Bob Pitt, Emeritus Cudworth Professor of Urban Water Systems
Department of Civil, Construction, and Environmental Engineering
University of Alabama, Tuscaloosa, AL USA

B.S. Engineering Science, Humboldt State University, Arcata, CA 1970.
MSCE, San Jose State University, San Jose, CA 1971.
Ph.D., Environmental Engineering, University of Wisconsin, Madison, WI 1987.

50 years working in the area of urban water and wet weather flows, focusing on the effects, sources, and control of stormwater. About 100 publications, including several books.

Biofilter Media Performance Updates for WinSLAMM

Bob Pitt, Emeritus Cudworth Professor of Urban Water Systems, University of Alabama

Shirley Clark, Professor, Penn State – Harrisburg, Middletown, PA

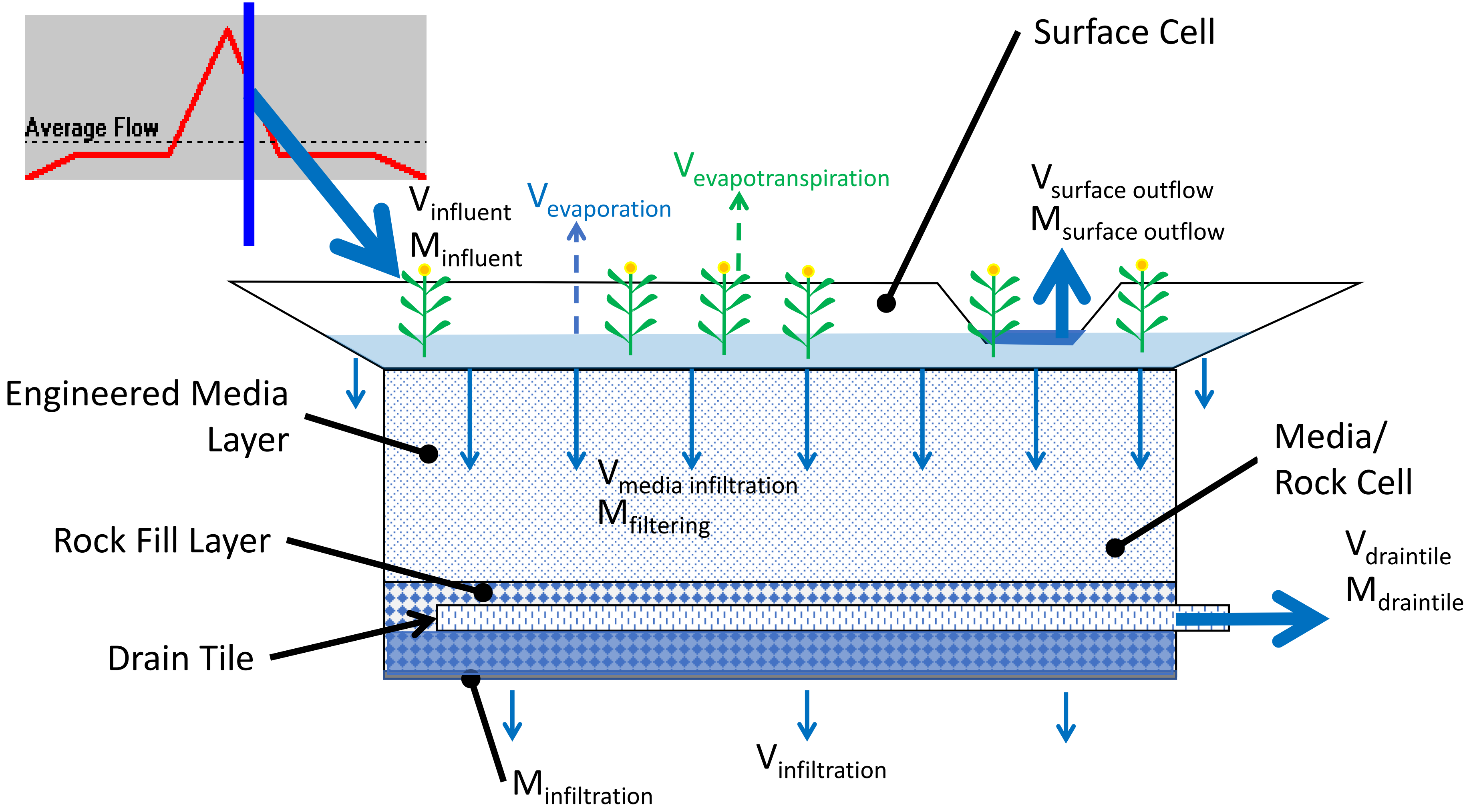
Redi Sileshi, Associate Professor, University of North Georgia, Gainesville, GA

John Voorhees, Principal, PV & Assoc., Madison, WI

Stormwater Infiltration Controls Included in WinSLAMM

- Bioretention/biofiltration areas
- Rain gardens
- Porous pavement
- Grass swales and grass filters
- Infiltration basins and trenches
- Disconnections of paved areas and roofs from the drainage system
- Also considers evapotranspiration, tree canopy interception, effects of compacted soils, and beneficial uses of stormwater (such as landscape irrigation)

Biofilter Runoff and Pollutant Removal Processes in WinSLAMM



$$V_{surface\ effluent} = V_{influent} - V_{infiltration} - V_{evapotranspiration} - V_{evaporation} - V_{surface\ overflow} - V_{media\ infiltration}$$
$$V_{media/rock\ cell\ effluent} = V_{media\ infiltration} - V_{infiltration} - V_{draintile}$$
$$M_{effluent} = M_{influent} - M_{filtering} - M_{infiltration} - M_{surface\ outflow}$$

Example Laboratory and Pilot-Scale Research of Stormwater Treatment Media (mostly funded by US EPA, Water Environment Research Foundation, and Industry)

Developing Media Mixtures Targeting Treatment Objectives



Some laboratory and field pilot-scale test setups (EPA and WERF-supported research at Univ. of Alabama). Critical that tests use actual stormwater, not artificial mixtures.

Typical Laboratory Media Tests

Media	Description
Granular Activated Carbon (GAC)	VCC 8X30 Virgin Coconut Shell Activated Carbon (Baker Corp.); 29 lbs/ft^3 (1.8 to 2.1 g/cm^3); \$0.98/lb
Rhyolite Sand	D1 biofilter media sand (Rhyolite Topdressing Sand) from Golf Sand, Inc., North Las Vegas, NV;75 in/hr infiltration rate; particle density 2.38 g/cm^3; bulk density 1.28 g/cm^3; 98.6% sand, 1.1% silt, 0.3% clay; 45.4% greater than 0.25 mm; 44.6% between 0.18 and 0.25 mm.
Site Zeolite	Z-200 Modified Zeolite (Baker Corp.); \$1.36/lb
Surface Modified Zeolite	14-40 Saint Cloud Zeolite with 325 µm Modified Zeolite at 3% Vol:Vol
Sphagnum Peat Moss	Purchased from nursery in Elizabethtown, PA
Site Sand	Fine textured silica sand

Laboratory Column Flow Tests

Three levels of compaction were used to modify the density of the media in the columns during the tests (hand compaction, standard proctor compaction, and modified proctor compaction) on the infiltration rates through the various media mixtures.

