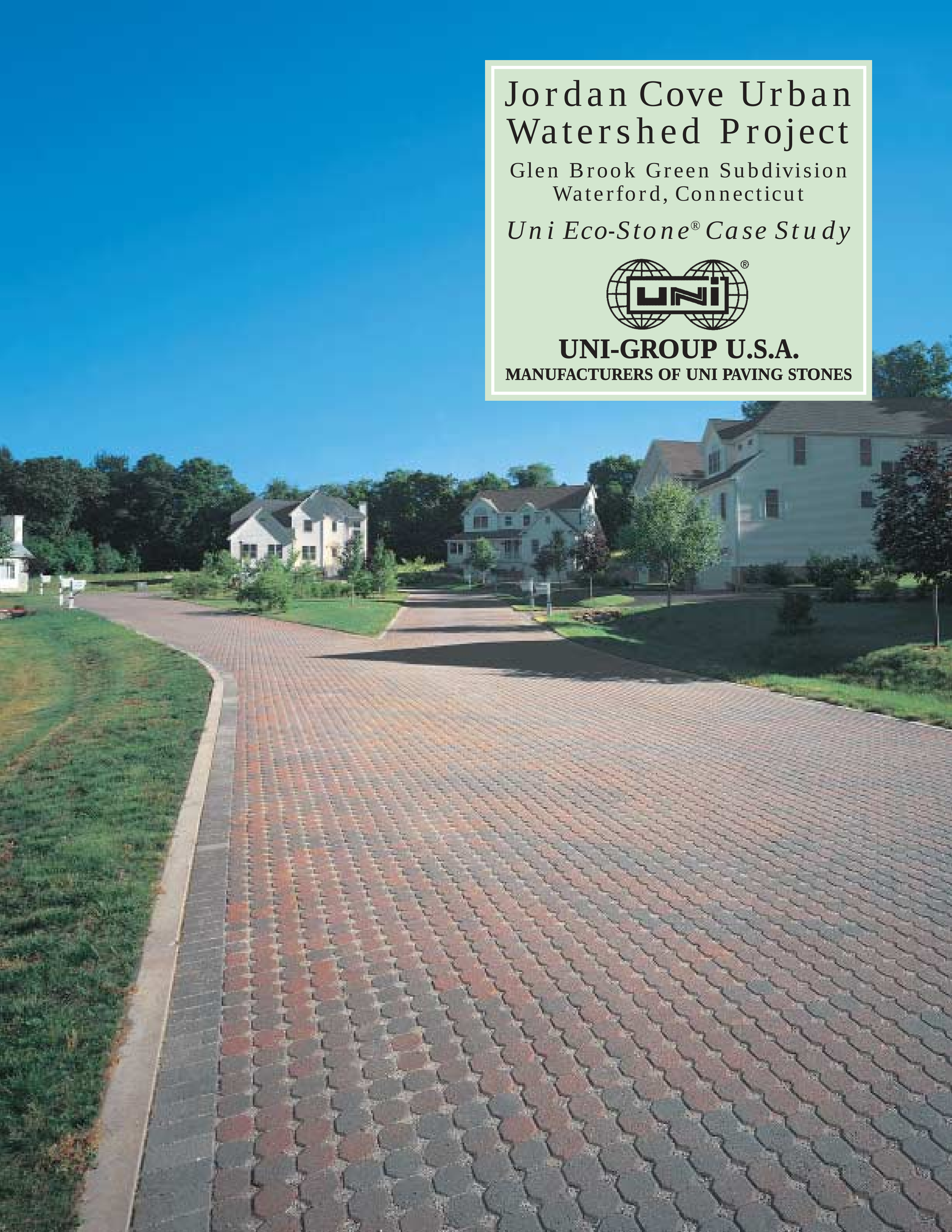
Jordan Cove Urban Watershed Project

Glen Brook Green Subdivision
Waterford, Connecticut

Uni Eco-Stone® Case Study

UNI-GROUP U.S.A.
MANUFACTURERS OF UNI PAVING STONES



PROJECT/DEVELOPER:
Lombardi Inside/Out L.L.C.
Glen Brook Green - Jordan Cove Urban Watershed
Waterford, Connecticut

