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November 7, 2011

John S. Sklenak, Chairman
Conservation Commission
Town of Sudbury
275 Old Lancaster Road
Sudbury, MA 01776

Subject: Residences at Johnson Farm (the "Project")
Supplemental Porous Pavement Information

Dear Chairman Sklenak:

In response to your request at the October 24th Conservation Commission hearing, we are providing additional information pertaining to the proposed use of porous pavement within the Project. Specifically, this letter includes the following additional information, in response to the issues raised:

1. Summary of key benefits to the use of porous pavement on the site;
2. Examples of Federal, State and Local policies of governmental agencies and local conservation organizations recommending or encouraging the evaluation and use of porous pavement as a recognized Low Impact Development (LID) design technique and best management practice (BMP);
3. Local and regional examples of projects using porous pavement and studies indicating associated long-term, proven environmental benefits; and
4. Proposed maintenance protocols to be employed on the site to ensure longevity of this LID technique.

Further information on each of these topics is set forth below for the Commission's consideration:

1. Benefits of Use of Porous Pavement on the Site:

   It is significant to note that all paved areas associated with the Johnson Farm project, i.e., site access drives, parking areas and walkways are proposed as porous asphalt (and aesthetic interlocking permeable pavers on sidewalks in front of the buildings). Since porous pavement serves as a stormwater management system that provides significant reductions in runoff volumes, peak discharges and pollutant loads through its ability to capture, treat, store and infiltrate rainfall, there is no need for the

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conventional-type drainage systems consisting of catch basins, drain pipe and large detention basins that

necessitate significant additional tree clearing and earthworks. The porous asphalt pavement, unlike impervious pavement with a conventional drainage system, reduces environmental site impacts and replicates more closely the natural, pre-developed ability of a site to manage rainfall. Studies of sites on similar soils have shown volume and pollutant load reductions of as much as 95%. This results in enhanced protection of numerous interests protected under the Wetlands Protection Act and for these reasons, early in the design process, we dismissed the use of impervious pavement on this site, despite the considerable cost savings that would result from implementation of a more conventional stormwater management system.

2. Porous Pavement as a Recognized LID Technique and Best Management Practice:

Permeable pavement is recognized for its significant environmental benefits at state and federal levels. It is endorsed by MassDEP as a recommended BMP for stormwater management (Volume 2, Chapter 2 of the Massachusetts Stormwater Handbook); by the Massachusetts Smart Growth/Smart Energy Toolkit as a desired LID technique; and by the US EPA as a desirable Green Infrastructure/LID approach. The 2008 National Research Council report on Urban Stormwater Management identifies infiltration/filtration strategies including permeable pavements as central to watershed protection.

Additionally, numerous local environmental organizations recommend the use of porous pavement as a LID technique for sensitive environmental areas. For example, the Charles River Watershed Association (CRWA) has focused a great deal of research on LID/BMPs and "is advocating communities and private developers to look for every opportunity to capture and treat stormwater prior to its entry into local surface waterways". CRWA is building a database of information on techniques and methods used to manage stormwater. The first LID BMP techniques listed on their website are Permeable Pavement and Permeable Pavers. Similarly, the Sudbury Assabet & Concord River Stewardship Council "promotes the use of LID techniques in any new project proposals that may affect the river", and states that "LID is an approach to environmentally friendly land use planning."

Furthermore, Sudbury's Stormwater Management Bylaw and Regulations "require the evaluation and implementation of LID practices"; Appendix D of the Bylaw lists porous pavements and rain gardens (proposed in the Johnson Farm design) among the strategies with beneficial stormwater management objectives. These objectives, specifically listed in Appendix D and incorporated into the Johnson Farm stormwater design, for rain gardens are "to remove suspended solids, metals and nutrients" and "reduce peak discharge rates and total runoff volume"; and for porous pavement are to "reduce stormwater runoff volume from paved surfaces"; "reduce peak discharge through infiltration"; and "reduce pollutant transport through direct infiltration".

3. Examples of Porous Pavement Applications and Studies:

Porous pavement has proven, long-term environmental benefits, having been successfully used and maintained in environmentally-sensitive areas. For example, locally, it was installed 34 years ago at Walden Pond in Concord, Massachuetts as a "demonstration project by MassDEP and MassDEM". Today, a sign posted at Walden Pond states, "These parking areas are paved with Porous Pavement--Pavement That Leaks. Since 1977, it has raised the water table while reducing erosion, pollution and the need for storm drains or road salt". Permeable pavement was also implemented by the Massachusetts Department of Conservation and Recreation (DCR) in 2006 at the Silver Lake Beach parking lot in Wilmington, Massachusetts. As noted by the DCR, "porous asphalt was ideal for this parking lot abutting a popular swimming, fishing and boating lake."

As you are aware, the University of New Hampshire has been testing porous asphalt, as well as other types of permeable pavements, for several years at their UNH Stormwater Center testing facility on campus. In 2004 a porous asphalt parking lot was installed adjacent to a standard impervious dense-mix asphalt lot for comparison testing and monitoring. The porous asphalt has been monitored and analyzed for water quality filtering showing tremendous treatment performance, storage capacity and infiltration rates and compared to the standard pavement for effectiveness and functionality with regards to surface runoff, water quality and ambient temperature, structural durability, safety, particularly in wet and winter conditions, and operation and maintenance requirements. The results for porous asphalt are very favorable, relative to impervious surfaces.

As you are familiar with, the UNH Stormwater Center conducts a Porous Pavement Tour and Workshop. In addition to the porous asphalt test site, there are other locations on the UNH campus and vicinity that are part of this program, including parking, access driveways and sidewalks successfully using porous asphalt, pervious concrete and interlocking permeable pavers. Similarly, in Greenland, NH, the Great Bay Discovery Center installed permeable pavements as a LID retrofit of an old gravel parking area using environmentally sensitive site design. Also, the Greenland Meadows Shopping Center, consisting of Lowe's, Target and a supermarket (designed and permitted by Tetra Tech) is the largest porous pavement installation in New England and a prime example of an environmentally beneficial LID technique functioning well as both a stormwater management system and a transportation system.

A porous asphalt installation in 2009 for a multi-unit condominium community in Pelham, NH features the state's first porous asphalt road and is a design and use very similar to the proposed Johnson Farm. The Pelham development was built 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 1,300 linear feet of roadway, all of the driveways and sidewalks in the development are composed of porous asphalt. The LID design reduced the need for stormwater infrastructure that would have included two large detention basins, resulting in 1.3 acres of reduced land disturbance.

Other examples of proven and functioning porous pavement installations include a portion of State Highway near the Maine Mall in South Portland by the Maine DOT; a parking lot expansion at the hospital in New London, NH; and a new parking lot at the Porter and Chester Institute in Canton, MA. Compared to adjacent paved areas with impervious dense-mix pavements, these installations have all proven to have substantial reductions in surface runoff and to be safe and effective during the most extreme winter snow and icing conditions.

Based on UNH testing, porous pavement is proven to be a better surface for dealing with winter conditions than impervious pavement. Winter maintenance of porous asphalt was found to achieve up to 75% reductions in salt usage. Snow on porous asphalt is plowed the same as standard pavement, however sunshine acts quickly to melt snow and ice sooner than on frozen standard pavement. The melting snow infiltrates from the surface directly through the open-graded porous asphalt into the stone sub-base. The result is a safer, cleaner pavement surface that clears faster than standard pavement, does not cause black ice that typically occurs on impervious surfaces from the constant freeze-thaw cycles and therefore dramatically reduces the need for salt deicing. For any deicing required in shady areas that don't receive as much sunlight, calcium chloride, rather than environmentally unfriendly sodium chloride, will be used as necessary to maintain safe site conditions, as may be authorized by the Commission.

4. Maintenance of Porous Pavement within the Project:

   Maintenance of the porous asphalt is performed four times per year using a regenerative air vacuum truck that picks up large particles such as leaves and debris, as well as smaller particles such as sand and sediments. As stated previously, since the melting snow infiltrates down from the surface, there is very little, if any snow and ice buildup, and therefore the cleaner, dryer porous paved surface does not require winter sanding. It is undesirable and not recommended since sanding would clog the pores of the asphalt and reduce its effectiveness to infiltrate. The On-Site Property Manager, who will be responsible for implementing the submitted Stormwater Management Operations & Maintenance Plan, and posted signage will ensure that snowplow operators on this private property do not apply sand as part of winter maintenance.

   The proposed Johnson Farm rental apartment community is an ideal property use for maximizing the environmental benefits of porous pavement and minimizing the potential for occurrences of accidental spills of hazardous materials or contaminants.

   With on-site property management providing accountability and coordinated control over the trained maintenance staff doing the lawn mowing, snow blowing, house painting and staining, this significantly reduces the chance for potential spills that might otherwise occur by residents performing these tasks. In addition, the proposed private access and loop drive to be used primarily by residents (it is not a cut-through road) promotes slow driving speeds designed for 25 mph posted speed limits, which also minimizes the potential for spills or leaks caused by vehicle accidents. However, should a spill ever occur on the porous asphalt, the spill response procedure plan is to apply Oil-Dri granular absorbent and then dispose properly of the used product. If necessary, the area of porous asphalt can be cut out and the dirty stone removed, replaced and pavement patched. Compared to impervious pavement and a conventional closed drain pipe conveyance system, the spill in porous asphalt stays in one area and does not runoff, potentially spread downstream and get discharged to basins.

Finally, to ensure a successful porous pavement design and installation, Dr. Robert Roseen, Director of the UNH Stormwater Center who heads up the Porous Pavement Tour and Workshop, has been added to the design team for Johnson Farm and

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will be attending the Conservation Commission hearing next week. Robert has been instrumental in providing quality assurance as a reviewer of porous pavement designs, porous asphalt mix productions and construction inspections for many of the installations mentioned in this letter, and he has assumed that role for this project as well.

For these reasons, we have designed the project to include porous pavement as a proven LID technique, consistent with the Town's Stormwater Bylaw and Best Management Practices.Based on review of this information, we believe the Commission has sufficient information to conclude that, comparatively, the use of impervious pavement and a conventional stormwater management system in the Project would be far less preferable under the Sudbury Bylaw and other applicable environmental policies, due to the significantly greater potential environmental impacts, as summarized above. We trust this information is helpful for your review and we will be prepared to respond to any further questions that you or other members of the Commission may have at the next Commission hearing.

Very truly yours,
TetraTech

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cc: Jody Kablack
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Enc.

