

**Hartley Nature Center
Pervious Surface Demonstration Project**

Final Report: December 2003

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by NOAA's Office of Ocean and Coastal Resource Management, in
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Overview of Materials

In designing the Hartley Nature Center (HNC) facility, HNC staff, board members and design consultants set the goal of using environmentally sensitive materials and design techniques. In conjunction with this effort, the design team developed a plan to use pervious paving systems for the building's entrance walkway, new parking spaces and emergency vehicle access. A grant from the Lake Superior Coastal Program helped make this initiative possible. In the spring of 2003, the pervious surfaces were installed.

These materials provide a comprehensive overview of pervious surfaces, including their environmental advantages, basic composition and a listing of system suppliers. Also included is a detailed description of the Hartley Nature Center pervious surface project and curriculum materials for educators interested in teaching about such systems.

The report was written by HNC's building project manager Bill Maier. Curriculum materials were reviewed by HNC educator and park stewardship coordinator Erik Hahn.

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- EPA fact sheet on hydrological impacts of urbanization on streams
- Ohio State University fact sheet: Coping with Polluted Runoff
- NEMO fact sheet: Non-point Source Water Pollution
- NEMO fact sheet: Impacts of Development on Waterways

Part II. The Promise of Pervious Paving Systems

- Booth and Leavitt (1999) study: Field Evaluation of Permeable Pavement Systems for Improved Stormwater Management.
- Environmental Building News 1994 article: "Paving with Grass"
- Stormwater Resource Center Article 129: "The Peculiarities of Perviousness"
- Stormwater Resource Center Fact Sheet: Porous Pavement

Part III. How to Pave with Pervious Systems

- Pennsylvania Department of Environmental Protection article: Standard for Pervious Paving Systems
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Hartley Nature Center Pervious Surface Demonstration Project

Part I. The Problem with Impervious Pavement

Asphalt and concrete roads, driveways and parking areas are impervious to water. That is, their surfaces do not allow rainwater or snowmelt to percolate down into them. Thus, stormwater forms puddles on these surfaces or runs off them laterally. Water traveling over impervious pavement can absorb heat, take up pollutants and sediment and gain velocity as it heads down hill.

In urban areas, stormwater runoff from impervious surfaces can have significant environmental impacts on neighboring streams, rivers and lakes. Numerous studies have identified the following effects on waterways:

- increased peak water flows in streams
- increased stream temperature
- increased sediment loads
- increased pollutant concentrations
- erosion and widening of stream and river banks

Stream banks erode naturally, but when disturbed by human activity are eroded in an accelerated speed. Such erosion generates elevated levels of sedimentation into streams.

In addition to carrying pollutants (e.g. oil, grease, lawn treatment chemicals and road salt) sediment particles in runoff have several adverse effects on stream habitat and organisms. If the sediment is of small particle size (e.g. clay), it becomes suspended in water, interfering with foraging by fish and other visual predators. Further, just as particles suspended in air can affect human breathing function, suspended sediments can harm gills of fish and invertebrates.

Sediment of larger size (silt and sand) can become deposited on stream beds, sometimes burying and suffocating aquatic life, including invertebrates, fish eggs and fry. This is especially problematic for fish of the salmonid family.

For more information on these effects, please see the following fact sheet by the US Environmental Protection Agency or related information provided in Section VI – Resources.

A common, yet expensive stormwater mitigation strategy is to construct holding ponds to collect runoff from impervious parking areas and roads. Here, runoff water gradually evaporates or seeps into the ground.

An emerging alternative is to pave with pervious surfaces that prevent or reduce runoff by allowing water infiltration into the ground. This strategy is described in detail in the following sections.

Part II. The Promise of Pervious Paving Surfaces

An emerging strategy for preventing runoff is to build parking and transportation facilities with surfaces pervious or permeable to water. This does not simply mean going back to the “old days” of gravel and dirt surfaces, which once compacted, are almost as impervious as asphalt.

Pervious paving surfaces consist of a supporting lattice (usually made of concrete, brick or plastic) and a matrix of permeable fill (usually gravel, sand or topsoil). The lattice supports the weight of intended users, like vehicles and pedestrians, thus preventing compaction of the matrix material. That’s the key feature – preventing users from compacting a material that can then let water infiltrate. For examples, please see the resources in Section VI or the Hartley Nature Center case study described in Section IV. Also see the enclosed article from Environmental Building News.