PROJECT MANAGER:
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ENVIRONMENTAL AGENCIES:
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Connecticut Department of the Environment
Mellville Cote - New England Region
U.S. Environmental Protection Agency

CONCRETE PAVER MANUFACTURER:
Ideal Concrete Block Co., Inc.
Westford, Massachusetts

PAVERS:
UNI Eco-Stone®
Streets & Driveways 15,000 sq ft
Red and Charcoal Blend - 3 1/8 in. (80mm)

Clean water is one of our country's greatest and most vital resources. Implemented in 1972, the Clean Water Act has greatly reduced threats to water resources by identifying and controlling point sources of pollution.

However, according to the United States Environmental Protection Agency (USEPA), nonpoint sources of pollutants, such as stormwater runoff, are reported to cause the majority of water pollution problems in the United States today. Sediment, pesticides, salts, metals, and chemicals are deposited into our rivers, lakes, and estuaries from nonpoint sources. The EPA reports that nearly 40% of America's surveyed waterways are still too polluted for fishing or swimming and that 90% of the nation's population lives within 10 miles of these bodies of water.

With the implementation of the EPA's National Pollutant Discharge Elimination System (NPDES) stormwater regulations in the early 1990s, new options in stormwater management were needed. Effective management of stormwater runoff offers a

The Jordan Cove estuary empties into the Long Island Sound

number of benefits, including improved quality of surface waters, protection of wetland and aquatic ecosystems, conservation of water resources, and flood mitigation. Traditional flood control measures that rely on detention of peak flow are typical of many stormwater management approaches, but generally do not target pollutant reduction, and often cause unwanted changes in hydrology and hydraulics. The EPA recommends an integrated approach to the control of stormwater flows and the protection of natural systems to sustain aquatic habitat.

Effective stormwater management is often achieved through a comprehensive management systems approach instead of individual practices. Practices that may not be effective alone, may be extremely effective when used in combination with other systems. The EPA's Phase II rule encourages "system building" to allow for the use of appropriate situation-specific practices that will achieve the minimum measures. Governing authorities must develop and implement strategies that include a combination of structural and non-structural best management practices (BMPs) appropriate for their communities.

Glen Brook Green features shared Eco-Stone® permeable pavement driveways

The EPA has developed the Section 319 National Monitoring Program (NMP) to address nonpoint source pollution specifically. It was designed to support watershed projects throughout the country that meet a minimum set of planning, implementation, monitoring, and evaluation requirements. The Section 319 National Monitoring Program has selected watersheds across the country to be monitored over a 6 to 10-year period to evaluate how improved land management reduces water pollution.

Jordan Cove, a small estuary fed by Jordan Brook, is located along the Connecticut side of the Long Island Sound. Water quality sampling has shown that the cove does not meet bacteriological standards for shellfish growing, and sediment sampling has revealed high concentrations of arsenic. The watershed is comprised of mostly forest and wetlands (74%), with some urban (19%) and agricultural (7%) uses. The average annual precipitation is 49.8 inches, including 35 inches of snowfall. Soils in the study areas are well-drained soils (hydrologic soil group B), bedrock is typically at a depth greater than 60 inches, and the water table is below 6 feet.

Selected for the 319 National Monitoring Program in 1996, this project is located in a residential section of the watershed and is the only NMP project to study the impact of residential development on stormwater runoff quantity and quality, as well as the best management practices being implemented to manage it. Runoff from three subdivisions is being monitored to assess the effects of construction and urban development. An existing 43-unit subdivision serves as a control, with a 10.6 acre traditionally-zoned subdivision and another 6.9 acre area using cluster zoning and a variety of best management practices paired as test watersheds.

