University of New Hampshire Stormwater Center

2009 BIANNUAL REPORT

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Contents

About the Center

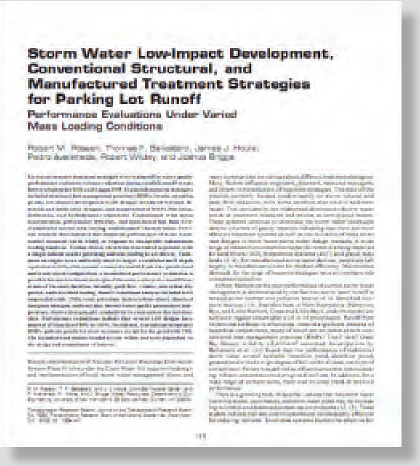
The University of New Hampshire Stormwater Center (UNHSC) is dedicated to the protection of water resources through effective stormwater management.

Center researchers evaluate and enhance the ability of stormwater treatment systems to treat the pollution in stormwater runoff and reduce the flooding that it can cause. The Center provides information on performance, cost, design, and maintenance to people who select, review, permit, design, install, and maintain stormwater management systems. The research is integrated with an evolving outreach program that supports a wide range of stormwater managers and professionals who seek to build programs that protect water quality, preserve environmental values, and reduce the impact of stormwater runoff.

The Center receives its primary funding and program support from the Cooperative Institute for Coastal and Estuarine Environmental Technology (CICEET), a partnership of UNH and the National Oceanic and Atmospheric Administration (NOAA). It is housed within the University’s Environmental Research Group, a division of the College of Engineering and Physical Sciences.

Resources for Stormwater Managers

The Center’s research has served as the foundation for a range of outreach products—from best management practice (BMP) workshops geared to support municipal decision makers and stormwater engineers to peer-reviewed publications that explore the frontiers of stormwater science. Learn more about these resources at www.unh.edu/erg/cstev.



Storm Water Low-Impact Development, Conventional Structural, and Manufactured Treatment Strategies for Parking Lot Runoff
Performance Evaluations Under Varied Mass Loading Conditions

Robert M. Roseen, Thomas P. Ballestero, James J. Houle, Pedro Avellaneda, Robert Wildey, and Joshua Briggs

- BMP Fact Sheets
- Data Reports
- Design Drawings
- Design Specs
- Journal Articles
- Web Resources

Workshop at
UNHSC field site

Directors' Message

UNH Stormwater Center
field site

These economic times challenge all of us to make difficult choices about what we can and cannot afford. For state and local governments facing budget shortfalls, the University of New Hampshire Stormwater Center has some welcome news: when it comes to effective stormwater management, you do not have to choose between affordability and healthy waters.

People often tell us that they think they do have to choose, that even if Low Impact Development (LID) stormwater techniques do a better job of protecting water quality, they are too costly to install and maintain. Yet our research is demonstrating that this is not the case. Since 2004 we have monitored the ability of 23 stormwater systems to treat pollution and reduce the volume of runoff. We have worked with hundreds of municipal officials, regulators, engineers, contractors, and educators on dozens of stormwater demonstration and education projects.

In the process, we have found that projects that use LID approaches to managing stormwater runoff can be both more effective in treating pollution and in some instances less expensive to install than those that rely on curbs, pipes, and ponds. LID systems do require maintenance to function properly, but so do all of the commonly used systems that are believed to require little or no attention. In particular, our research has demonstrated that when retention ponds are not adequately maintained, they not only fail to remove pollutants from runoff; they can magnify the negative impact of polluted stormwater on receiving waters.

Using LID approaches for stormwater management involves decentralizing runoff and maximizing infiltration, which ultimately reduces the stress on urban stormwater infrastructure. Metropolitan areas like Portland, OR., are already seeing the economic benefits of using LID to reduce the runoff flowing through their combined sewers. These savings extend to residential and commercial development and redevelopment projects. Homeowners that use techniques like rain barrels, drought resistant rain gardens, and porous pavements can save on water utility bills and help prevent flooded basements.

By allowing for these less familiar but more effective techniques in stormwater ordinances, municipalities can help insure these benefits at every level. In so doing, they anticipate the inevitable. Federal laws requiring LID-style approaches to stormwater are already in place as part of Phase II of the Clean Water Act. It is only a matter of time before all municipalities will have to comply with mandates to clean up impaired waters, and our research is showing that in many case an LID approach to stormwater management is essential in meeting that goal.

A proactive response to federal regulations has the added benefit of preparing us for the impacts of climate change. Whether climate change has brought severe storms or drought to a community, LID stormwater techniques can help mitigate the flooding associated with impervious surfaces, can allow rainfall to replenish aquifers, and can be powerful tools for adaptive management.

This report is one of many tools we use to communicate our work in a way that we hope stormwater managers from many backgrounds will find useful. We welcome your comments and questions, about this report and all of the work we do.

Sincerely,

Robert Roseen
Director

Thomas Ballestero
Senior Scientist

Jamie Houle
Program Manager
and Outreach Coordinator

Highlights from 2008 & 2009

Spreading the Word

UNHSC stormwater treatment system demonstration workshops continue to bring approximately 500 people to the Center's research field facility each year. Participants represent a wide spectrum of organizations engaged in stormwater management, including municipalities, planning and conservation boards, consulting firms, watershed alliances, state and federal departments of transportation, environmental agencies, and science training and extension programs. At these workshops, participants learn about system performance and design, while UNHSC researchers and educators learn about the priorities of stormwater managers.

In 2008, researchers began to develop and offer specialized workshops to help design engineers learn about innovative BMPs. A new and popular workshop combines current UNHSC data and observations on porous pavement performance with a tour of local porous pavement installations. This full-day training gives participants the opportunity to learn the design principles necessary to install porous pavements successfully.

LID in Practice

UNHSC partnered with the Great Bay National Estuarine Research Reserve to design and install an LID demonstration project at the reserve's Great Bay Discovery Center. A retrofit of an existing gravel parking area, the project used environmentally sensitive site design and a combination of LID structural controls, including a porous asphalt parking lot, pervious concrete walkways and parking areas, a rain garden, an eco-stone and aqua-brick permeable concrete paver walkway, and an outdoor exhibit area for children. The project eliminated 20,000 square feet of effective impervious cover (EIC), which include nearly all parking and pedestrian surfaces.

Gold-Star Commercial Stormwater Management

In southern New Hampshire, the site of a former Sylvania industrial light bulb factory has been redeveloped using some of the most advanced stormwater treatment systems in the Northeast. Numerous redevelopment projects had been proposed at the site over the past 15 years, yet none could meet the strict effluent requirements for Pickering Brook, which is listed as an impaired water under EPA 303(d) rules. In 2007, Packard Development, the Conservation Law Foundation, UNHSC, and Gove Environmental Services partnered to negotiate a redevelopment proposal that protects water quality. The proposal was accepted, and the current installation—which includes three franchise stores and is estimated to accommodate nearly 10,000 vehicles daily—uses porous asphalt parking lots and subsurface gravel wetlands as anchors of the stormwater management plan.

Impacting Policy

In 2005, UNHSC began working with the Rhode Island Coastal Resources Management Council (CRMC) to advance stormwater practices in the state. By 2007, Rhode Island passed the Smart Development for a Cleaner Bay Act, mandating LID statewide. The Horsley Witten Group, in cooperation with UNHSC, is now working with the CRMC and the Rhode Island Department of Environmental Management (RIDEM) to develop the new state Stormwater Manual, expected to be published in 2010.

New Resources

In 2006, UNHSC and the University of Connecticut's Nonpoint Education for Municipal Officials program (NEMO) launched an online inventory of innovative BMPs, including LID designs, from across New England. The inventory's goal is to link those who would like to use innovative systems with designers and installers who are experienced in implementing them. Populated by designers, property owners, and installers, the inventory now contains hundreds of examples, ranging from rain gardens on a residential property in Maine to a green roof on City Hall in Boston, MA. Users can submit examples of innovative projects through a form on the homepage. One can search the inventory either by state or by LID technique. Learn more at www.erg.unh.edu/stormwater/index.asp.

LID Weathers the Cold

As a long-term field research program based in New England, UNHSC is uniquely suited to monitoring stormwater treatment system performance over a wide range of seasonal conditions. With four years of data complete, UNHSC research demonstrates that Low Impact Development (LID) stormwater treatment systems function well in the harsh winters of cold climate regions. This finding contradicts widely held perceptions that LID systems do not perform as well as more conventional systems in winter conditions. In fact, UNHSC researchers have observed that conventional systems, such as swales, actually perform less effectively in winter months.

Advancing Effective Stormwater Management

UNHSC participated in the design of numerous LID and advanced stormwater management systems related to the City of Portsmouth, N.H.'s wastewater and combined sewer overflow improvement initiatives. This New Hampshire community received EPA stimulus funds as part of the 2009 American Recovery and Reinvestment Act. The designs call for bioretention systems to remove nitrogen from roof top runoff, tree filters to replace the conventional catch basins used to treat road runoff, and a large-scale treatment train using an ADS Water Quality unit and an underground (D.C.) sand filter. The systems will combine to treat more than 75 percent of urban runoff from 13.5 acres and will remove an estimated 11 cubic yards of sediment annually.

First Porous Asphalt Road in the State of New Hampshire

UNHSC worked with Pike Industries, Stickville LLC, and SFC Engineering to design and install the first porous asphalt road in the state of New Hampshire. The Boulder Hills Project, located in the town of Pelham, N.H., was permitted in 2006 and constructed in 2009. The project consists of 24 units in a 55+ active adult community and employed many Low Impact Development stormwater management strategies. The use of porous asphalt for a road is distinctive in that to date it has been used primarily for parking lots. This private road uses porous asphalt for the entire 900 feet of roadway, as well as all driveways and walkways. It is unique in that sections of the road are up to 9 percent grade, which for porous asphalt is typically limited to low grades. Of particular note is the use of both polymer fibers and latex in the porous asphalt mix. This has long been held as the mix of choice for porous asphalt installations but has been hard to procure. Another high use roadway has just been completed in South Portland, Maine using a similar mix.

Updated Stormwater Regulations

In early 2009 the UNHSC was contracted by the Piscataqua Region Estuaries Partnership to update the town of Newington, N.H.'s local regulations and incorporate modern stormwater management controls. The goal of the project was to develop site-plan regulations that provided the planning board with the regulatory tools needed to mitigate the impacts of stormwater runoff from impervious surfaces in the town's commercial and industrial zones. The regulations completed and adopted in December, 2009 provide a framework to require Low Impact Development approaches that will directly benefit water quality in the Piscataqua River and the Great Bay Estuary. The regulations also addressed both new development and redevelopment proposals of properties that require site plan approval from the planning board and included standards for the redevelopment or expansion of existing sites in order to reduce the impact of stormwater runoff.

Introducing LID in the Hodgson Brook Watershed

UNHSC is partnering with the Hodgson Brook Watershed Association and the city of Portsmouth, N.H., on the use of LID retrofits in a residential subdivision and commercial redevelopment site. This project involves the identification of potential retrofit opportunities within the watershed, and the development and installation of appropriate designs of LID systems in cooperation with city personnel. The project outcomes include an LID-technology demonstration and increased familiarity of city personnel with the installation of LID practices. UNHSC is also currently on a project team to provide similar services for a sister project in the Willow Brook watershed located in the city of Rochester NH.

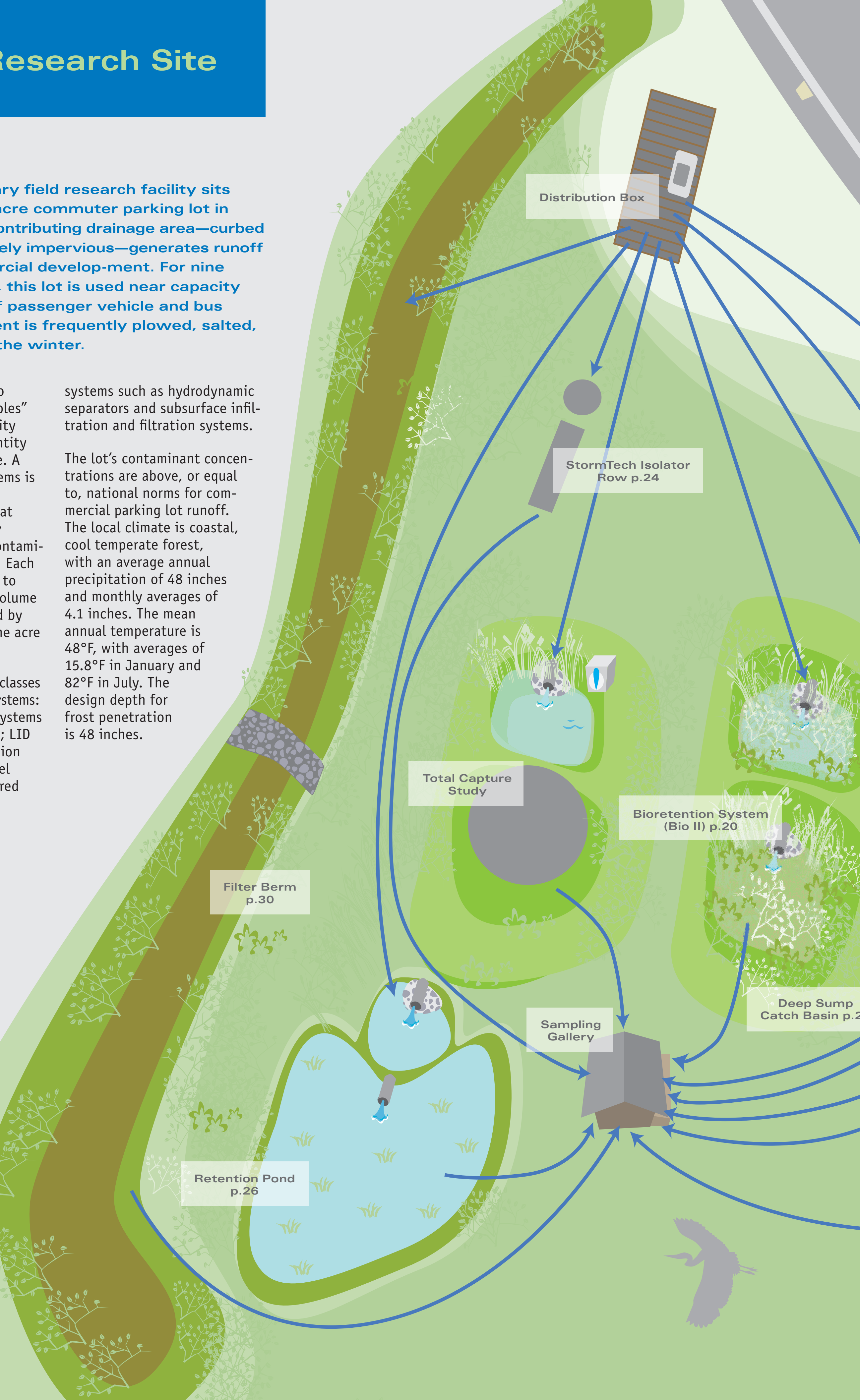
Field Research Site

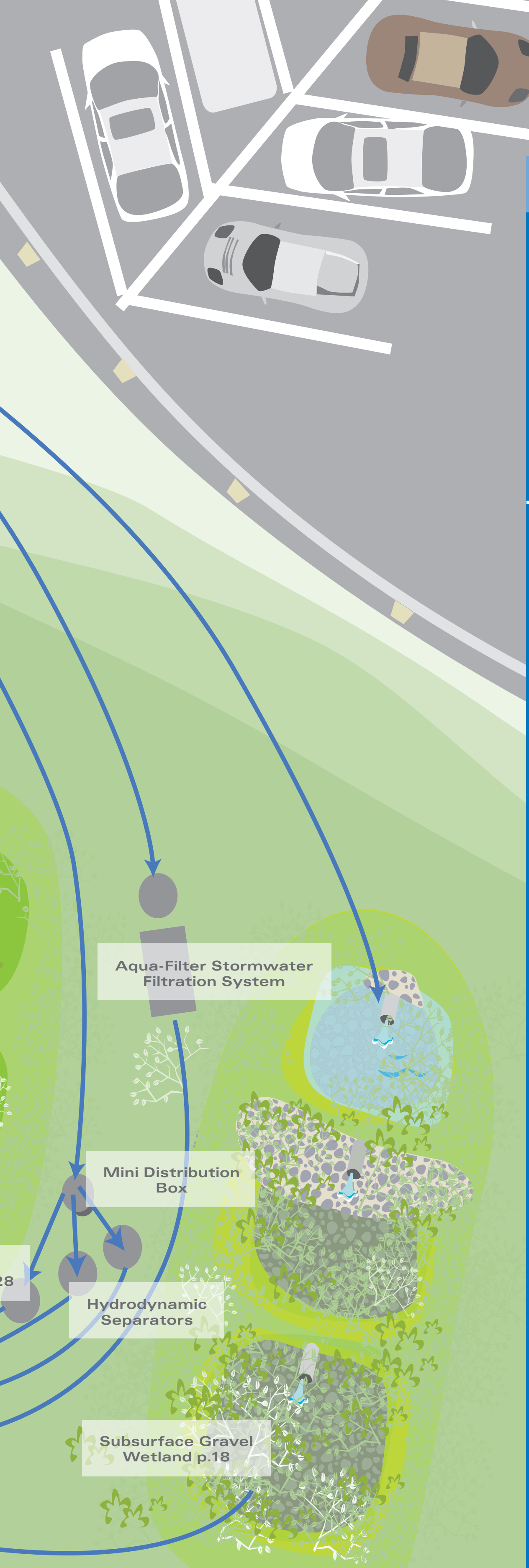
The UNHSC's primary field research facility sits adjacent to a nine-acre commuter parking lot in Durham, N.H. The contributing drainage area—curbed and almost completely impervious—generates runoff typical of a commercial develop-ment. For nine months of the year, this lot is used near capacity by a combination of passenger vehicle and bus traffic. The pavement is frequently plowed, salted, and sanded during the winter.

The facility is designed to provide an "apples-to-apples" comparison of water quality treatment and water quantity management performance. A range of stormwater systems is installed in a parallel yet separate configuration that normalizes the variability inherent in stormwater contaminant loading and rainfall. Each system is uniformly sized to address a Water Quality Volume (WQ_V) of runoff generated by one inch of rainfall off one acre of impervious surface.

The facility contains three classes of stormwater treatment systems: conventional, structural systems such as swales and ponds; LID designs such as bioretention cells and subsurface gravel wetlands; and manufactured systems such as hydrodynamic separators and subsurface infiltration and filtration systems.

