

NC STATE UNIVERSITY

## Urban Stormwater Fill Media: Bioretention Cells and Green Roofs

Bill Hunt, PE, PhD and Bill Lord  
NC State University

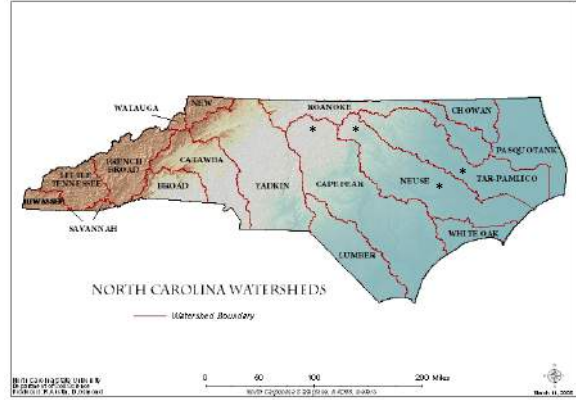
As presented by  
Deanna Osmond  
Department of Soil Science  
NC State University

[www.bae.ncsu.edu/stormwater](http://www.bae.ncsu.edu/stormwater)

Bio&Ag  
ENGINEERING

NC STATE UNIVERSITY

## Nutrient Impairments in North Carolina



The map displays the boundaries of various watersheds in North Carolina, including Watauga, New, Roanoke, Chowan, Pamlico, Tar-Pamlico, White Oak, Lumber, Cape Fear, Yadkin, Iredell, Catawba, French Broad, and Savannah. A legend indicates the watershed boundary. A scale bar shows 0, 50, 100, and 200 miles. The map is dated March 11, 2009.

[www.bae.ncsu.edu/stormwater](http://www.bae.ncsu.edu/stormwater)

Bio&Ag  
ENGINEERING

NC STATE UNIVERSITY

## The Neuse: Where It All Started



The map shows the Neuse and Tar-Pamlico River Basins in North Carolina. Key locations marked include Cary, Greenville, Goldsboro, Kinston, and New Bern. A scale bar indicates 0, 12,000, and 20 miles. The map is dated March 11, 2009.

[www.bae.ncsu.edu/stormwater](http://www.bae.ncsu.edu/stormwater)

Bio&Ag  
ENGINEERING

NC STATE UNIVERSITY

## Neuse Education Team



A group photograph of seven individuals standing outdoors in front of trees. The team consists of six men and one woman, all dressed in professional attire.

[www.bae.ncsu.edu/stormwater](http://www.bae.ncsu.edu/stormwater)

Bio&Ag  
ENGINEERING

NC STATE UNIVERSITY

### Urban Stormwater Best Management Practices: Water Quality Protection



[www.bae.ncsu.edu/stormwater](http://www.bae.ncsu.edu/stormwater)

Bio&Ag  
ENGINEERING

NC STATE UNIVERSITY

### Urban Stormwater Practice Construction: Media Requirements



[www.bae.ncsu.edu/stormwater](http://www.bae.ncsu.edu/stormwater)

Bio&Ag  
ENGINEERING

NC STATE UNIVERSITY

### Urban Stormwater Practice Construction: Bioretention Cells

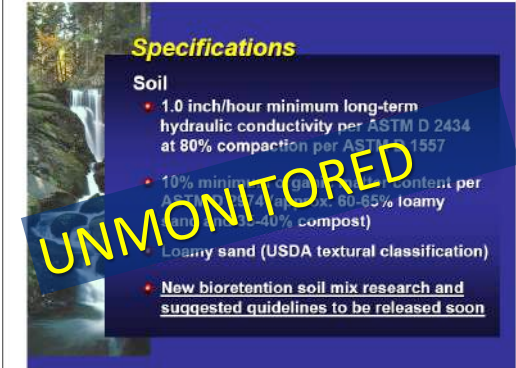


[www.bae.ncsu.edu/stormwater](http://www.bae.ncsu.edu/stormwater)

Bio&Ag  
ENGINEERING

NC STATE UNIVERSITY

### Example Soil Specifications from Another State



**Specifications**

**Soil**

- 1.0 inch/hour minimum long-term hydraulic conductivity per ASTM D 2434 at 80% compaction per ASTM 1557
- 10% minimum organic matter content per ASTM 3740 (max. 60-65% loamy sand and 35-40% compost)
- Loamy sand (USDA textural classification)
- New bioretention soil mix research and suggested guidelines to be released soon

**UNMONITORED**


[www.bae.ncsu.edu/stormwater](http://www.bae.ncsu.edu/stormwater)

