Pennsylvania

Villanova University Stormwater Best Management Practice

Section 319

National Monitoring Program Project

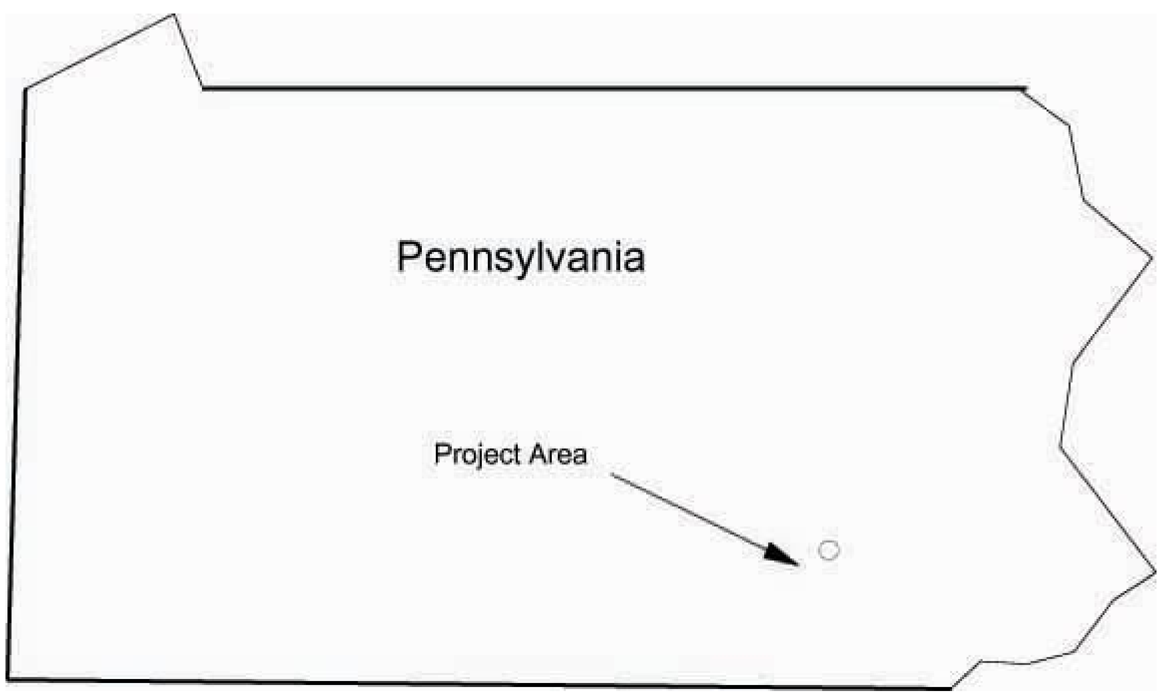


Figure 42: Villanova University Stormwater Best Management Practice (BMP) Monitoring Project.

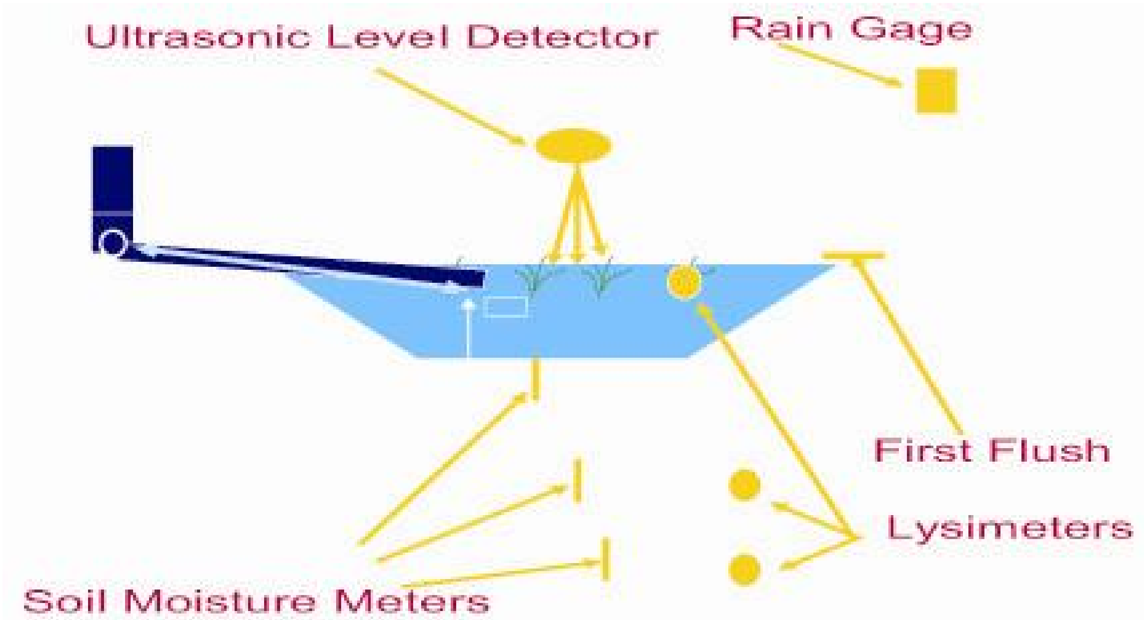


Figure 43. Bio-Infiltration Traffic Island Monitoring Setup

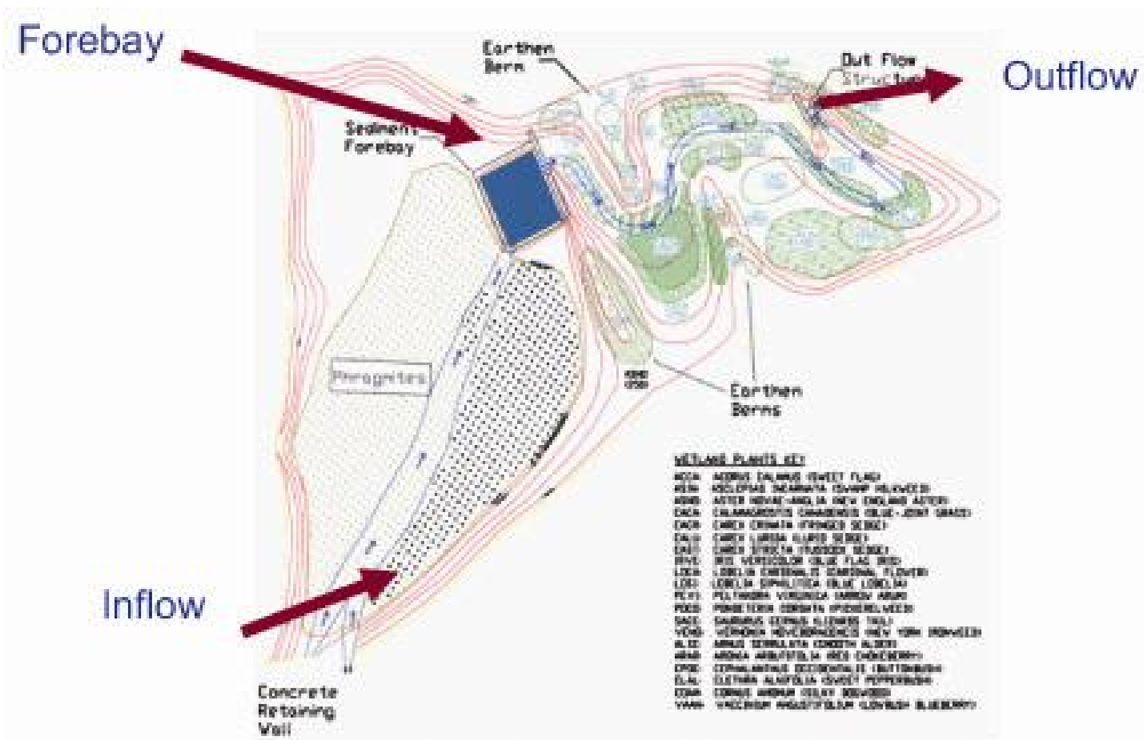


Figure 44. Stormwater Wetland Monitoring Setup

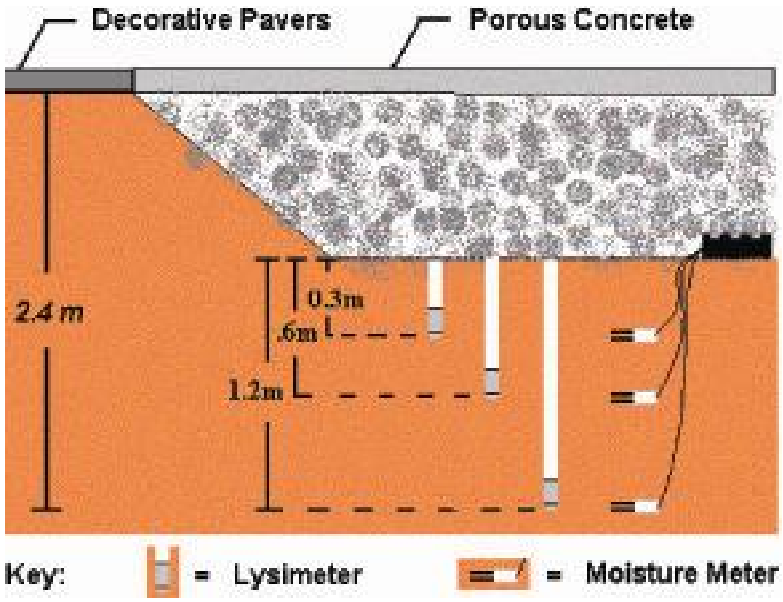


Figure 45 – Porous Concrete – Cross section of instrumentation (Kwiatkowski 2003)

PROJECT OVERVIEW

The goals of the the EPA National Monitoring Program and the Villanova University Stormwater Best Management Practice Park Research and Demonstration Park are (NCSU 2000):

1)To scientifically evaluate the effectiveness of watershed technologies designed to control nonpoint source pollution; and

2)To improve our understanding of nonpoint source pollution.

By monitoring wet weather flows and pollution entering and exiting multiple stormwater Best Management Practices (BMP) in both storm and baseflow conditions, the effectiveness of these technologies can be measured and evaluated. Indirect results will provide data that can be used for research on nonpoint source pollution modeling and TMDL development.

During the last decade there has been a rapidly increasing interest in the use of BMPs to treat various forms of water pollution including runoff and peak flows. Recognizing the need for research and public education, Villanova has created a Stormwater BMP Research and Demonstration Park on campus. To date, multiple BMP devices have been constructed including a Stormwater Wetlands, a Bio-Infiltration Traffic Island, a Pervious Concrete Infiltration area, an Infiltration Trench, a porous asphalt site, and a green roof. Also existing sites include traditional wet and dry ponds, and a historic seepage pit.

Monitoring of smaller urban devices is extremely complex. During 2006, the Pervious Concrete site concluded monitoring, while the Infiltration Trench, and BioInfiltration Traffic Island were considered the main focus of the National Monitoring program. The Laboratory QA/QC was made more stringent, and new sampling locations were added to intensify the study. For 2007 these sites will be continued, and a new site, a Pervious Concrete / Posous Asphalt site is under construction to be added to the National Monitoring Program.

PROJECT BACKGROUND

Project Area

Funding for developing the BMP park concept, as well as for construction of the BMPs was provided by PaDEP through Section 319 Nonpoint Source Pollution Program and the Growing Greener initiative.

Figure 1 - VU Bioinfiltration Traffic Island BMP

Bioinfiltration Traffic Island. – (Growing Greener Grant, 2001 – concluded) A traffic island was retrofitted creating a Bioinfiltration BMP during summer 2001. The facility provides for infiltration of the initial first flush. Educational signage has been installed to enhance the learning experience, and a website has been created to facilitate technology transfer. Groundwater Monitoring has been added to this site for 2007.

Figure 2 - VU Porous Concrete BMP

Porous Concrete Demonstration Site – (319 Grant, 2002 – concluded) The 319 grant was to create a porous concrete infiltration facility in an existing central paved area on the Villanova University campus. The porous concrete site was built in 2002, but the initial concrete pour failed. This surface was replaced in the summer of 2003, but again some material problems have reemerged. Similar to the concept of the Bioinfiltration Traffic Island, runoff from the site and surrounding buildings are captured and infiltrated, decreasing the flows and pollution to a high priority stream segment on the 303(d) list. The site has a much higher capacity than the Bioinfiltration Traffic Island as it overlies a large rock holding bed. Educational signage has been installed to enhance the learning experience, and a website has been created to facilitate technology transfer. Sampling was halted at this site in Dec 2006.