The lot's contaminant concentrations are above, or equal to, national norms for commercial parking lot runoff. The local climate is coastal, cool temperate forest, with an average annual precipitation of 48 inches and monthly averages of 4.1 inches. The mean annual temperature is 48°F, with averages of 15.8°F in January and 82°F in July. The design depth for frost penetration is 48 inches.





Satellite Testing Sites

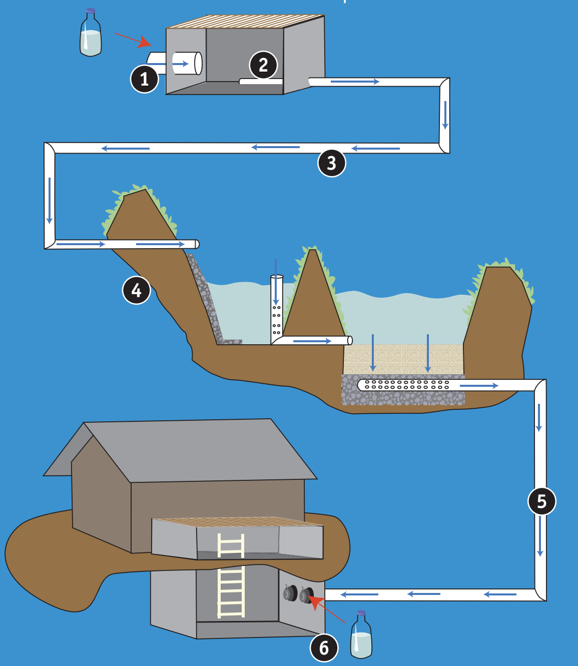
UNHSC also operates field test sites for porous asphalt (p.14) and pervious concrete (p.16) on the University's Durham campus.

How We Evaluate Performance

A detailed quality assurance project protocol governs all UNHSC's methods, procedures, maintenance tasks, and analyses related to the evaluation of stormwater treatment systems. All systems are installed with an impermeable liner so that researchers can provide a strict accounting of the runoff flowing through the systems, as well as the contaminants it contains.

Here's How Our Performance Evaluation Process Works

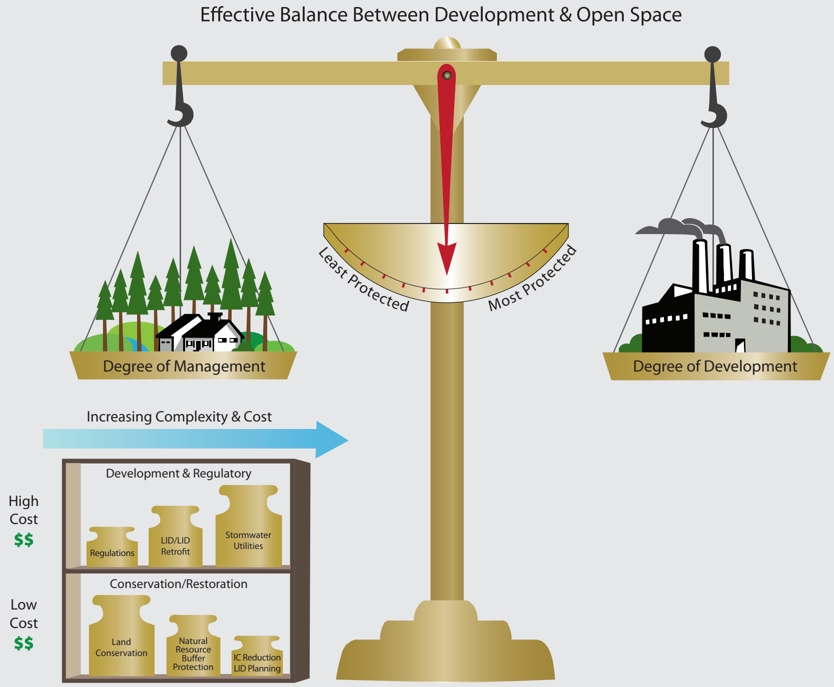
1. Stormwater runoff from the parking lot is channeled into a 36-inch pipe where it is monitored in real time for flow, pH, conductivity, dissolved oxygen, temperature, and turbidity. Concurrently, automated devices collect flow-weighted samples of runoff throughout the runoff hydrograph. These samples are processed and evaluated for a range of contaminants, or frozen for future evaluation.
2. Runoff then flows into a distribution box with a floor that rests slightly higher than the invert of the outlets that direct runoff to the various stormwater treatment systems. This configuration insures that runoff will scour the floor of the box, thereby preventing sediment accumulation. Baffles and flow splitters help to distribute the runoff evenly among systems.
3. From the distribution box, runoff flows through a network of pipes and into each system.
4. Runoff moves through the stormwater treatment systems.
5. Runoff leaves the systems through perforated subdrains and is conveyed into a sampling gallery.
6. In the gallery, runoff is monitored in real time for the same characteristics monitored in step one. Concurrently, automated devices collect flow-weighted samples of runoff throughout the runoff hydrograph. These samples are evaluated for the same range of contaminants as step one, thereby serving as the basis for system performance evaluation.



Applying UNHSC Research

Balancing Development

Clean, adequate water supplies are essential to life, yet many factors threaten our water resources, in particular, the increase of development and impervious surfaces coupled with reductions of natural lands that have historically cleaned and protected water resources for millennia. The graphic on the right represents the relative complexity and costs involved when trying to balance the negative impacts of land development on water quality. It is well established by scientific research that more intense development often impairs water quality and leads to shifts in the distribution of surface and groundwaters. The weights represent management strategies through conservation and restoration efforts as well as regulatory management measures and the establishment of stormwater utilities. Some measures are more effective than others; here the larger the weight, the more effective the balancing potential. The shelves represent a tiered approach with both cost and complexity.



Over the past six years, we have learned that structural stormwater management systems can be designed to treat for peak flow, volume reduction, and water quality control. Though each system design can be unique, pollutant removal capabilities are highly correlated to the unit operations and treatment processes the systems incorporate. There is much discussion as to whether pollutant removal efficiencies are the best approach for estimating system performance, yet most regulations require percent reductions of target pollutants. In the final analysis, receiving water quality is affected more by overall mass loading than by any single storm event. In these cases the best approach to assessing performance would be to conduct studies detailing what the quality of the water leaving the system is (also referred to as effluent probability) and whether the pollutant ranges are at acceptable levels for the receiving water. In most parts of the country, detailed studies of this nature are still in great demand. Until there are in-depth regional references, UNHSC data provides an apples-to-apples comparison of a variety of systems tested at a single site where the variability that generally renders removal efficiencies an ineffective measure is normalized. At the UNHSC, removal efficiencies are a very useful measure because all the systems receive the same quantity and quality of stormwater at the same time.

The data collected and compiled at the UNHSC also serves as the basis for the development of other tools such as analytical or stochastic models that help improve system design and improve water quality treatment performance.

UNHSC Research in Context

We can say with a very high degree of confidence that pipe and pond stormwater treatment strategies do not meet general water quality guidelines. Our research clearly indicates that structures designed without explicit consideration for stormwater quality improvements are generally ineffective. Our research also clearly indicates that many water quality issues are regional, highly complex, and require studied approaches as opposed to attempts at silver-bullet solutions.

UNHSC Pollutant Removal Efficiencies

Treatment Unit Description	Reference	TSS Total Suspended Solids (% Removal)	TPH-D Total Petroleum Hydrocarbons in the Diesel Range (% Removal)	NO3-N (DIN) Dissolved Inorganic Nitrogen (% Removal)	TZn Total Zinc (% Removal)	TP Total Phosphorus (% Removal)	Average Annual Peak Flow Reduction (% Removal)	Average Annual Lag Time (Minutes)
Conventional Treatment Devices								
Retention Pond	UNH	68	82	33	68	NT	86	455
Stone (rip-rap) Swale	UNH	50	33	NT	64	–	6	7
Vegetated Swale	UNH	58	82	NT	88	NT	52	38
Berm Swale	UNH	50	81	NT	50	8	24	58
Deep Sump Catch Basin	UNH	9	14	NT	NT	NT	NT	NT
Manufactured Treatment Devices (MTDs)								
ADS Infiltration Unit	UNH	99	99	NT	99	81	87	228
StormTech	UNH	80	93	NT	56	49	76	274
Aquafilter	UNH	62	26	NT	52	59	NT	NT
Hydrodynamic Separators	UNH	27	1	NT	24	42	NT	NT
Low Impact Development (LID)								
Surface Sand Filter	UNH	51	98	NT	77	33	69	187
Bioretention								
Bio I - 48” depth	UNH	97	99	44	99	–	75	266
Bio II - 30” depth	UNH	87	99	NT	68	34	79	309
Gravel Wetland	UNH	99	99	98	99	56	87	251
Porous Asphalt	UNH	99	99	NT	75	60	82	1,275
Pervious Concrete	UNH	97	99	NT	99	NT	93	1,144
Tree Filter	UNH	93	99	3	78	NT	NT	62

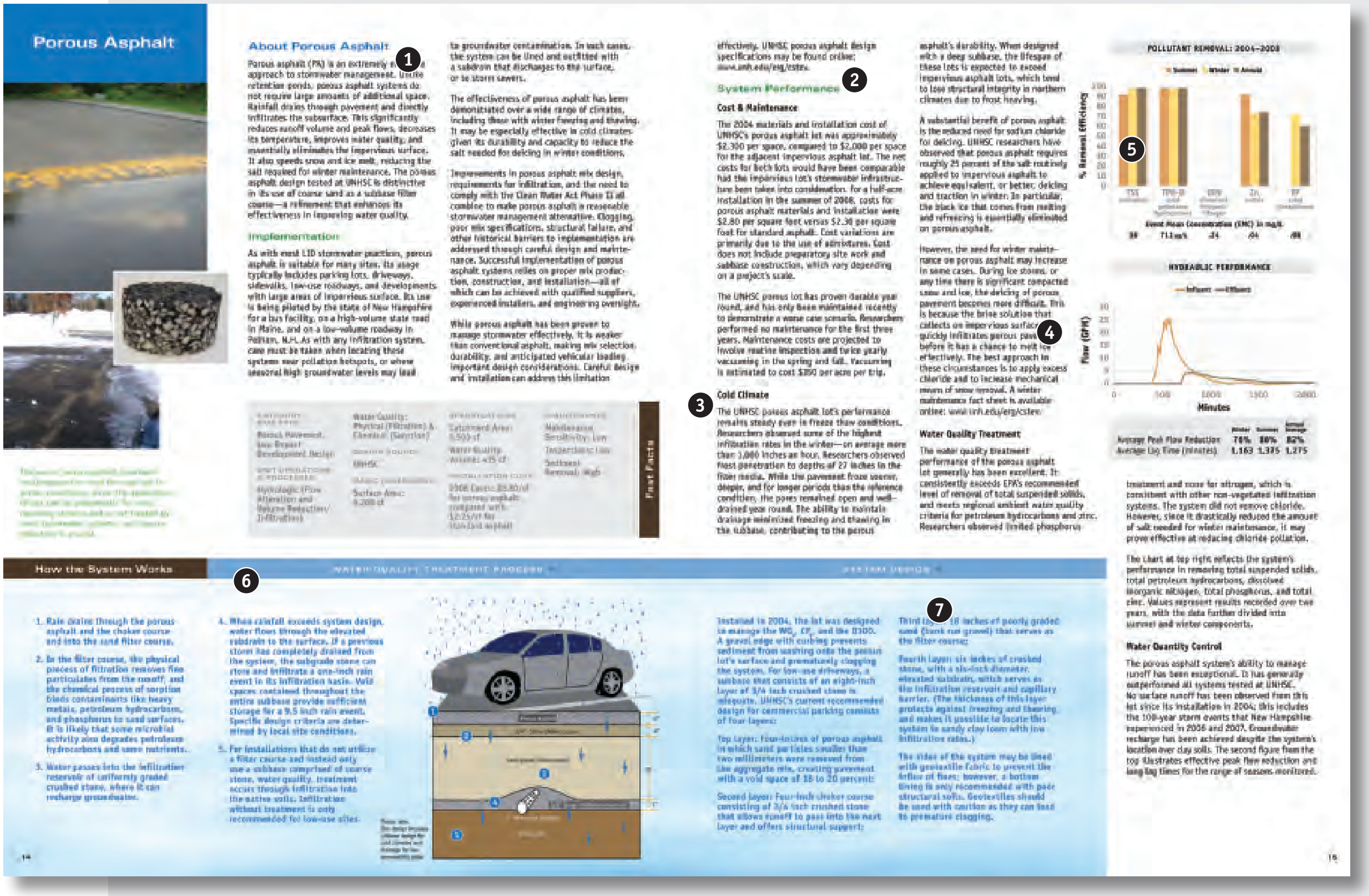
Reference Published Pollutant Removal Efficiencies

Treatment Unit Description	Reference	TSS Total Suspended Solids (% Removal)	TPH-D Total Petroleum Hydrocarbons in the Diesel Range (% Removal)	NO3-N (DIN) Dissolved Inorganic Nitrogen (% Removal)	TZn Total Zinc (% Removal)	TP Total Phosphorus (% Removal)
Sub Surface Detention/Infiltration	EPA Fact Sheet: Infiltration Trenches	–	–	–	–	60
Sand Filter	EPA Fact Sheet: Sand Filters	70	–	NT	45	33
	Claytor & Schueler, 1996	85	–	–	71	50
	Bell, W., et al, 1995	61-70	–	–	>82	–
	Winer, R., 2000	87	–	NT	80	59
Retention Pond	EPA Fact Sheet: Wet Detention Ponds	50-90	–	–	40-50	30-90
	EPA Fact Sheet: Wet Detention Ponds	80-90	–	–	–	–
Bioretention	Winer, R., 2000	79	–	36	65	49
	EPA Fact Sheet: Bioretention	90	–	–	–	70-83
Bio - 12” depth	Winogradoff, 2001	–	–	-97	87	NT
Bio - 24” depth	Winogradoff, 2001	–	–	-194	98	73
Bio - 36” depth	Winogradoff, 2001	–	–	23	99	81
	EPA website	84	–	–	–	–
Hydrodynamic Separators	various	52-84	–	–	–	30
Gravel Wetland	Claytor & Schueler, 1996	80-93	–	75	55-90	80-89
	Winer, R., 2000	83	–	81	55	64
Vegetated Swale	EPA Fact Sheet: Vegetated Swales	81	–	38	71	9
	Claytor & Schueler, 1996	30-90	–	0-80	71	10-65
Porous Pavement	NAPA, undated	89-95	–	–	62-99	65-71
	EPA Fact Sheet: Porous Pavement	82-95	–	–	–	65
	Winer, R., 2000	95	–	–	99	65

How to Read this Report

Over the last four years, UNHSC evaluated 22 stormwater treatment systems for their ability to improve runoff water quality and reduce quantity during 63 rainfall-runoff events with a range of seasonal and storm characteristics. A summary of our analysis of nine of these systems starts on page 14 of this report. This analysis is complemented by basic information on how these systems work, their design, cost of installation, implementation and maintenance considerations, and where to go for more information.

As you review this information, please keep in mind that no single stormwater treatment system is appropriate for all situations. Many factors must be considered when designing an effective stormwater management program. Our research and this report are intended to support better decision-making—not to suggest that any one system addresses all stormwater problems at every site.



System Performance Analysis Key

This key was created to help you navigate the information and data about the stormwater treatment systems found on pages 14 to 31.

❶ About this System

This section provides a general description of the system, including the land-use setting in which it can be deployed, the type of application to which it is best suited, and easy-to-reference information on system specifications, design sources, and installation cost.

System Performance

❷ Cost & Maintenance

This section provides information on stormwater treatment system installation cost and maintenance. Cost estimates are based on installation at the UNHSC field site. These can only be used as rough estimates, given that the expense of installation routinely fluctuates with location, site conditions, commodity and labor costs.

Maintenance information is based on UNHSC observations and recommendations from stormwater manuals. UNHSC does not perform significant system maintenance as a matter of experimental design. Since these systems are often maintained minimally in practice, we want to be able to determine whether lack of maintenance contributes to system failure. Decisions to perform minimal maintenance are related to the need to keep the systems working well enough to evaluate performance. Minimal maintenance includes mowing slopes, vegetating bare spots, and removing trash.

❸ Cold Climate

This section contains observations about performance of different systems in cold climates. For an in-depth discussion of permeable pavement stormwater treatment systems in cold climate conditions, see page 32.

❹ Water Quality Treatment

This section presents data on a system's ability to remove contaminants from stormwater. It includes annual median event mean concentration values and median removal efficiencies for contaminants of concern. The "Pollutant Removal" chart represents collective water quality treatment data for one-to-three years, broken out into two seasons for each monitoring year. "Summer" extends from May to October and "winter" is from November to April. UNHSC monitors runoff—before it enters and after it leaves stormwater treatment systems—for the following contaminants:

- Total suspended solids (TSS): While there is great debate over current methods of sampling and analyzing sediments in stormwater, TSS remains the dominant yardstick of comparison for water quality performance of stormwater treatment systems nationwide.
- Total petroleum hydrocarbons in the semi-volatile (diesel) range (TPH-D): This is the only range of hydrocarbons where the concentrations in stormwater runoff measured at UNHSC are always well above the detection limits. Petroleum hydrocarbons are often included in regional ambient water quality criteria.
- Dissolved inorganic nitrogen (DIN): DIN includes nitrate, nitrite, and ammonia. Excessive amounts of these compounds in coastal and estuarine waters can lead to harmful algal blooms and oxygen poor conditions. Nutrients like nitrogen are often included in regional ambient water quality criteria.
- Total phosphorus (TP): Excessive amounts of TP in freshwater systems can result in harmful algal blooms and oxygen poor conditions. Nutrients like phosphorus are often included in regional ambient water quality criteria.
- Total zinc (Zn): Runoff can contain a range of toxic metals from a variety of sources. Zn is the metal of highest concentration for this study area. The primary sources of Zn pollution are tire wear and galvanized metal (guard rails). Heavy metals like Zn are often included in regional ambient water quality criteria.

For some systems, the UNHSC also provides information on other water quality issues such as thermal impacts.

❺ Water Quantity Control

This section presents data on the ability of each stormwater treatment system to reduce the flooding characteristics of runoff during a specific rain event. This ability is represented by measures of peak flow reduction and lag time.

