BIOSORPTION ACTIVATED MEDIA (BAM) TO REDUCE NUTRIENTS IN STORMWATER

By Marty Wanielista

OVERVIEW

- ~ 15 years of lab and field data collection to validate removal and perfect designs and operations
- Biogeochemical assessment of pre/post data at areas using Biosorption Activated Media (BAM)
- Design and construction using BAM
- Quantitative analysis of N budget and flux beneath stormwater basins that use BAM
- Input – Output data on BMPs

PARTNERS in this work

- U.S. EPA, Edison NJ Stormwater Program
- Florida Department of Environmental Protection
- Marion County, Florida
- Florida Department of Transportation
- St. Johns River Water Management District
- Southwest Florida WMD
- Universities: UCF, USF, FSU and UF
- U.S. Geological Survey, Water Science Center
- Plastic Tubing Industries and
- Suntree Technologies

Special Thanks to many students and co-PIs on BAM, namely
Drs. Ni-Bin Chang, UCF; & Andy O'Reilly, U of Mississippi
In addition to the speakers in this workshop.

BAM Media SELECTION

Ones for which we have effectiveness lab experiments

- Expanded Clay
- Peat
- Natural Sandy/Loamy/ Clayey soils
- Sawdust (untreated)
- Paper/Newspaper ← Toxic Results
- Palm Tree Frauds
- Zeolite ← Costly

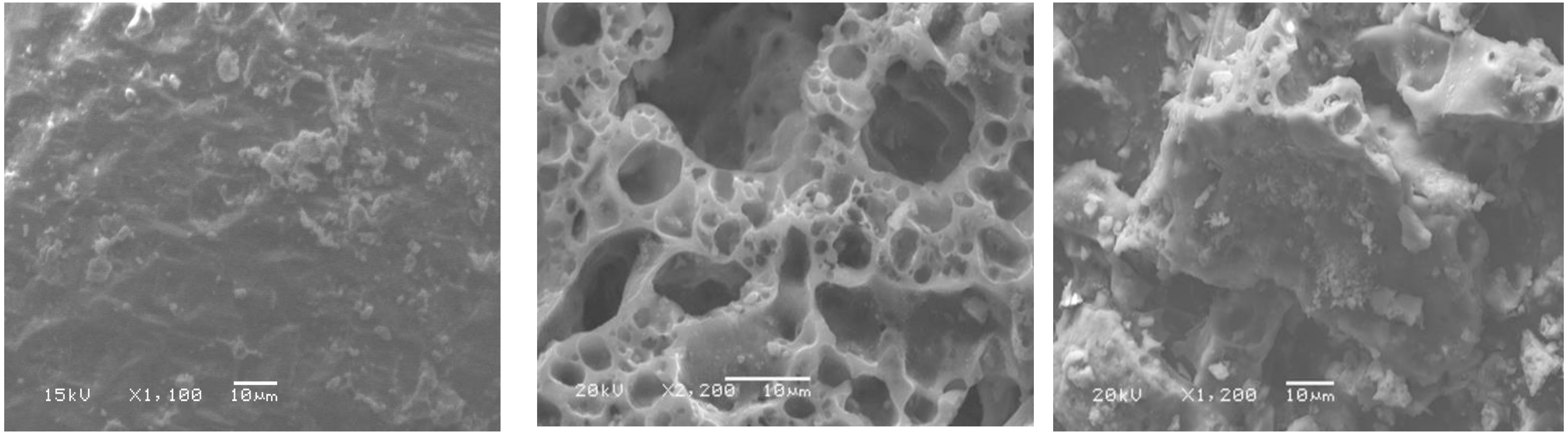
- Tire Crumb
- Tire Chips
- Activated Carbon ← Costly
- Limestone
- Crushed Shells
- Wood Fiber/Chips/ ← Toxic Results
- Compost
- Coconut coir

LABORATORY SOIL COLUMNS

- Test selected media mixtures to quantify their nutrient attenuation capabilities (removal)
- Life Expectancy

Trying to estimate
1. mg P/g media
2. Residence time
3. Environment, DO conditions

surface area of BAM identify using **Scanning Electron Microscope**



SEM of *(a)* concrete sand1,000 x, *(b)* expanded clay 2,200 x, and *(c)* tire crumb 1,200 x magnification showing the surface structure and characteristics after residing in 24 days of column testing.

Roof and Lawn Gardens

vegetated areas with special media for water treatment and other benefits such as

- First used as a light weight media to “hold” N&P for plants
- Improving the “looks” of the area or property
- Reducing water pollution in runoff waters
- Replacing potable water used for irrigation
- Removing air pollutants and adding Oxygen
- Helping reduce heat island effects
- Reducing energy use within a building with greenroofs
- Providing for plant and animal diversity

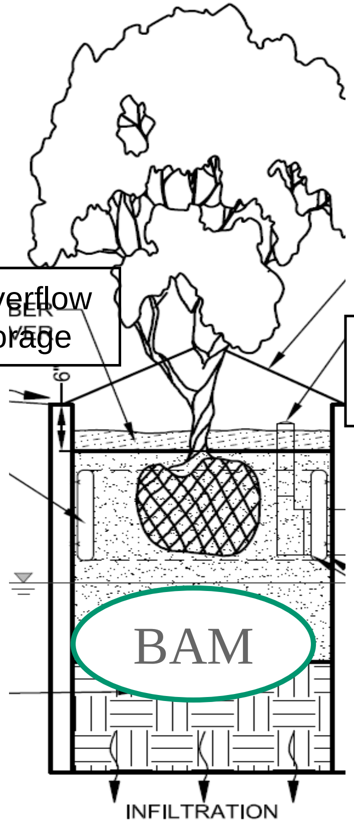
Florida Greenroofs

- Scientific and engineering support introduced in Florida in 2003:
  - UCF Student Union, physical science and Stormwater Lab (3)
  - FSGE (Envirohome) (5) in Indialantic (2009 green roofs for healthy cities)
  - Bonita Bay (first one and has been modified for irrigation and media)
  - New American Home in Orlando
  - Charlotte County Stadium
  - UF Perry Construction Yard Building
  - Tecta-America Building in Sanford (tray vs. continuous)
  - Honda Headquarters in Clermont (greenroofs.com roof of the week)
  - Escambia County One Stop Permit Building (largest ~ 33,000 SF)
  - Residence on Casey Key
  - Orlando Fire Station #1
  - Environmental Center, Key West
  - Kimley-Horn Building in Vero Beach
  - First Green Bank with Tecta-America Southeast in Mount Dora
  - City of Sarasota Bay Front Park
  - Gulf Coast College, Panama City
  - Brickell City Center, Miami
  - WAWA gas station, Altamonte Springs
  - Starbucks, Walt Disney World

