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Figure 1. Villanova Urban Stormwater Partnership.

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PROJECT SPOTLIGHT

Villanova University Stormwater Best Management Practice National Monitoring Program Project

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Introduction

During the last decade there has been a dramatic shift in the practice of stormwater management. The field has moved away from a single-minded flood prevention approach to one that embraces both water quality and quantity. A new suite of control measures termed Best Management Practices (BMPs) have been developed to treat various forms of water pollution including runoff volume and peak flows from urban stormwater. These practices are still evolving, as recognized by the National Academies report entitled *Urban Stormwater Management in the United States* (National Research Council 2008).

Recognizing the need for research and public education, Villanova University, in collaboration with the Pennsylvania Department of

Mission Statement: *The mission of the Villanova Urban Stormwater Partnership is to advance the evolving field of sustainable stormwater management and to foster the development of public and private partnerships through research on innovative stormwater Best Management Practices, directed studies, technology transfer and education.*

EDITOR'S NOTE

In this issue of *NWQEP NOTES*, we continue our series on National Nonpoint Source Monitoring Program (NMP) projects that have documented improvements in water quality due to implementation of best management practices (BMPs).

As the field of stormwater management continues to evolve towards on-site infiltration and treatment approachs, researchers at Villanova University in southeastern Pennsylvania are at the forefront, studying individual BMPs installed at their campus research and demonstration park. The stormwater practices under evaluation and discussed in our feature article include a bioinfiltration rain garden, pervious concrete/porous asphalt parking lot, and an infiltration trench. Other "green infrastructure" infiltration stormwater control practices are also under study at the research campus. Each BMP is instrumented to evaluate runoff volume, peak flow and surface water quality as well as groundwater quality entering and exiting the site.

The author presents the following conclusions: 1) green infrastructure infiltration BMPs are effective at capturing pollutants and reducing runoff volumes, with greater efficiency when designed for smaller storms; 2) the rate of infiltration during a specific storm is extremely variable and should be considered when monitoring or conducting inspections; 3) longevity in BMP performance is achieved with minimal maintenance through proper design, construction, and siting as long as sites are protected from large sediment loads; 4) runoff from different sources can vary greatly in quality, indicating the potential need for pretreatment to extend longevity; and 5) research on bioinfiltration rain gardens at three universities, including Villanova, shows repeatability of performance of volume reduction.

Green infrastructure infiltration research programs, such as Villanova's, will continue to guide the evolution of stormwater management in the right direction, offering greater protection to our water resources and the life they support.

As always, please feel free to contact me with your ideas, suggestions, and possible contributions to this newsletter.

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Environmental Protection (PaDEP), formed the Villanova Urban Stormwater Partnership (VUSP) in 2002 and created a Stormwater Best Management Practice Research and Demonstration Park on its campus near Philadelphia, PA.

This project was accepted into the U.S. EPA National Nonpoint Source Monitoring Program (NMP) in 2003.

The goals of the Villanova University Stormwater BMP Research and Demonstration Park are:

1) To improve our understanding of nonpoint source pollution;

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

3) To export our results and lessons learned to the stormwater community.

Since 1999, VUSP has constructed and monitored multiple innovative BMP devices including a stormwater wetland, bioinfiltration and bioretention rain gardens, pervious concrete/porous asphalt installations, an infiltration trench, and a green roof. Other practices on campus include both wet and dry ponds, rain barrels, a bioswale and a seepage pit estimated to have been built in the 1890s. Information on the design and construction of some of these BMPs, as well as the design of monitoring efforts, was presented in a previous article in *NWQEP Notes* (Traver 2004). By monitoring wet weather flows and pollution entering and exiting each BMP, the effectiveness of these technologies can be measured and evaluated. As the research ends on a specific site, a new one is brought on line. Each site is instrumented to facilitate study of runoff volume, peak flow and quality.

Financial support for the construction and monitoring of the BMPs has come from a variety of sources. Construction has been funded through the Pennsylvania Section 319 Nonpoint Source program, the Pennsylvania Growing Greener I and II programs, and Villanova University Facilities Department. Monitoring has been supported by EPA Section 319 NMP, along with funds from the William Penn Foundation, Pennsylvania Growing Greener, the VUSP corporate partners, the NOAA Coastal Zone Program, EPA Region III 104B3, and several targeted EPA grants. A project comparing bioretention sites across multiple universities, including Villanova University, is underway, funded by the Cooperative Institute for Coastal and Estuarine Environmental Technology (CICEET).

Educational signage has been installed at each BMP site to enhance the learning experience and a website has been created to facilitate technology transfer. The experiences gained through the construction, operation, monitoring, and evaluation of these sites form the basis for the outreach and education component of the Research and Demonstration Park.

BMP Research Sites

Even before the term was developed, "Green Infrastructure" infiltration BMPs have been the focus of much research at Villanova. Each of the sites described below has been under study since construction. Websites for each stormwater BMP project can be viewed through the following link: http://www.villanova.edu/vusp.

Figure 2. Photograph of VU Bioinfiltration Rain Garden BMP (2007).

Bioinfiltration Rain Garden (BRG) (PA Growing Greener Grant, constructed summer 2001). This bioinfiltration BMP (previously termed Bioinifiltration Traffic Island) was created by retrofitting an existing traffic island on Villanova's campus as shown in Figure 2. The facility intercepts runoff from a highly impervious (50%) student parking area and road (0.53 ha) that previously would be collected by inlets and delivered through culverts to a dry detention basin. The BMP is designed to control runoff from smaller storms (1-3 cm) through capture and infiltration of the first flush. Capture of these small storms treats more than 80% of the annual rainfall, thus improving water quality, reducing downstream bank erosion and maintaining baseflow.

Figure 3. Photograph of VU Infiltration Trench BMP (2005).

Infiltration Trench (IT) (EPA Section 319 grant, constructed August 2004). This BMP has a very large drainage area to infiltration area ratio to stress the capacity of the BMP. It is designed to capture approximately the first 0.6 cm of runoff from an elevated parking deck (0.16 ha) and infiltrate it through a rock bed into the ground. The rock bed has a surface area of approximately 7.2 m^2, and is 3 m deep (under the influent box and picnic table in Fig. 3). Overflow from the trench first exits through a pipe at the surface to the inlet pictured (far left of Figure 3). During extreme events, if the overflow pipe is full, any additional runoff exits through the porous pavers placed above the infiltration trench (Figure 3). Of the demonstration sites under study, this site is the only one with a 100% impervious drainage area. The drainage area receives continuous use by faculty and staff vehicles.

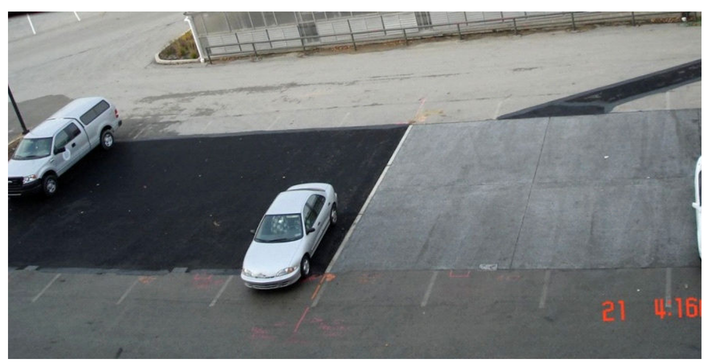

Figure 4. Photograph of VU Pervious Concrete / Porous Asphalt BMP (2007).

