EAST LYME ZONING COMMISSION
SPECIAL MEETING
Thursday, FEBRUARY 1st, 2007
MINUTES

The East Lyme Zoning Commission held a Special Meeting presentation on Storm water on February 1st, 2007 at Town Hall, 108 Pennsylvania Avenue, Niantic, CT.

PRESENT: Mark Nickerson, Chairman, Rosanna Carabelas, Secretary, Marc Salerno, Ed Gada, Norm Peck

ALSO PRESENT: Bruce Morton, Speaker from Aqua Solutions LLC
Michael Giannattasio, Public Works Director
Bill Scheer, Town Engineer
Bob Bulmer, Alternate
Joe Barry, Alternate
William Mulholland, Zoning Official

FILED IN EAST LYME TOWN CLERK'S OFFICE
Feb 9 2007 at 1:35 PM
Esther B Williams
EAST LYME TOWN CLERK

ABSENT: Pamela Byrnes, William Dwyer, Alternate

Presentation:
The East Lyme Zoning Commission will host a presentation from Bruce Morton of Aqua Solutions LLC, on Ecosystem Management on the Jordan Cove Water Shed project in Waterford and a brief presentation on storm water by the East Lyme Director of Public Works.

Pledge of Allegiance
The Pledge was observed.

Chairman Nickerson called this Special Meeting to order at 6:35 PM. The Commission members seated themselves in the audience for this presentation. Mr. Nickerson introduced Bruce Morton.

Bruce Morton of Aqua Solutions passed out some new brochures on the Jordan Cove project and on permeable pavers. He said that they could see this project over in Waterford and that it has been a really nice project to work on. They had to present it to the Planning and Zoning Commission in Waterford and Conservation and that all of the approvals were obtained ten years ago to do this project. It is now ten years old and they are looking at how it has evolved. At the time that it was done, the Town of Waterford wanted it in their Town and worked with them on this project. He said he would do the short slide presentation.
The site - Giovanni Drive in Waterford was a gravel pit and former chicken farming area which allowed for 'real world' monitoring of the watershed. The land was privately owned by the developer (Lombardi) and was a public/private partnership that worked. They employed BMP's – Best Management Practices with an LID – Low Impact Development oriented towards storm water which is only a small part of the Smart Growth program.

One of the project goals was to keep Peak Volume flow the same in pre and post development. The Jordan Cove subdivision has a central road leading in that goes from the 28' standard to 24' in width. It is comprised of all single family homes. They designed a unique cul-de-sac that pulled the houses closer to the front to allow for more open space in the back. They employed conservation areas and natural swales to control and treat water run-off. The grassed swales not only worked – but worked well. They also employed the use of rain gardens and used permeable pavers that have spaces in-between them for better infiltration.

Ms. Carabelas asked how they held up for plowing of snow and during heavy rain periods.
Mr. Morton said that they held up well and that the basic maintenance involved filling in the areas that had worn out or settled between the pavers. He noted that one problem they found that they had was when the

hydrants were flushed that the spray of the water with the intensity that it came out in the swath that it covered, 'flushed' out the material between the pavers. They have since worked with the Town on this issue.

Mr. Morton said that they also tried to control pets in the project area although they found that people came from other areas to walk their pets and they have advised that pet waste needs to be picked up as it is a source of bacteria in residential areas.

Mr. Peck asked if this project could be done almost anywhere or if there is a need for a certain soil type and other considerations.
Mr. Morton said that it could be done anywhere. He added that this project had 10-year deed restrictions that stated that the swales and rain gardens had to be maintained; that they had to restrict impervious surface additions and maintain the conservation zone and low-mow area. He said that during heavy rain periods that the run-off was reduced by these best management practices.

Mr. Salerno asked what the goal of decreased run-off was.
Mr. Morton said that it is to control the upper watershed areas that are recharging. He thanked them for having him and suggested that they visit the NEMO website and the UConn website for more information on smart growth and these practices.

Michael Giannattasio, Town of East Lyme Public Works Director said that the Town looks to retain and treat the first inch of rainfall to try to mitigate the off-site impacts of peak flow. He said that the Town seeks to and does employ Best Management Practices. He cited the qualities of flood control noting that 85-90% of the storm events that we have as 1" rainfall and are treated. They look at retention and infiltration and running the water through swales and other mechanisms as they are looking for 80% of the total suspended solids to be removed. They are also looking for them to be floatable so they can be kept out before they float downstream. They consider aquifer protection and recharge and try to reduce large impervious surfaces so that they can reduce the peak flow and the volume of flow from the surfaces.

Mr. Nickerson asked about a site such as the Starbucks where the water will run off and go into the street –
Mr. Giannattasio said that every piece is different and that residential is much less impervious than commercial. He added that they also look at pollution prevention plans. He said that education is key and also important in talking about this with the end user. Best Management Practices get built into this and they are looking for recharge of clear storm water.

Mr. Nickerson asked about enforcement and who puts this in place.
Mr. Giannattasio and Mr. Mulholland said that it is he and the Zoning Commission as it is tied to the permits and staff reviews the various aspects as necessary.

Bill Scheer, Town Engineer added that at least once a year they try to go to the schools to educate the kids about this and the kids in turn go back to the parents with this information.

Mr. Nickerson and Mr. Mulholland thanked Mr. Morton, Mr. Giannattasio and Mr. Scheer for their presentations.

A brief break was taken here prior to closing this Special Meeting and commencing the Public Hearings and Regular Meeting of the Zoning Commission.

****MOTION (1)**
Ms. Carabelas moved to adjourn this Special Meeting of the East Lyme Zoning Commission at 7:36 PM.
Mr. Gada seconded the motion.
Vote: 6 – 0 – 0. Motion passed.

Respectfully submitted,

Karen Zmitruk,
Recording Secretary

Jordan Cove

URBAN WATERSHED PROJECT

University of Connecticut
College of Agriculture and Natural Resources

www.canr.uconn.edu/jordancove

ABOUT THE PROJECT

THE JORDAN COVE URBAN WATERSHED PROJECT IS LOCATED IN WATERFORD, CONNECTICUT ALONG THE COAST OF LONG ISLAND SOUND. THE STUDY BEGAN IN 1996, AND WAS DESIGNED TO DETERMINE WATER QUANTITY AND QUALITY BENEFITS OF USING POLLUTION PREVENTION BEST MANAGEMENT PRACTICES (BMPS) IN A RESIDENTIAL SUBDIVISION. MONITORING TOOK PLACE FOR 10 YEARS.

Project funding was through the U.S. Environmental Protection Agency's Clean Water Act Section 319 National Monitoring Program, and administered by the Connecticut Department of Environmental Protection, Nonpoint Source Management Program.

This brochure provides prospective developers, contractors, land use commissioners and others with low impact development project planning, study results and recommendations for reducing impacts of residential development on stormwater and runoff quality.

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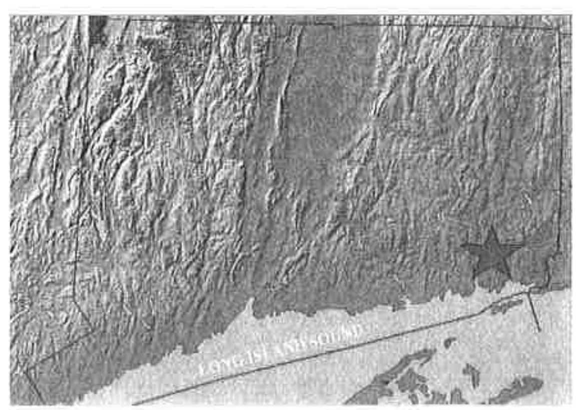
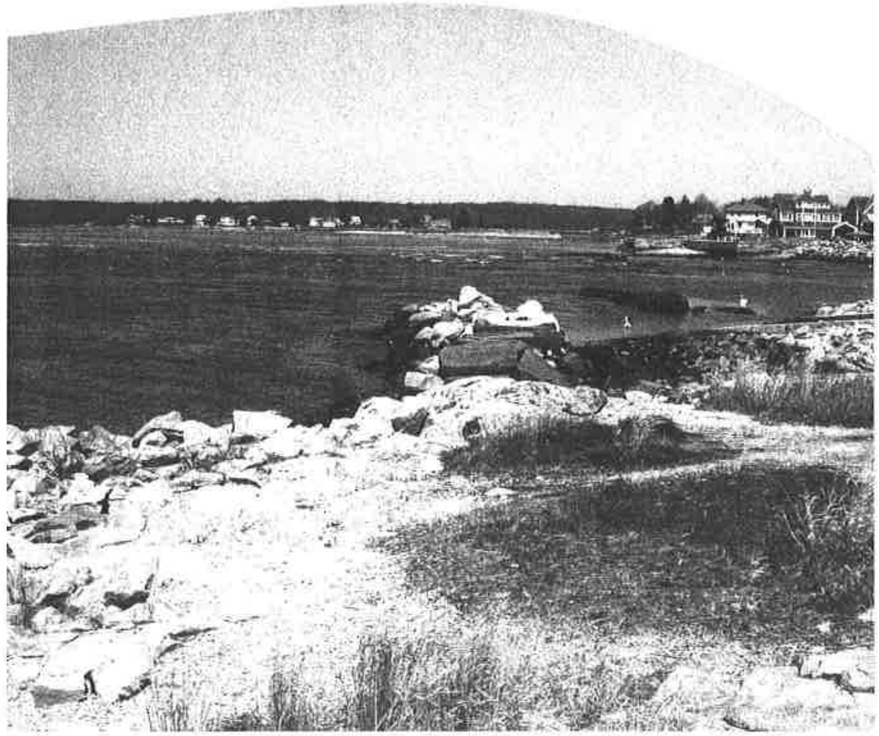


WHAT IS THE PROBLEM? JORDAN COVE IS A SMALL ESTUARY IN LONG ISLAND SOUND FED BY JORDAN BROOK. THE COVE HAS IMPAIRED WATER QUALITY BASED ON FECAL BACTERIA. LONG ISLAND SOUND SUFFERS FROM HYPOXIA RELATED TO EXCESS NITROGEN.



