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Public information digests in support of the UNH Stormwater Center and the NH Stormwater Commission

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Final Report

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Problem

New Hampshire faces a host of water resource-related issues, including flooding, drought, non-point source pollution, lake eutrophication, erosion and sedimentation, and perhaps even climate change. Each of these issues (and more) are associated with environmental consequences and management responses (or lack thereof) related to stormwater runoff. New Hampshire is late in addressing stormwater in relation to other states as a number of northeastern states already have new stormwater laws in place, whereas New Hampshire is only now formally addressing a number of the issues in the legislature's Stormwater Commission.

There is a critical need for the public, municipal officials, and policy makers to understand the scope of this issue, and to devise broadly acceptable management solutions to reduce impacts of stormwater runoff. Finding information to educate this audience is elusive, because translation from scientific research for the lay person is sparse for this topic. Information in New Hampshire is so limited that the New Hampshire Department of Environmental Services, (NHDES) distributes copies of a stormwater Digest from Maine (Morse and Kahl, 2003) in its public information sessions on protecting water quality.

Objectives

The objective of this project was to develop and publish two Information Digests for a lay audience on stormwater topics. Fortunately resources existed to prepare additional documents totaling 6 digests in all. The intent of this outreach product was to transform existing technical research information into a publication that is readily usable and to provide it to those parties involved in everyday decision-making, with particular emphasis on the target audience of municipal decision makers.

Methods

Information from other outreach documents and from research (including research results and best management practice (BMP) solutions from the University of New Hampshire Stormwater Center (UNHSC)) was assessed and streamlined for the target audience. The authors used their experience with the Stormwater Commission, and from interactions with other municipalities through the UNHSC to address common issues and misunderstandings of the target audience.

The outline of each Digest generally follows the format of a) overview, b) social need, c) impacts, d) technical solutions, and e) policy or management options. Each document is approximately 2-8 pages pages long and was intentionally kept simple, short, and non-academic to reach as broad an audience as possible. Drafts of each document were prepared in text with images and concepts for review. When finalized, the files were provided to a graphic designer for final preparation.

These documents were developed for both print distribution and electronic distribution and will be made available through the Stormwater Center website which currently hosts a wide range of resources. To reach a broad audience of citizens, legislators, municipal officials, lay board members, and public works staff will require distribution of hard copies. Each document was also formatted for PDF and HTML availability via email and the internet.

Major findings and significance

Creative management and effective new legislation/policy for stormwater in New Hampshire is needed and public education on stormwater in New Hampshire has been minimal to date. The information transfer documents created by this project will educate the public by translating some of the technical research conducted by the UNHSC that have direct relevance to current stormwater management issues. We expect that these documents will be the first of a series of public educational Digests oriented toward environmental solutions from the Stormwater Center as the mission of the UNHSC is to advance effective stormwater management through research-based outreach education.

This project will also serve a vital information technology role for the legislature's Stormwater Commission, which is staffed by the NHDES. We expect that NHDES will post the documents on their website, as will the New Hampshire Lakes Association. The documents will be made available to other governmental and non-governmental organizations as well. This expansion will permit a broader reach of the UNHSC to inform state and local land use decision makers in the New England region and beyond.

Publications, presentations, awards

The following Fact Sheets were developed as part of this project:

1. Stormwater Commission Summary
2. Winter Maintenance
3. Thermal Impacts of Stormwater BMPs
4. Greenland Meadows LID Case Study: Economics
5. Greenland Meadows LID Case Study: Water Quality
6. Boulder Hills LID Case Study: Economics

The fact sheets are listed in Appendix A.

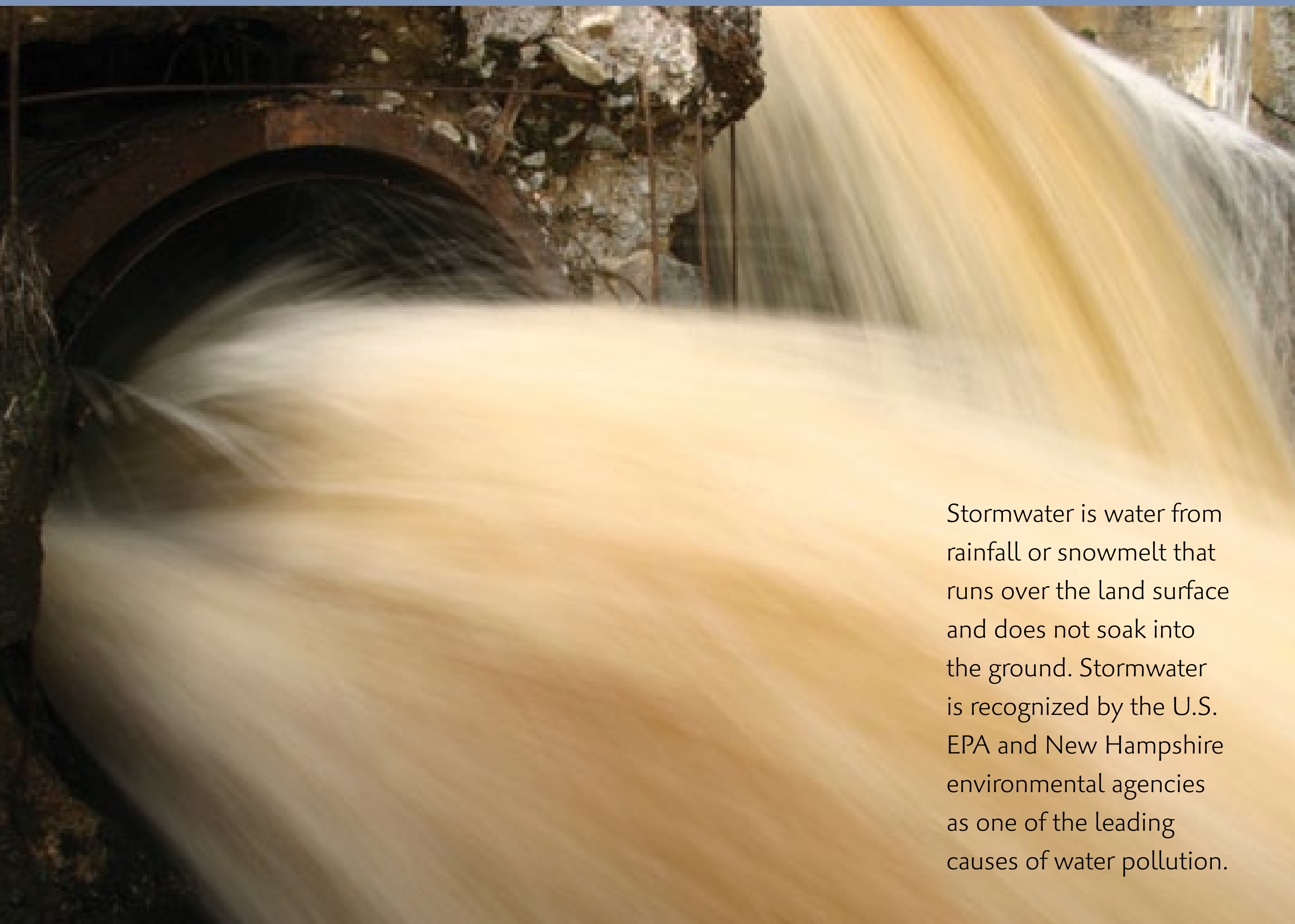
Outreach or Information Transferred

These documents have been developed for both print distribution and electronic distribution. The documents are available through the Stormwater Center website which currently hosts a wide range of resources (http://www.unh.edu/unhsc/specs-and-fact-sheets-0). To reach a broad audience of citizens, legislators, municipal officials, lay board members, and public works staff will require distribution of hard copies. Each document was formatted for PDF and available via the internet.

