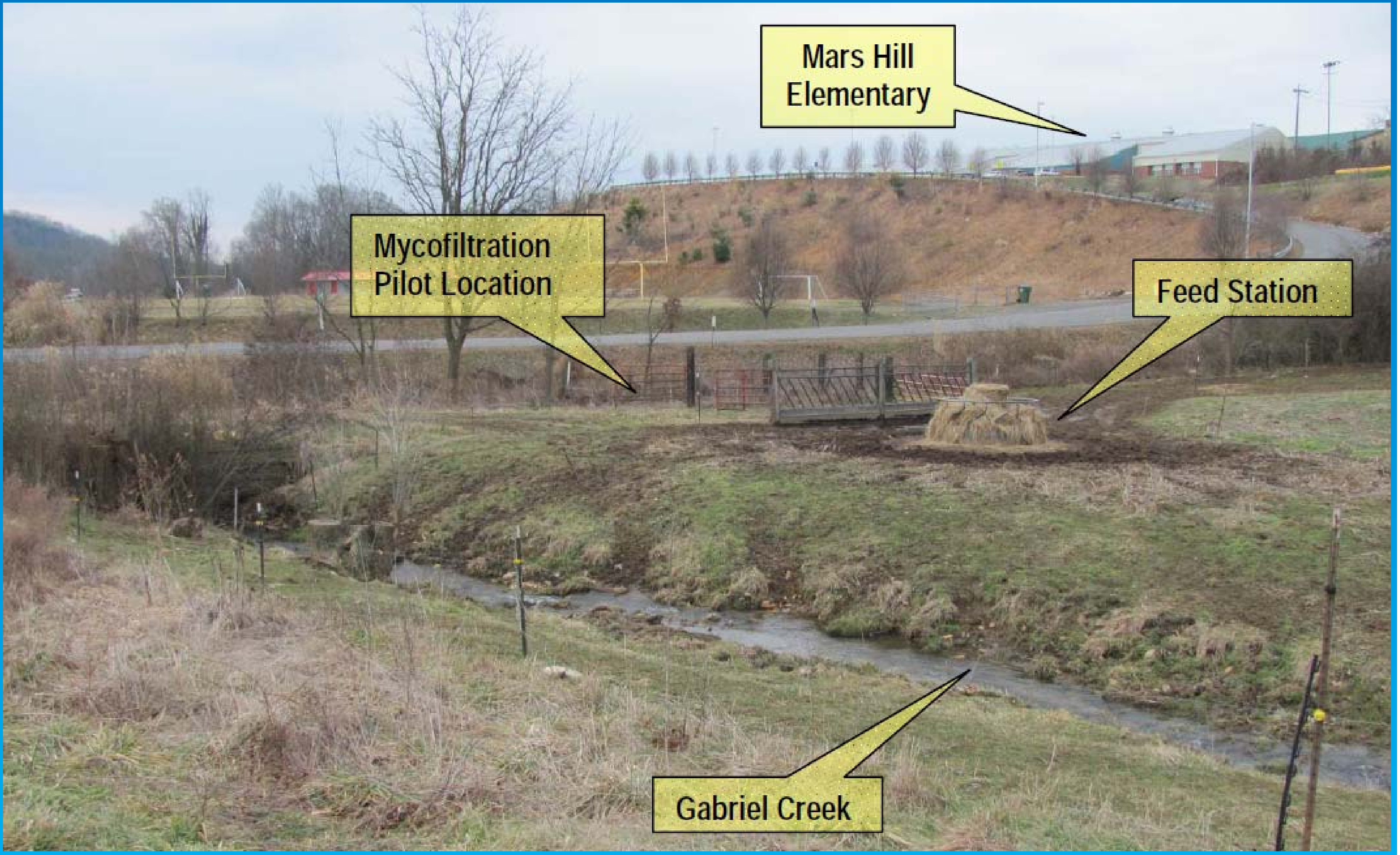
Photo: TED.com

Example Applications

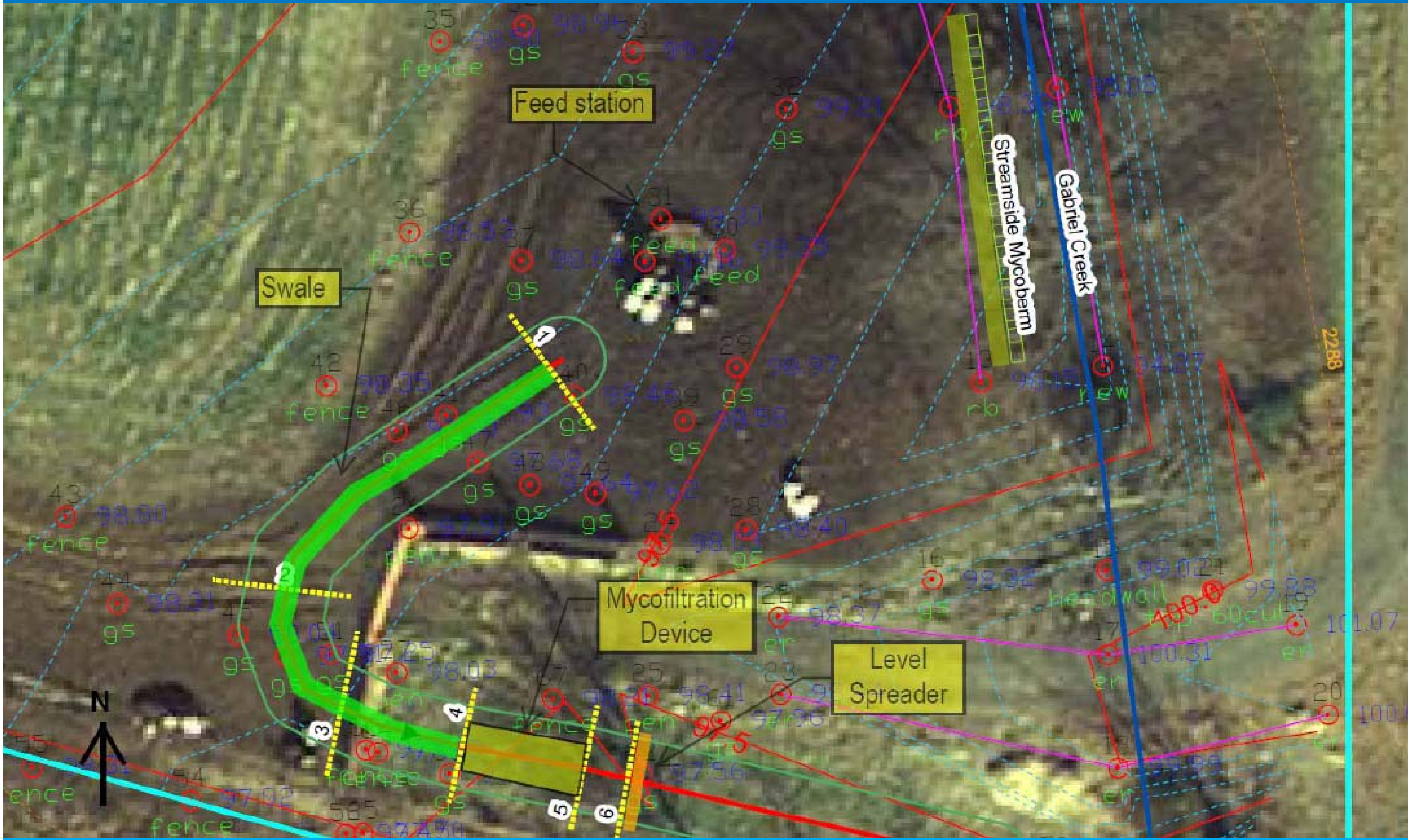
- Inoculate wood chips with mycelium
- Place wood chips in burlap sacks (or trenches)
- Secure burlap sacks in path of stormwater
- Other media and methods

Design

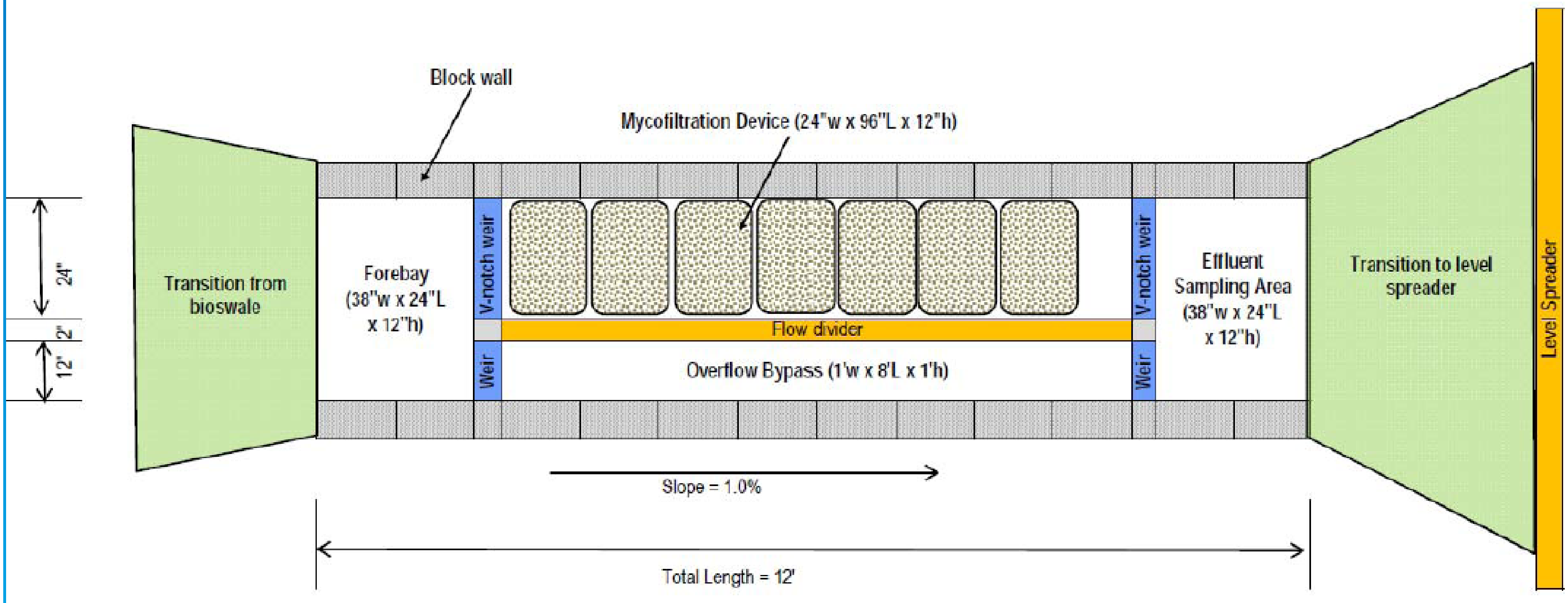
Project Site



System Layout

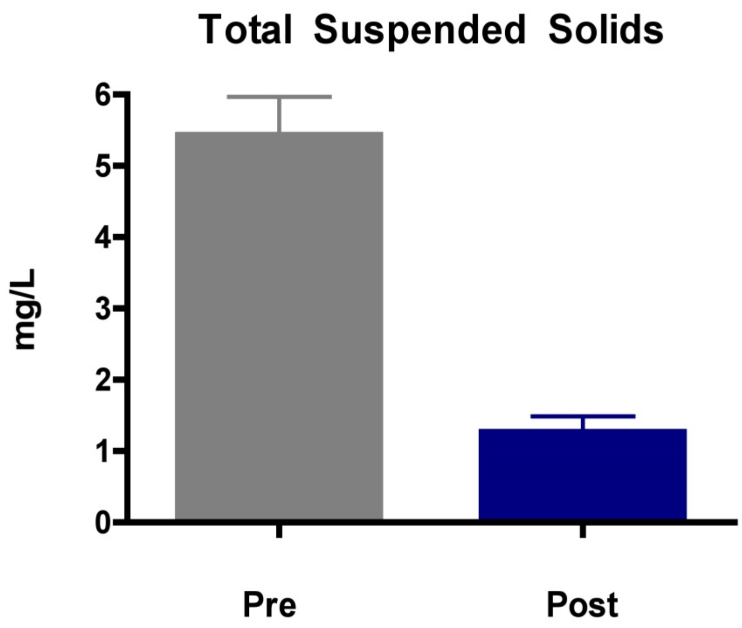


Pilot System Design

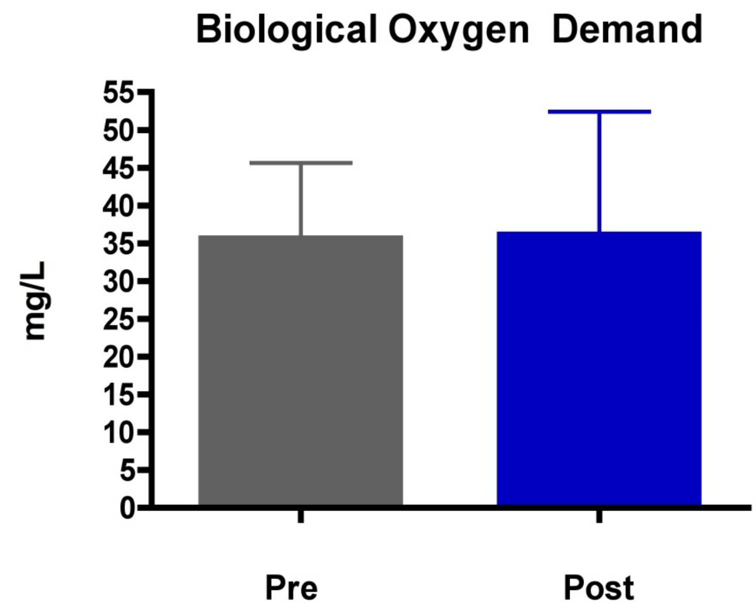


Plan View

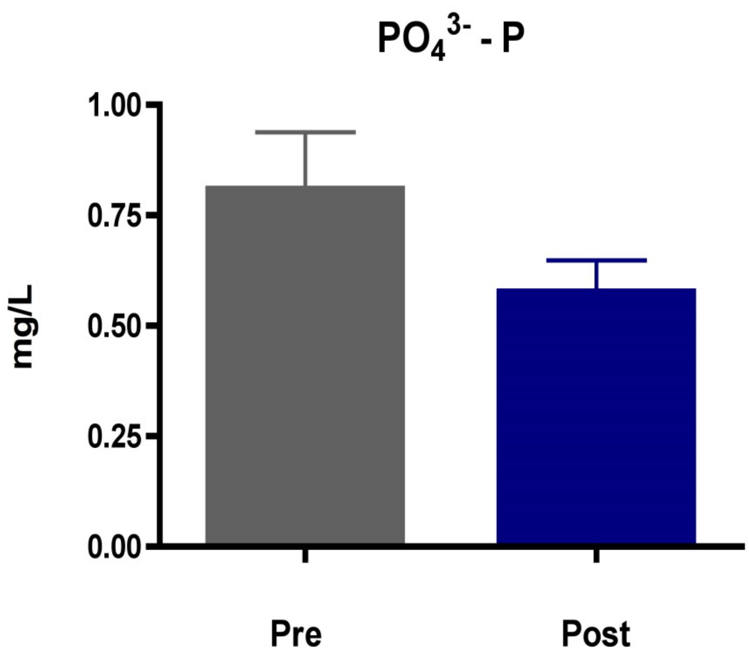

Asheville Fungi
Mushroom Central
OPEN



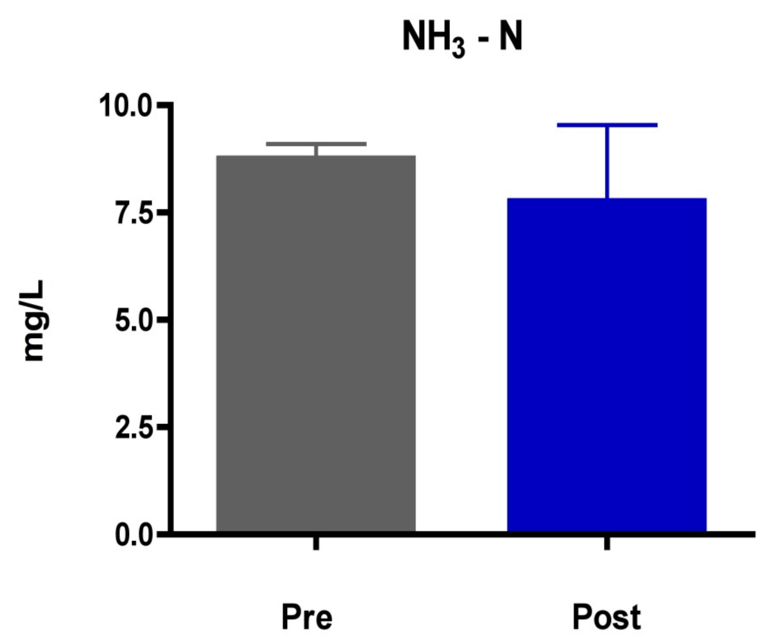
Total Suspended Solids
mg/L
0
1
2
3
4
5
6
Pre
Post



