Pennsylvania

Villanova University Stormwater Best Management Practice
Section 319
National Monitoring Program Project

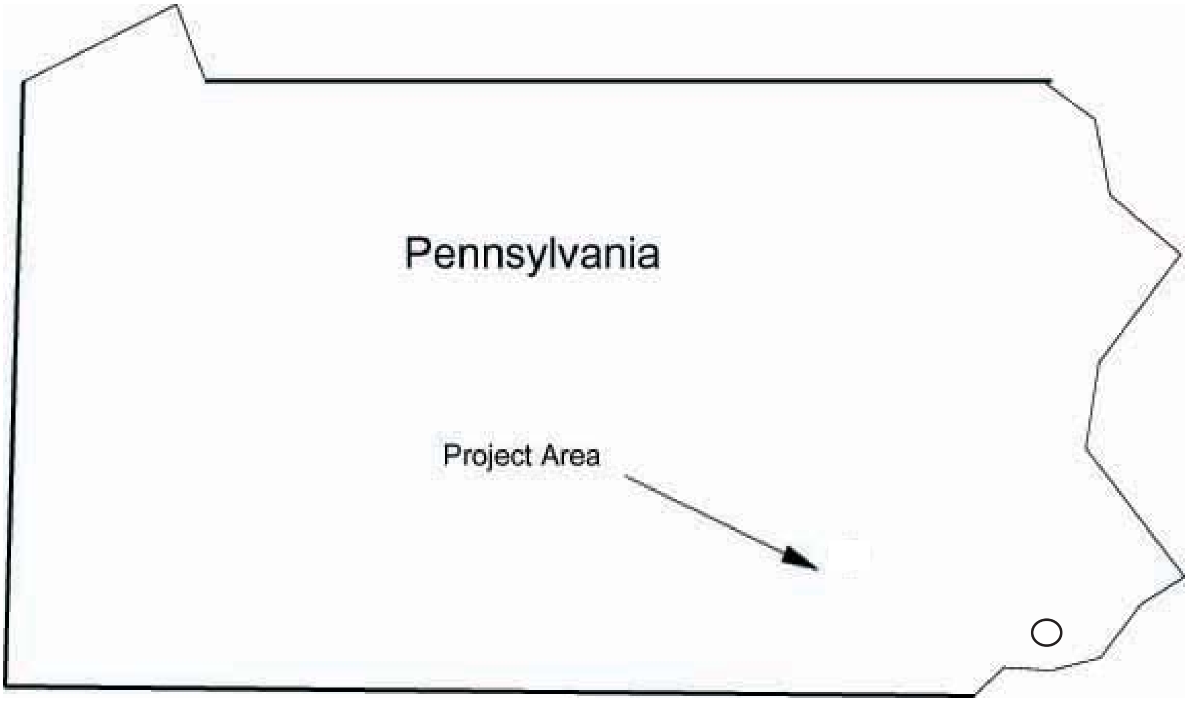


Figure 42: Villanova University Stormwater Best Management Practice (BMP) Monitoring Project.