Do they work?

A few studies have examined the effectiveness of pervious paving systems at reducing or preventing runoff. A thorough study is provided in the following pages. This study (Booth and Leavitt, 1999) found that several such systems, both concrete and plastic-based, were vastly more effective at allowing water infiltration than traditional asphalt. However, there is very little research on how these surfaces perform in northern Minnesota’s climate and soils.

Part III. How to Pave with Pervious Surfaces

A. Choosing the Right System

There are several factors one needs to consider when selecting the right pervious surface:

- Level of use
- Maintenance capabilities
- Accessibility requirements
- Aesthetics
- Desire for vegetated surface

Different systems are designed to meet different levels of use, ranging from able to support fire trucks to suitable for pedestrian use only. Most systems require maintenance of the pervious qualities as well as the structural qualities. For example, some surfaces require occasional sweeping to remove silt and organic material, which can reduce the infiltration capabilities of the surfaces.

Finding a pervious surface for pedestrian use that is highly accessible to wheel chair users can be difficult. Concrete-based systems have voids or spaces in the concrete that are filled with gravel. The voids can eventually lose some gravel and thus make the surface very bumpy. The best choice might be plastic grid systems with crushed gravel surfaces. However, increasing the degree of surface stability (by using finer particles in the gravel or a surface stabilizing product), may cause a loss of permeability. (Note: if you find a way to maintain high levels of permeability while providing a smooth, stable surface, please call us!)

One also needs to study the site. The success of pervious paving depends on the characteristics of the local environment. The subsurface needs to have permeability and porosity to allow stormwater to drain from the pervious system. Otherwise, if the material under the paving surface is too compacted or poorly draining (or worse, if the site is right above bedrock or the water table), these systems will not perform as intended. You'll see puddling and possibly runoff after even moderate rainfall events.

It is recommended that moderately pervious native material, with a depth or at least three feet to the seasonally high water table or bedrock exist at the site.

For more information, please refer to the following fact sheet on designing with pervious paving systems or contact the suppliers of various systems.

Part IV. Case Study: The Hartley Nature Center Project

A. Project Goals

During the course of the design of the Hartley Nature Center facility, HNC board and staff established the goal of using environmentally sensitive materials for the project. Our strategy for paved surfaces was to use pervious surfaces for the following facilities:

1. An entrance walkway, 142 feet long and 8 feet wide, which would provide pedestrian access from the parking area to the nature center building
2. Additional parking area: we needed to add approximately 10-12 spaces to accommodate visitor use of the facility; these spaces would occupy an area approximately 1,972 square feet.
3. An emergency vehicle access was needed to serve the building. The required access way needed to be 20 feet wide. The entrance walkway would provide eight feet of this width. The remainder would be a third surface, approximately 12 feet wide and 123 feet long.

See attached site plan.

B. Systems Used and Evaluation

1. Entrance Pathway

For the entrance pathway, we used the EnviroPave paver spacer system. This system uses a plastic spacer that allows brick pavers to be positioned one inch apart. Permeable gravel and or soil is placed between the pavers. Thus, the bricks carry the load and the spacers maintain the spaces between bricks, where grass or other vegetation can grow.

Evaluation:

No puddling has been observed on this surface. Its permeability appears to be functioning well.

While the surface is attractive, with its herring bone design and reminiscence of old brick roads, we have had difficulty making it smooth enough for comfortable wheel chair use. The voids are currently filled with crushed bluestone and soil. Some plants are already established within them. We will attempt to increase the soil content and grass cover to help smooth out the void areas in the spring of 2004.

One issue of concern was snow removal. However, given the herring bone surface, snow shovels and our snow blower do not get caught in the voids. Thus, this problem has not come to bear.

2. Emergency Vehicle Access

We used the GrassPave2 plastic grid paving system here. Because this surface does not need to support pedestrians or frequent vehicle use, we chose the NetPave system because we felt we could make this accessway appear very natural, with a high level of vegetation. We covered the system with soil an annual grass and native plant seed supplied by Boreal Natives. After a partial season of growth, vegetated cover is about 30-40%. We'd like to see that increased and will plant more seed next spring.