Pervious Concrete / Porous Asphalt (PCPA) (EPA Section 319 grant, National Ready-Mixed Concrete Association – Prince Georges County, constructed October 2007). This BMP captures runoff from a campus parking area, passes the flow through either a pervious concrete or porous asphalt surface course, and infiltrates it through a rock bed into the ground (Figure 4). The site, formerly a standard asphalt paved area, is located behind Mendel Hall at the Villanova campus. The site consists of an infiltration bed overlain by a 15.2 x 9.1 m pervious concrete surface and an adjacent, equally sized porous asphalt surface. The site receives continuous use by faculty and staff vehicles. The site is designed to capture and infiltrate storms of up to five cm of rainfall. From these events there is no runoff from the site. The pervious pavements receive water solely from parking areas. The infiltration beds are level and range from 0.9 to 1.5 m deep and are filled with washed stone, with approximately 40% void space. In extreme events when the capacity of the storage beds is exceeded, flows are permitted to exit the site and flow out to the original storm sewer system.

This overflow eventually makes its way to a stormwater wetland.

Two additional BMP sites that were reported in the previous *NWQEP Notes* (Traver 2004) have been retired. These include the Villanova Stormwater Wetland and Porous Concrete BMP. Details of these sites are available both in the *NWQEP Notes* from 2004, and the VUSP website.

Monitoring Design

Each BMP has a custom-designed monitoring system to evaluate the surface water quality and quantity, as well as groundwater (vadose zone) quality. Each site has rain gages, water sampling devices, and flow or level recorders as appropriate. Water quality samples were collected using automated samplers, first flush samplers, grab samples, and lysimeters. Flow leaving the site is split into infiltration and overflow for large storm events. As sampling is conducted from the vadose zone, soil lysimeters are 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 volume is limited, occasionally limiting the number of tests performed.

Bioinfiltration Rain Garden (Figures 2, 5 and 6)

Stormwater quantity: The bioinfiltration rain garden has been equipped to accept runoff entering the system via two inlets (north and south), and from a culvert that intercepts runoff from an adjacent culvert.

- Rainfall is measured in 5-minute intervals with a tipping bucket rain gage.
- Overflow is measured through use of a combination V notch weir / pressure transducer.
- Depth within the bowl is measured directly, initially using an ultrasonic level recorder and later a pressure transducer.
- Inflow is determined from a calibrated hydrologic model using all data mentioned previously.
- Multiple Pressure Transducers are installed in surrounding wells. This arrangement is still preliminary at present.

Stormwater quality: Surface runoff and sub-surface vadose zone samples are collected for approximately 12-18 storms/year.

- Two first-flush samplers catch the first two L of direct runoff from the impervious surface and the grass area adjacent to the basin.
- Initially, a grab sample was collected of surface water during the storm event, with a second sample collected at the conclusion of rainfall, if ponding had occurred. This has been replaced by an automated composite sampler.
- A composite grab sample is taken from the outflow weir.
- Lysimeters are located at depths of 0, 1.2, and 2.4 m beneath the surface. The sample is extracted from the soil through the use of a pressure-vacuum soil water sampler.
- Grab samples have been taken of the groundwater from surrounding wells. These samples are part of another project that is still at a preliminary stage.

Figure 5 shows a schematic drawing of the sampling locations for surface water samples at the bioinfiltration rain garden, and Figure 6 shows the horizontal position of the groundwater lysimeters.

Infiltration Trench (IT) (Figures 3 and 7)

Stormwater Quantity: The infiltration trench has been equipped to measure and sample runoff entering the system, storage within the system, and overflow. All data are recorded continuously and downloaded weekly.

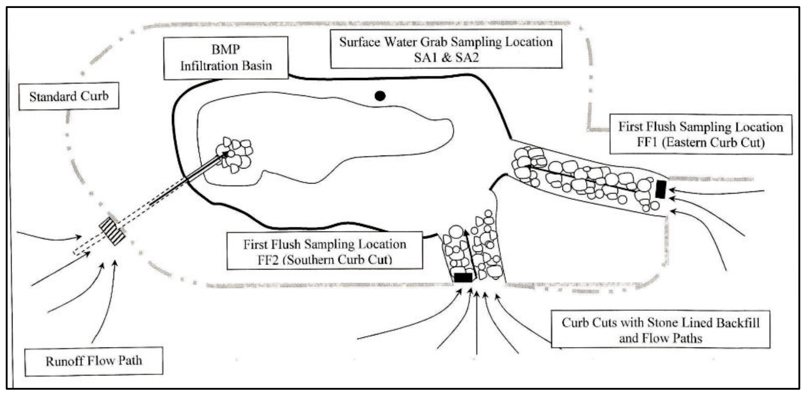

Figure 5. Schematic of BRG surface sampling locations (Ermilio 2005).

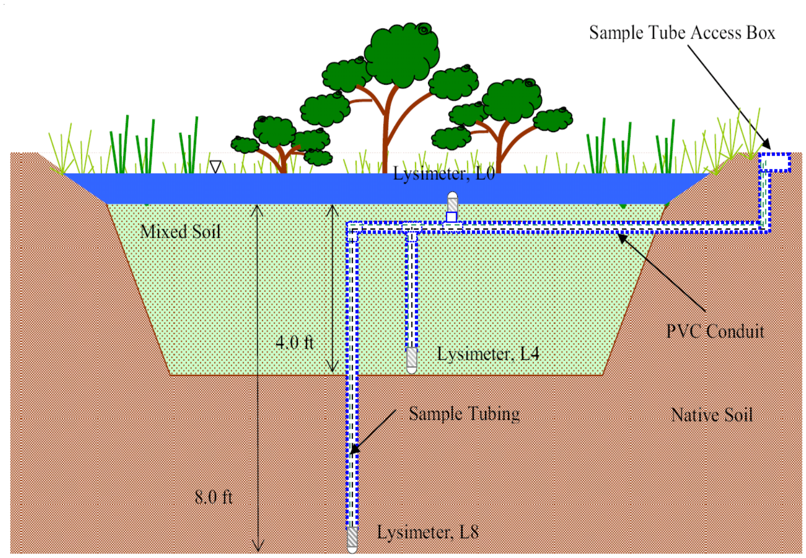

Figure 6. Diagram of BRG subsurface sampling locations.

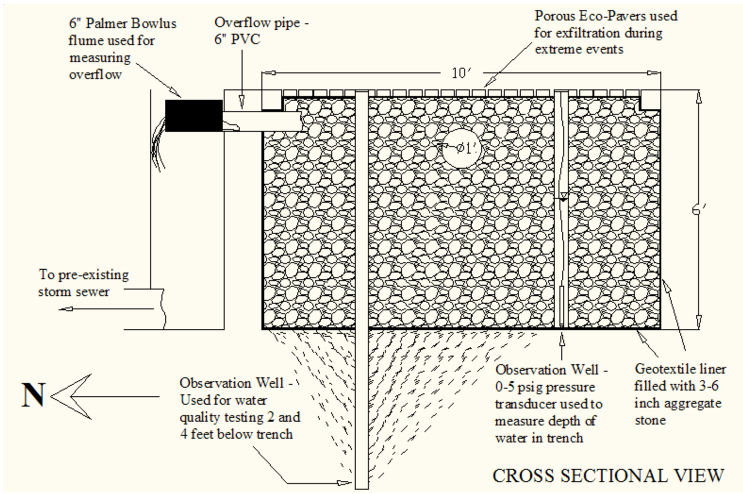

Figure 7. Diagram of IT cross section with subsurface sampling locations.