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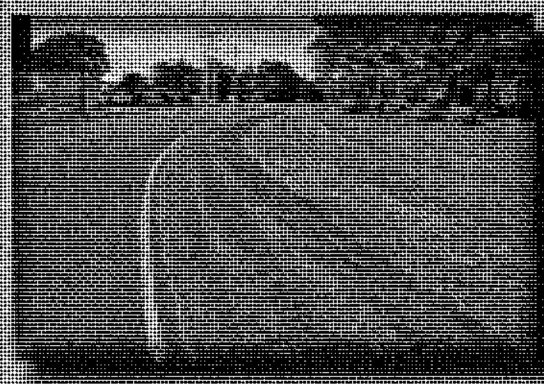
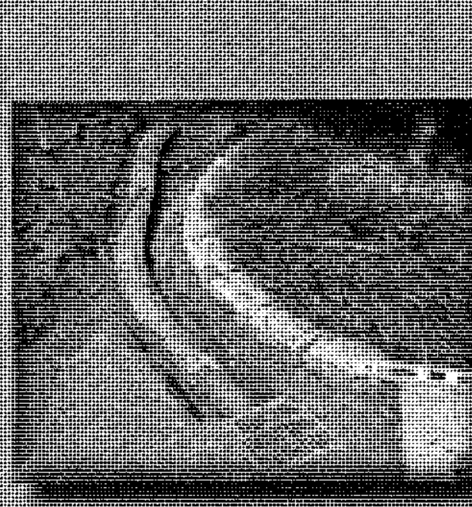
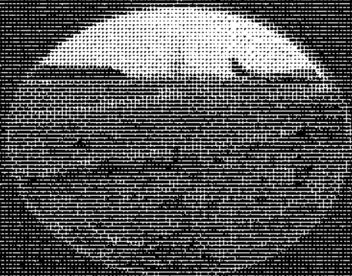
Volume 2 Chapter 2: Structural BMP Specifications for the Massachusetts Stormwater Handbook

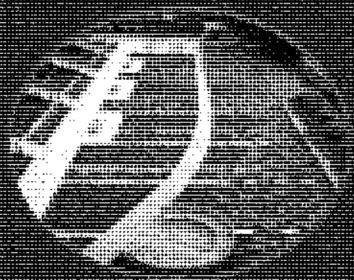




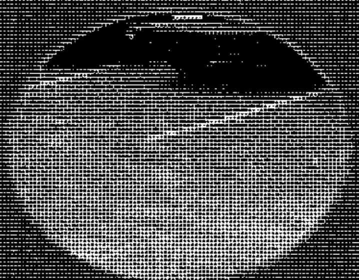
Other BMPs



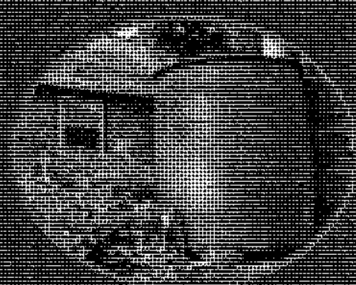
Dry Detention Basin



Green Roofs



Porous Pavement



Rain Barrels & Cisterns

Porous Pavement

Description: Porous pavement is a paved surface with a higher than normal percentage of air voids to allow water to pass through it and infiltrate into the subsoil. This porous surface replaces traditional pavement, allowing parking lot, driveway, and roadway runoff to infiltrate directly into the soil and receive water quality treatment. All permeable paving systems consist of a durable, load-bearing, pervious surface overlying a stone bed that stores rainwater before it infiltrates into the underlying soil. Permeable paving techniques include porous asphalt, pervious concrete, paving stones, and manufactured "grass pavers" made of concrete or plastic. Permeable paving may be used for walkways, patios, plazas, driveways, parking stalls, and overflow parking areas.

Ability to meet specific standards

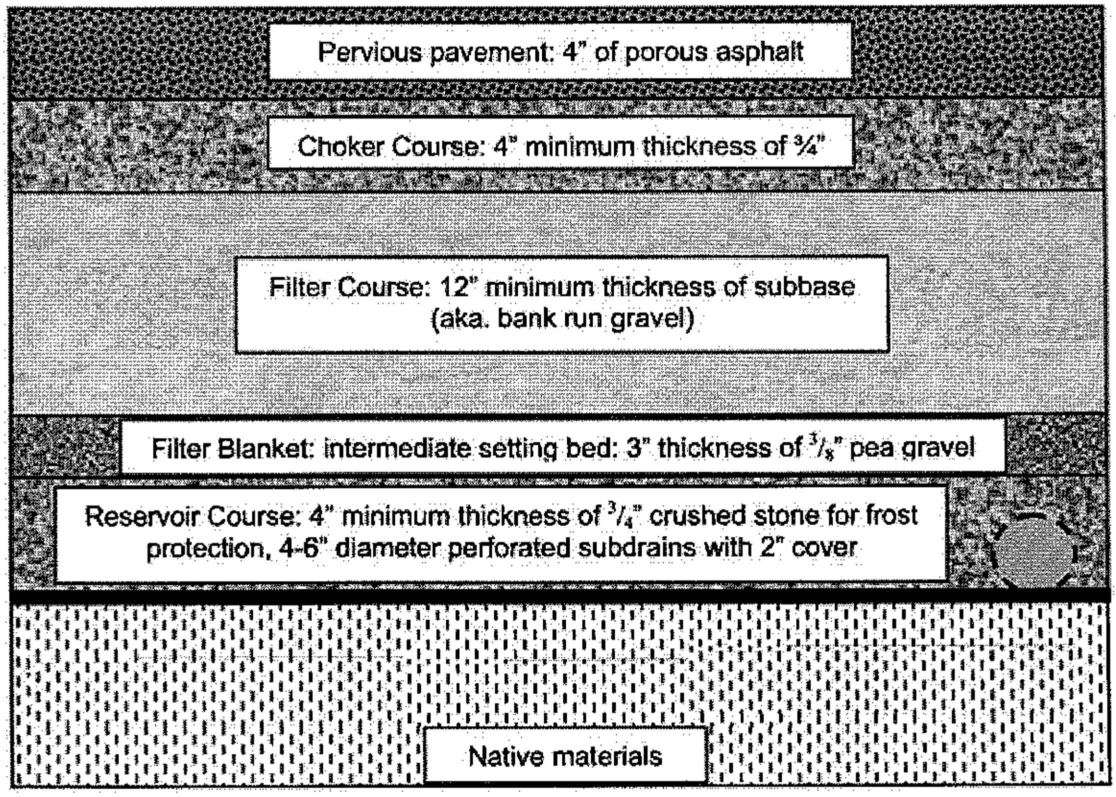
Standard	Description
2 - Peak Flow	Provides peak flow attenuation for small storms.
3 - Recharge	Provides groundwater recharge.
4 - TSS Removal	80% TSS Removal credit if storage bed is sized to hold ½-inch or 1-inch Water Quality Volume, and designed to drain within 72 hours.
5 - Higher Pollutant Loading	Not suitable.
6 - Discharges near or to Critical Areas	Not suitable especially within Zone IIs or Zone A's of public water supplies.
7 - Redevelopment	Suitable.

Advantages/Benefits:
- Reduce stormwater runoff volume from paved surfaces
- Reduce peak discharge rates.
- Increase recharge through infiltration.
- Reduce pollutant transport through direct infiltration.
- Can last for decades in cold climates if properly designed, installed, and maintained
- Improved site landscaping benefits (grass pavers only).
- Can be used as a retrofit when parking lots are replaced.

Disadvantages/Limitations:
- Prone to clogging so aggressive maintenance with jet washing and vacuum street sweepers is required.
- No winter sanding is allowed.
- Winter road salt and deicer runoff concern near drinking water supplies for both porous pavements and impervious pavements.
- Soils need to have a permeability of at least 0.17 inches per hour.
- Special care is needed to avoid compacting underlying parent soils.

Pollutant Removal Efficiencies

• Total Suspended Solids (TSS)	80%
• Nutrients (Nitrogen, phosphorus)	Insufficient data
• Metals (copper, lead, zinc, cadmium)	Insufficient data
• Pathogens (coliform, e coli)	Insufficient data



adapted from the University of New Hampshire

Maintenance

Activity	Frequency
Monitor to ensure that the paving surface drains properly after storms	As needed
For porous asphalts and concretes, clean the surface using power washer to dislodge trapped particles and then vacuum sweep the area. For paving stones, add joint material (sand) to replace material that has been transported.	As needed
Inspect the surface annually for deterioration	Annually
Assess exfiltration capability at least once a year. When exfiltration capacity is found to decline, implement measures from the Operation and Maintenance Plan to restore original exfiltration capacity.	As needed, but at least once a year
Reseed grass pavers to fill in bare spots.	As needed

Special Features

Most appropriate for pedestrian-only areas and for low-volume, low-speed areas such as overflow parking areas, residential driveways, alleys, and parking stalls.

Porous Pavement

Applicability

Porous pavement, also known as permeable paving, is appropriate for pedestrian-only areas and for low-volume, low-speed areas such as overflow parking areas, residential driveways, alleys, parking stalls, bikepaths, walkways, and patios. It can be constructed where the underlying soils have a permeability of at least 0.17 inches per hour. Porous paving is an excellent technique for dense urban areas, because it does not require any additional land. Porous pavement can be successfully installed in cold climates as long as the design includes features to reduce frost heaving.

Porous paving is not appropriate for high traffic/ high speed areas, because it has lower load-bearing capacity than conventional pavement. Do not use porous pavement in areas of higher potential pollutant loads, because stormwater cannot be pretreated prior to infiltration. Heavy winter sanding will clog joints and void spaces. On some highways, MassHighway Department uses an Open Graded Friction Course (OGF) that has a permeable top coat but an impermeable base course. MassDEP provides no Water Quality or Recharge Credit for OGC, because it does not provide treatment or recharge. The primary benefit of OGF pavements is reductions in noise and hydroplaning.

Effectiveness

Porous pavement provides groundwater recharge and reduces stormwater runoff volume. Depending on design, paving material, soil type, and rainfall, porous paving can infiltrate as much as 70% to 80% of annual rainfall. To qualify for the Water Quality and Recharge Credits, size the storage layer to hold the Required Water Quality or Required Recharge Volume, whichever is larger, using the Static Method, and design the system to dewater within 72 hours. Porous pavement may reduce peak discharge rates significantly by diverting stormwater into the ground and away from pipe-and-basin stormwater management systems, up to the volume housed in the storage layer. Grass pavers can improve site appearance by providing vegetation where there would otherwise be pavement. Porous paving can increase the effective developable area of a site, because the infiltration provided by permeable paving can significantly reduce the need for large stormwater management structures.

Planning considerations

Porous paving must not receive stormwater from other drainage areas, especially any areas that are not fully stabilized.

Use porous paving only on gentle slopes (less than 5%). Do not use it in high-traffic areas or where it will be subject to heavy axle loads.

Consider the setback requirements when considering porous pavement:

Considerations	Setback Requirements
Slope	Less than 5%
Septic system soil absorption system	50 feet
Private well	100 feet
Public well	Outside the Zone 1
Public reservoir	Outside the Zone A
Surface Waters	100 feet
Cellar Foundations	20 feet
Slab Foundations	10 feet
Property Lines	10 feet
Minimum depth	2 feet vertical separation above seasonal high groundwater from bottom of storage layer
Frost Line	Below frost line
Bedrock	As with any stormwater exfiltration system, determine if it is feasible in locations with high bedrock. Presence of bedrock near land surface reduces the ability of soils to exfiltrate to groundwater.

Porous paving reduces the need for other stormwater conveyances and treatment structures, resulting in cost savings.

Permeable paving also reduces the amount of land needed for stormwater management.