PROJECT GOAL: The key project goal was to measure the effectiveness of urban stormwater best management practices in reducing runoff and protecting water quality.

SPECIFIC OBJECTIVES WERE TO:

1. Reduce sediment, bacteria, nitrogen, phosphorus, and stormwater runoff quantity during and after construction.
2. Demonstrate residential Best Management Practices (BMPs).
3. Evaluate selected BMPs (e.g. driveways, lawn management).

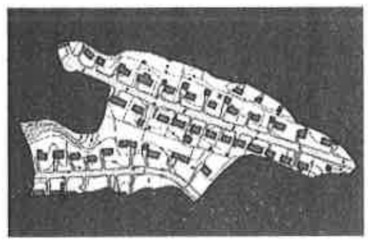
Stormwater Runoff

Runoff from urban areas is a major cause of water pollution throughout the United States. Pollutants can include bacteria, nutrients, sediment and metals. Common sources of pollutants are automobiles, lawn fertilizers, and pet wastes. Accelerated runoff comes from impervious surfaces, such as rooftops, sidewalks, streets, and driveways.

PROJECT DESIGN WAS BASED ON A PAIRED-WATERSHED APPROACH. ONE WATERSHED SERVED AS A CONTROL WHILE THE OTHER IS CALLED A TREATMENT WATERSHED.

CONTROL WATERSHED

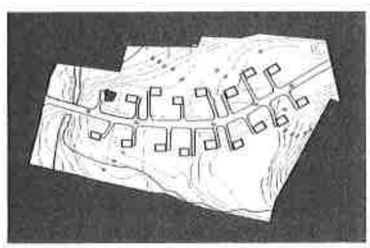
The control watershed was an existing 14 acre residential



watershed containing 43 lots built in 1988 in the same general vicinity of the treatment watersheds. Stormwater runoff was monitored at the outflow of a stormwater pipe at the watershed outlet. This watershed allowed us to adjust for weather differences year-to-year.

TRADITIONAL WATERSHED (TREATMENT)

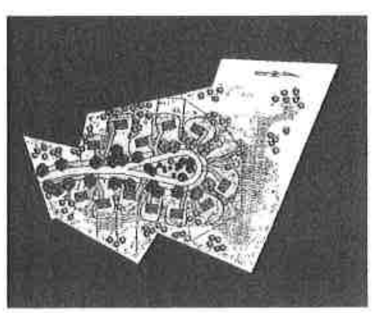
The traditional watershed was five acres in size and now contains 17 residential lots. This watershed was developed



using standard zoning and construction practices. It is accessed by a 24 foot wide asphalt road with typical curb and gutter stormwater conveyance system.

BMP WATERSHED (TREATMENT)

The four acre BMP watershed now contains 12 lots. A cluster approach was used to aggregate homes closer together, leaving more open space in the watershed. Shared driveway entrances reduce imperviousness. Lawn sizes are reduced and low-mow and no-mow areas are designated



to reduce fertilizer and maintenance impacts. The access road is narrower (20 ft.) than typically allowed by ordinance and is constructed of interlocking concrete pavers that allow infiltration.

PRECIPITATION, TEMPERATURE, AND DISCHARGE WERE CONTINUOUSLY RECORDED IN COMPUTERS.

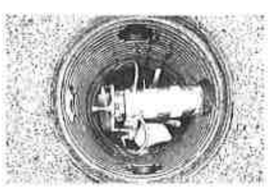
WATER QUALITY CHARACTERISTICS MONITORED USING AUTOMATED SAMPLERS INCLUDE:

- Total suspended solids, total phosphorus, nitrate, ammonia, total Kjeldahl nitrogen, copper, lead, zinc, fecal coliform bacteria, and biochemical oxygen demand.

WHY THESE VARIABLES?

These are common stormwater pollutants:

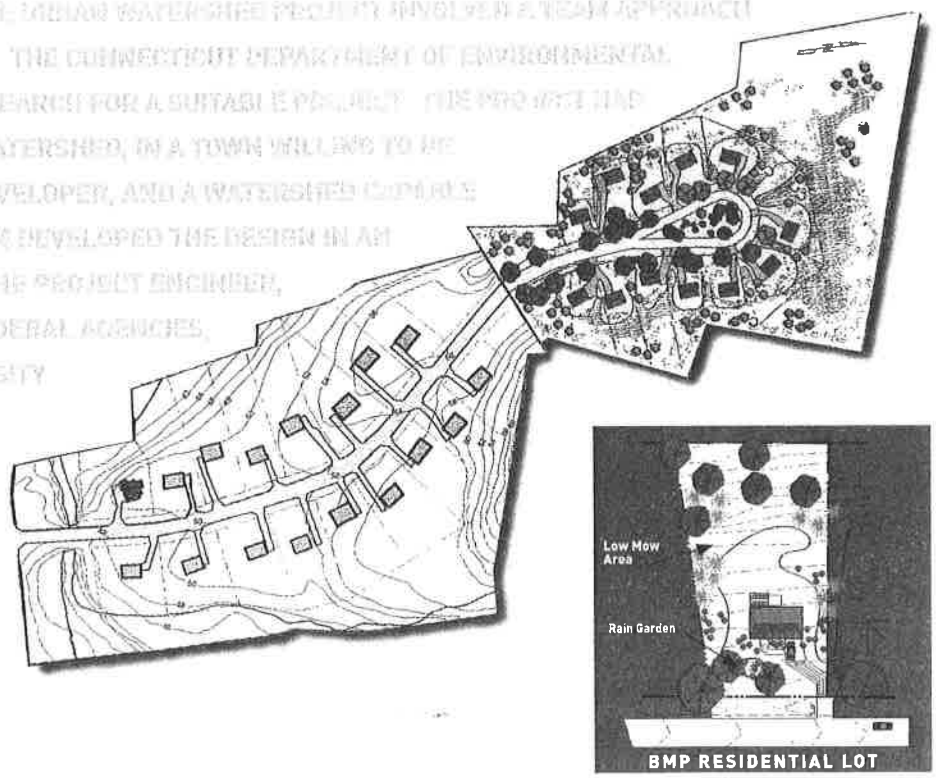
- Suspended solids cloud water and can harm fish habitat.
- Phosphorus and nitrogen stimulate excessive growth of algae; heavy metals can be toxic to aquatic life.
- Bacteria are indicators of potentially harmful pathogens.
- Biochemical oxygen demand can use up oxygen in lakes and rivers.



PROJECT SCHEDULE

Period	Traditional Watershed	BMP Watershed
Calibration Period	1996 - 1998	1996 - 1999
Construction Period	1998 - 2003	1999 - 2002
Post-construction Period	2003-2005	2002-2005

PLANNING FOR THE JORDAN COVE URBAN WATERSHED PROJECT INVOLVED A TEAM APPROACH COMPRISED OF MANY MEMBERS. THE CONNECTICUT DEPARTMENT OF ENVIRONMENTAL PROTECTION LED A STATEWIDE SEARCH FOR A SUITABLE PROJECT. THE PROJECT HAD TO BE LOCATED IN A PRIORITY WATERSHED, IN A TOWN WILLING TO BE INNOVATIVE, WITH A WILLING DEVELOPER, AND A WATERSHED CAPABLE OF BEING MONITORED. THE TEAM DEVELOPED THE DESIGN IN AN INTERACTIVE MANNER AMONG THE PROJECT ENGINEER, TOWN OFFICIALS, STATE AND FEDERAL AGENCIES, AND THE UNIVERSITY. A UNIVERSITY LANDSCAPE ARCHITECT CLASS PROVIDED DESIGN CONCEPTS.