"Water Quality Flow" is the maximum flow rate each system is designed for to treat. Each system is also designed to convey a peak flow, in some instances up to the 10–year storm (Q10). The associated graph shows the change in peak flow of runoff coming into the system (influent) and leaving the system (effluent). This observed data is then used to calculate the system's average reduction of hydrograph peak flow. Many communities have stormwater ordinances that require peak flow rates be reduced to a specified level.

"Lag time" is a measure of how long runoff remains within the system. Longer lag times mean that the system is reducing the "flashiness" (extreme changes in flow rate) of the runoff. This generally means that the runoff has more time to infiltrate underlying soils, thus reducing total runoff and increasing the effectiveness of water quality treatment. Because the systems tested at UNHSC are all lined for research purposes, volume reduction data is not developed.

How the System Works

❻ Water Quality Treatment Process

This section describes the system's basic mechanisms for water quality treatment. At the research field site, all systems are installed with an impermeable liner so that researchers can account for all of the stormwater runoff and the contaminants it contains. The diagrams in this section reflect how these systems would manage stormwater runoff in practice, and do not depict this lining.

❼ Design

This section includes information on the treatment's basic design, as well as specific variations or improvements employed by UNHSC at the field site. Generally, this description includes a water quality volume (WQ_v), or the volume of runoff produced by one inch of rainfall; channel protection volume (CP_v), or the two-year (Q2), 24-hour rain event based on one acre of impervious surface; and conveyance protection volume (Q10), or the ten-year, 24-hour storm (Q_p).

Porous Asphalt

The use of porous asphalt pavement could reduce the need for road salt in winter conditions. Since the application of salt can be problematic for small receiving streams and is not treated by most stormwater systems, such source reduction is crucial.

About Porous Asphalt

Porous asphalt (PA) is an extremely effective approach to stormwater management. Unlike retention ponds, porous asphalt systems do not require large amounts of additional space. Rainfall drains through pavement and directly infiltrates the subsurface. This significantly reduces runoff volume and peak flows, decreases its temperature, improves water quality, and essentially eliminates the impervious surface. It also speeds snow and ice melt, reducing the salt required for winter maintenance. The porous asphalt design tested at UNHSC is distinctive in its use of coarse sand as a subbase filter course—a refinement that enhances its effectiveness in improving water quality.

Implementation

As with most LID stormwater practices, porous asphalt is suitable for many sites. Its usage typically includes parking lots, driveways, sidewalks, low-use roadways, and developments with large areas of impervious surface. Its use is being piloted by the state of New Hampshire for a bus facility, on a high-volume state road in Maine, and on a low-volume roadway in Pelham, N.H. As with any infiltration system, care must be taken when locating these systems near pollution hotspots, or where seasonal high groundwater levels may lead to groundwater contamination. In such cases, the system can be lined and outfitted with a subdrain that discharges to the surface, or to storm sewers.

The effectiveness of porous asphalt has been demonstrated over a wide range of climates, including those with winter freezing and thawing. It may be especially effective in cold climates given its durability and capacity to reduce the salt needed for deicing in winter conditions.

Improvements in porous asphalt mix design, requirements for infiltration, and the need to comply with the Clean Water Act Phase II all combine to make porous asphalt a reasonable stormwater management alternative. Clogging, poor mix specifications, structural failure, and other historical barriers to implementation are addressed through careful design and maintenance. Successful implementation of porous asphalt systems relies on proper mix production, construction, and installation—all of which can be achieved with qualified suppliers, experienced installers, and engineering oversight.

While porous asphalt has been proven to manage stormwater effectively, it is weaker than conventional asphalt, making mix selection, durability, and anticipated vehicular loading important design considerations. Careful design and installation can address this limitation

Fast Facts

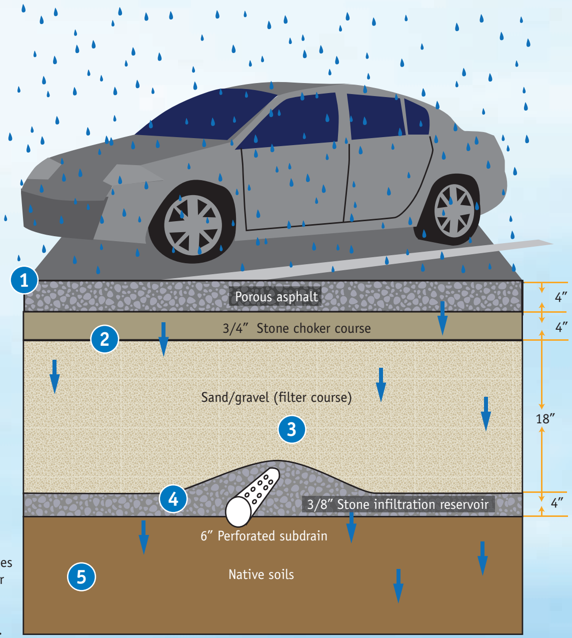
CATEGORY / BMP TYPE	Porous Pavement, Low Impact Development Design
UNIT OPERATIONS & PROCESSES	Hydrologic (Flow Alteration and Volume Reduction/ Infiltration) Water Quality: Physical (Filtration) & Chemical (Sorption)
DESIGN SOURCE	UNHSC
BASIC DIMENSIONS	Surface Area: 5,200 sf
SPECIFICATIONS	Catchment Area: 5,500 sf Water Quality Volume: 435 cf
INSTALLATION COST	2008 Costs: $2.80/sf for porous asphalt compared with $2.25/sf for standard asphalt
MAINTENANCE	Maintenance Sensitivity: Low Inspections: Low Sediment Removal: High

How the System Works

WATER QUALITY TREATMENT PROCESS ▼

1. **Rain drains through the porous asphalt and the choker course and into the sand filter course.**
2. **In the filter course, the physical process of filtration removes fine particulates from the runoff, and the chemical process of sorption binds contaminants like heavy metals, petroleum hydrocarbons, and phosphorus to sand surfaces. It is likely that some microbial activity also degrades petroleum hydrocarbons and some nutrients.**
3. **Water passes into the infiltration reservoir of uniformly graded crushed stone, where it can recharge groundwater.**
4. **When rainfall exceeds system design, water flows through the elevated subdrain to the surface. If a previous storm has completely drained from the system, the subgrade stone can store and infiltrate a one-inch rain event in its infiltration basin. Void spaces contained throughout the entire subbase provide sufficient storage for a 9.5 inch rain event. Specific design criteria are determined by local site conditions.**
5. **For installations that do not utilize a filter course and instead only use a subbase comprised of coarse stone, water quality, treatment occurs through infiltration into the native soils. Infiltration without treatment is only recommended for low-use sites.**

Please note:
This design includes subbase design for cold climates and drainage for low permeability soils.



effectively. UNHSC porous asphalt design specifications may be found online: www.unh.edu/erg/cstev.

System Performance

Cost & Maintenance

The 2004 materials and installation cost of UNHSC's porous asphalt lot was approximately $2,300 per space, compared to $2,000 per space for the adjacent impervious asphalt lot. The net costs for both lots would have been comparable had the impervious lot's stormwater infrastructure been taken into consideration. For a half-acre installation in the summer of 2008, costs for porous asphalt materials and installation were $2.80 per square foot versus $2.30 per square foot for standard asphalt. Cost variations are primarily due to the use of admixtures. Cost does not include preparatory site work and subbase construction, which vary depending on a project's scale.

The UNHSC porous lot has proven durable year round, and has only been maintained recently to demonstrate a worse case scenario. Researchers performed no maintenance for the first three years. Maintenance costs are projected to involve routine inspection and twice yearly vacuuming in the spring and fall. Vacuuming is estimated to cost $350 per acre per trip.

Cold Climate

The UNHSC porous asphalt lot's performance remains steady even in freeze thaw conditions. Researchers observed some of the highest infiltration rates in the winter—on average more than 1,000 inches an hour. Researchers observed frost penetration to depths of 27 inches in the filter media. While the pavement froze sooner, deeper, and for longer periods than the reference condition, the pores remained open and well-drained year round. The ability to maintain drainage minimized freezing and thawing in the subbase, contributing to the porous asphalt's durability. When designed with a deep subbase, the lifespan of these lots is expected to exceed impervious asphalt lots, which tend to lose structural integrity in northern climates due to frost heaving.

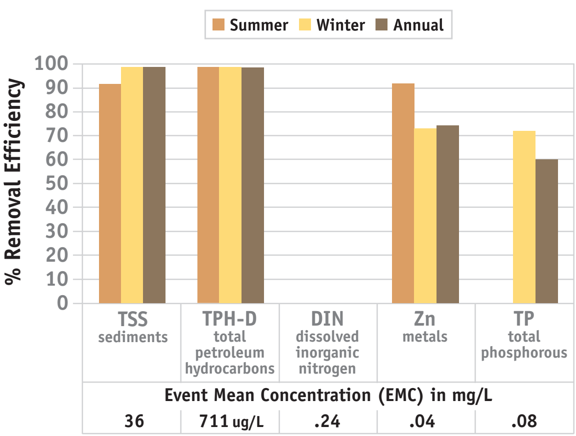
A substantial benefit of porous asphalt is the reduced need for sodium chloride for deicing. UNHSC researchers have observed that porous asphalt requires roughly 25 percent of the salt routinely applied to impervious asphalt to achieve equivalent, or better, deicing and traction in winter. In particular, the black ice that comes from melting and refreezing is essentially eliminated on porous asphalt.

However, the need for winter maintenance on porous asphalt may increase in some cases. During ice storms, or any time there is significant compacted snow and ice, the deicing of porous pavement becomes more difficult. This is because the brine solution that collects on impervious surfaces quickly infiltrates porous pavement before it has a chance to melt ice effectively. The best approach in these circumstances is to apply excess chloride and to increase mechanical means of snow removal. A winter maintenance fact sheet is available online: www.unh.edu/erg/cstev.

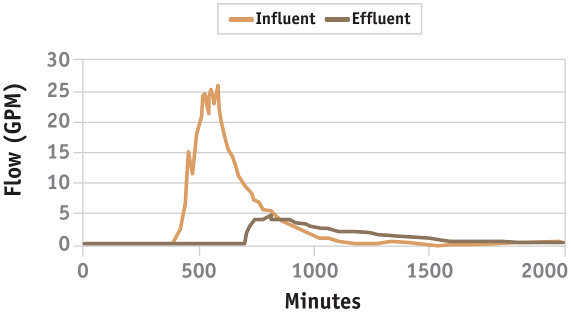
Water Quality Treatment

The water quality treatment performance of the porous asphalt lot generally has been excellent. It consistently exceeds EPA's recommended level of removal of total suspended solids, and meets regional ambient water quality criteria for petroleum hydrocarbons and zinc. Researchers observed limited phosphorus treatment and none for nitrogen, which is consistent with other non-vegetated infiltration systems. The system did not remove chloride. However, since it drastically reduced the amount of salt needed for winter maintenance, it may prove effective at reducing chloride pollution.

POLLUTANT REMOVAL: 2004–2008



HYDRAULIC PERFORMANCE



	Winter	Summer	Annual Average
Average Peak Flow Reduction	76%	86%	82%
Average Lag Time (minutes)	1,163	1,375	1,275

The chart at top right reflects the system's performance in removing total suspended solids, total petroleum hydrocarbons, dissolved inorganic nitrogen, total phosphorus, and total zinc. Values represent results recorded over two years, with the data further divided into summer and winter components.

Water Quantity Control

The porous asphalt system's ability to manage runoff has been exceptional. It has generally outperformed all systems tested at UNHSC. No surface runoff has been observed from this lot since its installation in 2004; this includes the 100-year storm events that New Hampshire experienced in 2006 and 2007. Groundwater recharge has been achieved despite the system's location over clay soils. The second figure from the top illustrates effective peak flow reduction and long lag times for the range of seasons monitored.

SYSTEM DESIGN ▼

Installed in 2004, the lot was designed to manage the WQ_v, CP_v, and the Q100. A gravel edge with curbing prevents sediment from washing onto the porous lot's surface and prematurely clogging the system. For low-use driveways, a subbase that consists of an eight-inch layer of 3/4 inch crushed stone is adequate. UNHSC's current recommended design for commercial parking consists of four layers:

Top layer: Four-inches of porous asphalt in which sand particles smaller than two millimeters were removed from the aggregate mix, creating pavement with a void space of 18 to 20 percent;

Second layer: Four-inch choker course consisting of 3/4 inch crushed stone that allows runoff to pass into the next layer and offers structural support;

Third layer: 18 inches of poorly graded sand (bank run gravel) that serves as the filter course;

Fourth layer: six inches of crushed stone, with a six-inch diameter, elevated subdrain, which serves as the infiltration reservoir and capillary barrier. (The thickness of this layer protects against freezing and thawing, and makes it possible to locate this system in sandy clay loam with low infiltration rates.)

The sides of the system may be lined with geotextile fabric to prevent the influx of fines; however, a bottom lining is only recommended with poor structural soils. Geotextiles should be used with caution as they can lead to premature clogging.

Pervious Concrete

Pervious concrete salt reduction will vary and is heavily dependent upon shading. For shaded areas, pervious concrete may not achieve salt reduction. Even in shaded areas, deicing is not required for black ice development as meltwater readily drains through porous surfaces thereby preventing black ice.

About Pervious Concrete

Pervious concrete (PC) is an effective approach to stormwater management. Rainfall drains through pavement and directly infiltrates the subsurface. This significantly reduces runoff volume and peak flows, decreases its temperature, improves water quality, and essentially eliminates impervious surface. In areas with sufficient sun exposure, pervious concrete can also speed snow and ice melt, reducing the salt required for winter maintenance. The PC design tested at UNHSC is distinctive in its use of coarse sand as a filter course—a refinement that enhances its effectiveness in improving water quality.

Implementation

With proper design, production, and installation, pervious concrete can be an excellent transportation structure and reasonable stormwater treatment system. As with most LID stormwater practices, PC is suitable for many sites. Typical usage includes parking lots, low-use roadways, sidewalks, and commercial developments with large areas of impervious surface. Care must be taken when locating PC—or any infiltration system—near pollution hotspots or where seasonal high groundwater levels may lead to contamination. In such cases, the system can be lined and outfitted with a subdrain that discharges to the surface or to storm sewers.

The effectiveness of porous pavements has been demonstrated over a wide range of climates; however, impervious and pervious concrete can be damaged by the freeze thaw cycle. To address this, it is essential that PC designs have an 18–20 percent void space and high subbase permeability. To ensure adequate curing, PC should not be installed within 28 days of freezing conditions and the potential application of chloride. (More conservative estimates call for a longer curing period.) Because of its permeability and high degree of reflectivity, PC can be challenging to maintain in the winter. In areas with good sun exposure, snow and ice melt more readily and less salt needs to be applied. However, snow and ice tend to accumulate in areas with significant shading, increasing the need for salt application and plowing. Designs involving PC in cold climate regions should take shade cover into account.

Improvements in mix design, requirements for infiltration, and the need to comply with the Clean Water Act Phase II all combine to make pervious concrete a reasonable stormwater management alternative. Clogging, poor installation practices, and complications from extreme temperatures during or soon after

Fast Facts

CATEGORY / BMP TYPE
Pervious Pavement, Low Impact Development Design

UNIT OPERATIONS & PROCESSES
Hydrologic (Flow Alteration, Volume Reduction/ Infiltration)
Water Quality: Physical (Filtration) & Chemical (Sorption)

DESIGN SOURCE
UNHSC & Northern New England Concrete Promotion Association (NNECPA)

BASIC DIMENSIONS
Surface Area: 21,000 sf

SPECIFICATIONS
Catchment Area: 21,000 sf
Water Quality Volume: 1,750 cf

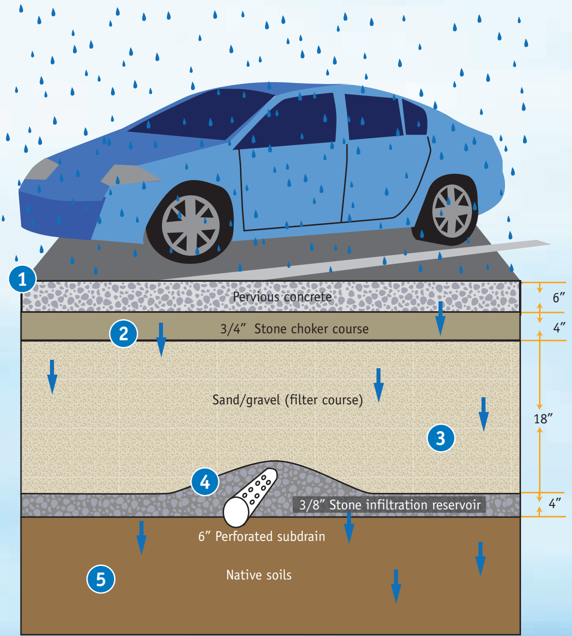
INSTALLATION COST
$4–5sf for materials and installation (does not include subbase)

MAINTENANCE
Maintenance Sensitivity: Low
Inspections: Low
Sediment Removal: High

How the System Works

WATER QUALITY TREATMENT PROCESS ▼

1. **Rain drains through the pervious concrete and choker course and into the sand filter course.**
2. **In the filter course, the physical process of filtration removes fine particulates from the runoff, and the chemical process of sorption binds contaminants like heavy metals, petroleum hydrocarbons, and phosphorus to sand surfaces. It is likely that some microbial activity also degrades petroleum hydrocarbons and some nutrients.**
3. **Water passes into the infiltration reservoir of uniformly graded crushed stone, where it can recharge groundwater.**
4. **When rainfall exceeds system design, water flows through the elevated subdrain to the surface. If a previous storm has completely drained from the system, the subgrade stone can store and infiltrate a one-inch rain event in its infiltration basin. Void spaces contained throughout the entire subbase provide sufficient storage for a 9.5 inch rain event. Specific design criteria are determined by local site conditions.**
5. **For installations that do not utilize a filter course and instead only use a subbase comprised of coarse stone, water quality treatment occurs through infiltration into the native soils. Infiltration without treatment is only recommended for low-use sites.**



Please note: This design includes subbase design for cold climates and drainage for low permeability soils.

placement may limit widespread adoption of PC in cold climate regions. Successful implementation of these systems relies on proper mix production (including appropriate admixtures), construction oversight, and timely installation—all of which can be achieved with qualified suppliers and engineering oversight.