Biological Oxygen Demand
mg/L
0
5
10
15
20
25
30
35
40
45
50
55
Pre
Post



PO_4^{3-} - P
mg/L
0.00
0.25
0.50
0.75
1.00
Pre
Post



NH_3 - N
mg/L
0.0
2.5
5.0
7.5
10.0
Pre
Post

Results

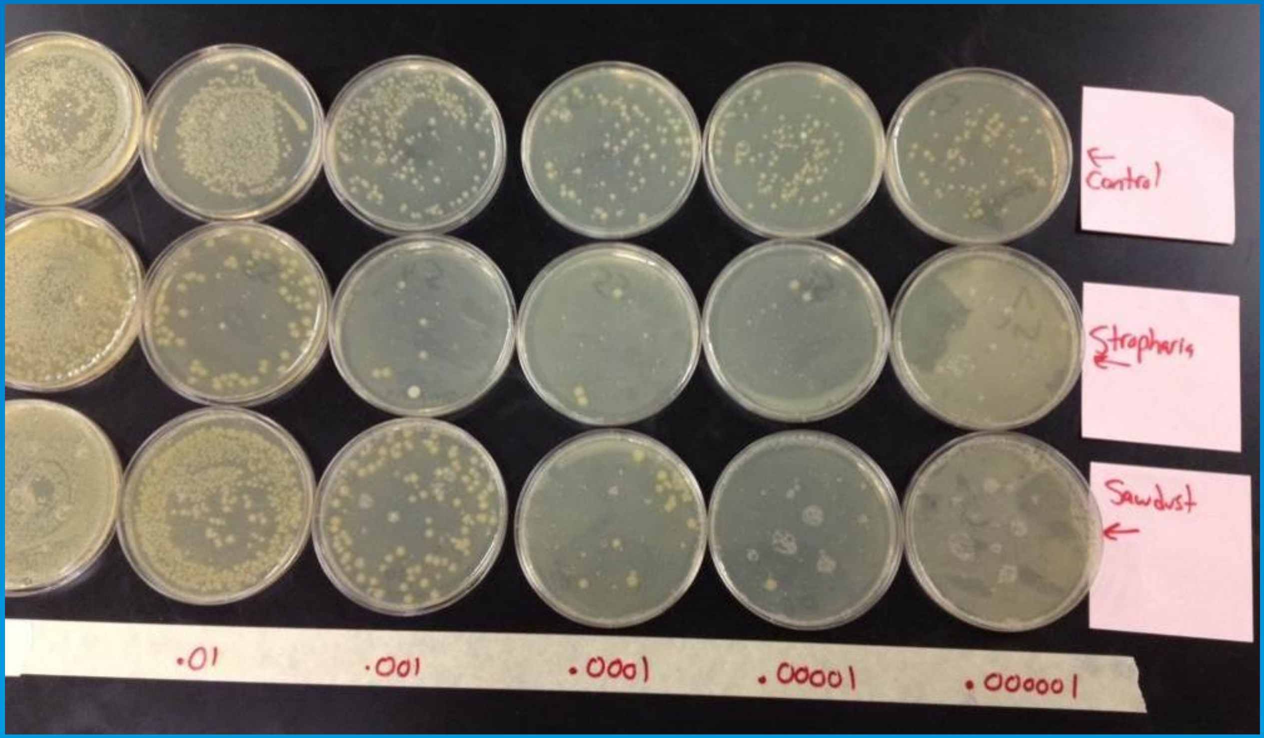
Phase II


5 months after installation


10 months after installation

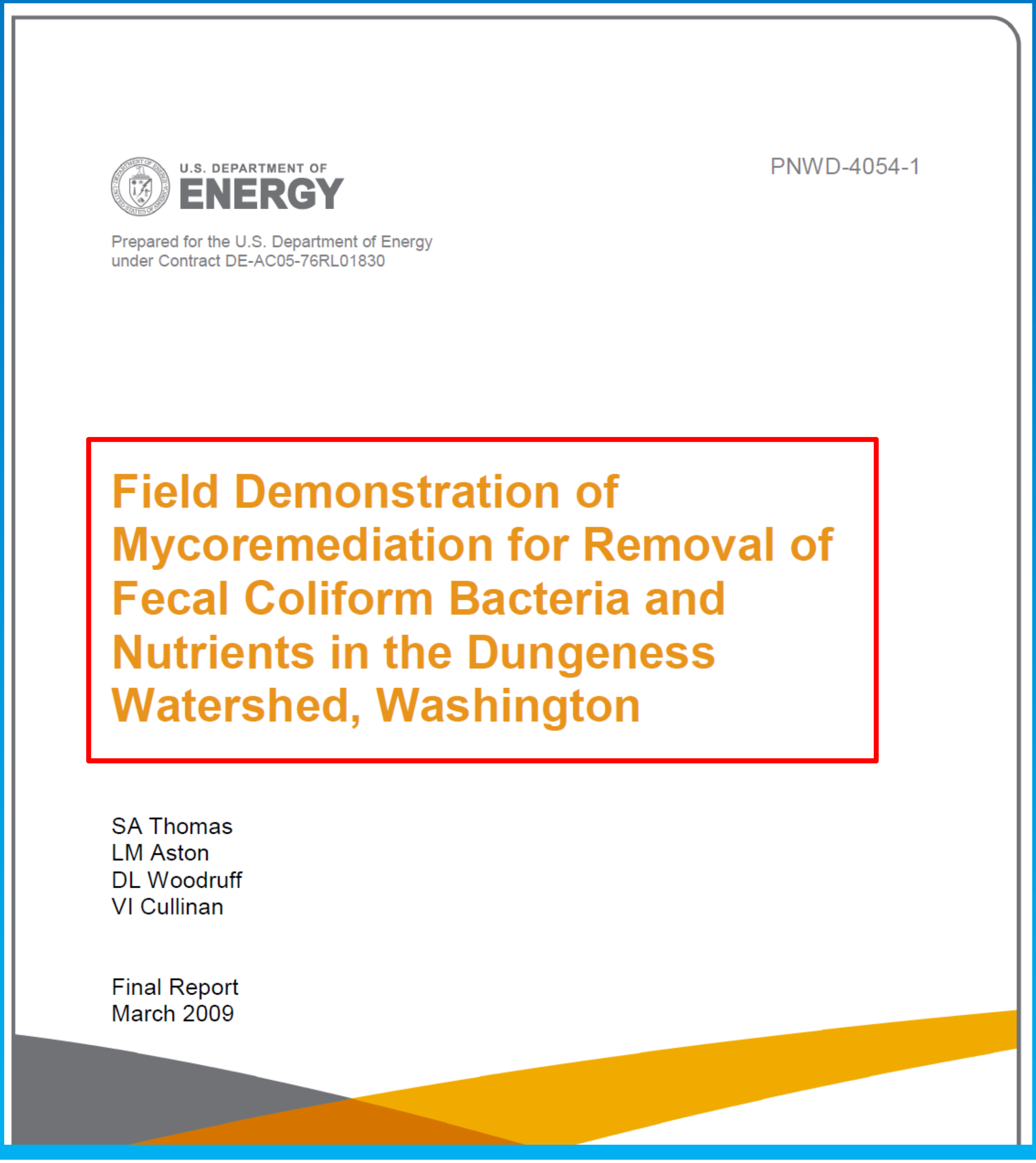
Additional Research

Bench Scale Study



- A-B Technical Community College
- King Stropharia Mushroom Mycelium
- 93% Reduction in E. coli vs. Control Filter

Bioretention with Mycelium



U.S. DEPARTMENT OF ENERGY

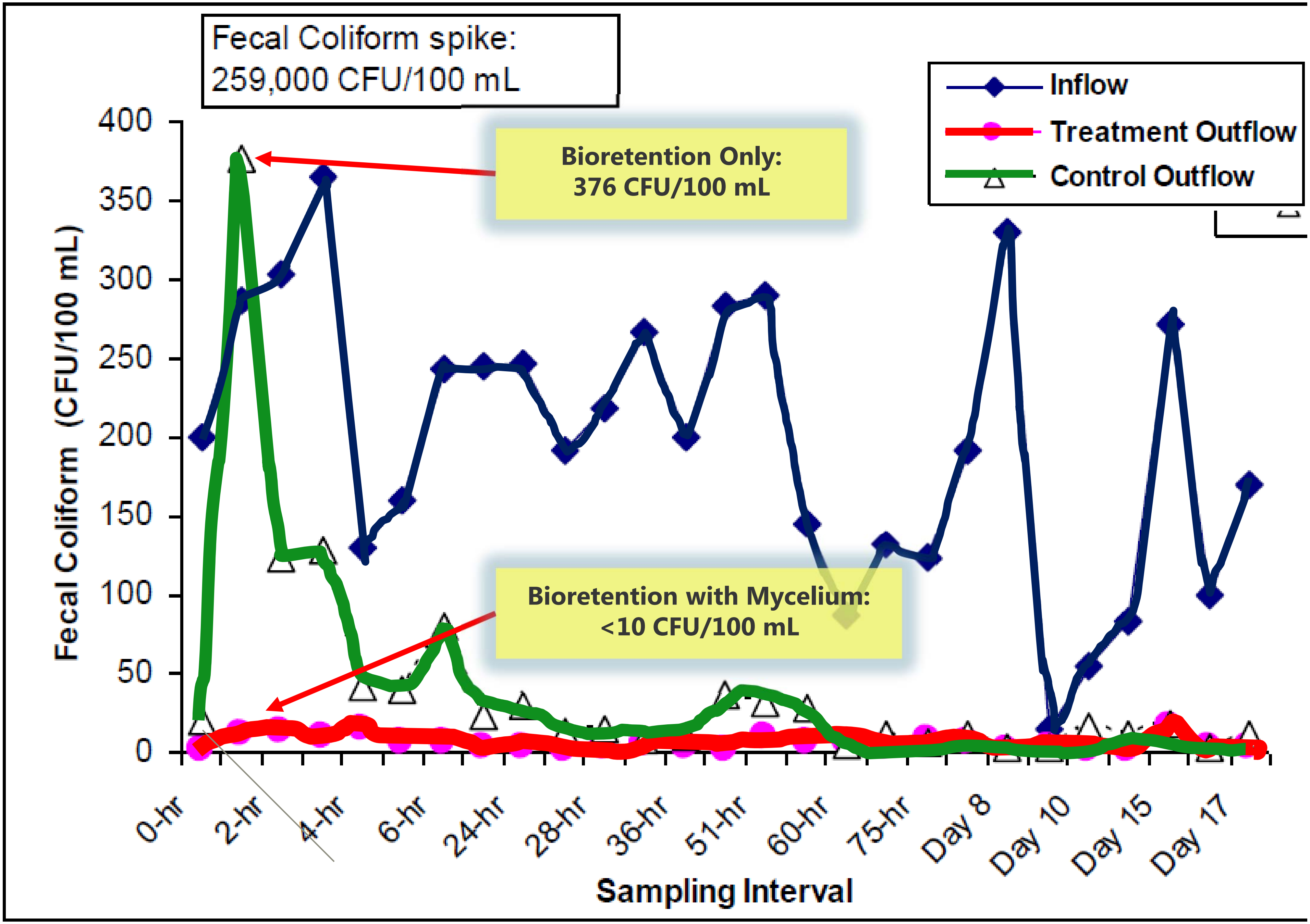
PNWD-4054-1

Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

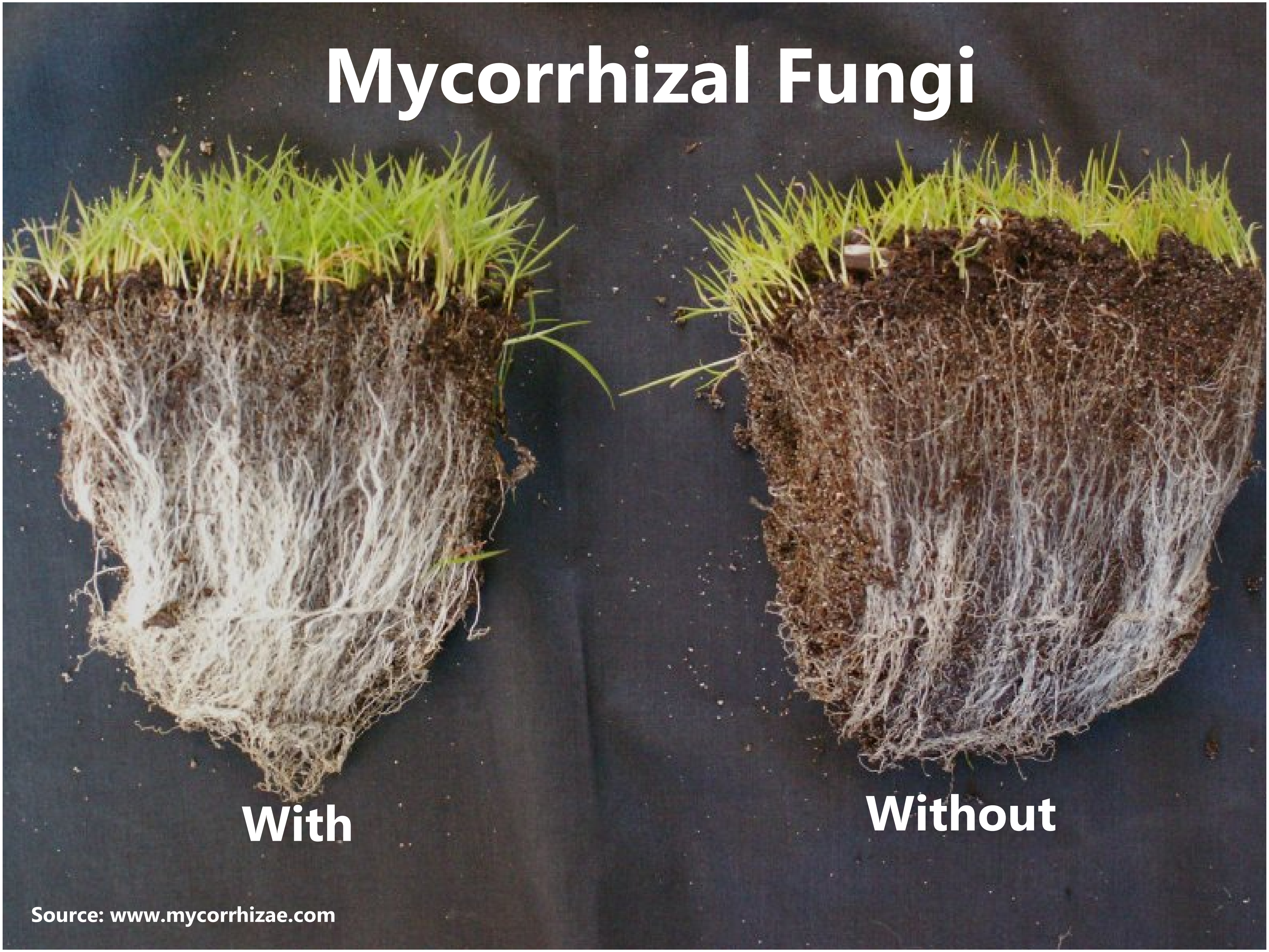
Field Demonstration of Mycoremediation for Removal of Fecal Coliform Bacteria and Nutrients in the Dungeness Watershed, Washington