Figure 3 - VU Infiltration Trench BMP

Infiltration Trench (319 Grant – Constructed August 2004). The project is designed to capture runoff from an elevated parking deck and then infiltrate it through a rock bed into the ground. The project presents some unique possibilities. As the water is piped through storm drains to the site, filtration devices can be used and tested at this site. It is the only site available with a 100% impervious drainage area. Educational signage has been installed to enhance the learning experience, and a website has been created to facilitate technology transfer.

Figure 4 - VU Pervious Asphalt BMP

Pervious Concrete / Pervious Asphalt (319 Program – NRMCA – Prince Georges County). This project is designed to capture runoff from a faculty staff parking area on campus, and then pass the flow through either a pervious concrete or porous asphalt surface course, and then infiltrate it through a rock bed into the ground. The project presents some unique possibilities, to include comparing the performance from both a hydrologic and environmental view of the technologies. Hydrocarbon testing is part of the project, and it will be added to the NMP in 2008. Educational signage will be installed to enhance the learning experience, and a website has been created to facilitate technology transfer. Note that the figure is from another similar site on campus, not the proposed PC/PA site.

http://www.villanova.edu/VUSP

Project Area

Bioinfiltration Traffic Island	Watershed – 0.53 hectares
Porous Concrete	Watershed – 0.52 hectares
Infiltration Trench	Watershed – 0.16 hectares
Pervious Concrete / Porous Asphalt	Watershed - TBD

Relevant Hydrologic, Geologic, and Meteorologic Factors

All BMPs are in the Philadelphia region. Rainfall is approximately 114 centimeters per year, with about 50% of the total volume falling in storms less then 2.5 cm. The soils are underlain by undisturbed sandy silt.

Land Use

Bioinfiltration Traffic Island - The watershed includes a student parking lot, roadway and lawn areas. It is approximately 50% impervious.

Porous Concrete - The watershed includes grassy surfaces, standard concrete/asphalt, and roof surfaces. It is approximately 64% impervious.

Infiltration Trench - The watershed consists of an elevated parking deck. It is 100% impervious.
Pervious Concrete / Porous Asphalt – Faculty / Staff Parking area – 100% impervious

Water Resources of Concern

All sites are built to mitigate the effects of urban stormwater runoff on the area streams and groundwater. This includes water quality, baseflow recharge, and stream bank protection. The Bioinfiltration Traffic Island is at the headwaters of the Darby Creek Watershed, while the other sites are in the headwaters of Mill Creek, which eventually reaches the Schuylkill River.

Water Uses and Impairments

Both Darby and Mill Creeks are degraded and listed on the 303d list, with urban runoff listed as the cause. Note that urban runoff is rated as the Nation's third highest leading source of water pollution (EPA, 1998 and 2002b). The EPA Region III website lists stormwater as the second highest cause of stream impairment as measured by river miles.

Pollutant Sources

Unlike many types of polluted water, stormwater typically is characterized by rapidly changing and widely fluctuating flows; in some instances high flow periods are accompanied by high concentrations of pollutants, leading to exceptionally elevated short-term loads to receiving waters. In addition to suspended solids, nitrogen and phosphorus, stormwater runoff may contain elevated concentrations of lead and zinc, which also have the potential to affect receiving waters adversely.

Pre-Project Water Quality

For this project, inflow to the stormwater BMP sites is treated as the pre-project water quality.

Water Quality Objectives

As stated earlier, all projects are developed to mitigate the effects of urban runoff. The three infiltration projects are designed to remove the first flush and infiltrate it into the ground, thus recharging baseflow and treating the first flush, as well as reducing volumes and peak flows.

Project Time Frame

The project time frame is to monitor all sites for six to ten years. Initial monitoring for water quality and quantity for the Pervious Concrete and Bioinfiltration Traffic Island commenced October 1, 2003. During this first year of monitoring, it was discovered that sampling from the traffic island bowl and the porous concrete rock bed did not adequately represent the inflow conditions so first flush samplers were installed for both these practices. It was also discovered that unexpected extremely large levels of chloride reduced the minimum detection level of the laboratory instruments for dissolved nutrients. These issues have been addressed through development of new laboratory techniques. The Pervious Concrete site has demonstrated that the water quality of the runoff is exceptionally clean. Thus water quality sampling for this site has been discontinued. Multiple wells were added to the Bioinfiltration site to facilitate monitoring of Groundwater.. The Infiltration Trench monitoring started in August 2004. One problem on the site is small rainfall events overflow the site and are difficult to monitor. Therefore an overflow weir and an automated sampler were added to the project during July/August of 2006. It was also determined that the grab sampler was not properly categorizing the inflows, so a composite sampler was added and previous inflow data was discarded.

Due to the experiences with these sites, the startup work is termed the "Initial Monitoring Period." Note that as all the original sampling locations are continued, the data collected during this first year will be used in analysis.

PROJECT DESIGN

Nonpoint Source Control Strategy

The control strategy is to assess flow volumes, rates and pollutant loads for wet weather flows entering and exiting the BMPs. The inflow and outflow of individual BMPs are examined.

Project Schedule

Site	Status	Initial Monitoring Phase	Notes
Bio-Infiltration Traffic Island	Monitoring Underway 10/01/04-09/30/10	10/01/03-09/30/04	IMP - added first flush samplers + bowl lysimeter. GW Well added 2006 Additional GW Wells added 2007
Porous Concrete Infiltration Site	Monitoring Concluded 10/01/04-12/30/06	10/01/03-09/30/04	IMP - added first flush samplers + gutter flow samplers. No changes after IMP.
Infiltration Trench	12/01/04-09/30/10	09/01/04-09/30/05	2006 added Automated inflow sampler Overflow Weir
Pervious Concrete / Porous Asphalt	9/1/2007- 9/1/2013		Under Construction

Water Quality Monitoring

Variables Measured

pH
Conductivity
Total Suspended Solids (surface samples)
Dissolved Solids (depending on volume collected)
Chlorides
Nutrients - N, P (Dissolved - Various Forms)
Metals - Various (Dissolved - Various Forms)
Hydrocarbons (start 9/2007)

This list is adjusted based upon what is found at the site and the direction of the research governing board. Note that some of these tests are only applicable to the surface or ground water samples (currently, spectrophometry, ion chromatography, and atomic adsorption equipment is in use - QAPP plan is in place). As stated earlier, unexpected extreme values of high chlorides from road salt interfered with the nitrates, nitrites, and orthophosphate HPLC analysis for the first several years. A new analysis technique was developed to address this situation.

Sampling / Flow Monitoring Scheme

Infiltration Sites – Each site has rain gages, water sampling devices, and flow or level recorders as appropriate. Flow leaving the site is split into infiltration and overflow for large storm events. As sampling is conducted from the vadose zone, soil lysimeters will be used to collect water samples under the beds (treated as a composite sample). Note that only dissolved fractions are collected from the vadose zone samples and that the sample size is limited, occasionally limiting the number of tests performed.

Bioinfiltration Traffic Island – A level detector is used to measure the rate of infiltration from the surface bowl, and outflow is measured using a weir in the culvert leaving the site. Soil moisture meters and lysimeters have been placed under the bed. For the past year, inflow water samples for quality analysis were taken from the water bowl above the bed. As considerable removal in the stone beds leading to this BMP has been observed, "first flush" flow samplers have been installed to better represent the inflows to the site. These devices are installed to capture water samples where the runoff enters the site through curb cuts. Ground water quality (outflow) is measured using lysimeters located at the bottom of the made soil (multiple depths and locations). Surface water outflow (only large storms) grab samples are taken from the bowl. A well was added to the site in 2006 to learn more about the site interaction with the groundwater. In 2007 several more were drilled, and pressure transducers with conductivity meters were added to allow for study of the groundwater hydrology from both the hydrology and environmental perspective.

Pervious Concrete Demonstration Site – Inflow water quality is measured using first flush and gutter composite samples. Two sets of six soil moisture meters and lysimeters are placed both under and adjacent to the bed at two locations. These are used to determine the outflow groundwater quality and quantity. Overflow outflow (large storms only) from the site is measured at a weir in the culvert leaving the site. Composite water samples for quality measurement of the surface water overflows are taken through a port in the rock bed.

Infiltration Trench – As the site is unique in categorizing the nonpoint pollutant contribution of a paved area, this site is treated differently. A rain gage is on site, and runoff inflow is measured using a pressure transducer and V-notch weir. An automated sampler has been added to measure the inflow water quality at the V notch weir. Pressure transducers and soil lysimeters are used to evaluate the depth within the rock bed, volume of infiltration (outflow), and and pollutant loadings (Outflow). An overflow weir was added to improve outflow measurements for larger storm events. Again, as the overflow outflows are essentially untreated, the outflow surface water quality is considered the same as the inflow.

Pervious Concrete / Porous Asphalt – will follow the concept as developed for the porous concrete site. This will be developed and reported in nest years report.

Modifications Since Project Start

2005 - "First Flush" samplers were added to the Bioinfiltration Traffic Island and Pervious Concrete and a gutter flow collection device was added to the Pervious Concrete site in 2004.

2006 - A groundwater well was added to the Bioinfiltration Site, and an overflow weir and an automated sampler was added to the infiltration Trench.

2007 Additional Groundwater Wells added to the Bioinfiltration Site. Second weir added to the Infiltration Trench inflow.

DATA MANAGEMENT AND ANALYSIS

Data from the data collection have been entered into the ASCE / EPA Stormwater BMP database and are the focus of numerous theses available through the VUSP website. Multiple Journal articles have been published with more under review. What is new this year is the ability to compare performance across multiple sites for the same storm event.

Flow Example – All Infiltration Sites.

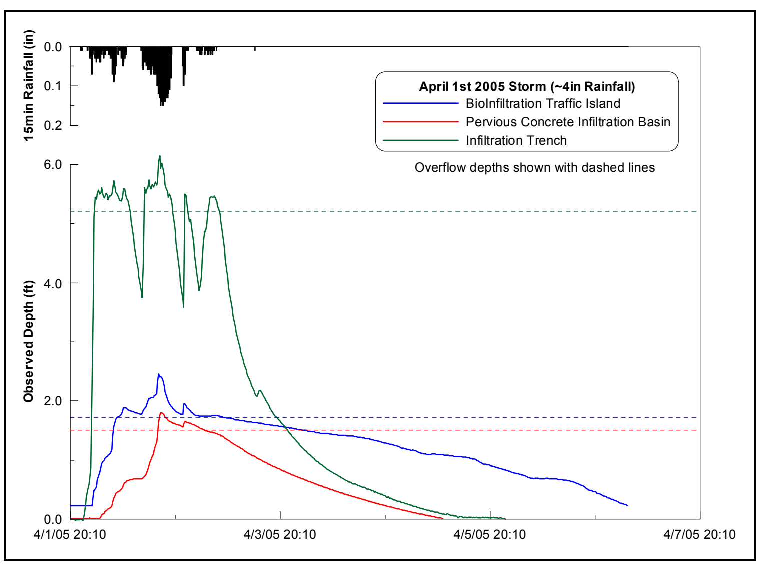


Figure 5 - BMP Volume performance (Emerson 07)