Bio&Ag  
ENGINEERING

NC STATE UNIVERSITY

## Bioretention Media Selection

- Constituents
  - Sand, fines, organic matter/ compost added on volume basis
  - High fraction of organic matter in some mixes
- Infiltration Rate
  - Results in “named” soil texture (in this case, Sandy Loam)



www.bae.ncsu.edu/stormwater

**Bio&Ag**  
ENGINEERING

NC STATE UNIVERSITY

## Bioretention Research: Greensboro Battleground Ave



www.bae.ncsu.edu/stormwater

**Bio&Ag**  
ENGINEERING

NC STATE UNIVERSITY

## Bioretention Research Chapel Hill University Mall



www.bae.ncsu.edu/stormwater

**Bio&Ag**  
ENGINEERING

NC STATE UNIVERSITY

## Initial NCSU Bioretention Cell Research

	Greensboro	Chapel Hill
TP	<b>+ 240%</b>	- 65%

	Greensboro	Chapel Hill
Soil Test P	85-130	4-12

(Hunt 2003)

www.bae.ncsu.edu/stormwater

**Bio&Ag**  
ENGINEERING

## Bioretention Cell Functionality: Blame it on the Media

- Soil test P is a measure of how much phosphorus is already in the soil and its ability to supply plant needs.
- High soil test P soils release more phosphorus

North Carolina Soil Test P Index Ratings for Agronomic Crops

Very High: > 100 High: 50-100  
Medium 25-50 Low: 0-25

- Greensboro Soil Test Phosphorus = High to Very High
- Chapel Hill Soil Test Phosphorus = Low

[www.bae.ncsu.edu/stormwater](http://www.bae.ncsu.edu/stormwater)

### Crop Fertilization Based on North Carolina Soil Tests

Table 1.4 Multiplication factors for converting soil test index values to a quantitative equivalent\*

Soil Test Index Value	mg/dm <sup>3</sup>	kg/ha	lb/acre
P-I	1.2	2.40	2.138

Mg% x CEC	121.0	242.2	276.09	7.0	70.0
Na	230.0	460.0	409.95	1.0	10.0
Mn-I	0.16	0.32	0.285	N/A	N/A
Zn-I	0.04	0.08	0.071	N/A	N/A
Cu-I	0.02	0.04	0.036	N/A	N/A
S-I	0.48	0.96	0.857	N/A	N/A

## Bioretention Cells: Trying out the New Mix

- Can a low soil test fill media reliably reduce phosphorus, while allowing plant growth?
- Monitored Sites in...
  - Charlotte
  - Louisburg
  - Elsewhere

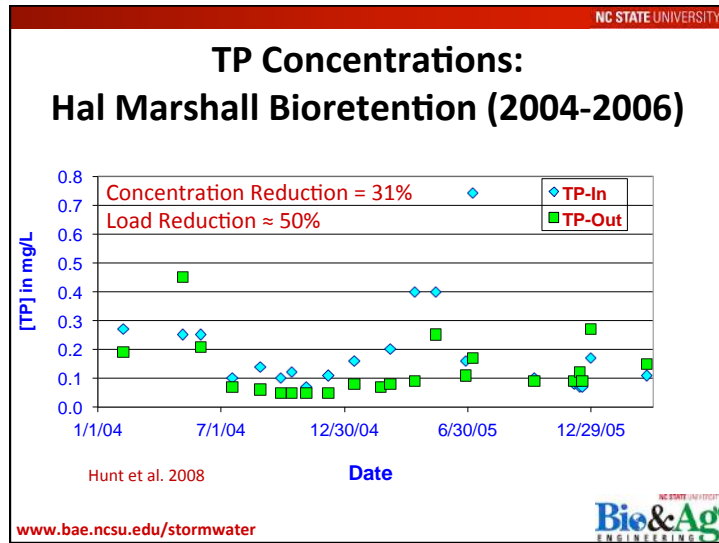
[www.bae.ncsu.edu/stormwater](http://www.bae.ncsu.edu/stormwater)

## Mecklenburg Co. Hal Marshall Bioretention Cell (2004-2006)

Fill Soil/ Media

- 80% Mason Sand
- 15% Fines
- 5% Compost
- Soil test P = 6
- 4 ft (1.2 m) Depth

[www.bae.ncsu.edu/stormwater](http://www.bae.ncsu.edu/stormwater)