System Performance

Cost & Maintenance

Current estimates for pervious concrete materials and installation range between $4 and $5 per square foot. This does not include site work and subbase construction. Researchers have not performed routine maintenance since the lot was installed in 2007 as a matter of experimental design. Maintenance costs are projected to involve routine inspection and vacuuming at least two times per year (spring and fall). Vacuuming is estimated to cost $350 per acre per trip. Increased vacuuming frequency is expected at sites with a large amount of run-on and/or organic debris (leaves, pine needles, etc.).

Cold Climate

The winter performance of the pervious concrete system was exceptional year round for water quality, hydraulics, and infiltration capacity. Throughout the winter, the surface infiltration capacity averaged approximately 4,000 inches per hour with minimal change. Researchers observed frost penetration to depths of 15 inches in the filter media. While the pavement froze sooner, deeper, and for longer periods than the reference condition, the pores remained open and well-drained year round. This ability to maintain drainage limits freezing and thawing and contributes to the pavement's long-term durability. When designed with a deep subbase, the lifespan of these lots is expected to exceed impervious pavements parking lots, which in northern climates tend to lose structural integrity after 12 to 15 years due to frost heaving.

When placed in areas with good sun exposure, PC reduces the need for chloride applications in winter. Sunnier parts of the UNHSC lot performed better than the nearby reference impervious asphalt pavement for traction and reduced snow and ice cover. In these areas, the formation of black ice resulting from melting and refreezing was essentially eliminated. However, in other parts of the lot, shading from adjacent tree cover increased the winter maintenance load, leading to reduced traction and a need for excess chloride for successful deicing.

As with other porous pavements, deicing PC is more difficult during ice storms, or any time there is significant compacted snow and ice. This is because the brine solution that collects on impervious surfaces quickly infiltrates the porous pavement before it has a chance to melt ice effectively. The best approach in these circumstances is to apply excess deicing agents and to increase mechanical means of snow removal. A winter maintenance fact sheet is available online: www.unh.edu/erg/cstev.

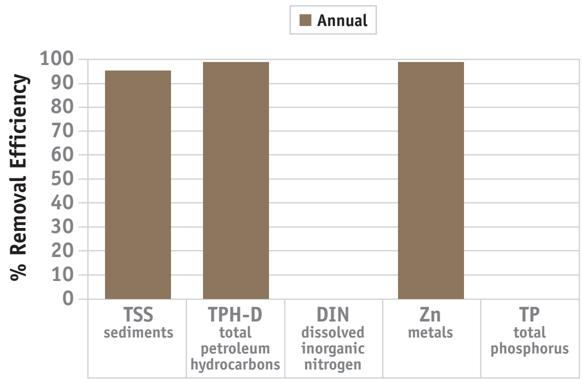
Water Quality Treatment

The water quality treatment performance of the pervious concrete lot is similar to that of the porous asphalt, which has been excellent, consistently exceeding EPA's recommended levels of most contaminants with the exception of nitrogen. Due to the high infiltration capacity of the underlying native soils, coupled with the system's capacity to store large volumes of water, researchers observed a 95 percent runoff volume reduction since the lot was constructed in 2007. The storage and infiltration of this magnitude limited the assessment of water quality within the system to six storms that flowed enough for monitoring to occur. The performance observed was similar to installations such as the porous asphalt lot.

Water Quantity Control

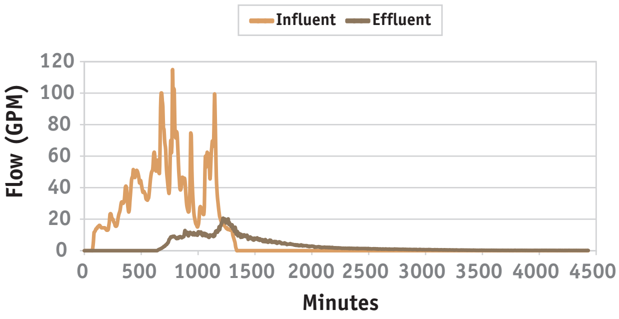
The pervious concrete system's ability to manage runoff was exceptional, with 95 percent volume reduction on an HSG-B soil. No surface runoff has been observed from this lot since its installation in 2007. This replaced a preexisting asphalt lot that created a local problem of severe surface erosion and gullying. Significant groundwater recharge has been achieved—far in excess of predevelopment conditions. The figure above illustrates effective peak flow reduction and long lag times for the range of seasons monitored.

POLLUTANT REMOVAL: 2007–2009



	TSS	TPH-D	DIN	Zn	TP
Median Annual Influent Event Mean Concentrations (EMC) in mg/L	141	310 ug/L	.3	.05	.06

HYDRAULIC PERFORMANCE



	Winter	Summer	Annual Average
Average Peak Flow Reduction	88%	97%	93%
Average Lag Time (minutes)	848	1,365	1,144
Average Volume Reduction	91%	98%	95%

SYSTEM DESIGN ▼

Installed in August 2007, the UNHSC pervious concrete lot was designed with a subsurface storage capacity similar to a retention pond. Water quality volume (WQ_v), channel protection volume (CP_v), and higher flows, such as those associated with a ten-year event (Q_p) or greater, are managed in the system through storage, infiltration capacity, and subdrains. A gravel edge with curbing prevents sediments from washing onto the surface and prematurely clogging the system. For low-use driveways or bike paths, a subbase that consists of six inches of 1.5 inches crushed stone may be adequate. The recommended design for commercial parking lots consists of four basic layers:

Top layer: Six-inches of pervious concrete in which the aggregate is open graded and contains 3/8 inch stone (Admixtures are traditionally included to address hydration, strength, and workability.);

Second layer: Four-inch choker course consisting of 3/4 inch stone, which allows runoff to pass into the next layer and offers structural support to the concrete trucks during installation;

Third layer: 16 inches of poorly graded sand (bank run gravel), which serves as a filter course;

Fourth layer: At least a minimum of 4 inches of 3/8 inch crushed stone that serves as an infiltration reservoir and capillary barrier. The thickness of this layer protects against freezing and thawing, and makes it possible to locate this system in clayey loam soils with moderate infiltration rates. The installation of elevated perforated subdrains is optional and depends on soil type, water quality, and water quantity treatment objectives.

The sides of the system may be lined with geotextile fabric to prevent the influx of fines; however, a bottom lining is only recommended with poor structural soils or when infiltration is not desired. Geotextiles in horizontal layers should be used with caution as they can lead to premature clogging.

Subsurface Gravel Wetland

Subsurface gravel wetlands do an exceptional job of treating stormwater quality and managing water quantity. The design for the gravel wetland pictured above is helping New Hampshire's Department of Transportation meet Total Maximum Daily Load (TMDL) standards for numerous transportation improvement projects.

About the Subsurface Gravel Wetland

The subsurface gravel wetland is a recent innovation in Low Impact Development (LID) stormwater design. It approximates the look and function of a natural wetland, effectively removing sediments and other pollutants commonly found in runoff, while enhancing the visual appeal of the landscape and adding buffers or greenscape to urban areas. The subsurface gravel wetland evaluated at UNHSC is a horizontal-flow filtration system that should not be confused with stormwater wetlands that function more like ponds. Instead, it relies on a dense root mat, crushed stone, and an anaerobic, microbe rich environment to improve water quality. Like other filtration systems, it demonstrates a tremendous capacity to reduce peak flow and improve water quality.

Implementation

Subsurface gravel wetlands can be used in many regions, with the exception of those too arid to support a wetland system. Since they can be space intensive, they may not be appropriate for densely developed areas. However, they can be retro-fitted into existing dry ponds as a water quality retrofit. Large detention basins used for flood control can house a subsurface gravel wetland without affecting storage capacity—an innovation that would dramatically improve water quality treatment and peak flow control. Like any system that relies on infiltration or filtration, these wetlands should be lined and outfitted with subdrains that discharge to the surface if they are to be used in pollution hotspots. Dissolved oxygen levels may fluctuate within biologically active subsurface systems like the gravel wetland, yet if this is a problem for local receiving waters it can easily be dealt with through appropriate design.

Constructed wetlands are widely used. While subsurface gravel wetlands are more costly and less common, they represent a dramatic performance improvement over surface wetland ponds. Subsurface gravel wetland systems are especially effective at removing nitrogen from contaminated runoff, one reason they have been used for some time in wastewater treatment.

System Performance

Cost & Maintenance

The installation cost of a subsurface gravel wetland large enough to treat runoff from one acre of impervious surface was $22,500. This does not include maintenance. Removal of system biomass (mowing of vegetation) should occur at least once every three growing

Fast Facts

CATEGORY / BMP TYPE

Stormwater Wetland, Low Impact Development Design

UNIT OPERATIONS & PROCESSES

Hydrologic (Flow Alteration)

Water Quality: Physical (Sedimentation, Filtration), Biological (Vegetative Uptake, Microbial Mediation), & Chemical (Sorption)

BASIC DIMENSIONS

Filter Basin Footprint: 15 ft long X 32 ft wide

Forebay Footprint: 10 ft long X 32 ft wide

Total Area: 5,450 sf

SPECIFICATIONS

Catchment Area: 1 acre

Water Quality Flow: 1 cfs

Water Quality Volume: 3,300 cf

INSTALLATION COST

$22,500 per acre treated

MAINTENANCE

Maintenance Sensitivity: Low

Inspections: Low

Sediment Removal: High

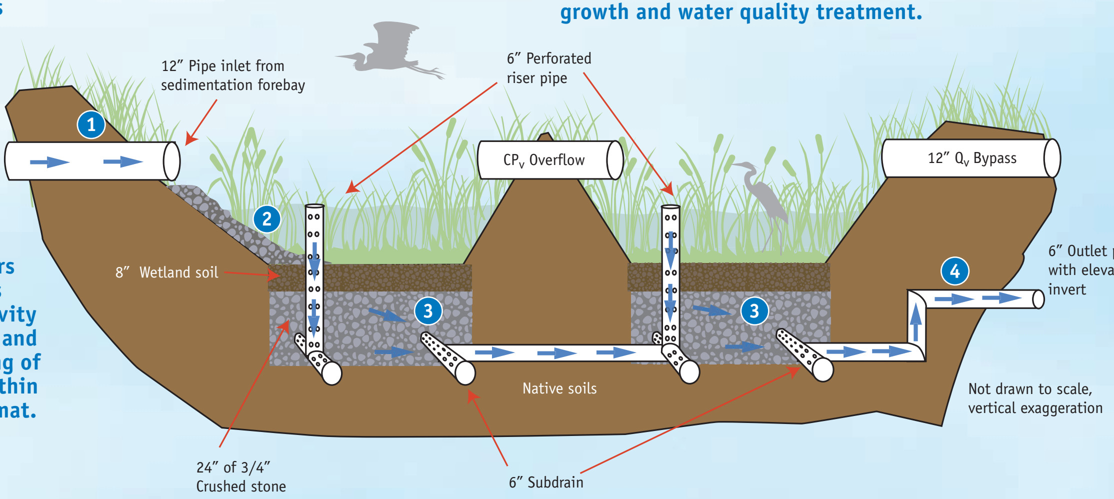
How the System Works

WATER QUALITY TREATMENT PROCESS ▼

1. **Runoff flows into a forebay, which removes large objects and allows larger-sized sediment particles to settle.**
2. **Runoff exits the forebay through a perforated standpipe and flows into the vegetated treatment basins, where it is treated through a variety of physical, chemical, and biological unit operations and processes (UOPs).**
3. **Perforated riser pipes in the treatment basins conduct water to the subsurface gravel layer. There, biological treatment occurs through the uptake of pollutants by vegetation and microbial activity within the root system. Physical and chemical treatment—the trapping of contaminants—occurs on and within the gravel filter media and root mat.**

Other UOPs include sedimentation, transformation through reduction/oxidation, and sorption with organic matter and mineral complexes.

4. **Treated runoff exits to the surface via an outlet pipe that includes an elevated invert located four inches below the wetland surface. This insures that the soil is nearly continuously saturated—a condition that promotes vegetation growth and water quality treatment.**



seasons. The dense vegetation tends to experience fewer problems with invasive plants and insect infestations, and the use of 3/4 inch crushed stone for filtration and subsurface water storage further reduces the maintenance load.

UNHSC first performed maintenance on the subsurface gravel wetland after its third year of operation. Maintenance activities included removal of vegetation in the forebay and cutting back and removing vegetation from the treatment cells. Research has demonstrated the value of biomass removal for long-term nutrient uptake, without which, nitrogen release will begin to occur. Maintenance will be critical to ensuring effective water quality treatment performance in systems employing microbial mediated processes such as denitrification. Vegetation needs to be periodically trimmed and removed so that influent (runoff) can remain well aerated before it enters the oxygen-limited environment of the subbase. Reducing the amount of forebay vegetation also avoids the reintroduction of pollutants, particularly nitrogen and phosphorus, which are sequestered in the plants. Sediment removal from the forebay, or any pretreatment device installed with this system, will reduce maintenance on the treatment basins.

Cold Climate

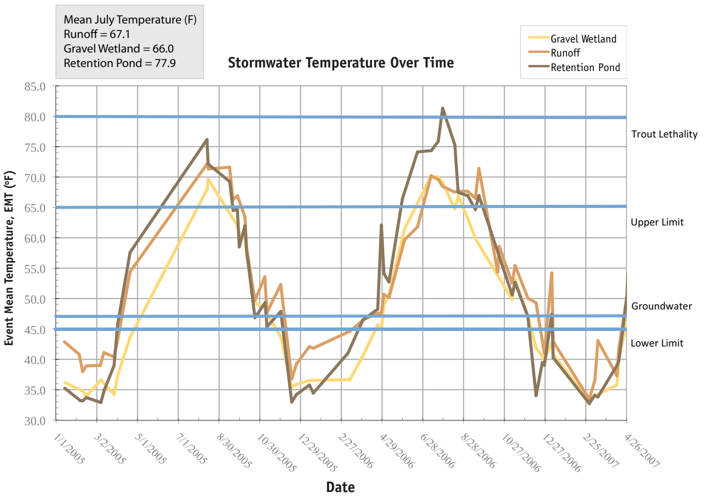
The subsurface gravel wetland's water quality treatment and water quantity control capacity remained strong in all seasons. Nitrate removal declined briefly in the winter while phosphorus removal improve,reinforcing the conclusion that filtration systems perform well, even in cold climates. Because the flow is subsurface and enters the system through riser pipes, freezing of the wetland surface does not impact its function.

Water Quality Treatment

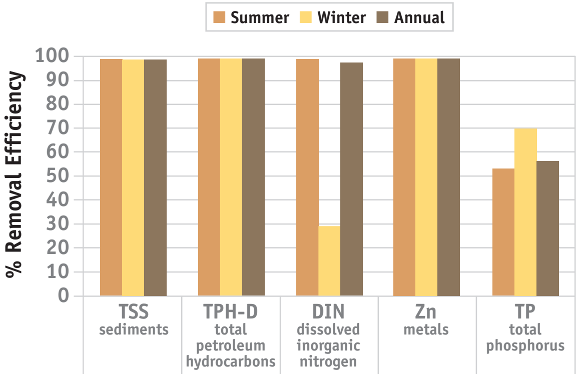
The subsurface gravel wetland does an exceptional job of removing nearly all of the pollutants commonly associated with stormwater treatment performance assessment. It consistently exceeds EPA's recommended level of removal for total suspended solids and meets regional ambient water quality criteria for nutrients, heavy metals, and petroleum hydrocarbons. Like all other systems monitored at UNHSC, it does not provide chloride removal, but does exhibit an ability to dampen chloride peaks by dilution and attenuation mechanisms.

The chart at the middle right reflects the gravel wetland's performance in removing total suspended solids, total petroleum hydrocarbons, dissolved inorganic nitrogen, total phosphorus, and zinc. Values represent results recorded over three years, with the data further divided into summer and winter components. The subsurface gravel wetland has now also been studied to examine its performance for removal of aircraft deicer fluid. Additional sites for subsurface gravel wetlands are being monitored for long-term performance.

As a major threat to cold water fisheries, the increased temperature of runoff has become a contaminant of concern in many watersheds. During the UNHSC's evaluation of the gravel wetland, the mean July temperature of runoff leaving the system was 66.0 degrees Fahrenheit—roughly one degree lower than the runoff before it entered the system and 12 degrees lower than the retention pond. The graph at the top right shows the modest decrease in temperature of parking lot runoff that can be observed in subsurface gravel wetland systems during summer months. These temperatures are important to note when considering lethality indices of aquatic species.



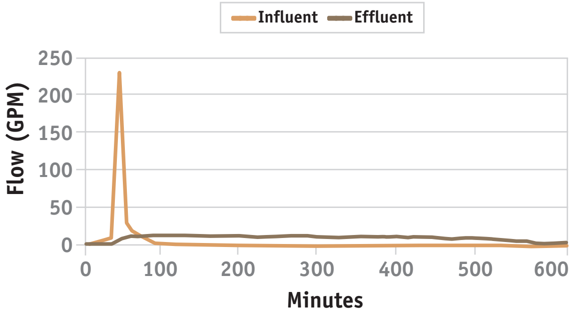
POLLUTANT REMOVAL: 2004–2007



Median Annual Influent Event Mean Concentrations (EMC) in mg/L

TSS	TPH-D	DIN	Zn	TP
45	712 ug/L	.38	.04	.09

HYDRAULIC PERFORMANCE



	Winter	Summer	Annual Average
Average Peak Flow Reduction	86%	88%	87%
Average Lag Time (minutes)	238	265	251

Water Quantity Control

Like other filtration systems, the subsurface gravel wetland exhibits a tremendous capacity to reduce peak flows of stormwater entering the system. The figure above illustrates effective peak flow reduction and long lag times for the range of seasons monitored.

SYSTEM DESIGN ▼

This subsurface gravel wetland was designed by UNHSC. Its rectangular footprint occupies 5,450 square feet and can accommodate runoff from up to one acre of impervious surface. It includes a pretreatment forebay, followed by two flow-through treatment basins. (Other pretreatment approaches may be used.) Each treatment basin is lined and topped with two feet of gravel and eight inches of wetland soil.

The system is designed to retain and filter the water quality volume (WQv) 10 percent in the forebay and 45 percent above each treatment cell. It can detain a channel protection volume (CPv) of 4,600 cubic feet, and release it over 24 to 48 hours. The conveyance protection volume (Q10) is bypassed. For small, frequent storms, each treatment basin filters 100 percent of the influent it receives. For larger storms that do not exceed the design volume, some stormwater bypasses the first treatment basin and is only processed by the second. When storms exceed the design volume, the first inch of rain (first flush) is treated, while the excess is routed to conveyance structures or receiving waters.

Since standing water of significant depth is not expected, except during heavy rains, the side slopes of the system are graded at 3:1 or flatter to facilitate maintenance.