BMP RESIDENTIAL LOT

DEED RESTRICTIONS:

- Maintain swales and rain gardens.
- Restrict impervious additions.
- Maintain conservation zone and low-mow area.

CALIBRATION PERIOD

The calibration period is when baseline data is collected to compare to future monitoring data. Calibration allows year-to-year weather differences to be accounted for in the anaylsis. Calibration was conducted prior to construction.

TECHNICAL MODIFICATIONS OF EXISTING DEVELOPMENT STANDARDS

Consideration	Traditional Design	BMP/Cluster Design	Comments
Waivers needed	Specified materials	Alternative pavement	Must be approved by police and public works
	Typical road width = 28 feet, reduced to 24 feet	Reduced road width to 20 feet for travel lane	Must be approved by police, fire and public works
	Curb required	No curb, grassed swales	Pavers installed to maintain road edge
	90 ft paved cul-de-sac radius	One way cul-de-sac to reduce road width and turn radius, center unpaved	Further reduction in width and less need for snow plowing
Special design/ operational control	Planning and zoning standards	Rain gardens	Retain roof runoff on site.
	Home owner discretion	Vegetative management	Reduces fertilizer use
	Home owner discretion	Domestic animal management	Reduces pathogen runoff
Mitigation required	Road runoff piped to storm sewer		Need to manage stormwater entering site from adjacent public road
	Creation of 13,400 sq ft wetland at subdivision entrance		Required to mitigate filling 5,000 sq ft of wetlands within subdivision
Discretionary actions	R-20 single-family zoning	Cluster and zero setback from lot lines	Allows more open space and natural landscaping
	Open space not contiguous with all lots	Open space layout contiguous to all lots	Compact housing, natural landscaping
	A driveway for each home	Combined driveways	Reduces curb cuts and impervious surface

A BMP IS A PRACTICE DESIGNED TO MINIMIZE NONPOINT SOURCE POLLUTION. BELOW ARE EXAMPLES OF BMPs PRESENT IN THE JORDAN COVE URBAN WATERSHED PROJECT.

Rain Gardens
Each lot contains a rain garden. These shallow depressions are designed to temporarily collect and treat runoff from roofs and yards.

Driveways
Driveways are constructed of different materials (crushed stone, pavers, asphalt) to compare runoff and pollution from them. Most driveways have shared entrances to reduce impervious surfaces.

RAIN GARDENS • OPEN SPACE • SWALES • EDUCATION

Open space
A large portion of the subdivision is dedicated to open space and common usage.

Road
The main road is constructed with concrete pavers. These pavers allow infiltration of water through their open corners, and reduce stormwater runoff.

Swales
Located along the sides of the roadway, these grass-lined channels are intended to slow runoff and allow water to infiltrate into the ground before leaving the subdivision. They replace a curb-and-gutter stormwater collection system.

Cul-de-sac
Another rain garden (bioretention area) is located in the middle of the cul-de-sac. It is designed to collect and filter runoff from the road.

DRIVEWAYS • ROAD • CUL-DE-SAC • PETS

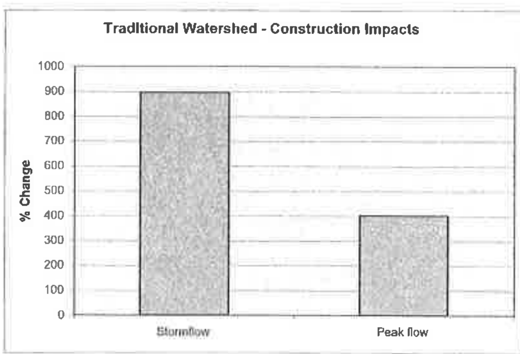
Education
Education programs focused on lawn fertilization and maintenance.

Pets
Pet waste is a large source of bacteria in residential areas. Pet wastes should be picked up and disposed of properly.

Results: Construction

BMPS WORK! BMP STORMWATER RUNOFF WAS MUCH LOWER THAN FROM THE TRADITIONAL WATERSHED DURING CONSTRUCTION.

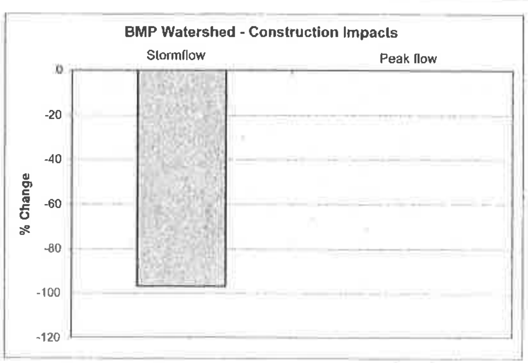
★ Monitoring Locations



RUNOFF

Traditional Watershed

- Runoff volume increased from the Traditional Watershed because of the impervious road and curb and gutter conveyance system.



% change from level expected by calibration.

BMP Watershed

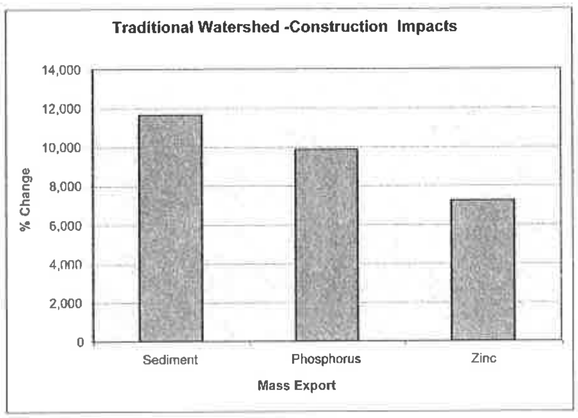
- Runoff volume did not increase from the BMP Watershed because of a berm, swales, pavers, temporary retention basins, and bioretention.

Results: Construction

WATER QUALITY

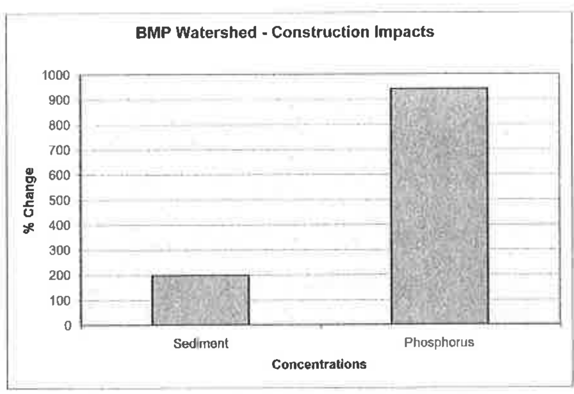
Traditional Watershed

- Concentrations of pollutants in runoff did not increase for the Traditional Watershed because erosion & sediment control practices worked.
- The mass export of pollutants increased for the Traditional Watershed because flow increased.



BMP Watershed

- Concentrations of pollutants in runoff increased for the BMP Watershed because the swales were not stabilized.
- The mass export of pollutants did not increase for the BMP Watershed, except phosphorus and suspended solids, because concentrations of phosphorus and sediment did increase.



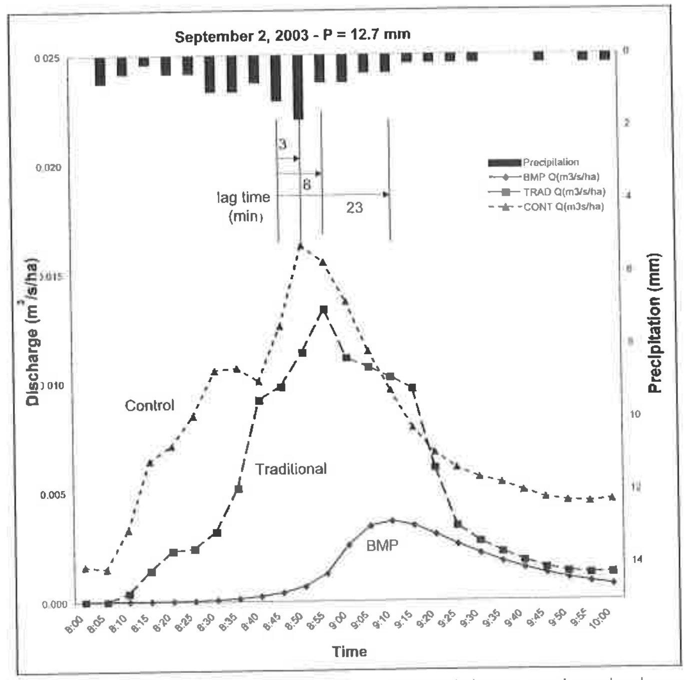
% change from level expected by calibration.

Concentration - the amount of a substance in a liter of water.

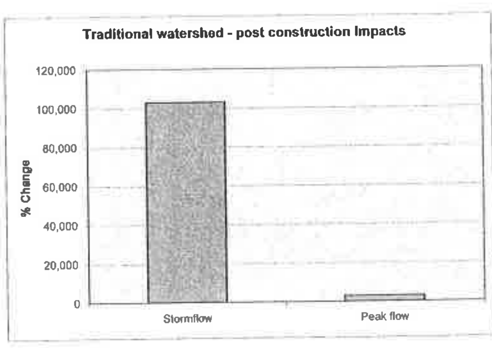
Mass Export - the total mass leaving the site calculated by multiplying the concentration times the runoff amount.