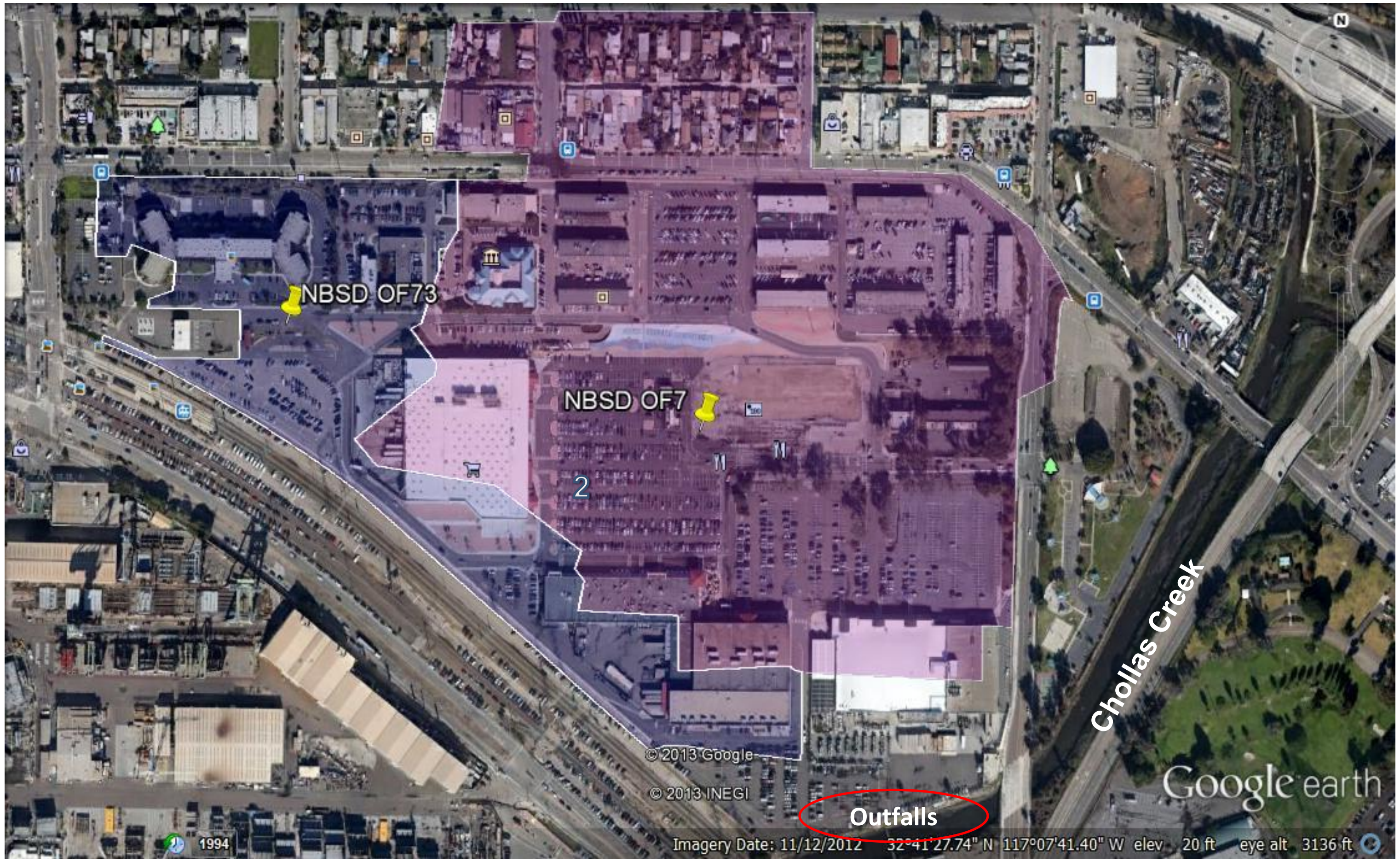
- The bottom of the columns had a fiberglass window screen and a gravel layer to contain the media.
- The columns were filled with the various media mixtures on top of the gravel layer.
- Both standard and modified proctor compactions follow ASTM standard (D 1140-54).
- The densities were directly determined by measuring the weights and volume of the media material added to each column.
- More than 200 flow tests were conducted for many media mixtures and compaction levels.

Example Full-Scale Monitoring of Stormwater Treatment using Media

Confirming Measured Results of Laboratory Tests and WinSLAMM Model Use (funded by US EPA, States, Municipalities, Industry, and US Navy)

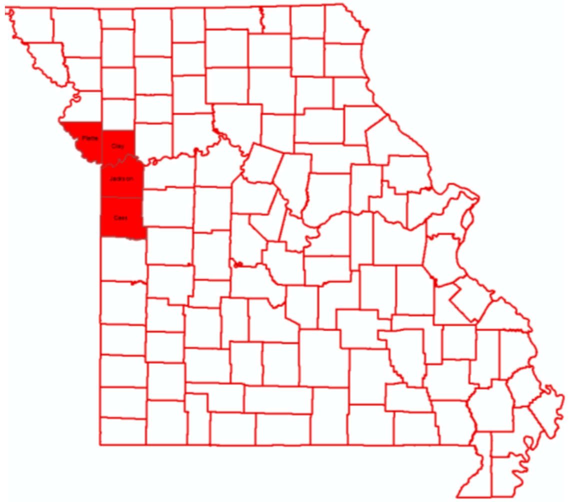
Minocqua, WI, MCTT (multi-chambered treatment train) Installation

Naval Base San Diego (NBSD) Monitoring and Modeling to Identify Major Pollutant Sources and Control Options (many outfalls and drainage areas at 15 naval bases investigated)