With the exception of the forebay, the wetland hosts a diverse mix of native wetland grasses, reeds, herbaceous plants, and shrubs. The forebay must be stabilized with vegetation and be well drained to remain aerobic.

Bioretention Systems

UNHSC research is showing that bioretention systems are most effective when they serve as local source control devices, intercepting and managing relatively small areas of impervious cover, in a well-distributed network of runoff control measures.

About Bioretention Systems

Bioretention systems, also known as “rain gardens,” are among the most common LID stormwater approaches in use today. In general, runoff flows into landscaped depressions, where it ponds, filters through a soil mix, and infiltrates into the ground, or is connected to storm drains. The engineered soil mix and vegetation mimic the water quality treatment and infiltration similar to undeveloped areas. Soil mix design is essential to the performance and longevity of these systems. While the mix must contain enough fines and organic matter to sustain vegetation and slow down infiltration rates, too much of these components may cause systems to clog prematurely eliminating any water quality benefits. There are soil mix specifications available to support designers in successfully implementing bioretention systems in a wide range of site conditions. UNHSC has evaluated many such systems; this report looks at a design we call “Bio II.”

Implementation

Bioretention systems can be used throughout the United States, and their acceptance and implementation varies regionally. However, an increasing number of states require a level of water quality treatment and volume reduction that only can be achieved through the incorporation of LID designs like bioretention. In some regions, local acceptance is hindered by lack of performance data, unfamiliarity with the design, and suspicions about seasonal functionality.

To achieve maximum volume reduction, bioretention systems should be located in soils that accommodate infiltration, such as those in group “A” (sand, loamy sand, or sandy loam with high infiltration rates) and “B” (silt loam or loam with moderate infiltration rates). Careful site analysis is required to design an effective, integrated network of these systems that allows infiltration throughout a site. Bioretention systems can also be used to great effect in areas with poor soils, where pre-development infiltration would have been minimal. These systems in poor soils will require underdrains to ensure proper drainage and treatment.

UNHSC research is showing that bioretention systems are most effective when they serve as local source control devices, intercepting and managing relatively small areas of impervious cover in a well-distributed network of runoff control measures. They can be used as an end-of-pipe system; however, such usage requires a more sophisticated design for the system to function properly, particularly when

Fast Facts

CATEGORY / BMP TYPE

Infiltration, Low Impact Development Design

UNIT OPERATIONS & PROCESSES

Hydrologic (Flow Alteration)

Water Quality: Physical (Sedimentation, Filtration), Biological (Vegetative Uptake), & Chemical (Some Sorption possible with proper design)

DESIGN SOURCE

Low Impact Development Center, Maryland

BASIC DIMENSIONS

Filtration Basin: 8 ft wide X 34 ft long X 2.5 ft deep

Forebay: 14 ft long X 8 ft wide

Total Area: 272 sf

SPECIFICATIONS

Catchment Area: 1 acre

Water Quality Flow: 1 cfs

Water Quality Volume: 3,300 cf

INSTALLATION COST

$18,000 per acre

MAINTENANCE

Maintenance Sensitivity: Low

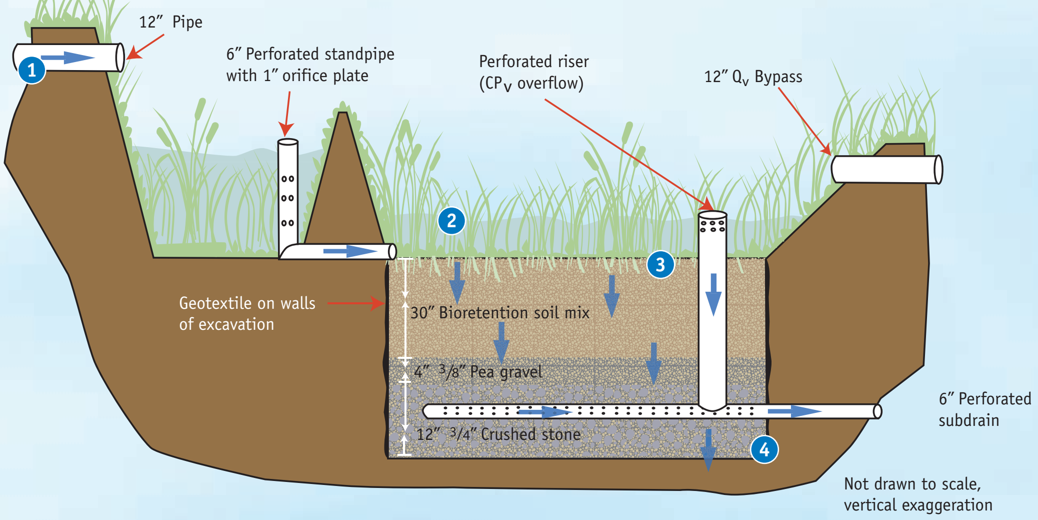
Inspections: Low

Sediment Removal: High

How the System Works

WATER QUALITY TREATMENT PROCESS ▼

1. **Runoff flows into a sedimentation forebay or other pretreatment chamber. From there, it is slowly released into the filter basin through a perforated standpipe. When forebay capacity is reached, the overflow spills across a weir into the bioretention basin.**
2. **Biological treatment occurs through the uptake of pollutants by vegetation and soil microorganisms. Physical and chemical unit operations and processes that occur within the soil media include sedimentation, filtration, and sorption with organic matter and mineral complexes.**
3. **Nutrients like nitrogen are taken up by the roots of the vegetation and metabolized by the system’s plants, shrubs, and trees.**
4. **The treated runoff can be allowed to infiltrate the native soils, or collected in a perforated subdrain and returned to a storm drain system or discharged to the surface.**



Not drawn to scale, vertical exaggeration treating one or more acres of impervious cover. As with any infiltration or filtration system, when used in pollution hotspots or poor soils, they should be lined and outfitted with subdrains that discharge to the surface.

System Performance

Cost & Maintenance

The cost to install Bio II to treat runoff from a one-acre parking lot was $18,000. However, UNHSC expects this cost to come down as installers and designers gain familiarity with the systems. The Center installed a third bioretention system in 2007 at $14,000 per acre for the total cost; labor and installation were calculated to be $8,500 per acre, and materials and plantings cost $5,500 per acre. This indicates that for a municipality that has both equipment and personnel, the cost for retrofits is nearly $5,500 per acre of drainage.

Bioretention systems are designed to minimize maintenance. Generally, the highest maintenance burden is in the first three to four months, as the vegetation grows and the system begins to stabilize. Once vegetation is established, the maintenance decreases and becomes similar to that required for standard landscaping, such as seasonal mowing, raking, and pruning of vegetation. Systems with fine media may require more frequent attention due to clogging. However, since most clogging occurs on the surface, servicing these systems is simple. Long-term maintenance may involve routine inspection and occasional scraping and removal of surface fines.

Cold Climate

Bio II's ability to treat water quality and control water quantity remained relatively consistent in all seasons. UNHSC researchers have observed that most LID stormwater systems, when properly designed and installed, are not negatively impacted by cold climate. In fact, these systems showed fewer seasonal variation than many conventional approaches that depend on sedimentation as the primary unit operation. While some seasonal variation did occur in Bio II, significant design alterations do not appear to be necessary for cold weather applications of this system.

Water Quality Treatment

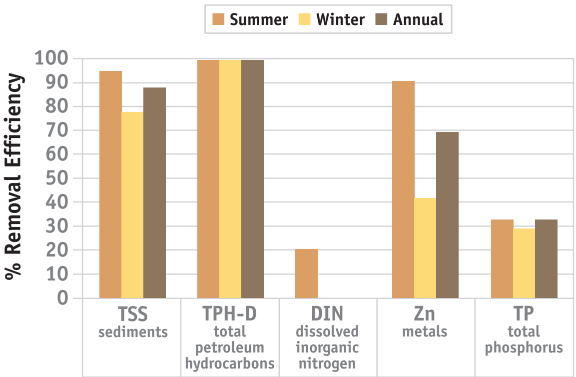
Bio II has proven effective at removing nearly all of the pollutants commonly associated with stormwater treatment performance assessment. It consistently exceeded EPA's recommended level of removal for total suspended solids and meets regional ambient water quality criteria for petroleum hydrocarbons. This system had lower removal of nitrogen and phosphorous than the previous bioretention system tested at the UNHSC. This may be due to reduced contact time and/or less dense root mat. These design variations are being examined in Bio III and Bio IV presently. Like the other systems monitored at UNHSC, Bio II does not provide chloride removal, although it does exhibit an ability to dampen chloride peaks.

The chart at top right reflects the bioretention performance in removing total suspended solids, total petroleum hydrocarbons, dissolved inorganic nitrogen, total phosphorus, and zinc.

Water Quantity Control

Like other infiltration and filtration systems, Bio II has a tremendous capacity to reduce peak flows and runoff volume in appropriate soils, i.e., those belonging to groups A and B. In the figure at bottom right, Bio II demonstrates effective peak flow reduction and large lag times regardless of season. Vegetation contributes to stormwater volume reduction through the process of evapotranspiration.

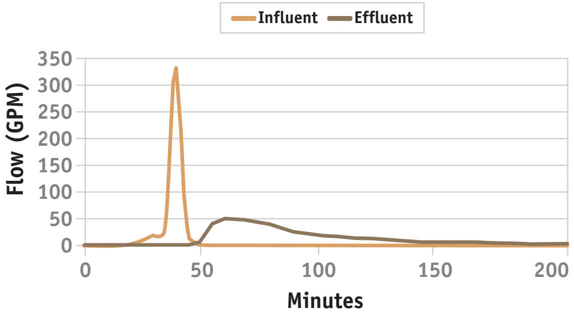
POLLUTANT REMOVAL: 2006–2008



Median Annual Influent Event Mean Concentrations (EMC) in mg/L

TSS	TPH-D	DIN	Zn	TP
48	754 ug/L	.21	.043	.09

HYDRAULIC PERFORMANCE



	Winter	Summer	Annual Average
Average Peak Flow Reduction	76%	82%	79%
Average Lag Time (minutes)	376	254	309

SYSTEM DESIGN ▼

Bio II is comprised of a sedimentation forebay and a bioretention filtration basin. The basin is filled with a 30 inch bioretention soil mix (BSM), consisting of 60 percent sand, 20 percent woodchips, 10 percent compost, and 10 percent native soil. The filtration basin is well vegetated. Researchers selected vegetation for flood and drought tolerance, the capacity for maximum ground cover, and aesthetics.

The forebay holds 25 percent of the water quality volume (WQ_v), and drains through a stone level spreader into the bioretention basin, which holds 75 percent of the WQ_v. The basin allows eight inches of ponding, and the BSM has an infiltration rate of eight feet per day. Overflow contingencies exist for channel protection volume (CP_v) and conveyance protection volume (Q10) events. Typically Q2 events are conveyed over 24 to 48 hours, and Q10 events bypass to the surface.

The appropriate BSM design is important to ensure adequate drainage, support plant growth, and achieve water quality treatment objectives. It is important for soils to slowly percolate enough to achieve high quality treatment, yet fast enough to filter sufficient volumes of water such that the filter area not be inordinately large. Bio II's BSM specifications were developed with input from the Low Impact Development Center. The resulting BSM had reduced silts and clays of about 6 percent maintains an infiltration rate of approximately 8 feet per day, and had about 3 percent organic matter. Results indicate that this BSM had reduced removal performance for nitrogen and phosphorus, in comparison to Bio I that had an infiltration rate of 0.5 feet per day.

UNHSC is currently studying BSM for two other designs with high infiltration rates that use outlet controls to slowly release the WQ_v. One with 8 percent fines and 10 percent organic matter, and infiltration rate of 100 feet per day, and another with 10 percent fines, 7 percent organic matter, and an infiltration rate of 40 feet per day. Soil chemistry is important, especially when targeting phosphorus reduction. BSMs must contain relatively low levels of phosphorus to maintain a sorption capacity that can remove phosphorous from runoff. Studies from North Carolina State University recommend BSMs with a Phosphorus Index (P-Index) of 25 to 40.

Tree Box Filter

Unlike many other forms of urban landscaping, tree filters are not isolated behind curbs and deprived of water and nutrients from runoff. Instead, they receive runoff through breaks in the curbing, and demonstrate strong water quality treatment.

About the Tree Box Filter

Tree box filters are mini bioretention systems (see pages 20 to 21) that combine the versatility of manufactured devices with the water quality treatment of vegetated systems. They serve as attractive landscaping and drainage catch basins. Unlike many other forms of urban landscaping, they are not isolated behind curbs and can therefore take advantage of the water and nutrients in runoff. Their water quality treatment performance is high, often equivalent to other bioretention systems, particularly when well distributed throughout a site. Because of their small size, they are commonly treating relatively small areas (<10,000 sf) typical of a catch basin drainage. The first tree box filter at UNH was installed in 2004.

Implementation

Tree box filters are a relatively recent innovation that are being used increasingly throughout the United States. They are often installed along sidewalks in place of, or adjacent to catch basins, but are highly adaptable, and can be used in many development scenarios. They are especially useful in settings where there is minimal available space.

In urban areas, tree box filters can be used in the design of an integrated street landscape—a choice that transforms isolated street trees into stormwater filtration devices. They also can be used in designs that seek to convert non-functional streetscapes into large stormwater or combined sewer flow reduction systems. They can be installed in open-bottomed chambers in locations where infiltration is desirable or in closed-bottomed chambers where infiltration is either impossible (clay soils) or undesirable (high groundwater or highly contaminated areas).

In general, tree box filters are sized and spaced much like catch basin inlets, and design variations are abundant. Common catch basin drainage areas may range from 3,000 to as large as 30,000 square feet of impervious area. The system evaluated at UNHSC was designed by Center researchers to treat 5,000 square feet. A similar patented design made by AmeriCast, the Filterra, is also available. Contact UNHSC for more information about the design of the tree box filter.

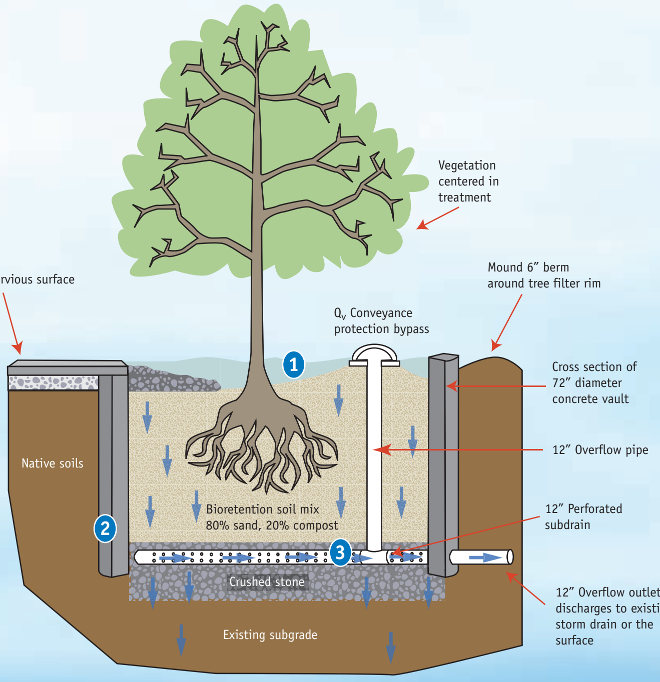
Fast Facts

CATEGORY / BMP TYPE	DESIGN SOURCE	SPECIFICATIONS	INSTALLATION COST
Filtration, Infiltration, Urban Retrofit, Low Impact Development Design	UNHSC	Catchment Area: 0.1 acre Water Quality Flow: 0.1 cfs Water Quality Volume: 425 cf Tree: Two-inch Caliper Ash	$3,000 per unit for materials, $3,000 for installation ($30,000 per acre treated)
UNIT OPERATIONS & PROCESSES	**BASIC DIMENSIONS**		**MAINTENANCE**
Water Quality: Physical (Filtration), Biological (Vegetative Uptake) & Chemical (Sorption)	Diameter: 6 ft Depth: 4 ft		Maintenance Sensitivity: Low Inspections: Medium Sediment Removal: Low

How the System Works

WATER QUALITY TREATMENT PROCESS ▼

1. Runoff flows into the tree box filter from the street and passes into the filter media.
2. Biological treatment occurs through the uptake of pollutants by vegetation and soil microorganisms. Physical and chemical unit operations and processes that occur within the soil media include sedimentation, filtration, and sorption with organic matter and mineral complexes.
3. Filtered runoff is collected in a perforated subdrain and returned to a storm drain system, infiltrated into the subgrade, or discharged to the surface, or storm sewer system.



System Performance

Cost & Maintenance

The cost to install a tree box filter to replace a single catch basin is about $6,000 per system assuming the drainage area is not excessive. Labor and installation costs were $3,000, and materials and plantings were an additional $3,000. This indicates that for a municipality that has both equipment and personnel, the cost for retrofits can be relatively low at $3,000 per system. Treatment efficiencies for nutrients may diminish as the hydraulic loading rate (treatment area to filter area) increases.

Since the installation in 2004, this system has had minimal maintenance. Aside from routine trash removal, the highest maintenance burden is associated with periodic inspection to assure that the bypass and soils are adequately conveying water. Systems with fine media may require more frequent attention due to clogging. However, since most clogging occurs in the top two inches of surface soil, servicing these systems is simple. Long-term maintenance may involve periodic removal (vacuuming) or raking of surface fines similar to that of deep sump catch basins. The system at the UNHSC was maintained in 2008 by removal of the top two inches of surface accumulation. Maintenance was initiated after a noticeable reduction in infiltration and increased incidence of bypass following parking lot sealcoating in the contributing lot. An accumulation of sealcoat fines and flakes caused a noticeable infiltration reduction. This raised the concern that coincidence of filter systems and sealcoating may be problematic long-term.

Trees may need to be replaced, depending on hardiness of the selected species and aggressiveness of the root growth. Adaptations to the design can prevent root constriction in the planting vault.