SA Thomas
LM Aston
DL Woodruff
VI Cullinan

Final Report
March 2009

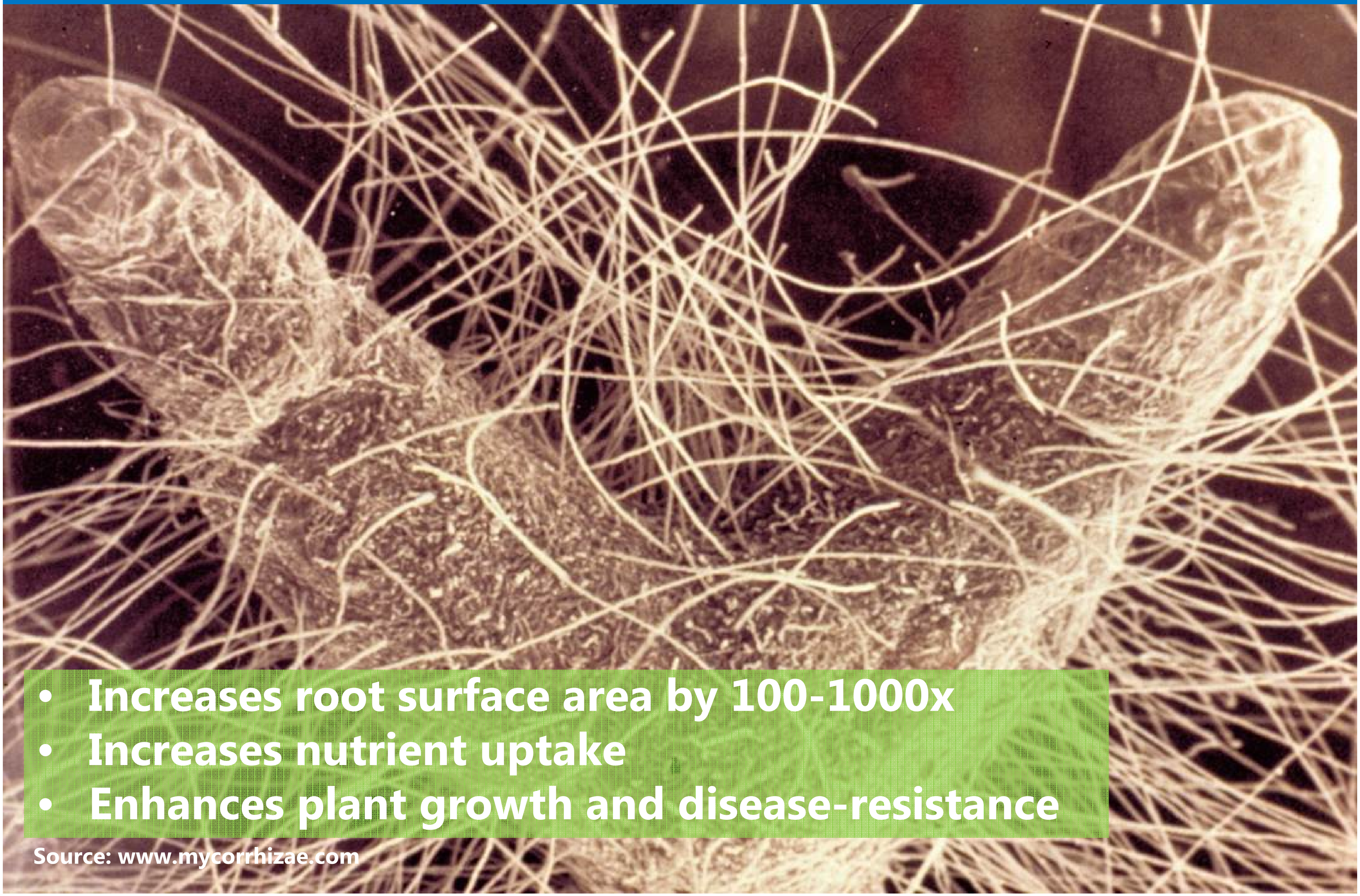


Fecal Coliform spike:
259,000 CFU/100 mL
Inflow
Treatment Outflow
Control Outflow
Bioretention Only:
376 CFU/100 mL
Bioretention with Mycelium:
<10 CFU/100 mL
Fecal Coliform (CFU/100 mL)
400
350
300
250
200
150
100
50
0
0-hr
2-hr
4-hr
6-hr
24-hr
28-hr
36-hr
51-hr
60-hr
75-hr
Day 8
Day 10
Day 15
Day 17
Sampling Interval



Mycorrhizal Fungi
With
Without
Source: www.mycorrhizae.com

Mycorrhizal Fungi



- Increases root surface area by 100-1000x
- Increases nutrient uptake
- Enhances plant growth and disease-resistance

Source: www.mycorrhizae.com

Bioretention with Mycelium

Conclusions

1) Delivery method with mycelium filter bags with wood chips not consistently reliable.
2) Mycelium growth peaked within 2 months; replacement necessary in less than five months.
3) Isolated wood chip bag system may be too sensitive to provide consistent treatment benefits.
4) Decreased temperatures result in dormancy of the mycelium and decreased treatment effectiveness.
5) Likely to require excessive monitoring and maintenance (not low cost/low maintenance).
6) Larger storms may bypass the bag/berm system.
7) Evidence that filter bags may be accumulating pollutants and fostering the growth of bacteria.
8) Bench scale test successful; King Stropharia mycelium highly effective at removing E. coli.

Recommendations

1) Consider and apply eco-mimicry.

2) Integrate mycelium into proven natural vegetated soil-based stormwater treatment systems.

3) Design systems which create the conditions for mycelium to thrive (moisture, food, temp)

4) Consider the use of mycorrhizal fungi in stormwater treatment systems.

5) Consider the use of mycorrhizal fungi in restored riparian buffers.

6) Develop plant and tree guilds with mycorrhizal fungi appropriate for riparian zones

Thank you.

HydroCycle Engineering, PC

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828.989.8075
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Protecting Water Resources: NCSU Resources & Research

Mitch Woodward
Area Spec. Agent – Watersheds & Water Quality
NCSU Cooperative Extension

Meet the NCSU Stormwater Team…….

- <u>Campus -</u>

  - Teaching

  - Research

- <u>County -</u>Extension/ Outreach:

  - Demonstration

  - Teaching

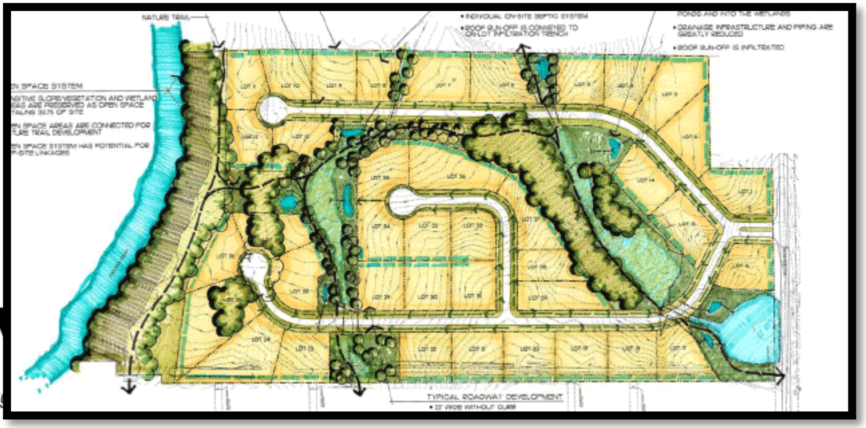
- **One Goal - Accelerate the Adoption of Solutions!!!**

Goals of Low Impact Development

- Reduce impervious surfaces
- Retain runoff on-site
- Promoting infiltration and evapotranspiration

- Replicating pre-development hydrologic conditions as closely as possible

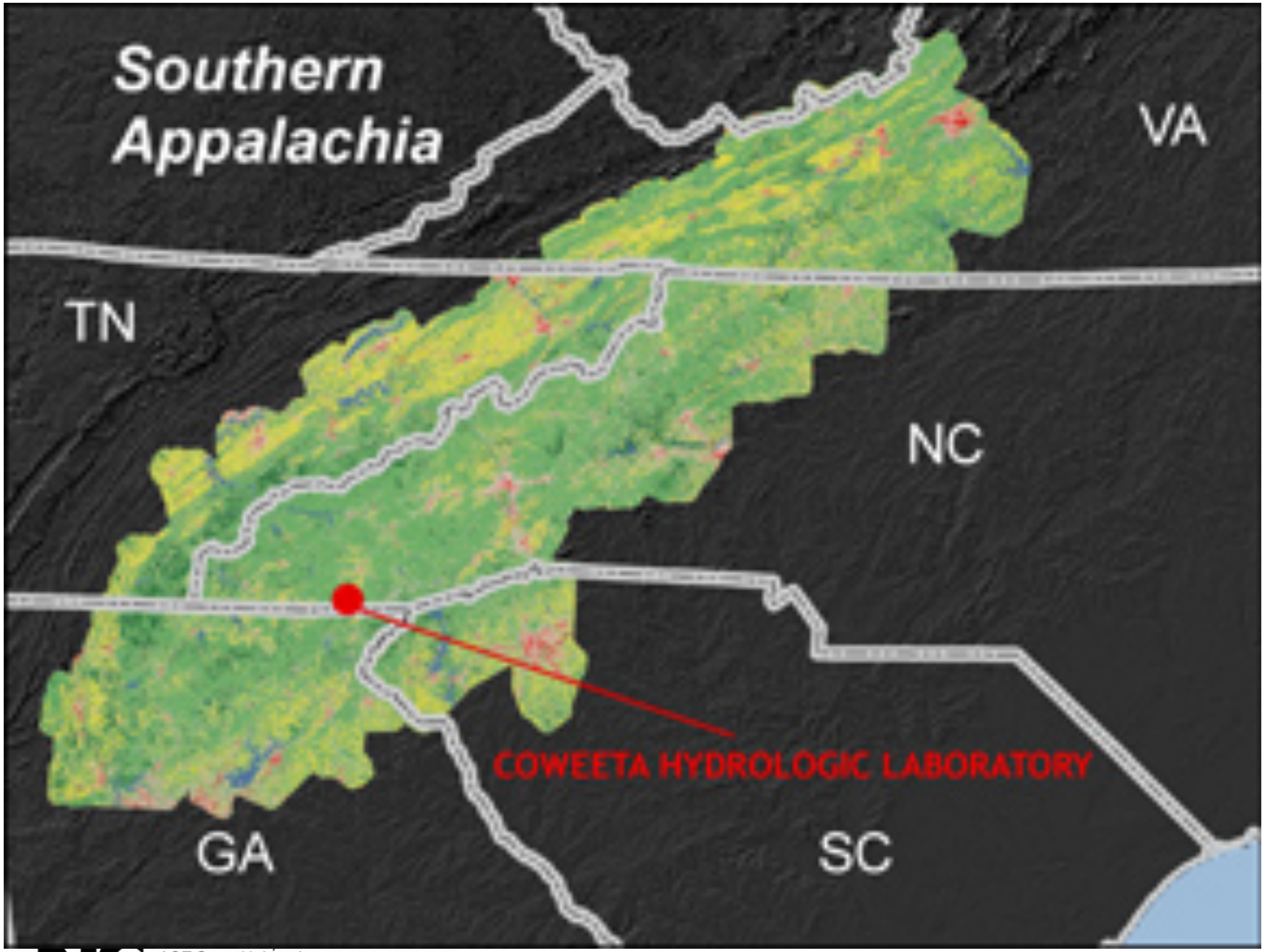
- Davis, 2005



1 inch of rainfall on 1 sqft = 0.63 gallons*

*Note – We get 45 – 50 Inches of rainfall / yr

Coweeta Hydrologic Laboratory



One of the oldest continuous environmental studies in North America, Coweeta is a centerpiece of a long-term cooperation between the University of Georgia and the USDA Forest Service.

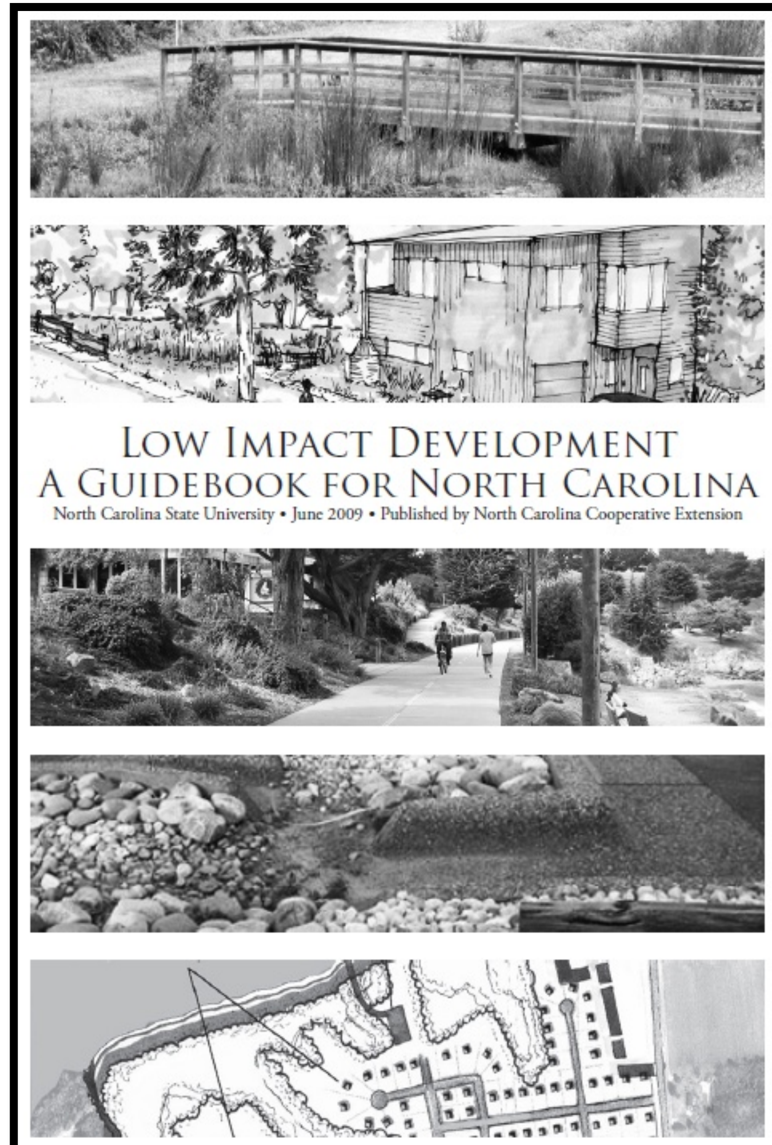
For Example:

BIORETENTION HYDROLOGY:

Outflow (Drainage)	Infiltration	ET
50%	40%	10%

COWEETA (PRE-DEV.) HYDROLOGY:

Runoff	5%
Evapotranspiration	50%
Infiltration	45%
Shallow Interflow	43%
Deep Seepage	2%



www.ces.ncsu.edu/depts/agecon/WECO/lid/documents/NC_LID_Guidebook.pdf

OK, so what works?

What can we do to make things better?

SCM Benefits

- Determine benefits of SCMs for:
  - TN and TP removal
  - Streambank protection
  - Stream temperature
  - Removal of bacteria
  - Annual runoff treated
- Rated either:
  - Excellent, Good, Fair, or Poor
  - Based on previous research

SCM Crediting Document

Sarah Waickowski, E.I.