BMPS CONTINUED TO WORK! BMP STORMWATER RUNOFF WAS NOT HIGHER THAN PRE-DEVELOPMENT LEVELS.

Aerial photo taken April 2004.

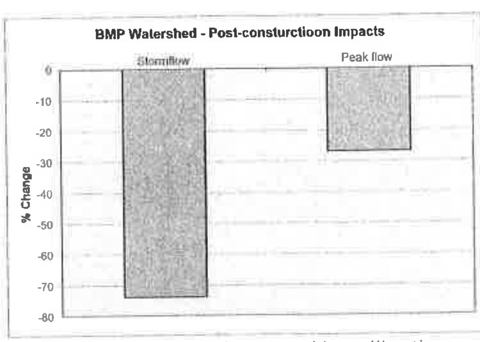


Runoff during this storm in 2003 showed a much lower peak and volume of runoff from the BMP watershed than from the others. The peak was delayed 15 minutes after the peak from the traditional watershed.



Traditional Watershed

- Runoff volume and peak increased from the Traditional Watershed because of the impervious road surface.



% change from level expected by calibration.

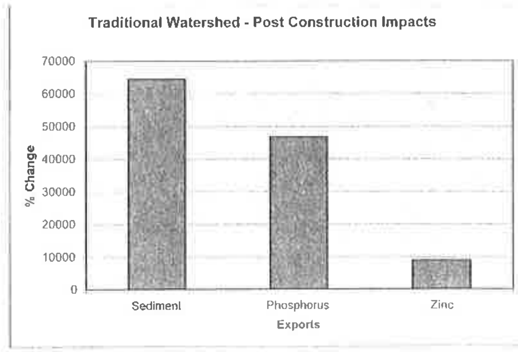
BMP Watershed

- Runoff volume and peak did not increase from the BMP Watershed because of swales, pavers, and bioretention.
- This is the goal of Low Impact Development.

WATER QUALITY

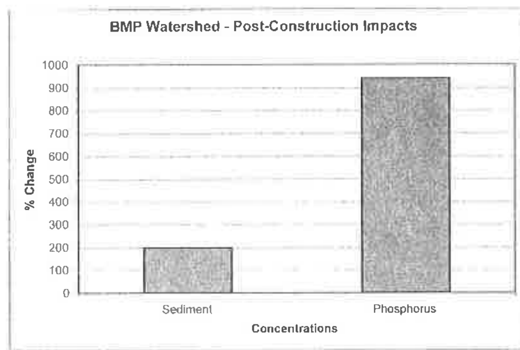
Traditional Watershed

- Concentrations of pollutants in runoff did not increase for the Traditional Watershed because the asphalt road conveys relatively clean water.
- The mass export of pollutants increased for the Traditional Watershed because flow increased.



BMP Watershed

- Concentrations of pollutants in runoff did not increase except for phosphorus and sediment. Sediment was low and below national averages.
- The mass export of pollutants increased for the BMP Watershed for sediment and phosphorus because concentrations increased. However, mass exports were less than from the traditional watershed.



% change from level expected by calibration.

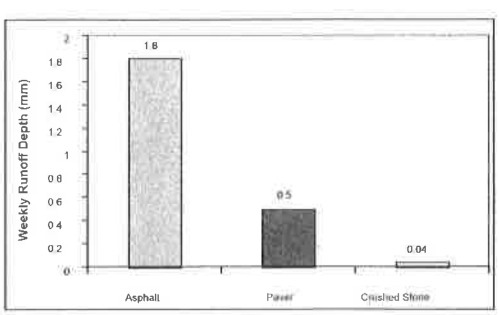
DRIVEWAY STUDY

A study of three driveway types found that both paver and crushed stone driveways could reduce runoff.

asphalt

paver

crushed stone



Runoff from the asphalt driveway was most, followed by the concrete paver driveway, and then the crushed stone driveway.

EDUCATION RESULTS

One-on-one education was not as successful as anticipated. Based on survey results, we learned the following:

- There was no difference in lawn care practices among the three watersheds, including fertilization frequency.
- There were no differences in car washing practices among the three watersheds.
- There were no differences in pet waste handling among the three watersheds.
- More BMP residents composted leaf wastes.
- More BMP residents mowed their own lawns.

Conclusions:

- Low impact development can maintain pre-development peak runoff and volume of runoff levels. Pollutant export is generally not increased, except for phosphorus and sediment.
- Traditional development increases runoff by two orders of magnitude. Pollutant export is also increased.

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US Environmental Protection Agency
University of Connecticut
University of Connecticut Cooperative Extension System
Town of Waterford
Eastern Connecticut Conservation District
USDA Natural Resources Conservation Service
D. W. Gerwick, Engineering
Aqua Solutions, LLC
John Lombardi, landowner

This project is partially funded by the CT DEP through a US EPA, nonpoint source (NPS) grant under section 319 Clean Water Act.

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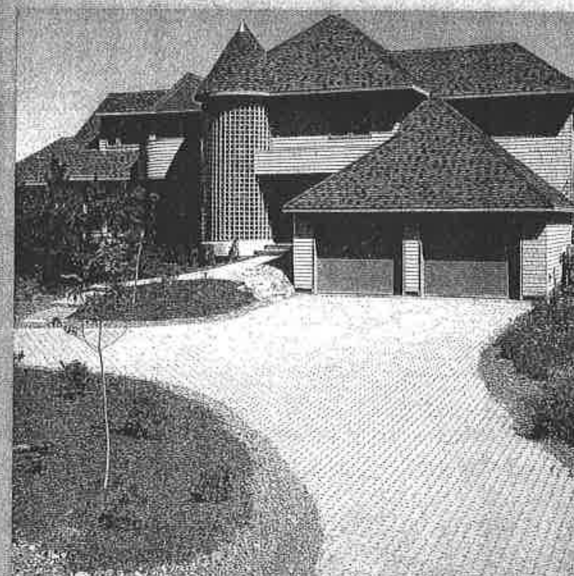
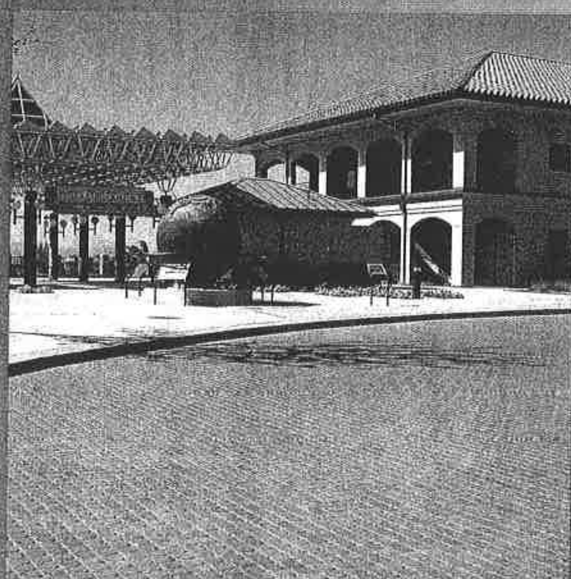
Project Profiles

Permeable Interlocking Concrete Pavements





ICPI

INTERLOCKING CONCRETE PAVEMENT INSTITUTE

Introduction

As urbanization increases, so does the concentration of pavements, buildings and other impervious surfaces. These surfaces generate additional runoff and pollutants during rainstorms causing streambank erosion, as well as degenerating lakes and polluting sources of drinking water. Increased runoff also deprives groundwater from being recharged, decreasing the amount of available drinking water in many communities. Recreational opportunities from lakes, streams and rivers decline from the impacts of urban runoff. Commercial fishing productivity can decline in estuaries and bays thereby negatively impacting regional economies.

In response to environmental and economic impacts from stormwater runoff, U.S. federal law mandates that states control water pollution in runoff through the National Pollutant Discharge Elimination System (NPDES). Among many things, the law requires that states and localities implement best management practices (BMPs) to control non-point source pollution in runoff from development. BMP's can include storage, filtration and infiltration land development practices. Infiltration practices capture runoff and rely on infiltration through soils, vegetation, or aggregates for the reduction of pollutants. Detention ponds are a common example of a BMP used to hold, infiltrate, and release stormwater. Infiltration trenches are another that reduce stormwater runoff and pollution, and replenish groundwater. All of these BMPs provide some treatment and reduction of runoff pollutants.