Cold Climate

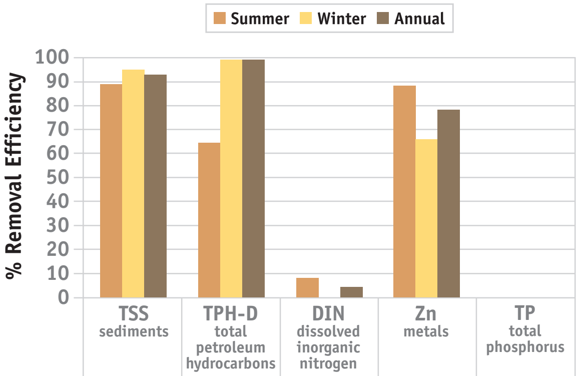
The tree box filter's ability to treat water quality remained relatively stable in all seasons. This is consistent with UNHSC observations of most LID stormwater systems—when they are properly designed and installed, they are not dramatically impacted by seasonal fluctuations. While some seasonal variation in infiltration capacity and nitrogen removal does occur, cold conditions do not seem to warrant significant design alterations.

Water Quality Treatment

The tree box filter does a good job of removing many of the pollutants commonly associated with stormwater treatment performance assessment. It consistently exceeded EPA's recommended level of removal for total suspended solids and meets regional ambient water quality criteria for petroleum products, and total zinc. However, UNHSC research demonstrates that water quality treatment effectiveness can be negatively influenced by an increased hydraulic loading rate, i.e., the filtration of a large surface area by a small filter area. The system does not remove chloride, but does exhibit an ability to dampen chloride peaks.

The chart at top right reflects system performance in removing total suspended solids, total petroleum hydrocarbons, dissolved inorganic nitrogen, total phosphorus, and zinc. Values represent results recorded over four years, with data further divided into summer and winter components.

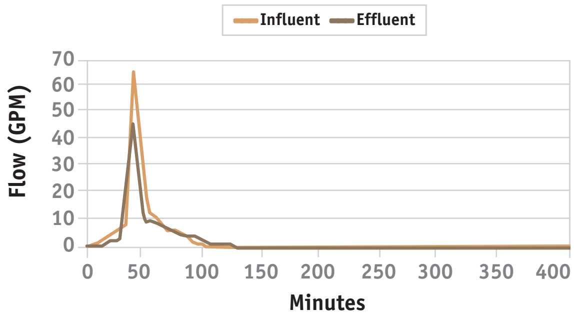
POLLUTANT REMOVAL: 2004–2008



Median Annual Influent Event Mean Concentrations (EMC) in mg/L

TSS	TPH-D	DIN	Zn	TP
37	644 ug/L	.23	.04	.07

HYDRAULIC PERFORMANCE



	Winter	Summer	Annual Average
Average Peak Flow Reduction	NT	NT	NT
Average Lag Time (minutes)	59	66	62

Water Quantity Control

Without additional engineering, the tree box filters do little to reduce peak flows unless sited in appropriate soils, such as those in groups "A" (sand, loamy sand, or sandy loam with high infiltration rates) and "B" (silt loams or loams with moderate infiltration rates). In the figure above, the tree box filter displays no significant peak flow reduction or lag time for the range of seasons monitored.

SYSTEM DESIGN ▼

The tree box filter's basic design is a concrete vault filled with a bioretention soil mix (BSM), planted with vegetation, and underlain with a subdrain. The system evaluated at the UNHSC field site is a six-foot diameter, concrete vault with an internal bypass. It is underlain by a subdrain that discharges to existing stormwater drainage. The vault is open-bottomed to enhance infiltration.

The filter media is three feet deep, and composed of 80 percent sand and 20 percent compost. The mix was designed to maximize permeability while providing enough organic content (~ 10 percent) to sustain vegetation, and maintain a high infiltration rate of 100 feet per day. These systems should use native, drought- and salt-tolerant vegetation. Plants with aggressive root growth may clog the subdrain, and therefore may not be suitable for this type of system.

This tree box filter was sized for the water quality volume (WQ_V), and should allow for four to six inches of ponding. Larger storm events will be bypassed internally through a grate with an equivalent capacity as a catch basin.

StormTech Isolator Row

The StormTech Isolator Row is an effective filtration/infiltration system best suited to locations where space is at a premium and the system's relatively expensive installation cost can be offset by increasing available space for development.

About the StormTech Isolator Row

The StormTech Isolator Row is a manufactured system designed to provide subsurface water quality treatment and easy access for maintenance. It is typically used to remove pollution from runoff before it flows into unlined infiltration chambers designed for detention and water quantity control. The Isolator Row consists of a series of StormTech chambers installed over a layer of woven geotextile, which sits on a crushed stone infiltration bed surrounded with filter fabric. The bed is directly connected to an upstream manhole for maintenance access and large storm bypass. At UNHSC, the Isolator Row has met a TSS median annual removal standard of 80 percent, and exhibited an enhanced capacity to remove phosphorus. The Isolator Row is well suited for urban environments where space is at a premium.

Implementation

The StormTech Isolator Row is part of a class of manufactured, subsurface filtration/infiltration systems that are being used more and more throughout the United States. In general, these systems are best suited to locations where above ground space is at a premium. They are often used in urban areas, where they are located beneath parking lots and other infrastructure. As with any infiltration system, care must be taken when locating these systems near pollution hotspots, or where seasonal high groundwater levels may lead to groundwater contamination. In such cases, if installed, the systems should be lined to prevent infiltration into groundwater, and outfitted with subdrains that discharge to the surface. Designs for the StormTech Isolator Row are available from the manufacturer.

System Performance

Cost & Maintenance

While subsurface HDPE systems such as the Isolator Row tend to be more expensive than conventional stormwater treatments like retention ponds, the costs are ameliorated by the increase in available space for development. The cost to install a StormTech Isolator Row system large enough to treat runoff from one acre of impervious surface was $34,000 in 2006.

In more than two years of operation, the system is at less than 50 percent of its recommended maintenance trigger point. Maintenance should be conducted when the sediment in the chambers reaches approximately three inches in depth according to recommendations from the manufacturer. Sediment accumulation can be monitored through inspection ports. When maintenance is needed, the entire row can be

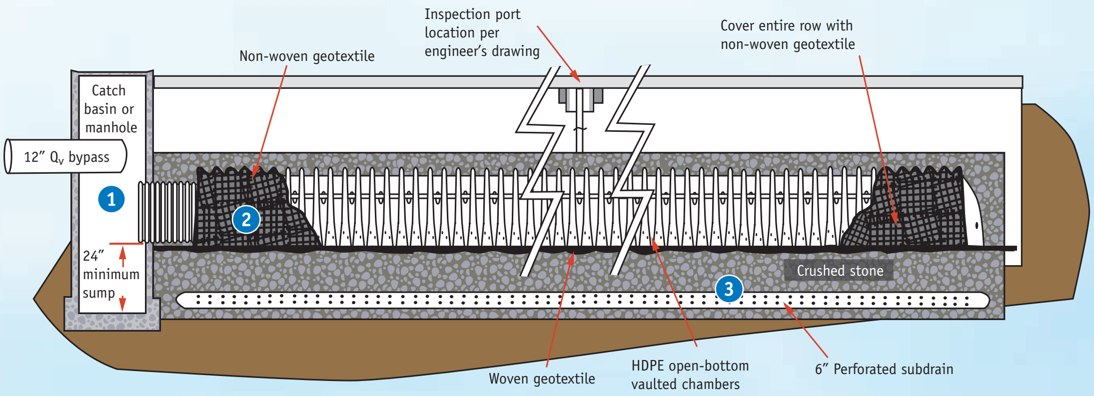
Fast Facts

CATEGORY / BMP TYPE	Filtration, Infiltration, Manufactured Treatment Device
UNIT OPERATIONS & PROCESSES	Hydrologic (Flow Alteration) Water Quality: Physical (Sedimentation, Filtration) & Chemical (Sorption)
DESIGN SOURCE	StormTech, LLC
BASIC DIMENSIONS	Chamber: 51″ wide X 30″ high X 85.4″ long
SPECIFICATIONS	Catchment Area: 1 acre Water Quality Flow: 1 cfs Water Quality Volume: 3,300 cf
INSTALLATION COST	$34,000 per acre treated
MAINTENANCE	Maintenance Sensitivity: Low Inspections: High Sediment Removal: Moderate

How the System Works

WATER QUALITY TREATMENT PROCESS ▼

1. Runoff flows into the Isolator Row chambers from a catchbasin or pipe.
2. Runoff slowly passes from the chambers through a woven geotextile fabric and into the crushed stone reservoir below the system. The runoff passes through the fabric, leaving behind sediments and associated contaminants through the physical unit operations of filtration and sedimentation. As an organic filter cake develops over the fabric, phosphorus is also removed via the chemical process of sorption.
3. Filtered runoff collects in a perforated subdrain and returns to a storm drain system, infiltrates into the subgrade, or is discharged to the surface.



washed clean through an access manhole and by a hydro-jet with sediment removed by vactoring (vacuuming). Entry into the system is considered a confined space entry and requires trained personnel and equipment.

During two years of evaluation at UNHSC, the Isolator Row has accumulated, at most, one and one half inches of sediment in its chambers. As a result, researchers have not performed maintenance on the system. The Isolator Row presents an interesting opportunity to study the relationship between maintenance and performance. Researchers have observed enhanced phosphorus removal as the system develops an organic filter cake between the chambers and the woven geotextile fabric that lies beneath them. This enhancement is tempered by the likelihood that, as the filter cake continues to grow, hydraulic efficiency will decline and more runoff will bypass the system untreated until maintenance is performed. Analyses are underway to develop maintenance recommendations that balance and optimize the water quality and water quantity management abilities of this system.

Cold Climate

This system's water quality treatment and volume control capacity remained strong in all seasons, reinforcing the conclusion that filtration and infiltration systems perform well, even in cold climates.

Water Quality Treatment

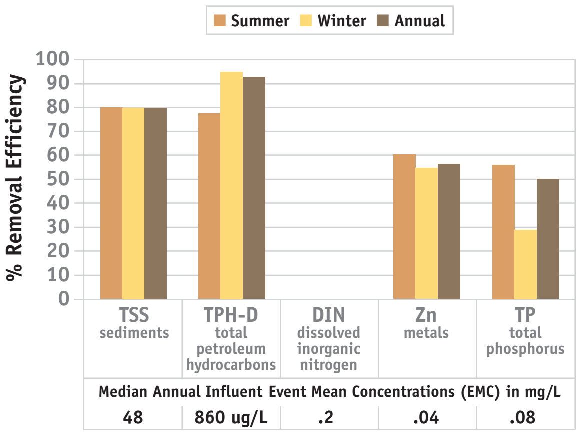
The StormTech Isolator Row system does a good job of reducing the concentration of common pollutants associated with stormwater performance assessment with the exception of nitrogen. It generally meets EPA's recommended level of removal for total suspended solids, and meets regional ambient water quality criteria for heavy metals and petroleum hydrocarbons. The system has a capacity to achieve modest levels of total phosphorus removal, which may be enhanced over time. (See Cost & Maintenance Section.) The lack of nitrogen treatment is typical for non-vegetated aerobic systems. Nutrient load reduction would be further increased through volume reduction by infiltration. Like all other systems monitored at UNHSC, it does not provide chloride removal.

The chart at top right reflects the system's performance in removing total suspended solids, total petroleum hydrocarbons, dissolved inorganic nitrogen, total phosphorus, and zinc. Values represent results recorded over a two-year monitoring period, with the data further divided into summer and winter components.

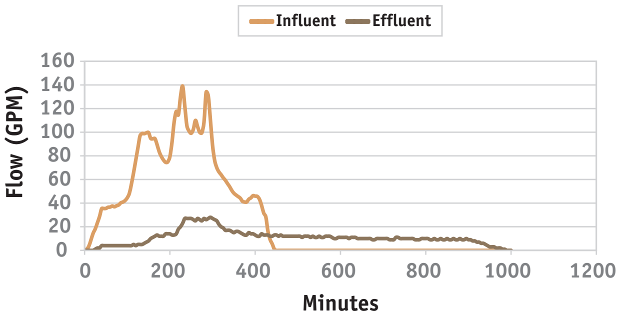
Water Quantity Control

Like other infiltration and filtration systems, the StormTech Isolator Row system exhibits the capacity to reduce peak flows and could be used to reduce runoff volume in appropriate soils, such as those belonging to groups "A" or "B." The figure at bottom right provides information on peak flow reduction and lag times for the system.

POLLUTANT REMOVAL: 2006–2008



HYDRAULIC PERFORMANCE



	Winter	Summer	Annual Average
Average Peak Flow Reduction	71%	81%	76%
Average Lag Time (minutes)	358	190	274

SYSTEM DESIGN ▼

The StormTech Isolator Row is designed to provide subsurface water quality treatment for small storms. The manufacturer adapts the system's design in accordance with local watershed conditions and target treatment objectives.

Chamber units are made of high-density polyethylene (HDPE) pipe and are designed to bear loads consistent with those experienced by parking lots. The UNHSC chamber dimensions are 51 x 30 x 85.4 inches and can be linked together to form linear rows up to 200 feet long. The chambers are laid over woven geotextile, which rests on an infiltration base composed of one foot of three quarter inch crushed stone. The entire excavation is then wrapped in nonwoven geotextile to protect the system from the migration of fine particles from the surrounding soil.

A three- to five-foot separation from seasonal high groundwater table (as designated by regulations) is necessary to minimize the potential for groundwater contamination. Stormwater flows of up to one cubic foot per second (cfs) enter the system through an upstream manhole or other flow diverter. This is representative of flow-based sizing of a BMP common for devices that have limited detention or storage. Such devices are often better described by a maximum treatable flow rate as opposed to a treatment volume.

A bypass is incorporated in the StormTech system where flows exceeding the design rate are bypassed around the device and flow directly into adjacent chambers that can be sized to treat the CP_v and Q_p. Because of the bypass design, maintenance requirements are extremely important. A poorly maintained device would bypass prematurely into the unlined chamber systems and eventually clog subsurface soils resulting in system failure.

Retention Ponds

During the first year of operation, the retention pond at UNHSC was reasonably effective in removing many of the pollutants commonly found in runoff. However, during its second year, researchers observed a reduction in its water quality performance and by the third year a negative removal efficiency indicating a net sediment export.

About Retention Ponds

Retention ponds, or “wet ponds,” are among the most common stormwater treatment systems used today. They are designed to retain a permanent pool of runoff in order to allow for water quality treatment between storms. They are not to be confused with detention basins or dry basins, which detain runoff only for a specified period of time. Retention ponds are typically designed for flood control, but are sometimes retrofitted for water quality treatment through the installation of additional outlets. UNHSC research has found that a lack of maintenance and poorly established vegetation along the wetted perimeter of the basin can lead to in-system erosion and the export of pollutants into receiving waters.

Implementation

Acceptance of retention ponds is widespread; these systems are found in every climate, soil, and development setting. In many areas, they have been the system of choice, a preference likely due to the simplicity of their design.

Yet their use raises some concerns. Standing water can be a drowning hazard, and it can provide habitat for mosquitoes that harbor disease. Retention ponds also may contain excess nutrients, which can lead to harmful algal blooms. In hot weather, ponds can further increase the temperature of already warm parking lot runoff, which negatively impacts aquatic habitats and cold water fisheries.

Finally, and perhaps most importantly for municipalities, these ponds are an inadequate response to federal and state regulations. Meeting the water quality and volume reduction targets set by these regulations requires a more advanced approach to stormwater management—one that moves beyond the standard “pave and pond” and uses instead integrated site designs involving a combination of interception, pretreatment, filtration, detention, or infiltration of runoff.

System Performance

Cost & Maintenance

The cost to install a retention pond system to treat runoff from one acre of impervious surface was $13,500. This does not include maintenance expenditures, which may involve routine inspection, periodic mowing, and sediment removal, as needed.

The perception that ponds require minimal maintenance contributes to their popularity. However, while little maintenance may be required to support their ability to manage peak flow and floods, more frequent attention is critical if they are to maintain effective water quality treatment performance.

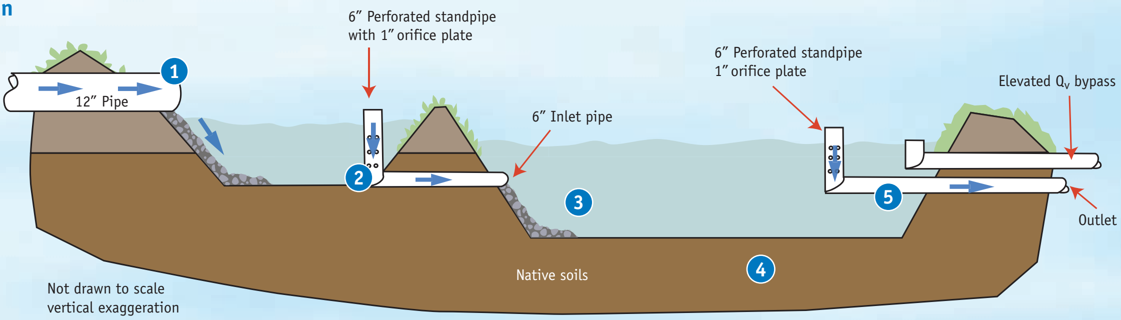
Fast Facts

CATEGORY / BMP TYPE	DESIGN SOURCE	SPECIFICATIONS	MAINTENANCE
Stormwater Pond	New York State Stormwater Management Design Manual	Catchment Area: 1 acre Water Quality Flow: 1 cfs	Maintenance Sensitivity: Low Inspections: Low Sediment Removal: Low
UNIT OPERATIONS & PROCESSES	BASIC DIMENSIONS	INSTALLATION COST	
Hydrologic (Flow Alteration) Water Quality: Physical (Sedimentation) & Biological (Vegetative Uptake)	46 ft X 70 ft	$13,500 per acre treated	

How the System Works

WATER QUALITY TREATMENT PROCESS ▼

1. **Runoff flows into a forebay that removes large objects and allows larger sediment particles to settle.**
2. **The influent exits the forebay through a perforated standpipe and flows into the pond. When forebay capacity is reached, the overflow spills across a weir into the retention pond basin.**
3. **Water quality treatment is a function of storage volume and retention time—larger storage volumes and longer retention times promote better treatment. The removal of TSS, some phosphorus, petroleum hydrocarbons, and metals occurs primarily through sedimentation.**
4. **Several components contribute to biological treatment. Nutrients removal occurs primarily through the activity of macroinvertebrates, microorganisms, and plants. Long-term breakdown of petroleum hydrocarbons that accumulate is through microbial processes. Metals in the sediment may be taken up by the roots of aquatic vegetation.**
5. **A perforated standpipe modified with a one-inch outlet regulates the flow of effluent from the system.**



Not drawn to scale
vertical exaggeration

No maintenance was performed on this system during the three-year monitoring period at UNHSC. In that time, it was observed that the gradual erosion of the wetted perimeter and the re-suspension of benthic sediments in the retention pond lead to the export of sediments and the pollutants they carry. These finding support related research on the subject by Ballestero, et al.