Appendix A: Fact Sheets

1. Stormwater Commission Summary
2. Winter Maintenance
3. Thermal Impacts of Stormwater BMPs
4. Greenland Meadows LID Case Study: Economics
5. Greenland Meadows LID Case Study: Water Quality
6. Boulder Hills LID Case Study: Economics

SUMMARY BRIEF
NH Stormwater Commission Final Report



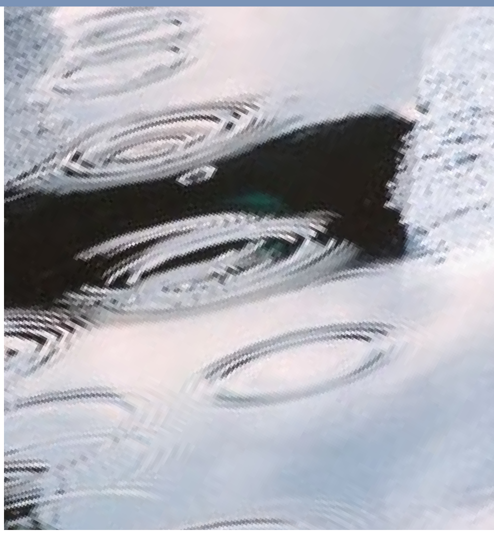
Stormwater is water from rainfall or snowmelt that runs over the land surface and does not soak into the ground. Stormwater is recognized by the U.S. EPA and New Hampshire environmental agencies as one of the leading causes of water pollution.

This document summarizes the major points from the Stormwater Study Commission November 2010 Final Report. The New Hampshire legislature established the Stormwater Commission in 2008 to identify issues and find solutions to reduce impacts from stormwater runoff. This Summary Brief is a non-technical overview intended for the legislature and other public officials.

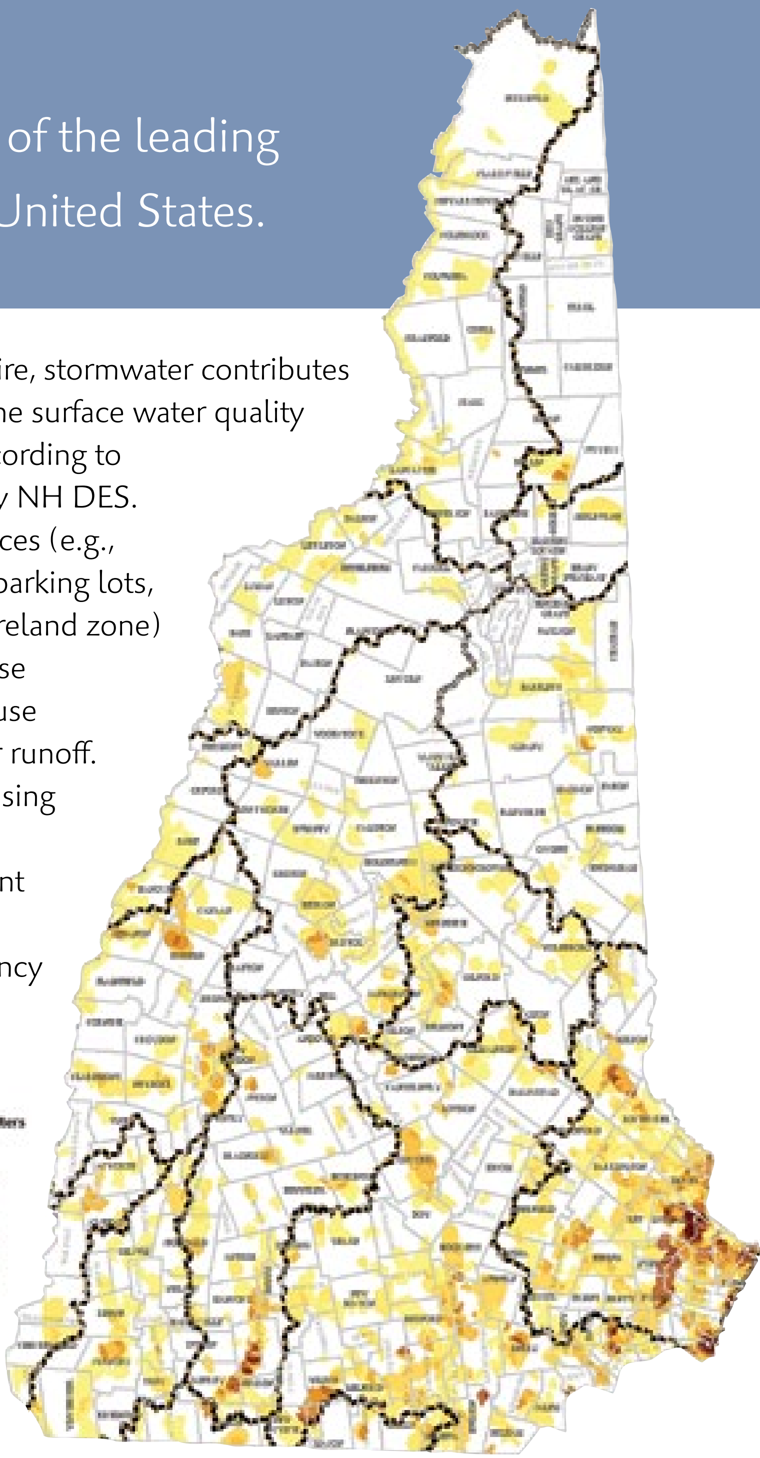
The full commission report can be found at www.nh.gov/oep/legislation/2008/hb1295/index.htm

OVERVIEW

Stormwater is recognized as one of the leading causes of water pollution in the United States.



In New Hampshire, stormwater contributes to over 80% of the surface water quality impairments, according to data compiled by NH DES. Impervious surfaces (e.g., roads, rooftops, parking lots, lawns in the shoreland zone) and other land use development cause most stormwater runoff. Moreover, increasing imperviousness from development contributes to increased frequency and magnitude of flooding.



2010 surface water impairments related to stormwater with 1-mile buffer (NHDES, 2010).

Recent flooding in New Hampshire, exacerbated by imperviousness, has resulted in a tragic loss of life and millions of dollars of damage to our road and highway systems, private residences, and business properties. New regulations and action is needed on a state level in preference to and advance of new Federal regulations.