Depression or Lawn Garden Areas

Existing for 36 years, particulate fraction removal plus

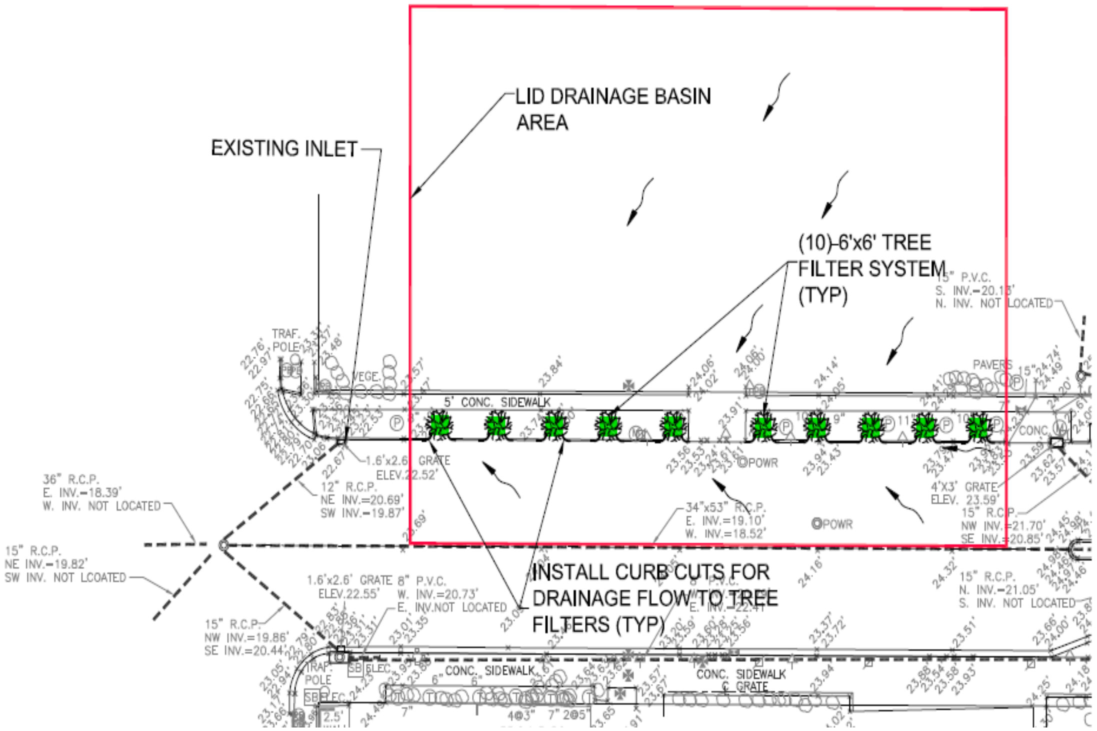
Tree Box Filter Retention Design



Overflow storage

tree anchors

Overflow if not diverted



Overflow

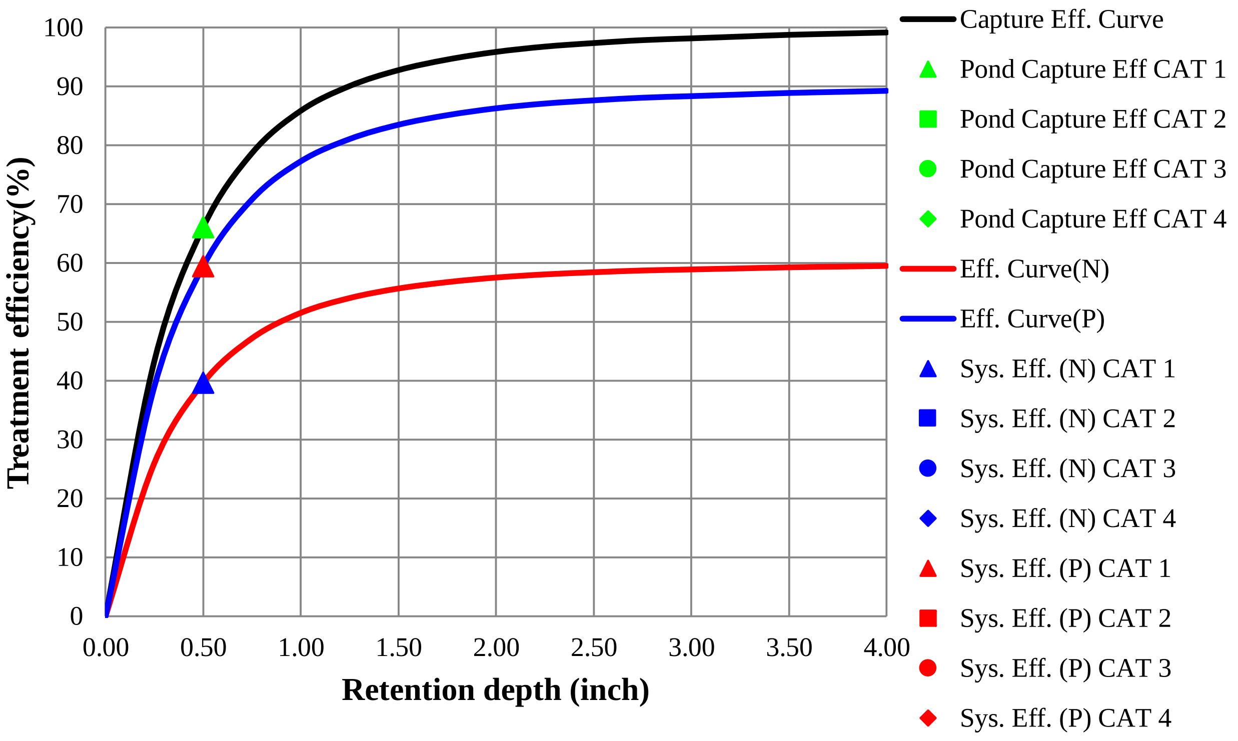
Flow to Tree Wells

Flow to Tree Well

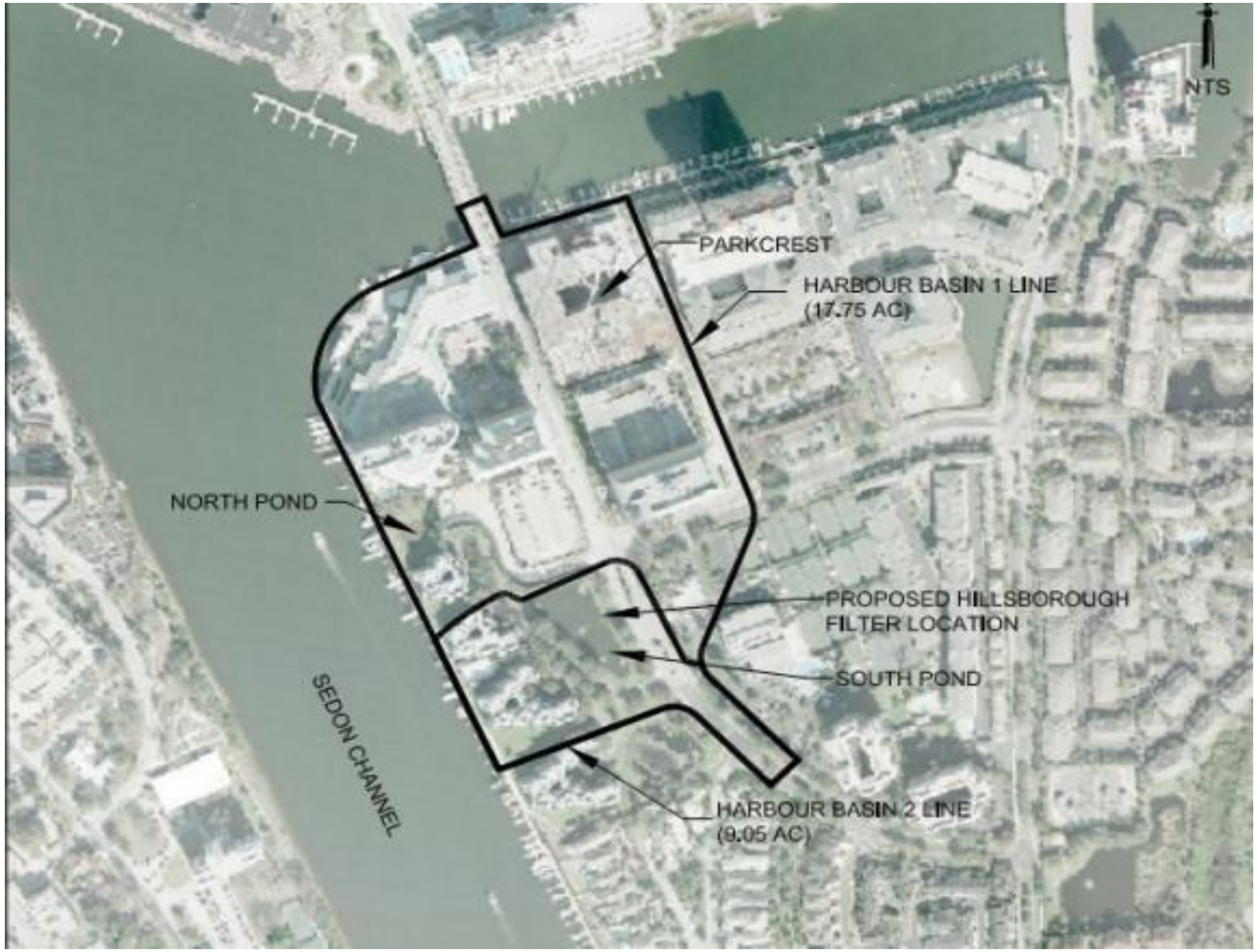
Overflow

Nitrogen and Phosphorus removal depends on media, (typical is > 70%)