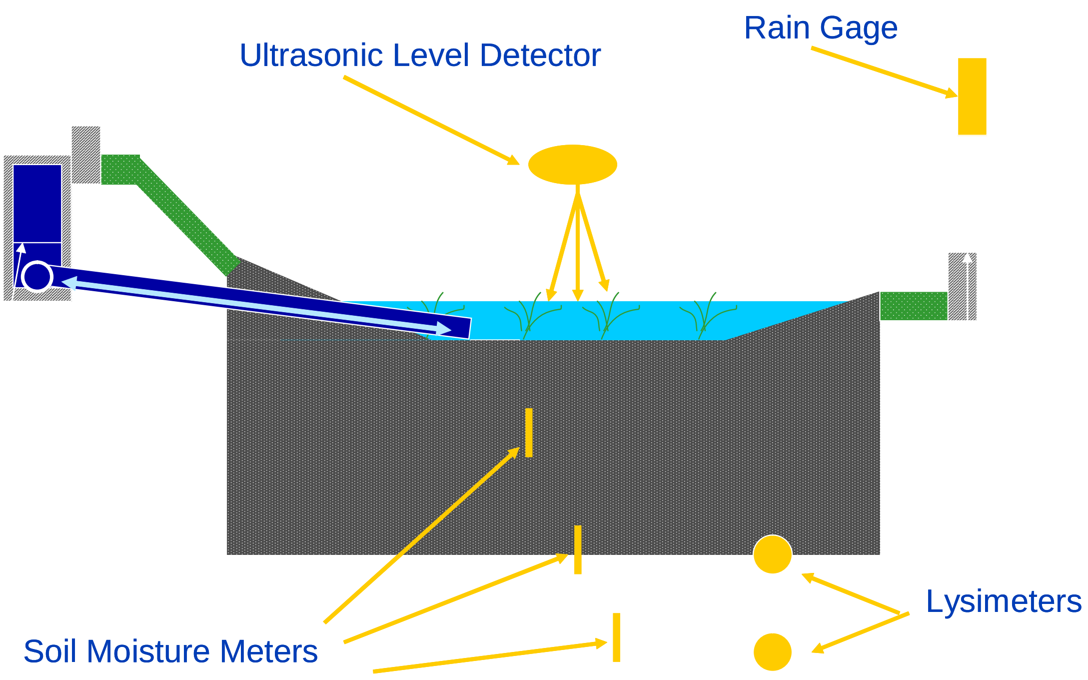


Figure 43. Example Infiltration Monitoring Setup

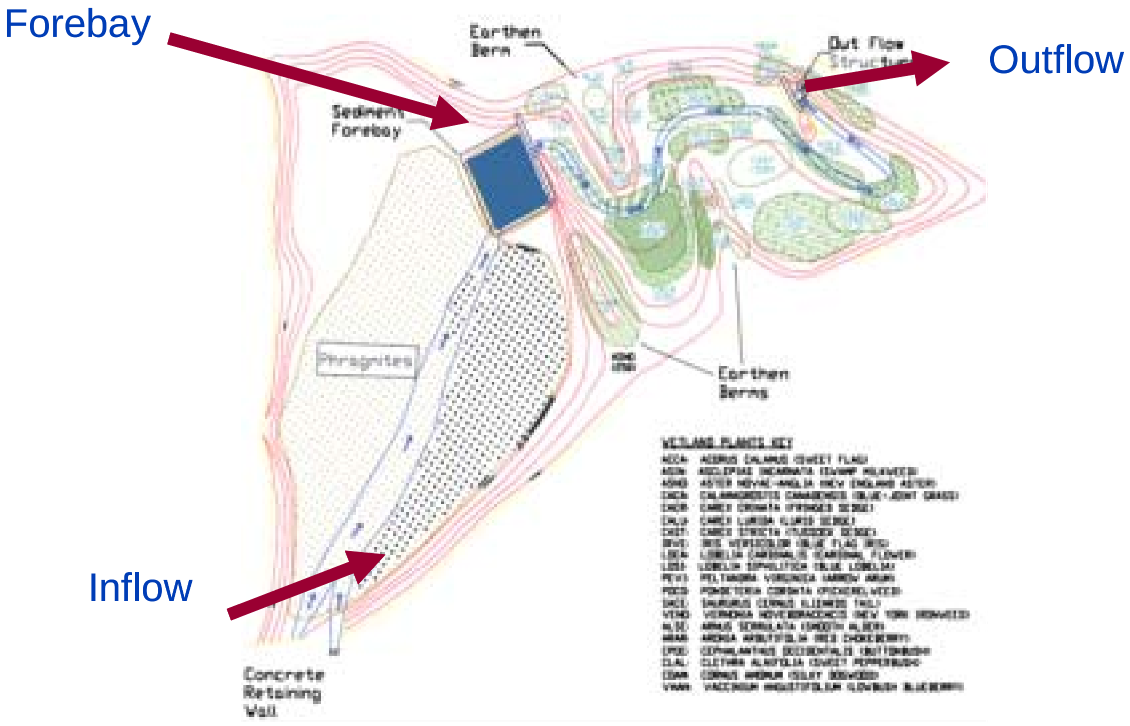


Figure 44. Example Stormwater Wetland Monitoring Setup

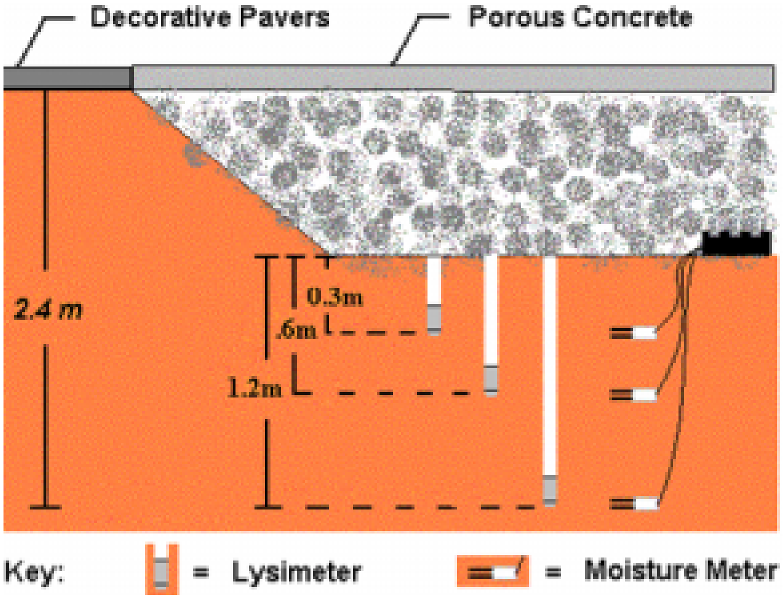


Figure 45 - Porous Concrete - Cross section of instrumentation (Kwiatkowski 2003)