NC STATE UNIVERSITY

### Louisburg Bioretention Cells

- Soil Media:
  - 85% Sand
  - 10% Fines
  - 5% Organics
  - Nominally 0.75 m Deep
- Soil Test P = 2
- Constructed Spring 2004

www.bae.ncsu.edu/stormwater

Bio&Ag  
ENGINEERING

NC STATE UNIVERSITY

### Load Reductions: Louisburg

Cell	TN	TP
L-1 (unlined)	64%	66%
L-2 (lined)	68%	22%

June 2004- February 2005

www.bae.ncsu.edu/stormwater

Bio&Ag  
ENGINEERING



NCDA&G Agronomic Division Phone: (919)733-2655 Web Site: www.ncagr.com/agronomist Report No: 05855

Grower: Perry, Tracey  
163 South Backet Blvd  
Lenoir, NC 27549

Form: Franklin County

10/25/2007 SERVING N.C. RESIDENTS FOR OVER 60 YEARS

Agreement Comments P = 11.6

Field Information	Applied Lime	Recommendations
Sample No. Last Crop Mo Yr T/A	Lime	
WNS01		
1st Crop: Nursery	Side 11	5M 3M 0 0 0 0 0
2nd Crop:		0

Test Results

Soil Class	BN%	WY	CCC	BS%	Ac	P/I	P/I	S-I	NO <sub>3</sub> -N	NH <sub>4</sub> -N	Nd
MS	0.09	1.27	5.2	100.0	0.0	14	14	180	110.00		0.1

**P Index sand fraction = 14**

Field Information	Applied Lime	Recommendations
Sample No. Last Crop Mo Yr T/A	Lime	
WNS04		
1st Crop: Nursery	Side 11	0 0 0 0 0 0 0
2nd Crop:		0

Test Results

Soil Class	BN%	WY	CCC	BS%	Ac	P/I	P/I	S-I	NO <sub>3</sub> -N	NH <sub>4</sub> -N	Nd
MS	0.27	0.31	2.1	100.0	0.0	73	73	180	110.00		1.1

**P Index Compost = 894**

Field Information	Applied Lime	Recommendations
Sample No. Last Crop Mo Yr T/A	Lime	
WNS04		
1st Crop: Nursery	Side 11	0 0 0 0 0 0 0
2nd Crop:		0

Test Results

Soil Class	BN%	WY	CCC	BS%	Ac	P/I	P/I	S-I	NO <sub>3</sub> -N	NH <sub>4</sub> -N	Nd
MS	0.09	1.20	4.4	100.0	0.0	57	57	180	110.00		0.1

**P index clay fraction = 67**

Field Information	Applied Lime	Recommendations
Sample No. Last Crop Mo Yr T/A	Lime	
WNS02		
1st Crop: Nursery	Side 11	5.5M 4M 0 20-25 5 5 5
2nd Crop:		20-25

Test Results

Soil Class	BN%	WY	CCC	BS%	Ac	P/I	P/I	K/I	Ca%	Mg%	Mn-I	Mn-AI(1)	Mn-AI(2)	Zn-I	Zn-AI	Cu-I	S-I	SS-I	NO <sub>3</sub> -N	NH <sub>4</sub> -N	Nd
MS	0.09	1.35	2.8	100.0	0.0	8.5	7	21	78.0	18.0	180	95	19	19	20	8	3.00	110.00			0.1

NC STATE UNIVERSITY

## Soil Media Phosphorus with 2.5% Compost

NCDA&G Agronomic Division Phone: (919)733-2655 Web Site: www.ncagr.com/agronomist Report No: 05901

Grower: Lord, Bill G. (William) Moore, Wilup  
861 NC 161 Hwy  
Lenoir, NC 27549

Form: Franklin County

10/25/2007 SERVING N.C. RESIDENTS FOR OVER 60 YEARS

Agreement Comments P = 4

Field Information	Applied Lime	Recommendations
Sample No. Last Crop Mo Yr T/A	Lime	
WNS02		
1st Crop: Nursery	Side 11	0 (10 lbs 10-10-10 or eqvt) PER 1000 sq FT)
2nd Crop:		0

Test Results

Soil Class	BN%	WY	CCC	BS%	Ac	P/I	P/I	Mg%	Mn-I	Mn-AI(1)	Mn-AI(2)	Zn-I	Zn-AI	Cu-I	S-I	SS-I	NO <sub>3</sub> -N	NH <sub>4</sub> -N	Nd	
MS	0.04	1.22	4.2	100.0		26	26	18.0	188			20	20	23	64					0.1

