WHERE DOES WATER RUN OFF AFTER SCHOOL?

OBJECTIVE

Students will be able to describe relationships between precipitation, runoff and aquatic habitats.

METHOD

Students measure and calculate the area of the schoolground; calculate the volume and weight of water falling on the schoolground; determine specific and annual rainfall and runoff; and trace the course of that water to aquatic habitats.

BACKGROUND

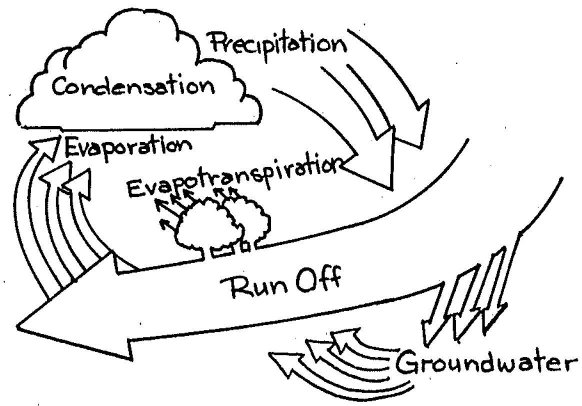
Rainfall is obvious—but runoff from rainfall is a relatively abstract concept. Although we may notice and in fact get drenched in a rainstorm, we don't typically stop to wonder **how much** rain is falling. The volume and mass of the water in a rainstorm is astounding to those who calculate the values. NOTE: See "Puddle Wonders" for an interesting related activity.

Developing an understanding of precipitation and runoff is an important part of understanding the water cycle. Rainfall is one form of precipitation. Rainfall is one way water re-enters aquatic habitats. Once rain falls upon a surface, water begins to move both laterally outward and vertically downward. Lateral movement is runoff and finds its way into streams, rivers and lakes. Vertical movement seeps into the soil and porous rock and re-charges groundwater supplies.

Paving and soil compaction can reduce an area's water absorbing ability and therefore increase runoff. Reduced absorption rates can negatively impact vegetation and groundwater recharge.

Runoff is the dominant way that water flows from one location to another. It is in runoff that many pollutants find their way into moving waters. These are kinds of pollutants called "nonpoint source." What this means is that widespread sources of pollution such as garden insecticides, automobile emissions caked on parking lots, lead from paints and exhaust, etc., are washed by runoff into streams, rivers, lakes and oceans. Eventually the water becomes part of an aquatic habitat and the toxins begin their damage.

Runoff is also responsible for erosion, transportation and deposition of sediments scoured from the land's surface. Substandard agricultural and other land practices often prepare fields and their topsoil to be washed away.



On the positive side, the contamination levels in much of runoff are negligible. Runoff waters are necessary to renew many aquatic habitats that are dependent upon inflow for continuity. The inflow prevents lakes from shrinking due to evaporation and it prevents streams from going below minimum flow levels. Inflow thus helps support aquatic life. Without some runoff, aquatic habitats would suffer. In this activity, the students calculate both the volume and the weight of rainfall. They consider relationships between rainfall and runoff, including effects on wildlife and the environment.

The major purpose of this activity is for students to increase their awareness and appreciation of some things they may take for granted—rainfall, runoff and the connections between surface waters and aquatic habitat.

MATERIALS

writing materials; meter or yardsticks; long piece of twine with marks every yard or meter; rain gauge; local rainfall data
OPTIONAL: calculator; trundle wheel.

PROCEDURE

1. In this activity, students will find out how much rain falls on their schoolground—and how much it weighs! First, the students must determine the total area of the schoolground. For the purposes of this activity, the outer dimensions of the property will satisfy. There is no need to subtract the area of the buildings since it is assumed that rain falls upon them as well.

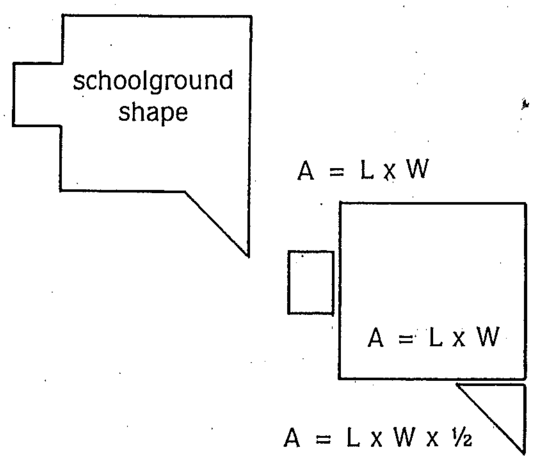
The formula for calculating area is:
Area = Length x Width (or A = LW)