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 four 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, four BMP devices have been constructed including a Stormwater Wetlands, a Bio-Infiltration Traffic Island, a Porous Concrete Infiltration area, and an Infiltration Trench.

Monitoring of smaller urban devices is extremely complex, and involves both flow and quality parameters. Based upon the first year monitoring, we have solidified our monitoring scheme to insure that the sampling is capturing the flow and quality parameters required to categorize both the inflow and outflow of each BMP. We have also invested in upgrades of the laboratory equipment to increase the measurement range sensitivity, and to counteract laboratory challenges encountered with chlorides found on all sites. Data on has been submitted to the EPA / ASCE Stormwater BMP Database.

PROJECT BACKGROUND

Project Area

As of August 2004, a stormwater wetland, an infiltration traffic island, a porous concrete facility, and an infiltration trench have been constructed and are under study. The stormwater wetland was not included in the NMP due to lack of research funding, but is scheduled to be included in Spring 2005. 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.

Stormwater Wetland – (319 Grant, 1998 – concluded) An existing stormwater detention basin on Villanova University property has been converted into an extended detention Stormwater Wetland BMP (Center for Watershed Protection, 1996) using the design concepts presented in the Pennsylvania Handbook of Best Management Practices for Developing Areas (PACD, 1998). Educational signage has been installed to enhance the learning experience, and a website has been created to facilitate technology transfer. The project has been published in EPA 319 Success Stories Part III (EPA, 2002a). Some limited unfunded flow studies have been made at this site, and exploratory water quality work is underway through the Villanova Urban Stormwater Partnership (VUSP). With the awarding of a Coastal Zone Grant, this site is scheduled to be included in the NMP in spring 2005.

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. A recent thesis estimates that annually over 8 inches of water is infiltrated by this site.

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 then 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.

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. Constructed in August of 2004, this structure is being monitored and is under initial testing. Monitoring for the NMP will begin as of 1 October 2004, with educational signage and a website soon to follow.

Featured websites on these projects can be viewed through the below link:

http://www.villanova.edu/VUSP

Project Area

Stormwater Wetland	Watershed – 16.6 hectares
Bioinfiltration Traffic Island	Watershed – 0.53 hectares
Porous Concrete	Watershed – 0.52 hectares
Infiltration Trench	Watershed – 0.16 hectares

Relevant Hydrologic, Geologic, and Meteorologic Factors

All BMPs are in the Philadelphia region. Rainfall is approximately 1.14 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

Stormwater Wetland - The watershed includes large parking lots, university buildings and dormitories, roadways and train tracks. It is approximately 40% impervious.

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.

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 three 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 (bioinfiltration traffic circle, porous concrete, infiltration trench) 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. The Stormwater Wetland is designed to treat the water quality and to reduce the erosive 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 Porous Concrete and Bioinfiltration traffic island commenced 1 Oct 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 of the Best Management Practices. It was also discovered that unexpected extremely large levels of chloride reduced the minimum detection level of the laboratory instruments for dissolved nutrients. To address these issues, additional sampling locations were added to both sites, and additional laboratory HPLC instrumentation was purchased. The QAPP plan is under revision to reflect these changes. To separate these sampling periods and to protect the integrity of the data analysis this period 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. This concept is parallel to the Paired Watershed Study Design (Clausen, 1993) except instead of studying two separate sites, the inflow and outflow of individual BMPs are examined.

Project Schedule

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	Added first flush samplers Added bowl lysimeter
Porous Concrete Infiltration Site	Monitoring Underway 10/01/04-09/30/10	10/01/03-09/30/04	Added first flush samplers Added gutter flow samplers
Infiltration Trench	12/01/04-09/30/10	09/01/04-12/01/04	Construction complete Aug. 2004
Stormwater Wetland	Baseflow Monitoring Underway 06/01/04-09/30/10	Complete	Need modifications to pressure transducers
	Wet Weather Flow Awaiting Contract 02/01/05-09/30/10	Complete	Scheduled to be added to the NMP Spring 2005

Water Quality Monitoring

Variables Measured

pH
Dissolved Oxygen (Wetland only - probe)
Temperature (Wetland only - probe)
Fecal Coliform (Wetland only)
Turbidity (Wetland only)
Conductivity
Total Suspended Solids (surface samples)
Dissolved Solids (depending on volume collected)
Chlorides
Nutrients - N, P (Dissolved - Various Forms)
Metals - Various (Dissolved - Various Forms)

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.