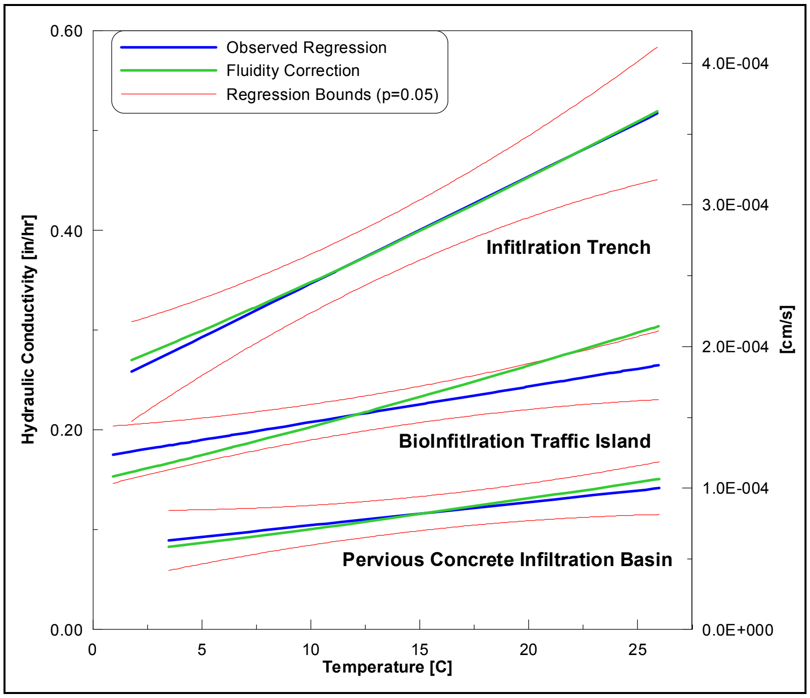


Figure 6 - Overlay of linear regressions for all three infiltration BMPs (Emerson 07)

Water Quality / Quantity Findings To Date

Bio-Infiltration Traffic Island

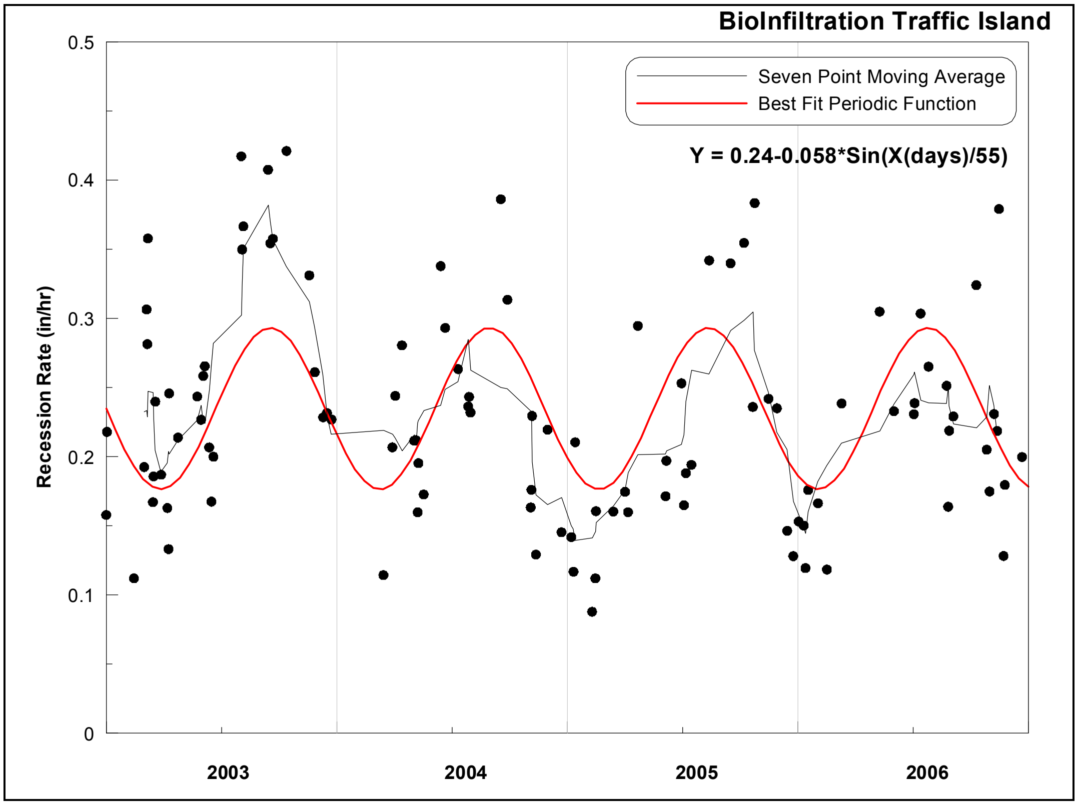


Figure 7 - Seasonal Infiltration Rate (Emerson 07)

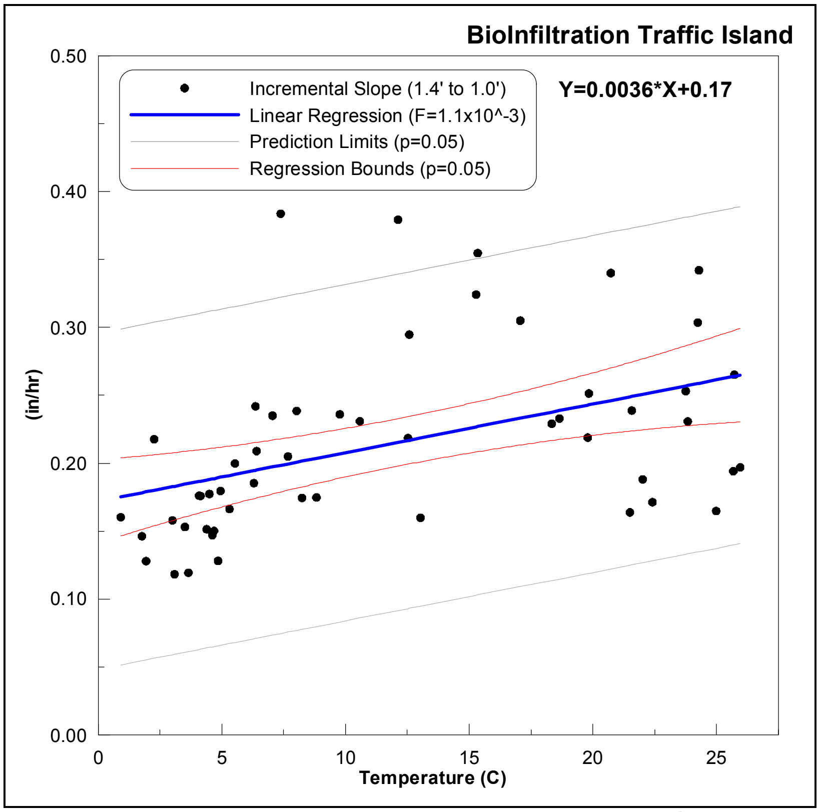
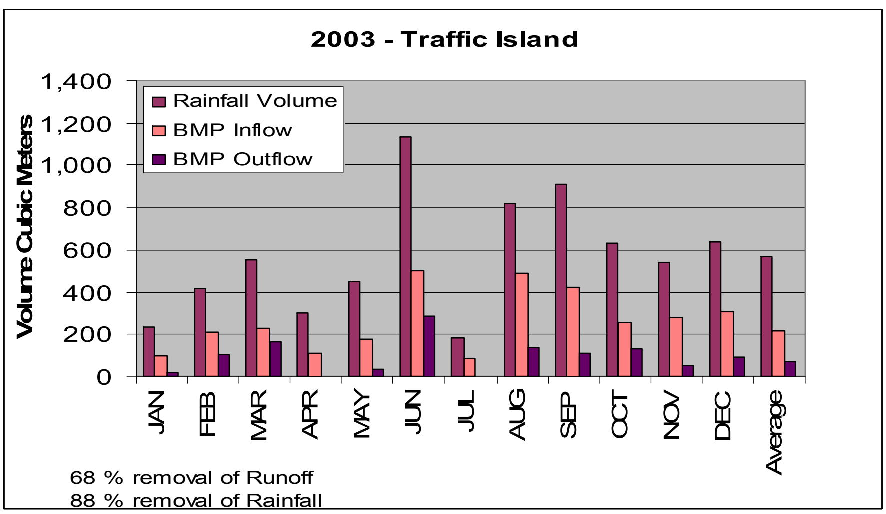
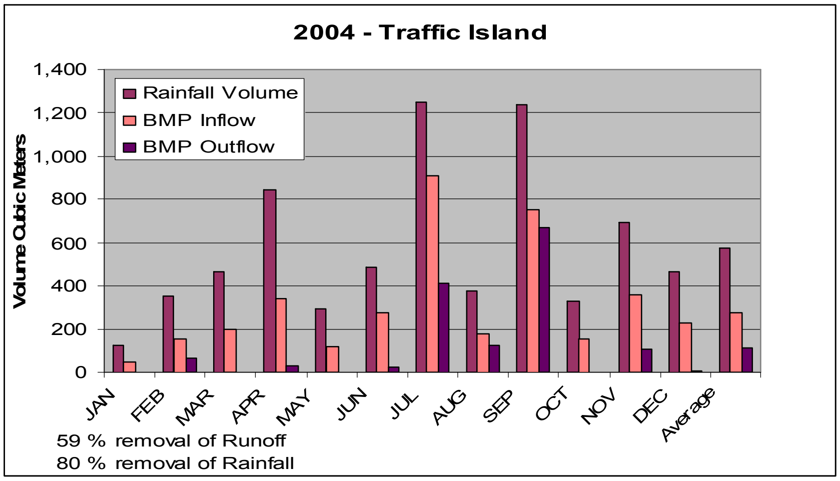
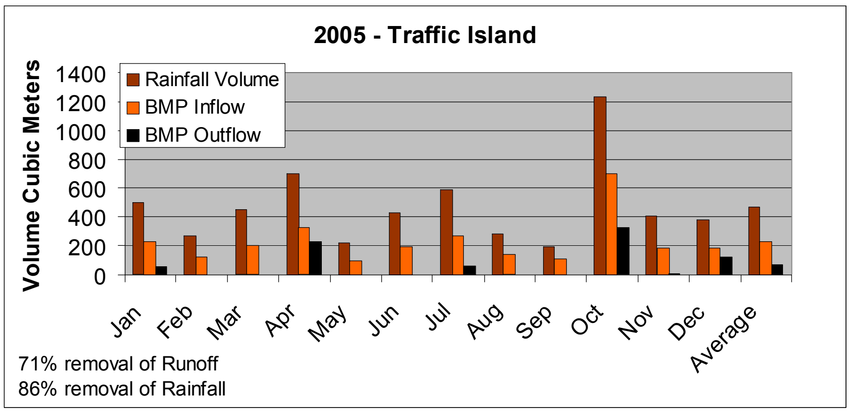
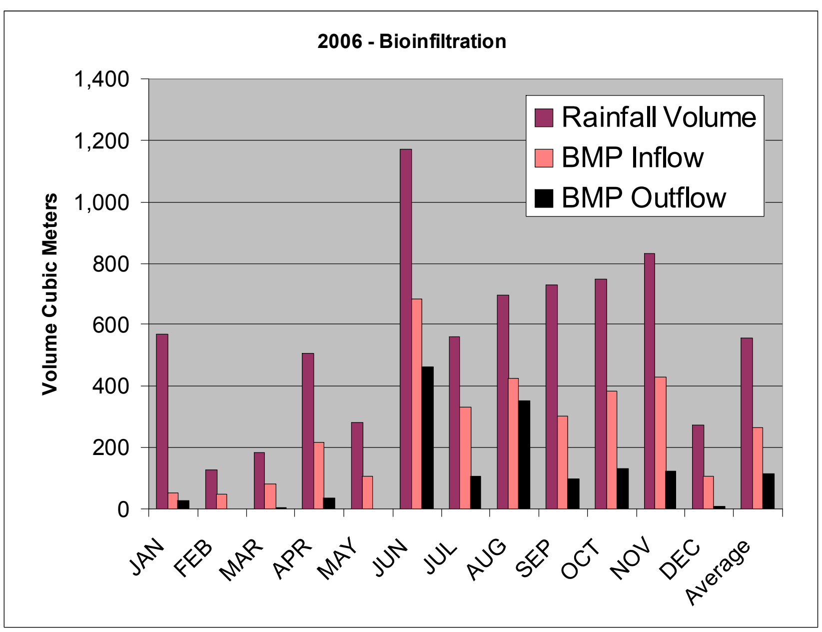


Figure 8- Temperature Dependency Linear Regression (Emerson 07)









Note that 2006 had similar performance levels to 2004.