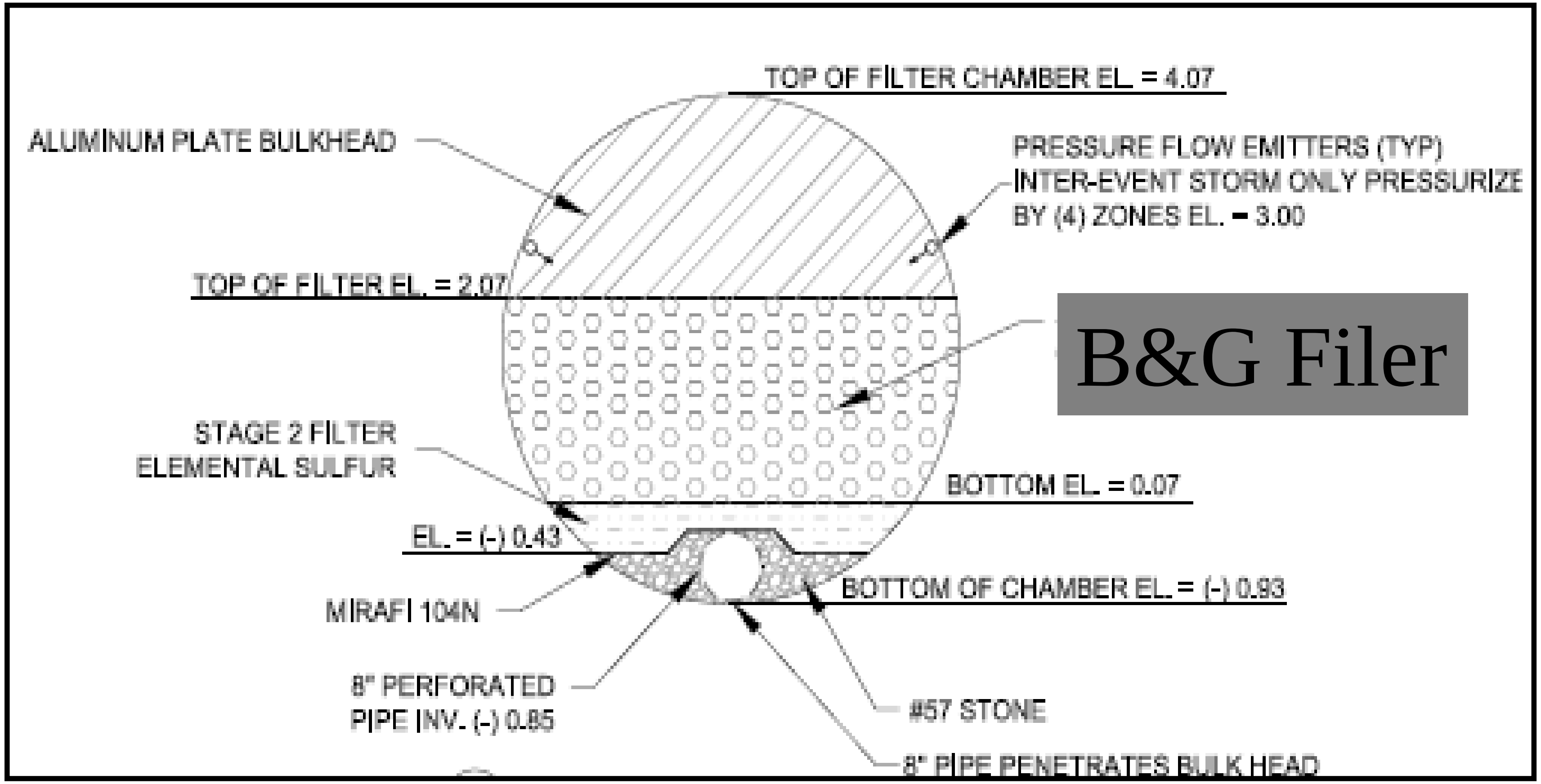
Example Capture and Effectiveness with Retention BMPs



Pipe filter near an Estuary
Area can not infiltrate, thus filter



Bold & Gold Filter in a pipe



85% reduction of Nitrate, 76% reduction of TP

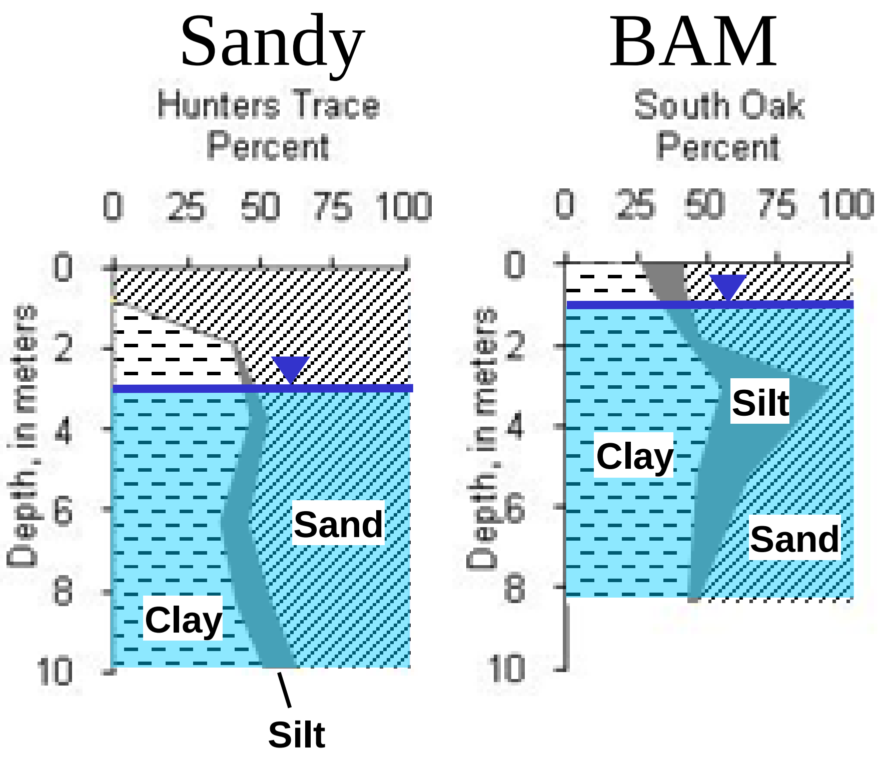
Credit Watermark Engineering

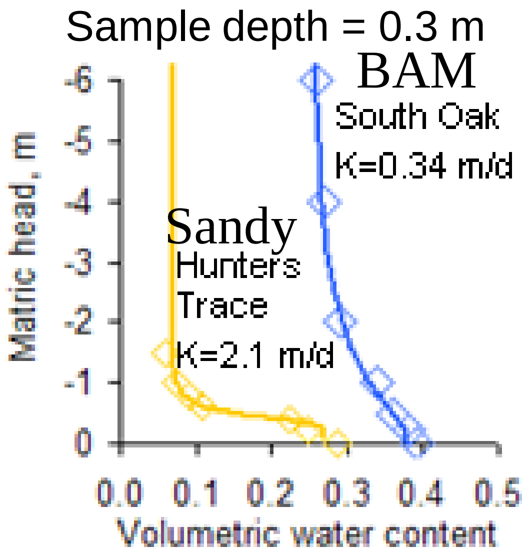
Field SITE COMPARISONS

Sandy Soil SW Basin	Parameter	BAM type Soil SW Basin
Deeper	Water Table	**Shallower**
Less	Silty/Clayey Soils	**More**
Lower	Cation Exchange Capacity	**Higher**
Higher	Infiltration Rate	**Lower**
Higher	Dissolved Oxygen	**Lower**
Lower	Alkalinity	**Higher**
Lower	Organic Carbon	**Higher**
Higher (median=2.2 mg/L)	Groundwater Nitrate	**Lower (median=0.03 mg/L)**
No	Nitrate Decline with Time	**Yes**

SOIL CHARACTERISTICS

- Textural differences contributed to large differences in the soil moisture retention curves.