Evaluation:

Although we haven't tested the surface with a fire truck, it does support cars and pickup trucks well. The permeability seems to be working, as no puddling has been observed.

One concern is how well such a surface would stand up to moderate vehicle use. Gravel can become loose on the surface, thus exposing the plastic grid. We've seen a small area of our grid get exposed and pulled up. Once the grid is pulled up, it's very difficult to lay back into the proper position. We will likely have to excise that part of the grid.

3. Additional Parking Spaces

Here, we again used the GrassPave2 system. Part of our desire to use this system for parking stemmed from our interest in having a grass-paved surface – something we felt would make an impression on nature center visitors. We wanted people to think “hmm, this is different”, which could heighten interest in the concept and thus create an educational opportunity.

The grid system is covered with a course soil/gravel mixture, with a thin layer of topsoil. Vegetation has become established through natural seeding to a 5-10% cover level. In the spring, we will temporarily restrict use of the surface to increase vegetative cover.

Evaluation

All summer long, we observed extensive puddle formation on this surface after moderate and heavy rain events. That may be the result of heavy compaction of underlying material in this area during the construction process. Hopefully, we'll see better infiltration as the compaction decreases due to freezing and thawing of the ground in spring.

We were also concerned about whether snow plows would destroy the system during the winter. We asked City snow plow crews to avoid plowing the area until the ground was frozen. This has helped, and as of mid-December, the ground was sufficiently frozen to allow plowing without harm of the pervious surface.

C. Costs

Kraus Anderson Construction was the general contractor for this project, which was a component of the overall Hartley Nature Center building project. Their cost for the pervious surface installation was \$38,500, for a per square foot cost of \$8.40/SF. Northern Lights Landscaping was the subcontractor that installed the surfaces, while Nels Nelson was the subcontractor responsible for site grading and earthwork.

Short-Elliot-Hendrickson was the civil engineering firm responsible for construction administration during the project. Their cost was \$2,100.

It is the impression of the author that smaller pervious surface projects can be installed by small civil contractors, including landscaping firms, or even by ambitious do-it-yourselfers. This would remove the overhead cost having a subcontractor, which can be 15% or more.

Part V. Curriculum

Summary: The following activities are designed to help students (grades 4 and up) compare different types of paving surfaces and more natural surfaces with regard to their potential to prevent or reduce stormwater runoff. The activities are intended for use within lessons on stream ecology, water quality and general lessons on sustainable design.

Objectives

1. Students will gain an awareness of what stormwater is, how it occurs and its environmental effects on streams.
2. Students will compare the water infiltration rates and levels of soil compaction of the following surfaces:
 - Asphalt pavement
 - Net-Pave 50 plastic grid pervious surface
 - EnviroPave brick paver surface
 - Gravel trails
 - Trails on native soils
 - Native forest or field surfaces
3. Students will analyze the runoff-prevention effectiveness of various surfaces and discuss their suitability for various applications, including:
 - city street
 - parking area at a public picnic area
 - driveway
 - alley
 - golf course cart path
 - mall parking lot
 - heavily used hiking trail
 - infrequently used hiking trail
4. (If it's raining...) students will observe and compare first-hand the runoff prevention effectiveness of various surfaces and follow runoff from these surfaces to see where it might be having an adverse environmental impact. Students will also tour a stormwater retention pond to learn about this mitigation strategy.

Activities

Note: the following activities are intended to be integrated into a broader lesson. If teaching about stream ecology or water quality, you may want to begin with a general introduction about stream ecosystems, the importance of water quality and the threats to

healthy stream ecosystems. Then have the class conduct a field investigation of a stream, to observe invertebrates and other organisms and measure various indicators of water quality, such as “bioindicators”, dissolved oxygen and phosphorous levels. Afterwards, use the following activities to highlight an example of what people can do to protect streams and water quality.

Activity 1: Watersheds and Sources of Water Pollution

A. Introduction: After your class has conducted its field investigation of a stream environment, ask students what kinds of human activities have an adverse effect on streams. Students may mention the dumping of pollution into streams (“point-source”), since this is a direct and obvious means of stream degradation, but students may not be aware of less direct means, called “non-point-source” pollution. Tell the students that some activities NEAR the stream can affect the stream. Ask them to develop this concept. Crystallize the key term “runoff” and provide a rough definition.