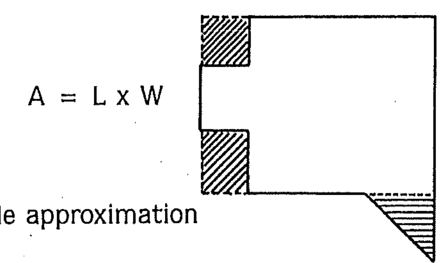
NOTE: See the extensions to this activity for metric approximations.

The length and width of the schoolground must be measured. The students can use a length of twine (approximately 100 feet in length). Mark the twine every three feet. The marking can be done with an ink marker, short pieces of string tied every yard, or a knot each three feet. If a trundle wheel is available, it is convenient to use for measuring.
NOTE: A trundle wheel is a device that makes the measurement of linear distance simple. It is a wheel that operates a counter or clicks as it is rolled over the surface attached to a handle. Each revolution of the wheel represents one yard or meter. Check to see if the school has one. City road crews often have them and may loan one to you for a few days.

The main difficulty with calculating the area in this activity comes from irregularly-shaped schoolgrounds. Try not to get bogged down in detailed exactness. A healthy approximation will do. Here are a few examples:

most accurate





workable approximation

2. Once the area of the schoolgrounds has been established, the next step is to determine the amount of rain that falls in the area. Three options are possible:

- Calculate the annual rainfall on the schoolgrounds using information from resource agencies, e.g., weather bureau, soil conservation service, local TV weatherpersons, local newspapers.
- Using a rain gauge, measure the amount of rain over a period of time.
- Calculate the amount of rain that falls in a given storm.

When the students have decided on a way to measure the amount of rain that falls on their schoolground during a specified period of time, ask them to calculate the amount. This provides the students with a value for the depth of rainfall on the surface of the land.

3. With the depth of rainfall determined, and the area of the schoolground measured, the next step is to calculate the volume of rainfall. For example, suppose the area of the schoolground is 50,000 square feet and the annual rainfall is six inches or .5 feet. Then the volume of rain would be:

50,000 square feet x .5 ft of rain =
25,000 cubic feet of rain

The volume of rain is 25,000 cubic feet of rain.

4. Knowing the volume, the students can now calculate the weight of the rain. Water weighs 62.5 pounds per cubic foot, thus the weight of six inches of rain (25,000 cubic feet) is:

25,000 x 62.5 = 1,562,500 pounds or 781.25 tons of rain.

5. All of the measurements and calculations done in this activity are intended to impress upon students that there are remarkable volumes and weights of water moving through the water cycle. Even short periods of rainfall produce amazing amounts of water. All the water that the students measure eventually finds its way to a wildlife habitat. A major issue of concern is how humans affect the quality and quantity of water that eventually reaches aquatic habitats. Consider and discuss the following questions:

- Where does the water from rainfall go when it leaves the school site?
- How much water is absorbed by the different surfaces on the school site?
- With what kinds of potential pollutants does the water come in contact?
- Where is the location of the nearest wildlife habitat that receives the school's runoff?
- How do people use the water between the time it leaves the school and arrives in the wildlife habitat?
- What are some of the positive and negative effects that the water may have on the environment at various points on its journey?

EXTENSIONS

1. Obtain a map of the school and check it against the accuracy of the one you made. Make a copy of the school district map, or use your own map, and plot runoff routes on it. Check periodically during rainstorms to identify the drainage patterns. Try to find a way to estimate how much water is draining in specific places.

NOTE: Most school districts have maps in the administrative department concerned with buildings and grounds.

2. If you did not already, place a rain gauge on the schoolground and measure actual amounts of rain. Repeat your calculations.

3. Do this activity in metric:
   - 100 feet = 30.48 meters
   - 3 feet = 1 yard = .9114 meter
   - Square feet x .0929 = square meters
   - Inches x 2.54 = centimeters
   - Feet x .3048 = meters
   - Pounds x .4536 = kilograms

4. A serious modern concern is the contamination of groundwater. How might water in the groundwater table or aquifer become contaminated with chemicals potentially harmful to human health? To the health of other animals, including wildlife? Identify as many sources of contamination to groundwater and runoff in your area s possible. What can, or is, being done to reduce or eliminate these sources and their effects?