The full commission report can be found at www.nh.gov/oep/legislation/2008/hb1295/index.htm

COSTS OF STORMWATER

A preliminary estimate of the capital costs to properly manage stormwater in New Hampshire is more than $180 million. The estimate was widely acknowledged by the commission to be low. While the monetary cost of managing stormwater is high, **the potential cost of inaction is even higher.**

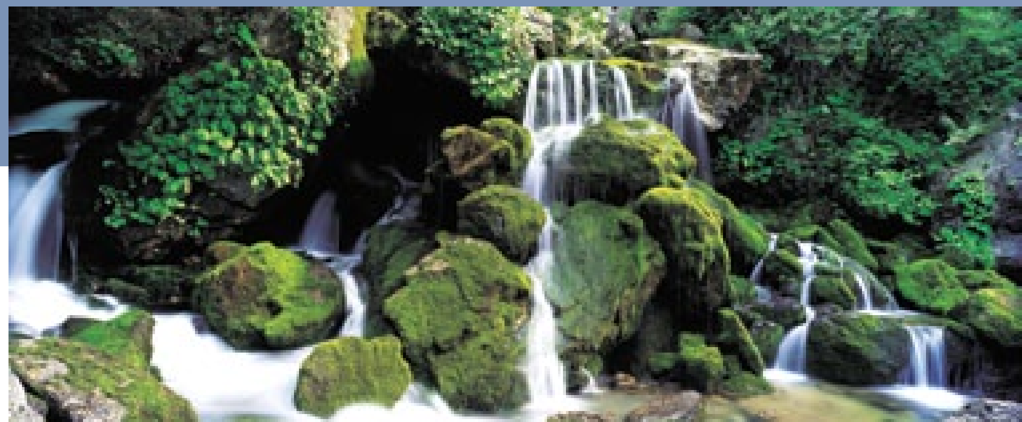
Without significantly changing our approach to managing stormwater, New Hampshire will likely experience even more extensive flooding and degradation of water resources that will impact drinking water quality, aquatic habitat, recreational opportunities, and tourism.

In consideration of these issues, the Stormwater Study Commission was tasked with examining the following issues related to stormwater:

- The effect of stormwater and stormwater management on water quality, water supply and quantity, terrestrial and aquatic habitat, flooding, and drought hazards
- The relationship between land use change and stormwater
- The relationships among and adequacy of federal, state, and local regulations and practices that pertain to stormwater management
- State and municipal infrastructure construction and maintenance practices
- The role of design, construction, and maintenance practices by residential, commercial, and industrial property owners
- The effects of climate change on stormwater and stormwater management

The full commission report can be found at www.nh.gov/oep/legislation/2008/hb1295/index.htm

THE STORMWATER PROBLEM



In contrast to a forested landscape, which infiltrates and naturally filters most precipitation and snowmelt, impervious surfaces in a watershed prevent water from soaking into the ground.

This overland flow is stormwater, which becomes polluted when it causes erosion and picks up contaminants such as nutrients and pesticides.

Even aside from pollution issues, the volume of storm-water runoff alone causes erosion and often warms surface waters, degrading aquatic habitats and damaging fisheries. Left untreated, stormwater can severely degrade the water quality of New Hampshire's waters.

Population growth and traditional development practices typically create more impervious surfaces, and in the next 20 years New Hampshire is projected to add about 180,000 new residents. Without adequately addressing the existing statewide stormwater problems and preparing for growth through improved planning and improved stormwater management strategies, additional degradation of the State's water resources from stormwater pollution will occur.

Compounding these problems are the potential impacts of climate change, which are predicted to bring about increasing rainfall, made worse by increased development and the risk of flooding.

To adapt to these changes and to protect our water resources, the Commission recommends a number of changes to the way stormwater is managed and land is developed in New Hampshire. A watershed-based strategy that distributes the responsibility and cost of stormwater management is essential to restoring and protecting the State's water resources, drinking water supplies, aquatic habitat, and recreational opportunities. Also essential is a shift away from traditional landscape development and stormwater management practices to a low impact development (LID) approach. LID is a development and stormwater management approach that focuses on controlling stormwater through better site planning, good housekeeping, and the use of small, decentralized stormwater treatment practices such as rain gardens, vegetated swales, green roofs, and porous pavement to treat stormwater close to the source.

The full commission report can be found at www.nh.gov/oep/legislation/2008/hb1295/index.htm

ECONOMIC ADVANTAGES OF LID

Municipalities and developers are realizing economic benefits by incorporating Low Impact Development (LID) strategies.

LID strategies, including 'green infrastructure', infiltrate stormwater back into the ground instead of allowing stormwater to run over the land surface. On a national level, substantive economic benefits for commercial development and municipal infrastructure projects are increasingly being observed when using a combination of conventional and green infrastructure for stormwater management. New York, Philadelphia, Chicago, Kansas City, and Portland, Oregon, as well as other major cities, are using green infrastructure tools as a cost-effective means of managing stormwater runoff, in addition to providing aesthetic benefits to their communities.

Green infrastructure is often viewed as more expensive. However, costs savings are frequently realized because expensive traditional infrastructural elements can be reduced or eliminated.


rain gardens


porous pavement


bioretention systems

Green infrastructure is often viewed as more expensive. However, cost savings are frequently realized because expensive traditional infrastructural elements, such as curbing, catch-basins, piping, ponds, and other hydraulic controls, can be reduced or eliminated. Other economic benefits include land development savings because projects require less land disturbance, a reduction in home cooling from use of natural vegetation and reduced pavement area, and higher property values. Increasing use of LID strategies will reduce the cost of development and managing stormwater as the markets develop for these products and methods.

The economic benefits of incorporating LID strategies were shown in two particular case studies in New Hampshire. These projects included a commercial and a residential development, each of which resulted in savings of 6% to 26% over the cost of permitting and construction using conventional designs, in addition to substantial environmental benefits.

The full commission report can be found at www.nh.gov/oep/legislation/2008/hb1295/index.htm

RECOMMENDATIONS

Based on research over two years of study, the Commission developed a set of recommendations, draft legislation, and findings. While the Commission recognizes the broader implications of current economic conditions, it feels that its report recommendations are necessary for improving New Hampshire's stormwater infrastructure and water quality statewide, and funding the proposed implementation process. The Commission's recommendations include the following:

1 Define the Term "Stormwater" in State Law

Add a definition of stormwater in state law to clarify that stormwater is not sewage or waste. Expand upon and make the stormwater definition consistent with the federal definition of 40 CFR 122.26(b)(13):

"Stormwater means stormwater runoff, snow melt runoff, and surface runoff and drainage."

2 Property Owner's Responsibility for Stormwater

Include the concept in state statute that property owners are responsible for stormwater that originates on and discharges from their property and that such stormwater discharges shall not cause or contribute to a violation of water quality standards.

3 Statewide Stormwater Utility Program

Create a statewide stormwater utility program to:

1. raise revenue for stormwater best management practices ("BMPs") construction and management, and
2. create incentives, through the utility fee structure, for property owners to install and maintain stormwater BMPs. This approach eliminates the unfunded mandate problem, and charges only those responsible for stormwater runoff, rather than imposing a broad-based tax to solve the problem.