Design

There are three major types of permeable paving:

- Porous asphalt and pervious concrete. Although it appears to be the same as traditional asphalt or concrete pavement, it is mixed with a very low content of fine sand, so that it has from 10%-25% void space.

- Paving stones (also known as unit pavers) are impermeable blocks made of brick, stone, or concrete, set on a prepared sand base. The joints between the blocks are filled with sand or stone dust to allow water to percolate to the subsurface. Some concrete paving stones have an open cell design to increase permeability.

- Grass pavers (also known as turf blocks) are a type of open-cell unit paver in which the cells are filled with soil and planted with turf. The pavers, made of concrete or synthetic material, distribute the weight of traffic and prevent compression of the underlying soil.

Each of these products is constructed over a storage bed.

Storage Bed Design
The University of New Hampshire has developed specifications for storage beds used in connection with porous asphalt or pervious concrete. According to UNH, the storage bed should be constructed as indicated in Figure PP 1 with the following components from top to bottom:
- a 4-inch choker course comprised of uniformly graded crushed stone,
- a filter course, at least 12 inches thick, of poorly graded sand or bankrun gravel to provide enhanced filtration and delayed infiltration
- a filter blanket, at least 3 inches thick, of pea stone gravel to prevent material from entering the reservoir course, and
- a reservoir course of uniformly graded crushed stone with a high void content to maximize the storage of infiltrated water and to create a capillary barrier to winter freeze thaw. The bottom of the stone reservoir must be completely flat so that runoff can infiltrate through the entire surface.

The size of the storage bed may have to be increased to accommodate the larger of the Required Water Quality and the Required Recharge Volume.

If paving stones or grass pavers are used, a top course of sand that is one inch thick should be placed above the choker coarse.

Overflow Edge
Some designs incorporate an "overflow edge," which is a trench surrounding the edge of the pavement. The trench connects to the stone reservoir below the surface of the pavement and acts as a backup in case the surface clogs.

Preparation of Porous Asphalt
Care must be taken in batching and placing porous asphalt. Unless batched and installed properly, porous pavement may have a reduced exfiltration ability. At Walden Pond State Reservation, several of the areas paved with porous asphalt did not meet the target exfiltration rate. Cores were taken and it was found that the batches had more sand and/or asphalt than was specified, and those sections had to be removed and repaved.

It is critical to minimize the amount of asphalt binder. Using greater amounts of asphalt binder could lead to a greater likelihood of "binder" or asphalt drawdown and clogging of voids. Sun light heating can liquefy the asphalt. The liquefied asphalt then drains into the voids, clogging them. Such clogging is not remedied by power washing and vacuuming. The topcoat in such instances needs to be scarified and resurfaced. The University of New Hampshire has prepared detailed specifications for preparing and installing pourous asphalt that are intended to prevent asphalt problems.

Additional Design Considerations

- Provide an open-graded subbase with minimum 40% void space.
- Use surface and stone beds to accommodate design traffic loads
- Generally, do not use porous pavement for slopes greater than 5 %.
- Do not place bottom on compacted fill.
- Provide perforated pipe network along bed bottoms for distribution
- Provide a three-foot buffer between the bed bottom and the seasonal high groundwater elevation, and a two-foot buffer for bedrock.

Cold Weather Design Considerations

Porous pavement performs well in cold climates. Porous pavement can reduce meltwater runoff and avoid excessive water on the road during the snowmelt period.

In cold climates, the major concern is the potential for frost heaving. The storage bed specifications prepared by the University of New Hampshire address this concern.

Maintenance

In most porous pavement designs, the pavement itself acts as pretreatment to the stone reservoir below. Consequently, frequent cleaning and maintenance of the pavement surface is critical to prevent clogging. To keep the surface clean, frequent vacuum sweeping along with jet washing of asphalt and concrete pavement is required. No winter sanding shall be conducted on the porous surface.

As discussed, designs that include an "overflow edge" provide a backup in case the surface clogs. If the surface clogs, stormwater will flow over the surface and into the trench, where some infiltration and treatment will occur. For proper maintenance:

- Post signs identifying porous pavement areas.
- Minimize salt use during winter months. If drinking water sources are located nearby (see setbacks), porous pavements may not be allowed.
- No winter sanding is allowed.
- Keep landscaped areas well maintained to prevent soil from being transported onto the pavement.
- Clean the surface using vacuum sweeping machines monthly. For paving stones, periodically add joint material (sand) to replace material that has been transported.
- Regularly monitor the paving surface to make sure it drains properly after storms.
- Never reseal or repave with impermeable materials.
- Inspect the surface annually for deterioration or spalling.
- Periodically reseed grass pavers to fill in bare spots.
- Attach rollers to the bottoms of snowplows to prevent them from catching on the edges of grass pavers and some paving stones.

Adapted from:
MassDEP, Massachusetts Nonpoint Source Pollution Management Manual, 2006.

References

Ferguson, Bruce, K., Porous Pavements, 2005, CRC Press. Taylor and Francis Group, Boca Raton

UNH, 2007, UNHSC Design Specifications for Porous Asphalt Pavement and Infiltration Beds, Revised October 2007, http://www.unh.edu/erg/cstev/pubs_specs_info/unhsc_pa_apec_07_07_final.pdf

Asphalt Pavement for Stormwater Management, http://www.unh.edu/erg/cstev/pubs_specs_info/porous_ashpalt_fact_sheet.pdf

University of New Hampshire Center for Stormwater Technology Evaluation and Verification; this research group tests and evaluates stormwater BMPs on the UNH campus.

- An article about the use of permeable pavers at the Westfarms Mall in Connecticut.
- Case Studies from Uni-Group USA, a block paver manufacturer.
- The Nonpoint Education For Municipal Officials program at the University of Connecticut has been involved in numerous permeable paving pilot projects.
- Permeable paver specifications courtesy of the Low Impact Development Center.
- Porous pavement design and operational criteria from the US Environmental Protection Agency, which also publishes a Low Impact Development Page. Also see this report on a Field Evaluation of Permeable Pavements for Stormwater Management (PDF.)
- New Jersey Stormwater Best Management Practices Manual February 2004.

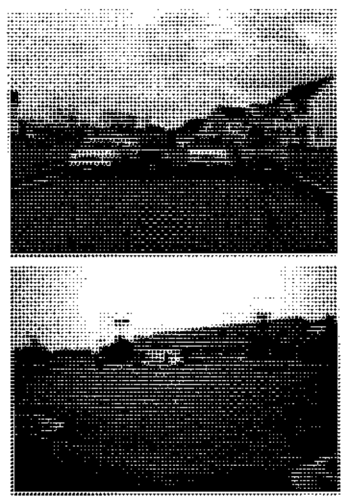
Smart Growth / Smart Energy Toolkit

Low Impact Development (LID)

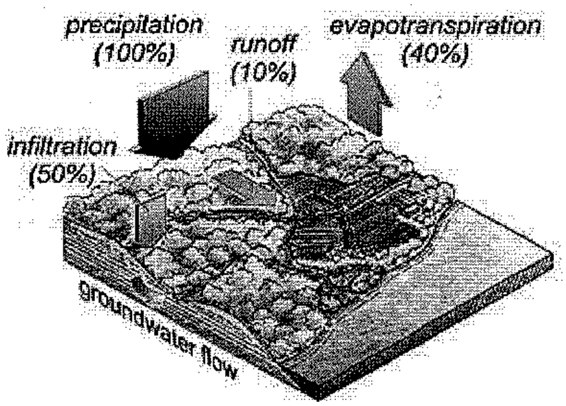
In Brief: **Low Impact Development** (LID) is a more sustainable land development approach that begins with a site planning process that first identifies critical natural resource areas for preservation. Then, once the building envelope is established, LID techniques, such as maintaining natural drainage flow paths, minimizing land clearance, clustering buildings, and reducing impervious surfaces are incorporated into the project design. A series of small stormwater best management practices (BMPs) that preserve the natural features and hydrology of the land are used instead of the conventional methods of collecting, conveying, and piping away runoff.

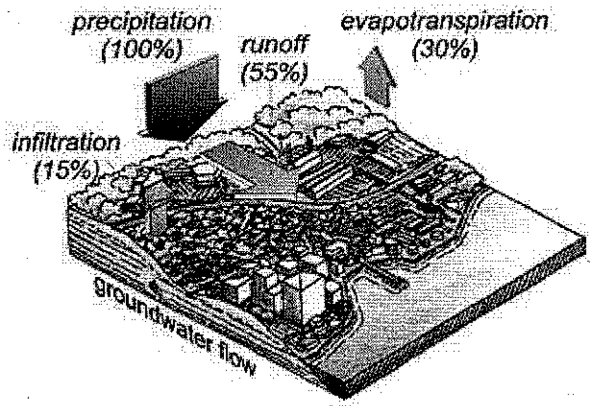
The Problem

Development patterns based on conventional zoning codes in Massachusetts often result in "sprawl" with its associated large impervious areas, loss of natural resources and habitat, increase in nonpoint source pollution, and alteration of hydrologic systems. Conventional developments often start with clearing and leveling of the entire parcel. Then the construction of wide, paved roads and over-designed large parking lots follow. These sprawling impervious areas eliminate vegetation (nature's natural pollution filters), and prevent water from infiltrating into the ground (which normally replenishes groundwater supplies and supports nearby wetlands and streams with base flow). The result is the conveying of polluted runoff to water bodies In order to deal with stormwater that runs off of these sites, structural controls such as catch basins, pipes, and detention ponds are used. Instead of "greenscapes", conventional landscaping of these developments brings additional concerns including the introduction of non-native plants, use of herbicides, pesticides and fertilizers, and excessive water consumption.



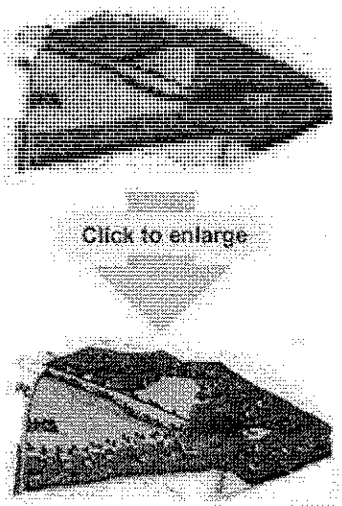
Large Impervious Surfaces





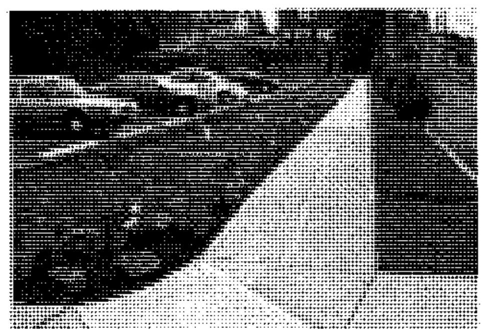
Besides loss of natural resource areas, habitat corridors, and buffers to wetlands and stream, conventional development (right hand graphic) creates large areas of impervious surfaces which prevent the infiltration of rainwater. Under natural (pre-development) conditions (left hand graphic), rain infiltrates through soils and percolates downward to the underlying water table, where it recharges the groundwater. Throughout the more permeable areas of Massachusetts approximately 50% of the annual precipitation infiltrates and recharges. Groundwater serves as drinking water supply and provides base flow to streams and wetlands. This base flow is critical to habitat quality for fish and other aquatic ecosystems. In many areas of eastern Massachusetts, where watersheds have become significantly urbanized with extensive impervious areas, the base flows of streams have been diminished. In some cases, such as the Ipswich River where the stream goes dry, eliminating habitat value. Surface runoff is also increased in urbanized watersheds creating greater peak flows which can cause flooding and channel erosion.