- Rainfall is measured in 1-minute intervals using a tipping bucket rain gage.
- Runoff entering the site is measured using two V-notch type weirs with corresponding pressure transducers.
- Depth of runoff stored in the rock bed is measured using a pressure transducer.
- Overflow is measured using a manufactured weir and a pressure transducer.

Stormwater Quality: Event-based samples of surface runoff and soil moisture are collected from an average of 12-18 storms/year.

- An autosampler takes rainfall-weighted discrete samples of surface water inflow.
- Lysimeters are located at 0.6 and 1.2 m depths beneath the surface to extract vadose zone water samples.
- A grab sample collector is used to capture overflow water quality samples.

Pervious Concrete / Porous Asphalt (PCPA) (Figures 3 and 8)

Note: Sampling was reduced in 2009 to focus on flow and temperature following conclusion of the water quality study. Notes below are on the original instrumentation.

Stormwater Quantity: The PC/PA has been equipped to monitor runoff entering the system through the porous surface. These flows are correlated to the rainfall amounts measured by a rain gage located on site. The site is further equipped to measure ponded depths and potential overflow. All data are recorded continuously in a data logger.

- Rainfall is measured in 10-minute intervals using a tipping bucket rain gage.
- Pressure transducers that measure the depth in 5 minute intervals are used to measure depths in each rock bed. They are also used in conjunction with a V-notch weir to measure any overflow.

Stormwater Quality: Precipitation event data are collected for surface runoff and sub-surface soil moisture. On average, 12 to 18 storms are sampled yearly.

- Two first-flush samplers catch the first two L of direct runoff from the impervious surfaces upstream of each pervious surface.
- Grab samples of runoff stored in the rock bed are collected following the storm.
- Lysimeters located at 0.15, 0.30, and 0.46 m beneath the surface extract samples from the soil through the use of porous ceramic cups placed under suction during a storm event and pressure after completion using a pressure-vacuum soil water sampler.

The project used Sigma 900 autosamplers capable of taking up to 24 discrete water samples or one composite sample per storm event. To get a consistent sampling routine, the automated samplers are triggered through the data logger through rainfall or depth of water in the BMP. A consistent sampling protocol is established for each site.

First flush samples were collected using the GKY First Flush Sampler, a passive stormwater sampler that can hold up to 5 L of water (Figure 9). The lid of each sampler is constructed with 5 sampling ports, each of which can be plugged to control the rate at which collected runoff enters the sampler. Plastic flaps on the underside of each port function as closing mechanisms, preventing additional water from entering the sampler once it has reached its capacity. Each

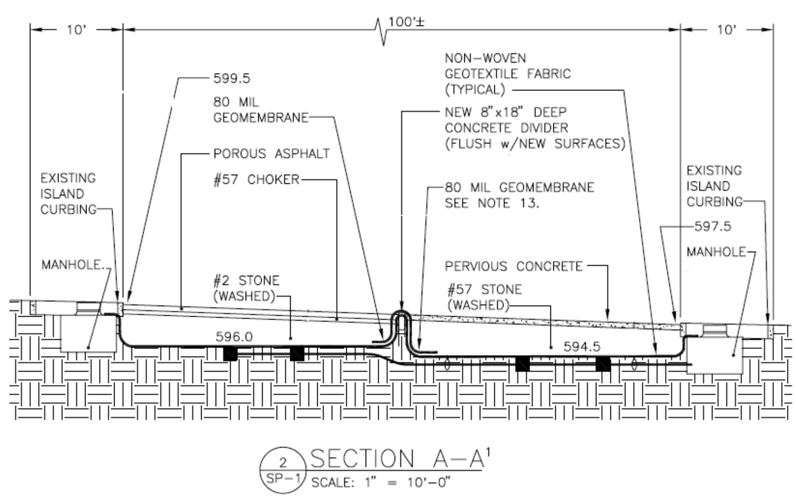

Figure 8. Diagram of PCPA cross section.

Figure 9. Photograph of GKY First Flush sampler.

sampler is fitted with a 5 L removable plastic container and lid to permit sample transport.

Lysimeters work by overcoming soil water tension or negative pressure created by capillary forces. By creating a vacuum or negative pressure greater than the soil suction holding the water within the capillary spaces, a hydraulic gradient is established for the water to flow through the porous ceramic cup into the sampler.

The samples are analyzed in Villanova University's Civil and Environmental Engineering Water Resources Laboratory, beginning within 30 minutes of sample collection; all analyses are typically completed within 24 hours of sample collection. Any samples not analyzed within 24 hours are preserved according to appropriate protocols established for each analysis. Variables measured include:

- 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)

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, analyses are performed using spectrophotometry, ion chromatography, and atomic adsorption equipment. An approved Quality Assurance Project Plan (QAPP) is in place. Unexpected extreme values of chlorides from road salt interfered with the nitrate, nitrite, and orthophosphate HPLC analysis for the first several years. This was corrected through the purchase of new laboratory equipment in 2008.

Monitoring Results

Each of the green infrastructure BMPs is monitored for both quality and flow. Research results are used to further our understanding of how each BMP performs from both a surface and subsurface water perspective. Data from the Bioinfiltration Rain Garden are presented in depth, with selected examples of data from the other sites.

Bioinfiltration Rain Garden *(Previously known as the Bioinfiltration Traffic Island)*

The surface water results of pollutants and flows entering and exiting the BRG from a surface water perspective are presented in Tables 1 and 2. Table 1 is a record of all storm events sampled, while Table 2 presents results from 2008 to allow comparison of the removal percentages for that individual year to that of the complete record.

Note the significant reduction of surface water pollutants achieved through bioinfiltration. It is interesting to observe how much higher the TSS removal is than that of the flow volume. The surface water capture is underrepresented in this report as storms less then 6.3 mm are not included in the statistics, and these storms would be completely captured. The comparison of 2008 to the long term record is used to further our understanding of the volume and pollutant removal of the site as it ages. It appears that the site is increasing in pollutant removal effec-

Table 1. Bioinfiltration Rain Garden – Surface Flow Performance 2003-2008.

Bioinfiltration Rain Garden Surface Water Analysis				
Lifetime Totals				
	# of Storms	Inflow	Outflow	Removal Efficiency
Water Quantity (Measured Events)	253	14,548,858 L	7,297,715 L	49.8%
Total Suspended Solids (TSS)	74	410 kg	10 kg	97.5%
Total Dissolved Solids (TDS)	76	408 kg	94 kg	76.9%
Total Nitrogen (TN) as N	41	2848 g	287 g	89.9%
Total Kjeldahl Nitrogen (TKN) as N	1	0 g	0 g	NA
NO2 as N	51	162 g	21 g	87.0%
NO3 as N	55	1226 g	142 g	88.4%
Total Phosphorus (TP) as P	70	2844 g	2073 g	27.1%
Phosphate (PO4) as P	51	254 g	75 g	70.3%
Chloride (CHL)	62	257 kg	4 kg	98.5%
Total Cadmium	25	2243 mg	222 mg	90.1%
Total Chromium	38	42337 mg	14698 mg	65.3%
Total Lead	41	44428 mg	6580 mg	85.2%

Note: Smaller storms less then 6.3 mm are not included.