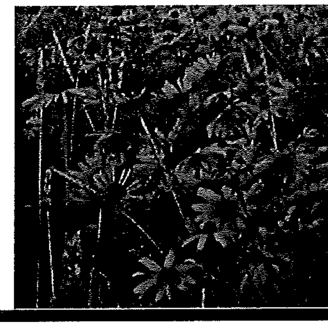
EVALUATION

1. Describe at least two relationships between aquatic habitats, precipitation, runoff and surface water.
2. Name two human activities that have affected the quality of runoff.
3. Name two human activities that have affected the quantity of runoff.
4. Name two ways that runoff can affect humans.
5. Name and describe two ways that runoff can affect aquatic wildlife.
6. Write an advertising campaign slogan to convey the importance of runoff to wildlife. Include the need for clean water without toxins.
7. Write a short list of steps to take for wildlife to protect the quality of runoff water.

Age: Grades 6-12
Subjects: Math, Science
Skills: analysis, computation, description, discussion, estimating, inference, measuring
Duration: two 45 to 60-minute class periods; one period, if dimensions of the school grounds are provided
Group Size: any
Setting: outdoors and indoors
Conceptual Framework Reference: III.A.1., III.B., III.B.1., III.B.3., III.C., III.C.1., I.A.1., I.A.2., I.A.3., I.B., I.C., I.C.2., I.C.3., I.C.4., I.D.
Key Vocabulary: runoff, precipitation, volume, area, weight
Appendices: Outdoors, Metric Charts

Wisconsin Rain Garden Educator's Kit CD Contents • Version 3

- PowerPoint Presentations
- How To Build a Rain Garden
- Plant Lists & Resources
- Demonstration Sites
- Articles
- Websites
- Speakers List
- Workshops & Tours - Sample Materials
- Rain Garden Displays
- Educational Sign
- Research Projects
- Digital Photo Library
- *Into the Outdoors* Video
- Ways that Municipalities can Encourage Rain Gardens
- Contact Us



PowerPoint Presentations

- Digging Into Rain Gardens (overview)
- The Value of Rain Gardens (stand-alone or use as Part A of a workshop)
- How To Build a Rain Garden (stand-alone or use as Part B of a workshop)

How To Build a Rain Garden

- *Rain Gardens: A how-to manual for homeowners* -UWEX/DNR Manual
- *How to build a rain garden* brochure -Dane Co. Lakes & Watersheds Commission
- *Build your own rain garden* design sheet - Taylor Creek Nursery
- Tips for Clay Soils
- *Rain Gardens: A household way to improve water quality in your community* -UWEX/DNR brochure
- *Design guidelines for stormwater bioretention* facilities –University of Wisconsin-Madison

Plant Lists & Resources

- Rain Garden Plant List for Birds & Butterflies - In interactive, Word, and pdf formats
- Shady Rain Garden Plant List - In interactive, Excel, and pdf formats
- *Native Plant Sources* -DNR/UWEX, updates available at http://dnr.wi.gov/org/water/wm/dsfm/shore/documents/nativeplants.pdf
- *Stormwater Basins: Using Natural Landscaping for Water Quality and Esthetics* – UWEX, DNR
- *Plants for Stormwater Design - Species Selection for the Upper Midwest* -MN Pollution Control Agency

Demonstration Sites

Lists rain garden sites around the state that are open for the public to visit, including ones on residential, commercial, and public land. Descriptions of each site's rain garden and the process they used to create it are included, and a map to the site is provided.

Articles

Approximately 30 newspaper and magazine articles about rain gardens

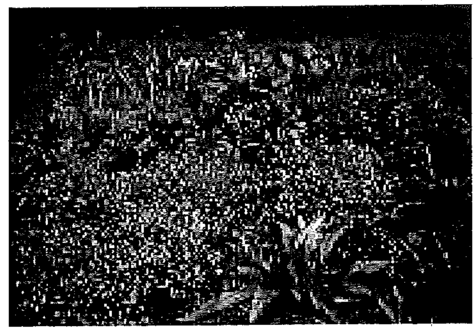
Websites

Internet resources on the following topics:

- Rain Garden Basics
- How to Build a Rain Garden
- Rain Garden Publications
- Rain Garden Plant Resources
- Rain Garden Examples and Case Studies
- Links to More Links
- Rain Barrels
- Model Weed Ordinance
- Stormwater

Speakers List

Lists individuals who can speak about rain gardens from around the state, by city.