Introduction to LID



LID begins with effective site planning which focuses on mapping of environmental resources to be preserved; identification of building areas which best accommodate development economically and ecologically; and the use of design techniques to reduce impervious covering and the impacts to water quantity and quality, such as clustering, permeable surfaces, reduced roadway pavement widths, and the preservation of natural drainage pathways.. For more information on site planning, click here.

The LID approach provides opportunities to build the homes and businesses that we need, while conserving natural areas and drainage patterns. LID is accomplished as a two-step process; FIRST--thoughtful site planning and, SECOND--incorporation of "natural" stormwater best management practices (BMPs).

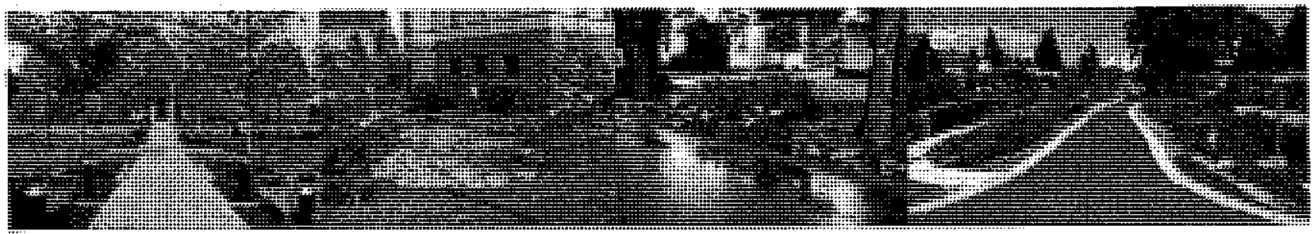


This rain garden placed between the parking lot and sidewalk captures rainfall, allowing it to infiltrate rather than flowing onto the street

Thoughtful site planning begins with the identification of critical site features such as wetlands, habitat areas, or drinking water protection areas that should be set aside as protected open space. Natural features, such as vegetated buffers and view sheds, will also play an integral role in any LID planning exercise. After the critical open space areas are identified and set aside, sustainable development areas are then identified as "building envelopes".

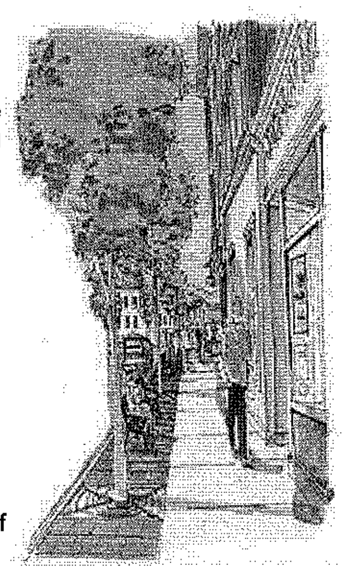
Within the delineated building envelopes, a broad range of design techniques or BMPs, such as shared driveways, permeable pavers, and bioretention are used to reduce the level of impervious cover and improve the quantity and quality of stormwater drainage. Other LID design techniques include green roofs, rain barrels, rain gardens, grassed swales, stormwater infiltration systems, and alternative landscaping. Through these techniques, natural drainage pathways are conserved, open space is preserved, and the overall impact from development is significantly reduced.

Often LID techniques provide benefits beyond those related to water and drainage. For example, green roofs also muffle noise by reducing reflective sound, mitigate "urban heat island" effects by creating microclimates that cool and humidify air in their immediate area, absorb dust and smog as well nitrates and other aerosol contaminants from air and rainfall, and generally provide natural habitat for wildlife including birds, butterflies, and insects.



These four examples of rain gardens look like conventional landscaped areas but are actually LID features that capture, treat, and slowly release rainfall to replenish local groundwater resources while beautifying parking lots, buildings, and roadways

Benefits



LID techniques implement several basic tenets of the Patrick Administration's Sustainable Development Principles including:

• **Concentrate Development and Mix Uses:** The LID site planning process sets aside key natural features and focuses development into clustered patterns on the remaining land.

• **Protect Land and Ecosystems:** The reduction of impervious surfaces reduces the amount of surface runoff and through the infiltration of stormwater, recharges the groundwater system, thereby restoring the natural hydrologic cycle. This preserves groundwater supplies and base flow to streams and wetlands.

• **Use Natural Resources Wisely:** The LID planning process results in housing that makes more efficient use of land and conserves critical natural features such as wetlands, vegetated buffers, and drinking water protection areas.

LID can increase property values. Converting or designing normally unused roof areas into green roofs, can increase your property value by reclaiming that elevation of a building and make it an amenity to be used by the buildings occupants.

LID results in reduced energy costs. Green roofs reduce heating and cooling costs for the building between 30 - 50%, compared to buildings with conventional roofs

Access Issues

There is a perception that LID projects may have to sacrifice good access to achieve the goal of reduced impact on natural systems. This is a real issue, but one that planners, engineers, public safety officials, and regulators can manage with careful design and common sense. Key issues and concerns include:

- Adequate street width for everyday traffic, parking, snow removal, service vehicles, and emergency vehicles;
- Adequate turning radii for school buses, service vehicles, and emergency vehicles;
- Adequate surface and structural integrity of permeable pavements for emergency vehicles; and
- Safety and maintenance of roadside swales and other surface vegetated stormwater management practices.

Key Design Elements:

- Street width needs to be correlated to traffic volume, land use, and parking demand. Residential streets with less than 500 trips per day (generally serving less than 50 houses), can be designed at a minimum width so as to accommodate a fire truck (generally as narrow as 18 to 20 feet);
- Snow removal and storage is a design component. The designer must identify where snow will be plowed, how much room might be required for snow piles, and at what level snow must be removed from street sides;

- On-street parking is a major consideration for street width and public safety. Options include parking on one side of the street only, shared travel and parking lanes for very low volume roads, or off-street visitor parking.
- Turning radii for streets and cul-de-sacs need to be designed to accommodate service and emergency vehicles. The requirements for school buses depend on the number of houses served by a street and local school district pick-up policies.
- Permeable pavements are designed to accommodate the design loading. If fire truck access is required, pavements and subgrades need to be designed accordingly. Alternative pavements, such as reinforced turf, are capable of supporting emergency vehicle travel, but special provisions may be necessary for stabilizing outriggers in the immediate vicinity of stationary vehicles.
- Roadside swales and other surface vegetated practices can be a safety issue for high volume, higher speed roads. Designers can apply a range of options such as roadside curbs with drainage slots or guard rails to protect traffic from the swale. For low volume, low speed residential roads, shallow swales represent very low risks to drivers, and sidewalks can be located on the opposite side of the swale, away from the road, to minimize risk to pedestrians.

Cost Considerations

Some critics of LID have raised the question of whether it costs more to design, implement, and maintain LID practices than it is does for conventional practices. While this is a very simple question to ask, the answer can be quite complex. First, the term "cost" must consider all costs, including: planning, design, and capital costs; long term maintenance costs; land values; and potential environmental impacts. One cannot simply assert that a practice costs less if it is less expensive to construct, since it may cost more to maintain, may result in environmental degradation, or lead to decreased property values in the long run.

This being said, costs for LID practices as well as for the conventional approach vary as a result of many factors, and generic costs cannot be easily quantified. Typical factors affecting cost include:

- Material costs;
- Site specific constraints such as access, topography, soils, groundwater, and parcel area;
- Land use;
- Location;
- Designer, reviewer, and contractor experience;
- Local regulations; and
- Overall economic climate.

The table below is offered to help planners, engineers, regulators, and developers compare the costs and benefits of LID with a more conventional land development approach.

Qualitative Cost Comparison – How LID Practices Compare with Conventional Practices

LID Practice	Design Costs	Construction Costs	Long-Term Maintenance Costs	Increased Land Values	Decreased Environmental Impact
Better Site Design					
Better Local Roads					
Bioretention/Rain Gardens					
Infiltration/Permeable Pavements		(1)	(1)		
Stormwater Planters					
Vegetated Swales					
Vegetated Buffers					
Cisterns/Rain Barrels			(1)		
Green Roofs		(1)			
Key :					

- LID practice compares favorably with conventional approach (e.g., costs less)
- LID practice compares unfavorably with conventional approach (e.g., costs more)
- Too close to determine, site conditions or other factors may affect cost

(1) - Costs may be too close to call, or even favorable when all costs such as heating, cooling, roof replacement, irrigation, or additional downstream detention are considered.

Financial Considerations

LID provides important benefits to the municipality, the developer, and the general public. More concentrated (cluster) design, with less impervious area and smaller infrastructure (stormwater drainage and other utilities), means significant cost savings to developers and reduces maintenance costs for municipalities.

LID reduces demand on public stormwater infrastructure. LID reduces the amount of water that flows into public storm sewers; the result is fewer combined sewer overflows and expenditures on maintenance and capital improvements.

LID promotes recharge to and the preservation of aquifers thereby reducing the need for and high cost of providing additional public water supply sources.

LID reduces non-point source pollution to drinking water supplies, recreational waters, and wetlands, saving future expenditures for restoration of valuable water resources.

LID reduces building costs. A green roof protects the roof membrane from climatic extremes and physical abuse, thereby greatly increasing the life expectancy of the roof - typically up to 40 years.

Case Studies Bylaw Slideshow Links

EPA United States Environmental Protection Agency

Water: Green Infrastructure/ Low Impact Development

Low Impact Development (LID)

LID is an approach to land development (or re-development) that works with nature to manage stormwater as close to its source as possible. LID employs principles such as preserving and recreating natural landscape features, minimizing effective imperviousness to create functional and appealing site drainage that treat stormwater as a resource rather than a waste product. There are many practices that have been used to adhere to these principles such as bioretention facilities, rain gardens, vegetated rooftops, rain barrels, and permeable pavements. By implementing LID principles and practices, water can be managed in a way that reduces the impact of built areas and promotes the natural movement of water within an ecosystem or watershed. Applied on a broad scale, LID can maintain or restore a watershed's hydrologic and ecological functions. LID has been characterized as a sustainable stormwater practice by the Water Environment Research Foundation and others.

LID Works Everywhere

LID can be applied to new development, redevelopment, or as retrofits to existing development. LID has been adapted to a range of land uses from high density ultra-urban settings to low density development.