Traffic Island Surface Water Analysis (10/03 - 6/05)			
39 Storms Sampled for Water Quality Analysis			
	Inflow	Outflow (Weir)	Removal Efficiency
Water Quantity (06/03 - 12/05 total)	58.72	24.98	57.5
Water Quantity (10/03 - 12/05 sampled)	26.9	10.7	60.2
Ph	2.78 < ph < 8.85	2.74 < ph < 8.63	
Conductivity (µS/cm)	15 < cond < 1432	26.2 < cond < 2476	
Total Nitrogen (mg)	No Longer Testing		
Nitrite (mg)	163930.6	53821.9	67.2
Nitrate (mg)	11949855.0	6075475.3	49.2
Total Phosphorous (mg)	2695102.5	1812647.9	32.7
Phosphate (mg)	738190.1	747124.9	-1.2
Copper (µg)	20590039.1	8051088.1	60.9
Lead (µg)	924717.4	357898.7	61.3
Chromium (µg)	52213272.3	2460865.6	95.3
Zinc (µg)	43199661.2	10505194.6	75.7
Chloride (mg)	39980298.7	1425561.6	96.4
Suspended Solids (mg)	553088005.6	5845805.9	98.9
Dissolved Solids (mg)	299420406.9	58725183.3	80.4

Sample locations:

"first flush #1" (FF1) – located on the perimeter of the basin. Assumed to collect the first segment of runoff from the surrounding landscape to the south and east of the basin

"first flush #2" (FF2) – located on the perimeter of the basin. Assumed to collect the first segment of runoff from the surrounding landscape to the north of the basin.

"grab sample 1" (GS1) – Sample taken during the rain storm from the ponded water within the basin. Assumed to represent surface water inflow into the site.

"grab sample 2" (GS2) – Sample taken once the rain has ended from the ponded water within the basin – Assumed to represent outflow leaving the site as either surface water if the depth is above the weir or infiltration into the ground.

"L0" – lysimeter located at ground level within the drainage bowl. Assumed to represent water infiltrating into the bed.

"L4" – lysimeter located within the bowl approximately 4 feet beneath the ground surface.

"L8" – lysimeter located within the bowl approximately 8 feet beneath the ground surface.

To further explore the data., the changes in values was examined.

Ground Water Analysis (GS 2) (10/03 - 12/05)	Concentration					
39 Storms Sampled for Water Quality Analysis	Quartiles					
	25%	50%	75%	Min	Max	Median
Ph	6.865	7.365	7.813	2.74	8.63	7.365
Conductivity (µS/cm)	38	58.1	76.9	26.2	2476	58.1
Total Nitrogen (mg/l) (2.0 mg/l)	No Longer Testing					
Nitrite as Total N (mg/l) (0.1 mg/l)	0.1	0.16	0.3	0	0.74	0.16
Nitrate as Total N (mg/l) (0.1 mg/l)	0.04	0.11	1.07	0	61.31	0.11
Total Phosphorous (mg/l) (0.015 mg/l)	0.39	0.62	1.135	0.04	1.94	0.62
Ortho-Phosphate as Total P (mg/l) (0.1 mg/l)	0.053	0.27	0.543	0	3.35	0.27
Copper (µg/l) (1.7 µg/l)	3.08	5.77	17.24	0.15	84.29	5.77
Lead (µg/l) (5.4 µg/l)	0	0.08	1.303	0	3.56	0.08
Chromium (µg/l) (7.2 µg/l)	0	0.62	7.56	0	95.65	0.62
Zinc (µg/l) (8.6 µg/l)	27.2	45	82.4	1.1	127.7	45
Chloride (mg/l) (0.1 mg/l)	1.1	2.1	4.7	0.6	747.5	2.1
Suspended Solids (mg/l)	3	5	9.25	0	87.5	5
Dissolved Solids (mg/l)	28.9	50.4	71.3	0	805.5	50.4

Ground Water Analysis (L0) (10/03 - 12/05)	Concentration					
39 Storms Sampled for Water Quality Analysis	Quartiles					
	25%	50%	75%	Min	Max	Median
Ph	6.78	7.04	7.55	6.34	8.01	7.04
Conductivity (µS/cm)	41.3	56.6	92	33.5	463	56.6
Total Nitrogen (mg/l) (2.0 mg/l)	No Longer Testing					
Nitrite as Total N (mg/l) (0.1 mg/l)	0.058	0.135	0.165	0.000	0.260	0.135
Nitrate as Total N (mg/l) (0.1 mg/l)	0.115	0.290	0.758	0.080	2.580	0.29
Total Phosphorous (mg/l) (0.015 mg/l)	0.400	0.590	0.920	0.300	1.620	0.59
Ortho-Phosphate as Total P (mg/l) (0.1 mg/l)	0.000	0.195	0.485	0.000	0.550	0.195
Copper (µg/l) (1.7 µg/l)	3.550	5.350	11.180	0.000	62.830	5.35
Lead (µg/l) (5.4 µg/l)	0.000	0.450	1.880	0.000	27.710	0.45
Chromium (µg/l) (7.2 µg/l)	0.000	0.390	12.250	0.000	46.340	0.39
Zinc (µg/l) (8.6 µg/l)	13.700	36.400	69.800	0.400	417.500	36.4
Chloride (mg/l) (0.1 mg/l)	1.570	2.790	4.090	0.820	89.510	2.79
Suspended Solids (mg/l)	--	--	--	--	--	--
Dissolved Solids (mg/l)	28.500	32.400	56.700	19.500	152.100	32.4

Ground Water Analysis (L4) (10/03 - 12/05)	Concentration					
39 Storms Sampled for Water Quality Analysis	Quartiles					
	25%	50%	75%	Min	Max	Median
Ph	6.69	6.8	7.02	5.97	7.7	6.8
Conductivity (µS/cm)	369	500	656	54	5193	500
Total Nitrogen (mg/l) (2.0 mg/l)	No Longer Testing					
Nitrite as Total N (mg/l) (0.1 mg/l)	0.270	1.180	1.368	0.000	2.780	1.18
Nitrate as Total N (mg/l) (0.1 mg/l)	0.090	0.150	0.640	0.000	3.000	0.15
Total Phosphorous (mg/l) (0.015 mg/l)	0.220	0.390	0.613	0.030	1.180	0.39
Ortho-Phosphate as Total P (mg/l) (0.1 mg/l)	0.000	0.000	0.000	0.000	0.210	0
Copper (µg/l) (1.7 µg/l)	0.050	1.690	7.210	0.000	111.490	1.69
Lead (µg/l) (5.4 µg/l)	0.000	1.000	2.380	0.000	26.700	1
Chromium (µg/l) (7.2 µg/l)	0.000	3.860	7.120	0.000	12.200	3.86
Zinc (µg/l) (8.6 µg/l)	24.000	45.100	47.100	0.000	165.300	45.1
Chloride (mg/l) (0.1 mg/l)	4.000	15.400	41.800	0.600	1619.500	15.4
Suspended Solids (mg/l)	0.000	1.500	16.000	0.000	26.300	1.5
Dissolved Solids (mg/l)	222.800	309.100	481.000	0.500	2820.000	309.1

Ground Water Analysis (L8) (10/03 - 12/05)	Concentration					
39 Storms Sampled for Water Quality Analysis	Quartiles					
	25%	50%	75%	Min	Max	Median
Ph	6.728	6.86	6.995	4.33	7.86	6.86
Conductivity (µS/cm)	388.5	443	567.5	52.2	1450	443
Total Nitrogen (mg/l) (2.0 mg/l)	No Longer Testing					
Nitrite as Total N (mg/l) (0.1 mg/l)	0.610	1.470	2.233	0.000	3.480	1.47
Nitrate as Total N (mg/l) (0.1 mg/l)	0.000	0.300	0.600	0.000	199.800	0.3
Total Phosphorous (mg/l) (0.015 mg/l)	0.270	0.410	0.558	0.050	1.800	0.41
Ortho-Phosphate as Total P (mg/l) (0.1 mg/l)	0.000	0.000	0.000	0.000	0.280	0
Copper (µg/l) (1.7 µg/l)	0.000	2.380	4.990	0.000	17.380	2.38
Lead (µg/l) (5.4 µg/l)	0.000	0.840	2.855	0.000	4.960	0.84
Chromium (µg/l) (7.2 µg/l)	0.000	2.080	7.600	0.000	86.700	2.08
Zinc (µg/l) (8.6 µg/l)	2.350	46.090	68.680	0.000	125.700	46.09
Chloride (mg/l) (0.1 mg/l)	2.300	16.200	72.700	0.900	273.900	16.2
Suspended Solids (mg/l)	19.200	25.000	75.300	19.200	75.300	25
Dissolved Solids (mg/l)	250.400	297.100	391.400	209.200	772.600	297.1

Ground Water Analysis (10/03 - 12/05)	Concentration					
Comparison GS2 traveling to L0	Quartiles					
(-) = removal	25%	50%	75%	Min	Max	Median
Ph	-0.085	-0.325	-0.263	3.6	-0.62	-0.325
Conductivity (µS/cm)	3.3	-1.5	15.1	7.3	-2013	-1.5
Total Nitrogen (mg/l)	No Longer Testing					
Nitrite (mg/l)	-0.0425	-0.025	-0.135	0	-0.48	-0.025
Nitrate (mg/l)	0.075	0.18	-0.312	0.08	-58.73	0.18
Total Phosphorous (mg/l)	0.01	-0.03	-0.215	0.26	-0.32	-0.03
Phosphate (mg/l)	-0.053	-0.075	-0.058	0	-2.8	-0.075
Copper (µg/l)	0.47	-0.42	-6.06	-0.15	-21.46	-0.42
Lead (µg/l)	0	0.37	0.577	0	24.15	0.37
Chromium (µg/l)	0	-0.23	4.69	0	-49.31	-0.23
Zinc (µg/l)	-13.5	-8.6	-12.6	-0.7	289.8	-8.6
Chloride (mg/l)	0.47	0.69	-0.61	0.22	-657.99	0.69
Suspended Solids (mg/l)	--	--	--	--	--	--
Dissolved Solids (mg/l)	-0.4	-18	-14.6	19.5	-653.4	-18

Ground Water Analysis (10/03 - 12/05)	Concentration					
Comparison L0 traveling to L4	Quartiles					
(-) = removal	25%	50%	75%	Min	Max	Median
Ph	-0.09	-0.24	-0.53	-0.37	-0.31	-0.24
Conductivity (µS/cm)	327.7	443.4	564	20.5	4730	443.4
Total Nitrogen (mg/l)	No Longer Testing					
Nitrite (mg/l)	0.2125	1.045	1.203	0	2.52	1.045
Nitrate (mg/l)	-0.025	-0.14	-0.118	-0.08	0.42	-0.14
Total Phosphorous (mg/l)	-0.18	-0.2	-0.3075	-0.27	-0.44	-0.2
Phosphate (mg/l)	0	-0.195	-0.485	0	-0.34	-0.195
Copper (µg/l)	-3.5	-3.66	-3.97	0	48.66	-3.66
Lead (µg/l)	0	0.55	0.5	0	-1.01	0.55
Chromium (µg/l)	0	3.47	-5.13	0	-34.14	3.47
Zinc (µg/l)	10.3	8.7	-22.7	-0.4	-252.2	8.7
Chloride (mg/l)	2.43	12.61	37.71	-0.22	1529.99	12.61
Suspended Solids (mg/l)	--	--	--	--	--	--
Dissolved Solids (mg/l)	194.3	276.7	424.3	-19	2667.9	276.7

Ground Water Analysis (10/03 - 12/05)	Concentration					
Comparison L0 traveling to L8	Quartiles					
(-) = removal	25%	50%	75%	Min	Max	Median
Ph	-0.052	-0.18	-0.555	-2.01	-0.15	-0.18
Conductivity (µS/cm)	347.2	386.4	475.5	18.7	987	386.4
Total Nitrogen (mg/l)	No Longer Testing					
Nitrite (mg/l)	0.5525	1.335	2.068	0	3.22	1.335
Nitrate (mg/l)	-0.115	0.01	-0.158	-0.08	197.22	0.01
Total Phosphorous (mg/l)	-0.13	-0.18	-0.3625	-0.25	0.18	-0.18
Phosphate (mg/l)	0	-0.195	-0.485	0	-0.27	-0.195
Copper (µg/l)	-3.55	-2.97	-6.19	0	-45.45	-2.97
Lead (µg/l)	0	0.39	0.975	0	-22.75	0.39
Chromium (µg/l)	0	1.69	-4.65	0	40.36	1.69
Zinc (µg/l)	-11.35	9.69	-1.12	-0.4	-291.8	9.69
Chloride (mg/l)	0.73	13.41	68.61	0.08	184.39	13.41
Suspended Solids (mg/l)	--	--	--	--	--	--
Dissolved Solids (mg/l)	221.9	264.7	334.7	189.7	620.5	264.7