Selected individual BMP monitoring is being conducted, as well as monitoring of precipitation, air temperature, and storm-event sampling for total suspended solids, phosphorus, nutrients, nitrates and nitrites, metals, fecal coliform, and bio-chemical oxygen demand (BOD). The treatment period includes two phases - the construction phase and the long-term, post-implementation monitoring phase.

The water quality objectives of the project are:

- To retain sediment on site during construction;
- To reduce nitrogen, bacteria, and phosphorus export by 65%, 85%, and 40%, respectively;
- To maintain post-development runoff peak rate and volume at pre-development levels; and
- To maintain the total suspended solids load at pre-development levels.

One of Glen Brook Green's vegetated bio-retention areas

Stormwater runoff from the traditional section is collected by curbs and catch basins, then piped through a stormwater treatment system. The BMP neighborhood utilizes a number of structural and non-structural practices including grass swales, vegetated bio-retention areas, roof leader rain gardens, "low-mow" zones, street sweeping, fertilizer and pesticide management, and reduced use of deicing agents. In addition, UNI Eco-Stone® permeable interlocking concrete pavers were selected for the project's reduced-width street and some of the shared driveways.

The Eco-Stone® paving system is an innovative, environmentally-beneficial pavement designed to mitigate stormwater runoff through natural infiltration, as well as provide a method for increased groundwater recharge and/or storage for future use. An Eco-Stone® permeable pavement possesses the structural strength and stability of interlocking concrete pavements, combined with the environmental benefit of stormwater management. Eco-Stone® pavers have a minimum compressive strength of 8000 psi, maximum 5% absorption, and meets or exceeds ASTM C-936 and freeze-thaw testing. UNI Eco-Stone® pavements can be designed to meet a number of stormwater management objectives under a variety of site, soil, climate, and traffic loading conditions.

Variable	Traditional Watershed				BMP Watershed			
	Control Watershed	Predicted	Observed	% Change	Control Watershed	Predicted	Observed	% Change
Stormflow (m^3/wk)	120.47	0.11	16.48	+99	117.90	15.92	0.17	- 9,265
Peak flow (m^3/sec/wk)	0.028	0.001	0.005	+80	0.027	0.0004	0.001	- 300

Table 1. *Construction Period Stormflow and Peak Flow Monitoring (from UCONN Jordan Cove Website - May 24, 2002)*

A "rain garden" is incorporated into the Eco-Stone® cul-de-sac

Over 15,000 square feet of Eco-Stone® pavers in a red and charcoal blend were produced by UNI® manufacturer Ideal Concrete Block Company, Inc. of Westford, Massachusetts, for the project. An angular, processed 1 1/2" gravel with less than 5% passing the #100 and #200 sieves was installed for the 12" thick base. The bedding layer and drainage opening fill material was selected to meet the following sieve specifications: 1/4" - 100% passing; #4 - 0-20% passing; and #10 - 0-5% passing.

Bruce Morton of Aqua Solutions, manager for the project, noted that the Eco-Stone® segmental paving used for the roadway and some driveways slows water flow, thus allowing time for oxidation and filtering of some contaminants, filtering of suspended solids, and cooling of water temperature. "This form of pavement offers new possibilities in surface water control with the potential of reducing the size or need for special stormwater retention facilities," he said. He added that it mitigates pollution impact on surrounding surface waters and contributes to groundwater recharge. "When properly designed, these pavement systems can provide functional requirements for most loading conditions and can be designed to accommodate stormwater management requirements," he noted.

The vegetated bio-swales and rain garden adjacent to the UNI Eco-Stone® permeable pavement also help provide filtration of sediments and contaminants in the stormwater runoff draining onto the pavement.

Though there was initially some concern about snow plowing the Eco-Stone® cul-de-sac by Ronald Cusano, Director of Public Works for the Town of Waterford, the pavement posed no problem for their equipment during the winter months.