Since sedimentation is the pond's primary unit operation process (UOP), inspections are critical to maintaining performance in sites with heavy sediment loads.

Cold Climate

The system's ability to treat water quality and manage water quantity remained effective during cold winter months. While some variation in both kinds of performance does occur in cold conditions, it does not warrant significant alterations to system design to compensate.

Water Quality Treatment

During the first year of operation, the retention pond was effective in removing many of the pollutants commonly found in runoff. It consistently met EPA's recommended level of removal for total suspended solids, as well as regional, ambient water quality criteria for petroleum products, metals, and nutrients. However, as the graph on the right, second from the bottom illustrates, the pond exhibited a dramatic decline in its ability to treat sediments over the subsequent two years of monitoring.

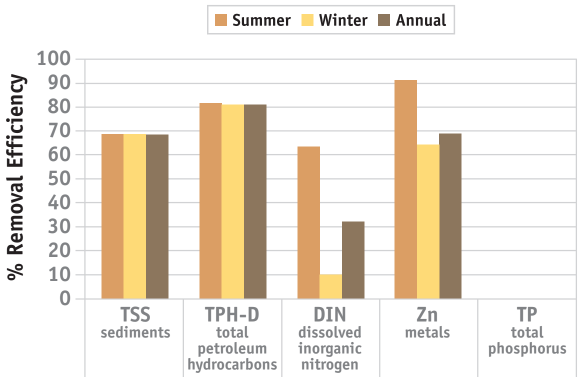
In year two, UNH researchers observed a 26 percent reduction in the pond's TSS median removal efficiency—from 81 percent removal to 55 percent. A 124 percent reduction in year three resulted in a 17 percent net export of sediment. The graph at top right reflects the system's overall water quality performance. Values represent results recorded over a three-year monitoring period, with the data further divided into summer and winter components.

As a major threat to cold water fisheries, the increased temperature of runoff has become a contaminant of concern in many watersheds. During the UNHSC's evaluation of the retention pond, the mean July temperature of runoff leaving the system was 77.9 degrees Fahrenheit—over ten degrees higher than the runoff before it entered the system. The graph at the bottom right shows the increased temperature of parking lot runoff that can be further elevated in retention ponds during summer months. In general UNHSC researchers have observed that larger surface systems will export runoff with greater thermal extremes, both hot and cold. In contrast, the temperature of runoff leaving large subsurface systems is heavily moderated due to the system's greater capacity for thermal buffering.

Water Quantity Control

Retention ponds exhibit a tremendous capacity to reduce peak flows, retain channel protection volume, and provide flood protection. In the second figure from the top on the right, the retention pond demonstrates effective peak flow reduction and long lag times, regardless of season. In general, these systems do nothing to reduce runoff volumes. Research indicates that the extended effluent flows typical of retention ponds negatively impact receiving streams, particularly when increased postdevelopment runoff volumes subjects streams to erosion-causing flows for long periods. This phenomenon is observed in urbanized watersheds, where it leads to stream channel instability and lost ecological value and function.

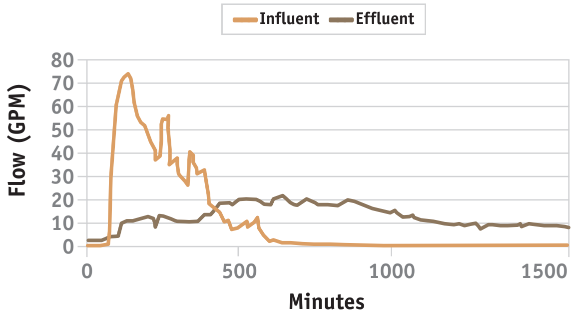
POLLUTANT REMOVAL: 2004–2007



Median Annual Influent Event Mean Concentrations (EMC) in mg/L

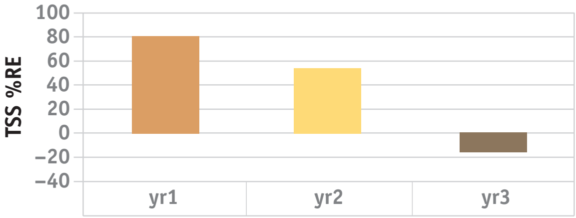
TSS	TPH-D	DIN	Zn	TP
61	711 ug/L	.27	.046	.08

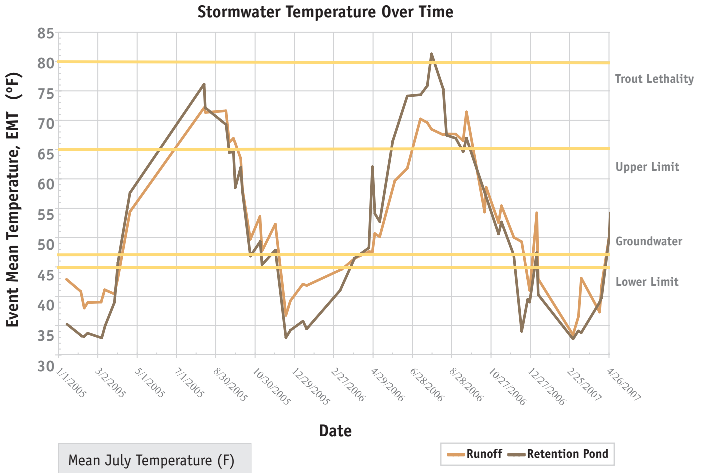
HYDRAULIC PERFORMANCE



	Winter	Summer	Annual Average
Average Peak Flow Reduction	84%	88%	86%
Average Lag Time (minutes)	497	418	455

3-YEAR PERFORMANCE BREAK-DOWN





Mean July Temperature (F)
Runoff = 67.1
Retention Pond = 77.9

SYSTEM DESIGN ▼

Retention ponds are commonly designed to enhance a site's aesthetics and provide habitat. The pond tested by UNHSC was comprised of a sedimentation forebay and a larger basin sized to hold a resident pool of water. It was installed below the water table to maintain this permanent pool of water, and in clay soils, which effectively act as a lining for the system. (In general, these ponds can be designed to be either above or below the groundwater table.)

The pond's side slopes were stabilized with grass, and its spillways with stone and geotextile. Superior designs, not tested here, would stabilize the wetland's entire perimeter with stone and fabric. This research illustrates the importance of stabilization along a wetted perimeter on erodible soils with steep side slopes. Vegetation alone was insufficient to stabilize the soils. In the UNHSC demonstration, this wetland perimeter was the location of the pond's failure where vegetation did not establish and soils were prone to erosion.

The pond was designed to treat the water quality volume and convey up to the 10 year storm event (Q10). The channel protection volumes (CP_v) were conveyed through the system within 24 to 48 hours.

Deep Sump Catch Basins

Deep sump catch basins are standard in many drainage designs but to be used most effectively, care should be taken with respect to their drainage configuration.

About Deep Sump Catch Basins

Deep sump catch basins are a basic component of many stormwater drainage networks. Relatively inexpensive and readily available, they serve the rudimentary function of removing and accumulating coarse sediment from the runoff that flows through the storm drain network. Deep sump catch basins are sized and spaced much like regular catch basin inlets, the difference being that they include a sump—four feet in depth (resevoir)—below the outlet pipe that allows water and sediments to settle temporarily. The configuration of catch basin is likely to influence the observed water quality treatment performance. They are most effective if used in an offline configuration, with individual catch basins all feeding to a central trunkline. Historically, catch basins have been designed in series with cumulative flow draining to each sequential basin. This configuration of basins is susceptible to the re-suspension of sediment in runoff. This configuration is not uncommon as it is more affordable than an offline configuration in which peripheral basins receive flow from only the grated inlet and then feed a central trunkline that drains the watershed area. Generally offline configurations are more expensive as they require more basins and more piping. Affordable retrofits can be made to any deep sump catch basin using hooded outlets to enhance treatment. The effectiveness of such installations will be linked to their configuration.

Implementation

Deep sump catch basins are used throughout the United States. They are standard in any drainage design that provides conveyance beyond sheet flow and allow easy access for routine maintenance. Their use should be limited to offline configurations in which influent (runoff) flows into the basin through an inlet grate above the structure and then through an outlet that connects to the rest of the drainage network.

Online catchbasins are those that may receive influent runoff from multiple locations, including the surface via grated inlets and other catch basins upstream in the drainage network. Online configurations are not suitable for deep sumps and will generally yield poor sediment removal performance as observed by UNHSC. The Center is currently conducting additional studies to evaluate deep sump catch basin performance in an offline configuration.

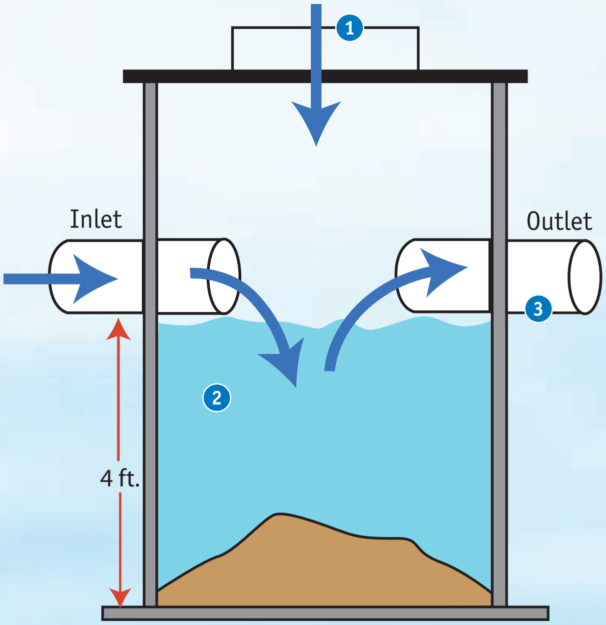
Fast Facts

CATEGORY / BMP TYPE	DESIGN SOURCE	SPECIFICATIONS	INSTALLATION COST
Sedimentation, Conventional Design	Standard State BMP Manual	Catchment Area: 0.3 acre Water Quality Flow: 0.33 cfs Water Quality Volume: 1,100 cf	$1,500 per unit for materials, $1,500 for installation
UNIT OPERATIONS & PROCESSES	**BASIC DIMENSIONS**		**MAINTENANCE**
Water Quality: Physical (Sedimentation)	Diameter: 6 ft Depth: 6 ft Sump: 4 ft		Maintenance Sensitivity: Low Inspections: Low Sediment Removal: Low

How the System Works

WATER QUALITY TREATMENT PROCESS ▼

1. **Runoff flows into the deep sump catch basin from the street and flows or drops into the sump.**
2. **The sump is a 4 feet deep by 6 feet diameter collection area below the outlet pipe. This area allows coarse sediments and trash to drop out of suspension during low flows while allowing flows to continue to a centralized drainage line. Physical settling is the only unit operation employed although other physical process could be employed within the structure such as trash grates, hoods, or filter skirts to enhance performance.**
3. **Runoff continues to a centralized drainage network, or is discharged to surface drainage.**



Deep sump catch basin

System Performance

Cost and Maintenance

Deep sump catch basins are low cost BMPs and generally run around $1,500 per unit with labor and installation requiring an additional $1,500. Inserts or retrofits such as outlet hoods to help detain oil and grease are economical as well-costing roughly an additional $500 per unit.

Typical maintenance of deep sump catch basins includes routine inspection and periodic trash and sediment using a vactor truck. For stormwater pre-treatment effectiveness, deep sump catch basins should be cleaned at least once per year.

No maintenance has been performed on the deep sump catch basin since it was installed in fall 2006.

Cold Climate

Performance of the deep sump catch basin while slightly reduced during the winter season is low year round. As a conveyance structure there are no apparent seasonal limitations for this systems use.

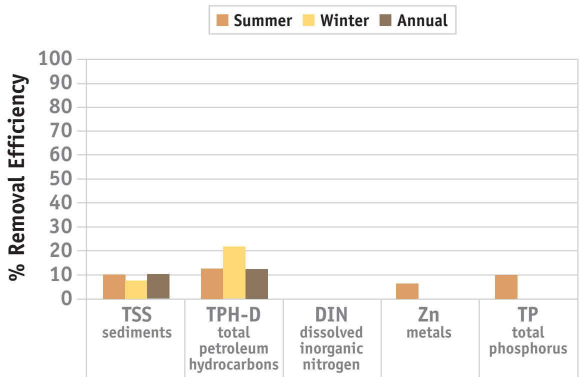
Water Quality Treatment

The deep sump catch basin provides minimal treatment in an online configuration as tested at the UNHSC. The poor treatment performance is due to minimal storage within the basin, and turbulence caused by of high flows resulting in sediment re-suspension. In an offline configuration deep sump catch basins may provide some additional pretreatment of coarse sediments. The chart at the top right reflects online system performance for removing total suspended solids, total petroleum hydrocarbons, dissolved inorganic nitrogen, total phosphorus, and zinc. Values represent results recorded over two years, with data further divided into summer and winter seasons.

Water Quantity Control

Not applicable

POLLUTANT REMOVAL: 2006–2008



Median Annual Influent Event Mean Concentrations (EMC) in mg/L

TSS	TPH-D	DIN	Zn	TP
46	510 ug/L	.2	.04	.08

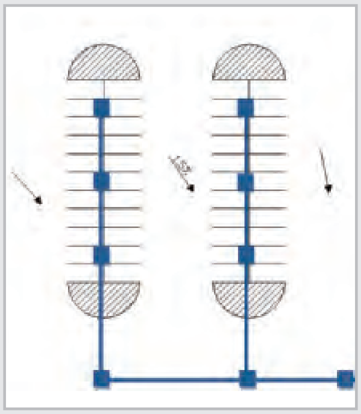
SYSTEM DESIGN ▼

The deep sump catch basin is a very basic design and is available through any precast concrete supply company. The sump may vary in depth from 2 to 4 feet.

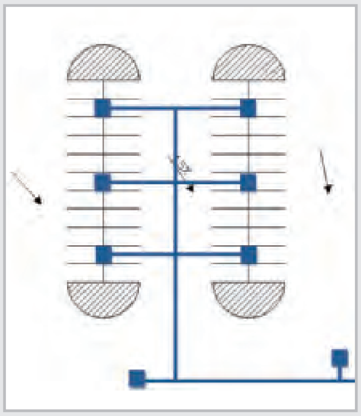
CATCH BASIN CONFIGURATIONS FOR PARKING LOTS ▼

Traditionally, the design of stormwater drainage systems has been focused on the collection and conveyance of stormwater runoff offsite as rapidly and as efficiently as possible. In contrast, LID drainage designs focus on conforming as much as possible to natural drainage patterns and discharging to natural drainage paths or landscape features within the watershed. Catch basins and stormwater drainage networks are efficient flow conveyance structures, yet when water quality treatment and runoff volume reduction are the goals of a stormwater management plan, this may not be an advantage. Where possible, runoff should be allowed to flow across pervious surfaces or through grass channels and buffers.

When it is necessary to design for a curb and gutter drainage network, using an off-line drainage configuration of deep sump catch basins is the most effective for coarse solids removal. Online configurations are the most common designs and consist of catch basins installed in series conveying water from multiple inlets as shown below in the figure on the left. An offline drainage configuration illustrated in the figure below on the right consists of catch basins receiving water from only one inlet (typically a surface grate) and conveying all flow through a single outlet to a central drainage pipe.



Example of an online catch basin configuration. Note: only those catch basins at the top of the network have one inlet. Drawing not to scale.



Example of an offline catch basin configuration. Note: all catch basins have only one inlet and one outlet to the central drainage line. Drawing not to scale.

Filter Berm Swales

About Filter Berm Swales

Stormwater Swales (a.k.a. grassed channel, dry swale, wet swale, stone-lined swale, vegetated swale, etc.) are constructed, open-channel structures primarily used to convey stormwater runoff. Swales are one of the most commonly selected and designed stormwater management systems. Swale designs differ substantially from simple conveyance channels to hybrid designs that incorporate filtration. The most typical vegetated swale, designed simply for conveyance, does not meet EPA water quality standards, especially in cold climates where substantial performance declines are observed in winter months. Because of the widespread usage of swales, and their generally poor water quality treatment, there is a great need for swale retrofits to improve performance. The UNHSC in cooperation with Maine Department of Transportation tested a filter berm retrofit for a vegetated swale. The design was studied to investigate the wide-scale potential for filter berm retrofits along the many miles of state highways as a measure to achieve phosphorus removals of 60 percent currently required by the state of Maine. The filter berm core consisted of a 50:50 mix of 1/2″ crushed stone and wood chips encased within an outer layer of 6-8″ diameter stone. The berm was constructed two feet high at the crest across a 12′ wide vegetated swale channel. The swale was designed to temporarily detain runoff to both enhance settling and more importantly, provide filtration through the filter berm core. At high flows, the berm would be overtopped and the downstream channel would provide simple conveyance.

Implementation

Swales are the most widespread stormwater management measure, and there is a wide range of design variations. Swales are often located along property boundaries or transportation features and are often constructed to the natural grade. They can be used wherever the site provides adequate space and elevation. In general, swales are not used in steep slope areas and ultra urbanized settings due to design and space requirements. Filter berms provide for increased detention time within the swale and would ideally provide additional filtration through the coarse stone and wood chip mix that traverses the flow path. While implementation of filter berm swale systems are not widespread, their importance as a potential retrofit is great.