B. The Watershed Model: Show the class the watershed model. Ask students to identify the various human activities shown. Have students volunteer to come to the front to demonstrate non-point source pollution using the tools and materials provided. For a more detailed description of the activities, please see the directions accompanying the model.

Activity 2: Runoff Awareness Slide Program

This is a slide presentation developed by the Stormwater Resource Center (see Resources). You may wish to present it during your general introduction to the overall lesson. Note: if you do not have the budget to purchase the slide program, you can rent it from Hartley Nature Center by calling (218) 724-6735.

Activity 3: Runoff Review

After conducting activity 1 or 2 (or both), review the types of impacts that can occur due to runoff. For more information, see Section I of this guide or Section VI - Resources. For each impact, give an example of an animal or habitat that could be affected. Examples include: brook trout, which are affected by increased temperature; fish breeding habitat, which is affected by increased sediment levels; and numerous invertebrates, which are affected by decreased dissolved oxygen levels (a secondary effect of runoff containing fertilizers).

In northeast Minnesota, many streams are particularly sensitive to runoff due to their characteristics. North Shore streams are generally small in volume and surrounded by thin soils or bedrock. These streams don’t have much of a “buffer”; that is, there’s little water holding capacity in watershed soil, and the volume of water is too low to dilute the effects of runoff.

Activity 4: Water Infiltration Study

We can't stop it from raining. Thus, to reduce runoff, we have to deal with water once it hits the ground. Reducing runoff means slowing water down and letting it percolate gradually into the ground. Ask the students how this can be done if we have an impervious surface. (At Hartley Park, stormwater from some impervious pavement, such as on the entrance road is routed to a retention pond).

Another option is to pave with an impervious surface. That means, we build a surface able to support and withstand certain uses (parking, driving, pedestrian), while still allowing water infiltration. Do these surfaces work? Let's find out. Have the students compare different surfaces with regards to infiltration rates. You can use either of two methods:

Method One: Using an Infiltrometer. This is a tool that measures the speed of infiltration of water into soil. Follow the instructions provided with the tool.

Method Two: Using household materials. Students will need the following to conduct this test: a ¼ cup measuring cup, a watch (or stop watch) and an empty cardboard juice concentrate can (with the bottom metal lid cutoff). To measure infiltration rate, hold the juice can vertically on the surface to be studied. You may want to rotate it around a few times to make a functional seal with the surface. Next, gently pour ¼ cup of water down into the juice can. Measure the time in seconds that it takes for the water to infiltrate.

Activity 5: Soil Compaction Study

Heavily compacted soil can prevent infiltration and thus cause puddling and runoff to occur. Compacted soil also retards plant growth. Plants themselves can reduce runoff by taking up water, filtering out pollutants and slowing down falling rain drops, thus reducing their collision impact with soil and slowing erosion.

Have the students guess which of the following surfaces has the greatest soil compaction. Have them make a hypothesis ranking in order of increasing compaction.

- GrassPave2 plastic grid surface
- Native Soil
- A soil-based hiking trail
- Asphalt pavement

Next, have them measure the compaction using a soil penetrometer (directions provided with the tool). Compare the results to hypothesis ranking. Were there surprises? (At Hartley, the trails on native soil can get extremely compacted. Don't be surprised to find the pervious paving system to be less compacted, even at the parking area, than the trail.)

Activity 6: Students as Civil Engineers

After these field investigations, have the students discuss different applications of the various surfaces. Break the class into small groups (2-3 students) and give them large piece of paper (to be posted for class presentations later) with a list of possible applications, including:

- city street
- parking area at a public picnic area
- driveway
- alley
- golf course cart path
- mall parking lot
- heavily used hiking trail along a stream
- infrequently used hiking trail

Next to each application, the students should write-in what surfaces they would use to best accommodate uses while reducing runoff as much as is practical. They can choose from the following list of surfaces: asphalt, gravel, native soil, GrassPave2 and EnviroPave. Afterward, have the students present their results with explanations. For discussion, ask them: Did anyone think hiking trails should use an impervious system? What factors did you consider when choosing a surface for the city street? What if the mall parking area is a long distance from a waterway – would that affect your decision? Ask the students what surfaces they have in their neighborhood. Where does the runoff go?