LID and Green Infrastructure

"Green infrastructure" is a relatively new and flexible term, and it has been used differently in different contexts. However, for the purposes of EPA's efforts to implement the Green Infrastructure Statement of Intent, EPA intends the term "green infrastructure" to generally refer to systems and practices that use or mimic natural processes to infiltrate, evapotranspirate (the return of water to the atmosphere either through evaporation or by plants), or reuse stormwater or runoff on the site where it is generated. Green infrastructure can be used at a wide range of landscape scales in place of, or in addition to, more traditional stormwater control elements to support the principles of LID.

To learn more about how EPA is promoting green infrastructure to manage wet weather impacts in urban areas, please visit EPA's Green Infrastructure Page. Be sure to read EPA's 2008 Action Strategy for green infrastructure.

NPS Categories

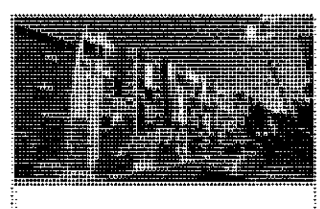
- Abandoned Mine Drainage
- Agriculture
- Forestry
- Hydromodification & Habitat Alteration
- Marinas & Boating
- Roads, Highways & Bridges
- Urban Areas
  - Low Impact Development
- Wetland & Riparian Management

What's New

EPA Releases Section 438 Guidance to Help Federal Facilities Better Manage Stormwater

New Water Quality Scorecard to help municipalities pinpoint and remove barriers to LID.

EPA Releases Video Highlighting Green Builders in Philadelphia



Building Green: A Success Story in Philadelphia

For more information visit:

- EPA's Green Infrastructure
- EPA's GreenScapes
- EPA's Stormwater Management at EPA Headquarters
- U.S. Botanic Garden Sustainability

Urban Stormwater Management in the United States

Committee on Reducing Stormwater Discharge Contributions to Water Pollution

Water Science and Technology Board

Division on Earth and Life Studies

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PREPUBLICATION

The unit process that is managed is the amount of impervious cover, which is strongly related to various residential and commercial zoning categories (Cappiella and Brown, 2000). Numerous techniques exist to forecast future watershed impervious cover and its probable impact on the quality of aquatic resources (see the discussion of the Impervious Cover Model in Chapter 3; CWP, 1998a; MD DNR, 2005). Using these techniques and simple or complex simulation models, planners can estimate stormwater flows and pollutant loads through the watershed planning process and alter the location or intensity of development to reduce them.

The level of control that can be achieved by watershed and land-use planning is theoretically high, but relatively few communities have aggressively exercised it. The most common application of downzoning has been applied to watersheds that drain to drinking water reservoirs (Kitchell, 2002). The strength of this practice is that it has the potential to directly address the underlying causes of the stormwater problem rather than just treating its numerous symptoms. The weakness is that local decisions on zoning and Smart Growth are reversible and often driven by other community concerns such as economic development, adequate infrastructure, and transportation. In addition, powerful consumer and market forces often have promoted low-density sprawl development. Communities that use watershed-based zoning often require a compelling local environmental goal, since state and federal regulatory authorities have traditionally been extremely reluctant to interfere with the local land-use and zoning powers.

Conservation of Natural Areas

Natural-area conservation protects natural features and environmental resources that help maintain the predevelopment hydrology of a site by reducing runoff, promoting infiltration, and preventing soil erosion. Natural areas are protected by a permanent conservation easement prescribing allowable uses and activities on the parcel and preventing future development. Examples include any areas of undisturbed vegetation preserved at the development site, including forests, wetlands, native grasslands, floodplains and riparian areas, zero-order stream channels, spring and seeps, ridge tops or steep slopes, and stream, wetland, or shoreline buffers. In general, conservation should maximize contiguous area and avoid habitat fragmentation.

While natural areas are conserved at many development sites, most of these requirements are prompted by other local, state, and federal habitat protections, and are not explicitly designed or intended to provide runoff reduction and stormwater treatment. To date, there are virtually no data to quantify the runoff reduction and/or pollutant removal capability of specific types of natural area conservation, or the ability to explicitly link them to site design.

Impervious Cover Reduction

A variety of practices, some of which fall under the broader term "better site design," can be used to minimize the creation of new impervious cover and disconnect or make more permeable the hard surfaces that are needed (Nichols et al., 1997; Richman, 1997; CWP, 1998a). A list of some common impervious cover reduction practices for both residential and commercial areas is provided below.

Elements of Better Site Design: Single-Family Residential

- Maximum residential street width
- Maximum street right-of-way width
- Swales and other stormwater practices can be located within the right-of-way
- Maximum cul-de-sac radius with a bioretention island in the center
- Alternative turnaround options such as hammerheads are acceptable if they reduce impervious cover
- Narrow sidewalks on one side of the street (or move pedestrian pathways away from the street entirely)
- Disconnect rooftops from the storm-drain systems
- Minimize driveway length and width and utilize permeable surfaces
- Allow for cluster or open-space designs that reduce lot size or setbacks in exchange for conservation of natural areas
- → Permeable pavement in parking areas, driveways, sidewalks, walkways, and patios

Elements of Better Site Design: Multi-Family Residential and Commercial

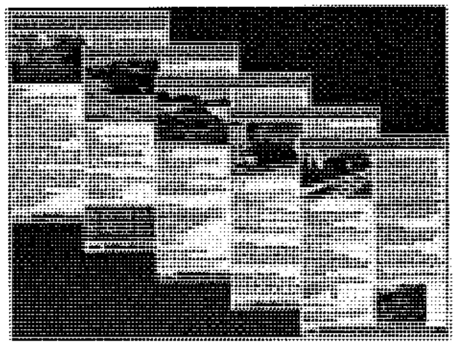
- Design buildings and parking to have multiple levels
- Store rooftop runoff in green roofs, foundation planters, bioretention areas, or cisterns
- Reduce parking lot size by reducing parking demand ratios and stall dimensions
- Use landscaping areas, tree pits, and planters for stormwater treatment
- → Use permeable pavement over parking areas, plazas, and courtyards

CWP (1998a) recommends minimum or maximum geometric dimensions for subdivisions, individual lots, streets, sidewalks, cul-de-sacs, and parking lots that minimize the generation of needless impervious cover, based on a national roundtable of fire safety, planning, transportation and zoning experts. Specific changes in local development codes can be made using these criteria, but it is often important to engage as many municipal agencies that are involved in development as possible in order to gain consensus on code changes.

At the present time, there is little research available to define the runoff reduction benefits of these practices. However, modeling studies consistently show a 10 to 45 percent reduction in runoff compared to conventional development (CWP, 1998b,c, 2002). Several monitoring studies have documented a major reduction in stormwater runoff from development sites that employ various forms of impervious cover reduction and LID in the United States and Australia (Coombes et al., 2000; Philips et al., 2003; Cheng et al., 2005) compared to those that do not.

Unfortunately, better site design has been slowly adopted by local planners, developers, designers, and public works officials. For example, although the project pictured in Figure 5-6 has been very successful in terms of controlling stormwater, the better-site-design principles used have not been widely adopted in the Seattle area. Existing local development codes may discourage or even prohibit the application of environmental site design practices, and many engineers and plan reviewers are hesitant to embrace them. Impervious cover reduction must be incorporated at the earliest stage of site layout and design to be effective, but outdated development codes in many communities can greatly restrict the scope of impervious cover reduction (see Chapter 2). Finally, the performance and longevity of impervious cover reduction are dependent on the infiltration capability of local soils, the intensity of development, and the future management actions of landowners.

STORMWATER



Low Impact Development
Stormwater Best Management Practices

CRWA is building a database of information on techniques and methods used to manage stormwater. One area where CRWA has been focusing a great deal of our research is on low impact development (LID) stormwater best management practices (BMPs) which capture and treat stormwater prior to its entry into local surface waterways. The conveyance of untreated stormwater into the Charles River and its tributaries continues to cause regular water quality violation throughout the watershed. CRWA is advocating communities and private developers throughout the watershed to look for every opportunity to capture, treat and infiltrate stormwater runoff prior to discharging it to the Charles, many of these techniques are designed to do just that!

To inform municipal officials, developers and watershed residents of some of the LID BMP technologies which may be appropriate for use in the Charles River watershed, CRWA has compiled a set of information sheets on select LID BMPs. Click on the link below to download the latest PDF versions of these documents:

- Permeable Pavement
- Permeable Pavers
- Stormwater Planters
- Vegetated Swales
- Stormwater Wet Ponds
- Green Roofs
- Rain Gardens
- Constructed Stormwater Wetlands
- Stormwater Tree Pits
- Gravel Wetlands

Check out additional LID resources on EPA's website!

If you have any questions or comments on these information sheets, please contact Julie Wood.

Permeable Pavement

Alternative Name: Porous Pavement
Types: Porous Concrete, Porous Asphalt

DESCRIPTION

Permeable pavement allows rain water and snow melt to infiltrate through it to be filtered and recharged into the ground as groundwater. Permeable pavement is asphalt or concrete mixed with fewer fine particles to create more air space which allows water to permeate through it. An underlying layer of fine sediment filters water and below it a bed of uniform-grade stones stores water as it infiltrates into the ground. Permeable pavement is ideal for use in parking lots, walkways and low-traffic roadways. Areas that are paved with traditional, non-permeable pavement are a significant source of polluted stormwater runoff. The use of permeable pavement can greatly decrease stormwater runoff.

BENEFITS

Overall

- Reduces stormwater runoff volume, flow rate and temperature
- Increases groundwater infiltration and recharge
- Provides local flood control
- Treats stormwater runoff
- Improves quality of local surface waterways
- Reduces soil erosion
- Reduces the need for traditional stormwater infrastructure and can reduce overall project cost
- Extends life of paved area in cold climates due to less cracking and buckling from freezing and thawing
- Reduces the need for salt and sand use during the winter due to low/no black ice development
- Increases traction when wet

Pollutant Removal

As water permeates through the porous pavement system and into the ground, pollutants are mainly captured within the paver system and the uppermost layers of underlying soil. Permeable pavement can be very effective at eliminating many pollutants that are of concern in the Charles River watershed:

- Total Suspended Solids: 85% – 95%
- Total Phosphorus: 65% – 85%
- Total Nitrogen: 80% – 85%
- Nitrate (as N): 30%
- Metals: 98%[5, 6]

Volume Attenuation/Flow Reduction

Permeably paved areas are typically designed to infiltrate runoff from at least a two-year storm; therefore runoff will be reduced by 100% for most rainstorms. Permeably paved areas generally infiltrate 70% - 80% of annual rainfall.[5]

MAINTENANCE

Needs and Frequency

Permeable pavement needs to be vacuum swept three to four times a year to prevent pores from becoming clogged and precluding infiltration.[3]