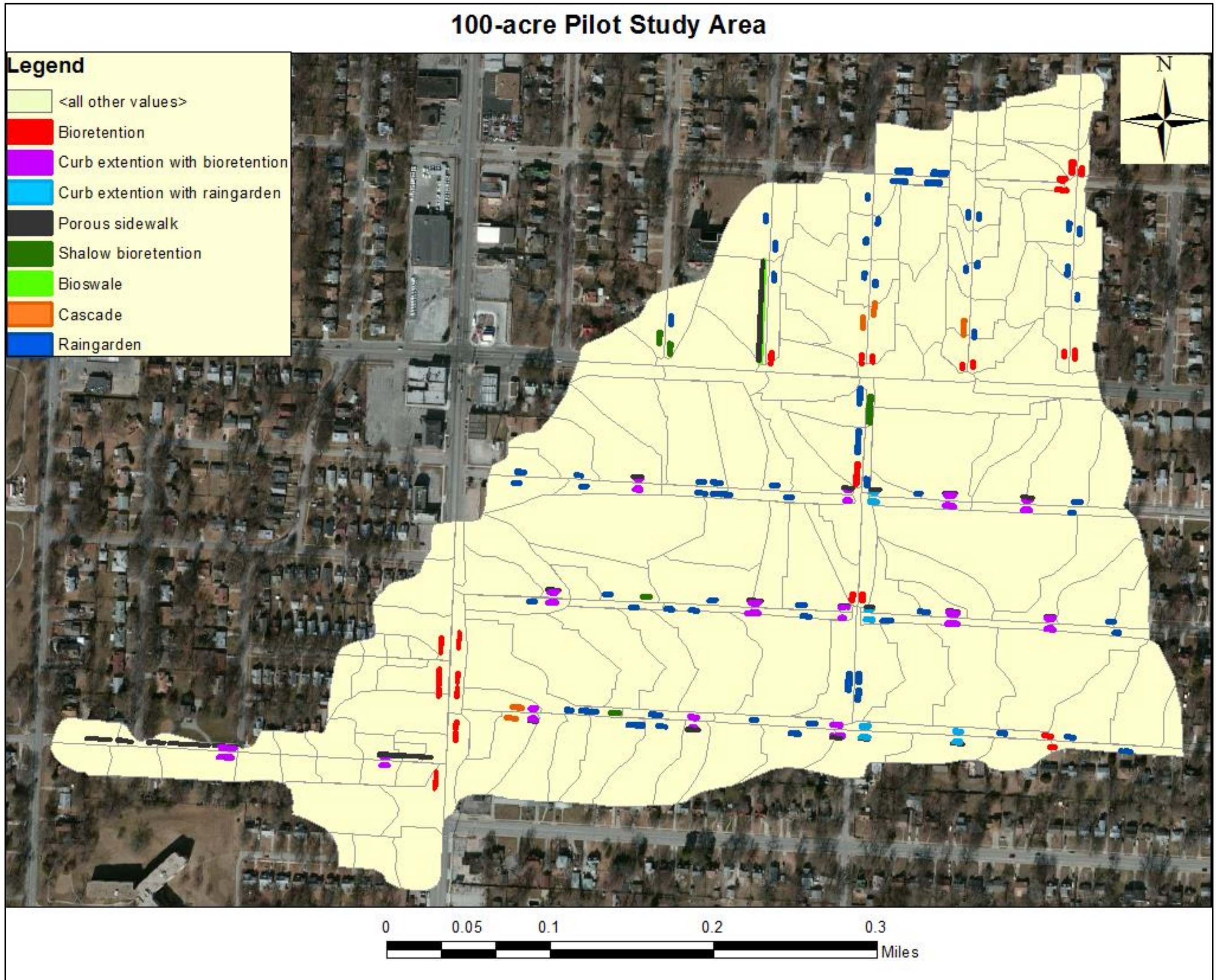


Previous modeling project identified roof runoff and paved parking as primary sources of copper and zinc in most drainage areas

Locations of Stormwater Controls in Test Watershed
Kansas City, MO
Main Combined Sewer Monitoring Supplemented with Performance Monitoring at Individual Stormwater Controls

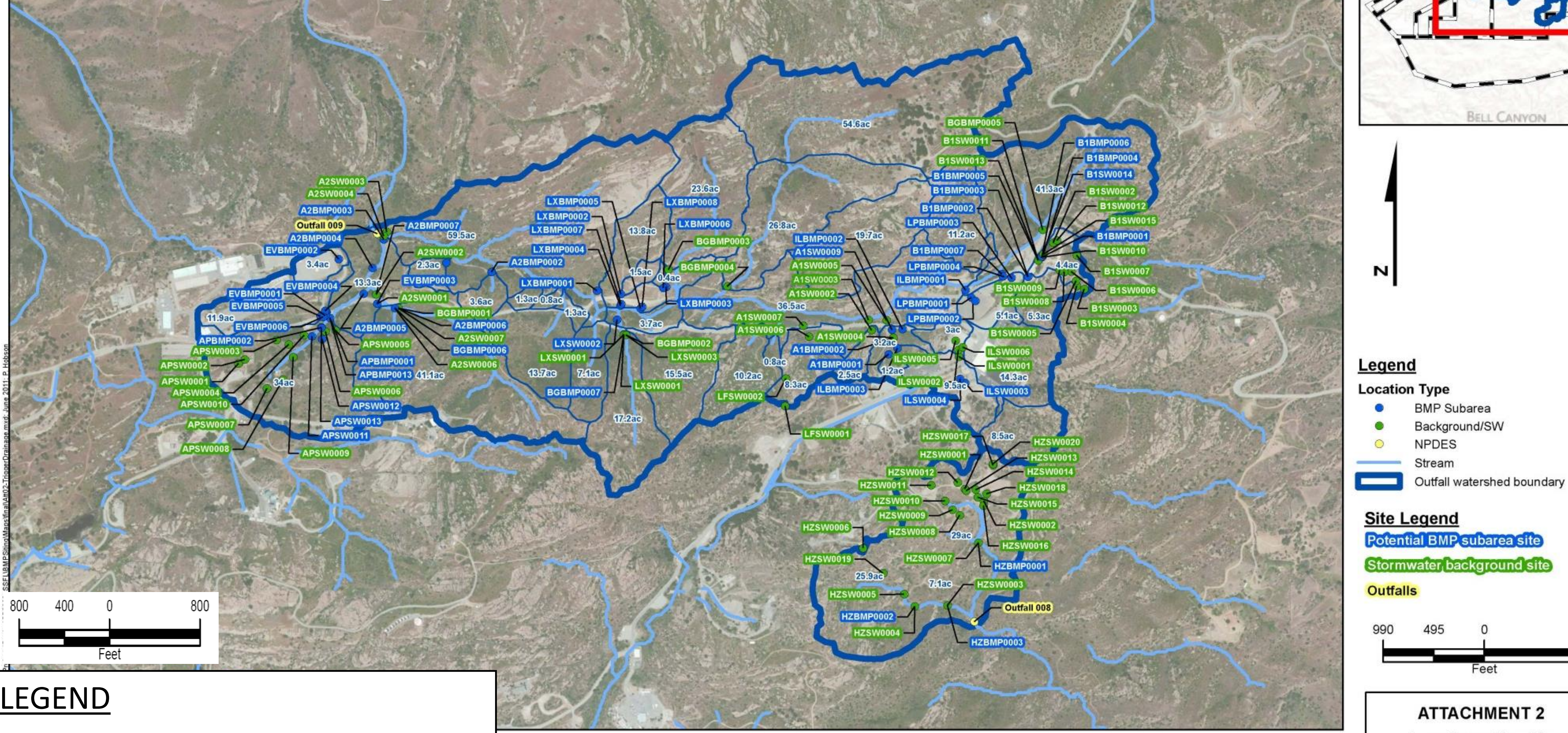


More than 100 stormwater controls located in right-of-ways along streets so city could legally maintain the practices as required in their CSO consent decree.