Activity 7: Tour de Runoff

If it's raining, use the opportunity to observe runoff first hand. At Hartley Park, students can tour the asphalt parking area and entrance road, two types of pervious paving systems, gravel and dirt trails and native surfaces. You may choose whether to divide the class into groups (depending on the need for adult supervision), to explore what happens to rain water when it hits the surface. Is water running off into the stream? From which surface? What particles and potential pollutants might be getting into the stream?

Activity 8: Impervious Surfaces on Your School Grounds

This is a “take-home” activity. Have the students conduct a field study of the percent of their school grounds (or home) that is impervious. The percent impervious surface can be a general indicator of environmental health with regards to runoff pollution. Students can use aerial photographs or create a map (to scale) using measuring tapes or pacing. During the investigation, students should keep a log of all the pollution they see and note whether that pollution could runoff. Where would the runoff go? Then ask the students what steps could be taken to reduce the runoff from their school grounds (or home).

Part VI. References and Resources

Books

Wildstream. A Natural History of the Free Flowing River. 2000. Thomas F. Waters. Riparian Press. St. Paul, MN.

Fundamentals of Urban Runoff Management. 1994 The Terrene Institute.

Introduction to Stormwater. 1998. Bruce Ferguson. University of Georgia.

Web Resources

Stormwater Runoff Pollution

Environmental Protection Agency: <epa.gov/owow/nps/urbanize/report.html>

Stormwater Resource Center: <stormwatercenter.net>

Center for Watershed Protection: <cwp.org>

Nonpoint Education for Municipal Officials (NEMO): <nemo.uconn.edu>

Pervious Surfaces - General

Green Builder Sourcebook: <greenbuilder/sourcebook>

State of New Jersey: <www.state.nj.us/dep/watershedmgt/docs>

A business consortium: <perviouspavement.com>

Cool Communities (a non-profit organization promoting pervious and low-heat paving):
<coolcommunities.org>

A case study of pervious alleyways in Vancouver:

<psat.wa.gov/Publications/LID_studies/permeable_pavement.htm>

Pervious Pavement Systems - Types

Grid Paver Systems

**Invisible Structures website (Surefoot⁴ | Beachrings² | Grasspave² |
Gravelpave²)**

www.invisiblestructures.com

Grid tech website (Advanced Turf | Turfguard | Flexipave)

www.netlon.co.uk/turfsystems/introduction.htm.

Geoblock Porous Pavement System by Geosystems

www.prestogeo.com

Grass-Securing-Honeycomb by Ritter Technik

www.ritter-technik.co.uk

Cellular Confinement System by EnviroGrid

www.aghindustries.com/geocell.htm

Tensar Geogrids by ConTech

www.contech-cpi.com

Block Paver Systems

EnviroPave

[<muerarosy.de>](mailto:muerarosy.de)

Pavestone

www.pavestone.com/commercial/erosion_control.html

Progressive Concrete Inc.

www.progressiveconcreteinc.com

Unilock (Eco-Stone | Turfstone)

www.unilock.com

Uni Group USA

www.uni-groupusa.org/uni-eco-.htm

Netlon Turf Systems

www.netlon.co.uk/turfsystems/introduction.htm

Pervious Concrete Systems

Stormwater's E-Journal

www.forester.net/sw_0103_porous.html - Rather than conveying runoff from a site, a number of systems are designed to let it simply sink in.

Cahill Associates - Environmental Consultants

www.thcahill.com/porous.htm - Porous Pavement for Stormwater Management

EPA - Storm Water Technology Fact Sheet, *Porous Pavement*

www.epa.gov/owm/mtb/porouspa.pdf

Porous Pavement - Pavement That Leaks

www.millermicro.com/porpave.html - Commentary, by A. Richard Miller

Presto - Porous Pavement Systems

www.prestogeo.com/files/pdfs/porous_pavement_overview.pdf

Managing Stormwater - Porous Pavement

www.greenworks.tv/stormwater/porouspavement.htm

Titan America

www.tarmacamerica.com

PermaPave™

www.permapave.com.au

Soil Pavement Systems

Stabilizer by Stabilizer Solutions, Inc.

www.stabilizersolutions.com

Road Oyl by Soil Stabilization Products Company, Inc.

www.sspco.org

PolyPavement

www.polypavement.com