Workshops & Tours - Sample Materials

- Suggested handouts
- Dane County Rain Garden Tours
- Jefferson County UWEX Rain Garden Workshops
- UW-Extension West Madison Ag Research Station Workshop
- Marketing Flyer-Boys & Girls Club of Dane County Rain Garden

Rain Garden Displays

A 3-panel displays that can be printed as a small table-top display or as a larger version for a room-size display.

Educational Sign

Want to help passers-by know about rain gardens? Post this yard sign by your rain garden to help teach your neighborhood about its benefits.

Sponsors Sign

Recognize and thank your sponsors with this yard sign.

Research Projects

Dane County, Wisconsin:

- Long Term Water Budget of Two Rain Gardens in Madison, WI
- Design and Evaluation of Rain Gardens for Enhancement of Groundwater Recharge
- Rain Garden Street Pilot Project

Seattle's Street Edge Alternatives Project:

- Hydrologic Monitoring of the Seattle Ultra-Urban Stormwater Management Projects

Digital Photo Library

About 200 photos in three sizes: thumbnail, screen quality, and print quality.

Video from *Into The Outdoors*

Watch the planting of a rain garden, aired on the kids' nature show, *Into The Outdoors*. Quicktime or Windows Media Player formats.

Ways that Municipalities can Encourage Rain Gardens

Lists several ways that municipalities can encourage residents and developers to establish rain gardens in their communities.

Contact Us

- Rain Garden Educator's Kit Order Form
- Contact information

WISCONSIN DEPT. OF NATURAL RESOURCES

Created by the
WI Department of Natural Resources Runoff Mgmt. Section
and the University of WI-Extension Basin Education Program
Version 3, 2007

UW Extension

Reducing Stormwater Costs through Low Impact Development (LID) Strategies and Practices

This fact sheet provides additional information about EPA's report *Reducing Stormwater Costs through Low Impact Development (LID) Strategies and Practices*, EPA publication number 841-F-07-006, December 2007.

BACKGROUND

Stormwater has been identified as a major source of pollution for all waterbody types in the United States, and the impacts of stormwater pollution are not static; they usually increase with land development and urbanization. The addition of impervious surfaces, soil compaction, and tree and vegetation removal result in alterations to the movement of water through the environment. As interception, evapotranspiration, and infiltration are reduced and precipitation is converted to overland flow, these modifications affect not only the characteristics of the developed site but also the watershed in which the development is located.

Parking lot runoff is allowed to infiltrate through a vegetated bioretention area

Low Impact Development (LID) is a stormwater management strategy that seeks to mitigate the impacts of increased runoff and stormwater pollution. LID comprises a set of site design approaches and small-scale stormwater management practices that promote the use of natural systems for infiltration, evapotranspiration, and reuse of rainwater. These practices can effectively remove nutrients, pathogens, and metals from stormwater, and they reduce the volume and intensity of stormwater flows.

COST ANALYSIS

This report is an effort to compare the projected or known costs of LID practices with those of conventional development approaches. Traditional approaches to stormwater management typically involve hard infrastructure, such as curbs, gutters, and piping. LID-based designs, in contrast, are designed to use natural drainage features or engineered swales and vegetated contours for runoff conveyance and treatment. In terms of costs, LID techniques can reduce the amount of materials needed for paving roads and driveways and for installing curbs and gutters. Other LID techniques can eliminate or reduce the need for curbs and gutters, thereby reducing infrastructure costs. Also, by infiltrating or evaporating runoff, LID techniques can reduce the size and cost of flood-control structures. Note that in some circumstances LID techniques might result in higher costs because of more expensive plant material, site preparation, soil amendments, underdrains and connections to municipal stormwater systems, as well as increased project management costs. Other considerations include land required to implement a management practice and differences in maintenance requirements. Finally, in some circumstances LID practices can offset the costs associated with regulatory requirements for stormwater control.