Small-scale performance monitoring at Kansas City, MO

Monitoring Locations at SSFL



LEGEND

- Potential BMP subarea site
- Stormwater background site
- Outfall monitoring site

About 50 performance locations, 12 background sites and up to 21 potential stormwater control subareas monitored each year, in addition to NPDES outfall locations.

Preparing Recommended Media for Large Biofilters

1. Filling individual media bags prior to mixing

2. Loading Rhyolite sand media bags into mixer

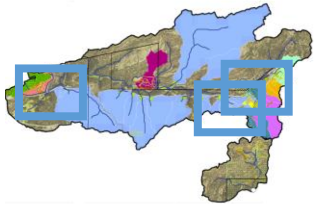
3. Loading surface modified zeolite media bags into mixer

4. Loading granular activated carbon media bags into mixer

5. Finished mixed media loaded into final bags

6. Mixed media ready for placement into biofilters

Example 009 Stormwater Controls

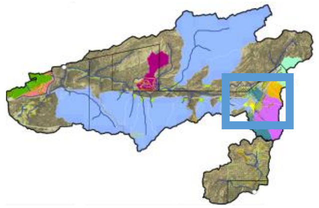


12 Culvert Modifications

Sedimentation Basin and Biofilter

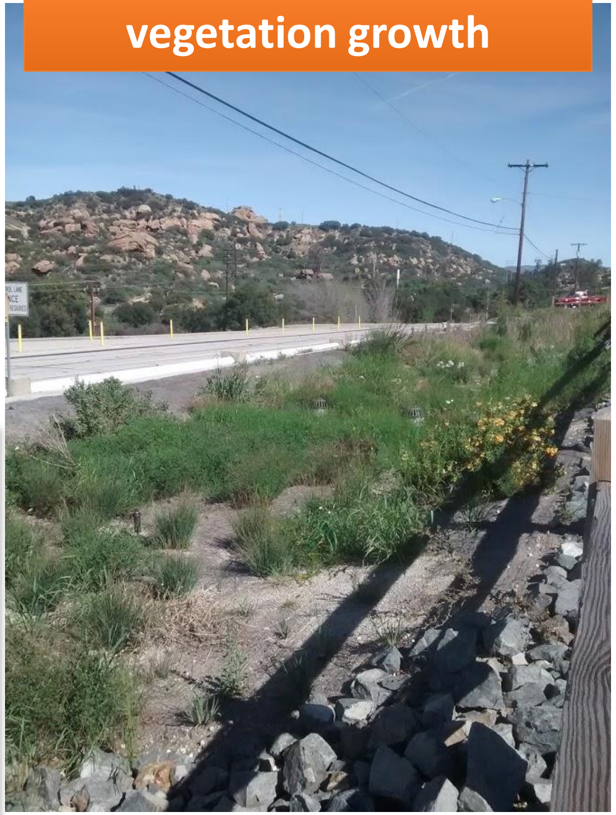
Expendable Launch Vehicle (ELV) Treatment System