Table 2. Bioinfiltration Rain Garden – Surface Flow Performance 2008.

Bioinfiltration Rain Garden Surface Water Analysis 2008	# of Storms	Inflow	Outflow	Removal Efficiency	Change in Removal Efficiency vs. long-term
Water Quantity (All Recorded Events > 0.25")	38	-	-	-	"+/-
Water Quantity (Measured Events)	29	1,501,589 L	706,432 L	53.0%	3.1%
Total Suspended Solids (TSS)	14	49 kg	3 kg	94.7%	-2.8%
Total Dissolved Solids (TDS)	15	62 kg	23 kg	62.4%	-14.5%
Total Nitrogen as N	12	310 g	17 g	94.5%	4.6%
Total Kjeldahl Nitrogen as N	1	0 g	0 g	-	
NO2 as N	10	72 g	3 g	95.3%	8.3%
NO3 as N	10	11 g	0 g	99.3%	10.8%
Total Phosphorus (TP) as P	11	127 g	12 g	90.6%	63.5%
Phosphate (PO4) as P	10	50 g	2 g	96.2%	25.8%
Chloride (CHL)	10	7 kg	2 kg	72.2%	-26.3%
Total Cadmium	8	1,244 mg	180 mg	85.5%	-4.6%
Total Chromium	5	30,186 mg	8,248 mg	72.7%	7.4%
Total Lead	8	37,233 mg	3,893 mg	89.5%	4.4%

Note: Smaller storms less then 6.3 mm are not included.

Table 3. Bioinfiltration Raingarden Vadose Zone Sampling 2008. Concentrations at 0, 25, 50, 75, and 100 percent levels refer to quantiles from cumulative frequency distribution of observed values.

BioInfiltration Traffic Island Groundwater Analysis - Concentrations at Soil Surface 2008

Water Quantity	Detection Limit	Num. of Storms	Concentration 0% (Min)	25%	50%	75%	100% (Max)
TDS (mg/l)	-	8	53	74	107	385	1445
pH	-	11	4.18	5.96	6.56	6.90	7.33
Conductivity (µS/cm)	-	11	54	68	81	95	135
TN (mg/l) as N	1.7 mg/l	10	0.85	0.85	1.28	2.05	2.40
NO2 (mg/l) as N	0.005 mg/l	9	0.03	0.52	0.74	1.19	4.22
NO3 (mg/l) as N	0.01 mg/l	9	0.00	0.00	0.03	0.21	0.44
TP (mg/l) as P	0.06 mg/l	10	0.14	0.19	0.26	0.48	0.95
PO4 (mg/l) as P	0.01 mg/l	9	0.01	0.02	0.03	0.07	0.94
CHL (mg/l)	0.5 mg/l	9	0.3	9.2	26.7	65.2	407.8
Dissolved Cadmium (µg/l)	0.1 µg/l	4	0.05	0.05	0.14	0.31	0.58
Dissolved Lead (µg/l)	0.5 µg/l	3	0.25	0.33	0.42	1.05	1.68

*Non-detects are reported as half of the detection limit

BioInfiltration Traffic Island Groundwater Analysis - Concentrations at 4 feet 2008

Water Quantity	Detection Limit	Num. of Storms	Concentration 0% (Min)	25%	50%	75%	100% (Max)
TDS (mg/l)	-	10	6	197	237	455	1344
pH	-	11	6.22	6.42	6.70	6.78	7.33
Conductivity (µS/cm)	-	11	330	339	349	397	774
TN (mg/l) as N	1.7 mg/l	12	0.85	0.85	0.85	0.85	1.90
NO2 (mg/l) as N	0.005 mg/l	10	0.03	0.22	0.53	0.83	1.29
NO3 (mg/l) as N	0.01 mg/l	10	0.01	0.01	0.14	0.64	2.12
TP (mg/l) as P	0.06 mg/l	11	0.07	0.17	0.20	0.23	0.34
PO4 (mg/l) as P	0.01 mg/l	10	0.01	0.01	0.03	0.11	0.80
CHL (mg/l)	0.5 mg/l	10	35.6	155.8	292.2	380.5	625.5
Dissolved Cadmium (µg/l)	0.1 µg/l	7	0.05	0.05	0.05	0.05	0.22
Dissolved Lead (µg/l)	0.5 µg/l	7	0.25	0.25	0.25	0.25	0.25

*Non-detects are reported as half of the detection limit

BioInfiltration Traffic Island Groundwater Analysis - Concentrations at 8 feet 2008

Water Quantity	Detection Limit	Num. of Storms	Concentration 0% (Min)	25%	50%	75%	100% (Max)
TDS (mg/l)	-	15	35	209	262	487	8659
pH	-	12	5.97	6.54	6.83	6.99	7.58
Conductivity (µS/cm)	-	12	80	313	383	421	476
TN (mg/l) as N	1.7 mg/l	12	0.85	0.85	0.85	0.85	3.50
NO2 (mg/l) as N	0.005 mg/l	10	0.03	0.24	0.53	0.86	1.19
NO3 (mg/l) as N	0.01 mg/l	10	0.01	0.01	0.02	0.38	1.08
TP (mg/l) as P	0.06 mg/l	11	0.03	0.15	0.19	0.29	0.44
PO4 (mg/l) as P	0.01 mg/l	10	0.00	0.01	0.02	0.04	0.70
CHL (mg/l)	0.5 mg/l	10	34.5	170.5	258.0	354.9	654.8
Dissolved Cadmium (µg/l)	0.1 µg/l	8	0.05	0.05	0.05	0.05	0.05
Dissolved Lead (µg/l)	0.5 µg/l	7	0.25	0.25	0.25	0.25	1.33

*Non-detects are reported as half of the detection limit

tiveness, but that has not as of yet been proven statistically. The exception is TDS / Chlorides / Cadmium, which are skewed due to snow melt operations for 2008. We will learn more as results from 2009 and 2010 are incorporated in the data base, as laboratory detection limits have improved.

The subsurface results (Table 3) are presented as concentrations (mg/L) of each pollutant as measured at the 0, 1.2, and 2.4 m level. As it is not yet known how much of the captured volumes are infiltrated versus evapotranspired, we are unable to estimate mass loadings.

Note that while TDS, conductivity, TN, and Chloride increase as the stormwater moves through the soil, the pollutants are slightly reduced.

While the pollutant reduction as percent effectiveness is a useful index of BMP performance, an advantage of long-term monitoring is the ability to study the behavior of the BMP based upon a larger data set, especially the more infrequent larger events. Figures 10 and 11 present analysis from the bioinfiltration rain garden with respect to flow volume and peak flow. In Figure 10, the relationship between inflow and outflow volume is bilinear, with smaller rainfall events being completely infiltrated or evapotranspired. Note that the x intercept of 41.6 m^3 represents the average inflow volume that is removed completely with no surface outflows. Based on the regression model, this volume is removed from larger events as well.