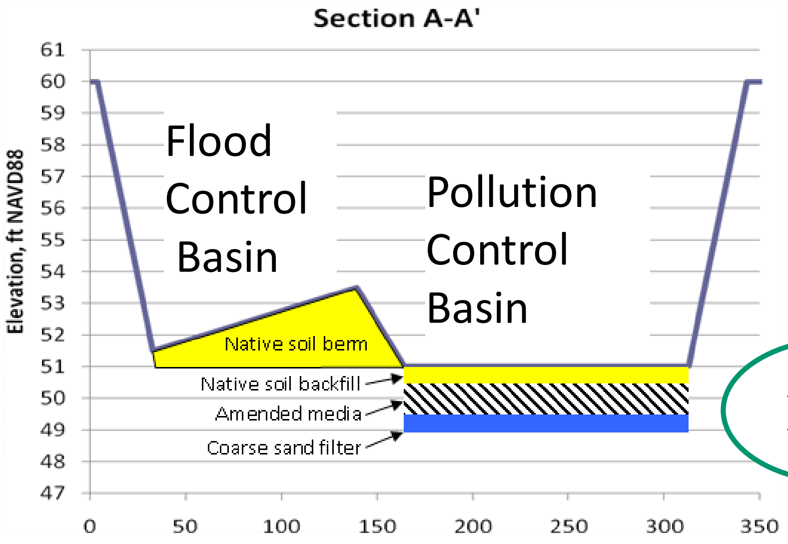
TREATMENT with BAM

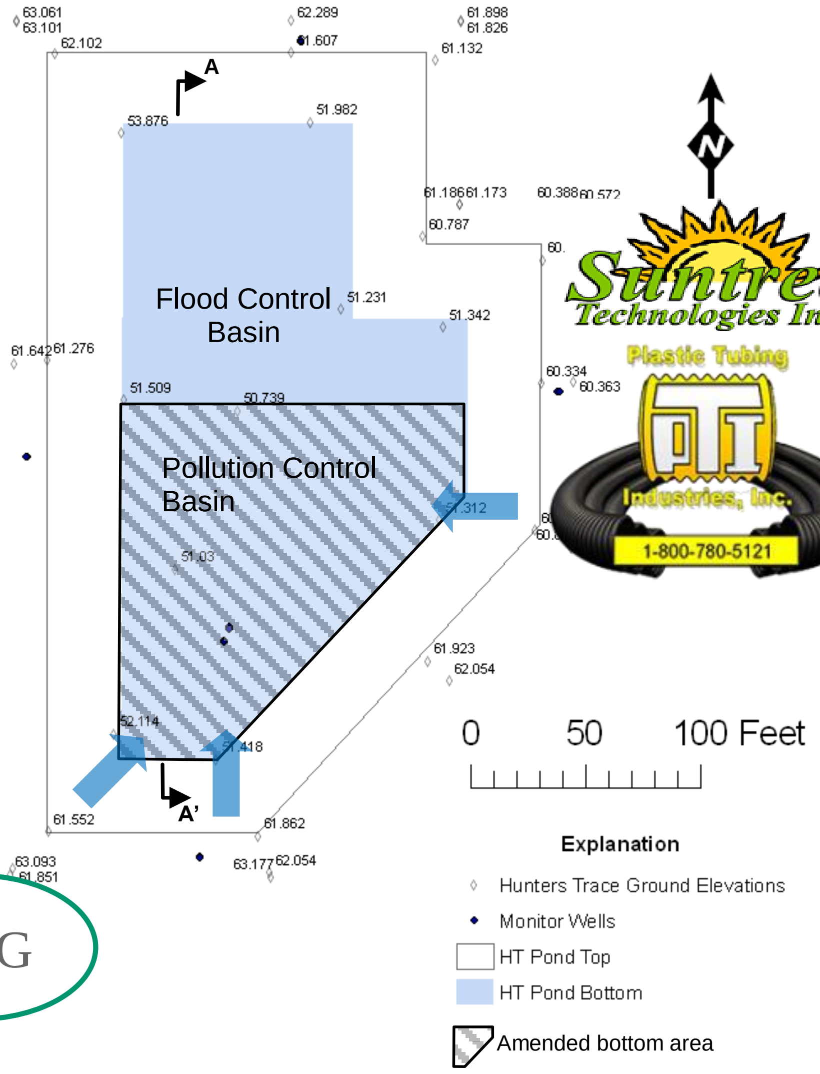
A retrofit to an existing area was completed based on the natural biogeochemical processes identified at an existing stormwater basins using naturally occurring BAM:

1. Excavation of native soil in the bottom of a portion of an area;
2. Emplacement of a 0.3 m thick amended soil layer ("Biosorption Activated Media" mix): 1.0:1.9:4.1 mixture (by volume) of tire crumb (to increase sorption capacity), silt+clay (to increase soil moisture retention), and sand (to promote sufficient infiltration); and
3. Construction of a berm forming separate nutrient reduction and flood control basins.

Marion County Basin– Uses BAM

- Reproduce soil conditions that exist at the SO basin by using an amended soil layer:
  - Increase soil moisture
  - Reduce oxygen transport
  - Increase sorption capacity





B&G

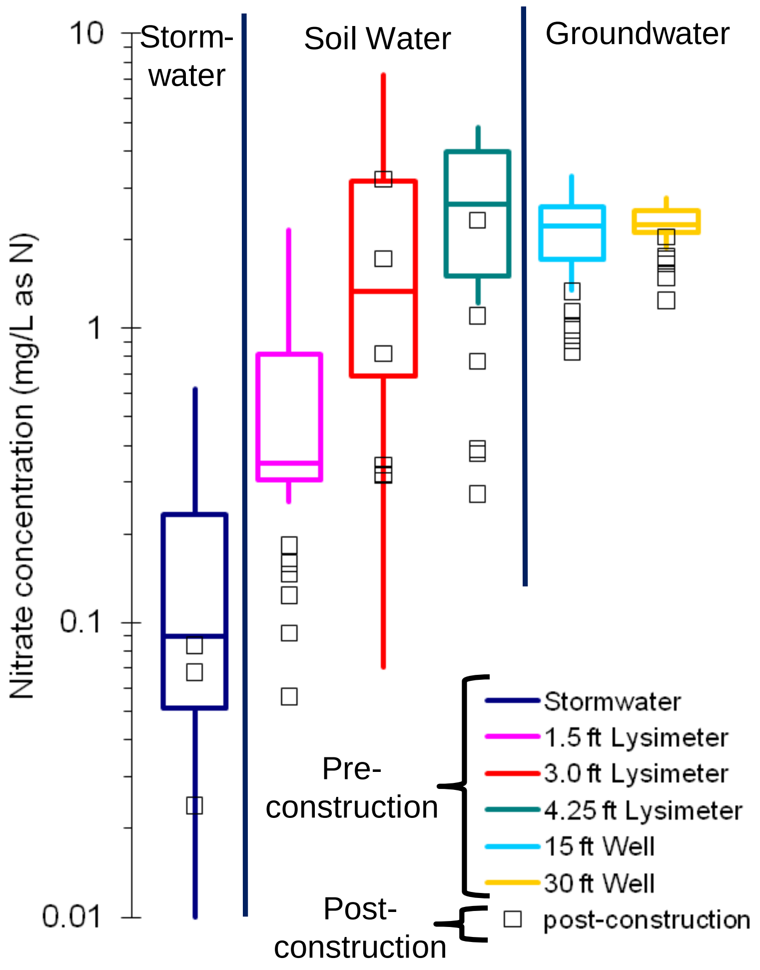
Suntree Technologies Inc.

Plastic Tubing
Industries, Inc.
1-800-780-5121

Basin with BAM – NITRATE

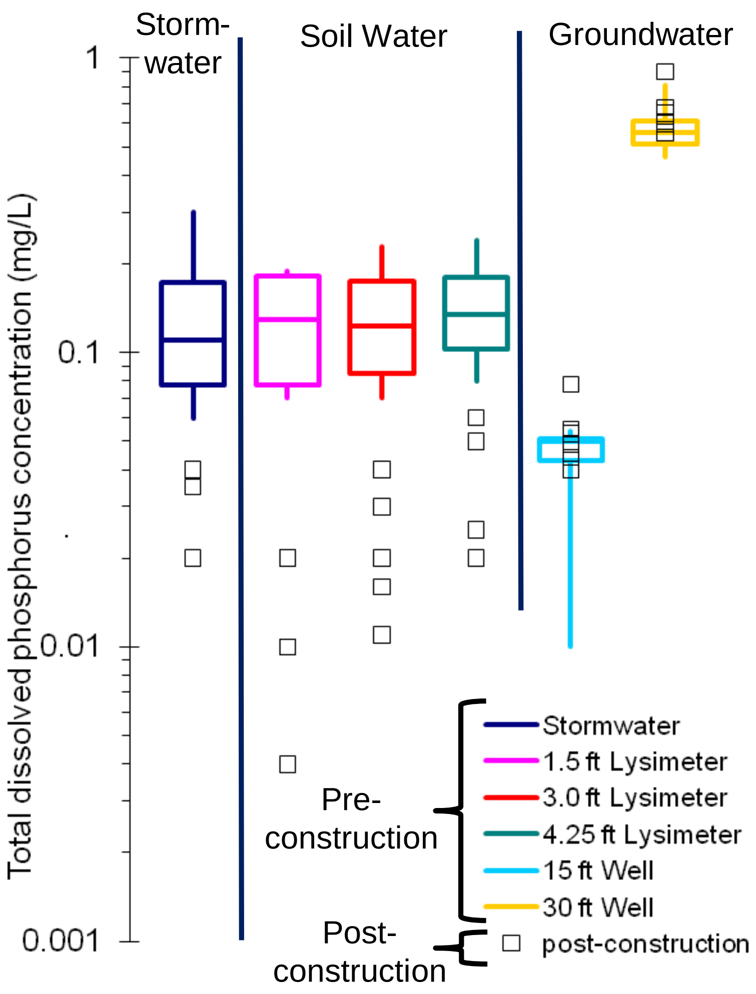
- ~ 60% reductions in nitrate from pre-construction (2007–2009) to post-construction (2009–2010) median concentrations with one foot deep BAM media.
- 73% reduction for two feet deep B&G layer.

Reference: Williams, Shane, Improving Nitrogen Removal Effectiveness, Annual FSA Meeting June 2015.