Ground Water Analysis (10/03 - 12/05)	Concentration					
Comparison L4 traveling to L8	Quartiles					
(-) = removal	25%	50%	75%	Min	Max	Median
Ph	0.038	0.06	-0.025	-1.64	0.16	0.06
Conductivity (µS/cm)	19.5	-57	-88.5	-1.8	-3743	-57
Total Nitrogen (mg/l)	No Longer Testing					
Nitrite (mg/l)	0.34	0.29	0.865	0	0.7	0.29
Nitrate (mg/l)	-0.09	0.15	-0.04	0	196.8	0.15
Total Phosphorous (mg/l)	0.05	0.02	-0.055	0.02	0.62	0.02
Phosphate (mg/l)	0	0	0	0	0.07	0
Copper (µg/l)	-0.05	0.69	-2.22	0	-94.11	0.69
Lead (µg/l)	0	-0.16	0.475	0	-21.74	-0.16
Chromium (µg/l)	0	-1.78	0.48	0	74.5	-1.78
Zinc (µg/l)	-21.65	0.99	21.58	0	-39.6	0.99
Chloride (mg/l)	-1.7	0.8	30.9	0.3	-1345.6	0.8
Suspended Solids (mg/l)	19.2	23.5	59.3	19.2	49	23.5
Dissolved Solids (mg/l)	27.6	-12	-89.6	208.7	-2047.4	-12

Ground Water Analysis (10/03 - 12/05)	Concentration					
Comparison GS2 traveling to L8	Quartiles					
(-) = removal	25%	50%	75%	Min	Max	Median
Ph	-0.137	-0.505	-0.818	1.59	-0.77	-0.505
Conductivity (µS/cm)	350.5	384.9	490.6	26	-1026	384.9
Total Nitrogen (mg/l)	No Longer Testing					
Nitrite (mg/l)	0.51	1.31	1.933	0	2.74	1.31
Nitrate (mg/l)	-0.04	0.19	-0.47	0	138.49	0.19
Total Phosphorous (mg/l)	-0.12	-0.21	-0.5775	0.01	-0.14	-0.21
Phosphate (mg/l)	-0.053	-0.27	-0.543	0	-3.07	-0.27
Copper (µg/l)	-3.08	-3.39	-12.25	-0.15	-66.91	-3.39
Lead (µg/l)	0	0.76	1.552	0	1.4	0.76
Chromium (µg/l)	0	1.46	0.04	0	-8.95	1.46
Zinc (µg/l)	-24.85	1.09	-13.72	-1.1	-2	1.09
Chloride (mg/l)	1.2	14.1	68	0.3	-473.6	14.1
Suspended Solids (mg/l)	16.2	20	66.05	19.2	-12.2	20
Dissolved Solids (mg/l)	221.5	246.7	320.1	209.2	-32.9	246.7

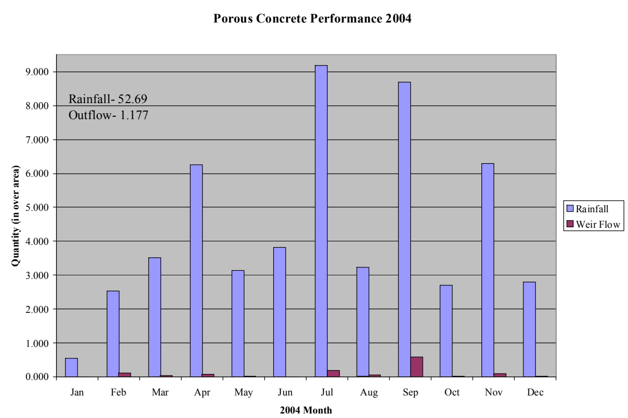
Bioinfiltration Traffic Island Preliminary Summary

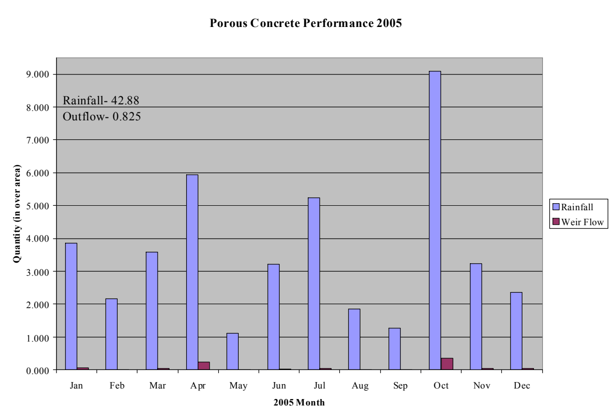
Hydrologic Performance – The performance of this site designed for a small volume (.84cm) continues to impress. To date no statistical loss of performance is able to be detected. It is believed the freeze thaw and root systems are maintaining the infiltration capacity. Current studies have linked infiltration rate to temperature, and are looking at the soil grain size distribution of the infiltration bed. As most storms are small, a high percentage of the yearly water cycle is captured (80+%). The working assumption continues to be that the surface is the controlling factor. The hydrologic performance has a direct relationship to the strong pollutant removal to the surface waters.

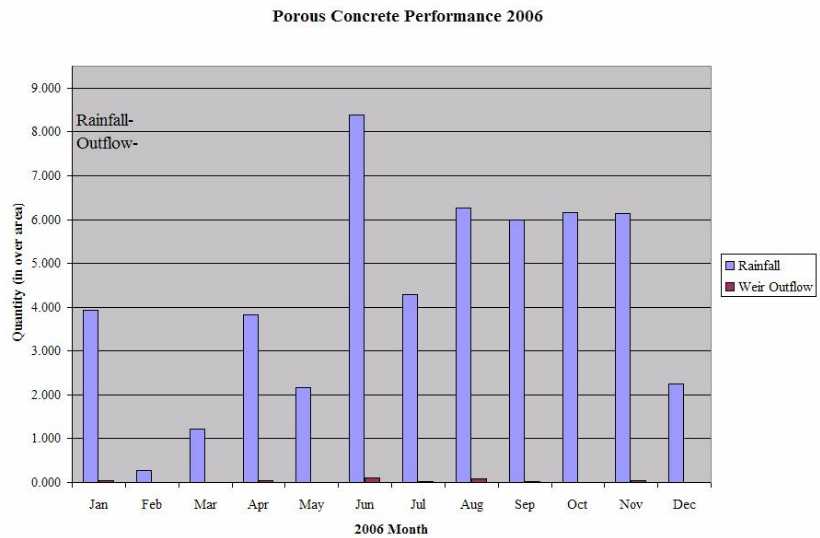
Chloride – Chlorides from snow melt chemicals are passed through with no reduction. Chlorides do not remain in the soils under the BMP as they are washed through. Note that the tremendous increases in chlorides masks all dissolved solid results.

Nutrients - Besides chloride, the level of detected nutrients and metals are extremely low. The area is well maintained by the university, and only light vehicle traffic is present in the watershed. The results indicate a small decrease in soil water total phosphorus levels, and most total nitrogen results are below the 2 mg/l limit of the test. It is interesting that total phosphorus does increase slightly at the bowl (Plants?) but as it moves through the soil is is reduced.

Pervious Concrete – Quantity







Note that some runoff bypasses the site during runoff events, so this efficiency may be overestimated. However the point is this large rock bed eliminates runoff from all but the largest events.

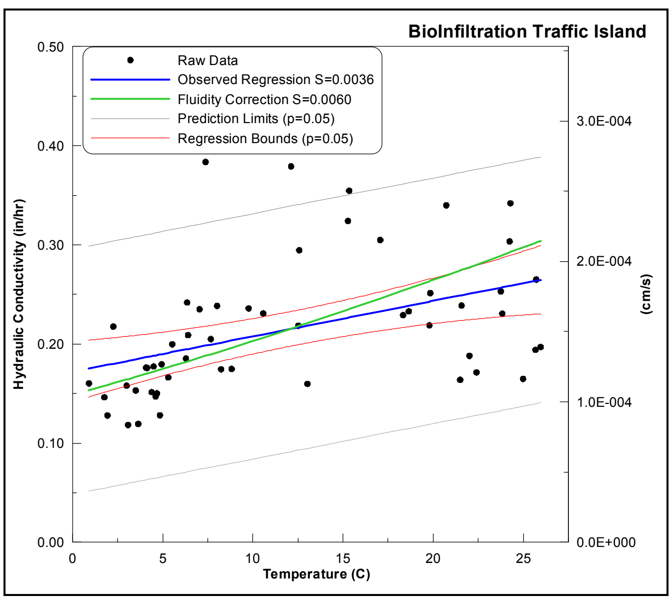


Figure 9 - Temperature Dependency

Porous Concrete Surface Water Analysis (Historical 06/03 - 09/06)				
55 Storms Sampled for Water Quality Analysis (25 for Port)				
	Number of Storms	Inflow (GFF / IFF)	Outflow (Port)	Removal Efficiency
Water Quantity (06/03 - 09/06 total)	106	48.866	2.779	94.3
Water Quantity (10/03 - 09/06 sampled)	55 (25)	25.6	2.2	91.3
Ph	40 (25)	3.09<pH<9.4	6.65<pH<9.75	-
Conductivity (µS/cm)	41 (25)	2.96<Cond.<174.4	8.92<Cond.<2860	-
Total Nitrogen (mg)	16 (20)	2206333.0	102791.0	95.3
Nitrite-NO3 (mg)	18 (6)	114408.2	4068.6	96.4
Nitrate- NO4 (mg)	22 (9)	1527830.5	25611.3	98.3
Total Phosphorous (mg)	39 (24)	1090247.0	28123.0	97.4
Phosphate-PO4 (mg)	10 (2)	19923.8	255.4	98.7
Copper (µg)	36 (27)	154154425.27	2911303.81	98.1
Lead (µg)	16 (6)	1736362	24766.8	98.6
Chromium (µg)	15 (7)	12328073.88	217882.0	98.2
Zinc (µg)	15 (6)	100174986.1	141849.8	99.9
Chloride (mg)	23 (13)	4117007.5	11643602.9	-182.8
Suspended Solids (mg)	34 (20)	299917689	426011.0	99.9
Dissolved Solids (mg)	38 (21)	58295056	2784598	95.2

Ground Water Analysis (6/03 - 09/06)			Concentration (mg/l)					
(Port)			Quartiles					
Water Quantity (25 Storms Sampled)		Number of Storms	25%	50%	75%	Min	Max	Median
Ph		25	6.98	7.19	7.81	6.65	9.75	7.19
Conductivity (µS/cm)		25	50.5	92.6	178	8.92	2860	92.6
Total Nitrogen (mg/l)	2.0 mg/l	20	--	--	--	--	--	--
Nitrite as Total N (mg/l)	0.1 mg/l	6	0.050	0.366	0.863	0.022	1.100	0.471
Nitrate as Total N (mg/l)	0.1 mg/l	9	0.578	1.835	2.955	0.050	8.210	2.375
Total Phosphorous (mg/l)	0.015 mg/l	24	0.148	0.225	0.300	0.050	0.700	0.225
Ortho-Phosphate as Total P (mg/l)	0.1 mg/l	2	0	0	0.015	0	0.04	0.009
Copper (µg/l)	1.7 µg/l	27	72.448	99.450	163.608	0.135	298.910	128.953
Lead (µg/l)	5.4 µg/l	6	0.805	3.750	6.375	0.000	17.430	3.75
Chromium (µg/l)	7.2 µg/l	7	1.305	2.765	5.283	0.000	40.850	2.765
Zinc (µg/l)	8.6 µg/l	6	54.878	114.795	158.310	0.263	171.110	101.447
Chloride (mg/l)	0.1 mg/l	13	2.500	6.460	14.170	0.930	781	88.960
Suspended Solids (mg/l)		20	3.713	5.750	9.875	1.500	31.710	5.75
Dissolved Solids (mg/l)		21	33.500	56.940	101.800	12.500	1832.000	191.94