Figure 11 presents a similar look at the effect of the bioinfiltration BMP on peak flows. While the relationship between inflow and outflow peaks are not as linear as for volume, a clear reduction in peaks is evident.

Extended monitoring allows the researcher to examine the record in new ways to more fully understand the characteristics of the technology under investigation. Figures 12 and 13 present the TSS and TDS results using a probabilistic approach. For each rainfall event, the inflow and outflow TSS or TDS mass values are sorted and assigned probabilities based on the cumulative distribution of observed data in order to understand their significance. For ex-

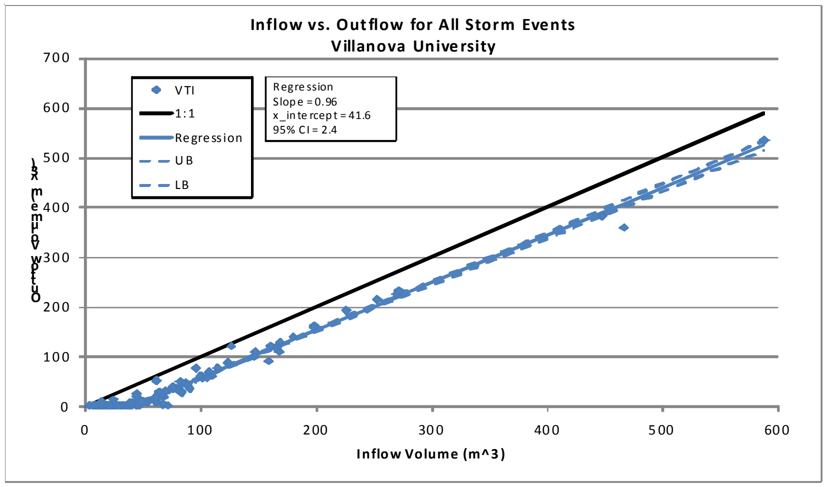

Figure 10. Plot of volume inflow / outflow relationship for Bioinfiltration Rain Garden.

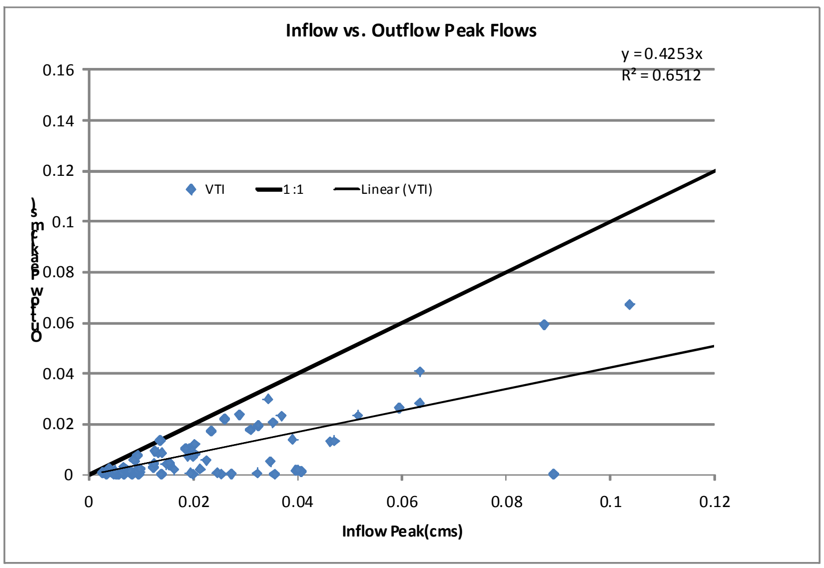

Figure 11. Plot of flow inflow / outflow relationship for Bioinfiltration Rain Garden.

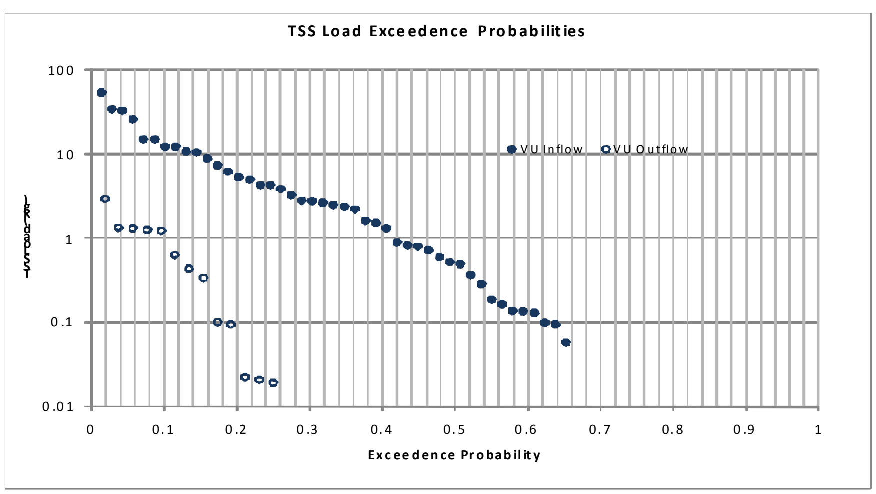

Figure 12: TSS exceedence probability plot for the Bioinfiltration Rain Garden.

ample, it can be stated that a 40% chance exists of the inflow carrying a TSS load of 1 kg, but only an 11% chance of 1 kg of TSS exported in the outflow. Or there is a 15% chance of having less than 10 kg entering, with approximately 0.16 kg leaving at the same probability level.

Infiltration Trench

While no statistical change in performance over seven years was found for the Bioinfiltration Rain Garden (Emerson and Traver 2008) the same is not the case for the infiltration trench. Note in Figure 14 the rapid decrease in infiltration rate. We have concluded that the TSS entering the infiltration trench has been compressed at the bottom, and all current infiltration occurs through the side wall accounting for the reduction in volume removal. The influence of temperature is also depicted on this graph. The blue diamonds represent the ground temperature. Note the change in percolation rates with higher ground temperature, likely due to the temperature effect on water viscosity. This seldom reported property is seen on all infiltration sites under study (Heasom et al. 2006, Braga et al. 2007, Emerson and Traver 2008).

Pervious Concrete – Porous Asphalt

Research on the Pervious Concrete – Porous Asphalt site has shown a significant benefit in the reduction of thermal pollution (Fig. 15). The surface temperatures of A (asphalt) and C (concrete) reflect the temperatures of the air. Runoff is clearly heated by the surface (Porous Asphalt (PA) and Pervious Concrete (PC)). However, the runoff entering the bed is quickly cooled as shown by the almost constant bed temperature.