The full commission report can be found at www.nh.gov/oep/legislation/2008/hb1295/index.htm

RECOMMENDATIONS

3 Statewide Stormwater Utility Program (continued)

The Commission agrees that a statewide, watershed-based stormwater utility is the best way to achieve the successful implementation of stormwater management to meet water quality standards and to provide a consistent and dedicated revenue stream for a stormwater program to be viable and self-supporting. The goal of this program would include covering the entire state of New Hampshire under a statewide stormwater utility, or groups of individual municipal or regional utilities. Individual municipalities would have three options:

Option 1: Create a municipal stormwater utility with incentives.

Option 2: Join an inter-municipal stormwater utility district.

Option 3: In lieu of **1** or **2**, a municipality would automatically become part of a state-administered watershed utility.

A new state-administered stormwater mitigation fund (SMF) would also be created from an impact fee on new and redevelopment projects greater than 10,000 square feet which do not meet State requirements. The SMF should include incentives for developers to promote LID land use planning and development, and would reinforce the connection between stormwater, land use, impervious coverage, and stormwater-related impacts, such as pollution and flooding. Incentives would have a fee structure based on percent impervious cover for both new and redevelopment.

3A Statewide Stormwater Discharge Permit

In the absence of a statewide stormwater utility, NHDES should create a fee-based statewide stormwater discharge permit for all developed properties in the state. A statewide permit program would establish statewide requirements for mitigating potential adverse impacts to water quality from stormwater and the implementation of BMPs to control stormwater from developed areas. The Commission recommends the statewide stormwater utility option over the statewide stormwater discharge permit option because it is incentives-based and has greater flexibility with respect to fee reduction and environmental protection.

The full commission report can be found at
www.nh.gov/oep/legislation/2008/hb1295/index.htm

RECOMMENDATIONS

4 Municipal Authority to Regulate Stormwater

Clearly enable municipalities to regulate stormwater within their boundaries, including operation and maintenance aspects currently not authorized by enabling legislation for municipal land use planning and regulation. The Commission believes municipalities should be authorized to regulate stormwater, particularly small MS4 municipalities, so they can comply with the EPA's NPDES stormwater general permit requirements without fear of exceeding their jurisdiction under state statute.

5 Other Issues

The Commission concluded some additional issues in regards to a Municipal Authority to Regulate Stormwater include:

- Municipalities should be given authority to regulate stormwater originating from properties within their boundaries, even when not specifically initiated by or associated with zoning/land use approval process.
- Requirements placed upon property owners by municipal stormwater regulations should be identical, or at least very similar from one municipality to another to avoid a patchwork of different regulations and to promote watershed protection.
- Minimum performance standards for construction and maintenance of BMPs and stormwater management regulations should be developed by NHDES for adoption by municipalities.

The full commission report can be found at www.nh.gov/oep/legislation/2008/hb1295/index.htm

UNIVERSITY OF NEW HAMPSHIRE
STORMWATER CENTER

Road Salt: Problems and Solutions

THE PROBLEM:

The use of road salt is having a significant negative impact on the environment, on human health, and on local economies.

Each year, communities in colder regions use large amounts of road salt. Following its application, road salt percolates into the surrounding landscape, infiltrating soils and waters. This can cause a number of potentially harmful impacts.

Environmental

In addition to damaging trees and vegetation along roadways, excessive road salt use is linked to increased levels of chloride in surface and ground waters. Elevated chloride can inhibit plant growth, impair reproduction, and reduce the diversity of organisms in streams (USGS, 2009).

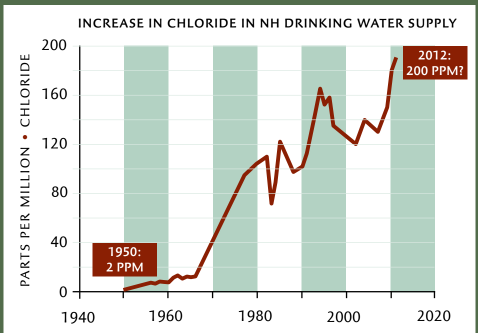
Human Health

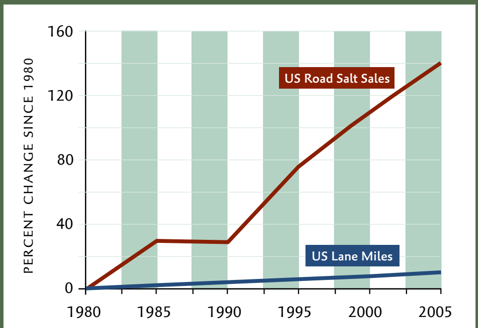
Road salt usage can contaminate our drinking water supplies with high levels of sodium and chloride. Traditionally, typical chloride background concentrations in New England high elevation lakes and unpolluted groundwater wells have been recorded between 1 to 10 parts per million (mg/L). Today it is not uncommon to find chloride concentrations in lakes, streams, and groundwater above the EPA drinking water limit of 250 mg/L.

Economic

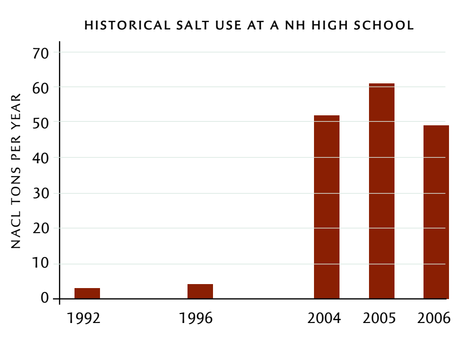
Water quality degradation in our lakes, rivers, and streams can negatively affect recreational and tourism revenue as well as decrease property values. Some New England cities even face federally-imposed development moratoria because of violations of water quality standards due to high salt concentrations in local streams. In addition, the escalating cost of road salt has had a financial impact on local and state budgets.

Compounding these concerns is the fact that nationally, road salt usage has increased considerably in recent years. The use of salt at a local high school (left) is typical of increases in local salt application over the past two decades.





US DOT Salt Institute



Sassan and Kahl, 2007

This document was prepared by the NH Water Resources Research Center, 2011 by Steve Kahl, Dari Sassan, and Robert Roseen.

Want to learn more?

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UNH Stormwater Center, a research resource for innovative methods to control stormwater and its impacts. **www.unh.edu/unhsc**

US DOT Salt Institute. U.S. annual salt sales. **www.saltinstitute.org**

THE SOLUTION:

Use common sense methods to reduce salt pollution.

SOLUTION #1

Reduce the application rates of salt.

Communities can use less salt and still meet public safety requirements. For example, research in Minnesota and Canada has demonstrated that salt use can be lowered by up to 50% without a reduction in public safety.

Alternative de-icers are available, but these solutions are much more expensive and also cause a host of environmental impacts. Instead, communities should recognize that salt is a contaminant of concern while focusing on reducing the need for de-icers of any kind.

Widely-available technology such as ground-speed-controlled spreaders, underbelly plows, and GPS-equipped trucks can prevent over-use of salt, as can simple measures such as sweeping snow instead of plowing.

SOLUTION #2

Reduce the need for salt.

If water didn't pond and freeze on roads and sidewalks, there would be no need for salt application. Therefore, the use of landscape designs and paving materials that work to infiltrate water will greatly decrease the need for salting.

Research at UNH has shown that 75% reductions in road salt are possible using porous pavements, including porous concrete and asphalt. By using these materials, water that would otherwise freeze on the surface is instead infiltrated to the soil.