Ground Water Analysis (6/03 - 09/06)			Concentration (mg/l)					
(A21)			Quartiles					
Water Quantity (55 Storms Sampled)		Number of Storms	25%	50%	75%	Min	Max	Median
Ph		50	6.63	6.76	7.015	6.06	7.8	6.76
Conductivity (µS/cm)		53	714.67	875	1023	395	1137	875
Total Nitrogen (mg/l)	2.0 mg/l	28	3.0	4.6	7.2	1.5	8.9	4.6
Nitrite as Total N (mg/l)	0.1 mg/l	19	0.627	0.938	1.310	0.000	2.400	1.064
Nitrate as Total N (mg/l)	0.1 mg/l	19	0.152	1.858	7.930	0.000	17.890	4.25
Total Phosphorous (mg/l)	0.015 mg/l	47	0.140	0.230	0.485	0.070	1.400	0.23
Ortho-Phosphate as Total P (mg/l)	0.1 mg/l	7	0.000	0.000	0.020	0.000	0.098	0.016
Copper (µg/l)	1.7 µg/l	43	1.42	5.02	9.09	0	28.29	7.09
Lead (µg/l)	5.4 µg/l	17	0.210	2.340	7.720	0.000	64.850	7.72
Chromium (µg/l)	7.2 µg/l	13	0.000	3.000	7.320	0.000	128.810	6.063
Zinc (µg/l)	8.6 µg/l	14	34.625	38.73	73.74	0.22	160.84	56.367
Chloride (mg/l)	0.1 mg/l	37	24.810	64.510	120.100	0.000	891.810	77.605
Suspended Solids (mg/l)		0	--	--	--	--	--	--
Dissolved Solids (mg/l)		1	--	--	--	--	--	--

Ground Water Analysis (6/03 - 09/06)			Concentration (mg/l)					
(B11)			Quartiles					
Water Quantity (55 Storms Sampled)		Number of Storms	25%	50%	75%	Min	Max	Median
Ph		52	6.705	6.91	7.103	5.93	7.68	6.91
Conductivity (µS/cm)		53	206	240.67	319	5.43	3876.67	240.67
Total Nitrogen (mg/l)	2.0 mg/l	29	0.8	1.1	2.0	0.1	3.6	1.11
Nitrite as Total N (mg/l)	0.1 mg/l	21	0.334	0.473	1.052	0.000	46.570	4.137
Nitrate as Total N (mg/l)	0.1 mg/l	28	1.186	2.579	6.138	0.110	95.010	7.382
Total Phosphorous (mg/l)	0.015 mg/l	48	0.100	0.200	0.390	0.000	0.770	0.2
Ortho-Phosphate as Total P (mg/l)	0.1 mg/l	7	0.000	0.000	0.000	0.000	0.040	0.035
Copper (µg/l)	1.7 µg/l	39	0.260	3.830	10.560	0.000	35.200	8.98
Lead (µg/l)	5.4 µg/l	17	0.045	1.270	5.363	0.000	173.570	1.27
Chromium (µg/l)	7.2 µg/l	13	0.000	0.970	4.620	0.000	30.490	4.2
Zinc (µg/l)	8.6 µg/l	15	47.303	71.745	125.155	4.500	190.450	83.821
Chloride (mg/l)	0.1 mg/l	33	6.130	11.200	61.230	2.220	1190.100	79.85
Suspended Solids (mg/l)		0	--	--	--	--	--	--
Dissolved Solids (mg/l)		1	--	--	--	--	--	--

Ground Water Analysis (6/03 - 09/06)			Concentration (mg/l)					
(B12)			Quartiles					
Water Quantity (55 Storms Sampled)		Number of Storms	25%	50%	75%	Min	Max	Median
Ph		54	6.978	7.15	7.258	6.53	7.64	7.15
Conductivity (µS/cm)		55	253.5	342	445.5	159.8	3220	342
Total Nitrogen (mg/l)	2.0 mg/l	29	0.6	0.9	1.5	0.0	2.7	0.9
Nitrite as Total N (mg/l)	0.1 mg/l	21	0.420	0.583	1.642	0.090	3.888	1.044
Nitrate as Total N (mg/l)	0.1 mg/l	26	0.863	1.546	6.013	0.100	290.920	3.35
Total Phosphorous (mg/l)	0.015 mg/l	48	0.178	0.270	0.488	0.030	1.830	0.27
Ortho-Phosphate as Total P (mg/l)	0.1 mg/l	7	0.000	0.000	0.017	0.000	0.040	0.01
Copper (µg/l)	1.7 µg/l	39	0.000	6.530	7.950	0.000	50.750	6.22
Lead (µg/l)	5.4 µg/l	18	0.041	1.365	5.270	0.000	58.040	1.365
Chromium (µg/l)	7.2 µg/l	14	0.000	1.170	3.010	0.000	22.370	3.18
Zinc (µg/l)	8.6 µg/l	15	43.120	101.420	116.495	0.177	207.440	95.089
Chloride (mg/l)	0.1 mg/l	32	8.580	11.200	61.230	2.220	362.700	54.574
Suspended Solids (mg/l)		0	--	--	--	--	--	--
Dissolved Solids (mg/l)		1	--	--	--	--	--	--

Ground Water Analysis (6/03 - 09/06)			Concentration (mg/l)					
(B13)			Quartiles					
Water Quantity (55 Storms Sampled)		Number of Storms	25%	50%	75%	Min	Max	Median
Ph		52	6.873	7.045	7.21	3.28	9.4	7.045
Conductivity (µS/cm)		53	162	195.8	334	114.6	3143.33	195.8
Total Nitrogen (mg/l)	2.0 mg/l	29	0.7	1.1	1.7	0.0	3.6	1.1
Nitrite as Total N (mg/l)	0.1 mg/l	21	0.156	0.228	0.418	0.000	1.584	0.389
Nitrate as Total N (mg/l)	0.1 mg/l	26	0.704	2.353	6.383	0.130	55.330	5.733
Total Phosphorous (mg/l)	0.015 mg/l	48	0.158	0.305	0.495	0.070	1.000	0.305
Ortho-Phosphate as Total P (mg/l)	0.1 mg/l	8	0.000	0.000	0.015	0.000	0.040	0.009
Copper (µg/l)	1.7 µg/l	34	0.280	3.200	8.530	0.000	120.110	4.67
Lead (µg/l)	5.4 µg/l	14	0.000	0.160	1.500	0.000	14.410	0.16
Chromium (µg/l)	7.2 µg/l	11	0.000	0.420	2.995	0.000	44.730	2.417
Zinc (µg/l)	8.6 µg/l	13	73.560	87.525	97.062	36.390	133.220	83.908
Chloride (mg/l)	0.1 mg/l	32	7.980	22.000	69.900	2.810	904.800	93.22
Suspended Solids (mg/l)		0	--	--	--	--	--	--
Dissolved Solids (mg/l)		1	--	--	--	--	--	--

Sample locations:

"Inlet first flush" (IFF) – located at the upstream end of the inlet pipe to the upper bed. Assumed to collect a representative sample of water entering the site as runoff from the surrounding rooftops and drainage system.

"gutter first flush" (GFF) – located at the upstream end of the inlet pipe to the upper bed. The device captures the first segment of runoff from the surrounding landscape which flows as overland flow to the site.

"Port" – located at the most downstream bed. Water from this location will either leave the site as surface water runoff via the weir (should the depth in the bed be higher then the weir), or infiltrate into the ground.

"A21" – lysimeter located to the side of the collection beds approximately 1 foot below the ground. Water / samples collected from this location are assumed to not enter the site, and are not used as part of the ground water analysis

"B11" – lysimeter located beneath the most downstream bed approximately 1 ftoot below the bottom of the bed.

"B12" – lysimeter located beneath the most downstream bed approximately 2 feet below the bottom of the bed.

"B13" – lysimeter located beneath the most downstream bed approximately 4 feet below the bottom of the bed

To further explore the data, the changes in values were examined.

Note that it appears that Total Phosphorus increases slightly as the runoff moves through the soil, and that Total N is recorded under the grass areas. Copper is removed, while chlorides are the same as found at the Traffic Island.

Pervious Concrete Preliminary Summary

Note: Two journal papers based on this work have been accepted for publication.

Hydrologic Performance – Once again the performance of the site is spectacular. In several years, only a handful of storms have filled the rock bed up to the overflow pipe. The infiltration rate is tied to temperature, and that for back to back storms the infiltration rate is actually higher. No evidence of clogging in the geotextile has been seen at the site, and no degradation of performance.

Pollutants- Besides chloride, the level of detected nutrients and metals are extremely low. The area is well maintained by the university, and the main use is for pedestrian traffic. Copper is seen from the downspouts, and is reduced going through the soil, as is acid rain. Note that the inflow levels of Copper are well below drinking water standards. Some Phosporus is leached out of the soil as the runoff infiltrates. It is speculated that as the soil is washed this till decrease.

Maintenance- Vacuum street sweepers are very effective at removing dust and dirt and maintaining the site porosity. Lessons learned from construction have been published in Stormwater Magazine.

This site has been discontinued as no changes in performance have been seen. Clearly when compared to the Infiltration Trench, it is clear that the low bed area / drainage area relationship and the relatively clean runoff of the site are contributing factors to the high level of performance observed..

Infiltration Trench

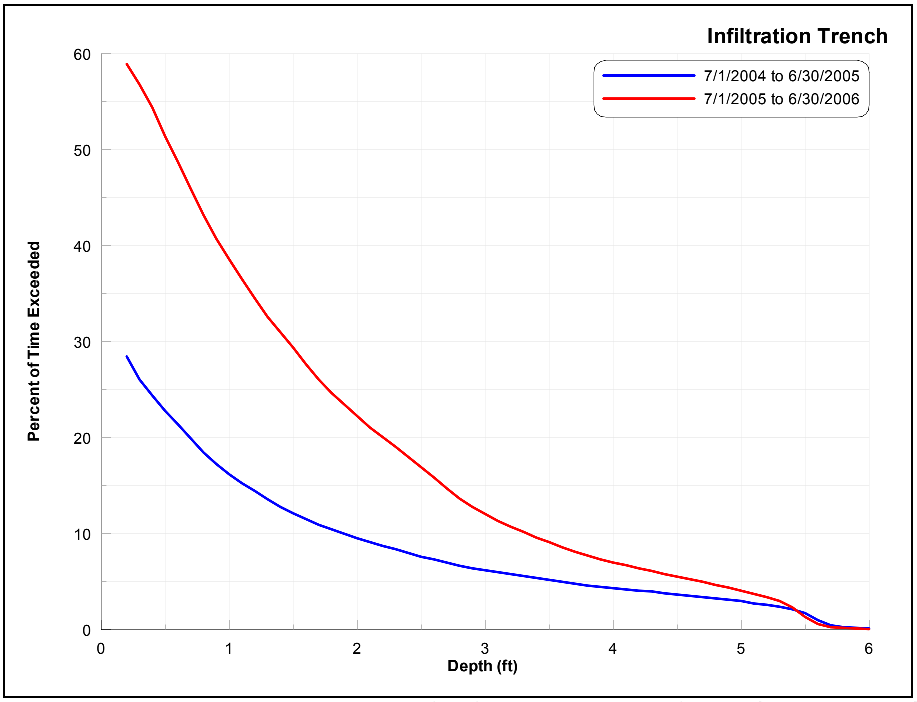


Figure 10 - Depth duration curves for first two years of data (Emerson 07)

Hydrologic Performance – The initial infiltration rates from this site exceed the others. This site was designed for a smaller amount of rain (.75 cm) to cause it to be stressed more frequently for research purposes. Over the first several years of operation the infiltration rate has reduced. From modeling, it is believed that the bottom of the trench has sealed, from the high volume of TSS entering, and the large depths of water within the trench. All current infiltration is through the sides. It is hoped that the next several years of monitoring will determine whether this has reached equilibrium.

Sample locations:

"In" – Sequential samples entering the BMP. Samples are taken after ¼", ½" and 1" of runoff.

"Overflow" – Grab Sample of overflow from the Infiltration Trench - captures the first segment of overflow.

"L2" lysimeter located approximately 2 feet below the bottom of the bed.

"L4" lysimeter located approximately 4 feet below the bottom of the bed

Note due to the small number of inflow events, a mass balance has not yet been established.