Porous 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 will be used to take samples to measure the inflow water quality at the V notch weir. Pressure transducers and soil lysimeters will be used to evaluate the depth within the rock bed, volume of infiltration (outflow), and and pollutant loadings (Outflow). Again, as the overflow outflows are essentially untreated, the outflow surface water quality is considered the same as the inflow. Note that this site has just been constructed (August 2004).

Stormwater Wetlands – Both wet weather and baseflow events are included. As the great majority of the inflow is piped to the wetlands through culverts, flow is measured using Sigma Corporation 950AV flowmeters. These units measure both velocity and level within the culvert at the inflow and outflow of the BMP (five minute intervals). A rain gage is connected to the flow meter to record the intensity and pattern of the storm. To measure quality, multiple discrete samples are taken during the storm events using automated samplers. Samples are taken at the inflow, the sediment forebay, and the outlet. Probes connected to the flowmeters continuously measure dissolved oxygen, pH, temperature and conductivity. Additional bimonthly baseflow samples are analyzed for fecal coliform. This site was not part of the NMP program for 2004 but is scheduled to be added through funding from the Coastal Zone Program by 1 Jan 2005.

Modifications Since Project Start

As stated above, “First Flush” samplers have been added to the Bioinfiltration Traffic Island and Porous Concrete site. In addition, a gutter flow collection device has been added to the Porous Concrete site. The use of HPLC and graphite furnace capabilities has been added to increase test sensitivity for the second year. The QAPP plan is under revision to reflect these changes.

DATA MANAGEMENT AND ANALYSIS

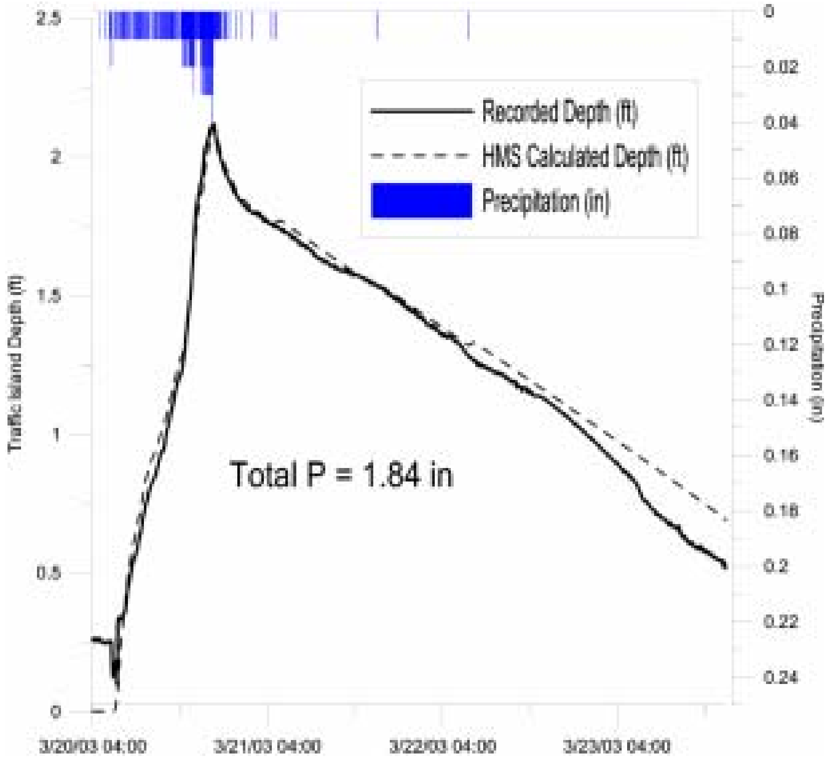
Data from the tests have been entered into the ASCE / EPA Stormwater BMP database and are the focus of numerous theses available through the VUSP website. Three journal articles are in progress.