Maintenance for this project is similar to that for a standard subdivision - the town keeps the Eco-Stone® road clean with conventional sweeper/vacuum equipment, while the residents maintain their property. Maintenance is an important aspect of permeable interlocking concrete pavements that helps ensure long-term performance. Inspection for ponding is conducted annually and aggregate in the drainage openings is replaced if necessary. During construction, sediment was carried onto the Eco-Stone® pavement by vehicles, which resulted in reduced infiltration. Permeability was easily restored to pre-construction levels with street sweeping.

Monitoring from the construction phase of the BMP site revealed that weekly storm-flow and peak discharge (Table 1) have decreased significantly and that runoff from the site has lower concentrations of most water quality parameters compared to the control site. Sampling results from a January 2000 EPA report showed that construction of the traditional neighborhood caused significant impacts on water quality and quantity, including observed increases in mean weekly flow volume, runoff frequency, and mean weekly peak discharge. Conversion of the watershed's topography, combined with an increase in impervious surfaces, appears to have caused a significant change in hydrologic responses, and concentrations of NO_3-N and Pb in the runoff also increased.

The USEPA, in coordination with the Connecticut Department of Environmental Protection, (DEP) spent $680,000 on the BMP implementation and monitoring of the project during construction and another $100,000 per year was allocated for 3 years of post-construction monitoring.

At a ceremony celebrating completion of construction at the Glen Brook Green subdivision in October 2002, Robert W. Varney, regional administrator of EPA's New England office noted the importance of the project. "Whether it's new homes or an office park, these projects need to be built in a way that minimizes damage to our water resources," he said. Jane Stahl, Deputy Commissioner of Connecticut's DEP also spoke at the celebration. "The Jordan Cove monitoring project is a real life example of neighborhood-level environmental stewardship where innovative land-use practices have been applied to reduce pollution and improve the quality of life of the residents who live in this urban subdivision," she noted. "Not only will the residents of this subdivision benefit from this national project, the ideas and practices utilized at Jordan Cove can be applied across Connecticut and the country to improve water quality, becoming the standard for the design and construction of residential neighborhoods nationwide."

In September 2003, the University of Connecticut released their annual report on the Jordan Cove Urban Watershed Project. The second phase of testing, conducted in 2002 and 2003, included infiltration tests on the asphalt, crushed stone, and UNI Eco-Stone® driveways in the BMP project. *Test results show the Eco-Stone® permeable pavement had the highest infiltration rates (Table 2).* What makes these results impressive is that they were recorded on driveways with slopes of 4.4% and 4.7%. Typically, maximum infiltration rates are achieved with slopes in the 1% to 2% range.

Test and Year	Asphalt	Eco-Stone® 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 2003	0	6 (15.3)	5 (12.7)
Flowing Infiltration test 2003	0	8.1 (20.7)	2.4 (6)

Table 2. *Average infiltration rates from asphalt, Eco-Stone® permeable pavement and crushed stone*

The report also included infiltration rates for other surfaces, such as soils, undisturbed forest floor, and unimproved pasture, as a comparison to the pavement infiltration rates (Table 3). This table indicates that the Eco-Stone® permeable pavement would fall under the category of *"rapid"* infiltration, even though it was constructed with a dense-graded base. The Eco-Stone® infiltration rates were substantially higher than those for natural forested and pasture areas.

Category	Infiltration rate in./hr (cm/hr)	Reference
Very rapid	> 9.8 (25)	Novotny 1993
Rapid	4.9 - 9.8 (12.5 - 25)	Novotny 1993
Moderately rapid	2.5 - 4.9 (6.3 - 12.5)	Novotny 1993
Moderate	0.8 - 2.5 (2.0 - 6.3)	Novotny 1993
Moderately slow	0.2 - 0.8 (0.5 - 2.0)	Novotny 1993
Slow	0.06 - 0.2 (0.12 - 0.5)	Novotny 1993
Very slow	< 0.06 (0.12)	Novotny 1993
Comparison of Infiltration Rates		
Non-compacted sandy soil	15 (38.1)	USEPA 1999
Compacted sandy soils	3 (7.62)	USEPA 1999
Non-compacted dry clay	8.9 (22.4)	USEPA 1999
All other clay soils	0.7 (1.8)	USEPA 1999
Undisturbed forest floor	2.4 (6)	CHOW 1964
Oak Hickory forest	3 (7.6)	CHOW 1964
Unimproved pasture	0.9 (2.4)	CHOW 1964