SCM Workshops: The 3 S's

Trainings on Practices That Slow that Water Down, Spread it Out, Soak it In!

What Can be Done?

- SCM Inspection & Maintenance
- Downspout Disconnection
- Bioretention - Raingardens
- Water Harvesting
- Stream Repair
- MDC Criteria + Trainings

Stormwater BMP Inspection & Maintenance

NCSU BMP Inspection and Maintenance Certification

Overview/Main | Certification Description | Upcoming Classes and Registration Information

Typical Agenda | Sample Powerpoint | Meet the Instructors | List of Certified Professionals

Why is Stormwater BMP Inspection and Maintenance Needed?

Communities across the State of North Carolina must manage rainfall that runs off roads, streets and parking lots. This runoff is called stormwater. To manage stormwater, many treatment devices, called BMPs, have been built. These devices include: wet retention ponds, bioretention areas, stormwater wetlands, permeable pavement, and level spreaders. *BMPs must have annual, and sometimes more frequent, maintenance to perform as intended.* Maintenance includes hydrologic and water quality function, aesthetic and human health concerns. Some communities are considering hiring contractors to do this work, but it is a specialized area, making education and training important before you begin. As a result of his training you will:

- Understand stormwater, how it affects water quality, and regulations associated with it
- Understand stormwater management devices used in North Carolina and how they function
- Understand inspection and maintenance requirements of each stormwater practice

About the Training

This workshop offers 7 PDHs (professional development hours) for professional engineers and surveyors, as authorized by the NC Board of Examiners for Engineers and Surveyors. Other professionals may appeal to their respective boards to obtain professional education credits. All participants who pass an examination at the end of the course will be certified by NC State Cooperative Extension. Certificates of Completion will be U.S. mailed to all attendees upon the posting of Exam Results.

NCSU-BAE is also a registered provider of continuing eduction for AICP and ASLA.

Recertification

What We Saw: Cary Stormwater BMPs (2007)

- Approximately 425 BMPs in Cary
- According to one of Cary's inspectors: Timothy Grady, RLA:
- 95% of BMPs failed initial inspection as they require repairs
- Most repairs are maintenance related: erosion, trash removal, tree removal

Enter the…BMP Inspection & Maintenance Certification

Has it Worked? Cary BMPs… (now)

- ~ 95% pass, as owners better appreciate value of maintenance after investing in repairs…

It Works!

- Over 3500 Certified
- Teaching how and why stormwater BMPs work
- Specialized maintenance program for stormwater BMPs developed
- ‘Students’ have adopted practices and are incorporating concepts into their designs / maintenance schedules

Stormwater Engineering

Bioretention / Rain Garden Research: They Work!

Bill Hunt, Ph.D., PE
Biological & Agricultural Engineering
NC State University

www.bae.ncsu.edu/stormwater

Where can you find Bioretention/ Rain Gardens?

www.bae.ncsu.edu/stormwater

NC STATE UNIVERSITY Bio&Ag ENGINEERING

NC STATE UNIVERSITY

Huntersville, NC - Residential

www.bae.ncsu.edu/stormwater

NC STATE UNIVERSITY Bio&Ag ENGINEERING

Rain Gardens Integrated throughout - Seattle

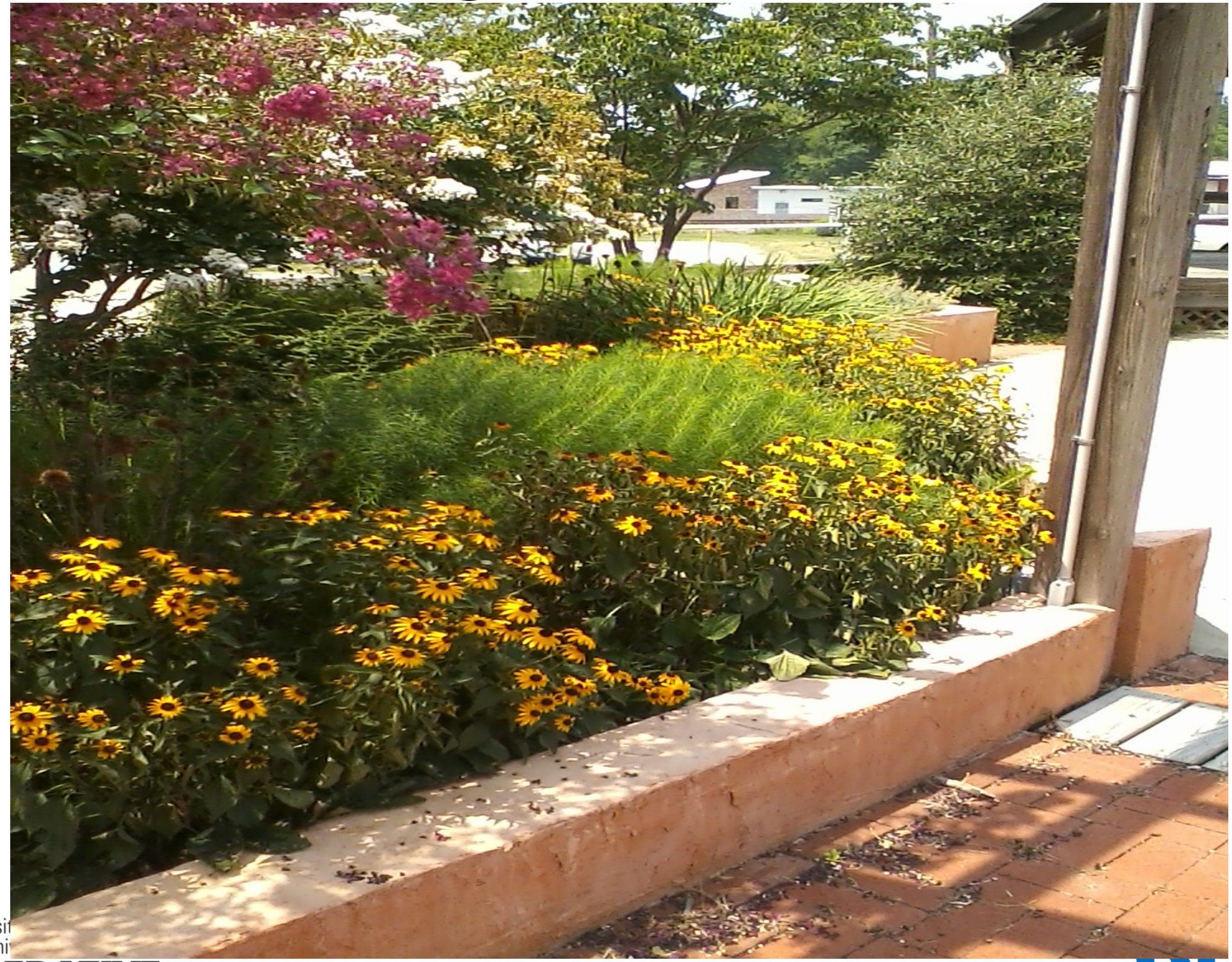
Filterra Bioretention System – “Ready Made” Rain Garden