**P-I**  
**26**

www.bae.ncsu.edu/stormwater

Bio&Ag  
ENGINEERING



NC STATE UNIVERSITY

## Phosphorus Content of Sample Media Components

Media Component	P Index
Washed Coarse Sand	2
'Infield' Mix, 40% clay	0
Aged Pine Bark Fines	22
Certified Compost	668
'Crush and Run' granite fines	8


www.bae.ncsu.edu/stormwater

Bio&Ag  
ENGINEERING

NC STATE UNIVERSITY

### Phosphorus Content of Soil Mixes: Organic Content


Media Mix Organic Matter	Phosphorus Content (P Index)
10 % Compost	50
20 % Compost	103
10 % Pine Bark Fines	2
20% Pine Bark Fines	1

www.bae.ncsu.edu/stormwater 

NC STATE UNIVERSITY

### NC State Media Recommendation: By Volume

- Concrete Sand (70%)
  - Coarse sand is described in ASTM D2487-10 as that retained by a No. 10 sieve.
  - Also known as concrete sand or 'non-spec' sand
- Ball Field Mix (25%)
  - Contains approximately 60% coarse sand and 40% red or orange clay.
  - Fe and Al in the soil are fixing the phosphorus in the stormwater
- Mulch (5%)
  - Commonly available
- Low soil test P (<30 PI)




www.bae.ncsu.edu/stormwater 

NC STATE UNIVERSITY

### Biorention: Designed to Reduce Water Flow and Nitrogen and Phosphorus

- Bioretention beds are water quality treatment devices NOT landscape features: *think clean water, not lush landscape*
- Design criteria
  - 1-2 inches per hour optimal
  - 8-12% fines recommended
  - Infiltration rates will slow over time
- Do not use nutrient rich soil – either amended with excessive compost or other nutrients, or due to prior fertilization BECAUSE the bioretention cell will be a net **EXPORTER** of nutrients

www.bae.ncsu.edu/stormwater 

NC STATE UNIVERSITY

### Urban Stormwater Practice Construction: Green Roofs



www.bae.ncsu.edu/stormwater 

NC STATE UNIVERSITY

## Perceived and Realized Green Roof Benefits

- Reduction of peak flows on small to moderate storms
- Increased roof life
- **Potential to improve water quality runoff**
- Reduction of heat island effect
- Reduced heating and cooling costs
- Aesthetics




www.bae.ncsu.edu/stormwater 

NC STATE UNIVERSITY

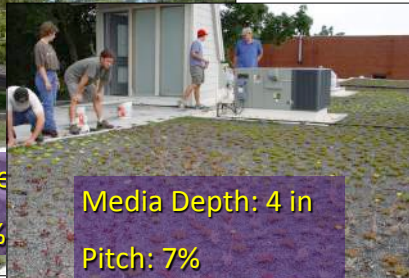
## Initial NCSU Research Greenroofs

**Goldsboro**




Media Depth: 4 in  
Pitch: 3%

**Kinston**



Media Depth: 4 in  
Pitch: 7%


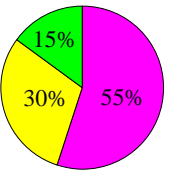
www.bae.ncsu.edu/stormwater 


NC STATE UNIVERSITY

## Original Soil (Media) Substrate: Green Roof

**Perma Till Lightweight Roof Garden Mix**

- Perma Till Expanded Slate
- Rootzone Sand
- Approved Compost

www.bae.ncsu.edu/stormwater 

NC STATE UNIVERSITY

## Green Roofs: Water Retention Data Summary

- Goldsboro Green Roof (April 2003 — Sept 2004)


Total Rainfall	Total Amount Retained	Total Percent Retained
59.6 in.	37.8 in.	63%

- Kinston Green Roof (July 2003 — May 2004)

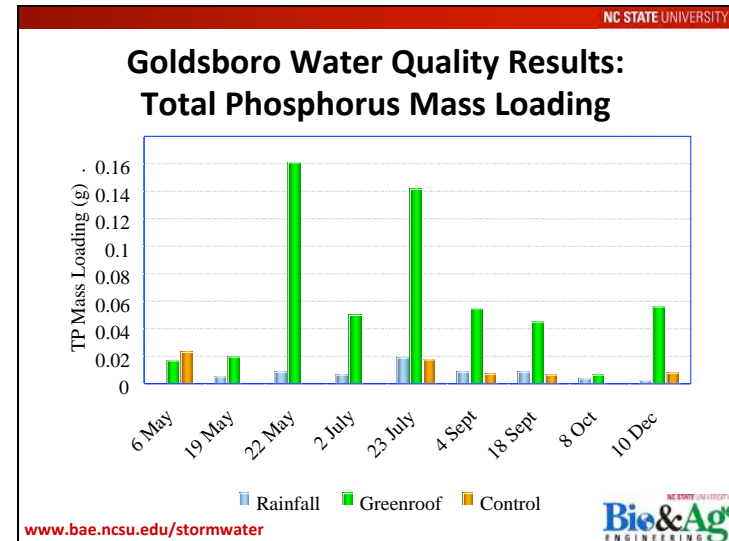
17.1 in.	12.1 in.	71%
----------	----------	-----