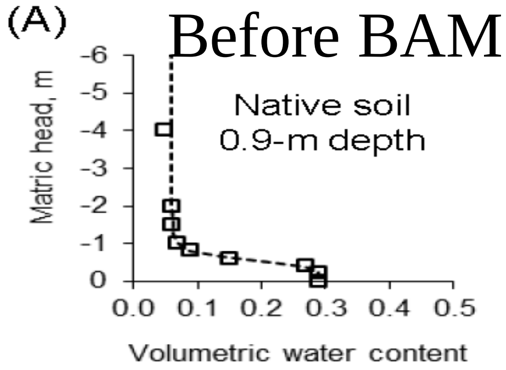


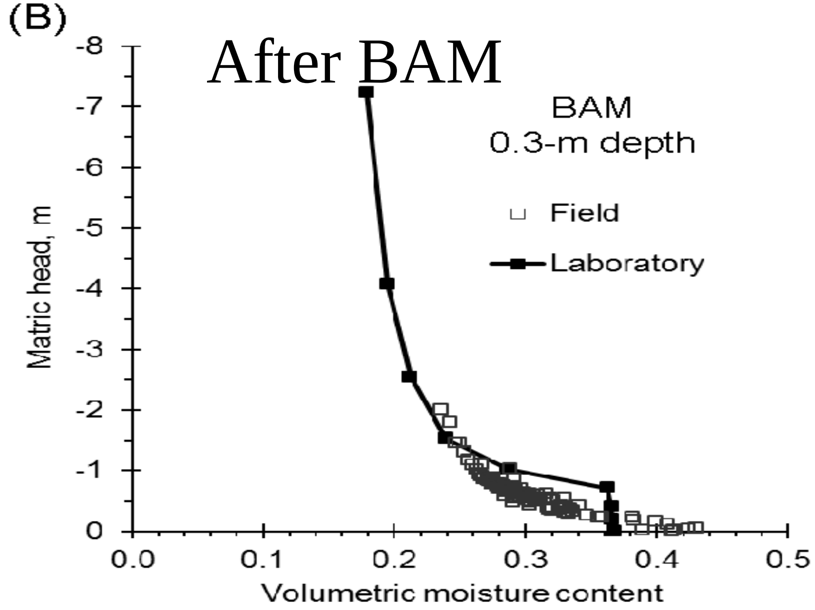
Basin with BAM – PHOSPHORUS

- > 80% reductions in total dissolved phosphorus (TDP) from pre-construction (2007–2009) to post-construction (2009–2010) median concentrations in soil water



Before and After BAM Residual Soil Moisture at a Regional Infiltration Basin





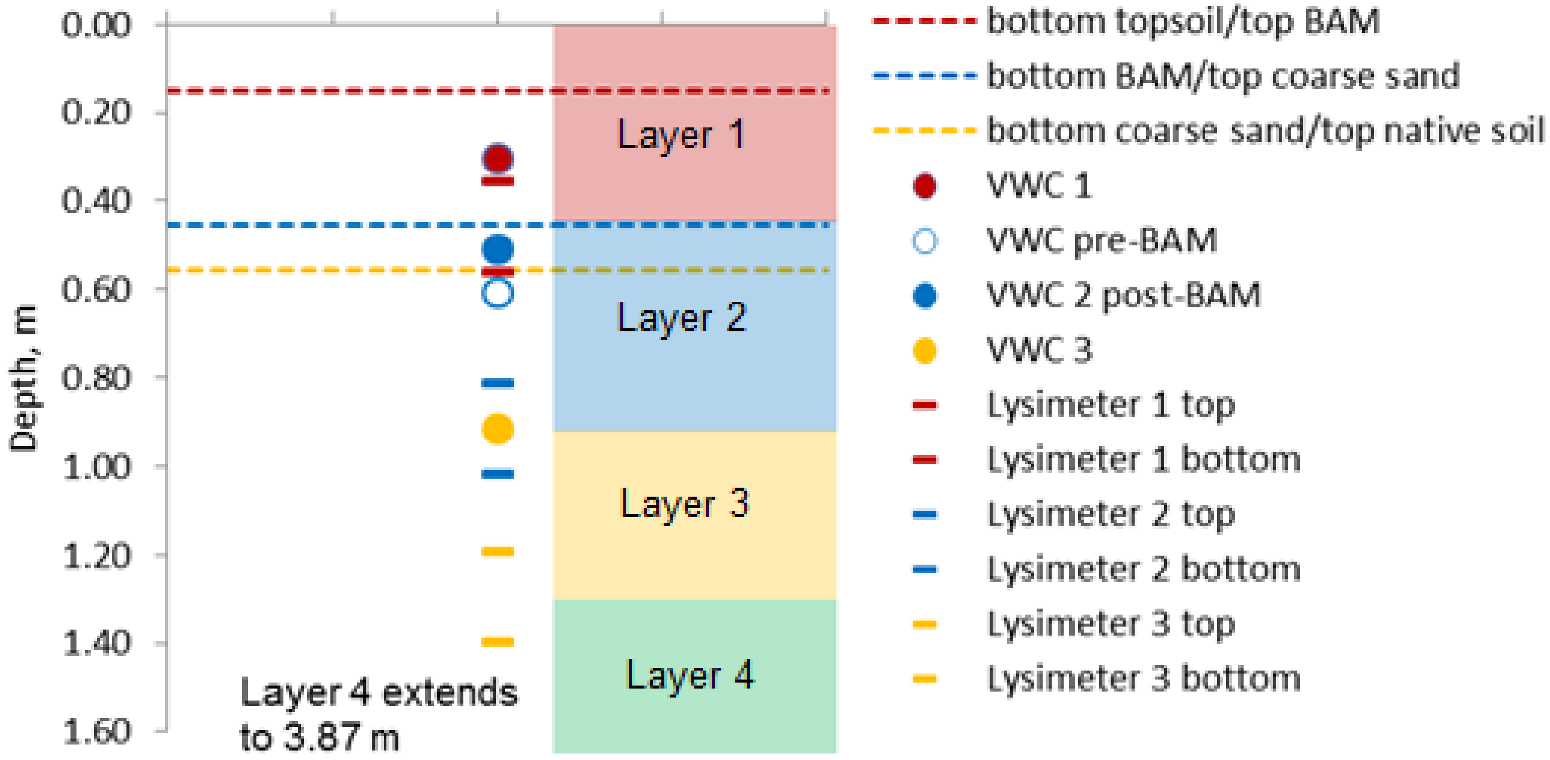
Field measurements were obtained by continuous monitoring using time domain reflectometry and tensiometers.

Laboratory derived soil moisture retention curves were measured for the main drying curve on undisturbed soil cores using the pressure cell method.

Note: 1 meter head = 9.8 kPa
Field Capacity of soil = ~ 3.3 meters

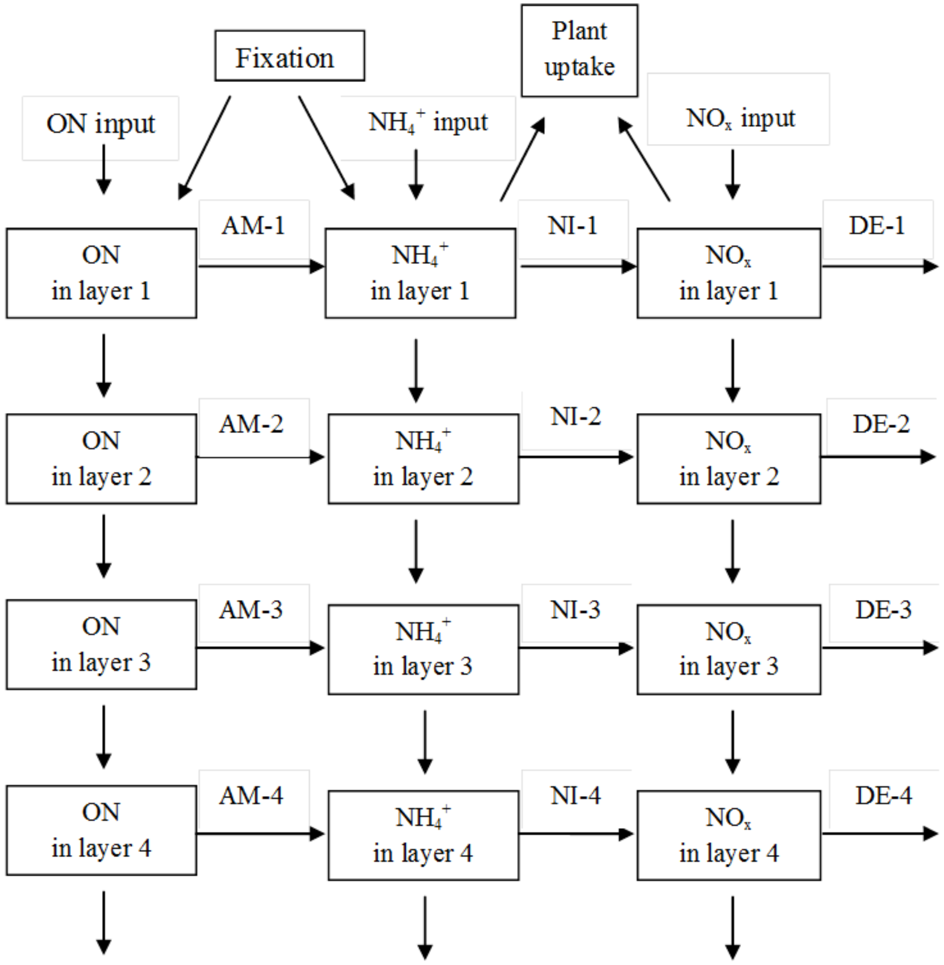
SYSTEM DYNAMICS MODEL

- 1-D vertical, 4 layers
- Only water phase (gas and solid phases not modeled)
- Model layers approximate field conditions, e.g. BAM layer and locations of instrumentation