Green Infrastructure Project Findings Year 1-6

The advantage of conducting long-term investigation into multiple BMPs has been the ability to track performance changes over time and to contrast performance of different BMP types. Further, additional research grants from CICEET and the Pennsylvania Growing Greener program among others has allowed us to perform expanded analysis beyond that funded by the EPA National Nonpoint Source Monitoring Program. This research work coupled with our day to day experiences have led to the following findings:

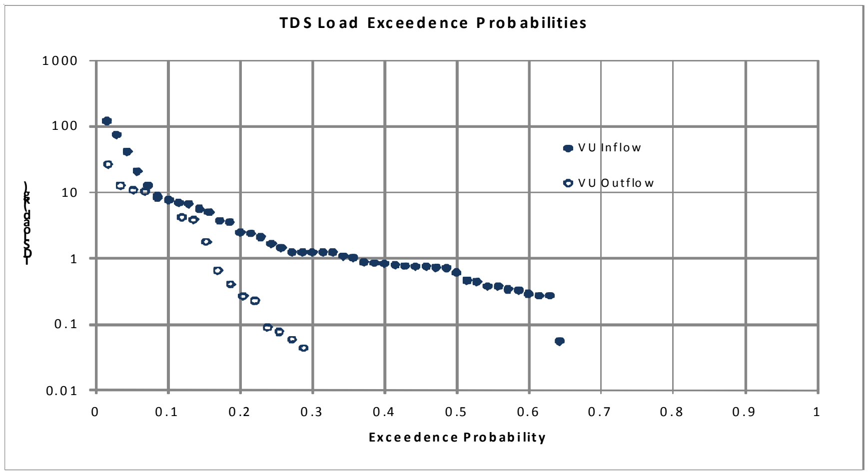

Figure 13. TDS exceedence probability plot for the Bioinfiltration Rain Garden.

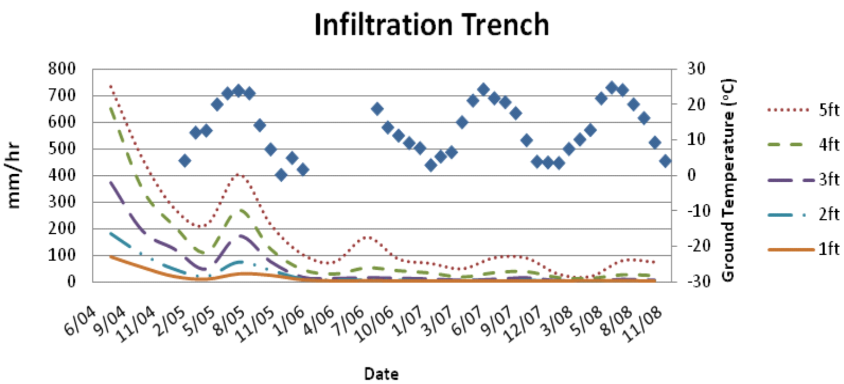

Figure 14. Plot of infiltration rates over time for the Infiltration Trench.

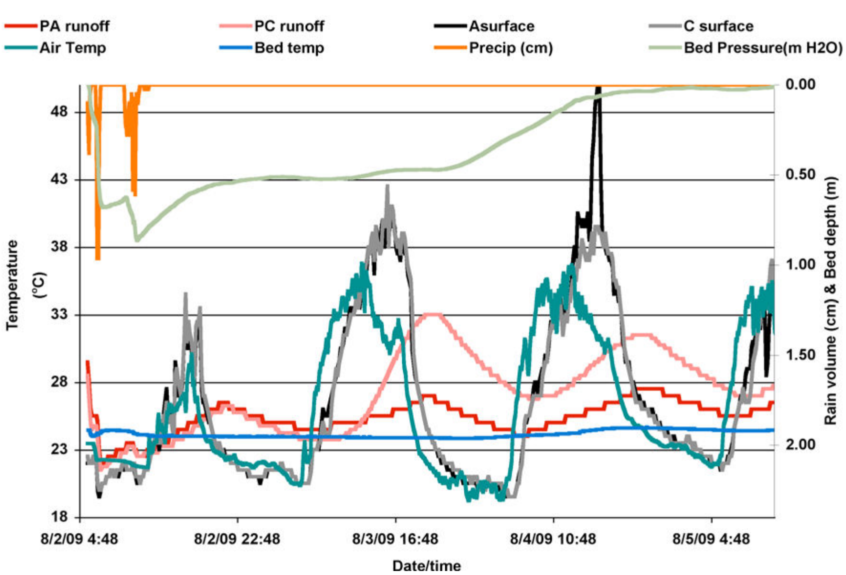

Figure 15. Plot of storm event temperature for the Pervious Concrete – Porous Asphalt site.

- *Proof of Concept:* Results from constructing, operating, and monitoring green infrastructure infiltration BMPs have proven that these devices are effective in removing pollutants and runoff volume from the surface stream.

- *Effectiveness of Small Storm Capture:* The efficiency of designing for small storms has been proven. Results from both the infiltration trench and bioinfiltration raingarden have shown that because the majority of the region's rainfall is produced by smaller storms, BMPs designed for smaller storms are extremely effective in reducing runoff volume and capturing surface pollutants in regions with similar climates.

- *Variability of Infiltration Rate:* Results from all three sites have shown that the rate of infiltration during a specific storm is extremely variable, and dependent on season, temperature, soil moisture, and rainfall pattern. Note that on a yearly basis, this variation has not interfered with performance, but must be considered when conducting municipal inspection / monitoring programs.

- *Longevity:* A study based on the results of this project has shown that there is no statistical reduction in performance for the bioinfiltration rain garden after 7 years, or from the pervious concrete site after 4 years (Emerson and Traver 2008). As long as the site is protected from large sediment loads (i.e., from upstream erosion) there is every expectation that these sites will remain effective for a very long time. Longevity is achieved through proper design, construction, and siting (characteristics of the drainage area). For the bioinfiltration BMP, freeze - thaw, soil processes and root systems are aiding in maintaining the infiltration capacity. For the pervious concrete site, the lack of suspended sediments in the rooftop runoff, the filtering through the pervious concrete, and the large surface area support its longevity. Conversely, a considerable change in performance has been seen at the infiltration trench due to the theorized clogging of the bottom layer. It should be noted that the ratio of drainage area to the infiltration trench greatly exceeds that of "normal" sites. Using the drainage area sizing recommendations of the Pennsylvania BMP manual, the infiltration trench has experienced a pollutant load equivalent to 80 years during its 5-year lifetime.

- *Robustness of Green Infrastructure*: Continuing performance of the Villanova University stormwater BMPs with minimal maintenance demonstrates the robustness of green infrastructure practices, as long as the systems are sited, designed, and constructed appropriately. After six years, no major maintenance has been required of the bioinfiltration sites, and only street sweeping for the porous concrete/porous asphalt site.
- *Variation in Pollutant Loading Rate / First Flush*: Runoff from different contributing areas has been found to vary considerably in quality. For example, roof runoff from taller buildings has been found to be remarkably free of TSS, which makes it an ideal candidate for infiltration. In contrast, runoff from the parking deck has delivered extremely high pollutant loads to the infiltration trench. Clearly pretreatment devices would extend the life of infiltration BMPs in high loading areas.
- *Raingarden Volume Removal Repeatability and Predictability* – Analysis of data from bioretention / bioinfiltration raingardens at Villanova University, NC State University, and the University of Maryland show repeatability of performance of volume reduction. These results will lead to new design criteria and regulatory approaches.