Porous asphalt after spring rain on snow event.

THIS FACTSHEET PRODUCED WITH SUPPORT FROM WRRC

April 2011

UNIVERSITY OF NEW HAMPSHIRE
STORMWATER CENTER

Examination of Thermal Impacts from Stormwater BMPs

In a study in Durham, New Hampshire, four years of runoff temperature data were examined for a range of stormwater best management practices (BMPs) in relation to established environmental indicators.

The stormwater BMPs examined included:

Conventional

- Vegetated Swale
- Detention Pond
- Retention Pond

Low Impact Development

- Bioretention
- Gravel Wetland

Manufactured Treatment Devices

- Storm Tech Isolator Row
- ADS Infiltration System
- Hydrodynamic Separator

Surface systems that are exposed to direct sunlight have been shown to increase already elevated summer runoff temperatures, while systems that provide treatment by infiltration and filtration can moderate runoff temperatures by thermal exchange with cool subsurface materials.

The storm drain system in this study had an annual average event mean temperature (EMT) greater than the mean groundwater temperature of 47^{o}F that commonly feeds coldwater streams.

The examination of BMPs indicates that outflow from the larger surface systems is warmer and more variable than from parking lots. The filtration and infiltration systems cooled stormwater runoff to temperatures close to groundwater temperature.

Top: A view of a healthy coldwater fishery. Center: Large parking areas store tremendous amounts of heat which is transferred into stormwater runoff. Bottom: Subsurface treatment systems such as gravel wetlands can buffer temperature impacts for stormwater runoff.

The full report can be found at www.unh.edu/unhsc/thermal-impacts.

SURFACE SYSTEMS:
Thermal Extremes

The summer temperatures of the two stormwater ponds, vegetated swale, and HDS (Hydrodynamic Separators) systems, indicate that they **provide little to no reduction of high runoff temperatures.**

The Retention and Detention ponds have the largest variation in temperature. The Retention Pond is the only system to exceed both the Upper Optimum Limit (UOL) and the Lethal Limit of 80ºF, however, the Detention Pond with a maximum temperature of 79.4ºF comes very close.

The permanent pool of water in the Retention Pond appears to act as a heat sink during periods of extreme heat.

FILTRATION & INFILTRATION SYSTEMS:
Thermal Buffers

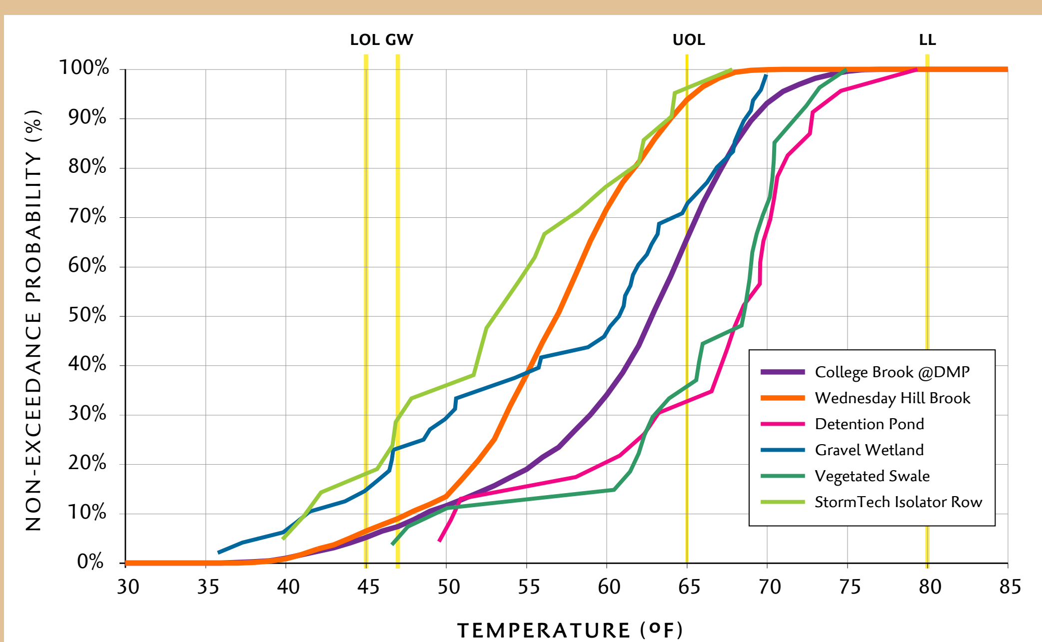
Filtration and infiltration systems **showed the strongest ability to reduce temperature variations.** The gravel wetland, the ADS (Advanced Drainage Systems™) Infiltration System, and the StormTech Isolator Row have a strong capacity to reduce temperatures of runoff.

StormTech Isolator Row.

The Bioretention system showed minor buffering capacity and was consistently cooler in the summer and warmer in the winter than the runoff. These filtration and infiltration systems are, on average, reducing the summer temperatures and increasing the winter temperatures of the runoff to near the average groundwater temperature of 47ºF.

The two subsurface infiltration systems, ADS and STIR, are the only systems with mean July temperatures within the optimum zone of 45ºF to 65ºF for coldwater aquatic species. All other systems result in runoff within the stress zone for aquatic species, between 65ºF and 80ºF.

The Gravel Wetland, the ADS infiltration system, and the Isolator Row systems have the lowest exceedance values of the UOL at 13.0%, 5.0%, 1.5% respectively.



Comparison of summer temperatures for two streams: Wednesday Hill Brook (unimpacted) and College Brook (impacted); a wet and dry pond, a gravel wetland, and subsurface infiltration (Stormtech Isolator Row) with environmental indicators for cold water fisheries:

Average Annual Groundwater Temperature (GW) = 47ºF

Lower Optimum Limit (LOL) = 45ºF

Upper Optimum Limit (UOL) = 65ºF

Lethal Limit (LL) = 80ºF

THIS FACTSHEET PRODUCED
WITH SUPPORT FROM WRRC

April 2011

UNIVERSITY OF NEW HAMPSHIRE
STORMWATER CENTER

Greenland Meadows LID Case Study: Economics

Utilizing an LID approach that featured porous asphalt and a gravel wetland, a cost-competitive drainage system was designed for a large retail development.

Greenland Meadows is a retail shopping center built in 2008 by Newton, Mass.-based New England Development in Greenland, N.H. The development is located on a 56-acre parcel and includes three, one-story retail buildings, paved parking areas consisting of porous asphalt and non-porous pavements, landscaping areas, a large gravel wetland, and advanced stormwater management facilities. The total impervious area of the development – mainly from rooftops and non-porous parking areas – is approximately 25.6 acres.

The development at Greenland Meadows features the largest porous asphalt and gravel wetland installation in the Northeast.

Framingham, Mass.-based Tetra Tech Rizzo provided all site engineering services and design work for the stormwater management system, which included two porous asphalt installations covering a total of 4.5 acres along with catch basins, a sub-surface reservoir for rooftop runoff, and a large gravel wetland for the treatment of nitrogen. The UNH Stormwater Center provided guidance and oversight with the porous asphalt installations and supporting designs.