System Performance

Cost & Maintenance

The cost to install the filter berm retrofit to treat runoff from a one acre parking area was

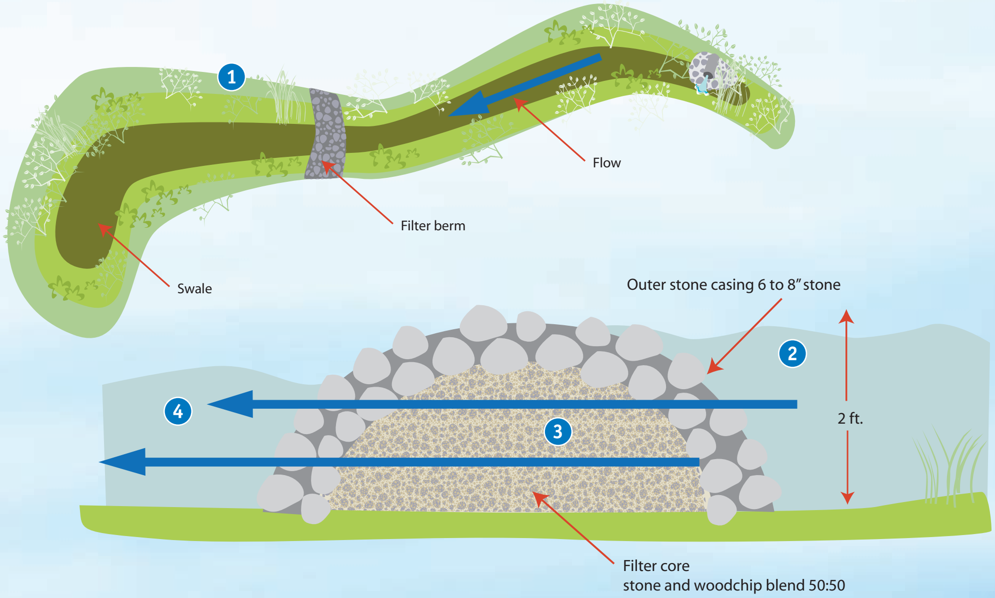
Fast Facts

CATEGORY / BMP TYPE	DESIGN SOURCE	SPECIFICATIONS	MAINTENANCE
Filter Berm Swale **UNIT OPERATIONS & PROCESSES** Water Quality: Physical (Sedimentation) & Chemical (Sorption)	MEDOT, UNHSC **BASIC DIMENSIONS** 2 ft high at crest within 12′ channel, 7.5′ wide longitudinally	Catchment Area: 1 acre Water Quality Flow: 1 cfs **INSTALLATION COST** $2,500	Maintenance Sensitivity: High Inspections: High Sediment Removal: Low

How the System Works

WATER QUALITY TREATMENT PROCESS ▼

1. Runoff flows into and along the swales vegetated channel to the base of the filter berm.
2. Water slowly backs up behind the berm. Water quality performance is a function of channel dimensions, density of vegetation, and detention time behind the berm.
3. Runoff slowly filters through the porous berm where it is cleaned through physical sedimentation and filtration, as well as limited chemical sorption to organic material associated with the wood chips.
4. Water flows through or over the filter berm and directly to a receiving water.



$2,500. This does not include initial vegetated swale installation ($12,000) or maintenance expenditures, which may involve routine inspection and the periodic mowing or removal of collected sediments, as needed.

The filter berm swale failed after a 100-year event in which the swale conveyed a 6.8 cfs peak flow (over 6 times the design flow). The outer stone casing washed off the downward side of the swale exposing the smaller stone core which then eroded rapidly. Prior to this failure, it had largely been concluded that the filter berm was not working effectively primarily due to high maintenance sensitivity. The poor pollutant removal and peak flow performance was immediately noticeable in the fall season from quickly accumulating leaves that resulted in clogging of the berm and subsequent over-topping. Regular removal of leaves and debris was a standard maintenance routine. Another element of failure began a few months after installation when water began to pond routinely for extended periods of time behind the filter berm. Presumably the fines were accumulating within the core of the filter berm and clogging from the bottom up. While the overall cost as a retrofit was very low, the effectiveness of such approaches would only be through high maintenance and inspection intervals, or on sites with no tree cover or lower levels of organic material loading.

Cold Climate

Winter conditions significantly limit this system's ability to treat water quality and quantity. It is likely that the filter berm swale performance would improve seasonally as the bulk of the testing was in the winter months when swales generally do very poorly. The coarse grained filtration combined with settling are typically not strong mechanisms for water quality performance making the filter berm swale most appropriate as a pretreatment device.

SYSTEM DESIGN ▼

Vegetated swales are generally designed with a trapezoidal or parabolic shape. State design criteria specify slopes of typically less than one percent, and flow velocities of less than one foot per second for the 10-year and lower flows. The filter berm itself is a simple structure installed perpendicular to the flow path and designed to increase detention time in the swale and filter a portion of the flow.

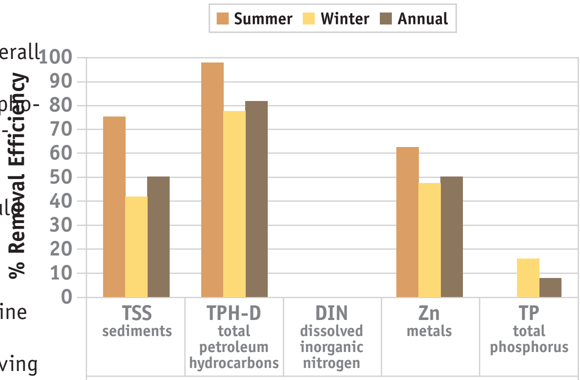
Water Quality Treatment

Ten storm events were monitored from 2006-2007. The filter berm swale provided modest treatment capacity. Surprisingly, overall performance did not vary substantially from a vegetated swale. The phosphorous removal, while improved from a conventional swale, was still very poor. Improved treatment could be expected in locations where infiltration would be possible. The modest performance of the filter berm is consistent with what has been observed from the range of other systems tested at the UNHSC in that filtration with fine grained materials is needed for marked water quality improvements. Unit operations involving filtration with fine grained materials achieve the highest degree of removal.

Water Quantity Control

Typical swale designs exhibit little to no peak flow reduction or lag time. The addition of the filter berm would seem to add lag time compared to the vegetated swale but did not record lower peak flow reductions. These can only be preliminary conclusions as the berm swale dataset was shortened by its failure during a 100-year storm event.

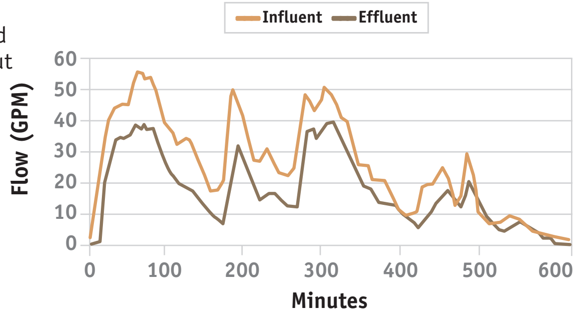
POLLUTANT REMOVAL: 2006–2007



Median Annual Influent Event Mean Concentrations (EMC) in mg/L

TSS	TPH-D	DIN	Zn	TP
51	637 ug/L	.24	.03	.07

HYDRAULIC PERFORMANCE

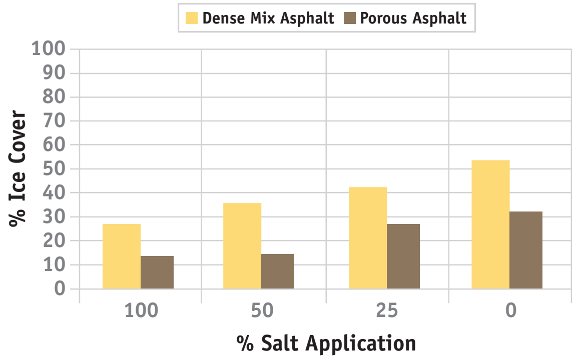


	Winter	Summer	Annual Average
Average Peak Flow Reduction	24%	23%	24%
Average Lag Time (minutes)	46	166	58

In April 2007 the filter berm swale failed after a torrential storm in which the swale conveyed a 6.8 cfs peak flow (more than six times the design flow).

Targeted Research

The University of New Hampshire Stormwater Center conducts targeted research into a range of topics, including how best to overcome the social and economic barriers that inhibit effective stormwater management; how to help decision makers understand the implications of their choices on the greater ecosystem; and how to advance the field of stormwater science so that it can address these needs effectively. In this section, we'll report on three such projects: the winter performance of permeable pavements, pollution loading related to sealcoating, and the total capture of sediments in stormwater samples.



Results from assessment of percent snow and ice cover on a typical dense mix asphalt parking lot and a porous asphalt parking lot adjacent to it. Results indicate equivalent snow and ice reductions on the porous asphalt with 75 percent less salt than conventional asphalt.

Graduate student Kris Houle measures friction resistance on a pavement during winter conditions with a British Pendulum Meter.

Snow and Ice Treatment for Porous Asphalt

There is little question that road salt (sodium chloride) is an effective way to melt snow and ice. Unfortunately, it also degrades water quality and harms aquatic life. Each year, roughly 100 million metric tons of salt are used to deice roads, parking lots, and walkways across the northern hemisphere. The net result? A steady supply of chloride-laden runoff flowing into our surface and groundwaters.

Given that the stormwater solutions available today do not treat salt pollution, it would appear we have to choose between safety and fishable, drinkable water. Fortunately, that's not the case. UNHSC research is showing that the use of permeable pavement parking lots in new and redevelopment projects is a promising watershed-scale strategy that can reduce our dependence on salt for deicing without compromising water quality treatment or water quantity management.

Over the course of two winters and 38 storms, researchers evaluated the performance of the porous asphalt (PA) parking lot and observed solid performance in a northern climate. When plowing was regularly performed, salting was needed only to mitigate icy conditions created by freezing rain or the development of compact snow and ice. Frost depth penetration and freeze thaw temperature cycles did not compromise the lot's safety or structural or hydraulic integrity. It exhibited greater frictional resistance and was cleared of snow and ice faster than the standard (impervious) asphalt tested along side it.

How Much Salt Is Enough?

Standard deicing of impervious pavements calls for three pounds of salt per 1,000 square feet of surface area. UNHSC researchers applied 100, 50, 25, and 0 percent of this standard to the PA lot and an adjacent impervious reference lot during light and heavy snowfalls, sleet, freezing rain, and rain. The salt was applied to dry, wet, snow, slush, compacted-snow, and ice covered pavement in temperatures ranging between – 2 to 40 degrees Fahrenheit. To assess effectiveness, researchers used a weighted number, based on skid resistance (friction) and snow and ice cover, which could be used to rank the relative safety of each level of salt application. They found that the PA generally was safer than the impervious lot when it was treated with as little as 25 percent of the standard application of salt, and sometimes no salt all.

One might ask whether the standard application is excessive for impervious asphalt. However, when researchers decreased the level of salt application from 100 to 0 percent on the impervious asphalt, it demonstrated a 27 percent decrease in friction, while the PA only exhibited a 4 percent decrease. In general no salt was needed to manage black ice formation on the PA lot.

Reducing Snow and Ice Cover

In general, significantly less snow and ice cover accumulated on the PA lot. On the impervious asphalt lot, the median amount of ice cover was at least three times greater than PA, regardless of the amount of salt applied. In fact, there was no statistical difference in snow and ice melt between 100 percent salt application on the impervious lot and no salt on the PA.

Though superior overall, PA did not perform better for all conditions. When the air temperature remained near or below 32 degrees Fahrenheit, freezing rain created icy conditions on both types of pavements. In such cases, the standard application of salt to impervious asphalt results in a brine solution that continues to melt remaining ice. On PA, standing water cannot collect—it drains through—and much less of the brine solution forms. As a result, when there is excessive, compacted snow and ice on PA, there may be a need for thorough, persistent plowing as well as increased salt application. Yet even with increased salt application during conditions like these, researchers applied substantially less salt overall to the PA lot throughout the course of the study.

Sealcoating & Polycyclic Aromatic Hydrocarbons

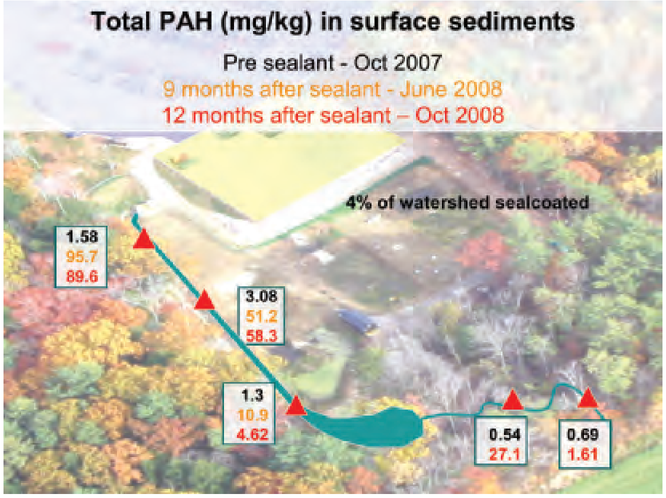
For decades, home and business owners have been sealcoating their driveways and parking lots. While these surfaces may look better with a fresh layer of sealcoat, there is little evidence that suggests sealcoat does anything other than recolor the pavement. Research conducted by UNHSC indicates that sealcoat may contribute to increasingly significant amounts of polycyclic aromatic hydrocarbons entering waterways from stormwater runoff.

Polycyclic aromatic hydrocarbons, more commonly known as PAHs, occur in oil, coal, and tar-based products, and are also produced as byproducts of fuel burning. The EPA considers these products to be carcinogenic and have heavily regulated activities known to be sources of PAHs such as coking operations and coal gasification processes. While the EPA currently regulates the industrial process that produces PAHs, it does not regulate the byproducts provided that they are "recycled" into consumer goods such as coal-tar based sealants.

The UNHSC is studying the impact of parking lot sealcoat on stormwater runoff. Two sections of the UNHSC parking lots were commercially sealcoated in October, 2007. PAH concentrations in stormwater runoff from each of the sealed lots, and from the unsealed main site were measured, as were concentrations in sediment downstream from the site and soil adjacent to the site. This N.H. Sea Grant-funded research confirmed what similar studies conducted by the United States Geological Survey (USGS) in Texas found: that total PAH loads washed off parking lots could be reduced significantly if parking lots remain unsealed. According to UNHSC Senior Scientist Tom Ballestero, "Our society has been sealcoating pavement for decades and there are things we've never asked about; now we're starting to probe and ask these questions." Ballestero and Research Professor Alison Watts have been studying the sealcoat environmental transport.

Although it is intended to remain on the pavement surface, UNHSC researchers found that much of the sealcoat flakes and then washes off during storm events, ending up in nearby streams and stormwater treatment devices. In the figure below, UNHSC field data shows that just nine months after sealing only 4 percent of the entire parking lot area, PAH levels increased in the swale receiving runoff from the entire lot to 95.7 mg/kg, double the regulatory limit of 44.7 mg/kg.

This is significant in that a very small proportion of the watershed was sealcoated yet resulted in such a quick and substantial increase of PAHs in the stormwater treatment system.



Sediment samples were collected before and after sealcoating in the swale. Results show PAH concentration to 95.7 mg/kg, which exceeds the NOAA Effects Range Median for sediments (44.7 mg/kg).

First flush samples taken from a storm after sealcoating. The sample on the left was taken from a parking lot recently sealcoated while the sample to the right was taken from an unsealed reference lot during the same event.

Dr. Alison Watts overseas sealcoating operations of the study area.

Stormwater captured during the first flush of a storm event awaits processing.

Sediment Concentration Monitoring: Total Capture Experiment

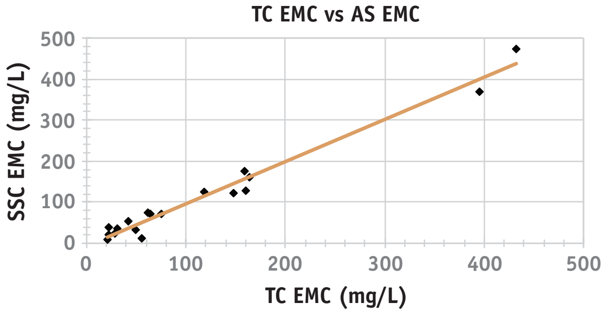
When monitoring stormwater runoff, automated samplers are widely used in replace of grab samples to ensure representative sample coverage throughout a storm. Auto-samplers have been widely used for stormwater and outfall sampling as they limit the number of personnel and the amount of time necessary for would-be storm chasers to grab representative samples. Some research has suggested that auto-samplers commonly used may impart biases on sediment sampling due to their perceived inability to pick up the coarser solids. The implications are significant considering the ever-increasing wet-weather monitoring requirements for stormwater BMPs, sediment and erosion control practices, and Federal National Pollutant Discharge Elimination System (NPDES) permit requirements.

A field study was conducted by UNHSC researchers to assess potential biases of total suspended solids (TSS) and suspended sediment concentration (SSC) analyses from samples obtained by auto-sampler in comparison with actual sediment concentrations from whole volume sampling. Whole volume sampling captures all water and sediment runoff during an event. The study used Teledyne Isco auto-samplers with model 6712 control heads utilizing peristaltic pumps capable of 13.0 ft of suction head and able to deliver samples above the EPA-recommended velocity of 2 ft/sec through a 3/8″ inside diameter vinyl tubing.

Whole volume samples (~4,000 gallon) were collected for eighteen storm events over the course of two years and monitored for concentration and particle size. Concurrently, flow weighted grab samples were obtained by auto-samplers throughout the entire whole volume sampling period. Sediments in the whole volume samples were settled and the excess water decanted and ultimately reduced to an actual mass of total solids that could be weighed and analyzed for particle size. Samples taken by auto-samplers were shipped to an EPA-certified laboratory to be analyzed for TSS, SSC, and particle size using laser diffraction.

This sampling methodology allowed for the direct comparison of sediments collected from a "whole storm" sample with that of "sub-samples" obtained by an auto-sampler. TSS, SSC, and particle size distributions were compared for the two respective field sampling methods. SSC and whole volume results were nearly identical for median sediment EMCs (R2=.9801, n=18), with large volume sampling suspended sediment concentration =69.0 mg/L and by auto-sampler 70.1 mg/L. Median TSS values were 53.0 mg/L. In general the TSS measurements by auto-sampler were lower than the SSC values. The discrepancy between the two values seems to increase as the value of SSC increases.

Results include the following: 1.) Monitoring of sediment event mean concentration and particle size distribution in parking lot runoff by auto-samplers can be representative when using SSC measurements; 2.) SSC is an excellent predictor of sediment concentration while TSS is dependent on a range of factors; 3.) Auto-samplers can adequately monitor stormwater suspended sediment concentration; 4.) The auto-samplers will under-sample larger particle sizes (> 2 mm), but this should not be problematic for the sediment particle size distribution for "normal" stormwater runoff.



Correlation between Sediment Concentration by Total Capture (TC) Versus SSC by Auto-Sampler

Graduate Student George Fowler begins the process of reducing sediments captured during a storm down to its actual mass.

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Joel Ballestero
Kyle Bastien
Trevor Branch
Darlene Brown
Heather Gilbert
Ethan Giles
Angela Gong
Eric Hadley
John Heaney
Jack Jackson
Eliot Jones
Matt Shump
Greg Sine
Federico Uribe
Kent Walker
Allison Wasiewski
Megan Wengrove

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DEDICATED TO THE PROTECTION OF
WATER RESOURCES THROUGH EFFECTIVE
STORMWATER MANAGEMENT

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