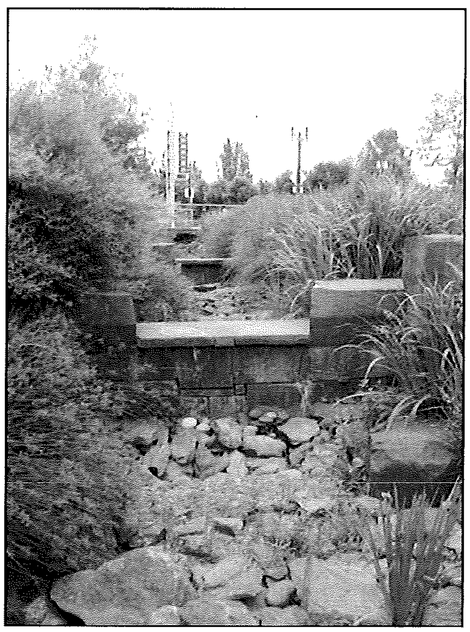
FINDINGS

Seventeen case studies were evaluated for this report. In general, the case studies demonstrated that LID practices can reduce project costs and improve environmental performance. Although not all the benefits of the projects highlighted in the case studies were monetized, with a few exceptions, LID practices were shown to be both fiscally and environmentally beneficial to communities. In a few case studies, initial project costs were higher than those for conventional designs; in most cases, however, significant savings were realized due to reduced costs for site grading and preparation, stormwater infrastructure, site paving, and landscaping. Total capital cost savings ranged from 15 to 80 percent when LID methods were used, with a few exceptions in which LID project costs were higher than conventional stormwater management costs. (Table 1)

Table 1. Cost Comparisons Between Conventional and LID Approaches

Project[a]	Conventional Development Cost	LID Cost	Cost Difference[b]	Percent Difference[b]
2nd Avenue SEA Street	$868,803	$651,548	$217,255	25%
Auburn Hills	$2,360,385	$1,598,989	$761,396	32%
Bellingham City Hall	$27,600	$5,600	$22,000	80%
Bellingham Bloedel Donovan Park	$52,800	$12,800	$40,000	76%
Gap Creek	$4,620,600	$3,942,100	$678,500	15%
Garden Valley	$324,400	$260,700	$63,700	20%
Kensington Estates	$765,700	$1,502,900	–$737,200	-96%
Laurel Springs	$1,654,021	$1,149,552	$504,469	30%
Mill Creek[c]	$12,510	$9,099	$3,411	27%
Prairie Glen	$1,004,848	$599,536	$405,312	40%
Somerset	$2,456,843	$1,671,461	$785,382	32%
Tellabs Corporate Campus	$3,162,160	$2,700,650	$461,510	15%

[a] Some of the case study results do not lend themselves to display in the format of this table (Central Park Commercial Redesigns, Crown Street, Poplar Street Apartments, Prairie Crossing, Portland Downspout Disconnection, and Toronto Green Roofs). [b] Negative values denote increased cost for the LID design over conventional development costs. [c] Mill Creek costs are reported on a per-lot basis.

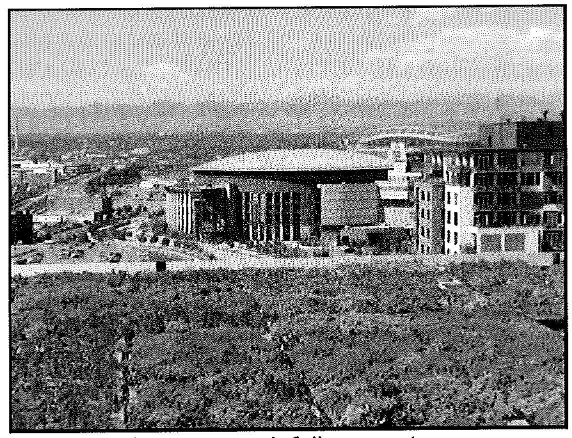


A rain garden manages runoff from impervious surfaces such as roofs and paved areas.

In all cases, LID provided other benefits that were not monetized and factored into the project bottom line. These benefits include improved aesthetics, expanded recreational opportunities, increased property values due to the desirability of the lots and their proximity to open space, increased total number of units developed, increased marketing potential, and faster sales. The case studies also provided other environmental benefits such as reduced runoff volumes and pollutant loadings to downstream waters, and reduced incidences of combined sewer overflows.

CONCLUSIONS

This report summarizes 17 case studies of developments that include LID practices and concludes that applying LID techniques can reduce project costs and improve environmental performance. In most cases, LID practices were shown to be both fiscally and environmentally beneficial communities. In a few cases, LID project costs were higher than those for conventional stormwater management projects. However, in the vast majority of cases, significant savings were realized due to reduced costs for site grading and preparation, stormwater infrastructure, site paving, and landscaping. Total capital cost savings ranged from 15 to 80 percent when LID methods were used, with a few exceptions in which LID project costs were higher than conventional stormwater management costs.