This case study shows how a combination of porous asphalt and standard pavement design with a sub-surface gravel wetland was more economically feasible than a standard pavement design with a conventional sub-surface stormwater management detention system. This analysis covers some of the site-specific challenges of this development and the environmental issues that mandated the installation of its advanced LID-based stormwater management design.

According to Austin Turner, a senior project civil engineer with Tetra Tech Rizzo, the Conservation Law Foundation feared that a conventional stormwater treatment system would not be sufficient for protecting water quality. "Since there was interest in this project from many environmental groups, especially CLF, permitting the project proved to be very challenging," Turner said. "We were held to very high standards in terms of stormwater quality because Pickering Brook and the Great Bay are such valuable natural resources."

ADDRESSING ENVIRONMENTAL ISSUES

During the initial planning stage, concerns arose about potential adverse water quality impacts from the project. The development would increase the amount of impervious surface on the site resulting in a higher amount of stormwater runoff compared to existing conditions. The development is located immediately adjacent to Pickering Brook, an EPA-listed impaired waterway that connects the Great Bog to the Great Bay.

Tetra Tech Rizzo worked closely with New England Development, the UNH Stormwater Center, the New Hampshire Department of Environmental Services, and the Conservation Law Foundation (CLF) on the design of this innovative stormwater management system with LID designs.

HYDROLOGIC CONSTRAINTS

Brian Potvin, P.E., director of land development with Tetra Tech Rizzo, said one of the main challenges in designing a stormwater management plan for the site was the very limited permeability of the soils. "The natural underlying soils are mainly clay in composition, which is very prohibitive towards infiltration," Potvin said. "Water did not infiltrate well during site testing and the soils were determined to not be adequate for receiving runoff." As such, Tetra Tech Rizzo focused on a stormwater management design that revolved around stormwater quantity attenuation, storage, conveyance, and treatment.

ECONOMIC COMPARISONS

Tetra Tech Rizzo prepared two site work and stormwater management design options for the Greenland Meadows development:

Conventional: This option included standard asphalt and concrete pavement along with a traditional sub-surface stormwater detention system consisting of a gravel sub-base and stone backfill, stormwater wetland, and supporting infrastructure.

LID: This option included the use of porous asphalt and standard paving, a subsurface stone reservior for rooftop runoff, a subsurface gravel wetland, and supporting infrastructure.

The western portion of the property would receive a majority of the site's stormwater prior to discharge into Pickering Brook.

TABLE 1: Comparison of Unit Costs for Materials for Greenland Meadows Commercial Development

ITEM	CONVENTIONAL OPTION	LID OPTION	COST DIFFERENCE
Mobilization / Demolition	$555,500	$555,500	$0
Site Preparation	$167,000	$167,000	$0
Sediment / Erosion Control	$378,000	$378,000	$0
Earthwork	$2,174,500	$2,103,500	–$71,000
Paving	$1,843,500	$2,727,500	$884,000
Stormwater Management	$2,751,800	$1,008,800	–$1,743,000
Addtl Work-Related Activity (Utilities, Lighting, Water & Sanitary Sewer Service, Fencing, Landscaping, etc.)	$2,720,000	$2,720,000	$0
Project Total	**$10,590,300**	**$9,660,300**	**–$930,000**

*Costs are engineering estimates and do not represent actual contractor bids.

TABLE 2: Conventional Option Piping

	TYPE	QUANTITY	COST
Distribution	6 to 30-inch piping	9,680 linear feet	$298,340
Detention	36 and 48-inch piping	20,800 linear feet	$1,357,800

TABLE 3: LID Option Piping

	TYPE	QUANTITY	COST
Distribution	4 to 36-inch piping	19,970 linear feet	$457,780
Detention*	—	0	$0

*Costs associated with detention in the LID option were accounted for under "earthwork" in Table 1.

Table 1 compares the total construction cost estimates for the conventional and the LID option. As shown, paving costs were estimated to be considerably more expensive (by $884,000) for the LID option because of the inclusion of the porous asphalt, subbase, and subsurface reservoir. However, the LID option was also estimated to save $71,000 in earthwork costs as well as $1,743,000 in total stormwater management costs, primarily due to piping for storage. Overall, comparing the total site work and stormwater management cost estimates for each option, the LID alternative was estimated to save the developers a total of $930,000 compared to a conventional design, or about 26 percent of the overall total cost for stormwater management. **Tables 2 and 3** further break down the differences in stormwater management costs between the conventional and LID designs by comparing the total amount of piping required under each option.

Although distribution costs for the LID option were higher by $159,440, the LID option also completely removed the need to use large diameter piping for subsurface stormwater detention. The elimination of this piping amounted to a savings of $1,357,800. "The piping was replaced by the subsurface gravel reservoir beneath the porous asphalt in the LID alternative," Potvin said. "Utilizing void spaces in the porous asphalt subsurface reservoir to detain stormwater allowed us to design a system using significantly less large diameter pipe. This represented the most significant area of savings between each option."

CONSERVATIVE LID DESIGN

Although the developers were familiar with the benefits of porous asphalt, Potvin said they were still concerned about the possibility of the systems clogging or failing. "The developers didn't have similar projects they could reference," he said. "For this reason, they were tentative on relying on porous asphalt alone."

To resolve this uncertainty, the Tetra Tech Rizzo team equipped the porous pavement systems with relief valve designs: additional stormwater infrastructure including leaching catch basins. "This was a conservative 'belt and suspenders' approach to the porous asphalt design," Potvin said. "Although the porous pavement system is not anticipated to fail, this design and strategy provided the developers with a safety factor and insurance in the event of limited surface infiltration."

To further alleviate concerns, a combination paving approach was utilized. Porous asphalt was limited to passenger vehicle areas and installed at the far end of the front main parking area as well as in the side parking area, while standard pavement was put in near the front and more visible sections of the retail center and for the loop roads, delivery areas expected to receive truck traffic. "This way, in case there was clogging or a failure, it would be away from the front entrances and would not impair access or traffic into the stores," Potvin said.

LID SYSTEM FUNCTIONALITY

The two porous asphalt drainage systems – one in the main parking lot and one in the side parking area – serve to attenuate peak flows, while the aggregate reservoirs, installed directly below the two porous asphalt placements, serve as storage. The subbase includes the use of a filter course of medium-grained sand, which provides an additional means of stormwater treatment. Peak flow attenuation is insured by controlling the rate at which runoff exits with an outlet control structure. Nearly the entire site is routed to the gravel wetland on the west side of the site. The gravel wetland is designed as a series of flow-through treatment cells providing an anaerobic system of crushed stone with wetland soils and plants. This innovative LID design works to remove nitrogen and other pollutants as well as mitigate the thermal impacts of stormwater.

CURRENT CONDITIONS

As of 2011, and 3 years of operation, LID in a commercial setting is functioning well both from a durability and water quality perspective. Water quality monitoring indicates a very high level of treatment (see accompanying water quality fact sheet). The porous pavements continue to function well for both permeability and durability. They retain a high level of permeability in part due to a routine maintenance schedule. Pavement durability for passenger vehicles has been strong. Durability has been an issue for non-design loads. In parking areas designed for passenger vehicles only, on occasion, tractor trailers have used the paved areas for turning resulting in damaged pavement. Damage and repairs to porous pavements were managed similarly to standard pavements. The durability is consistent with the standard asphalt and concrete areas where damage is also observed from the demands of high use. The inadvertent use of porous pavements for non-design loads can be prevented by careful design including the use of tight turning radius, obstructions for large vehicles, and the posting of signs.