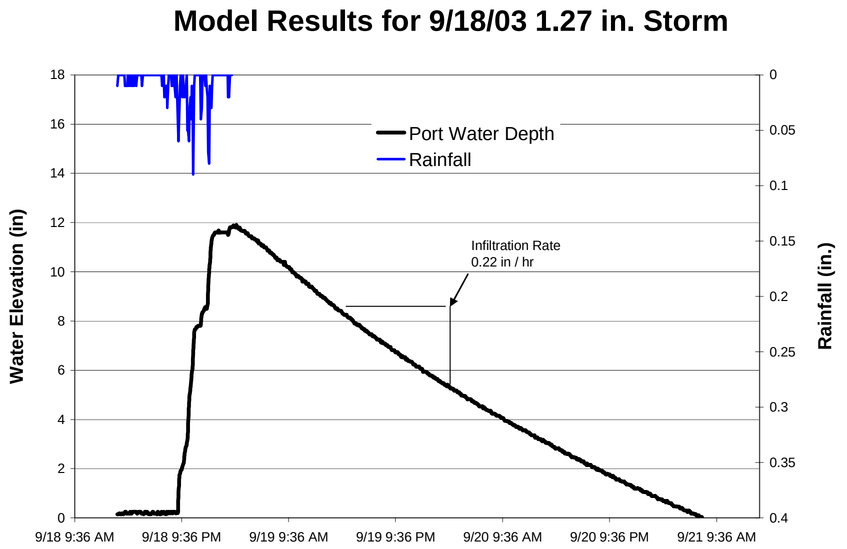
Flow Examples

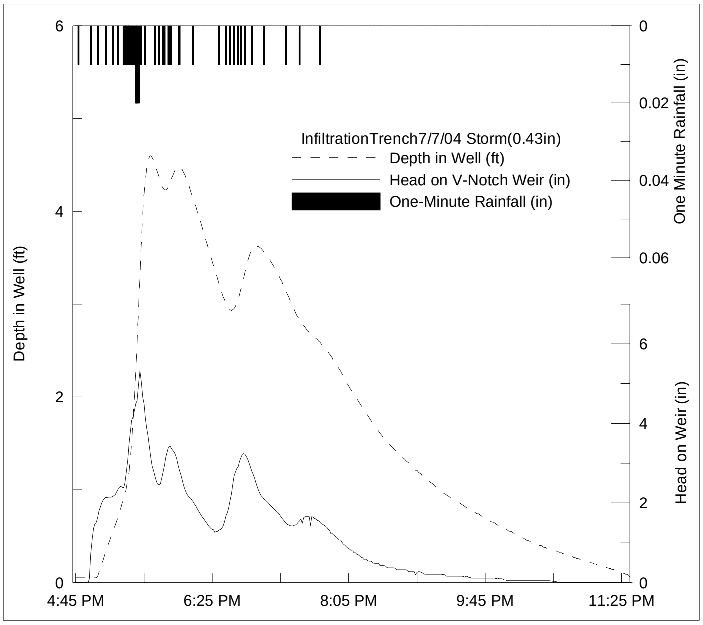
Bioinfiltration Traffic Island - This storm occurred March 20, 2003, with a rainfall of 1.84 in., runoff of 0.90 in., and an observed outflow of 0.48 in. The first graph represents increments of rainfall, and the lower lines are the depth of water in the infiltration bed. The blue line is the measured depth while the red line was developed using HEC-HMS a corps of engineers hydrologic computer model. The straight black signifies the depth where overflow occurs.

Porous Concrete – This storm occurred September 19, 2003 and was approximately 1.3 in. of rainfall. Again the first plot shows increment of rainfall. The graph below shows the depth within the rock bed. Note that no outflow to the surface waters occurred.

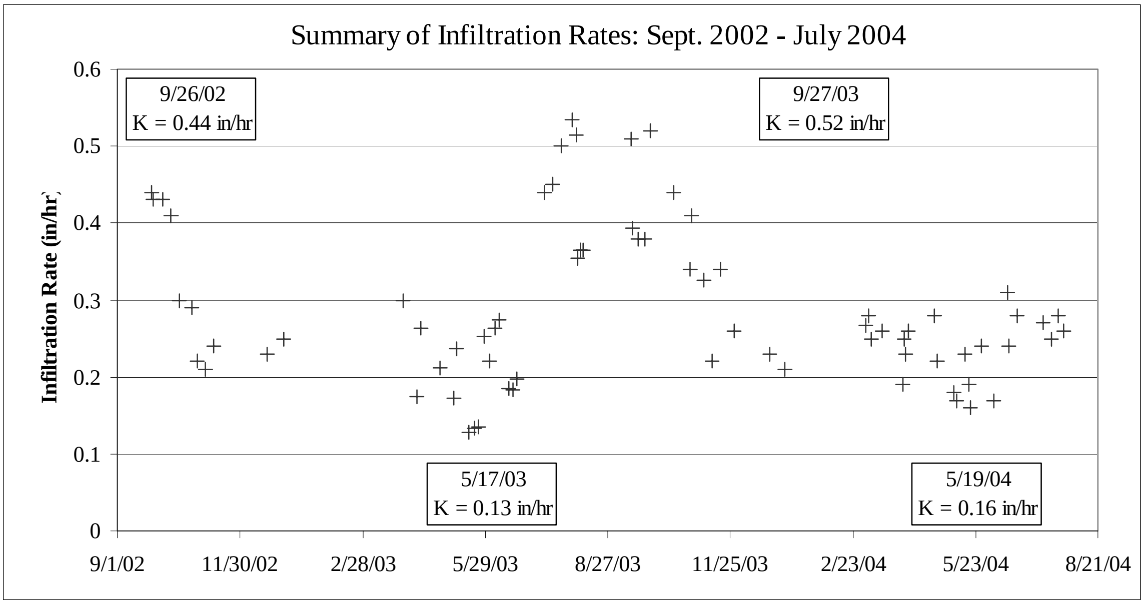
Infiltration Trench – This storm occurred July 7, 2004 and was approximately 0.42 in. of rainfall. The third graph shows the depth within the rock bed and the depth over the V-notch weir that has not as of yet been calibrated. Note that no outflow to the surface waters occurred during this storm.