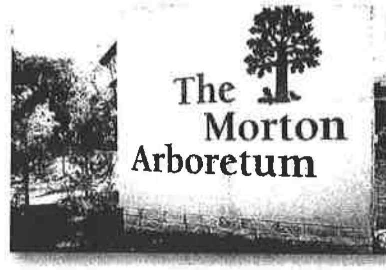
Pavement that Detains and Infiltrates Runoff

Like infiltration trenches, permeable interlocking concrete pavements (PICPs) are highly effective in providing infiltration, detention, and treatment of storm water pollution. The base can be designed to filter, treat, and slowly release water into a storm sewer or water course while providing a walking and driving surface. PICPs answer the call from municipal regulations that limit the amount of impervious cover flowing into storm drains working at capacity, or when sites have limited space for detention ponds.

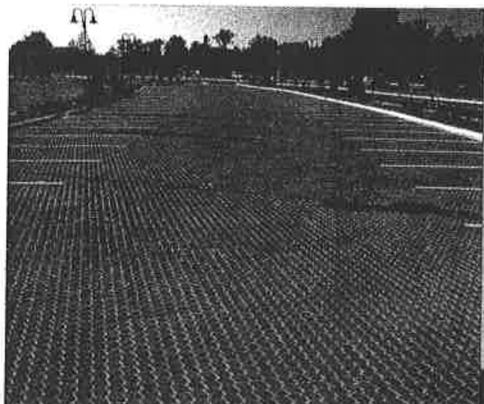
The U.S. Environmental Protection Agency and several state agencies consider PICPs an infiltration BMP. An increasing number of cities, counties and states are incorporating them into land development and runoff standards, low-impact development guidelines and design manuals on stormwater control. With proper design, material selection, construction and routine maintenance, PICP is a sustainable low-impact BMP used by landscape architects, architects, engineers, developers and public agency staff.

PICPs have been widely used across Europe, especially Germany since the early 1990s. The paving products shown in the following project profiles were supplied by members of the Interlocking Concrete Pavement Institute (ICPI). Several projects were also constructed by ICPI contractor members. The projects demonstrate runoff reduction and improved water quality in a range of climates, soils, hydrological and regulatory environments. ICPI appreciates the following contributions from member producing companies, designers, contractors and project owners.

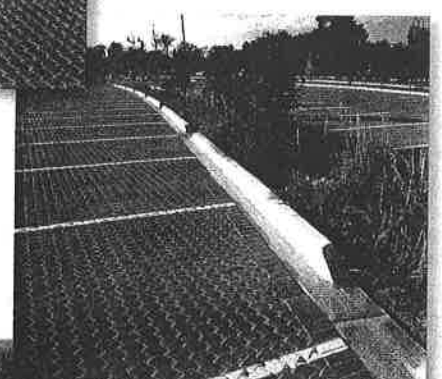
Morton Arboretum Visitor's Center Parking Lot, Lisle, Illinois



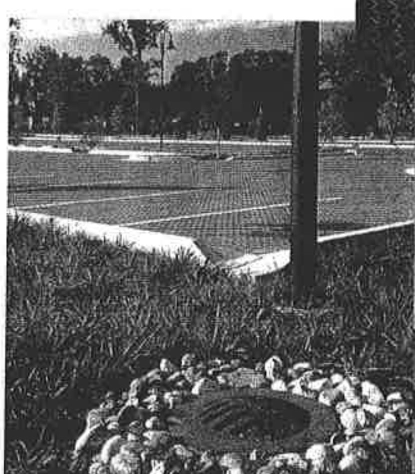
When Morton Arboretum in suburban Chicago decided to build a new visitor's center, it also developed a new entrance, parking lot and bus passenger drop off area. The need for detention facilities to capture runoff from these areas was unacceptable to the arboretum. Permeable pavers were instead chosen to protect water quality, manage stormwater and provide a durable surface for vehicular traffic. The Arboretum wanted to implement as many best management practices as possible into their new parking lot design since runoff from the project is being monitored under the U.S. EPA Section 319 National Runoff Monitoring Program. The parking lot consists of 173,000 sf (16,000 m^2) mechanically installed PICP as well as 32,000 sf (2,970 m^2) of interlocking concrete pavement. Constructed in 2003 and 2004, the paving units used custom color blends selected by the Morton Arboretum staff.



Morton Arboretum in suburban Chicago expanded its parking facilities with 173,000 sf (16,000 m^2) of PICPs without building detention ponds. The pavement absorbs rainfall from most rainstorms.



Indentations in the curbs allow runoff from heavy storms to overflow and seep into vegetated areas. Construction shows the open-graded, crushed stone base drainage layers under compaction equipment.



Drains are provided to remove excess water from the heaviest, infrequent rainstorms.

Three layers of open graded base enabled filtering and drainage while providing a stable structure during construction.

Typical cross-section:
3 1/8 in. (80 mm) thick permeable interlocking concrete pavers
1 1/2 in. (40 mm) Illinois DOT CA-16 (Class A) (10 to 1 mm) crushed stone bedding
6 in. (150 mm) Illinois DOT CA-7 (25 to 5 mm) crushed stone base
12 in. (300 mm) Illinois DOT CA-1 (63 to 25 mm) crushed stone subbase

Subgrade:
Clay soil

Construction Manager:
Hanscomb, Faithful, & Gould
Chicago, IL

Engineer:
Christopher B. Burke
Engineering West
St. Charles, IL

Landscape Architect:
Conservation Design Forum
Elmhurst, IL

General Contractor:
V3 Construction Group
Woodridge, IL

Wal-Mart Parking Lot, Rehobeth Beach, Delaware

Rehobeth Beach is situated along the Atlantic coast just north of the mouth of the Chesapeake Bay. When the shopping center owner needed to expand parking behind a Wal-Mart in 2002, there wasn't sufficient space for the parking lot and a separate detention pond. PICPs combined the two functions. PICP enabled partial exfiltration from the base to the soil, with backup from perforated pipe and surface drains for saturated conditions from heavy rainstorms.

Like many of the projects shown in this brochure, PICP at this Wal-Mart was mechanically installed. Mechanical installation requires that the pavers be manufactured in their final laying pattern, stacked, and delivered to the job site for installation by specialized equipment. The equipment includes a clamp that grabs a stacked layer of pavers (about a square yard or square meter) and places each on the screeded bedding material. After placing a layer, the machine operator returns to the stack to grab and place the next. With each layer only taking about 20 seconds to place, paving production rates can be increased as much as five times compared to manual installation.

A 2003 study of surface infiltration by North Carolina State University of this parking lot and several other permeable interlocking concrete pavement sites indicated a surface infiltration rate of 1000 in./hour (25 m/hr) using a modified double ring infiltration test equipment (2). This is considered excellent for new permeable pavements.

Typical cross-section:
$3^{1}/_{8}$ in. (80 mm) thick permeable interlocking concrete pavers
3 in. (75 mm) ASTM No. 8 crushed stone
6 in. (150 mm) ASTM No. 57 crushed stone
Geotextile

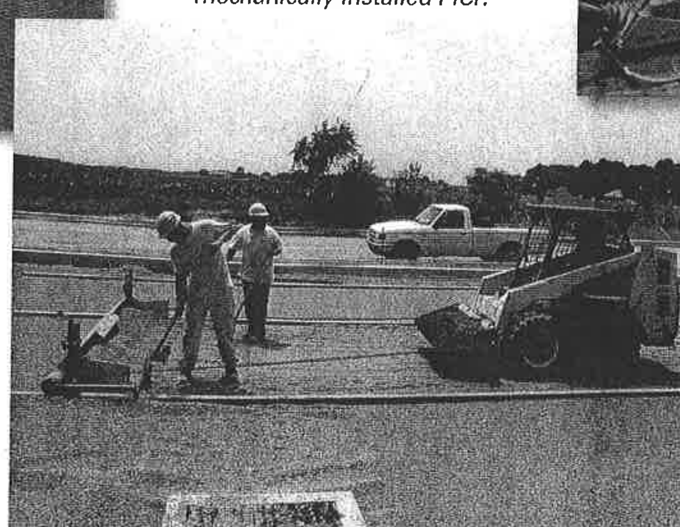
Subgrade:
Sandy soil

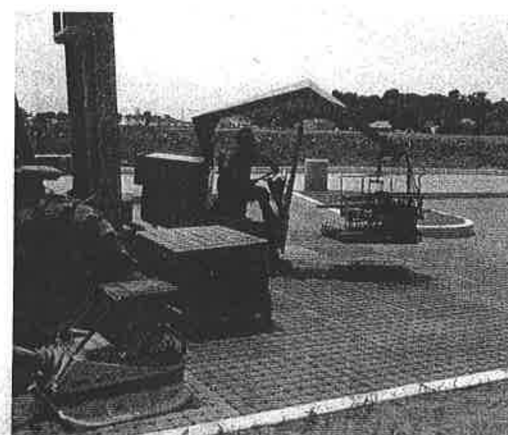
Designer:
Davis Bowen & Freidel Engineers
Milford, Delaware

General Contractor:
A.P. Croll & Son
Georgetown, Delaware

About 40,000 sf (3,716 m²) of PICP eliminated the need for building detention pond when a parking lot was expanded behind a Wal-Mart shopping center.