NC DOT - Transportation

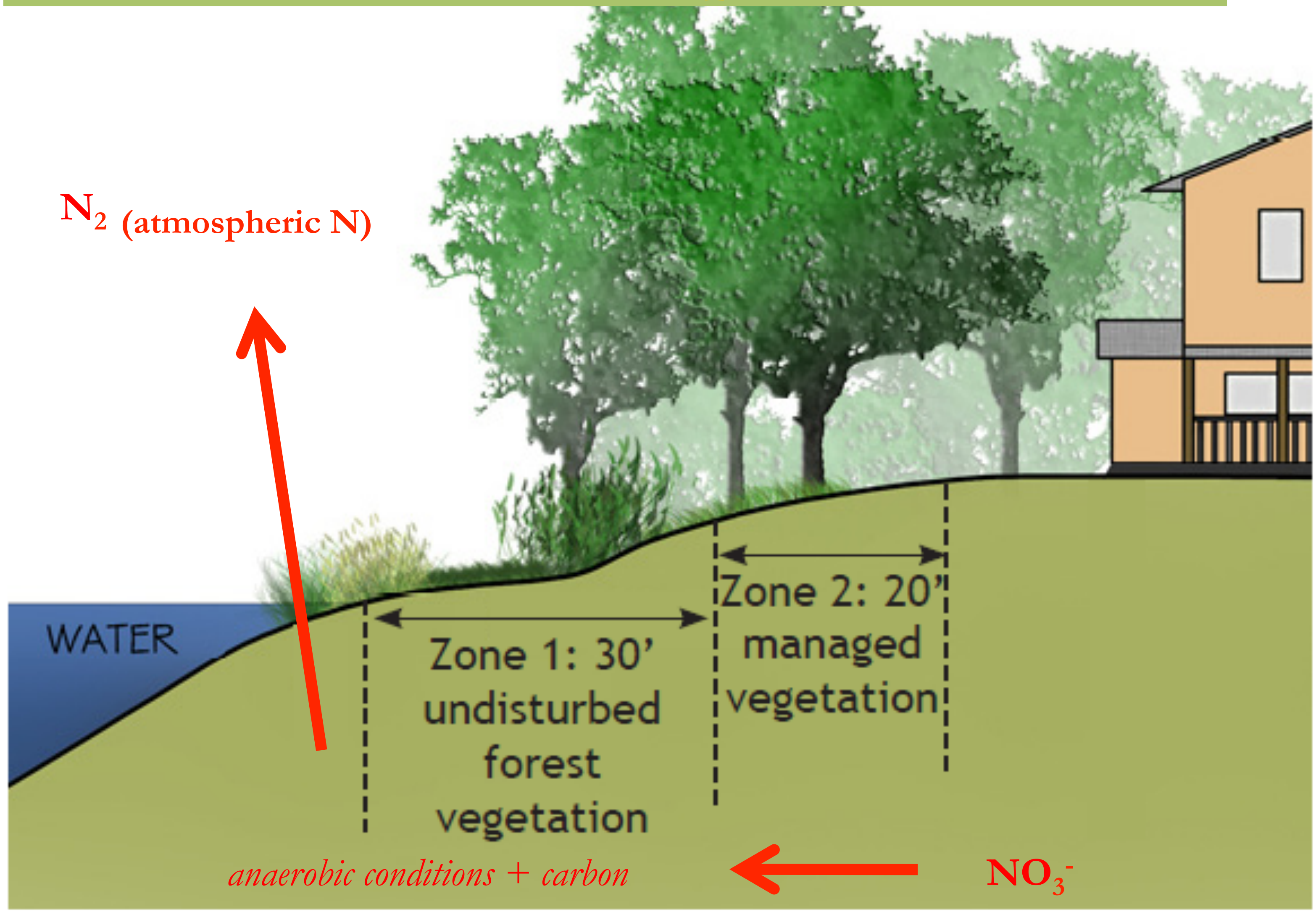

Birmingham, AL
Parking Lot Medians & Perimeters

Apex Town Hall

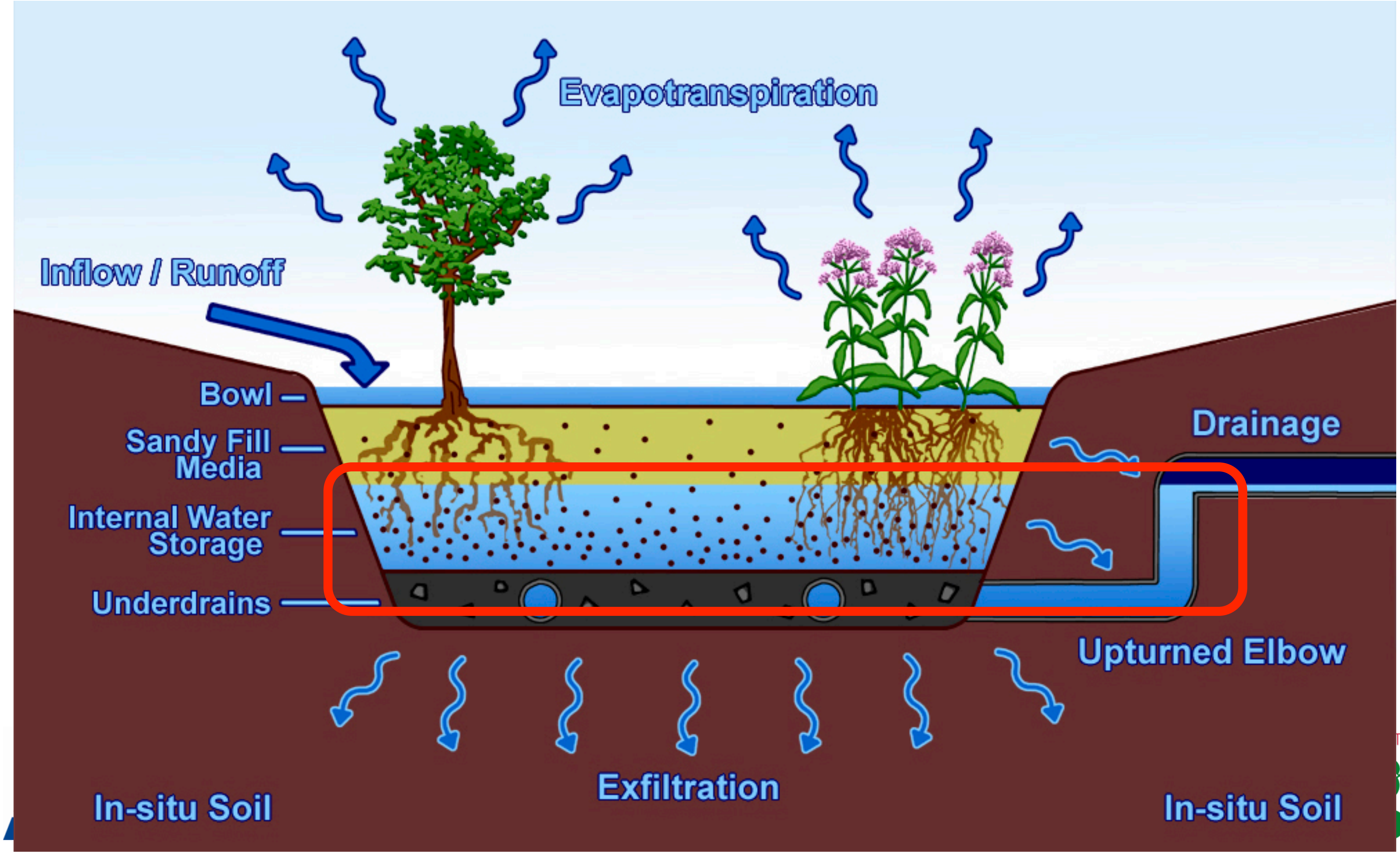
Siler City Town Center



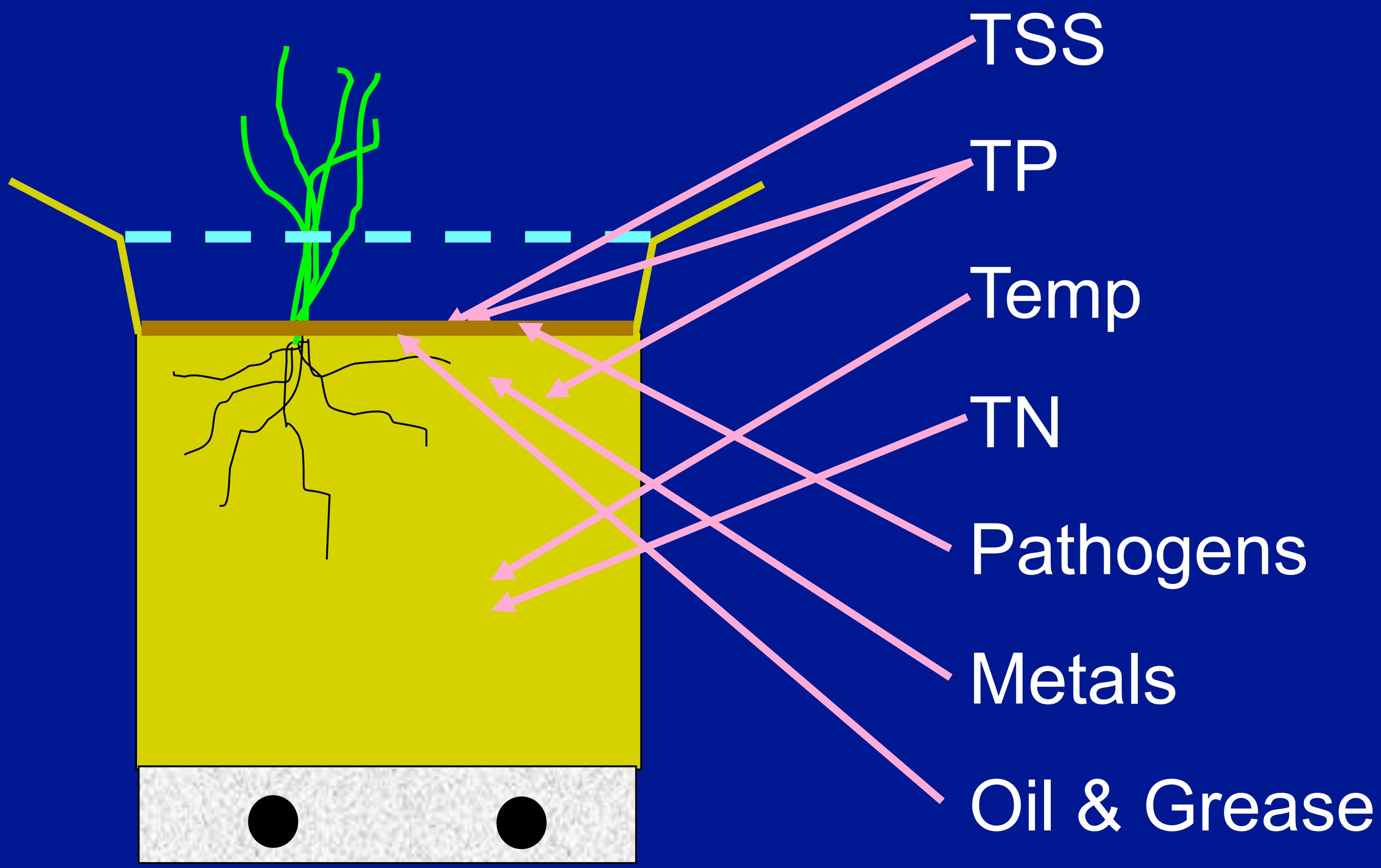
Denitrification in Riparian Buffers



Mimic Riparian Buffer Conditions



Where pollutants are removed



Take Home Point

- From a Long Term Hydrology Perspective, Bioretention Cells “Convert” Lots of Runoff to Infiltration & Evapotranspiration
- Often more than 50%
- Depends on Several Factors
  - Underlying Soil
  - Media Volume & Type
  - Relative Surface Area

Take Home Points: Bioretention…

- Improve Hydrology
  - Modest Peak Flow Mitigation
  - Long-term Hydrology Balance
  - Leads to Pollutant Load Reduction

Consider IWS!

- Reduce Pollutant Concentrations / Release Low Pollutant Concentrations
  - TSS
  - Metals & Hydrocarbons
  - TP & TN
  - Bacteria

But, must be careful with Media Selection.

Bioretention / Raingarden Workshops

www.bae.ncsu.edu/
stormwater

Trainings for Professionals: Rain Garden Certification

- Site Selection
- Design
- Proper Plants
- Sizing & Installation Options
- Maintenance Considerations
- > 400 Professionals Trained & Certified


CAUTION!
Rain Garden
Under
Construction
YOUTH PARTNER PROJECT

‘Downspout Disconnection’: Slow it down, spread it out, soak it in.


Is this a good thing?

Can be simple as protecting & maintaining a natural area during construction to receive runoff

Study of Four Homes in Durham, NC (8 Downspouts Total)
Jan 22 – Oct 8, 2013 Data

Site	*Study Design Factor*	*Infiltration Rate (in/h)*	*Slope (%)*	*Length (ft)*	*Loading Ratio (n:1)*	*Bulk Density (g/cm3)*	*Volume Reduction (%)*
1A	Length	.7	6.6	15	9.6	1.39	59
1B		.7	5.2	30	1.4	1.39	72
2A	Length	.5	6	5	15.0	1.67	76
2B		.4	5.5	10	7.5	1.66	76
3A	Loading Ratio	13.9	6.6	12	3.0	1.23	92
3B		13.9	6.6	12	6.3	1.23	73
4A	Slope	.3	27	12	4.6	1.53	62
4B		2.7	4.8	12	5.0	1.34	99

NC STATE UNIVERSITY
A&T STATE UNIVERSITY
COOPERATIVE EXTENSION
Helping People Put Knowledge to Work

Stabilizing and Protecting Streambanks:

- Backyard Stream Repair Workshops -

Backyard Stream Repair Workshops

This workshop is sponsored by NC State University, and NC Cooperative Extension.

NC STATE UNIVERSITY

NC State University A&T State University COOPERATIVE EXTENSION Empowering People · Providing Solutions

About the Workshop

Learn how to stabilize your backyard stream, improve the natural environment, and enhance your property. Learn about causes of streambank erosion and how to use native plants to create a healthy streamside environment. Participate "hands-on" in enhancing an eroding streambank using grading, matting, and various natural plants at a local stream. Attendees will have the opportunity to watch, ask questions, and even plant trees and shrubs to stabilize and beautify a streambank. Scroll down to the bottom of this page for a list of **resources**.

Stream Repair Workshops


6 Weeks After
Installation

Raleigh

Boone

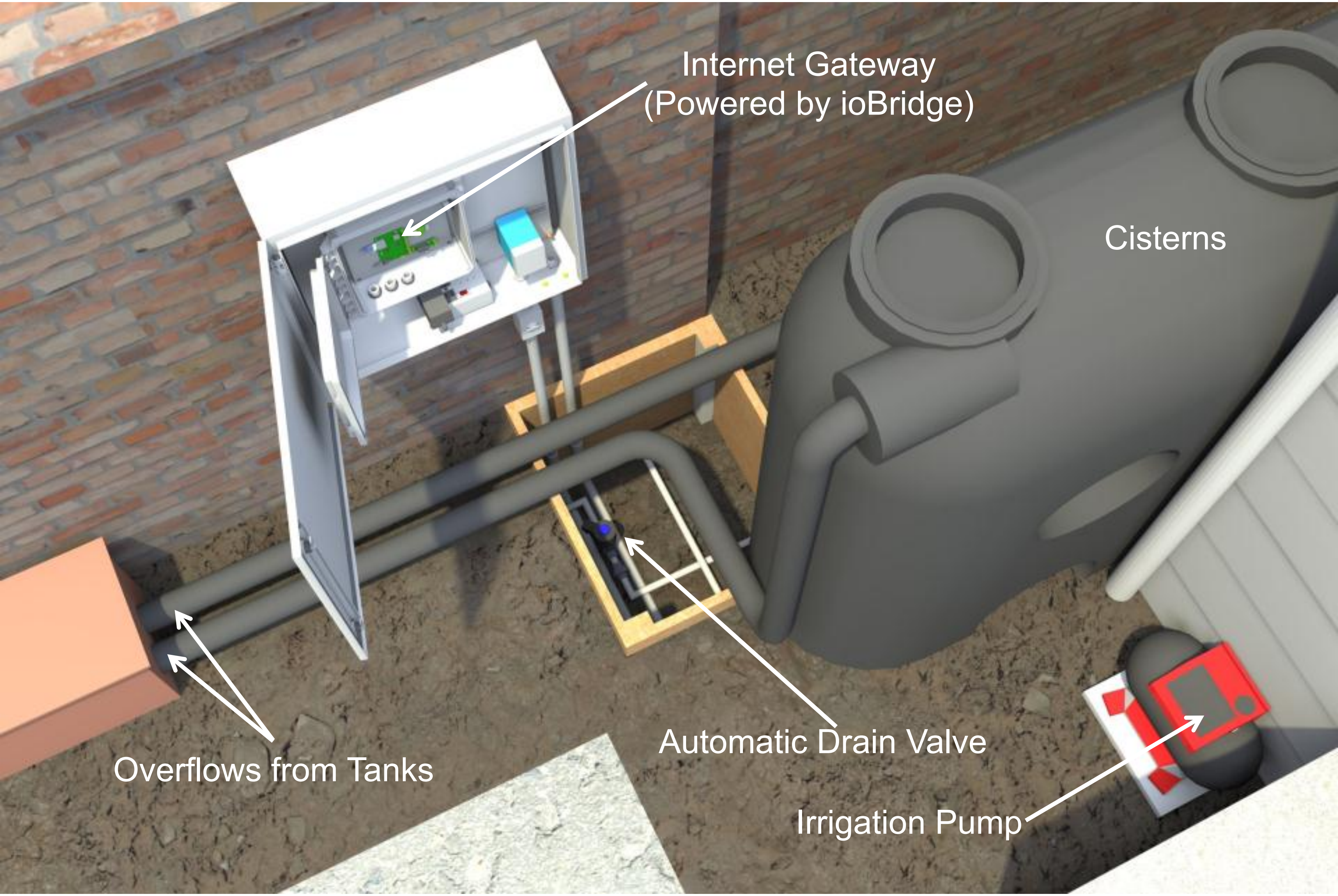
Backyard Stream Repair

Innovative Rainwater Harvesting Design & Construction:



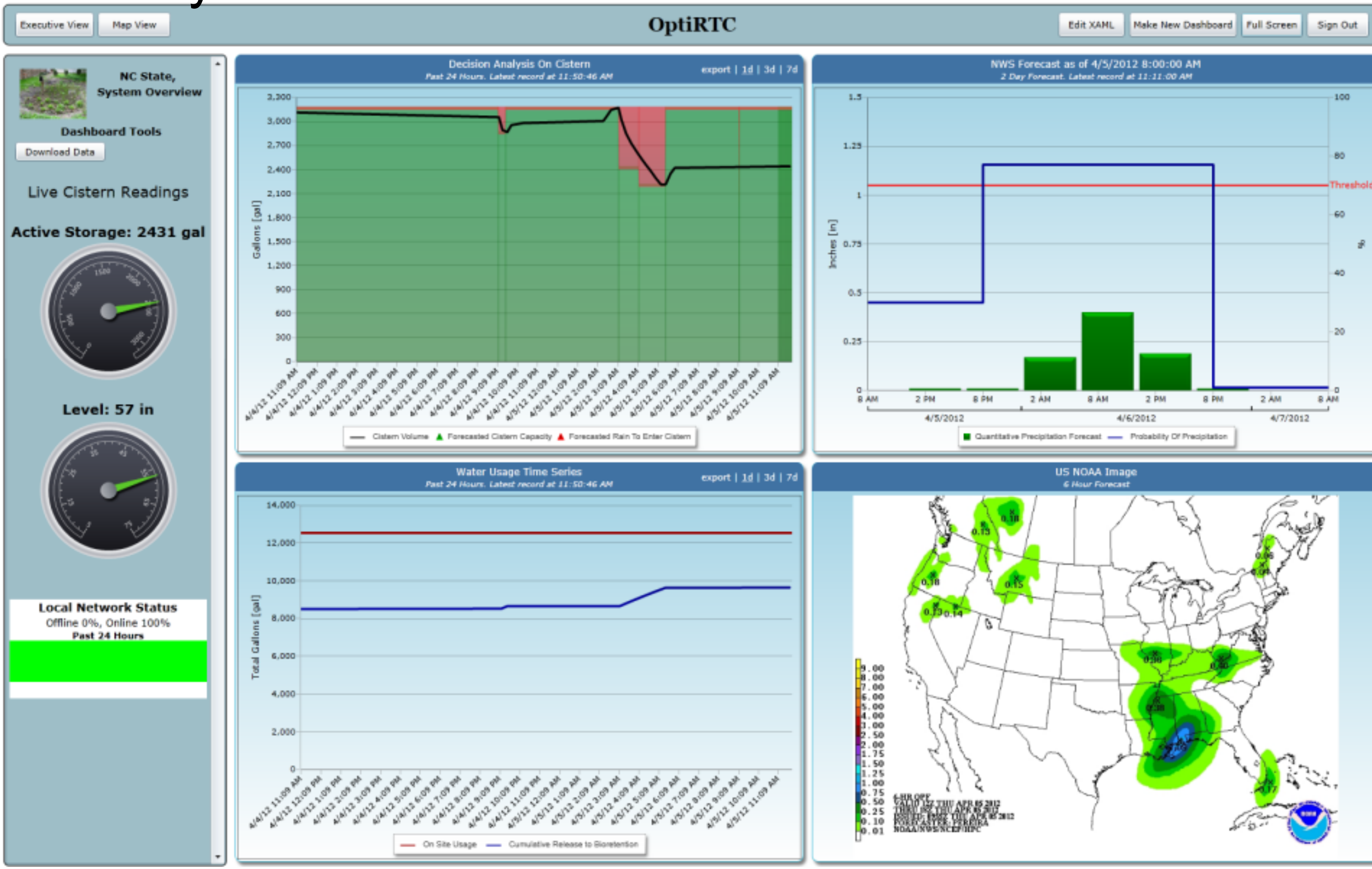


HYUNDAI


Internet Gateway
(Powered by ioBridge)
Cisterns
Automatic Drain Valve
Overflows from Tanks
Irrigation Pump