The graph below shows the measured recession limb infiltration rates by date.



Preliminary Water Quality Findings To Date

The data presented is from the initial monitoring period and has been used to validate monitoring procedures and laboratory work. Note that the sampling procedures have been revised based upon site observations and these results, so they will be reclassified in future reports. Also, the data have been simplified. For example, the lysimeters at 4 and 8 foot of depth have been combined to represent the groundwater outflow of the Porous Concrete BMP. This data has been presented to show the scope of the project, and as the inflow sampling locations have changed, it is not appropriate to make conclusions based on this data.

The following charts represent chloride concentration versus time for the Porous Concrete site. Note the Stations labeled A are outside the bed, and that B11, B12, and B13 are progressively deeper under the rock storage bed.

STATION TYPE: Inflow

Bio-infiltration BMP inflow locations: basin pond water, curb-cut flow. Note that in the future only the curb cut flow will be presented, and the other samples will be reclassified as within the bowl.

	Bio-infiltration BMP			
Parameter Name	**Date: October 2003 - June 2004**			
	HIGH	**MEAN**	**MEDIAN**	**LOW**
NITROGEN, TOTAL AS N (MG/L)	2.6	0.88	0.9	0
PHOSPHORUS, TOTAL AS PO4 (MG/L)	1.55	0.57	0.45	0.04
COPPER, TOTAL (MG/L)	0.04	0.01	0.01	0
CHLORIDE, TOTAL (MG/L)	747.50	72.94	3.60	0.19
NITRITE, AS NO2 (MG/L)	<MDL	<MDL	<MDL	<MDL
NITRATE, AS NO3 (MG/L)	3.78	1.65	2.31	<MDL
PHOSPHATE, AS PO4 (MG/L)	<MDL	<MDL	<MDL	<MDL
TOTAL SUSPENDED SOLIDS (MG/L)	95.0	8.4	5.2	0.0
TOTAL DISSOLVED SOLIDS (MG/L)	1201.3	137.1	51.9	0.0
CONDUCTIVITY (uS/cm)	2476	233	51	11

STATION TYPE: Outflow - Groundwater

Bio-infiltration outflow locations: inflitrated water sampled with lysimeter.

	Bio-infiltration BMP			
Parameter Name	**Date: October 2003 - June 2004**			
	HIGH	**MEAN**	**MEDIAN**	**LOW**
NITROGEN, TOTAL AS N (MG/L)	4	1.26	1.00	0.10
PHOSPHORUS, TOTAL AS PO4 (MG/L)	1.23	0.56	0.6	0
COPPER, TOTAL (MG/L)	0.17	0.080	0.080	0.000
CHLORIDE, TOTAL (MG/L)	1619.5	130.5	19.6	2.3
NITRITE, AS NO2 (MG/L)	<MDL	<MDL	<MDL	<MDL
NITRATE, AS NO3 (MG/L)	3	0.69	0.28	<MDL
PHOSPHATE, AS PO4 (MG/L)	<MDL	<MDL	<MDL	<MDL
TOTAL SUSPENDED SOLIDS (MG/L)	NA	NA	NA	NA