CONCEPTUAL MODEL

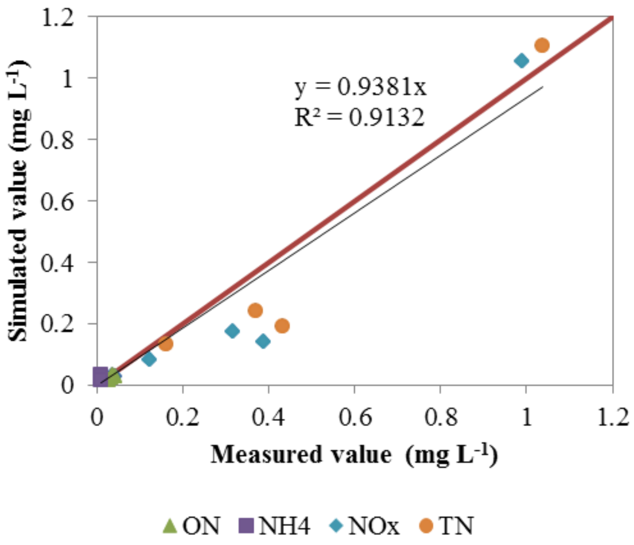
- Simulate advective inflow/outflow, fixation, ammonification, nitrification, denitrification, and plant uptake



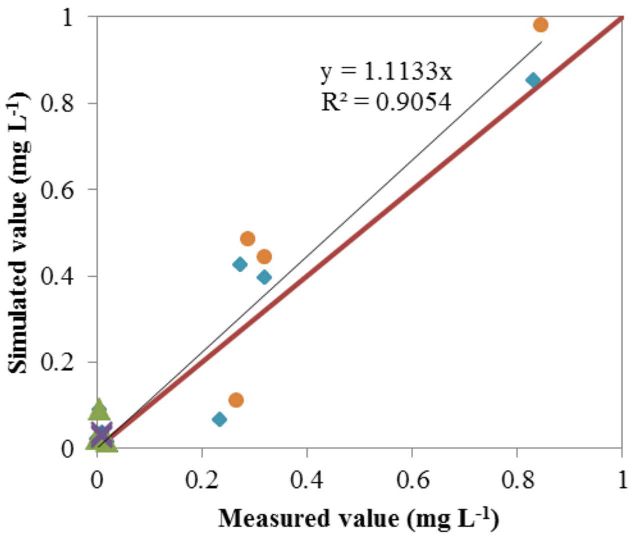
CALIBRATION & VALIDATION

- Calibrate model for period 1–15 December 2009
- Validate model for period 2 March – 7 April 2010