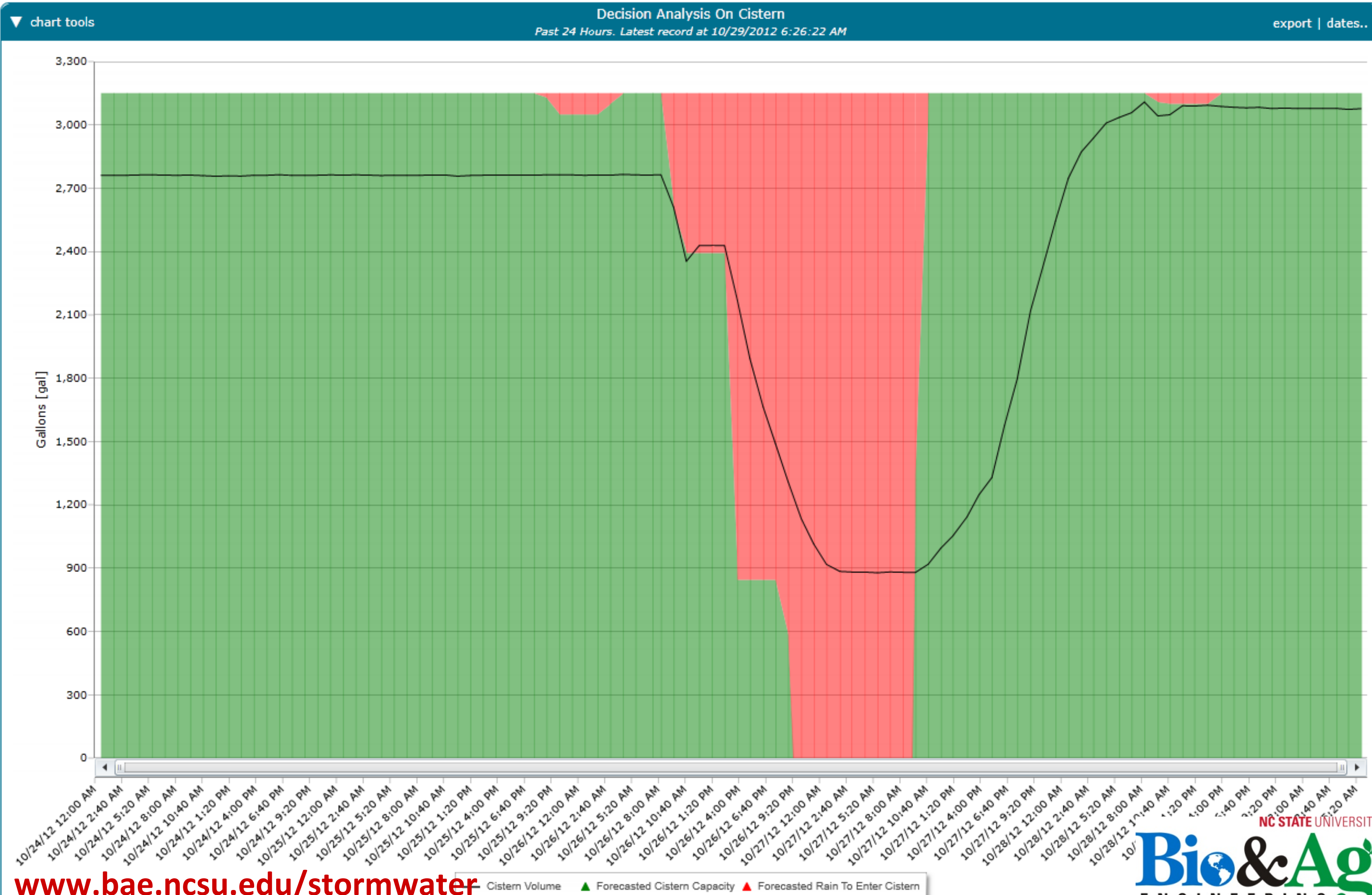

Discharge Location

Tryon Palace – Dashboard
System Behavior Week of 4/5/2012 11:52 AM



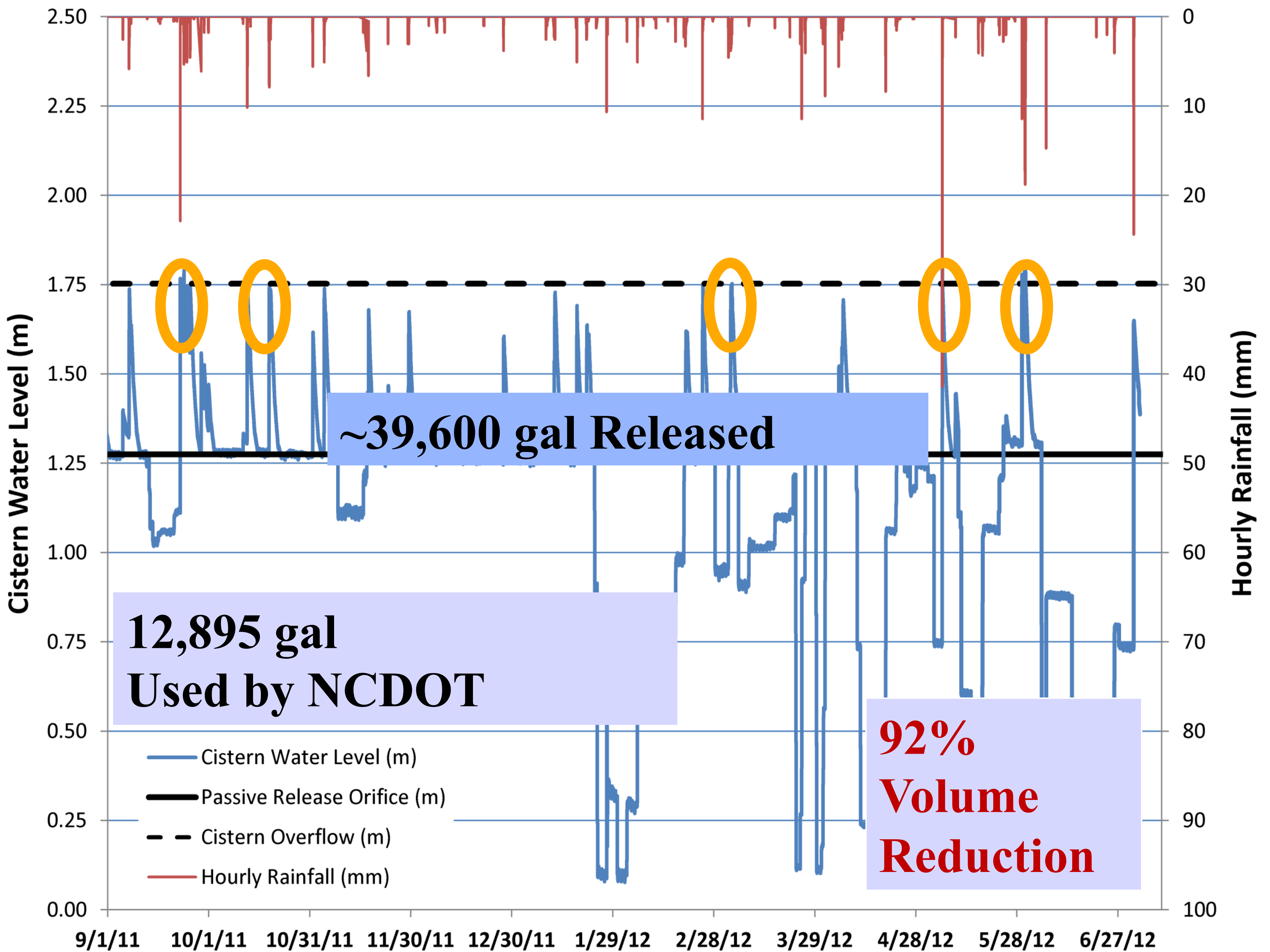
Geosyntec

Hurricane Sandy (10/29/12)



www.bae.ncsu.edu/stormwater

NC STATE UNIVERSITY Bio&Ag ENGINEERING



~39,600 gal Released
12,895 gal
Used by NCDOT
92%
Volume
Reduction
Cistern Water Level (m)
Hourly Rainfall (mm)
Cistern Water Level (m)
Passive Release Orifice (m)
Cistern Overflow (m)
Hourly Rainfall (mm)
2.50
2.25
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
0
10
20
30
40
50
60
70
80
90
100
9/1/11
10/1/11
10/31/11
11/30/11
12/30/11
1/29/12
2/28/12
3/29/12
4/28/12
5/28/12
6/27/12

Temperature/ Thermal Load Mitigation Provided by Stormwater BMPs

Stormwater Engineering

Biological & Agricultural Engineering

NC STATE UNIVERSITY

William F. Hunt, Ph.D., PE

Biological & Agricultural Engineering

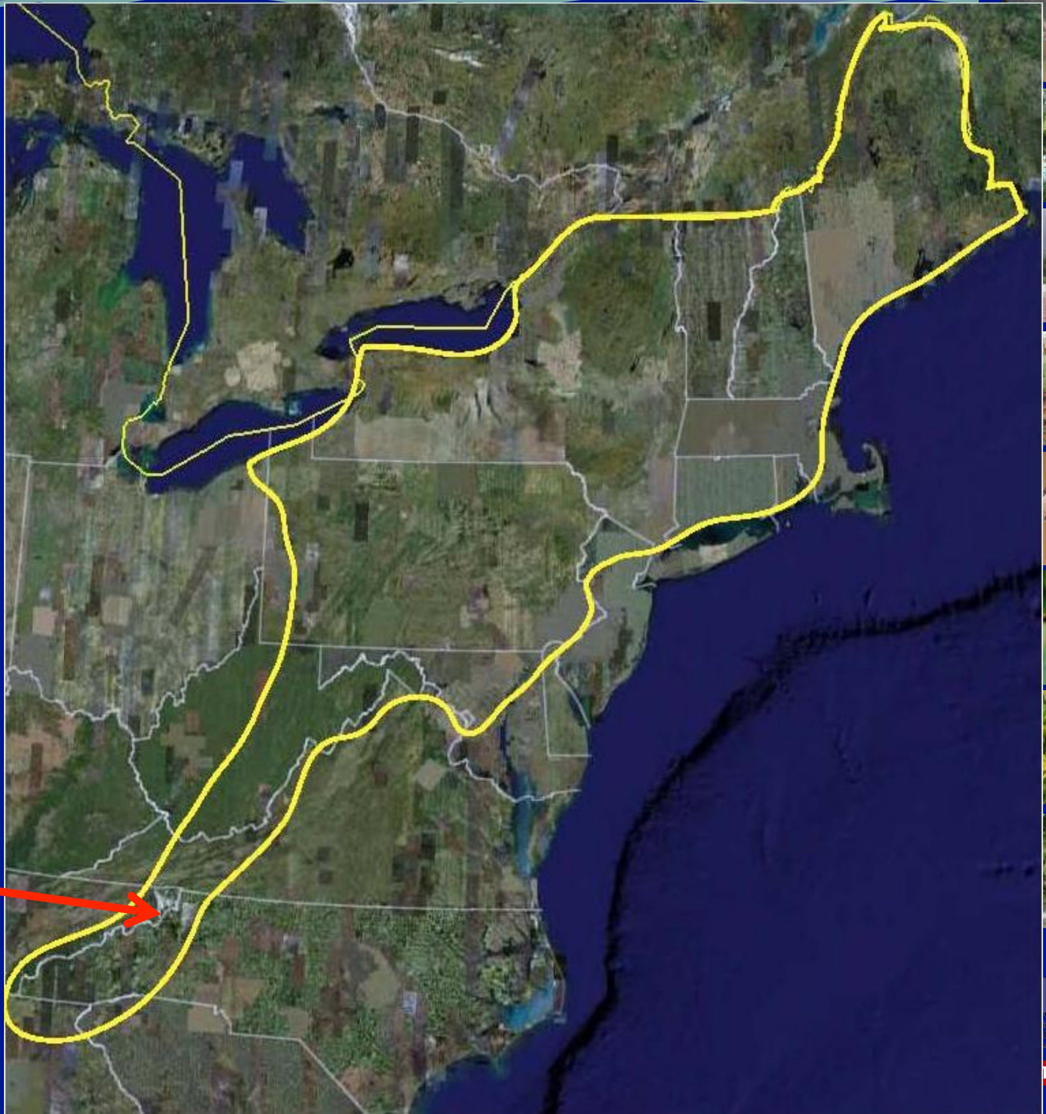
NC State University

www.bae.ncsu.edu/stormwater

NC Lies along the Southern Extent of Native Trout Ranges

Thanks to our Mountains

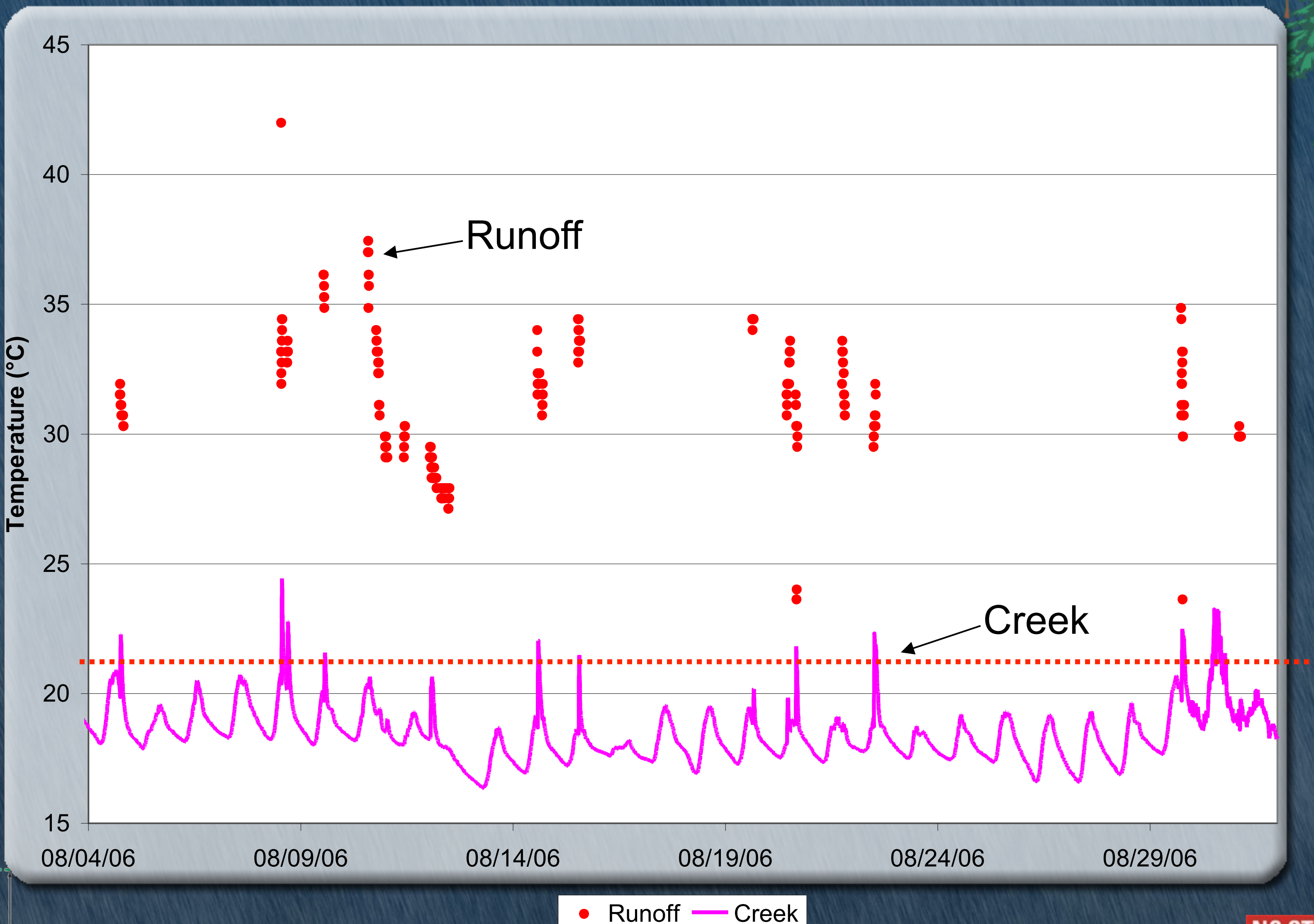
Extent of Brook Trout Range



Trout in North Carolina

- NC contains roughly 4,000 miles of streams capable of supporting trout
- Roughly 1.3 million people fish in NC, spending over $1 billion
- Nationwide, anglers spend a combined 83 million days fishing for trout
- Most NC trout prefer water temperatures between 40-70°F