Program Outreach

Project information is disseminated to the environmental, land development, scientific, and regulatory communities through a number of networks. First, the results are presented in peer reviewed journals as well as at industry conferences at both the national and local levels. Second, Villanova hosts a biannual statewide stormwater symposium that is used to support outreach. The Pennsylvania Stormwater Symposium is broadcasted and archived live at no charge over the internet. In addition, free or low cost seminars are held locally, and many groups request to visit and tour the research sites. Finally, all project reports and theses are available on the web (http://www.villanova.edu/VUSP). It should be noted that the work is incorporated in the graduate and undergraduate classes at Villanova, and that graduate students working on the project gain a wealth of experience.

Future Directions and Recommendations

The Villanova Stormwater Research and Demonstration Park remains a viable and valuable research tool. The proximity of the on-campus BMPs to the students and laboratory allow a depth of exploration and visibility not realistic elsewhere. These findings confirm the need to continue studying the operation of green infrastructure infiltration BMPs. While great strides have been made, the relations between site characteristics, load and volume to BMP design are still poorly understood. As the understanding of the processes involved advances, the VUSP expects that the design methods used for these BMPs will change to more accurately represent the hydrologic, chemical and biological processes involved. These changes will advance our ability to protect our waters. Currently, funding is in place through 2012, and it is the expectation of the researchers to continue this work on both current and future BMPs at the Villanova campus.

For More Information

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INFORMATION

USGS Releases WaterAlert

The USGS is pleased to announce the release of WaterAlert. WaterAlert evolved from the North Carolina Hydrologic Alert System (NC-HAS) released last September that allowed users access to real-time email or text message alert notifications when user-specified thresholds are met at USGS data-collection sites in North Carolina for streamflow, river-stage and rainfall. Now WaterAlert allows users that same functionality for USGS data-collection sites across the nation and adds the ability to receive notifications for groundwater levels, water temperatures, and water quality data too.

Sign up at http://water.usgs.gov/wateralert.

EPA Releases Handbook for Clean Water Act Section 319 Tribal Program

EPA's Office of Wetlands, Oceans, and Watersheds recently released the Handbook for Developing and Managing Tribal Nonpoint Source Pollution Programs Under Section 319 of the Clean Water Act. Tribal water quality programs continue to increase in number and to mature in their capacity to understand and improve the condition of reservation lakes, rivers, streams, wetlands, and coastal waters. Currently, 159 tribes have approved nonpoint source programs. EPA developed the Handbook to support the continued growth and sophistication of Tribal participation in the Clean Water Act Section 319 program.

The Handbook explains the role of both EPA and the Tribes in working together to help solve water quality problems caused by nonpoint source pollution. All aspects of the grants funding process are clearly explained, demonstrating how Tribes can use Section 319 program funds to implement programs and projects to reduce pollution and restore water quality. It also provides a great deal of useful technical information regarding nonpoint source pollution; how to develop and assess available data to develop a plan of action; and how to implement activities to solve the problem.

The Handbook is posted on the Tribal Nonpoint Source Web site at http://www.epa.gov/nps/tribal/

The NCSU Water Quality Group publications list and order form can be downloaded at
http://www.ncsu.edu/waterquality/issues/pub_order.html

Catch the Rain! Rainwater Harvesting Activities

The Arizona Cooperative Extension has developed a guide for 4-H Leaders and Teachers on rainwater harvesting. This collection of hands-on, interactive activities is designed to engage youth in understanding purposes, uses, applications, and designs of rainwater harvesting systems. Together, the activities promote a culture of conservation through the development of rainwater harvesting demonstration and use projects, encouragement of community awareness and action, and optimally the reduction of surface water and groundwater use. The activities were developed with grades 5-8 in mind. Topics include:

- Water Cycle
- Conservation
- Watersheds & Aquifers
- Rainwater Harvesting Basics
- Passive Rainwater Harvesting
- Active Rainwater Harvesting
- Rainwater Harvesting Outreach

To order individual copies of the publication on line, at a price of $15 per copy plus shipping, visit http://pubs1.cals.arizona.edu/sales/listspecial.cfm?PID=ACE710. The price is reduced for orders of 10 or more copies. To order bulk copies, call CALSmart at (877) 763-5315 or send a faxed order to (520) 795-8508.

EPA Releases New Video on Low Impact Development

EPA's Office of Wetlands, Oceans and Watersheds (OWOW) announced the availability of a new 11-minute video, "Building Green: A Success Story in Philadelphia," which highlights innovative efforts by green builders in Philadelphia who are helping protect and restore environmental quality and beautify the city. By installing cisterns, green roofs, porous pavers, solar panels, and Energy Star appliances, the builders are capturing rainwater, reducing stormwater runoff, and saving energy. In the video, the Director of Philadelphia's Office of Watersheds explains the importance of green stormwater infrastructure. The city is now offering incentives to builders and developers to use green techniques to help meet clean water and other environmental goals.

The video is available on-line at http://www.epa.gov/owow/nps/lid/video.html. A high resolution Digital Betacam version is also available upon request. For more information, contact Patty Scott at scott.patricia@epa.gov.

New USGS Study of Urban Development on Stream Ecosystem Health

A new USGS study examines effects of urban development on stream ecosystem health. Findings show that aquatic insect communities demonstrate little, if any, initial resistance to low levels of urban development that were previously thought to be protective of aquatic life. By the time a watershed reaches about 10 percent impervious cover in urban areas, aquatic insect communities are degraded by as much as 33 percent in comparison to aquatic insect communities in forested watersheds.

Comparisons among nine metropolitan areas show that not all urban streams respond in a similar way. Land cover prior to urbanization can affect how aquatic insects and fish respond to urban development and is important to consider in setting realistic stream restoration goals in urban areas.

The USGS determined the magnitude and pattern of the physical, chemical, and biological response of streams to increasing urbanization and how these responses vary throughout nine metropolitan areas, including Portland, OR; Salt Lake City, UT; Birmingham, AL; Atlanta, GA; Raleigh, NC; Boston, MA; Denver, CO; Dallas, TX; and Milwaukee, WI.

For more information, including access to USGS reports and video podcasts, visit http://water.usgs.gov/nawqa/urban/.

USGS Study Examines Mercury Trends in Fish from Rivers and Lakes

A recent U.S. Geological Survey study examined state and federal fish-monitoring data for trends in mercury levels in fish from 1969-2005 in rivers and lakes.

The study shows that concentrations of mercury in fish generally decreased in the 1970s and 80s, as indicated by samples collected at 50 sites across the Nation. Trends were more variable from 1996-2005, during which data were assessed for eight states in the Southeast and Midwest. More upward mercury trends in fish occurred in the Southeast compared to the Midwest, which may be attributed, in part, to a greater influence of long-range global mercury emissions in the Southeast.

A technical announcement is available online in the USGS newsroom at http://www.usgs.gov/newsroom/article.asp?ID=2522. More details about this study and other related information on mercury in stream ecosystems are available at http://water.usgs.gov/nawqa/mercury/.

Conservation Effects Assessment Project (CEAP) Cropland Report Release by USDA for Upper Mississippi River Basin

Conservation practices installed and applied by agricultural producers on cropland are reducing sediment, nutrient and pesticide losses from farm fields, according to Agriculture Secretary Tom Vilsack, who recently announced the release of a comprehensive study on the effects of conservation practices on environmental quality in the Upper Mississippi River Basin (UMRB). However, significant conservation treatment is still needed to reduce nonpoint agricultural sources of pollution.