Table 3. *Infiltration categories and comparison of infiltration rates*

Grass swales provide additional runoff control, help filter sediment, and offer pollutant reduction capabilities

While interlocking permeable pavements are typically constructed with open-graded or rapid-draining crushed stone base materials, the research does demonstrate a variety of aggregate materials might be used depending on design parameters. In all cases, however, fines passing the No. 200 sieve should be less than 3%. Permeable interlocking concrete pavement design is site specific and should be designed to meet local stormwater management objectives for the project.

Permeable pavements are considered structural BMPs under infiltration practices. Designed to mitigate stormwater runoff through infiltration, Eco-Stone® can reduce volume and peak flows, filter pollutants, capture "first flush", and help remove total suspended solids (TSS).

The pollutant reduction capability of the UNI Eco-Stone® pavement at Jordan Cove was also included in the annual report and is compared to the asphalt and crushed stone pavements (Table 4). These monitoring results demonstrate the statistically significant reductions of TSS and other pollutants such as ammonia, phosphorous, copper, and zinc.

Bruce Morton, whose firm provides guidance on the Jordan Cove runoff monitoring project in conjunction with John C. Clausen of the University of Connecticut and the USEPA, notes that the data is impressive. "Results have shown that the Eco-Stone® pavement in the driveways and street cul-de-sac have reduced runoff and water pollutants," he said.

Variable	Asphalt		Eco-Stone® 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

Table 4. *Mean weekly pollutant concentration in stormwater runoff from asphalt, Eco-Stone permeable pavement, and crushed stone driveways*

Note: Within each variable, means followed by the same letter are not significantly different at $\alpha = 0.05$

Concentrations of toxic levels to aquatic life	Copper	Lead	Zinc
Freshwater (acute/chronic), ug/l	13 / 9.0	65 / 2.5	120 / 120
Saltwater (acute/chronic), ug/l	4.8 / 3.1	210 / 8.1	90 / 81
Human consumption, ug/l	1300	0	9100

Table 5. *Toxic concentrations of metals (USEPA, 1999)*

Legend: mg/l = milligrams per liter
ug/l = micrograms per liter

With virtually all the water quality objectives for the project met, the Glen Brook Green subdivision in the Jordan Cove watershed clearly demonstrates the effectiveness of the BMPs implemented on the site and represents a powerful tool for promoting sustainable, green, LEED,® and low impact development practices. The project has gained nationwide attention in the design, engineering, land development, and building industries and is often cited in stormwater design and research, such as Bruce K. Ferguson's *Porous Pavements* book, for the sophisticated level of data collected and published on best management practices to control stormwater runoff.

The Eco-Stone® permeable pavement streets and driveways remain in excellent condition after several winters

"Urban communities around the country face increasingly stringent stormwater management requirements that often conflict with traditional subdivision regulations and construction standards. This project will help determine whether new subdivisions can use design features that are more sensitive to the environment," noted Peyton Fleming of the EPA's New England Office of the Regional Administrator.

References:
Annual Report - Jordan Cove Urban Watershed Section 319 National Monitoring Program Project, University of Connecticut, 2003.
National Monitoring Project in Waterford, CT Hits Major Milestone, Peyton Fleming, Office of Regional Administrator, EPA New England, 2002.

Thank you to the Interlocking Concrete Pavement Institute for project photos.

Note: An engineer or design professional should be consulted in permeable concrete paver applications to ensure good results. For more information:

- *Design Considerations for the UNI Eco-Stone® Concrete Paver*
- *Drainage Design and Performance Guidelines for UNI Eco-Stone® Permeable Pavement*
- *UNI Eco-Stone® Guide and Research Summary*
- *Lockpave® Pro structural design software featuring PC-SWMM™ PP hydraulic design software*

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