The bedding layer of No. 8 stone is screeded or smoothed to receive mechanically installed PICP.





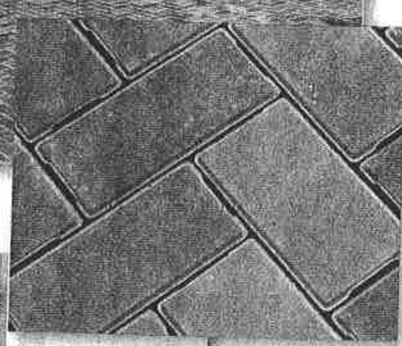
A clamp on specialized mechanical installation equipment grabs a layer of pavers for placement on the bedding. The pavers are compacted into the bedding layer, the openings and joints filled with the bedding material and compacted again to create interlock among the pavers.

Engineering/Computer Science Building Entrance, Victoria University, British Columbia

Home to over 18,000 students and 4,000 staff, the university follows an integrated campus plan that incorporates sustainable practices in construction and operation of all new buildings and facilities. A natural fit was permeable interlocking concrete pavement at a new pedestrian drop off and short-term parking for the expanding Engineering/Computer Science building. Completed in March 2004, University officials asked the design engineer to create the 8,000 sf (743 m^2) parking that exceeded LEED (Leadership in Energy and Environmental Design) criteria, specifically reducing the rate and quantity of runoff by 25% from a 2-year, 24 hour design storm. The open joints and notches in the paver surface enabled full infiltration of commonly occurring storms through a clean crushed jointing and bedding material.

The PICP pattern achieved a welcoming entrance with six parking spaces for disabled persons and six standard parking spaces. The pavement and subgrade slope gently to one end of the site where perforated pipe at the bottom of the subbase drains it within 24 hours. Existing catch basins handle overflows from extreme storm events.

According to Sarah Webb, the University's Sustainability Coordinator, "The paving stones have exceeded our expectations. Students, faculty and staff have commented on how aesthetically pleasing the drop off is. We have had no problems with wheelchair access, and the stones have continued to perform under our heaviest west coast rains." Maintenance has been minimal and deicers kept ice from the surface during the occasional winter freeze, nor have their been any problems from freeze-thaw cycles. Ms. Webb also noted that, "Paving stones, and other permeable products, will continued to be used on the campus as a part of our green building program and our commitment in our Integrated Stormwater Management Plan to reduce water runoff and improve water quality."



An 8,000 sf (743 m^2) entrance drop-off and parking lot creates a detention and infiltration for stormwater at the University of Victoria, British Columbia. The notched pavers and stone-filled joints infiltrate water from most commonly occurring storms.

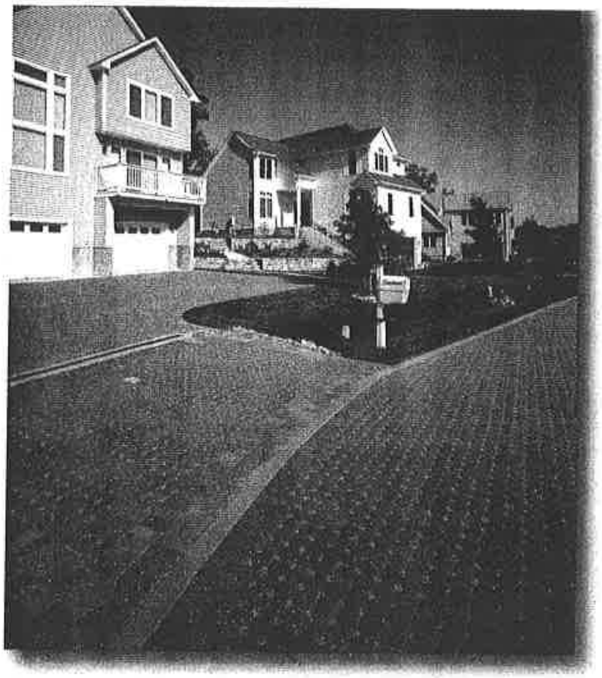
The project specifications called for crushed, open-graded base and subbase compaction with initial passes of a roller compactor in vibratory mode, then final passes in static mode.

Typical Cross-Section:
3 1/8 in. (80 mm) thick permeable interlocking concrete pavers
2 in. (50 mm) bedding layer (12.5 to 1.16 mm)
6 in. (150 mm) 19 mm clean crushed stone
10 in. (250 mm) 75 mm clean crushed stone

Subgrade:
Clay

Designer:
Bruce DeMaere, A.Sc.T.
Bullock Bauer Associates, Ltd.
Victoria, B.C.

General Contractor:
Excel Contracting
Victoria, B.C.

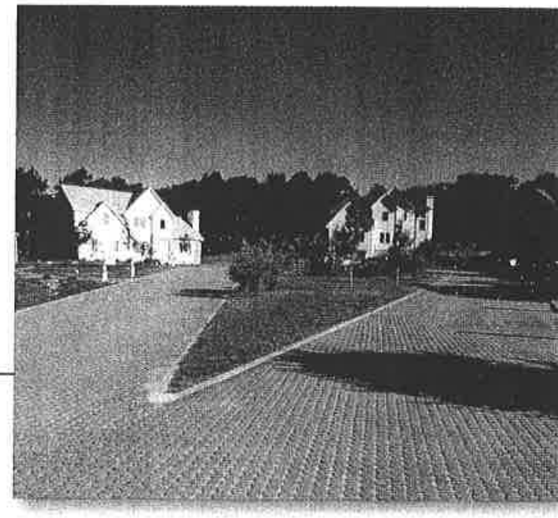


Runoff quantity and quality from driveways were monitored from water exiting slot drains.

Runoff and pollution monitoring has demonstrated the benefits of permeable interlocking concrete pavements in the U.S. EPA funded Jordan Cove Urban Watershed National Monitoring Project. Driveways and a municipal street were paved in this low-impact, environmentally sensitive residential development.

This watershed that drains to an estuary in Long Island Sound is participating in a 10-year monitoring project of runoff from a traditional subdivision, a single-family home development built with conventional pavements and stormwater management system, and a low-impact development built with runoff and pollutant-reducing BMPs. These include grass swales, bio-retention areas and PICP. The U.S. EPA Section 319 National Monitoring Program supports the monitoring project conducted by the University of Connecticut.

Built in 2001, the Glen Brook Green



Rather than being paved, the center of the cul-de-sac in Glen Brook Green subdivision provides a bioswale to absorb runoff and overflow from the permeable pavement.

Table 1. Average infiltration rates during 2002 to 2003 into pavements in the Glen Brook Green subdivision.

Test and Year	Asphalt	Permeable Pavement in./hr (cm/hr)	Crushed Stone in./hr (cm/hr)
Single Ring Infiltrometer test 2002	0	7.7 (19.6)	7.3 (18.5)
Single Ring Infiltrometer test 2002	0	6 (15.3)	5 (12.7)
Flowing infiltration test 2003	0	8.1 (20.7)	2.4 (6)

Table 2. Average weekly concentration of pollutants in stormwater during 2002 to 2003 from pavements in the Glen Brook Green subdivision. Within each variable, means followed by the same letter are not significantly different at σ=0.05.

Variable	Asphalt		Permeable Pavement		Crushed Stone	
Runoff depth, mm	1.8	a	0.5	b	0.04	c
Total suspended solids, mg/l	47.8	a	15.8	b	33.7	a
Nitrate nitrogen, mg/l	0.6	a	0.2	b	0.3	ab
Ammonia nitrogen, mg/l	0.18	a	0.05	b	0.11	a
Total Kjeldahl nitrogen, mg/l	8.0	a	0.7	b	1.6	ab
Total Phosphorous, mg/l	0.244	a	0.162	b	0.155	b
Copper, ug/l	18	a	6	b	16	a
Lead, ug/l	6	a	2	b	3.	b
Zinc, ug/l	87	a	25	b	57	ab

subdivision within the watershed features over 15,000 sf (1,400 m²) of PICP in a street and residential driveways that recharge the local aquifer, slow runoff velocities, oxidizes and filters some pollutants, filters suspended solids and cools water before it enters the estuary. Maintenance includes periodic sweeping and vacuuming with the same equipment used on other streets. An annual inspection ensures no ponding and aggregate is replaced in the pavement openings as needed.

The 2003 annual report of the multi-year monitoring project demonstrates the effectiveness of PICP in reducing runoff and pollutants (1). Runoff quantity and quality from asphalt, PICP (with a dense-graded base) and crushed stone driveways entering single family homes were studied for 12 months in 2002 and 2003. A plan of the neighborhood and driveway types is shown below.