Detention Bioswales

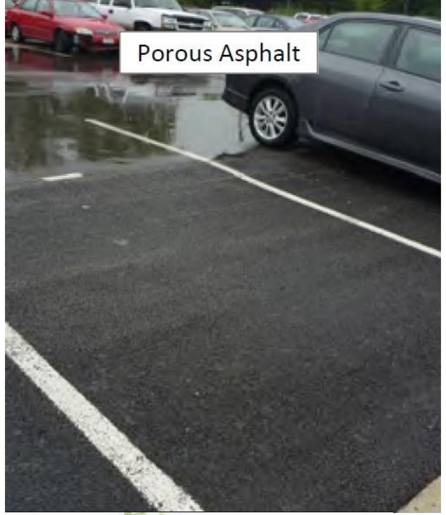


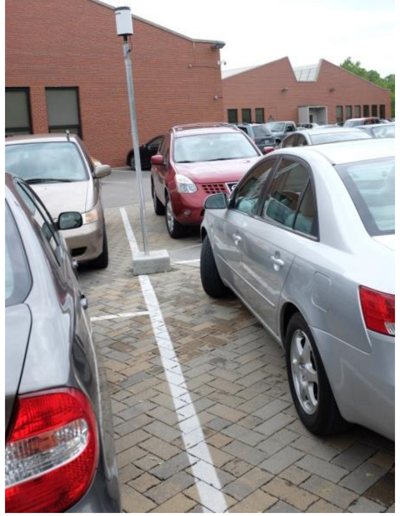
During construction

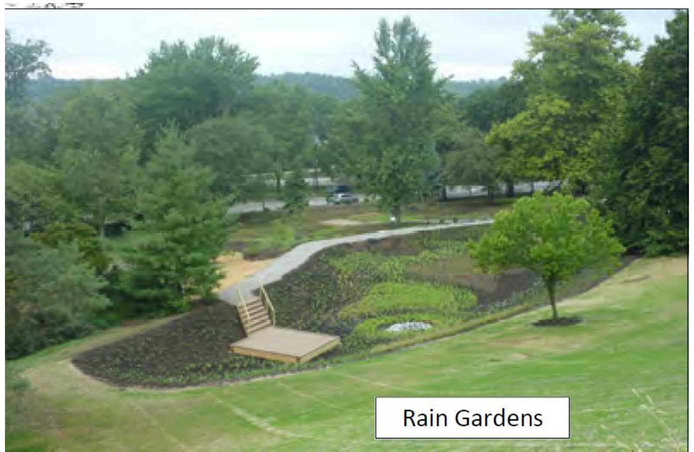
After construction/ vegetation growth

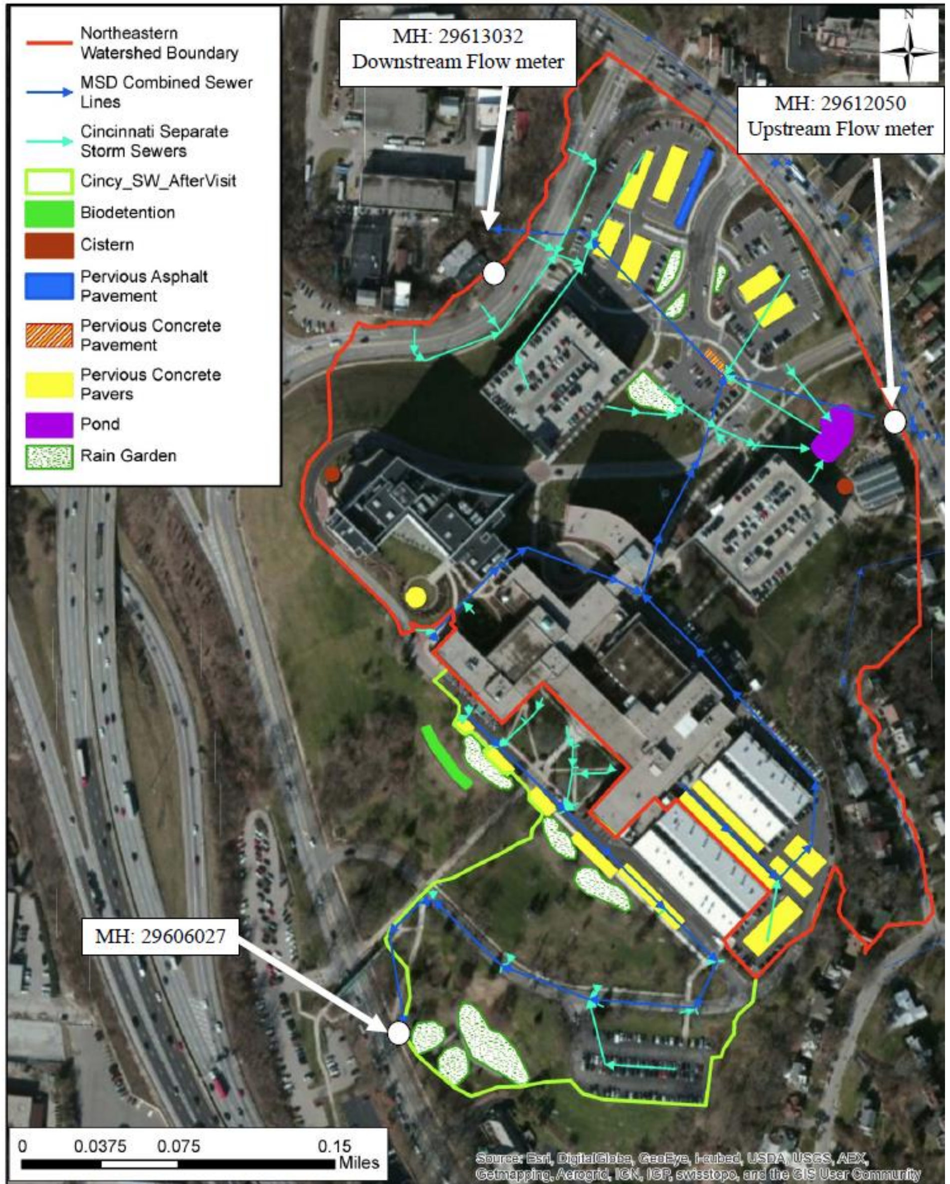


Cincinnati State Technical College, Example of Demonstration Site Monitoring



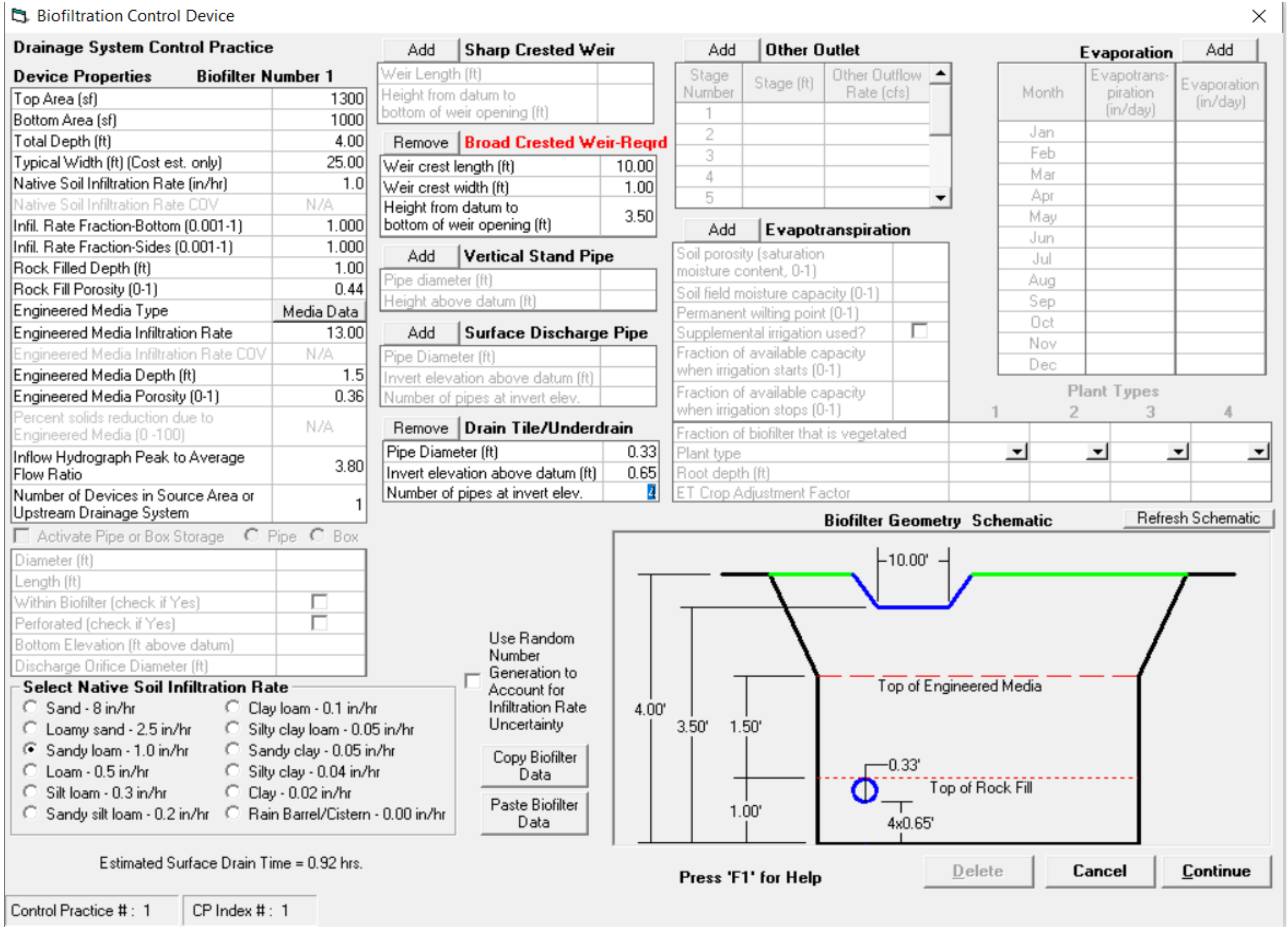






WinSLAMM Stormwater Treatment Evaluations using Media

Main WinSLAMM Biofilter/Bioinfiltration Data Input Form



Media Component Input Form

Media Categories and Types:

- Soil categories
- Sands
- Chemically active amendments (activated carbon, zeolites, compost, and peat moss)
- User defined amendments
- Pre-defined media mixtures
- Example biofilter media mixtures
- These are all extensively described, with statistical evaluations, on WinSLAMM web page