Monitoring Results



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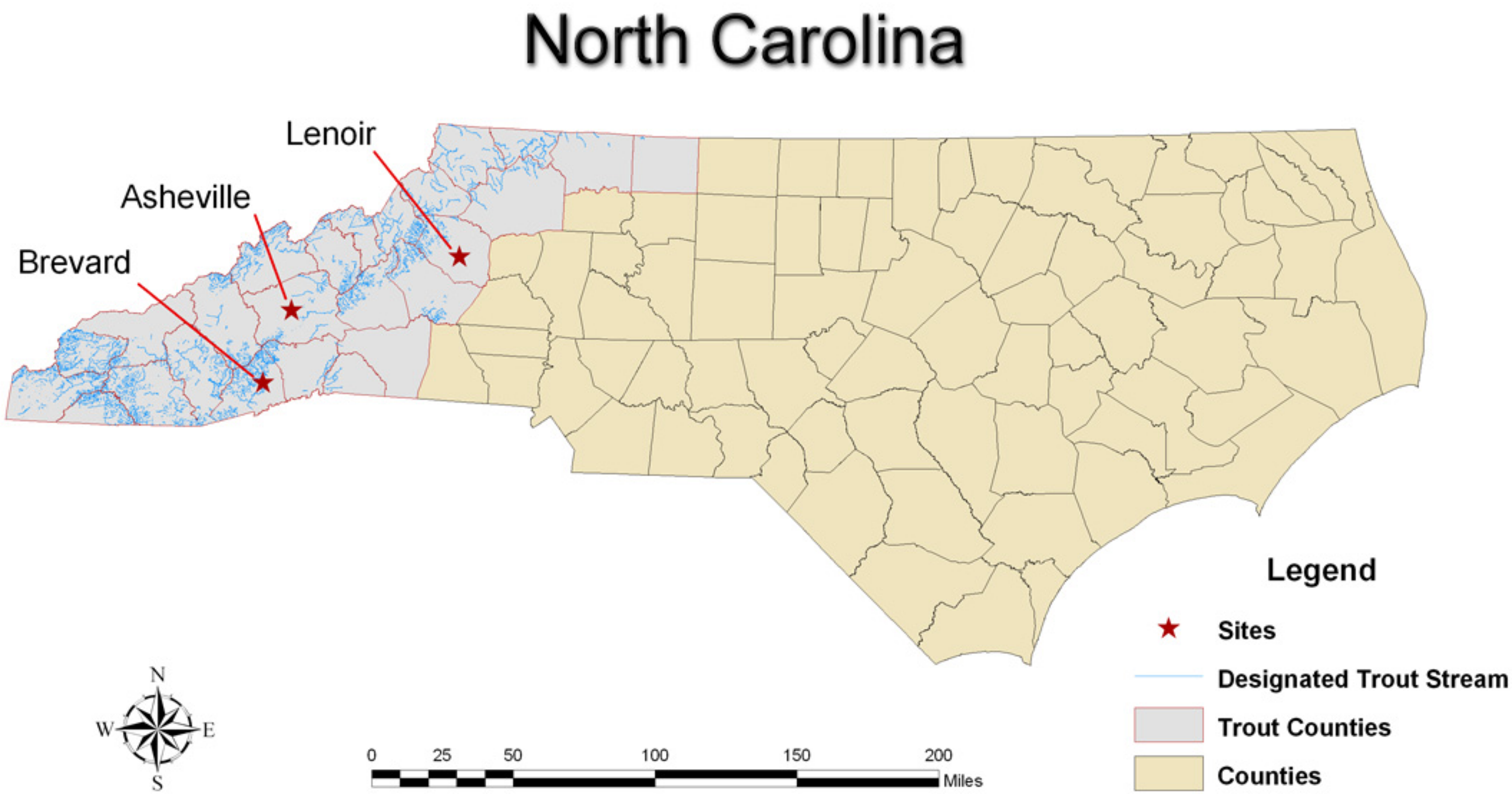
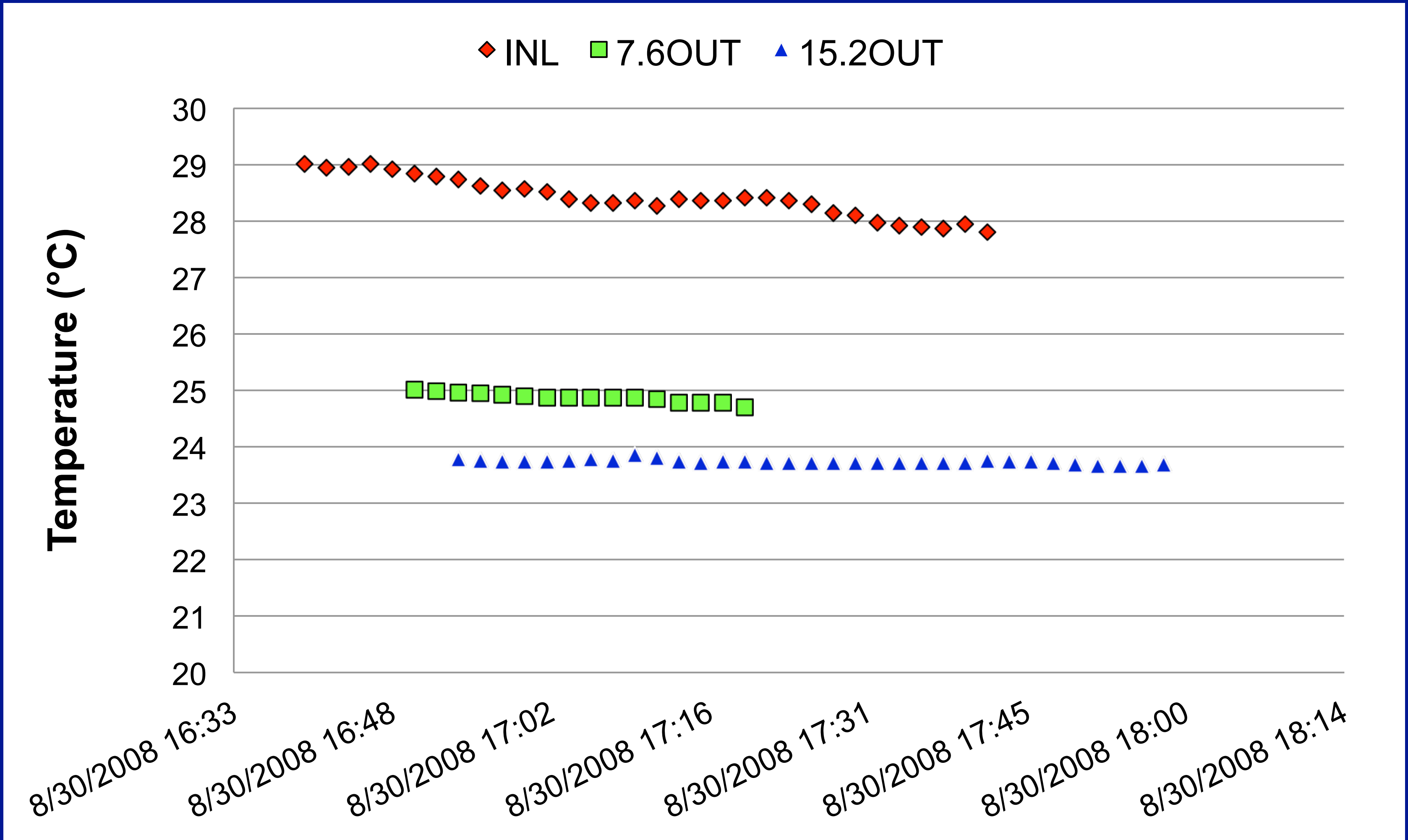
Site Locations



Brevard Bioretention 1

NC STATE UNIVERSITY

Storm Event Temperature Profile










NC STATE UNIVERSITY

Monitoring Summary

- BMPs can (will) contribute to thermal pollution
- Modifications to wetland and wet pond can reduce thermal impact while maintaining other water quality benefits
- Bioretention & LS-VFS able to reduce runoff temperature and volume
- Infiltration throughout the watershed may be best management strategy

Biological & Agricultural Engineering

NC STATE UNIVERSITY

SCM Benefits

- Determine benefits of SCMs for:
  - TN and TP removal
  - Streambank protection
  - Stream temperature
  - Removal of bacteria
  - Annual runoff treated
- Rated either:
  - Excellent, Good, Fair, or Poor
  - Based on previous research

NC STATE UNIVERSITY

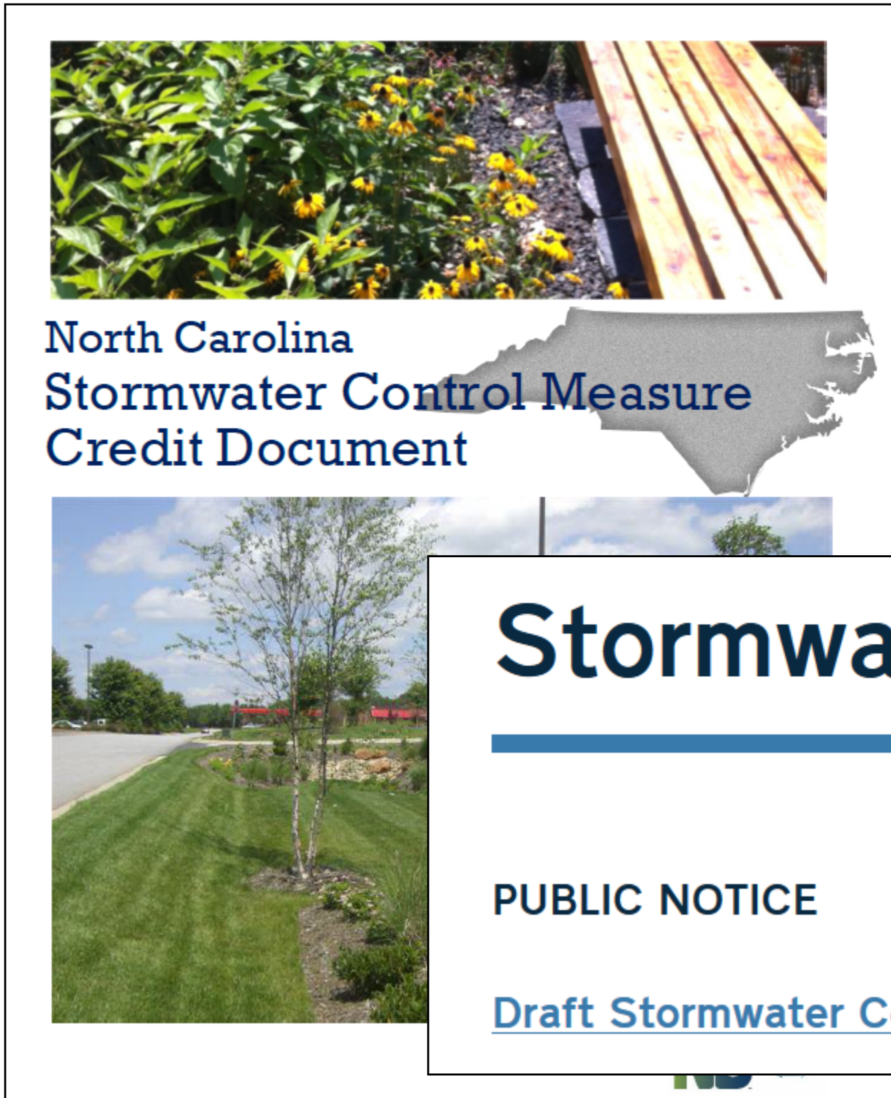
SCM Crediting Document

Sarah Waickowski, E.I.

https://stormwater.bae.ncsu.edu/

Bio&Ag ENGINEERING

SCM Crediting Document



- Can find document at: https://deq.nc.gov/sw-bmp-manual

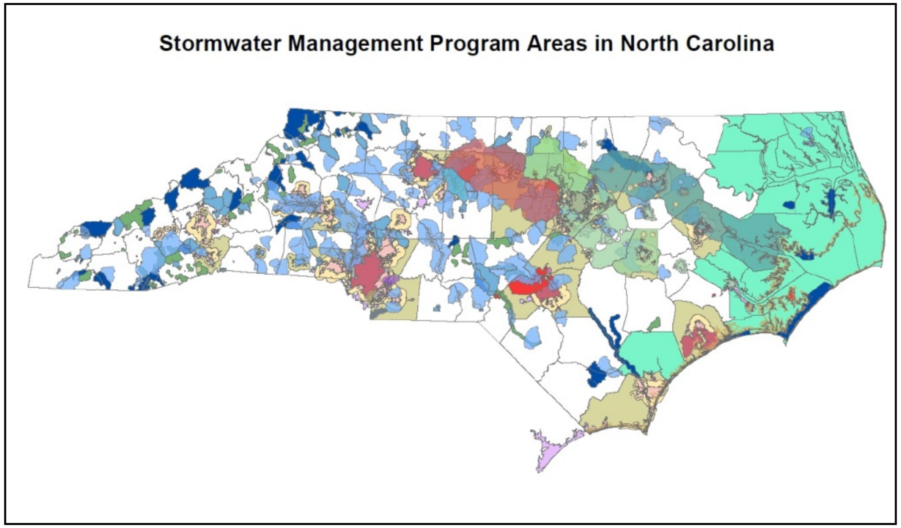
Stormwater Design Manual

PUBLIC NOTICE

Draft Stormwater Control Measure Credit Document

Purpose of Document

- Improve clarity and consistency of SCM crediting
  - Allow for better comparison between SCMs
- Facilitate credit updates using available research
- Meet goals of various state-wide stormwater programs



Purpose of Document

- Stakeholder meetings with designers, municipal stormwater officials, universities
  - NCDEQ and NCSU drafted document with stakeholder guidance

SCM	Percent Annual Runoff Treated if 100% Sized
Bioretention per MDC	94
Bioretention per MDC but without IWS	94
Bioretention with design variants per Hyper Tool	Tool Output
Infiltration per MDC	84
Permeable pavement (infiltration) per MDC	84
Permeable pavement (detention, unlined) per MDC	84
Permeable pavement (detention, lined) per MDC	84
Permeable pavement with design variants per Hyper Tool	Tool Output

SCM	Percent Annual Runoff Treated if 100% Sized
Wet pond per MDC	84
Wet pond per MDC with ≥ 5% covered by FWI	84
Stormwater wetland per MDC	84
Sand filter (open) per MDC	90
Sand filter (closed) per MDC	90
Rainwater harvesting per MDC	85
Green roof per MDC	100
DIS per MDC	90

SCM	Percent Annual Runoff Treated if 100% Sized
LS-FS per MDC	90
LS-FS with Virophos sand added to filter strip	90
Pollutant removal swale with dry conditions	90
Pollutant removal swale with wet conditions	90
Dry pond per MDC	84
StormFilter per MDC with PhosphoSorb media™	95

SCM	Percent Annual Runoff Treated if 100% Sized
LS-FS per MDC	90
LS-FS with Virophos sand added to filter strip	90
Pollutant removal swale with dry conditions	90
Pollutant removal swale with wet conditions	90
Dry pond per MDC	84
StormFilter per MDC with PhosphoSorb media™	95

SCM	$EMC_{Effluent}$ (mg/L)	
	TN	TP
Bioretention per MDC	0.58	0.12
Bioretention per MDC but without IWS	1.20	0.12
Bioretention with design variants per Hyper Tool	0.58/1.20	0.12
Infiltration per MDC	0	0
Permeable pavement (infiltration) per MDC	0	0
Permeable pavement (detention, unlined) per MDC	1.08	0.05
Permeable pavement (detention, lined) per MDC	1.08	0.05
Permeable pavement with design variants per the Hyper Tool	1.08	0.05

SCM	$EMC_{Effluent}$ (mg/L)	
	TN	TP
Wet pond per MDC	1.22	0.15
Wet pond per MDC with ≥ 5% covered by FWI	0.85	0.09
Stormwater wetland per MDC	1.12	0.18
Sand filter (open) per MDC	1.33	0.12
Sand filter (closed) per MDC	1.33	0.12
Rainwater harvesting per MDC	Custom based on water usage	
Green roof per MDC	2.44	0.76
DIS per MDC	2.44	0.76

SCM	$EMC_{Effluent}$ (mg/L)	
	TN	TP
LS-FS per MDC	1.04	0.19
LS-FS with Virophos sand added to the filter strip	0.87	0.10
Pollutant removal swale with dry conditions	1.10	0.14
Pollutant removal swale with wet conditions	0.82	0.11
Dry pond per MDC	1.65	0.66
StormFilter per MDC with PhosphoSorb media™	0.48	0.03

Stormwater Finance: Trends and Emerging Issues

WNC Stormwater Summit

February 22, 2017

Asheville, NC

Carol Rosenfeld

Environmental Finance Center at The University of North Carolina, Chapel Hill

UNC ENVIRONMENTAL FINANCE CENTER

www.efc.unc.edu

UNC ENVIRONMENTAL FINANCE CENTER

Dedicated to enhancing the ability of governments and other organizations to provide environmental programs and services in fair, effective, and financially sustainable ways through:

- Applied Research
- Teaching and Outreach
- Program Design and Evaluation

UNC SCHOOL *of* GOVERNMENT

How you pay for it matters

INTRODUCTION

Capital Wanted

U.S. communities are facing a total of $106 billion in needed stormwater management and combined sewer correction upgrades or improvements.