Besides lower infiltration rates than asphalt, PICP demonstrated lower concentrations of pollutants in runoff and similar concentrations to that from driveways with crushed stone. Table 1 shows the average infiltration rates from the surfaces in 2002 and 2003. Table 2 shows the average weekly concentration of pollutants in stormwater runoff for various pollutants. Concentrations are statistically significantly lower for all pollutants from PICP compared to asphalt. Pollutant levels in PICP are similar to that from the driveways with crushed stone.

Typical cross-section:
3 1/8 in. (80 mm) thick permeable pavers
8 to 10 in. (200 to 250 mm) dense-graded base
Geotextile

Subgrade:
Sandy gravel

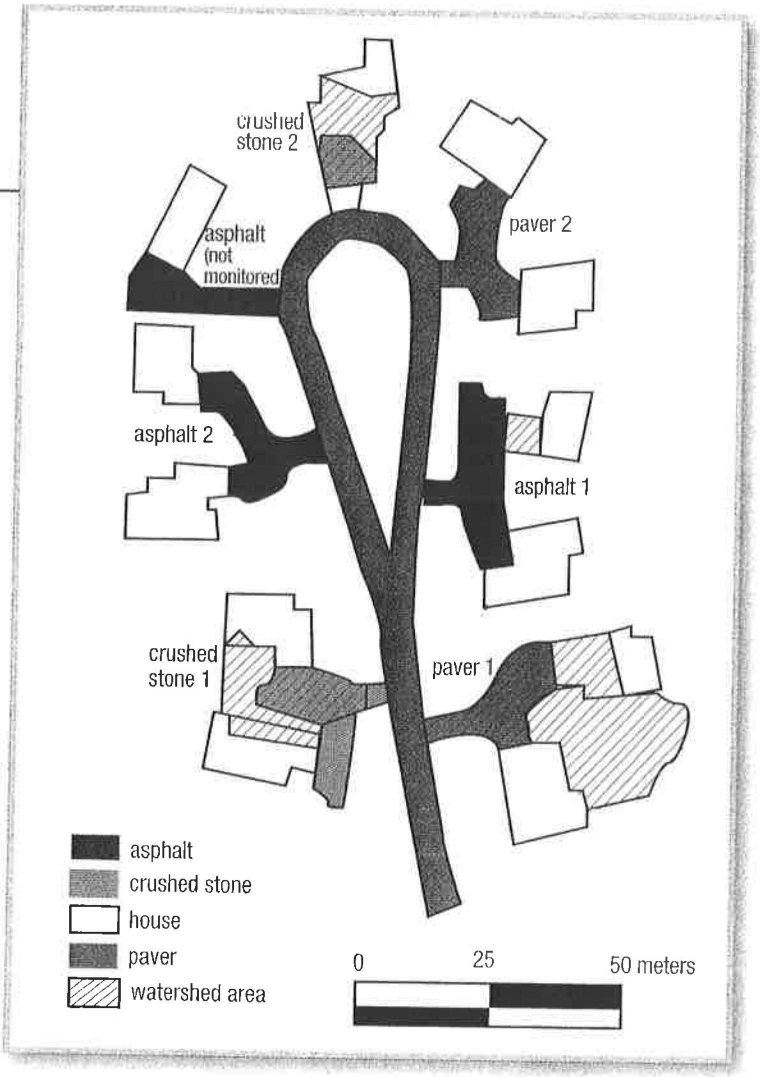
Developer:
Lombardi Inside/Out L.L.C.
Waterford, CT

Project Manager:
Aqua Solutions
East Hartford, CT

Engineering:
D.W. Gerrick Engineering
Waterford, CT

Landscape Architect:
John Alexopoulus
University of Connecticut

Water Quality Monitoring:
Dr. John Clausen
University of Connecticut



Runoff from various types of pavements are being monitored in the Glen Brook Green Subdivision in Waterford, Connecticut.

Robson Center, Gainesville, Georgia

Formerly known as the Southern Heritage Building, the Robson Center's 8,200 sf (760 m²) parking lot represents one of the first pavements of its type in Gainsville, a city of 25,000 on the shores of Lake Lanier in northeast Georgia. "The Robson Center pavement was installed (in 2003) in order to meet a new municipal limitation on impervious cover, while getting full economic development from the site's acreage," according to Bruce Ferguson, FASLA, Professor and Director, School of Environmental Design, University of Georgia and author of the book, *Porous Pavements* (2). The pavement surface located in the development's entry lanes used brick color to match the building.

"The base course or 'base reservoir' is made with open-graded No. 57 crushed granite rock, which has void space of 30%+ and very high permeability," said Ferguson. "The bedding layer and joint fill is similar but smaller No. 89 aggregate, which also has high porosity and permeability. The combination gives the pavement high permeability and water storage capacity."

Since the soil was largely clay fill that had to be compacted, very little infiltration into the soil is expected, explained Ferguson. "Instead, a perforated pipe at the bottom of the base reservoir drains to the city's storm sewer system. A previously installed stormwater detention basin had been designed for impervious surfaces throughout the development. This pavement's permeability and in-pavement storage are expected to make the project's stormwater performance exceed the design expectations. In the unlikely event the pavement should generate surface runoff due to an extremely intense storm or clogging occur somewhere in the system, the runoff will drain to grate inlets at the side of the pavement, then into the conventional storm sewer system."

Typical Cross-section:
3 1/8 in. (80 mm) thick permeable pavers
3 in. (75 mm) ASTM No. 89 bedding layer
8 in. (200 mm) ASTM No. 57 crushed stone base
Geotextile

Subgrade:
Clay soil

Designer:
Bruce Ferguson, FASLA, Athens, Georgia

General Contractor:
U.S. General Construction, Alpharetta, Georgia

Runoff from the impervious asphalt surfaces is infiltrated into the PICP. The runoff is detained, filtered and infiltrated into to the soil subgrade. Excess water is drained to storm sewers through perforated drain pipes in the base.

Even with low infiltration clay soil, permeable pavements manage runoff from typical rainstorms that fall on the parking lot at the Southern Heritage Building.

Hilton Garden Inn, Calabasas, California

The Hilton Garden Inn designers chose PICP to satisfy the City of Calabasas storm-water management requirements. These mandated at least 30% pervious cover to control the quantity and quality of runoff from the site, specifically by containing the "first flush" or the initial 1/4 in. (6 mm) of rain water within a 24-hour period. The site meets this requirement with PICP that filters runoff into an open-graded base, temporarily detaining water before passing it to the storm drain system.

A color blend of cream/brown, cream/charcoal and solid brown was selected for the 12,000 sf (1,110 m²) project completed in June 2002. This maintains some reflectivity without blinding pedestrians on sunny days. The pavers were placed in a random color pattern to yield mottled tones throughout the pavement surface. The pavement covers the hotel driveway, entry area and parking lot.

The position of the pavers changed over the design stages of the project. Instead of laying the pavers at the lower side, away from the building, they were installed on the uphill side next to the hotel. Placement of pavers next to the hotel entry provided area a visually pleasing appearance, but reduced the total amount of water infiltrated by the pavement's surface. Other measures were implemented to treat runoff which included a grassy swale to filter runoff next to the asphalt pavement and a filter in the catch basin.

PICPs at this hotel in Southern California capture and treat the first flush from the parking lot. The curbs are recessed to allow overflows to run into an adjacent grass swale.

PICPs accommodate markings for parking spaces and an access route for disabled persons.

Design:
Hewitt-Zollars Engineering
Irvine, California

General Contractor:
RD Olson
Irvine, California

Typical Cross-section:
3 1/8 in. (80 mm) thick permeable pavers
2 in. (50 mm) 1/4 by No. 10 (6 to 1 mm) crushed stone bedding layer
10 in. (250 mm) 3/4 to 1/2 in. (20 to 13 mm) crushed stone base
Geotextile

Subgrade:
Clay

Harbourfront Fire Station, Toronto, Ontario

Adjacent to the Toronto SkyDome and the CN Tower in Toronto, this fire station uses PICP to reduce runoff pollutants entering nearby Lake Ontario.

Located on a Lake Ontario, the Harbourfront Fire Station features 11,000 sf (1,022 m²) of PICP in its entrance and parking lot. Built in the winter of 1998, the City of Toronto required a pavement that would reduce runoff pollution to Lake Ontario through infiltration while providing a parking lot in a highly urbanized area.

Built with a dense-graded base, the project exemplifies the ability of PICPs to withstand heavy loads from fire trucks in a winter environment with deep penetration of frost in pavements. The pavement is plowed and salted in the winter, but not sanded to prevent clogging of the aggregate in the openings and reduced infiltration. The lack of raised curbs enables snow plows to push snow directly off the pavement.

PICP withstands salt and snow plowing, a regular part of Toronto winters.