SUMMARY

Although the use of porous asphalt and gravel wetlands in large-scale commercial development is still a relatively new application, this case study showed how LID systems, if designed correctly and despite significant site constraints, can bring significant water quality and economic benefits. With Greenland Meadows, an advanced LID-based stormwater design was implemented given the proximity of the development to the impaired Pickering Brook waterway. In addition to helping alleviate water quality concerns, the LID option eliminated the need to install large diameter drainage infrastructure. This was estimated to result in significant cost savings in the site and stormwater management design.

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UNIVERSITY OF NEW HAMPSHIRE
STORMWATER CENTER

Greenland Meadows LID Case Study: Water Quality

Greenland Meadows is a retail shopping center built in 2008 by Newton, Mass.-based New England Development in Greenland, N.H.

The development is located on a 56-acre parcel and includes three one-story retail buildings (Lowe's Home Improvement, Target, and a supermarket), paved parking areas consisting of porous asphalt and non-porous pavements, landscaping areas, a large gravel wetland, as well as advanced stormwater management facilities.

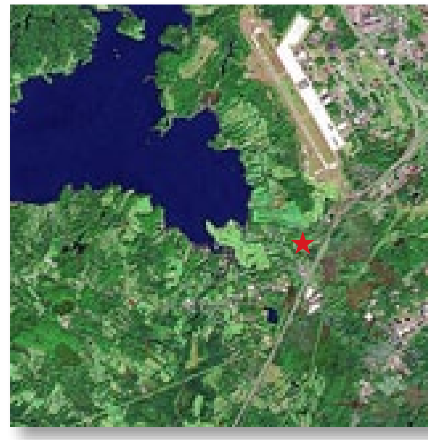
Greenland Meadows features the largest porous asphalt and gravel wetland installation in the Northeast.

The total impervious area of the development – mainly from rooftops and non-porous parking areas – is approximately 25.6 acres, considerably more as compared to pre-development conditions. Prior to this development, the project site contained an abandoned Sylvania light bulb factory with the majority of the property vegetated with grass and trees.

Framingham, Mass.-based Tetra Tech Rizzo provided site drainage engineering, which included the design of two porous asphalt installations covering a total of 4.5 acres along with a sub-surface gravel wetland. The University of New Hampshire (UNH) Stormwater Center provided design guidance, LID project review, and oversight with the LID installations.

ADDRESSING ENVIRONMENTAL ISSUES

During the project permitting stage, concerns arose about potential adverse water quality impacts from the project. The development would increase the amount of impervious surface on the site resulting in a higher amount of stormwater runoff compared to existing conditions. The development is located immediately adjacent to Pickering Brook, an impaired waterway that connects to the Great Bay. One group that was particularly interested in the project's approach to managing stormwater was the Conservation Law Foundation (CLF), an environmental advocacy organization.



LID SYSTEM FUNCTIONALITY

The two porous asphalt drainage systems – one in the main parking lot and one in the eastern parking area – serve to attenuate peak flows, while the aggregate reservoirs, installed directly below the two porous asphalt placements, serve as storage for the underlying sand filter.

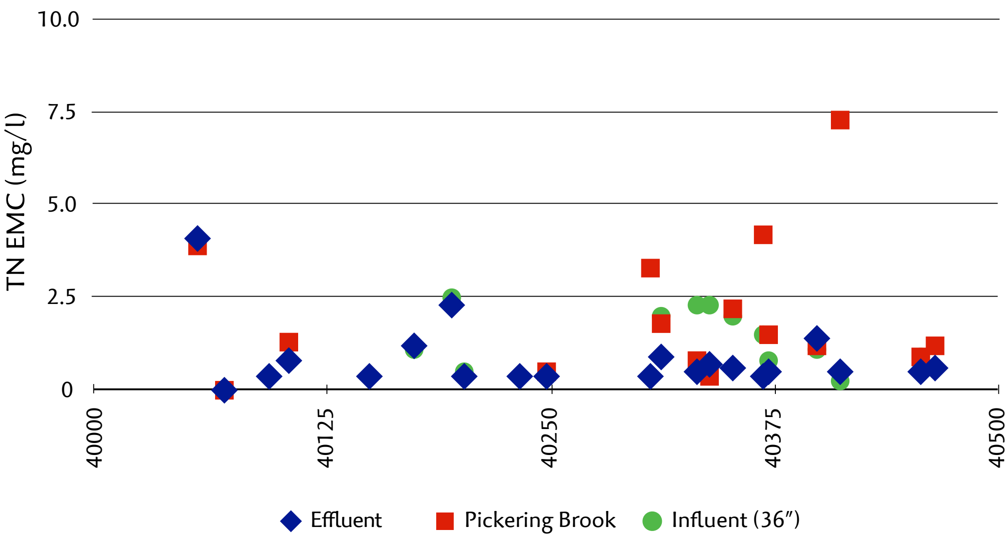
Runoff from the sand filter, which itself provides extended detention and filtration, flows through perforated underdrain pipes that converge to a large gravel wetland on the west side of the site. The gravel wetland is designed as a series of flow-through treatment cells providing an anaerobic system of crushed stone with wetland soils and plants. This innovative LID design works to remove pollutants as well as mitigate the thermal impacts of stormwater.

WATER QUALITY MONITORING

A four-phase wet weather flow monitoring program involving the use of automated samplers was implemented at the Greenland Meadows site in order to assess background conditions for Pickering Brook, evaluate stormwater quality runoff from the project site, and determine the resultant water quality of Pickering Brook downstream from Greenland Meadows. This effort is also being done to assess treatment system performance with respect to effluent concentrations (pre- and post-construction) and upstream receiving water conditions.

The first three phases of montoring were completed between July of 2007 and October 2010 and included:

- pre-construction monitoring (phase one),
- construction activity monitoring (phase two), and
- one year of post-construction monitoring (phase three).



The fourth phase is currently underway and will include four years of monitoring to determine the long-term performance of the system. Runoff constituent analyses routinely include total suspended solids (TSS), total petroleum hydrocarbons-diesel (TPH-D), total nitrogen (NO_3, NO_2, NH_4, TKN), and total metals (Zn). Additional analytes such as total phosphorus and ortho-phosphate have been added due to their relative importance in stormwater effluent characteristics.

	POST-CONSTRUCTION	PRE-CONSTRUCTION	PICKERING BROOK
Total Suspended Solids	3 mg/L	5 mg/L	53 mg/L
Total Nitrogen	0.50 mg/L	0.55 mg/L	1.35 mg/L
Total Phosphorus	0.005 mg/L	0.05 mg/L	.145 mg/L

WATER QUALITY PERFORMANCE

To date, the median TSS, TN, and TP concentrations for the post-construction treated runoff are below pre-construction monitoring concentrations and significantly below concentrations found in the receiving waters of Pickering Brook. The results are depicted above.