Cost

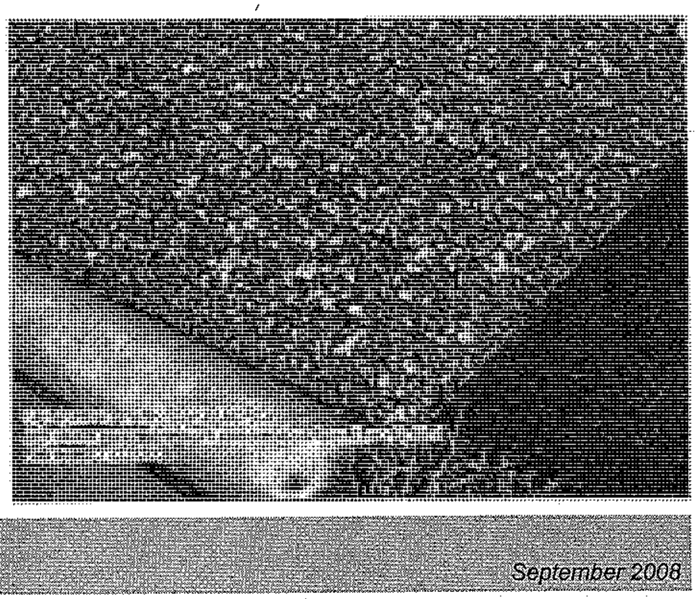
Approximately $400 - $500/year for vacuum sweeping of a half acre parking lot.[3]

Other

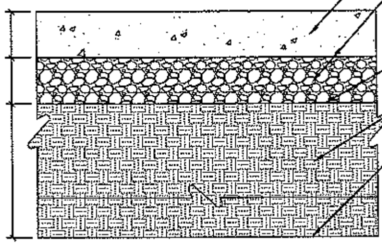
Area will need to be repaved roughly every 15 - 25 years in cold climates.[1, 3]

INSTALLATION COST

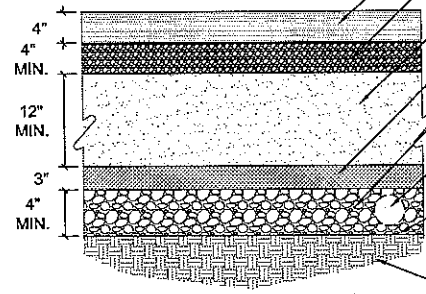
$7 - $15/square foot, including underground infiltration bed.[8] Can reduce overall project cost by eliminating the need for traditional stormwater infrastructure.



SCHEMATICS



Adapted from Porous Concrete
http://perviousconcrete.info
Accessed 01/22/2008



Adapted from Porous Asphalt and Infiltration Bed
http://www.unh.edu/erg/cstev
Accessed 01/22/2008

EXAMPLE PROJECTS

New London Hospital
New London, New Hampshire
Porous concrete was used to pave an employee parking lot to add parking without increasing flooding concerns.[7]

Silver Lake Beach Parking Lot
Wilmington, MA
Porous asphalt was used to pave approximately 16,600 square feet of parking area. Porous asphalt was ideal for this parking area as it abuts Silver Lake, a popular swimming, fishing and boating destination. Porous asphalt provides a sturdy parking surface without increasing polluted stormwater runoff into the lake.[4]

ADDITIONAL CONCERNS OR UNKNOWNS

- Porous pavements are ideally situated on shallow slopes above soils with permeability rates greater than 0.25 inches/hour.
- All permeably paved areas must be equipped with an overflow control structure so that the porous surface never becomes saturated to street level.
- Permeable pavement is not appropriate for areas where spills are likely, such as gas stations or loading docks.
- Proper maintenance is essential to the functionality of permeable pavement. Without proper maintenance, infiltration rates can be significantly reduced.
- Cost to volume of stormwater treated ratio is higher than many other stormwater best management practices.[2]

SOURCES

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[3]Low Impact Development Center (LIDC). (2005, November). Permeable/Porous Pavement. Low Impact Development for Big Box Retailers. Available at: http://www.lowimpactdevelopment.org/bigbox/lid%20articles/bigbox_final_doc.pdf.

[4]Massachusetts Department of Conservation and Recreation (DEP). Demonstration 3 Permeable Paving Materials in a Parking Lot. http://www.mass.gov/dcr/waterSupply/ipswichRiver/demo3-paving.htm.

[5]Milwaukee Metropolitan Sewerage District (MMSD). (2007). State of the Art Report; Chapter 4: Summary of Nonpoint Source Technology Analysis. Available at: http://www.mmsd.com/wqi/.

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[7]Quinton, A. (2007, November 13). Town Planners Look To New Designs to Control Floods. New Hampshire Public Radio Broadcast. Available at: http://www.nhpr.org/node/140608.

[8]Roy, S. (2007). Employee GeoSyntec. Personal Communication.

the SUDBURY ASSABET & CONCORD WILD & SCENIC RIVER STEWARDSHIP COUNCIL

the Rivers | the Organization | the Challenges | the Gallery

Water Quality | Water Quantity | Habitat Protection | Invasive Species Management | Raising Awareness

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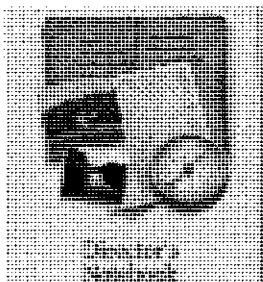
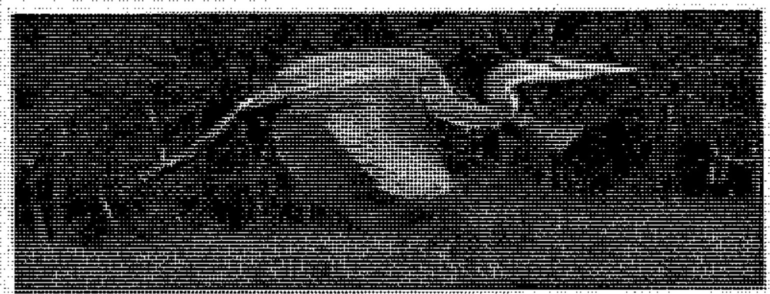


Water Quantity and Flow Protection



The rivers need a certain amount of water, or flow, in order to support aquatic life, wildlife habitat and recreational opportunities. Precipitation, both rain and snow, help 'feed' the stream flow during much of the year. However, at dry times of the year, especially in the summer and early fall, river flow is supplied by groundwater stored in aquifers.

In the metrowest area of Boston, there are strong development pressures and significant growth. This growth has atleast two effects on the aquifers and consequently the rivers. First, more of the land is covered with pavement and buildings which inhibit rain waters from percolating into the groundwater and recharging the aquifers. Second, the increased growth places increased demand on water supplies -- much of which is pumped from groundwater wells. Ultimately, the aquifers become depleted and are unable to provide adequate flow to the rivers.

In recent years, low river flow has been evident in the headwaters of the Sudbury River and tributaries of the Assabet River. Anecdotal information infers that the low flows are caused by less water in the aquifer, although this will not be verified until scientific studies are completed.

On the Assabet River, OAR has initiated, Streamwatch, a program to monitor the tributaries of the Assabet River to determine what happens to water levels during the year and what the impacts are on fish and habitat. For more information click on here.

On the Sudbury River, the United States Geological Survey has begun to study the water flow in the headwaters in order to develop a model which will simulate water behavior, so that alternative water management scenarios may be evaluated. To read the report, visit http://pubs.usgs.gov/sir/2010/5042/.

The RSC provides funding support to local organizations working on these flow issues. In addition, the RSC promotes the use of low impact development techniques in any new project proposals that may affect the river. Low Impact

Development is an approach to environmentally friendly land use planning. It includes a suite of landscaping and design techniques that attempt to maintain the natural, pre-developed ability of a site to manage rainfall. LID techniques capture water on site, filter it through vegetation, and let it soak into the ground where it can recharge the local water table rather than being lost as surface runoff. For more information on LID, click on here.

Most residents of the Sudbury, Assabet and Concord watershed are connected to public water supplies. It is the cumulative effect of each homeowner's water use that results in the growing demand for water, and increased pumping of ground water from water supply wells. Did you know that landscaping is by far the largest water consumer in the home, and in many cases lawn watering uses public water supplies? Most of this water does not return to the groundwater, as many may think, but is consumed by the grasses and/or evaporates to the atmosphere.

Massachusetts DEP has recently issued new guidelines to public water suppliers intended to reduce the amount of water used by residents and limit non-essential uses, such as lawn watering, in the summer. The guidelines will require residential water use to be no more than an average of 65 gallons per person per day -- many of the wild and scenic shoreline communities have average water use rates between 75 and 85 gallons per capita per day (in 2006). The new policy also suggests a ratio of summer and winter water use -- an effort to decrease the amount of water used for lawn watering in the summer.

The RSC has initiated an education campaign to alert the public to the connection between water use, the impacts on our rivers and what individuals can do to make a difference. The effort highlights 'water-wise' lawn care methods, as well as other changes individuals can make in their homes to reduce water use. To learn more about lawn care click on LAWN CARE SECTION. Many communities are proactively addressing this issue as well -- visit http://www.concordnet.org/dpw/index.html for extensive information for homeowners. This website also includes a program to help individuals estimate their water use.

These issues are not unique to the Sudbury, Assabet and Concord River; they are becoming more significant on many of the rivers in Massachusetts, especially those in the eastern part of the State. A number of organizations are creating and compiling resources to help address these issues.

- Massachusetts Audubon Society has created a river toolkit which can be viewed at http://www.massaudubon.org/rivers/index.php
- The Massachusetts Riverways Programs has developed the pilot River Instream Flow Stewards (RIFLS) to help local groups identify, document and restore rivers and streams suffering from abnormally low flows. Through this process, citizens and local officials will learn about the importance of healthy streamflow, work together to restore more natural flow regimes, and establish high quality streamflow data records for local, regional and state uses. For more information, please visit the RIFLS web page.
- Massachusetts Executive Office of Environmental Affairs has developed a Smart Growth Tool Kit. Smart growth techniques support well-planned development that protects open space and farmland, revitalizes communities, keeps housing affordable and provides more transportation choices. For more information please click on http://www.mass.gov/envir/smart_growth_toolkit/.

What you can do to help?