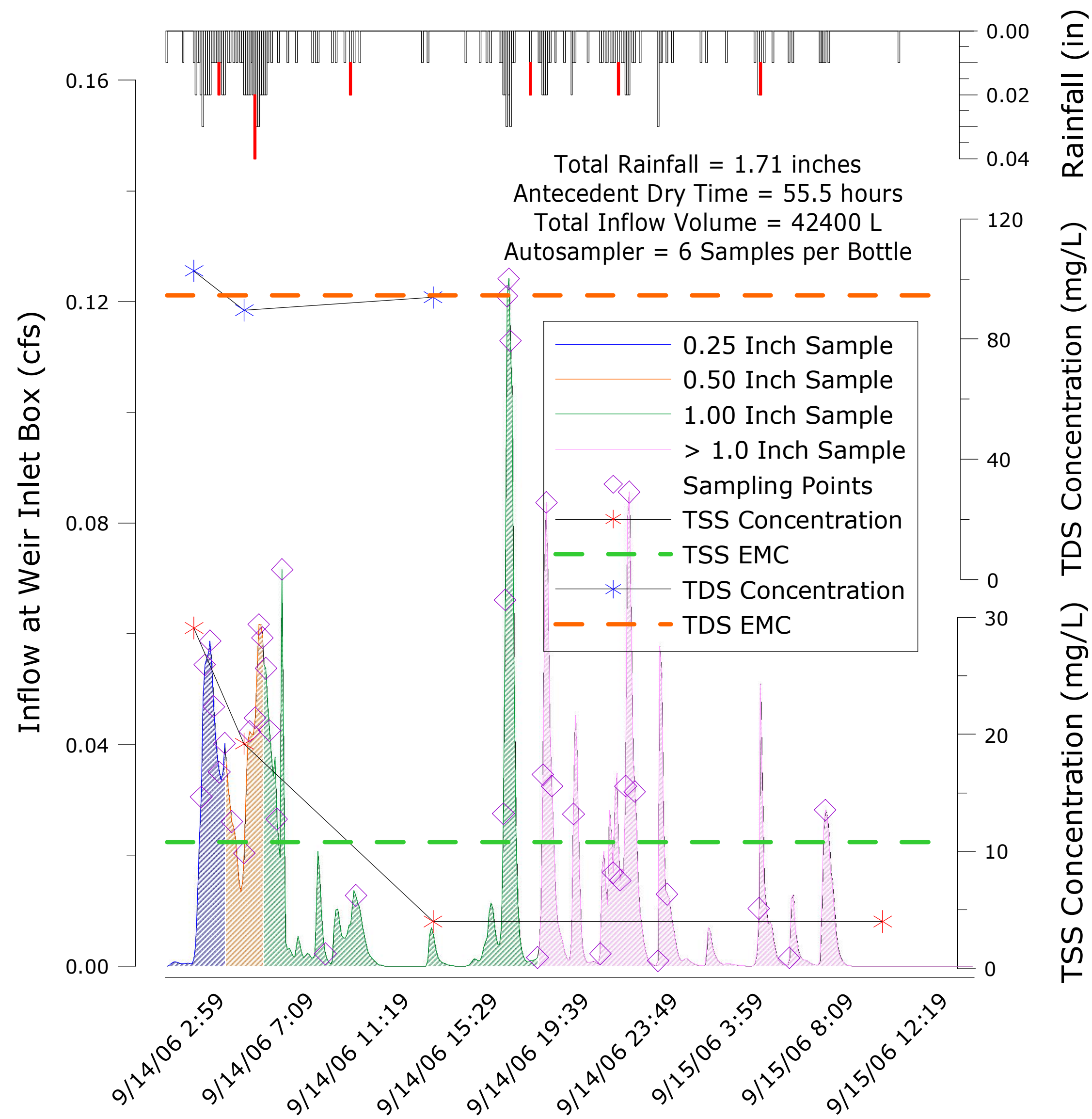


Figure 11- First Flush Analysis- Batroney 07

IN 0.25 for 2006 7 complete storms (17 for TSS TDS)	Concentration Quartiles 25%	50%	75%	Min	Max	Median
Ph	6.90	6.96	7.21	6.48	7.57	6.96
Conductivity (µS/cm)	43.73	50.05	59.83	36.20	66.40	50.05
Suspended Solids (mg/l)	10.52	14.40	22.00	7.00	94.00	14.40
Dissolved Solids (mg/l)	52.85	65.50	84.29	10.70	178.60	65.50
Total Nitrogen (mg/l) (2.0 mg/l)	0.38	2.05	8.83	0.00	10.80	2.05
Total Phosphorous (mg/l) (0.015 mg/l)	0.13	0.20	0.38	0.00	0.71	0.20
Copper (µg/l) (1.7 µg/l)	8.18	9.47	25.68	6.57	352.00	9.47
Lead (µg/l) (5.4 µg/l)	0.00	0.00	4.93	0.00	256.05	0.00
Chromium (µg/l) (7.2 µg/l)	0.31	2.99	9.18	0.00	63.46	2.99
Zinc (µg/l) (8.6 µg/l)	—	—	—	—	—	—
Nickel (µg/l)	—	—	—	—	—	—
Cadmium (µg/l)	0.30	0.45	0.65	0.22	1.15	0.45
Chloride (mg/l) (0.1 mg/l)	0.90	1.40	1.52	0.40	1.63	1.40
Nitrite as Total N (mg/l) (0.1 mg/l)	0.03	0.03	0.05	0.03	0.07	0.03
Nitrate as Total N (mg/l) (0.1 mg/l)	0.12	0.18	0.25	0.05	0.32	0.18
Ortho-Phosphate as Total P (mg/l) (0.1 mg/l)	0.02	0.04	0.06	0.00	0.08	0.04

IN 0.5 for 2006 7 complete storms (17 for TSS TDS)	Concentration Quartiles 25%	50%	75%	Min	Max	Median
Ph	6.89	6.98	7.31	6.19	7.62	6.98
Conductivity (µS/cm)	35.05	39.80	50.78	34.40	57.10	39.80
Suspended Solids (mg/l)	4.46	6.48	8.51	3.42	19.20	6.48
Dissolved Solids (mg/l)	43.73	50.00	57.14	27.30	89.60	50.00
Total Nitrogen (mg/l) (2.0 mg/l)	0.63	1.75	4.93	0.40	9.60	1.75
Total Phosphorous (mg/l) (0.015 mg/l)	0.19	0.25	0.36	0.12	3.07	0.25
Copper (µg/l) (1.7 µg/l)	3.22	4.59	8.33	2.67	9.50	4.59
Lead (µg/l) (5.4 µg/l)	0.00	0.00	3.78	0.00	5.14	0.00
Chromium (µg/l) (7.2 µg/l)	0.23	2.01	3.21	0.00	23.66	2.01
Zinc (µg/l) (8.6 µg/l)	—	—	—	—	—	—
Nickel (µg/l)	—	—	—	—	—	—
Cadmium (µg/l)	0.06	0.32	0.42	0.00	0.51	0.32
Chloride (mg/l) (0.1 mg/l)	1.93	2.57	3.18	0.59	4.41	2.57
Nitrite as Total N (mg/l) (0.1 mg/l)	0.02	0.02	0.06	0.00	0.19	0.02
Nitrate as Total N (mg/l) (0.1 mg/l)	0.04	0.10	0.16	0.00	0.18	0.10
Ortho-Phosphate as Total P (mg/l) (0.1 mg/l)	0.00	0.02	0.04	0.00	0.06	0.02

IN 1.0 for 2006 7 complete storms (17 for TSS TDS)	Concentration Quartiles 25%	50%	75%	Min	Max	Median
Ph	6.94	7.02	7.21	6.89	7.55	7.02
Conductivity (µS/cm)	34.43	37.60	42.75	33.90	49.20	37.60
Suspended Solids (mg/l)	2.80	4.30	7.00	1.33	8.57	4.30
Dissolved Solids (mg/l)	39.60	45.00	55.70	14.00	93.90	45.00
Total Nitrogen (mg/l) (2.0 mg/l)	0.00	0.80	3.80	0.00	13.10	0.80
Total Phosphorous (mg/l) (0.015 mg/l)	0.06	0.10	0.33	0.00	0.83	0.10
Copper (µg/l) (1.7 µg/l)	3.31	3.93	4.58	2.42	5.55	3.93
Lead (µg/l) (5.4 µg/l)	0.00	0.00	0.00	0.00	0.00	0.00
Chromium (µg/l) (7.2 µg/l)	1.37	2.21	2.75	0.00	3.23	2.21
Zinc (µg/l) (8.6 µg/l)	—	—	—	—	—	—
Nickel (µg/l)	—	—	—	—	—	—
Cadmium (µg/l)	0.00	0.08	0.18	0.00	0.24	0.08
Chloride (mg/l) (0.1 mg/l)	0.24	0.48	0.72	0.00	0.96	0.48
Nitrite as Total N (mg/l) (0.1 mg/l)	0.01	0.02	0.02	0.00	0.03	0.02
Nitrate as Total N (mg/l) (0.1 mg/l)	0.01	0.03	0.04	0.00	0.05	0.03
Ortho-Phosphate as Total P (mg/l) (0.1 mg/l)	0.01	0.02	0.03	0.00	0.04	0.02

IN >1.0 for 2006 7 complete storms (17 for TSS TDS)	Concentration Quartiles 25%	50%	75%	Min	Max	Median
Ph	7.69	7.69	7.69	7.69	7.69	7.69
Conductivity (µS/cm)	2.00	3.00	4.39	1.67	4.66	3.00
Suspended Solids (mg/l)	2.00	3.00	4.39	1.67	4.66	3.00
Dissolved Solids (mg/l)	27.30	29.30	45.00	14.30	46.50	29.30
Total Nitrogen (mg/l) (2.0 mg/l)	0.10	0.20	1.55	0.00	2.90	0.20
Total Phosphorous (mg/l) (0.015 mg/l)	0.06	0.12	0.13	0.00	0.14	0.12
Copper (µg/l) (1.7 µg/l)	2.04	2.42	3.40	1.65	4.37	2.42
Lead (µg/l) (5.4 µg/l)	0.00	0.00	0.00	0.00	0.00	0.00
Chromium (µg/l) (7.2 µg/l)	0.00	0.00	0.00	0.00	0.00	0.00
Zinc (µg/l) (8.6 µg/l)	—	—	—	—	—	—
Nickel (µg/l)	—	—	—	—	—	—
Cadmium (µg/l)	0.07	0.13	0.20	0.00	0.27	0.13
Chloride (mg/l) (0.1 mg/l)	0.21	0.21	0.21	0.21	0.21	0.21
Nitrite as Total N (mg/l) (0.1 mg/l)	0.05	0.05	0.05	0.05	0.05	0.05
Nitrate as Total N (mg/l) (0.1 mg/l)	0.00	0.00	0.00	0.00	0.00	0.00
Ortho-Phosphate as Total P (mg/l) (0.1 mg/l)	0.09	0.09	0.09	0.09	0.09	0.09

Concentration (mg/l)						
IN AVERAGED	Quartiles					
7 complete storms (17 for TSS TDS)	25%	50%	75%	Min	Max	Median
Ph	6.92	7.07	7.50	6.34	7.62	7.07
Conductivity (µS/cm)	4.66	37.20	42.20	1.67	59.75	37.20
Suspended Solids (mg/l)	6.87	10.05	17.43	4.80	94.00	10.05
Dissolved Solids (mg/l)	42.20	50.30	71.94	26.95	178.60	50.30
Total Nitrogen (mg/l) (2.0 mg/l)	0.99	1.59	6.33	0.20	9.15	1.59
Total Phosphorous (mg/l) (0.015 mg/l)	0.14	0.24	0.42	0.09	1.20	0.24
Copper (µg/l) (1.7 µg/l)	5.00	7.48	10.06	4.21	180.75	7.48
Lead (µg/l) (5.4 µg/l)	0.31	1.72	2.48	0.00	128.02	1.72
Chromium (µg/l) (7.2 µg/l)	0.94	2.43	13.75	0.00	33.29	2.43
Zinc (µg/l) (8.6 µg/l)	—	—	—	—	—	—
Nickel (µg/l)	—	—	—	—	—	—
Cadmium (µg/l)	0.21	0.24	0.41	0.15	0.79	0.24
Chloride (mg/l) (0.1 mg/l)	1.49	2.11	2.44	0.30	2.77	2.11
Nitrite as Total N (mg/l) (0.1 mg/l)	0.02	0.03	0.04	0.00	0.08	0.03
Nitrate as Total N (mg/l) (0.1 mg/l)	0.05	0.11	0.19	0.05	0.24	0.11
Ortho-Phosphate as Total P (mg/l) (0.1 mg/l)	0.00	0.02	0.04	0.00	0.06	0.02