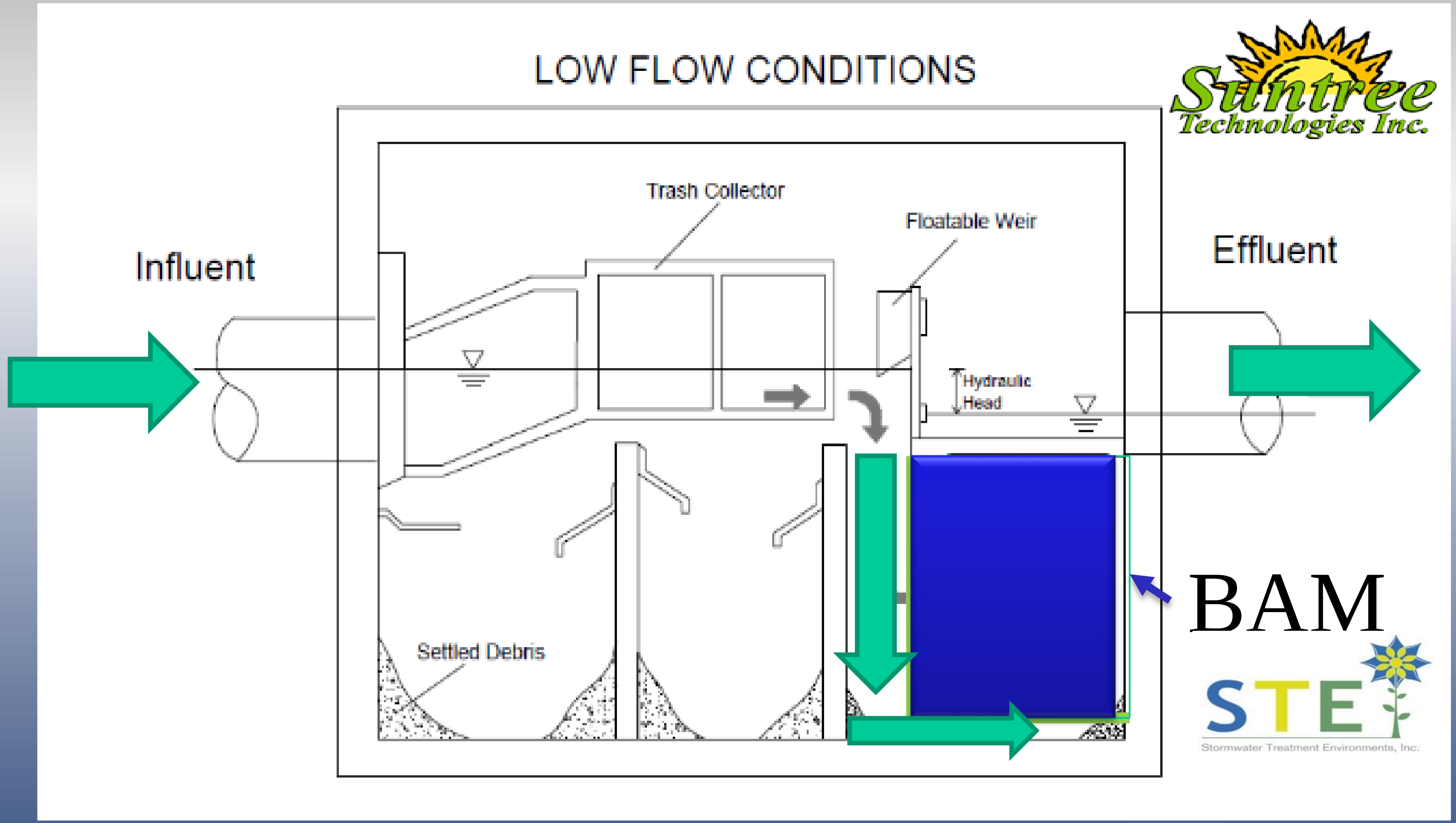
Calibration



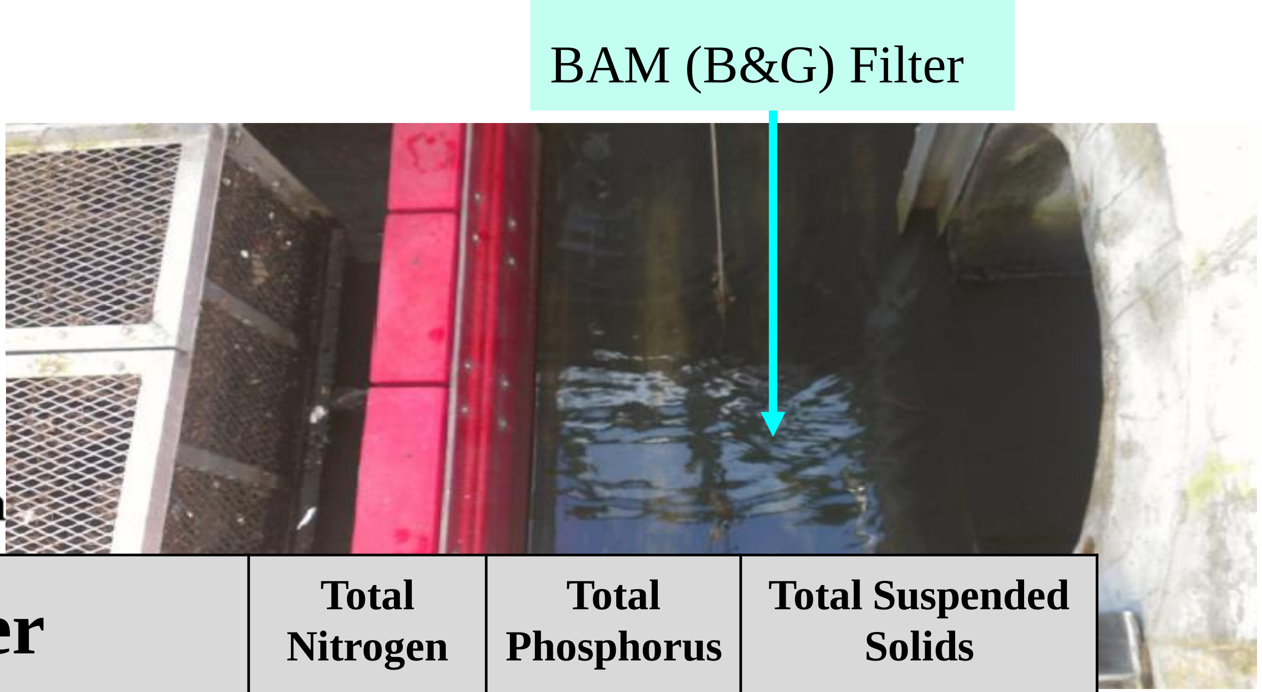
Validation



Underground Systems in high water table areas
Up-Flow Filter at the Discharge



Sampling Results (estimated 70% of flow through filter)



Parameter	Total Nitrogen	Total Phosphorus	Total Suspended Solids
Average Influent Concentration (mg/L)	1.87	0.281	105
Average Filter Removal (%)	45	58	40
Average System Removal (%) no by-pass of the up-flow filter	67	79	81
Average Annual Removal (%)	54	67	70

Water Quality Lab data by ERD, Orlando Florida

There was ~30% overflow (by-pass) of the up-flow filter during high flow per year

Improved Treatment Using Up-flow Filters with Wet Pond

Filters Work to remove more

- Filters can be designed to remove nitrogen without media replacement
- For phosphorus, media replacement time is specified
- Can be used in BMP & LID Treatment Train Applications with other treatment

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UCF
STORMWATER MANAGEMENT ACADEMY

WATERMARK
ENGINEERING GROUP

Up-Flow Input from Wet Detention to Filter

- Performance
  - Concentration
  - Averages based on field data
  - Average yearly based on

1.0 inch design for filter

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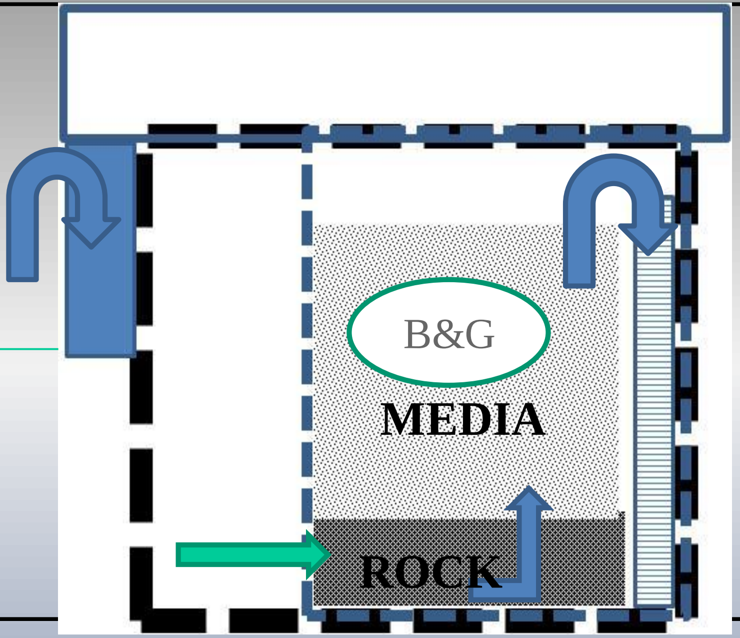


Parameter	TN	TP	TSS
Average Influent Concentration (mg/L)	1.83	0.73	42.7
Expected Average Pond Removal (%)	**38**	**63**	**79**
Average Pond + Filter Removal (%)	**70**	**72**	**91**
Average Annual System Performance	**67**	**70**	**89**

BMP Nutrient Model BMPTRAINS

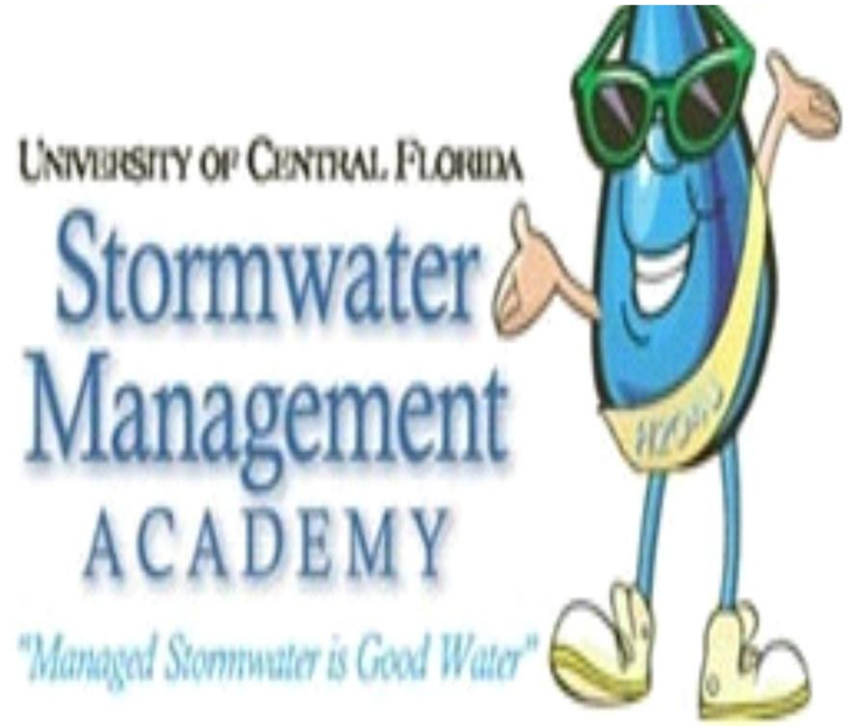
Stormwater BMP Treatment Trains [BMPTRAINS©]

CLICK HERE TO START

INTRODUCTION PAGE

This program is compiled from stormwater management publications and deliberations during a two year review of the stormwater rule in the State of Florida.
Input from the members of the Florida Department of Environmental Protection Stormwater Review Technical Advisory Committee and the staff and consultants from the State Water Management Districts is appreciated.

The State Department of Transportation provided guidance and resources to compile this program. The Stormwater Management Academy is responsible for the content of this program.



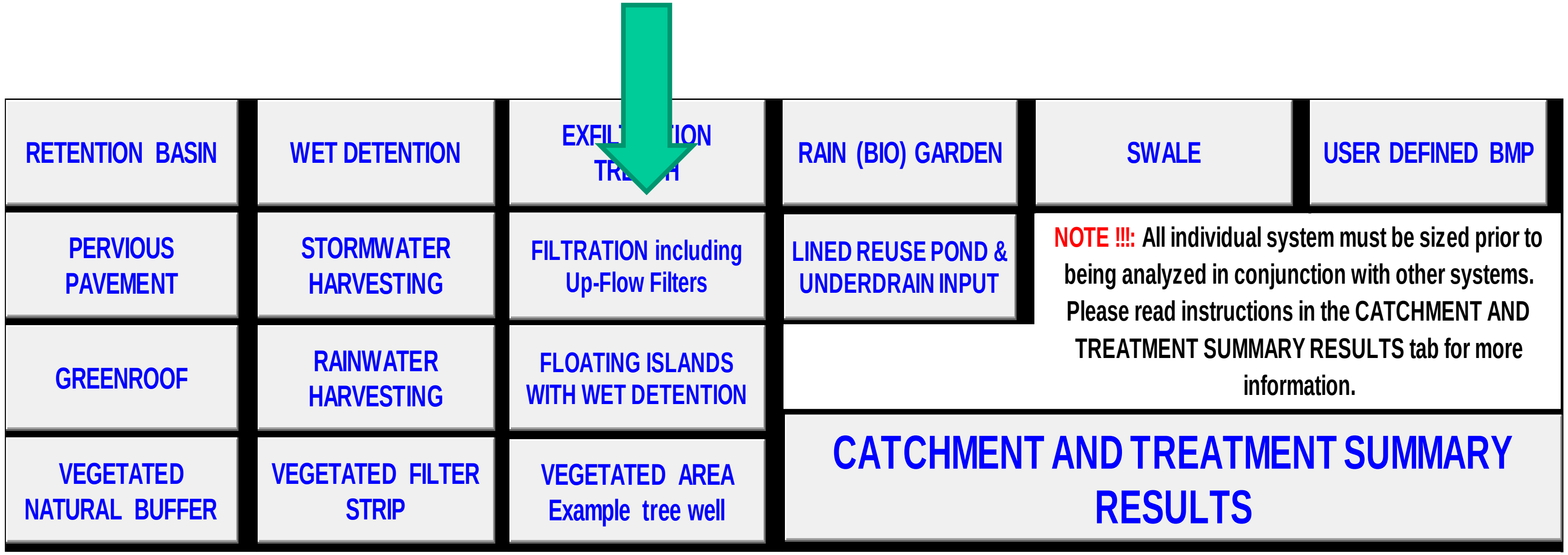
Download from www.stormwater.ucf.edu and use from www.smadaonline.com.