Typical cross-section:
3 1/8 in. (80 mm) thick permeable concrete pavers
2 in. (50 mm) bedding material
6 in. (150 mm) MTO Granular A aggregate base
12 in. (300 mm) MTO Granular B aggregate base

Architect:
Paul Jurecka Architect
Toronto, Ontario

Engineer:
Lloyd & Nodwell
Toronto, Ontario

General Contractor:
Dixon General Contractors
Missisauga, Ontario

Historic Tree Preservation at Alden Lane Nursery Livermore, California

Typical cross-section:
3 1/8 in. (80 mm) permeable pavers
1 in. (25 mm) 1/4 in. by No. 10 (6 to 1 mm) crushed stone bedding layer
6 in. (150 mm) 3/4 to 1/2 in. (25 to 20 mm) crushed stone base
Geotextile

Subgrade:
Clay soil

This upscale nursery in the San Francisco Bay area used 12,000 sf (1,115 m²) of environmentally friendly, mechanically installed PICP to allow air and water to nourish the roots of a very large, 300 year-old oak tree. It is so old it has been designated as a heritage tree which protects it from being removed. The tree lives in clay soil and PICP was built to ensure that additional air and water reach its roots. The nursery's owner decided on permeable pavers as a solution to preserve the historic tree and provide an environmentally sensitive entrance to the store. Local runoff regulations were not a significant motivating factor. The owner simply wanted to give the tree an opportunity to survive and grow.

Roots feeding a 300 year-old oak tree receive additional air and water from permeable paving units at a landscape nursery in Livermore, California.

The sidewalk adjacent to the nursery entrance uses permeable paving units to return water to nearby vegetation.

PICP FAQs

Should a dense-graded or open-graded aggregate base be used under PICPs?

An open-graded base is most commonly used because it has water storage capacity (void space between the aggregates) of typically 30% to 40%. The stone sizes in open-graded bases can be as large as 3 in. (75 mm) and as small as ¼ in. (6 mm). There is typically a thinner layer of small stone sizes (6 mm to 1 mm) used for bedding directly under the concrete pavers. The bedding and base bedding material maximizes storage, filtering, and treatment of pollutants in stormwater runoff entering the pavement surface. Open-graded bases are preferred because of the storage and treatment benefits.

Dense-graded bases are occasionally used under PICPs as in the Glen Brook Cove subdivision and the Harbourfront Fire Station. They may be used in areas of concentrated wheel loads from truck traffic. While there is additional structural support, most of the runoff from common rainstorms is stored in the bedding material and within the openings in the pavement surface. Maximum stormwater storage and infiltration benefits, however, come from PICP with an open-graded base.

What intensity and duration of storms can be managed?

That depends on amount of water that drains onto the PICP, the depth (and storage capacity) the base, the infiltration rate of the soil under an open-graded base, and the presence of drain pipes within an open-graded base. PICPs are intended to manage water quantities and pollutants from smaller, more frequent storms such as those with a return period of 10 years or less. These storms tend to be shorter in duration and often have the highest concentrations of pollutants. PICPs are not intended to control flooding from larger, infrequent rainstorms.

Are PICPs eligible for LEED credits?

Yes, they can under the U.S. and Canadian Green Building Councils (USGBC and CGBC) guidelines. PICPs typically can meet the requirements for Conservation of Material and Resources, Recycled Content under the USGBC LEED for new construction where at least 20% of the building products should be manufactured within a radius of 500 miles (800 km) of the project. Most paving units are locally manufactured and delivered to projects within 500 miles (800 km). To find the closest manufacturer or distributor, visit www.icpi.org and conduct a search for producers in the 'Find A Member' section.

PICPs can meet the LEED credit requirements under Sustainable Sites. These requirements limit site disruption and water pollution by managing stormwater. The pavements can reduce runoff-generating impervious cover and decrease the rate and quantity of runoff. PICPs meet these credits through the filtering action of the base that reduces total suspended solids and phosphorous in runoff, as well as other pollutants.

PICPs can also meet the sustainable sites requirement to reduce urban heat islands (thermal gradient difference between developed and undeveloped areas) and minimize impact on microclimate, as well as human and wildlife habitat. This is accomplished through increased albedo (a measure of the solar energy reflected from a surface) or use of a pavement system with less than 50% imperviousness. PICPs have substantially higher reflectivity than conventional asphalt pavement and can meet the requirement for less than 50% imperviousness. For additional information on U.S. or Canadian LEED credits see www.usgbc.org or www.cagbc.org

How well does the pavement perform in freeze and thaw conditions?

PICPs have been in service for years in freezing climates and have performed adequately as evidenced by the projects profiled in this publication. Many more projects throughout Canada and the northern U.S., in the United Kingdom and Germany speak to the durability of these pavement systems in cold climates, as well as their ability to accept snowplows and salts without paver damage. In order to ensure high durability in freezing climates, the paving units should conform to the requirements of ASTM C 936 in the U.S. or CSA A231.2 in Canada. Both of these product standards include tests for freeze-thaw durability.

When the sun and temperature are right, ice and snow on PICP can melt and immediately soak into the openings in the pavement surface. Water does not collect on the surface and re-freeze. This reduces slipping hazards. Obviously, sand shouldn't be used for foot or tire traction on PICPs. Deicing salts can be used. After plowing, melting of any remaining snow can occur if the temperature moves above freezing. This will help eliminate ice from forming and reduce salt contamination in groundwater.

Since the pavement base temporarily stores rainfall, will the base heave and damage the pavement surface when frozen?

Water in the base typically should drain within 24 hours. It's unlikely that ice will form in the base within this time period should temperatures drop below freezing. If the water does freeze before draining, there should be adequate space for the ice to expand within the open-graded base as it freezes, thereby minimizing the risk of heaving. Should soil heaving occur, the pavement surface is flexible and should not be damaged from minor upward movement or from resettlement during a thaw.

Does the surface conform to ADA requirements?

Yes. ADA Design Guidelines require that surfaces be firm, stable and slip resistant. PICP designs can provide a firm and stable surface for visually impaired persons and those using wheeled mobility devices. If the openings in the surface are not desirable, solid units can be used in areas subject to disabled persons. Such areas might include designated spaces in parking lots.

ADA requires that the static coefficient of friction for flat surfaces along accessible routes be 0.6 and 0.8 for ramps. ADA advisory material recommends various test methods to assess surface slip resistance. PICPs can meet slip ADA resistance requirements using test methods recommended in ADA advisory literature. For additional information on these see *ICPI Tech Spec 13 – Slip and Skid Resistance of Interlocking Concrete Pavements*. This and other technical bulletins are available at www.icpi.org and www.access-board.gov.

Is there any benefit to using PICPs on low-infiltration soils such as some types of clays?

Yes. If soil infiltration is slow (generally under 0.5 in./hour or 1.3 x 10^{-2} m/sec), perforated plastic pipe drains at the bottom of the base can remove excess water while still allowing some of the water to infiltrate into the soil. The drainage rate for the water contained in the base is typically no greater than 24 hours. For practically impervious soils or high bedrock, an impervious pond liner can be used to detain, filter and release the water through drain pipes. Regardless of the rate of soil infiltration, the filtering action of the open-graded base can reduce water pollutants.

All permeable pavements require periodic surface cleaning. How is a PICP surface cleaned and how often?

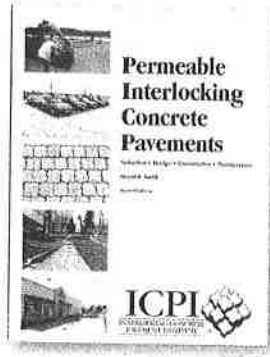
The openings in the surface of PICPs will require periodic removal of detritus and sediment trapped by the small sized crushed stone. Dirt is typically removed by a vacuum-sweeping street cleaning machine. Cleaning is done when the pavement surface and detritus are dry and can be loosened by sweeping and vacuuming. The frequency of cleaning will vary with the use of the pavement and deposition of sediment, leaves, etc. from adjacent areas. Cleaning should be done at least once a year, and the surface monitored during the early life of the pavement so that a regular cleaning schedule can be established.

A North Carolina State University study has shown that the initial surface infiltration rate of PICPs can be as high as 2000 in./hour (5080 cm/hour) (3). Other research has shown that near initial surface infiltration rates can be restored through cleaning and replacement of the initial 3/4 to 1 in. (20 to 25 mm) depth of small stones in the openings of PICPs (4). For highly clogged pavement openings, the stones can be removed with vacuuming and replaced with clean material. This is a distinct maintenance advantage over monolithic permeable pavements.

What about high heel shoes?

Solid pavers can be introduced into PICP paving patterns in pedestrian areas to accommodate a variety of shoes including high heels.

Permeable Pavement Resources



The Interlocking Concrete Pavement Institute (ICPI) offers a manual, *Permeable Interlocking Concrete Pavements*, that covers selection, design, specification, construction, and maintenance. It synthesizes literature on infiltration trenches, porous asphalt pavement, research on and practical experience with permeable interlocking concrete pavements. ICPI's manual is essential for design professionals and municipal authorities that regulate storm water runoff. It can be purchased at www.icpi.org.

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