Soil, Media Mixtures and Components Table

Soil Type Texture	Saturation Water Content % (Porosity)	Field Capacity (Percent)	Permanent Wilting Point (Percent)	Infiltration Rate (in/hr)	Fraction of Soil Type Texture in Engineered Soil (0-1)
Sandy Clay	40	34	17	0.05	
Silty Clay	55	33.5	18	0.015	
Clay	55	33.5	18	0.015	
Other Media					
Fine Rhyolite Sand	38	8	2.5	13	
Fine Sand	38	8	2.5	13	
Filter Sand	38	8	2.5	13	0.700
Coarse Sand	32	4	0	40	
Gravel	32	4	0	40	
Light Media for Green Roofs	50	20	5	13	
Chemically Active Amendments					
Activated Carbon	32	4	0	40	0.200
Fine Zeolite	32	4	0	40	
Coarse Zeolite	32	4	0	40	0.100
Compost	61	55	5	3	
Peat Moss	78	59	5	5.8	
User Defined Amendments					
Phosphorus Sorption Media					
Biochar					
Pre-Defined Media Mixtures					
Rhyolite Sand - SMZ	43	4	0	25	
Rhyolite Sand - SMZ-GAC	41	4	0	25	
Rhyolite Sand - SMZ-GAC-PM	43	10	0.5	25	
Iron Fillings (7.5%) / Sand	38	8	2.5	13	
Iron Fillings (10.2%) / Sand	38	8	2.5	13	
Biofilter Media Mixtures					
Kansas City	40	12	10	.55	
Wisconsin 1	40	10	5	25.1	
Wisconsin 2	40	10	5	20.5	
North Carolina	40	7	5	18.7	
Composite Soil Mixture Properties	36.2	6.8	1.8	13.000	1.000

Apply Soil Mixture Values as a User Defined Soil Mixture

☑ Apply Porosity ☑ Apply Field Capacity ☑ Apply Wilting Point ☑ Apply Infiltration Rate ☑ Apply All Values

Cancel Continue

The new data components for media types include:

- Flow rate equations based on media type, organic content, texture, and uniformity
- Regression equations for removal of several particle size ranges
- Flow rate reduction and clogging due to particulate retention
- Filterable and particulate pollutant retention
- Filterable pollutant retention based on contact time
- Breakthrough of pollutants as media retains filterable pollutants

Incorporating these data significantly expands the ability to compare alternative biofilter design options.

WinSLAMM Output Summary Form

File Name:

C:\WinSLAMM Files\Example Files\biofilter media tests\BF1.mdb

Outfall Output Summary

	Runoff Volume (cu. ft.)	Percent Runoff Reduction	Runoff Coefficient (Rv)	Particulate Solids Conc. (mg/L)	Particulate Solids Yield (lbs)	Percent Particulate Solids Reduction
Total of All Land Uses without Controls	75906		0.65	130.0	616.0	
Outfall Total with Controls	36939	51.34 %	0.32	43.69	100.8	83.64 %
Current File Output: Annualized Total After Outfall Controls	37041	Years in Model Run:	1.00		101.0	

Pollutant (1)	Concen-tration - No Controls	Concen-tration - With Controls	Concen-tration Units	Pollutant Yield - No Controls	Pollutant Yield - With Controls	Pollutant Yield Units	Percent Yield Reduction
Particulate Solids	130.0	43.69	mg/L	616.0	100.8	lbs	83.64 %
Total Phosphorus	0.2150	0.09217	mg/L	1.019	0.2126	lbs	79.14 %
Total Copper	21.15	13.88	ug/L	0.1002	0.03200	lbs	68.06 %

Print Output Summary to .csv File

Print Output Summary to Text File

Print Output Summary to Printer

Total Area Modeled (ac): 1.000

Total Control Practice Costs

Capital Cost	N/A
Land Cost	N/A
Annual Maintenance Cost	N/A
Present Value of All Costs	N/A
Annualized Value of All Costs	N/A

Perform Outfall Flow Duration Curve Calculations

Receiving Water Impacts Due To Stormwater Runoff

(CWP Impervious Cover Model)

	Calculated Rv	Approximate Urban Stream Classification
Without Controls	0.65	Poor
With Controls	0.32	Poor

Control Practice Output Screen

Land Uses | Junctions | **Control Practices** | Outfall | Output S

Runoff Volume | Part. Solids Yield (lbs) | Part. Solids Conc. (mg/L) | **Summary Tabl**

Data File: C:\WinSLAMM Files\E db
Rain File: WisReg - Madison WI
Date: 02-07-20 Time: 03:59:18 F
Site Description:

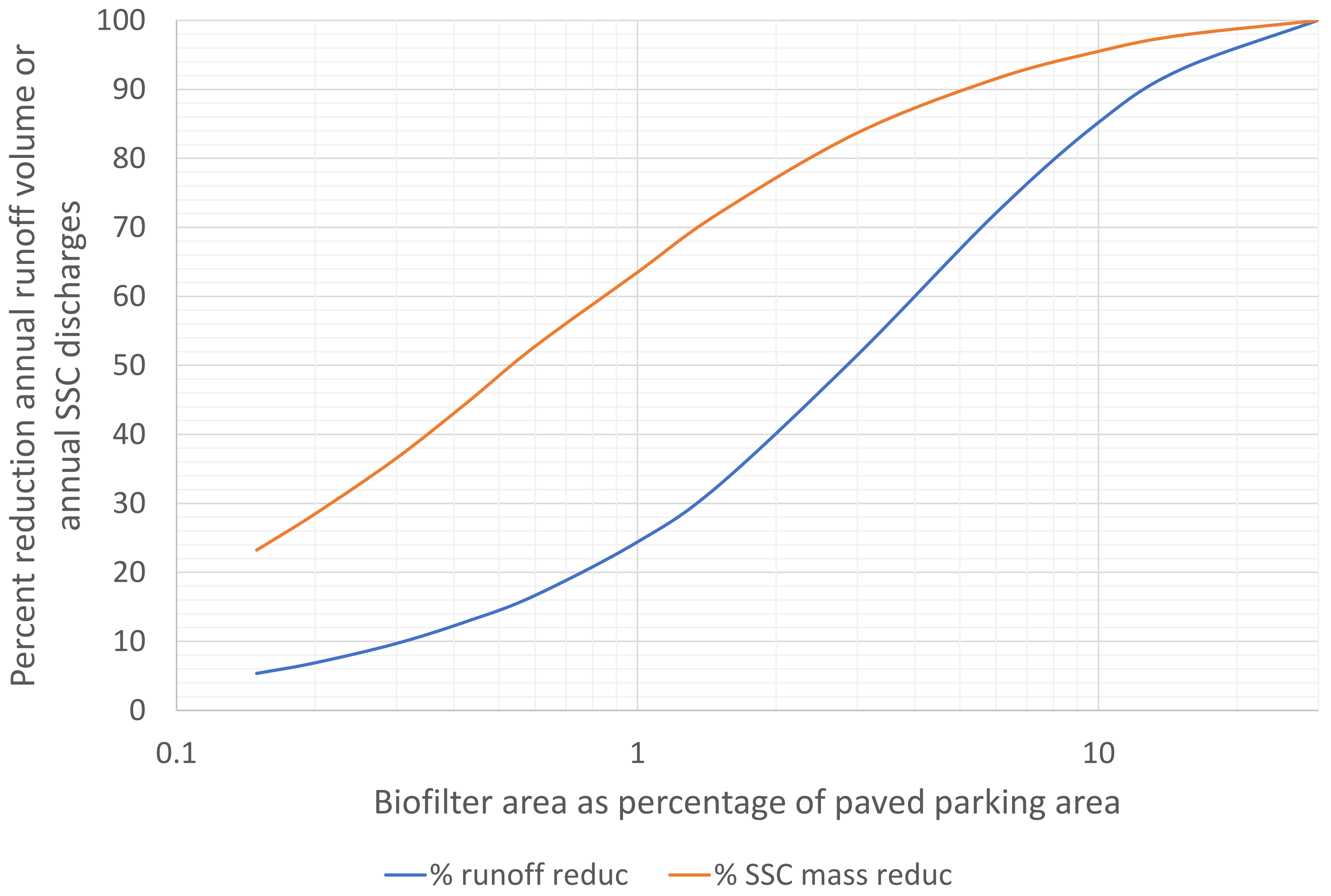
Col. #:	2	4	5	6	7	8	9	10	11	12	13	14	15
Control Practice No.	Control Practice Type	Total Inflow Volume (cf)	Total Outflow Volume (cf)	Percent Volume Reduction	Total Influent Load (lbs)	Total Effluent Load (lbs)	Percent Load Reduction	Flow Weighted Influent Conc (mg/L)	Flow Weighted Effluent Conc (mg/L)	Percent Conc. Reduction	Influent Median Part. Size (microns)	Effluent Median Part. Size (microns)	Notes
1	Biofilter	75906	36938	51.34	616.0	100.8	83.64	130.0	43.69	66.391	7.80	2.31	No Biofilter Overflows