American Rivers et al. 2012. Banking on Green: A Look at How Green Infrastructure Can Save Municipalities Money and Provide Economic Benefits Community-Wide.

Potential capital (revenue) sources

- **Cash / pay as you go** – rate or tax payers
- **Property tax** – all tax paying property owners and/or their tenants (includes district taxes)
- **Sales tax** – shoppers
- **Utility fees** – all eligible property owners and/or their tenants
- **Plan review/inspection fees** – property developers
- **Property tax assessments** – property owners
- **Impact fees / nutrient offset fees** – property developers
- **Mitigation funds** – off-site property developers
- **Grants** – federal or state tax payers

Potential capital sources, cont.

- **Bond market** –

3.5 to 5.5% funds

15 to 25 years

- **Bank loans** –

3.5 to 7% funds

10 to 20 years

- **State revolving loan funds** – Small pots of grants and loans

0 to 2%

20 years

Evolution of revenue sources

1. General tax revenue, cover what can for management on public land
2. Regulations -> private property projects
3. Offset fee programs / impact fees
4. **Establish enterprises and stormwater fees to generate revenue**
5. Rebates / cost-share programs
6. Fee credits for on-site improvements
7. Loans
8. Tax incentives
9. Trading
10. Property assessment backed (e.g. PACE-like)

NC STORMWATER FEES

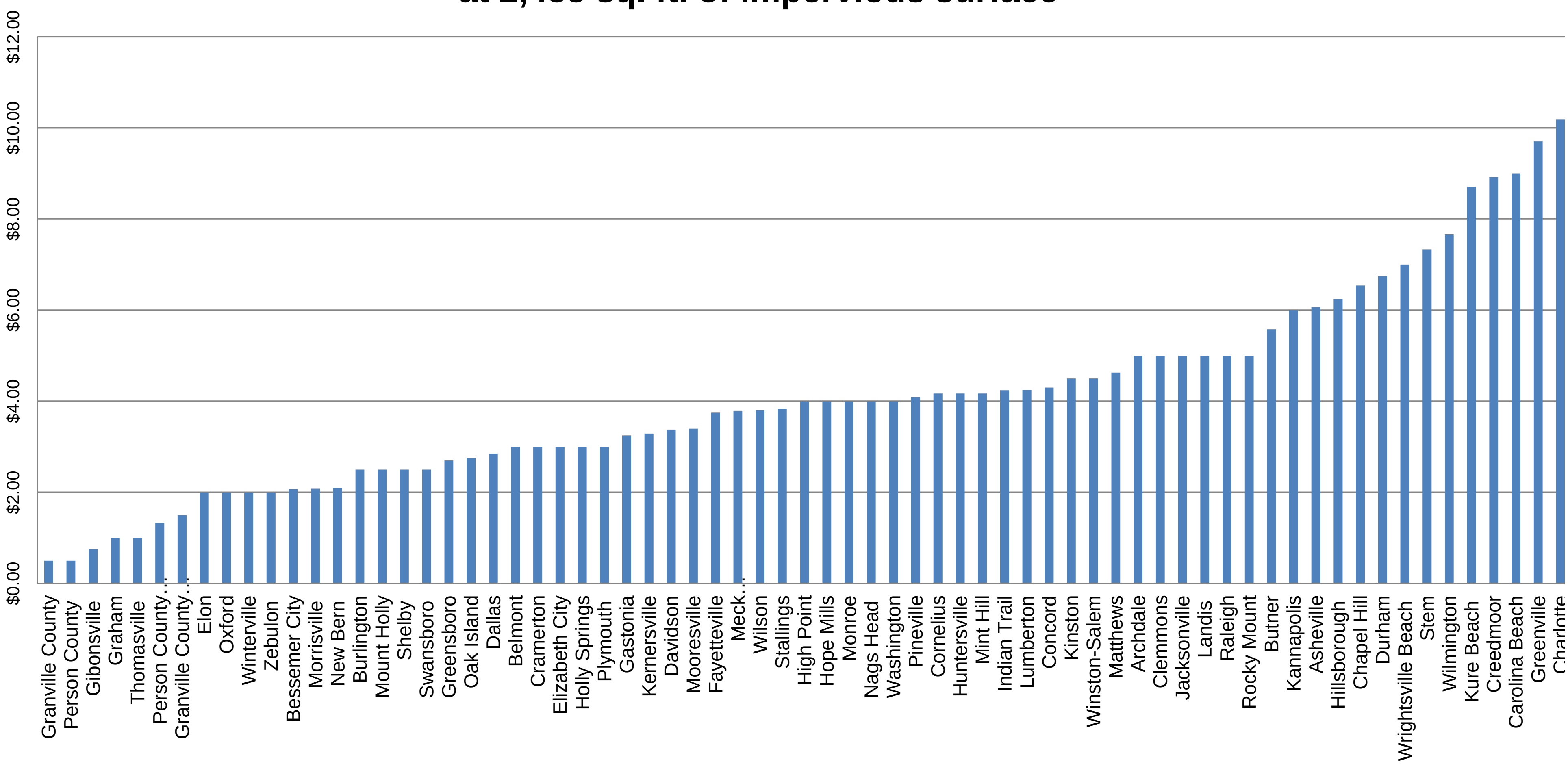
NC stormwater fees

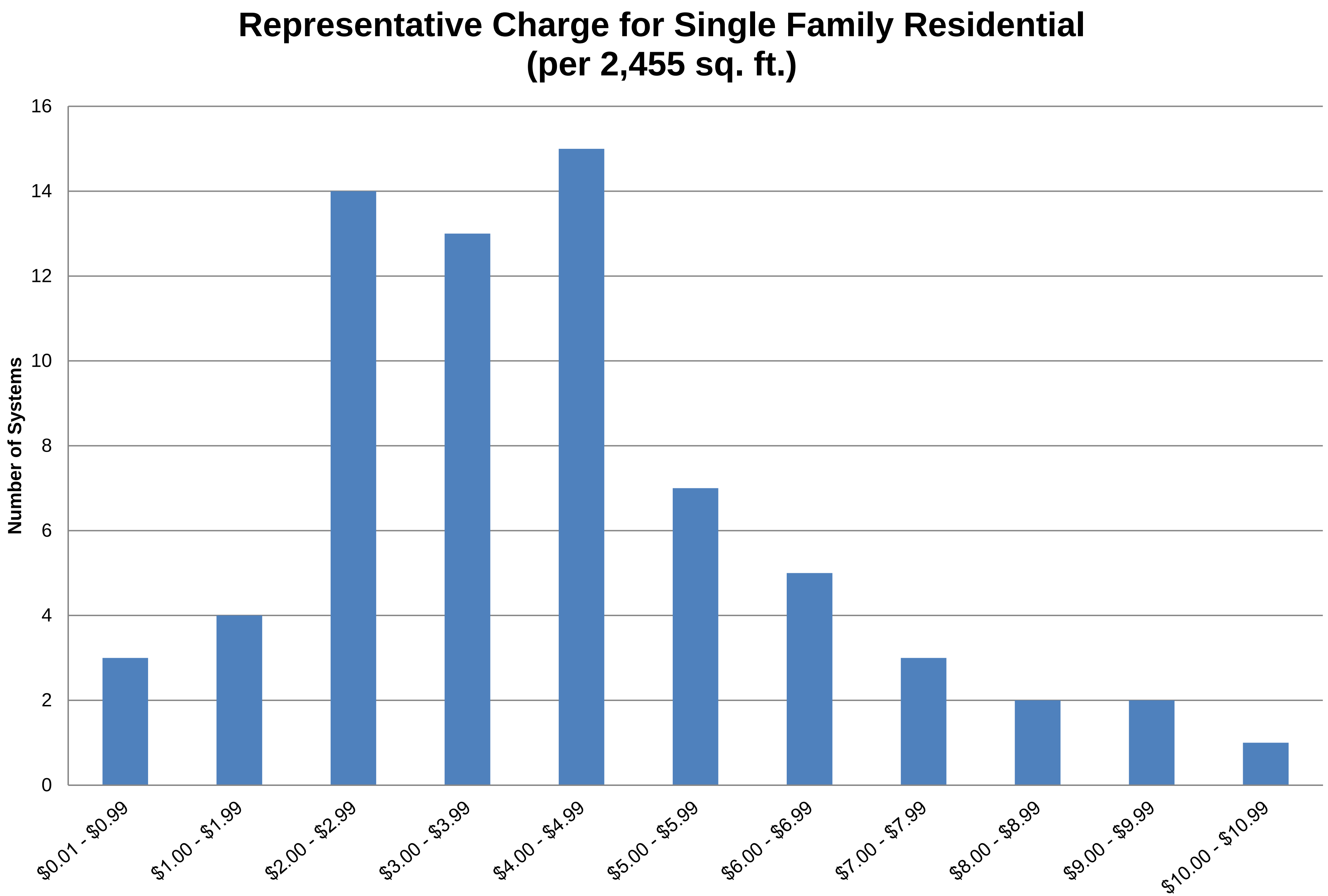
- Nine out of ten largest cities in North Carolina have utilities (34 of 50 largest cities)
- Total revenue reported for 63 municipal* utilities in 2015 was $182,313,937
- Total revenue reported for 56 municipal utilities in 2010 was $138,949,938

* Slight underestimate since reporting information not complete for several municipalities with storm water utilities

Source: Analysis prepared by the EFC using self reported information submitted to the Local Government Commission

Monthly Residential Stormwater Fees in North Carolina
at 2,455 sq. ft. of impervious surface

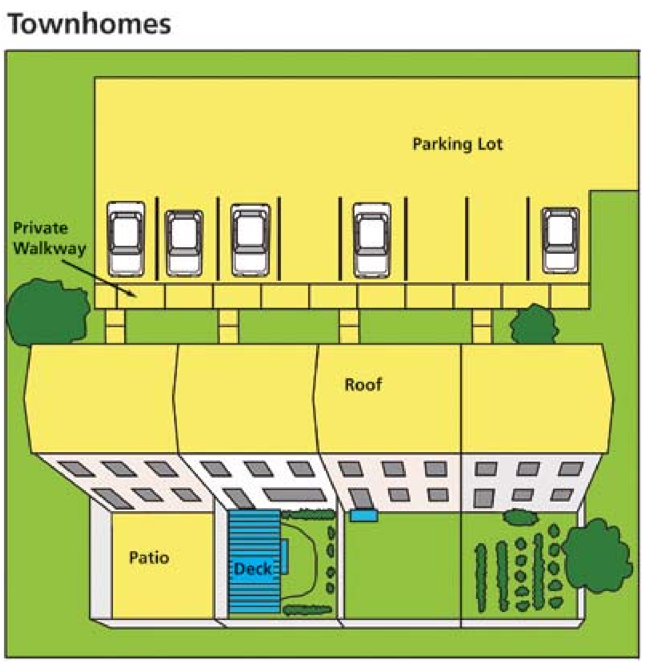


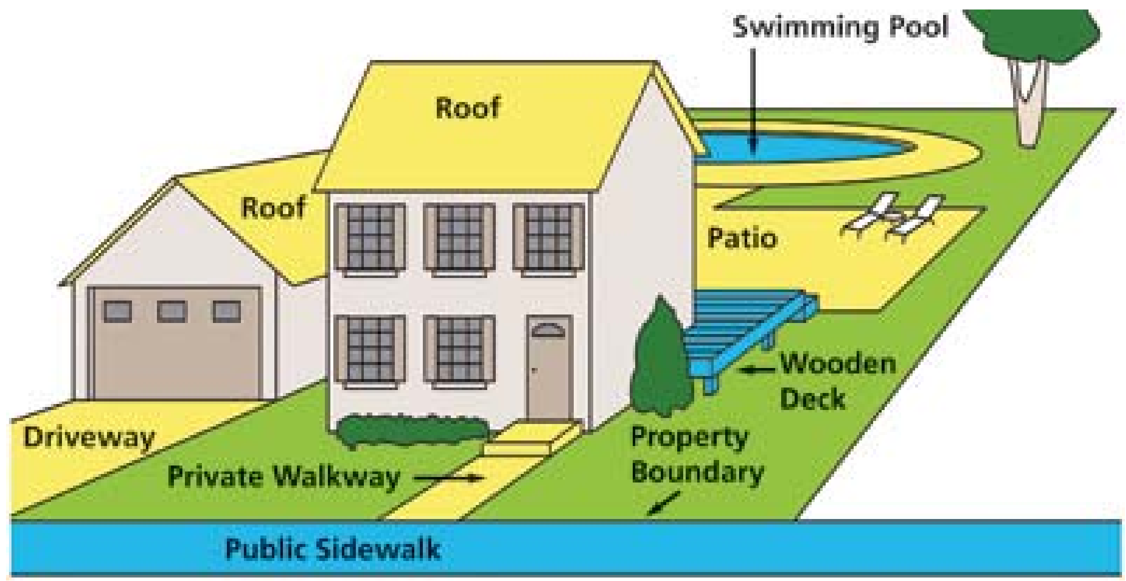


Representative Charge for Single Family Residential
(per 2,455 sq. ft.)
Number of Systems
0
2
4
6
8
10
12
14
16
$0.01 - $0.99
$1.00 - $1.99
$2.00 - $2.99
$3.00 - $3.99
$4.00 - $4.99
$5.00 - $5.99
$6.00 - $6.99
$7.00 - $7.99
$8.00 - $8.99
$9.00 - $9.99
$10.00 - $10.99

What’s “normal” for monthly stormwater fees?

- Median residential rate (at 2,455 sq ft) = $4.00
  - $1.63 per 1,000 sq ft of impervious surface





Stormwater fee revenue vs. other revenue sources for 63 municipalities reporting utility fees in 2015

- Total property tax: $1,730,008,002
- Total stormwater fees: $182,313,937
- Total solid waste fees: $146,039,610

  (Total reported for all municipalities = $224,792,896)
- Total water/wastewater fees: $1,380,988,150

  (Total reported for all municipalities = $2,019,495,974)

Source: Analysis prepared by the EFC using self reported information submitted to the Local Government Commission

RALEIGH'S QUALITY COST SHARE PROGRAM

Raleigh's stormwater quality cost share program

- Improve quality of stormwater runoff by sharing the cost of small scale distributed stormwater control projects with property owners
- City pays 90% of 'acceptable cost' in priority water quality target areas
- 75% in other areas

For permeable pavement:

Acceptable cost =

Total cost of implementing project

– Cost of installing conventional,

non-pervious pavement

(same dimensions, same location)

Source: City of Raleigh, North Carolina

https://www.raleighnc.gov/services/content/PWksStormwater/Articles/StormwaterQualityCostShareProgram.html

Eligible projects

Type of Stormwater Project (number of projects)	Project Benefits: Enhance landscapes	Lower water bills	Lower heating/ cooling costs	Replenish groundwater	Healthier Streams /lakes
Rainwater harvesting and beneficial water use (11)		✓			✓
Bioretention devices and rain gardens (3)	✓			✓	✓
Stormwater wetlands	✓			✓	✓
Green roofs (2)			✓		✓
Infiltration devices				✓	✓
Permeable pavers and permeable pavements (3)				✓	✓
Removing impervious surfaces ("depaving")	✓			✓	✓
Restoring stream buffers (1)	✓			✓	✓
Stream restoration and shoreline restoration (1)	✓				✓

These project types have been and are expected to remain the most popular.

Source: City of Raleigh, North Carolina
https://www.raleighnc.gov/services/content/PWksStormwater/Articles/StormwaterQualityCostShareProgram.html

Completed Projects

Green roof on park facility

(7,500 sq. ft.)

Residential rain garden

(175 sq. ft.)

Source: City of Raleigh, North Carolina
https://www.raleighnc.gov/services/content/PWksStormwater/Articles/CompletedQualityCostShareProjects.html

Continue the Discussion

http://www.efc.sog.unc.edu/programs/stormwater-wetlands-and-watersheds

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Efc.web.unc.edu

Follow us on Twitter: @EFCatUNC

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