- Calculate how much water you use in your home. How close are you to 65 gallons per person per day that the State recommends? Visit Tampa's Water Calculator to help determine how much you use.
- Calculate the difference between your summer and winter water use. This will help to estimate how much water you use on your lawn and garden. Lawn watering is the largest use of .Visit the LAWN SECTION to learn many ways to minimize water use on your lawn.
- Minimize the amount of lawn in your yard. Utilize native plants and

xeroscaping techiniques. See some example garden templates at Concord's website.
- Install water saving devices in your home, including low flow showerheads, low flow toilets, rain barrels and cisterns.

the SUDBURY ASSABET & CONCORD WILD & SCENIC RIVER STEWARDSHIP COUNCIL

The Concord, Assabet, & Sudbury Wild & Scenic River Stewardship Council • 15 State Street • Boston, MA 02109

STORMWATER MANAGEMENT BYLAW REGULATIONS
Town of Sudbury, MA
Adopted September 9, 2009

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a. The design of the project shall, to the maximum extent feasible, employ environmentally sensitive site design as outlined in the DEP handbook and shall attempt to reproduce natural hydrologic conditions with respect to ground and surface waters.

b. Evaluation of Low Impact Development practices is required and implementation of such practices is required, to the maximum extent practicable and where it provides a substantially equivalent alternative. Guidance on these practices is provided in Appendix D and the MA Stormwater Management Handbook.

c. The Stormwater Management Plan shall incorporate source controls of contaminants and employ Best Management Practices (BMPs) to minimize stormwater pollution.

d. The water quality volume for sizing of BMPs shall be based on 1-inch of runoff from the tributary area.

e. Hydrologic analyses using TR-55/TR-20 methodology shall be performed on the entire project site and include any off site areas that drain to or through the project site.

f. The analyses shall be analyzed for the 1 inch, and the 2, 10, 25 and 100-year design storms under pre-development and post-development conditions. The 24-hour rainfall amounts for the 2, 10, 25 and 100 year storms are to be based on the Northeast Regional Climate Center "Atlas of Precipitation Extremes for the Northeastern United States and Southeastern Canada." For Sudbury, the 24 hr rainfall amounts are as follows (rounded to the nearest one-tenth of an inch):
   2 yr, 24 hr event = 3.2 inches
   10 yr, 24 hr event = 4.8 inches
   25 yr, 24 hr event = 6.0 inches
   100 yr, 24 hr event = 8.6 inches

g. The analysis is to be performed on a pre and post sub-watershed basis with designated control points at each location where runoff leaves the site.

h. The same land area shall be used in the analysis to facilitate comparison of existing and proposed conditions.

i. The total volume of discharge as well as peak rate shall be evaluated at each control point.

j. Redevelopment Standards: Projects involving redevelopment of existing sites shall be designed in accordance with the redevelopment checklist provided in the latest MA Stormwater Handbook All redevelopment projects must provide a net improvement to stormwater conditions at the site, either in the area of disturbance or to other areas on the site. The Planning Board or its designated Reviewing Agent may require improvements to areas outside of disturbance activity where known problems exist and reasonable solutions are available. Such opportunities might include:
   - Reduce impervious surfaces
   - Implement source controls of potential stormwater pollutants on the entire site
   - Reroute drainage to maximize treatment efficiencies
   - Segregate roof runoff for direct infiltration or capture and re-use.
   - Update Operation and Maintenance plans and procedures for the entire site

4. Water Reuse/Water Conservation: In order to conserve potable water supplies and maximize recharge, it may be appropriate on some sites to store and reuse clean runoff (e.g. from roofs) for reuse on the site for irrigation or other graywater purposes. This can be accomplished through the use of cisterns and rain barrels. Where appropriate, a water budget may be required to be prepared to determine applicability.

5. Landscape Design

a. Landscape designs shall be developed based on soil, light and other site specific conditions. Plant species shall be chosen for their ability to thrive in the post-development soil, water and use conditions of the site without significant supplemental water or fertilizer, once established.

b. Plant species shall be native to inland Middlesex County or shall be cultivars of these native species.

3. Description of the following in narrative, calculations or drawings, as appropriate:

   a. Estimates of the total area expected to be disturbed by excavation, grading, or other construction activities, including dedicated off-site borrow and fill areas;

   b. All pollution control measures (structural and non-structural BMPs) that will be implemented as part of the construction activity to control pollutants in storm water discharges. Appropriate control measures must be identified for each major construction activity and the operator responsible for the implementation of each control measure must also be identified.

   c. The intended sequence and timing of activities that disturb soils at the site and the general sequence during the construction process in which the erosion and sediment control measures will be implemented;

   d. Structural practices to divert flows from exposed soils, retain/detain flows or otherwise limit runoff and the discharge of pollutants from exposed areas of the site. Placement of structural practices in floodplains must be avoided to the degree practicable;

   e. Interim and permanent stabilization practices for the site, including a schedule of when the practices will be implemented. Site plans should ensure that existing vegetation is preserved where possible and that disturbed portions of the site are stabilized. Use of impervious surfaces for stabilization should be avoided;

   f. Construction and waste materials expected to be stored on-site with updates as appropriate, including descriptions of controls, and storage practices to minimize exposure of the materials to stormwater, and spill prevention and response practices;

   g. Measures to minimize, to the extent practicable, off-site vehicle tracking of sediments onto paved surfaces and the generation of dust;

   h. Measures to prevent the discharge of solid materials, including building materials, to waters of the United States, except as authorized by a permit issued under Section 404 of the CWA;

   i. Pollutant sources from areas other than construction and a description of controls and measures that will be implemented at those sites to minimize pollutant discharges; and

   j. Proposed dewatering operations including proposed locations of discharge.

4. An Operation and Maintenance Schedule for structural and non-structural measures, interim grading, and material stockpiling areas;

5. Stamp and signature of a Professional Engineer (PE) licensed in the Commonwealth of Massachusetts to certify that the Stormwater Management Plan is in accordance with the criteria established in the Stormwater Management Bylaw and these Regulations.

6. Any other information required by the Planning Board or its designated Reviewing Agent.

APPENDIX D: LOW IMPACT DEVELOPMENT PRACTICES

Low Impact Development (LID) strategies use careful site design and decentralized stormwater management to reduce the environmental footprint of new growth. This approach improves water quality, minimizes the need for expensive pipe and pond stormwater systems, and creates more attractive developments. The following are LID strategies and various benefits of implementation.

1. Bioretention cells, commonly known as rain gardens, are relatively small-scale, landscaped depressions containing plants and a soil mixture that absorbs and filters runoff.

   Management Objectives:
   - Provide quality treatment.
   - Remove suspended solids, metals, nutrients.
   - Increase groundwater recharge through infiltration.
   - Reduce peak discharge rates and total runoff volume.

2. Green roofs are roof-tops partially or completely covered with plants. Used for decades in Europe, green roofs help mitigate the urban "heat island" effect.

   Management Objectives:

   - Reduce total runoff volume through rainwater storage and evapotranspiration.
   - Reduce peak discharge rates
   - Reduce heating and cooling costs through roof insulation.
   - Extend roof life.

3. Permeable and porous pavements allow water to soak through the paved surface into the ground beneath. Permeable pavement encompasses a variety of mediums including: porous concrete and asphalt, plastic grid systems and interlocking paving bricks.

   Management Objectives:

   - Reduce stormwater runoff volume from paved surfaces
   - Reduce peak discharge through infiltration.
   - Reduce pollutant transport through direct infiltration
   - Improve site landscaping benefits (grass pavers)

4. Grass swales are broad, open channels sown with erosion resistant and flood tolerant grasses. This has been used alongside roadways for years.

   Management Objectives:

   - Provide water quality treatment; remove suspended solids; heavy metals, trash.
   - Reduce peak discharge rate and total runoff volume.
   - Infiltrate water into the ground.
   - Provide a location for snow storage.

5. Infiltration Trenches and Dry Wells Dry wells are standard stormwater management structures that store water in the void space between crushed stone or gravel; the water slowly percolates downward into the subsoil.

   Management Objectives:

   - Remove suspended solids, heavy metals trash, oil, and grease.
   - Reduce peak discharge rate and total runoff volume.
   - Provide modest infiltration and recharge
   - Provide snow storage areas

6. Grass Filter Strips are low-angle vegetated slopes designed to treat sheet flow runoff from adjacent impervious areas.

   Management Objectives:

   - Remove suspended solids, heavy metals, trash, oil and grease.
   - Reduce peak discharge rate and total runoff volume.
   - Provide modest infiltration and recharge.
   - Provide snow storage areas.

7. Roadway and Parking Lot Design:

   Management Objectives:

History

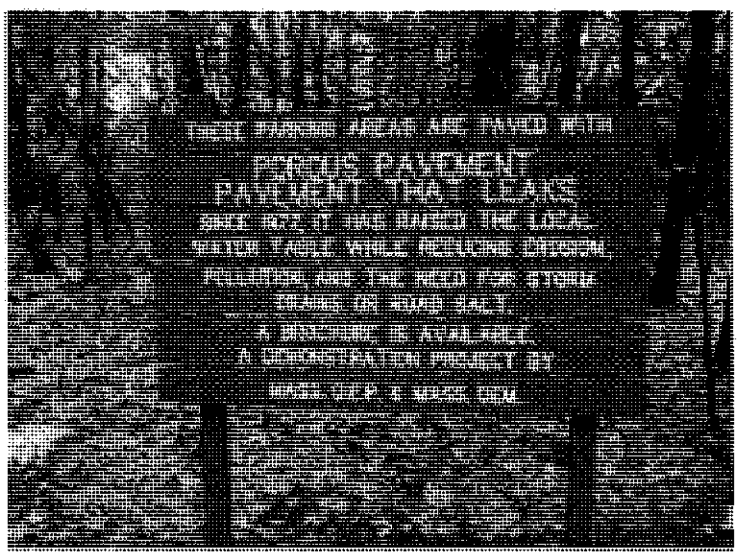
In the late 1960s, the concept of porous pavement was proposed to "promote percolation, reduce storm sewer loads, reduce floods, raise water tables, and replenish aquifers." Throughout the 1970s, the concept was discussed and refined to a point where the Environmental Protection Agency (EPA) contracted to "determine the capabilities of several types of porous pavements for urban runoff control, in terms of cost and efficiency."

Some of the initial installations of porous asphalt pavement were in Delaware, Pennsylvania, and Texas. The Woodlands site in Texas, which was constructed under an EPA grant, was the only site where substantial scientific monitoring instrumentation was installed in these early days. Today many sites around the country are being monitored by academic institutions.

In 1977, Edmund Thelen and L. Fielding Howe co-authored a design guide for porous pavement for the Franklin Institute in Philadelphia. This document has been widely referenced in subsequent years and provides a solid foundation for porous pavement designers. Click **here** to download a copy.

Many additional porous pavement sites have been constructed since the late 1970s. While there have been both successes and failures, the overwhelming majority have succeeded. Where porous pavements have failed, the reason cited most often was that silts and other fine material were allowed to enter the site uncontrolled, essentially clogging the pavement. Cahill Associates has been involved in the design and construction of more than 200 porous asphalt pavements since the 1980s and have reported no failures of pavements for which proper design and construction practices were followed.

Some of the benefits conferred by the successful installations include runoff control, aquifer recharge, reduction of drainage structures needed to comply with stormwater regulations, and increased skid resistance.



One of the earliest examples of a porous asphalt pavement is the parking lot for the visitor center at Walden Pond State Reservation in Massachusetts, which was constructed in 1977. This photo was taken in 2008.

Close Window

Great Bay Discovery Center, Greenland, NH

__Innovative BMPs__: **Porous Asphalt, Pervious Concrete, Permeable Pavers (AquaBrick and EcoStone), Raingarden.**

Asphalt Binder Type: PG64-28 with 5 lbs/ton of polyfibers added, 1-lift installation.
Concrete: water/cement ratio 0.28
Admixtures: Hydrator: DELVO®
Strength agent: PolyHead® 1025
Plasticizer: Rheomac® VMA 362
Compressive strength: ~3000 psi
Terra-cotta dye for color
Curing Time: PC and PA = 7 days

Description: LID Retrofit of an existing gravel parking area using environmentally sensitive site design and a combination of LID structural controls.