Junctions | **Control Practices** | Outfall | Output Summary

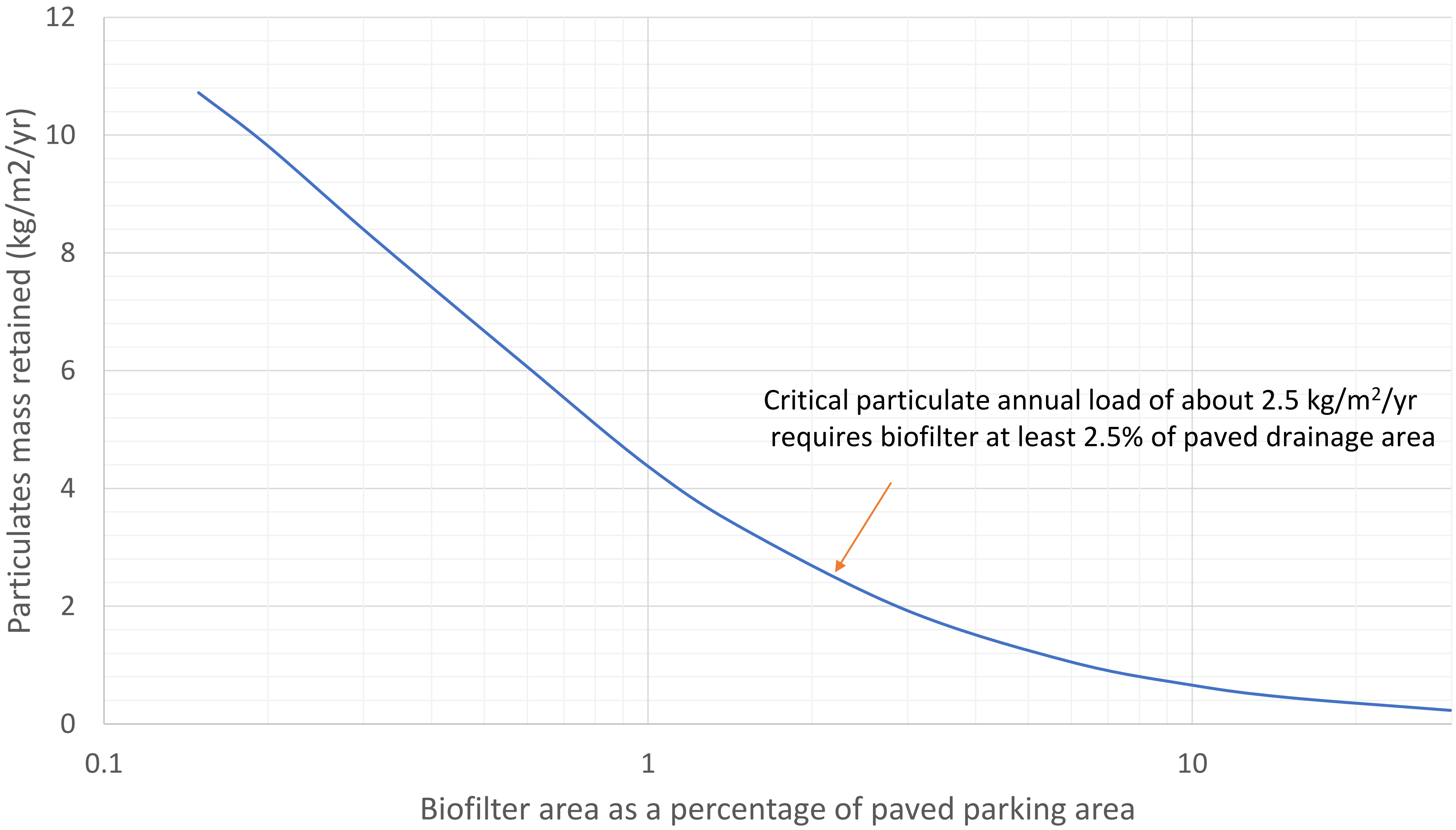
Part. Solids Yield (lbs) | Part. Solids Conc. (mg/L) | **Summary Table**

18	19	27	28	29	30	31	32	33	34	35	39	54	61
Maximum Stage (ft)	Hydraulic Volume Out (cf)	Maximum Surface Ponding Time (hrs)	Maximum Subsurface Ponding Time (hrs)	Volume Infiltrated (cf)	Underdrain Discharge Vol. (cf)	Evapo-Transpir. Vol. (cf)	Minimum Soil Moist. (frac)	Surface Discharge Bypass Vol. (cf)	Evap. Vol. (cf)	Volume Supplemtl. Irrig.(cf)	Surface Ponding Events >72 hrs (Count)	Residence Time in Media (hrs)	Runoff Producing Events/ Ttl. Rains
3.60	37049	4.4	6.96	39058.32	35265			1784.22			0	0.50	30/90