- Raleigh Green Roof (July 2004 — September 2004)

12.4 in.	6.8 in.	55%
----------	---------	-----

www.bae.ncsu.edu/stormwater 





**Soil (Media) Substrate Comparison: Green Roof**

**Carolina Stalite**

- 80% Expanded slate
- 10% Sand
- 10% Yard

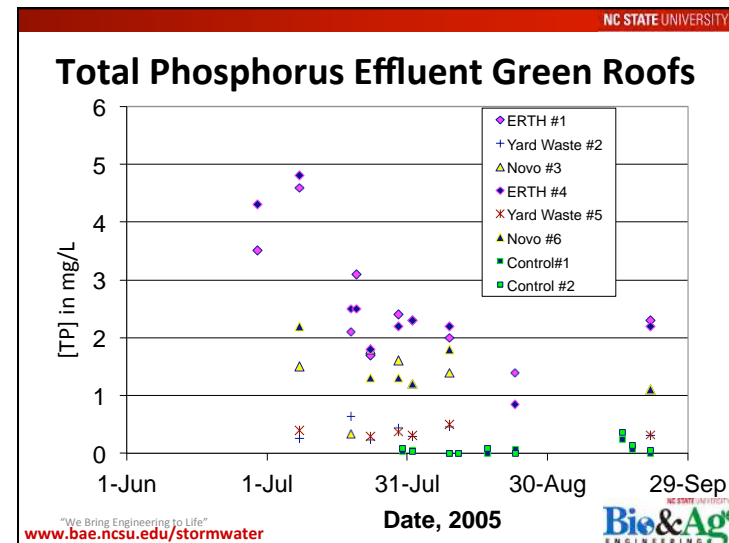
**ERTH Foods**

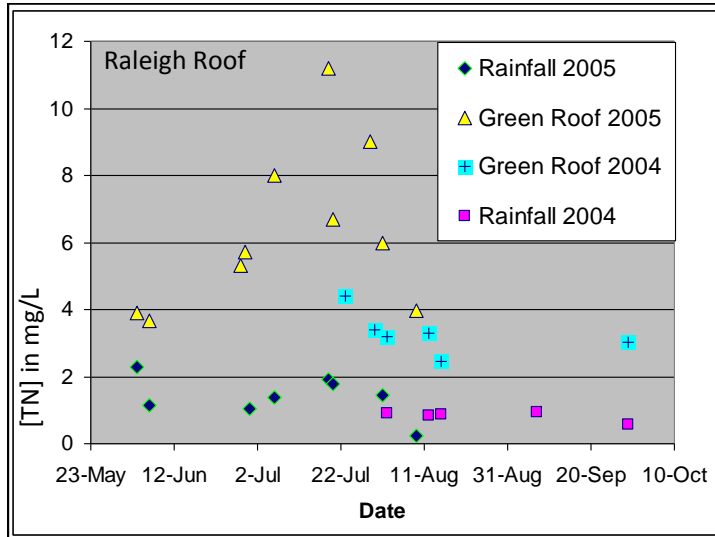
- 75% Brick base
- 10% Sand
- 15% Biosolids

**Novozyme**

- 85% Expanded slate
- 10% Sand
- 5% Novozyme material

www.bae.ncsu.edu/stormwater





NC STATE UNIVERSITY

### Total Phosphorus Loss: Asheville, NC

Date	Rainfall	ERTH Food (mg P/L)	Stalite (mg P/L)
30Jul04	<0.01	0.39	0.15
11Aug04	0.02	0.71	0.30
02Apr05	0.03	0.40	0.17
13Apr05	0.04	0.34	0.19
06Oct05	0.02	0.81	0.16
21Nov05	0.05	0.59	0.14

www.bae.ncsu.edu/stormwater



NC STATE UNIVERSITY

### Green Roof Planting Media Criteria

1. Good drainage and aeration
2. Water holding capacity (without getting too saturated or heavy)
3. Nutrient holding capacity (CEC)
4. **Low nutrient content**
5. Permanent
6. Lightweight but sturdy (can't shrink or blow away)
7. Stable (must support the plants)

www.bae.ncsu.edu/stormwater Image courtesy of Chuck Friedrich, Carolina Stalite

NC STATE UNIVERSITY

Questions?



[www.bae.ncsu.edu/stormwater](http://www.bae.ncsu.edu/stormwater)

NC STATE UNIVERSITY  
**Bio&Ag**  
ENGINEERING