STATION TYPE: Inflow

Porous Concrete BMP inflow locations: Port, Gutter

Parameter Name	Porous Concrete BMP Date: October 2003 - June 2004			
	HIGH	**MEAN**	**MEDIAN**	**LOW**
NITROGEN, TOTAL AS N (MG/L)	< 2	< 2	< 2	< 2
PHOSPHORUS, TOTAL AS PO4 (MG/L)	0.47	0.18	0.15	< 0.06
COPPER, TOTAL (MG/L)	2.09	0.61	0.42	< 0.02
CHLORIDE, TOTAL (MG/L)	773.00	71.76	9.70	< 1.0
NITRITE, AS NO2 (MG/L)	< 1	0.72	0.70	< 0.33
NITRATE, AS NO3 (MG/L)	9.40	4.27	1.93	< 1.0
PHOSPHATE, AS PO4 (MG/L)	<MDL	<MDL	<MDL	<MDL
TOTAL SUSPENDED SOLIDS (MG/L)	0.0178	0.0023	0.0015	0.0000
TOTAL DISSOLVED SOLIDS (MG/L)	1.8325	0.1482	0.0224	0.0000
CONDUCTIVITY (uS/cm)	2880	301	66	8

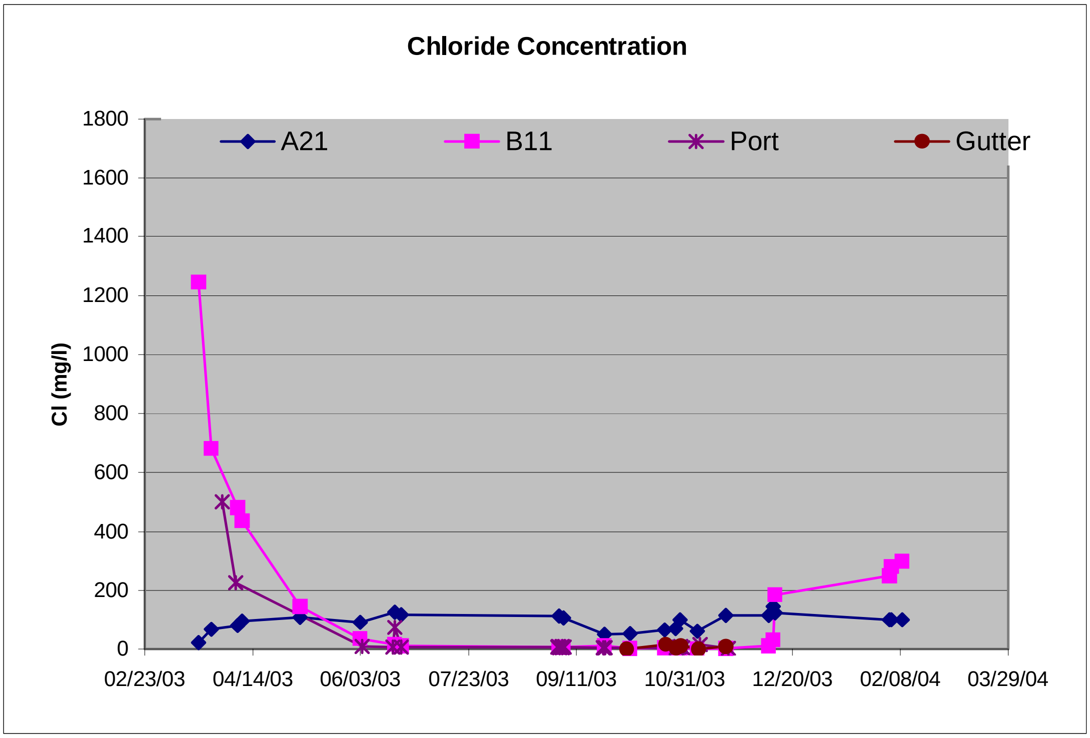
STATION TYPE: Outflow

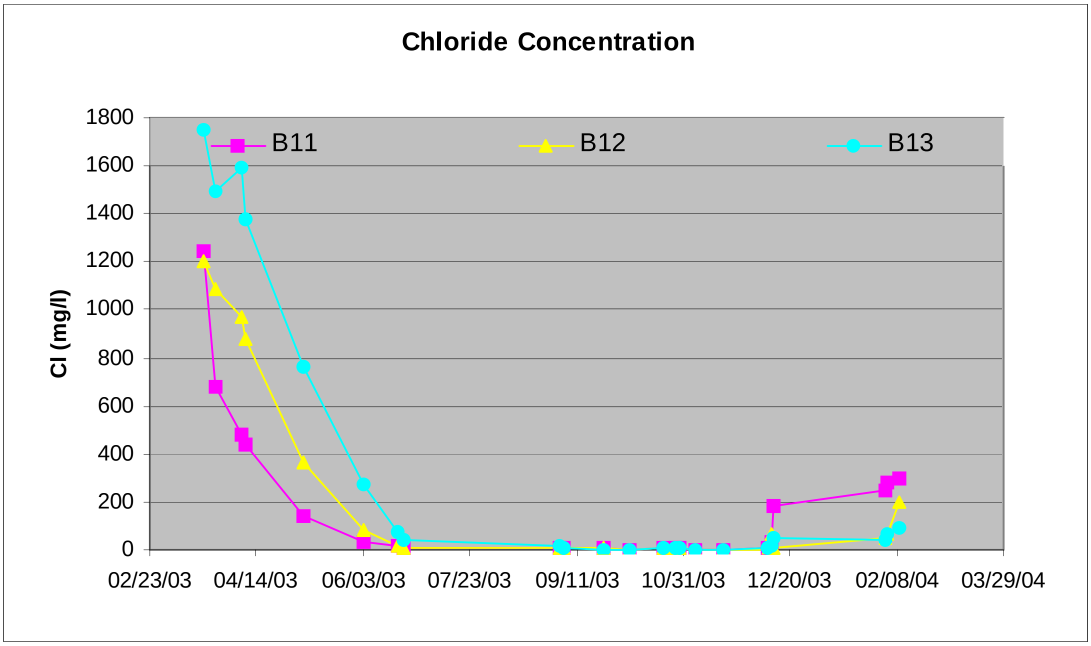
Porous Concrete outflow locations: inflitrated water sampled with lysimeter.

Parameter Name	Porous Concrete BMP Date: October 2003 - June 2004			
	HIGH	**MEAN**	**MEDIAN**	**LOW**
NITROGEN, TOTAL AS N (MG/L)	3.60	0.24	< 2	< 2
PHOSPHORUS, TOTAL AS PO4 (MG/L)	0.64	0.24	0.25	< 0.06
COPPER, TOTAL (MG/L)	0.055	0.024	< 0.021	< 0.021
CHLORIDE, TOTAL (MG/L)	1190.1	124.2	12.9	2.9
NITRITE, AS NO2 (MG/L)	3.90	1.41	< 1	0.43
NITRATE, AS NO3 (MG/L)	12.72	2.95	< 1	< 1
PHOSPHATE, AS PO4 (MG/L)	<MDL	<MDL	<MDL	<MDL
TOTAL SUSPENDED SOLIDS (MG/L)	NA	NA	NA	NA
TOTAL DISSOLVED SOLIDS (MG/L)	NA	NA	NA	NA
CONDUCTIVITY (uS/cm)	3890	627	387	162

Notes: All "less than" values are values that were below the Estimated Detection Limit of the Spectrophotometer. In order to calculate the Mean and Median Values the upper bound of the "less than" values were used. Minimum Detection Limits (MDL) for HPLC (ion-chromatography) analysis is currently reported at 0.5 mg/L (July 2004).

The two charts below represent chloride concentration versus time for the Porous Concrete site. Note the Stations labeled A are outside the bed, and that B11, B12, and B13 are progressively deeper under the rock storage bed.