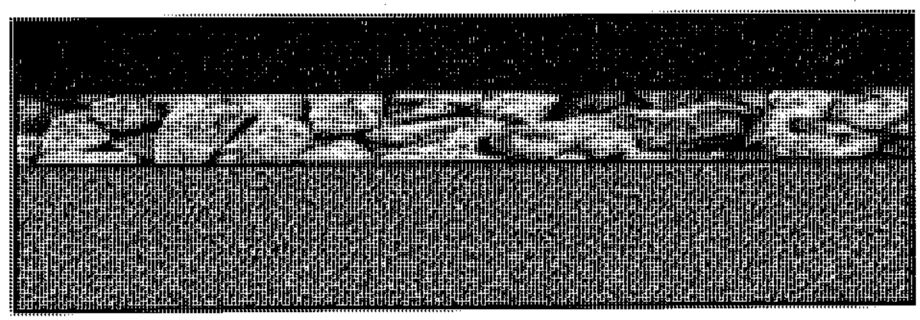
Reduced effective impervious cover (EIC) by ~20,000 sf which includes nearly all parking and pedestrian surfaces

Site Pavement Cross-Section

4" Porous Asphalt

4" Choker

Native Soil > 10 in/hr



UNIVERSITY OF NEW HAMPSHIRE STORMWATER CENTER

UNIVERSITY OF NEW HAMPSHIRE
STORMWATER CENTER

Greenland Meadows
LID Case Study: Water Quality

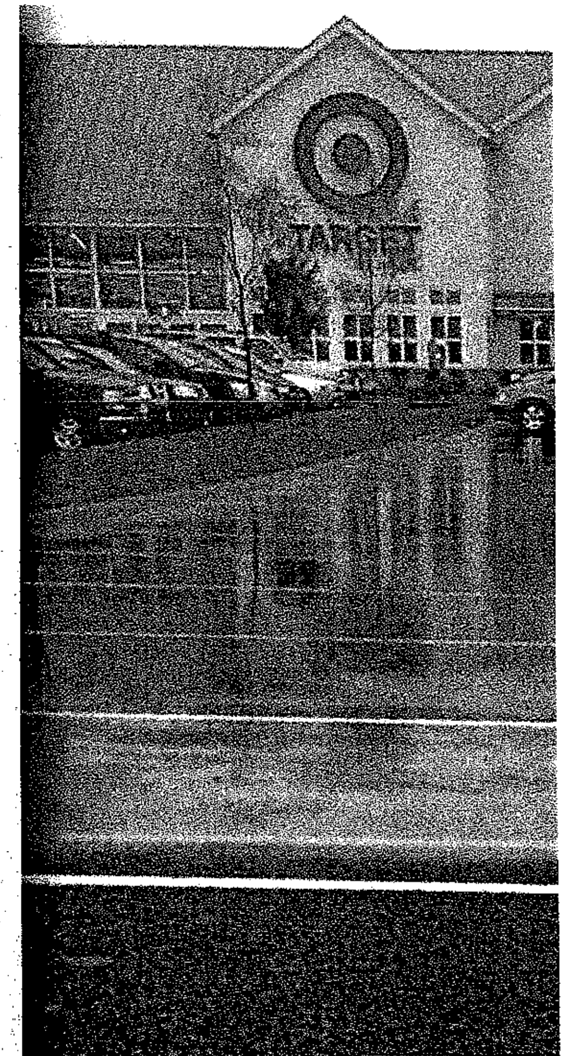
Greenland Meadows is a retail shopping center built in 2008 by Newton, Mass.-based New England Development in Greenland, N.H.

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.

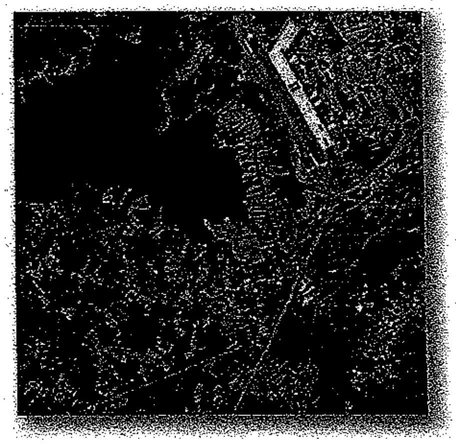
The total impervious area of the development – mainly from rooftops and non-porous parking areas – is approximately 25.6 acres, considerably more as compared to pre-development conditions. Prior to this development, the project site contained an abandoned Sylvania light bulb factory with the majority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

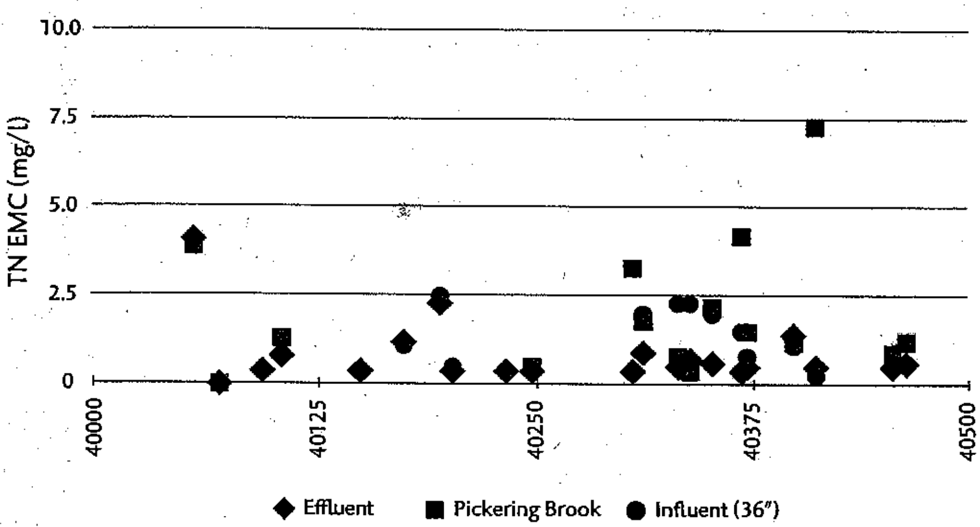
Runoff from the sand filter, which itself provides extended detention and filtration, flows through perforated underdrain pipes that converge to a large gravel wetland on the west side of the site. The gravel wetland is designed as a series of flow-through treatment cells providing an anaerobic system 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

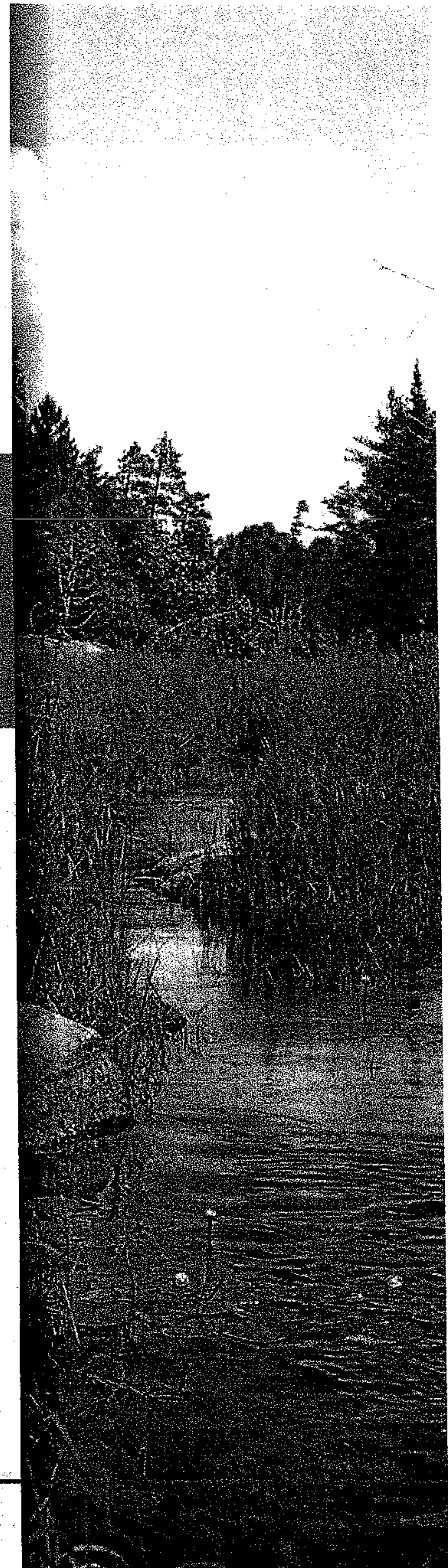
A four-phase wet weather flow monitoring program involving the use of automated samplers was implemented at the Greenland Meadows site in order to assess background conditions for Pickering Brook, evaluate stormwater quality runoff from the project site, and determine the resultant water quality of Pickering 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.

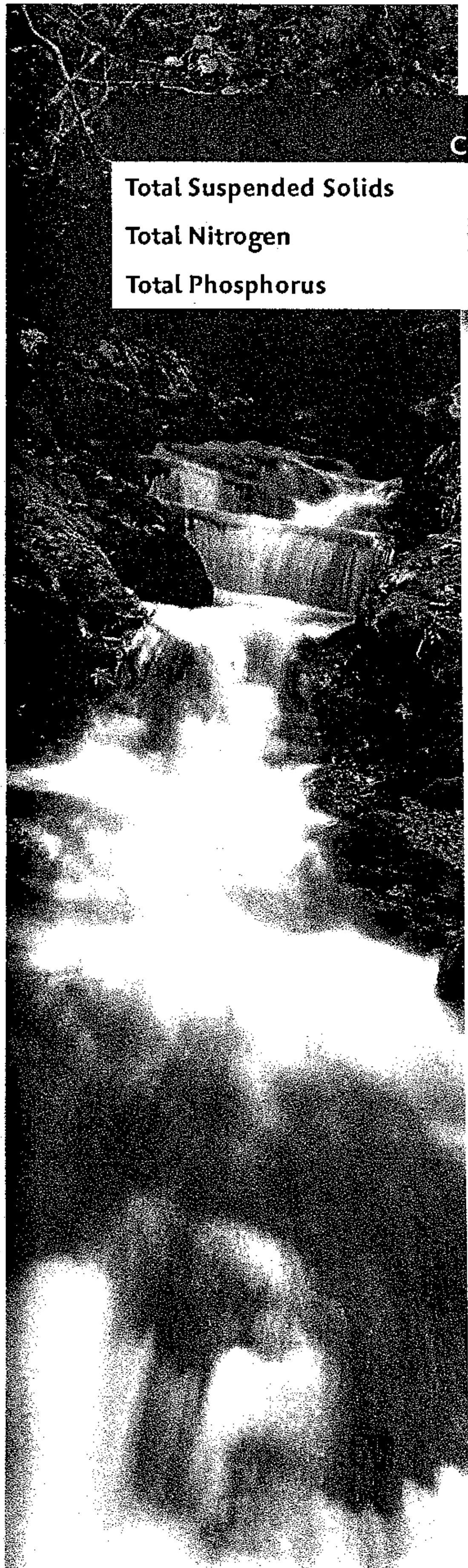
The first three phases of monitoring were completed between July of 2007 and October 2010 and included:

- 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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