Stormwater BMP Options

BAM can be used with many BMPs

RETENTION BASIN	WET DETENTION	EXFILTRATION TRENCH	RAIN (BIO) GARDEN	SWALE	USER DEFINED BMP
PERVIOUS PAVEMENT	STORMWATER HARVESTING	FILTRATION including BIOFILTRATION	LINED REUSE POND & UNDERDRAIN INPUT	NOTE !!!: All individual system must be sized prior t being analyzed in conjunction with other systems. Please read instructions in the MULTIPLE WATERSHEDS AND TREATMENT SYSTEMS ANALYSIS tab for more information.	
GREENROOF	RAINWATER HARVESTING	FLOATING ISLANDS WITH WET DETENTION			
VEGETATED NATURAL BUFFER	VEGETATED FILTER STRIP	VEGETATED AREA Example tree well	CATCHMENT AND TREATMENT SUMMARY RESULTS		

In-Line or Off-Line Up-flow Filters



Underground locations, thus do not take land

Removal and mixes

Filtration Media

DESCRIPTION OF MEDIA		PROJECTED TREATMENT PERFORMANCE *			TYPICAL LIMITING FILTRATION RATE (in/hr)
Media and Typical Location in BMP Treatment Train	**MATERIAL**	**TSS REMOVAL EFFICIENCY**	**TN REMOVAL EFFICIENCY**	**TP REMOVAL** ** **EFFICIENCY**	
B&G ECT (ref A) A first BMP, ex. Up-Flow Filter in Baffle box and a constructed wetland[#] (USER DEFINED BMP)	Expanded Clay[2] Tire Chips[1]	70%	55%	65%	96 in/hr
B&G OTE (ref A,B) Up-flow Filter at Wet Pond & Dry Basin Outflow (FILTRATION)	Organics[8] Tire Chips[1] Expanded Clay[4]	60%	45%	45%	96 in/hr
B&G ECT3 (ref C) Inter-event flow using Up-flow Filter at wet pond and Down-Flow Filter at Dry Basin (FILTRATION)	Expanded Clay[4] Tire Chip[1]	60%	25%	25%	96 in/hr
SAT (ref D) A first BMP, as a Down-flow Filter (FILTRATION)	Sand[3]	85%	30%	60%	1.75 in/hr
B&G CTS (ref E,F) Down-Flow Filters 12" depth*** at wet pond or dry basin pervious pave, tree well, rain garden, swale, and strips	Clay[6] Tire Crumb[5] Sand[7] & Topsoil[9]	90%	60%	90%	0.25 in/hr

Note: Other filter media being tested

Notes and References

[1] Tire Chip 3/8" and no measurable metal content (approximate dry density = 730 lbs/CY)

[2] Expanded Clay 5/8 and 3/8 blend (approximate dry density = 950 lbs/CY)

[3] Sand ASTM C-33 with no more than 3% passing # 200 sieve (approximate dry density = 2200 lbs/CY)

[4] Expanded Clay 3/8 in blend (approximate density = 950 lbs/CY)

[5] Tire Crumb 1-5 mm and no measurable metal content (approximate density = 730 lbs/CY)

[6] Medium Plasticity typically light colored Clay (approximate density = 2500 lbs/CY)

[7] Sand with less than 5% passing #200 sieve (approximate density = 2200 lbs/CY)

[8] Organic Compost (approximate density of 700 lbs/CY) Class 1A Compost or Mix of yard waste

[9] Local top soil is used over CTS media in dry basins, gardens, swales and strips, is free of roots & debris but is not used in other BMPs.

A - Demonstration Bio Media for Ultra-urban Stormwater Treatment, Wanielista, et.al. FDOT Project BDK78 977-19, 2014

B - Nutrient Reduction in a Stormwater Pond Discharge in Florida, Ryan, et al, Water Air Soil Pollution, 2010

C - Up-Flow Filtration for Wet Detention Ponds, Wanielista and Flint, Florida Stormwater Association, June 12, 2014.

D - City of Austin Environmental Criteria Manual, Section 1.6.5, Texas, 2012

E - Nitrogen Transport and Transformation in Retention Basins, Marion Co, Fl, Wanielista, et al, State DEP, 2011

F - Improving Nitrogen Efficiencies in Dry Ponds, Williams and Wanielista, Florida Stormwater Association, June 18 2015

Additional Support References

- Alternative Stormwater Sorption Media for the Control of Nutrients,
  - By Wanielista, Marty and Ni-Bin Chang, Southwest Florida Water Management District, Final Report, Project B236, 2008.
- Improving Nitrogen Treatment Efficiency in Dry Retention Ponds
  - By Shan Williams and Marty Wanielista, Florida Stormwater Association Annual Meeting, Ft Meyers, Fl, June 2015.
- Soil Property Control of Biogeochemical Processes beneath Two Subtropical Stormwater Infiltration Basins
  - Andrew M. O’Reilly, Martin P. Wanielista, Ni-Bin Chang, Willie G. Harris, and Zhemin Xuan: J Envir Quality, vol. 41, March 2012.
- Nutrient removal using biosorption activated media: Preliminary biogeochemical assessment of an innovative stormwater infiltration basin
  - Andrew M. O'Reilly, Martin P. Wanielista, Ni-Bin Chang, Zhemin Xuan , Willie G. Harris: Science of the Total Environment 432, 2012: 227–242

PUBLICATIONS continued

1. O’Reilly, et.al. 2011. “Soil Property Control of Biogeochemical Processes beneath Two Subtropical Stormwater Infiltration Basins, 2012.” *Journal of Environmental Quality 41(2), 564–581—*

2. O’Reilly, et. al. 2011. “Cyclic Biogeochemical Processes and Nitrogen Fate beneath a Subtropical Stormwater Infiltration Basin,” *Journal of Contaminant Hydrology* —

3. O’Reilly, et. al. 2012. “Nutrient Removal Using Biosorption Activated Media: Preliminary Biogeochemical Assessment of an Innovative Stormwater Infiltration Basin,” *Science of the Total Environment* —

4. O’Reilly, et.al. 2012. “System Dynamics Modeling for Nitrogen Removal through Biosorption Activated Media in a Stormwater Infiltration Basin,” *Science of the Total Environment* —

5. Wanielista, et.al. 2011. Nitrogen Transformation beneath Stormwater Retention Basins in Karst Areas. FDEP S0316, Tallahassee.

6. Wanielista, et.al. 2013. Stormwater Harvesting Using Retention and In-Line Pipes for Treatment Consistent with the new Statewide Stormwater Rule. FDOT BDK78 977-02, Tallahassee.

CONCLUSIONS

1. Over 15 years of experience measuring BAM (Bold & Gold) to remove nutrients from stormwater.

2. Sorption media controls surface/subsurface oxygen exchange by maintaining elevated moisture content, thereby controlling biogeochemical processes and N and C cycling.

3. Retrofitting infiltration areas using BAM resulted in decreased nitrate concentrations, which is partly due to intermittent denitrification, and decreased phosphorus, which is likely due to sorption.

4. About 60-90% reduction in nitrate, and about 80-90% reduction in phosphorus are achievable and typical removal ranges.

5. System dynamics modeling can provide quantitative estimates of N budget and fluxes, which indicated that in stormwater BMPs with BAM, there is nitrogen removal and it was occurring predominantly in the BAM layer.

6. Most WMDs giving credit.

COMMENTS AND DISCUSSION (BAM) TO REDUCE NUTRIENTS IN STORMWATER

By Marty Wanielista