Concentration (mg/l)						
OVER - IN AVERAGED	Quartiles					
(-) = Removal	25%	50%	75%	Min	Max	Median
Ph	-0.05	-0.01	0.02	-0.09	0.06	-0.01
Conductivity (µS/cm)	7.63	10.21	12.79	5.05	15.38	10.21
Suspended Solids (mg/l)	1.02	6.60	7.45	-3.39	48.00	6.60
Dissolved Solids (mg/l)	0.13	9.40	28.61	-19.23	35.77	9.40
Total Nitrogen (mg/l) (2.0 mg/l)	-0.33	0.21	0.76	-0.88	1.30	0.21
Total Phosphorous (mg/l) (0.015 mg/l)	0.04	0.11	0.19	-0.04	0.27	0.11
Copper (µg/l) (1.7 µg/l)	—	—	—	—	—	—
Lead (µg/l) (5.4 µg/l)	—	—	—	—	—	—
Chromium (µg/l) (7.2 µg/l)	—	—	—	—	—	—
Zinc (µg/l) (8.6 µg/l)	—	—	—	—	—	—
Nickel (µg/l)	—	—	—	—	—	—
Cadmium (µg/l)	—	—	—	—	—	—
Chloride (mg/l) (0.1 mg/l)	-1.02	-0.05	0.91	-1.98	1.88	-0.05
Nitrite as Total N (mg/l) (0.1 mg/l)	-0.03	0.00	0.03	-0.07	0.06	0.00
Nitrate as Total N (mg/l) (0.1 mg/l)	0.26	0.44	0.62	0.09	0.79	0.44
Ortho-Phosphate as Total P (mg/l) (0.1 mg/l)	-0.04	-0.03	-0.01	-0.06	0.00	-0.03

2006 Ground Water Analysis (L2) 16 Storms Sampled for Water Quality Analysis	Concentration Quartiles 0.25	0.50	0.75	Min	Max	Median
Ph	6.49	6.74	6.85	6.30	7.12	6.74
Conductivity (µS/cm)	184.55	211.00	306.50	175.20	45200.00	211.00
Suspended Solids (mg/l)	—	—	—	—	—	—
Dissolved Solids (mg/l)	155.20	204.13	224.00	116.60	4178.60	204.13
Total Nitrogen (mg/l) (2.0 mg/l)	0.20	1.05	1.75	0.00	6.40	1.05
Total Phosphorous (mg/l) (0.015 mg/l)	0.21	0.44	0.57	0.01	1.29	0.44
Copper (µg/l) (1.7 µg/l)	3.13	5.10	6.71	0.83	7.95	5.10
Lead (µg/l) (5.4 µg/l)	0.00	0.00	0.00	0.00	20.78	0.00
Chromium (µg/l) (7.2 µg/l)	0.00	1.22	3.00	0.00	3.38	1.22
Zinc (µg/l) (8.6 µg/l)	—	—	—	—	—	—
Nickel (µg/l)	—	—	—	—	—	—
Cadmium (µg/l)	0.00	0.24	0.39	0.00	0.40	0.24
Chloride (mg/l) (0.1 mg/l)	12.38	14.17	22.67	4.09	1115.12	14.17
Nitrite as Total N (mg/l) (0.1 mg/l)	0.13	0.19	0.27	0.00	2.47	0.19
Nitrate as Total N (mg/l) (0.1 mg/l)	0.30	0.41	0.64	0.14	39.50	0.41
Ortho-Phosphate as Total P (mg/l) (0.1 mg/l)	0.00	0.00	0.00	0.00	0.08	0.00

2006 Ground Water Analysis (L4) 16 Storms Sampled for Water Quality Analysis	Concentration Quartiles 0.25	0.50	0.75	Min	Max	Median
Ph	6.48	6.72	6.82	6.33	6.98	6.72
Conductivity (µS/cm)	181.70	289.00	607.00	143.90	54100.00	289.00
Suspended Solids (mg/l)	—	—	—	—	—	—
Dissolved Solids (mg/l)	152.10	262.10	455.60	103.50	33285.20	262.10
Total Nitrogen (mg/l) (2.0 mg/l)	0.40	1.00	1.90	0.00	7.80	1.00
Total Phosphorous (mg/l) (0.015 mg/l)	0.40	0.50	0.80	0.00	2.31	0.50
Copper (µg/l) (1.7 µg/l)	8.51	9.00	9.72	7.35	11.59	9.00
Lead (µg/l) (5.4 µg/l)	0.00	0.00	0.00	0.00	0.00	0.00
Chromium (µg/l) (7.2 µg/l)	1.63	2.72	3.34	0.00	3.56	2.72
Zinc (µg/l) (8.6 µg/l)	—	—	—	—	—	—
Nickel (µg/l)	—	—	—	—	—	—
Cadmium (µg/l)	0.00	0.00	0.06	0.00	0.24	0.00
Chloride (mg/l) (0.1 mg/l)	9.98	17.65	142.42	2.83	13648.40	17.65
Nitrite as Total N (mg/l) (0.1 mg/l)	0.08	0.19	0.28	0.00	0.80	0.19
Nitrate as Total N (mg/l) (0.1 mg/l)	0.16	0.29	0.43	0.00	0.59	0.29
Ortho-Phosphate as Total P (mg/l) (0.1 mg/l)	0.00	0.00	0.04	0.00	0.14	0.00

2006 Ground Water Analysis Comparison L2 Traveling to L4 (-) = removal	Concentration Quartiles 0.25	0.50	0.75	Min	Max	Median
Ph	-0.16	-0.07	0.04	-0.31	0.31	-0.07
Conductivity (µS/cm)	-23.60	28.10	339.00	-41.00	45058.00	28.10
Suspended Solids (mg/l)	—	—	—	—	—	—
Dissolved Solids (mg/l)	-19.11	-0.15	140.01	-71.90	29106.60	-0.15
Total Nitrogen (mg/l) (2.0 mg/l)	-0.70	-0.05	1.05	-1.90	7.60	-0.05
Total Phosphorous (mg/l) (0.015 mg/l)	-0.01	0.11	0.36	-1.29	2.15	0.11
Copper (µg/l) (1.7 µg/l)	2.20	5.00	7.88	-0.59	10.76	5.00
Lead (µg/l) (5.4 µg/l)	-5.19	0.00	0.00	-20.78	0.00	0.00
Chromium (µg/l) (7.2 µg/l)	0.14	0.22	0.43	0.00	0.95	0.22
Zinc (µg/l) (8.6 µg/l)	—	—	—	—	—	—
Nickel (µg/l)	—	—	—	—	—	—
Cadmium (µg/l)	-0.39	-0.19	0.00	-0.40	0.00	-0.19
Chloride (mg/l) (0.1 mg/l)	-3.75	12.25	119.74	-7.51	12533.28	12.25
Nitrite as Total N (mg/l) (0.1 mg/l)	-0.08	-0.02	0.06	-2.44	0.67	-0.02
Nitrate as Total N (mg/l) (0.1 mg/l)	-0.37	-0.13	-0.01	-39.50	0.34	-0.13
Ortho-Phosphate as Total P (mg/l) (0.1 mg/l)	0.00	0.00	0.01	-0.03	0.14	0.00

Pollutants – Analysis of the pollutant data is continuing. By comparing the incremental inflows, it is clear that a first flush is observed for TSS, but it is less clear for DSS. Removals annotated here are better thought of as rate reduction. Current studies are looking at a mass balance of this data. It is clear that this site as compared to the others has a high load of pollutants entering.

Research Summary: These results confirm the need to study the operation of these BMPs. The relations between site characteristics, load and volume to BMP design are still poorly understood. From these results, the VUSP expects that the design methods used for these BMPS will change, to more accurately represent the hydrologic, chemical and biological processes involved. For infiltration BMP's, geometry of the infiltration bed will become a component of infiltration design, and screening of TSS to extend operations is critical. The VUSP recommends designers consider emphasizing placement in areas that have cleaner runoff (rooftops, pedestrian malls, lightly traveled pavement, etc.) to maximize the volume removal efficiency and BMP longevity. The freeze thaw and biological actions observed at the bioinfiltration BMP play a large role in its continued operation.

INFORMATION, EDUCATION, AND PUBLICITY

Technical Transfer is a prime mission of the VUSP and represents the most dramatic success to date. This task is approached through on-campus symposium's, speaking engagements, publications, tours of the BMP research and demonstration park, and the VUSP website. Every two years the VUSP coordinates the Commonwealth of Pennsylvania Stormwater Management Symposium. This is a two-day event with featured speakers, paper sessions and BMP tours. In October 2005, well over 250 attendees attended the symposium. In addition, it was projected live over the internet and the presentations are available through the VUSP website. Prior to the symposium, a workshop for municipal officials was held. Note the symposium is run entirely from attendance fees and no grant monies are used. Faculty and students are also frequent participants at many area seminars. These engagements include everything from national EWRI / AWRA conferences to regional and community organizations. On the off year of the October Symposium, a one-day seminar with invited speakers on stormwater topics is held. Attendance at these events is usually around 150. The 2007 Symposium is scheduled for October, and will be available free over the internet.

Many many many visitors have toured the BMP Research and Demonstration Park. Many organizations (AWRA, EWRI, IECA, etc.) have held national conferences in Philadelphia and have included tours of the BMP park. Local watershed groups have also visited the park, as well as many Villanova University classes. Each BMP has an educational sign to help passersby (as well as a website devoted to the BMP).

The VUSP website is a significant tool for outreach. Within the website there are links to every BMP that has been built at the park (and some offsite) with a description, design information, streaming videos, and lessons learned. These sites are updated continuously as results from our studies continue. The website also includes a site for presentations and an interactive database with links to information on all aspects of stormwater BMPs. This structure has been a major emphasis of the VUSP and directly supports all project areas listed previously.

TOTAL PROJECT BUDGET

Year 1: 1 Oct 2003 – 1 Oct 2004
VUSP – PaDep Growing Greener $170,000 + VU Match $128, 197
NMP – PaDep (319 Funds) $ 53,933 + VU Match $ 28,497
NMP – PaDep (319 Funds) $ 11,733 (+ benefits match)
This was added to sustain efforts to match Fed Budget year
Note: several of these grants had differing starting dates, this is an estimate.

Year 2: 1 Oct 2004 – 1 Oct 2005
EPA Region III – 104b.3. funds $160,000 + VU Match $102,748
NMP – PaDep (319 Funds) $ 56,630 + VU Match $29,922

Year 3: Oct 2005 – 1 Oct 2006
TVSSI - William Penn Foundation $70,070 VU Match - $19,600 (est)
NMP – PaDep (319 Funds) $ 58,561 + VU Match $32,036
VUSP - PaDep Growing Greener $175,000 + VU Match $130,476

Year 4: all funding sources not yet secured.
TVSSI - William Penn Foundation $93,507 VU Match - $26,156 (est)
NMP – PaDep (319 Funds) $ 61,000 + VU Match $29,922
VUSP Corporate Donations and Carry Over from previous year.

Year 5: all funding sources not yet secured.
Carry over of TVSSI funds.
NMP – PaDep (319 Funds) $ 67,990 + VU Match $29,827
Note PC/ PA funds not included
VUSP Corporate Donations and Carry Over from previous year.

IMPACT OF OTHER FEDERAL AND STATE PROGRAMS

N/A

OTHER PERTINENT INFORMATION

Mission Statement:

The mission of the Villanova Urban Stormwater Partnership is to advance the evolving comprehensive stormwater management field and to foster the development of public and private Partnerships through research on innovative SWM Best Management Practices, Directed Studies, Technology Transfer and Education.

* Research and directed studies will emphasize comprehensive watershed stormwater management planning, implementation, and evaluation.

* Technology transfer will provide tools, guidance and education for the professional.

* Partnership Goal is to promote cooperation amongst the private, public and academic sectors.

http://www.villanova.edu/VUSP

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