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 2003, a record was set of close to 250 attendees, including representatives from all surrounding states and also Saipan and North Marianna Island. Prior to the symposium, a workshop for municipal officials was held. This was recorded and is available through the VUSP website for download or viewing. The 2005 symposium is projected to be broadcast in real time over the internet. 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.

Many visitors have toured the BMP Research and Demonstration Park. At least five organizations (AWRA, EWRI, IECA, etc.) have held national conferences in Philadelphia and have included tours of the BMP park over the last three years. 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 first two years 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
Coastal Zone Program (starts 1 Dec 2004) $50,000 + VU Match $59,753

Year 3 – funding sources not yet secured.

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

PROJECT CONTACTS

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REFERENCES

Center for Watershed Protection, New Advances in Urban BMPs (Draft), Silver Spring, MD 1996

Clausen, J.C., Paired Watershed Study Design, EPA Fact Sheet, Washington D.C., 1993

Kwiatkowski, M., Water Quality Study of a Porous Concrete Infiltration Best Management Practice - Masters Thesis, Villanova University, Villanova, PA, 2004

NCSU, Section 319 Nonpoint Source National Monitoring Program Successes and Recommendations – (EPA Report) - Raleigh, NC, 2000

Pennsylvania Association of Conservation Districts, Pennsylvania Manual of Best Management Practices for Developing Areas. Harrisburg, PA., 1998

U.S. Environmental Protection Agency (EPA). National Water Quality Inventory-1996 Report to Congress, Office of the Water Program Operations, Water Planning Division, Washington DC, 1998

U.S. Environmental Protection Agency (EPA), Section 319 Success Stories, Vol. III, Office of Water, Washington DC, 2002a

U.S. Environmental Protection Agency (EPA), National Pollutant Discharge Elimination System, Office of Wastewater Management, 2002b, http://cfpub2.epa.gov/npdes