Example Production Function Comparing Biofilter Performance for Different Biofilter Sizes

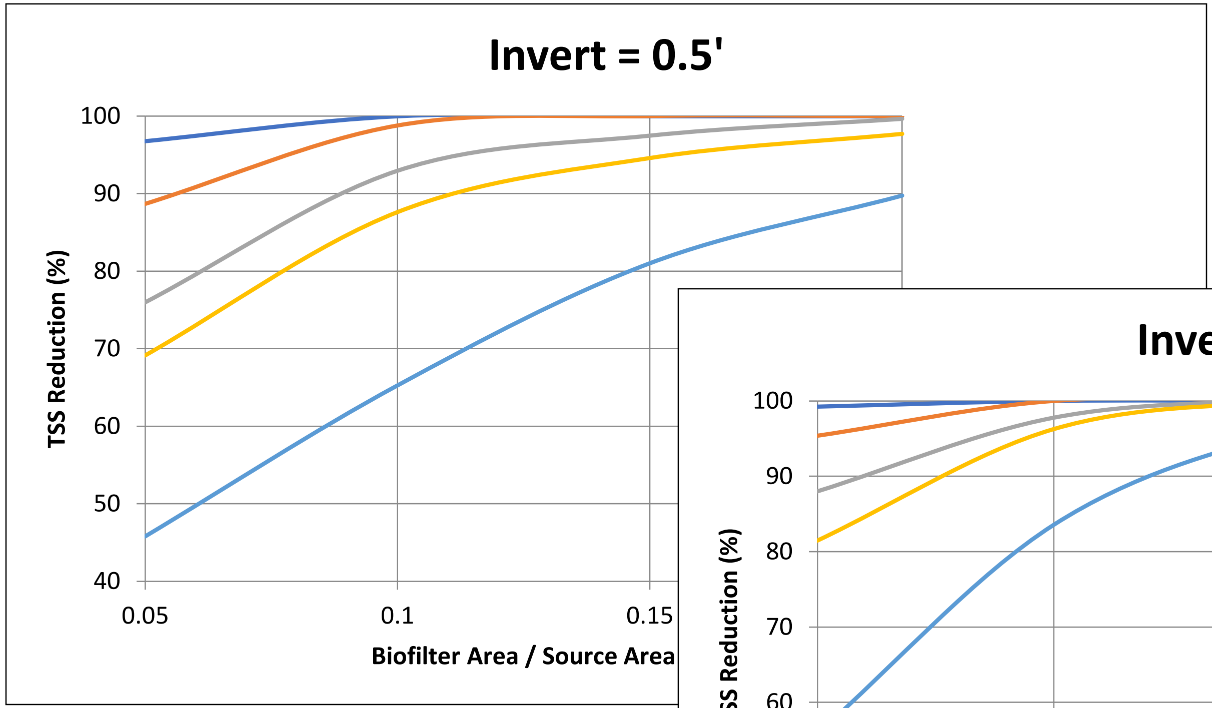


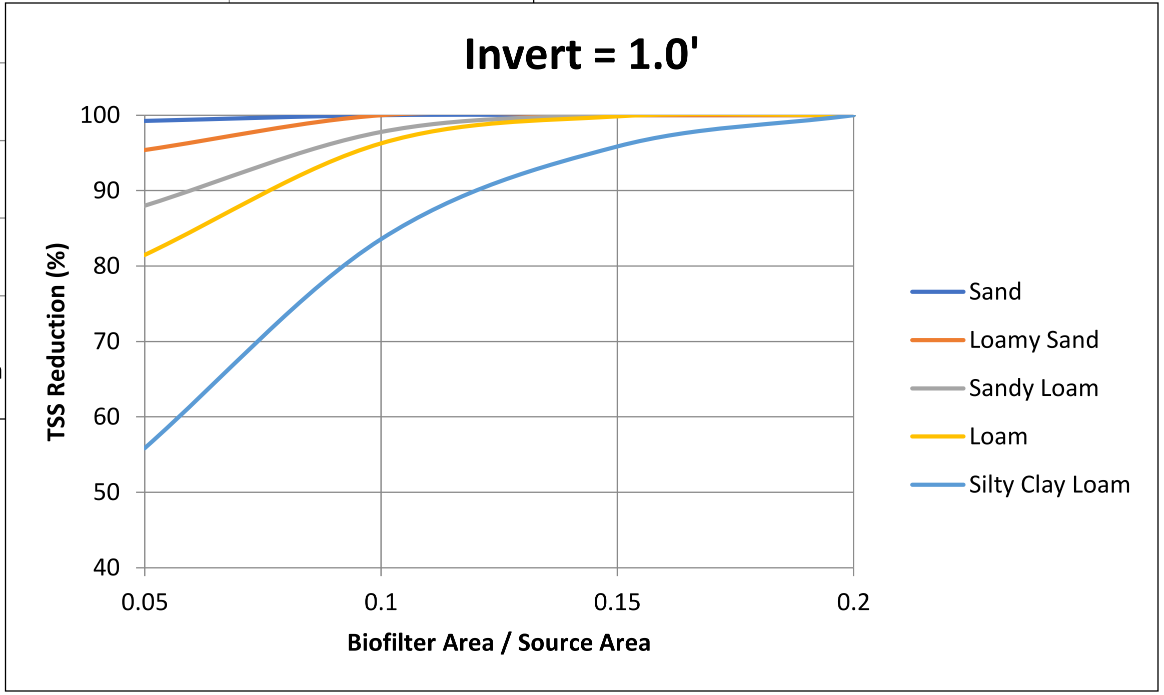
Example Plot of Cumulative Load and Useful Life of Media in Biofilter



WisDOT Design Charts Developed from WinSLAMM Model Runs

Soil Type	Static Infiltration Rate
Sand	3.60 in/hr.
Loamy Sand	1.63 in/hr.
Sandy Loam	0.50 in/hr.
Loam	0.24 in/hr.
Silty Clay Loam	0.04 in/hr.





Conclusions

- Media selection dramatically affects the treatment flow rate, and to a lesser extent the pollutant retention capacity of a biofilter.
- Most of the pollutant removals in bioinfiltration are likely through infiltration into the underlying native soils (with pretreatment provided by the media), while physical capture of particulates and associated particulate bound pollutants is mostly affected by the texture and uniformity of the media.
- Filtered pollutant retention in biofilters can be targeted by the proper selection of chemically active media.
- Biofilter performance can be limited by poor media selection causing compaction and clogging.
- The most robust biofilters are sized properly to decrease the effects of sediment induced clogging and to provide moderate treatment flow rates.
- The use of WinSLAMM can be used to produce production functions that relate accumulative load with size of the biofilter and useful life for specific site conditions and expected rainfall.