Key findings from the study, "Effects of Conservation Practices on Cultivated Cropland in the Upper Mississippi River Basin," include the following:

- Use of soil erosion control practices is widespread, but the most vulnerable acres require additional conservation practices.
- Complete and consistent use of nutrient management practices is generally lacking; 62% of the acres require additional treatment to reduce the loss of nitrogen or phosphorus from farm fields.
- The most critical conservation concern is the loss of nitrogen through leaching on half of the cropped acres, including losses from tile drainage systems.
- Treatment of erosion alone can exacerbate the nitrogen leaching problem by re-routing surface water to subsurface flow pathways.
- Nitrogen leaching loss is controlled by pairing erosion-control practices with nutrient management practices for rate, form, timing, and method of application.
- Conservation practices have the greatest effect on the more vulnerable acres, such as highly erodible land and soils prone to leaching.

This study is part of a larger effort - the Conservation Effects Assessment Project (CEAP) - to assess the effects of conservation practices on the nation's cropland, grazing lands, wetlands, wildlife and watersheds. CEAP is a multi-agency, multi-resource effort led by USDA's Natural Resources Conservation Service (NRCS).

The complete UMRB cropland study report and summary documents are available on the CEAP webpage at http://www.nrcs.usda.gov/Technical/nri/ceap/.

Putting Smart Growth to Work in Rural Communities

ICMA has released a new report, "Putting Smart Growth to Work in Rural Communities," which focuses on how to adapt smart growth strategies to rural communities. Funded by the U.S. Environmental Protection Agency's Office of Sustainable Communities, the report examines the challenges rural communities face, including rapid growth at metropolitan edges, declining rural populations, and the loss of working lands. It highlights smart growth strategies that can help guide rural growth while preserving the unique rural character of existing communities.

The report focuses on three central goals: 1) support the rural landscape by creating an economic climate that enhances the viability of working lands and conserves natural lands; 2) help existing places to thrive by taking care of assets and investments such as downtowns, Main Streets, existing infrastructure, and places that the community values; and 3) create great new places by building vibrant, enduring neighborhoods and communities that people, especially young people, don't want to leave. Featuring case studies from across the country, the report highlights how local governments, states, and non-profits have successfully implemented smart growth strategies to support rural lands, revitalize existing communities, and create great new places for residents and visitors.

To read the full report, visit http://www.icma.org/ruralsmartgrowth.

Army Corps of Engineers Launches Website on Water & Climate Change

According to the U.S. Army Corps of Engineers (USACE), climate change affects water availability, water demand, water quality, stormwater and wastewater infrastructure, flood and coastal storm infrastructure, wildfires, ecosystem functioning, coastal zone functioning, navigation, and energy production and demand. USACE's overall Responses to Climate Change (RCC) Program addresses the need to reduce potential vulnerabilities to the nation's water resources and infrastructure from climate change and variability. Its mission is to develop, implement, and assess adjustments or changes in operations and decision environments to enhance resilience or reduce vulnerability of USACE projects, systems, and programs to observed or expected changes in climate.

The new RCC Program website shares news and information about program activities as well as the potential impacts of climate change, interagency efforts, strategies for dealing with climate change, and more. View the website at http://www.corpsclimate.us/.

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MEETINGS

Meeting Announcements — 2010

October

Greening Midwest Communities: October 19-20, 2010. Jefferson City, MO. Visit conference website at http://muconf.missouri.edu/gmcc/

November

2010 AWRA Annual Water Resources Conference: November 1-4, 2010, Philadelphia, PA. View conference website at http://awra.org/meetings/Philadelphia2010/index.shtml

North American Lake Management Society 2010 Symposium: November 3-5, 2010. Oklahoma City, OK. Visit conference website at http://www.nalms.org

Fifth National Conference on Coastal and Estuarine Habitat Restoration: November 13-17, 2010. Galveston Island, TX. Visit conference website at https://www.estuaries.org/conference/

TMDL 2010: Watershed Management to Improve Water Quality: November 14-17, 2010. Baltimore, MD. View conference website at http://www.asabe.org/meetings/tmdl2010/index.htm

Stream Restoration in the Southeast: Connecting Communities with Ecosystems: November 15-18, 2010, Raleigh, NC. View conference website at http://www.ncsu.edu/srp/conference.html

18th National NPS Monitoring Workshop: Monitoring and Evaluation Workshop for Great Lakes Restoration Initiative: Nov 16-18, 2010. Milwaukee, WI. Visit conference website at http://npsmonitoring.tetratech-ffx.com/ (see highlight on page 14).

Meeting Announcements — 2011

January

2011 Land Grant and Sea Grant National Water Conference: January 31 - February 1, 2011, Washington, DC. View conference website at http://www.soil.ncsu.edu/training/training.php

February

10th Annual New Partners for Smart Growth: Building Safe, Healthy and Livable Communities: February 3-5, 2011, Charlotte, NC. View conference website at http://www.newpartners.org/index.html

May

American Ecological and Engineering Society Annual Meeting: May 20-26, 2011. Asheville, NC. View conference website at http:www.bae.ncsu.edu/workshops

August

4th National Conference on Ecosystem Restoration (NCER): August 1-5, 2011, Baltimore, MD. Visit conference website at http://www.conference.ifas.ufl.edu/NCER2011

September

2011 LID Green Infrastructure Congress: Greening the Urban Environment: September (dates to be announced), Philadelphia, PA. Three great conferences combined in one location: 19th National NPS Monitoring Workshop, EWRI LID Conference, Pennsylvania Stormwater Symposium.

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Production of NWQEP NOTES is funded through U.S. Environmental Protection Agency (EPA). Project Officer: Tom Davenport, Office of Wetlands, Oceans, and Watersheds, EPA. 77 W. Jackson St., Chicago, IL 60604. Website: http://www.epa.gov/OWOW/NPS

18th National NPS Monitoring Workshop: Monitoring and Evaluation Workshop for Great Lakes Restoration Initiative

http://npsmonitoring.tetratech-ffx.com/

November 16-18, 2010 – Milwaukee, Wisconsin

The Annual Nonpoint Source (NPS) Monitoring Workshop is an important forum for sharing information and improving communication for controlling and monitoring NPS pollution issues and projects. The focus of the 18th National Workshop is on nutrients and what lessons we have learned that can be factored into the projects funded under the Great Lakes Restoration Initiative (GLRI).

A number of technical workshops and interactive learning sessions will be offered to build knowledge and skills, transfer technology and promote innovative evaluation/documentation techniques. Technical workshops include Utilizing Social Indicators in Watershed Management Projects, Transforming Data into Information and Enhancing State Nutrient Reduction Strategies.

Specific topics that will be highlighted include:

- Controlled Drainage Practices for Agricultural
- Innovative Agricultural Conservation and Management Practices
- TMDL and Watershed Management Plan Implementation
- Section 6217 NPS Efforts
- Urban NPS / Stormwater Management
- NPS pollution and Great Lakes aquifers
- Integrating social indicators monitoring with environmental monitoring
- Monitoring the impacts of agricultural drainage management
- Innovative monitoring in agricultural and urban landscapes
- Monitoring for decision making
- Detecting change in water quality from BMP implementation
- Presenting monitoring data to the public
- Riparian area, Wetland Restoration and stream protection/restoration

Workshop Queries:
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