Monitoring results indicate that the stormwater management systems are operating well and are providing a high level of treatment for runoff originating from a high contaminant load commercial site, offering significant protection to the impaired receiving waters of Pickering Brook.

Water quality results show that effluent pollutant levels leaving the site at the gravel wetland are typically at or below ambient stream concentrations across a wide range of contaminants. In addition, baseflow benefits, while not yet quantified, are observed discharging in a manner similar to shallow groundwater discharge, providing a nearly continuous source of cool, clean baseflow from the site.

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Boulder Hills, New Hampshire LID Case Study: Economics

This case study shows how utilizing an LID approach to site drainage engineering, specifically with porous asphalt installation, led to more cost-effective site and stormwater management designs.

Utilizing an LID approach that featured porous asphalt resulted in economic benefits in addition to more effective stormwater management for this residential development project.

Boulder Hills, paved in 2009, is a 24-unit active adult condominium community in Pelham, New Hampshire that features the state's first porous asphalt road. The development was built by Stickville LLC on 14 acres of previously undeveloped land and includes a total of 5 buildings, a community well, and a private septic system. In addition to the roadway, all driveways and sidewalks in the development are also composed of porous asphalt. Located along the sides and the backs of the buildings are fire lanes consisting of crushed stone that also serve as infiltration systems for rooftop runoff.

The benefits of implementing an LID design as compared to a conventional development and stormwater management plan included cost savings and positive exposure for the developers, improved water quality and runoff volume reduction, as well as less overall site disturbance and the ability to stay out of wetland and flood zone areas. Over time, the porous asphalt placements are also anticipated to require less salt application for winter de-icing, resulting in additional economic and environmental benefits.

SFC Engineering Partnership Inc. designed the project site and development plan including all drainage. The University of New Hampshire (UNH) Stormwater Center advised the project team and worked with Pelham town officials, providing guidance and oversight with the installation and the monitoring of the porous asphalt placements.

Prior to development, the project site was an undeveloped woodland area sitting atop a large sand deposit. Soils on the parcel were characterized with a moderate infiltration rate and consisted of deep, moderately well to well drained soils. Wetland areas were located in the south and east sections of the parcel, with a portion of the site existing in a 100-year flood zone.

DESIGN PROCESS

Initially, SFC Engineering Partnership began designing a conventional development and stormwater management plan for the project. However, according to David Jordan, P.E., L.L.S., manager of SFC's Civil Engineering Department, difficulty was encountered because of the site's layout and existing conditions. "The parcel was burdened by lowland areas while the upland areas were fragmented and limited," Jordan said. "Given these conditions, it was challenging to make a conventional drainage design work that would meet town regulations.

Comparison of Two Designs, LID Design (top) and Conventional (bottom) for Boulder Hills, Pelham, NH (SFC, 2009).

We found ourselves squeezing stormwater mitigation measures into the site design in order to meet criteria. The parcel also did not have a large enough area that could serve as the site's single collection and treatment basin. Instead, we were forced to design two separate stormwater detention basins, which was more expensive. This approach was also cost prohibitive because of the necessity of installing lengthy underground drainage lines."

When LID and specifically, porous asphalt, emerged as a possible stormwater management option for the site, the developer, Stickville LLC, was receptive. Stickville was aware of the advantages of LID and porous pavement and was interested in utilizing these measures as a possible marketing tool which could help differentiate them as green-oriented developers. SFC advised Stickville LLC to pursue this option. Jordan had attended a seminar on porous pavement presented by The UNH Stormwater Center which covered the multiple benefits of utilizing this material, including its effectiveness for being able to meet stormwater quantity and quality requirements.

"Per regulations, the amount of stormwater runoff from the site after development could not be any greater than what it was as an undeveloped parcel," Jordan said. "In addition to controlling runoff, stormwater mitigation measures

also had to be adequate in terms of treatment. Porous pavement allows us to do both. For a difficult site such as Boulder Hills, that represents a huge advantage."

According to Jordan, the Town of Pelham responded very favorably to the idea of incorporating LID with the project. "The planning board was on board from the very beginning," he said. "They were very supportive of utilizing porous asphalt and recognized the many benefits of this option."

The project was paved by Pike Industries, a leader in the production of porous asphalt in the Northeast.

ECONOMIC COMPARISONS

SFC Engineering Partnership designed two development options for the project. One option was a conventional development and drainage plan that included the construction of a traditional asphalt roadway and driveways. The other option, an LID approach, involved replacing the traditional asphalt in the roadway and driveways with porous asphalt and using subsurface infiltration for rooftop runoff, essentially eliminating a traditional pipe and pond approach.

Although porous asphalt was more costly than traditional asphalt, the engineers found that utilizing this material would result in cost savings in other areas:

- Installing porous asphalt significantly lowered the amount of drainage piping and infrastructure required.
- Using porous asphalt reduced the quantity of temporary and permanent erosion control measures needed
- Using porous asphalt cut in half the amount of rip-rap, and lowering the number of catch basins from eleven to three.
- The LID design completely eliminated the need to install curbing, outlet control structures, as well as two large stormwater detention ponds.
- There was a 1.3 acre reduction in the amount of land that would need to be disturbed, resulting in lower site preparation costs.

ITEM	CONVENTIONAL	LOW IMPACT	DIFFERENCE
Site Preparation	$23,200.00	$18,000.00	–$5,200.00
Temp. Erosion Control	$5,800.00	$3,800.00	–$2,000.00
Drainage	$92,400.00	$20,100.00	–$72,300.00
Roadway	$82,000.00	$128,000.00	$46,000.00
Driveways	$19,700.00	$30,100.00	$10,400.00
Curbing	$6,500.00	$0.00	–$6,500.00
Perm. Erosion Control	$70,000.00	$50,600.00	–$19,400.00
Additional Items	$489,700.00	$489,700.00	$0.00
Buildings	$3,600,000.00	$3,600,000.00	$0.00
PROJECT TOTAL	**$4,389,300.00**	**$4,340,300.00**	**–$49,000.00**

This table shows the construction estimate cost comparisons between the conventional and the low impact development options. As shown, the LID option resulted in higher costs for roadway and driveway construction. However, considerable savings were realized for site preparation, temporary and permanent erosion control, curbing, and most noticeably, drainage.

Overall, the LID option was calculated to save the developers $49,000 ($789,500 vs. LID cost of $740,300) or nearly 6 percent of the stormwater management costs as compared to the conventional option.

CONCLUSIONS

Beyond its effectiveness at reducing stormwater runoff, facilitating more groundwater infiltration, and promoting water quality benefits, porous asphalt was shown in this case study to be capable of bringing positive economic results. Primarily, cost savings were achieved in the Boulder Hills site development design through a significant reduction in the amount of drainage infrastructure and catch basins required, in addition to completely eliminating the need for curbing and stormwater detention ponds. Moreover, with considerably less site clearing needed, more economic and environmental benefits were realized. Compared to a conventional development plan, an option utilizing LID featuring porous asphalt was shown in this example to be more economically feasible.

Overall, the LID option was calculated to save the developers $49,000, or nearly 6 percent of the stormwater management costs, as compared to the conventional option.

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