Green roofs capture rainfall, promote evapotransporation, and offer energy savings. This is a photo of a green roof on the EPA Region 8 building in Denver, CO.

EPA has identified several additional areas that will require further study. First, in all cases, there were benefits that this study did not monetize and did not factor into the project's bottom line. These benefits include improved aesthetics, expanded recreational opportunities, increased property values due to the desirability of the lots and their proximity to open space, increased total number of units developed, increased marketing potential, and faster sales. Second, more research is also needed to quantify the environmental benefits that can be achieved through the use of LID techniques and the costs that can be avoided. Examples of environmental benefits include reduced runoff volumes and pollutant loadings to downstream waters, and reduced incidences of combined sewer overflows. Finally, more research is needed to monetize the cost reductions that can be achieved through improved environmental performance, reductions in long-term operation and maintenance costs, and/or reductions in the life cycle costs of replacing or rehabilitating infrastructure.

AVAILABILITY

The full report is available for download at www.epa.gov/nps/lid.

United States
Environmental Protection Agency

Office of Water (4203)
Washington, DC 20460

EPA-841-B-00-005B
October 2000

Field Evaluation of Permeable Pavements for Stormwater Management

Olympia, Washington

Key Concepts:

- Structural Controls
- Volume Reduction
- Space Savings

LOW-IMPACT DEVELOPMENT CENTER

Project Benefits:

- Elimination of Stormwater Ponds
- Demonstration of Water Quality Benefits
- Lower Maintenance

Introduction

This study demonstrates the potential of permeable pavement systems to restore soil infiltration functions in the urban landscape. It is based on the results of a project that included installing and monitoring several porous pavement systems in a parking area. The project's objectives were to

- Review existing information on permeable pavements
- Construct full-scale test sites
- Evaluate the long-term performance of these systems

The report outlines the difficulties encountered, costs of installing and maintaining the systems, performance based on existing soil systems, special benefits of filling the open cells with grass as opposed to gravel, and other water quality benefits.

Project Area

The demonstration site was in an office parking lot in Olympia, Washington. Two adjacent parking stalls were constructed using four types of permeable pavement systems that consisted of a combination of grass and gravel, as shown in Figure 1. The designs were

1. A flexible system consisting of a plastic network of cells with grass infill and virtually no impervious area coverage.
2. A flexible system consisting of a plastic network of cells similar to design 1 but filled with gravel.
3. A system consisting of impervious blocks with the space between the blocks filled with grass. (Total surface area is 60 percent impervious).
4. A system consisting of impervious blocks with the space between the blocks filled with gravel. (Total surface area is 90 percent impervious).

A control stall was constructed out of traditional asphalt. A system of pipes, gutters, and automatic sampling gauges was installed to collect and measure the quantity and chemistry of surface runoff and subsurface infiltrate. Figure 2 shows a schematic of the test facility.

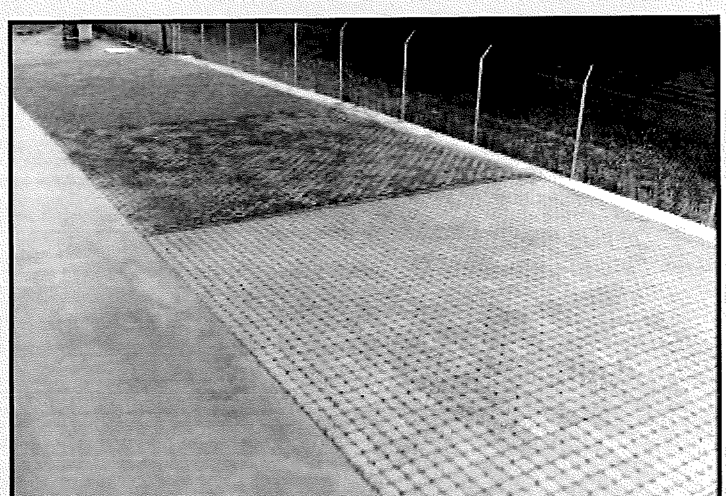


Figure 1. Different types of permeable pavement. From top left: reinforced gravel and grass pavement, reinforced grass pavement, 60% impervious concrete blocks with grass, 90% impervious blocks with gravel.

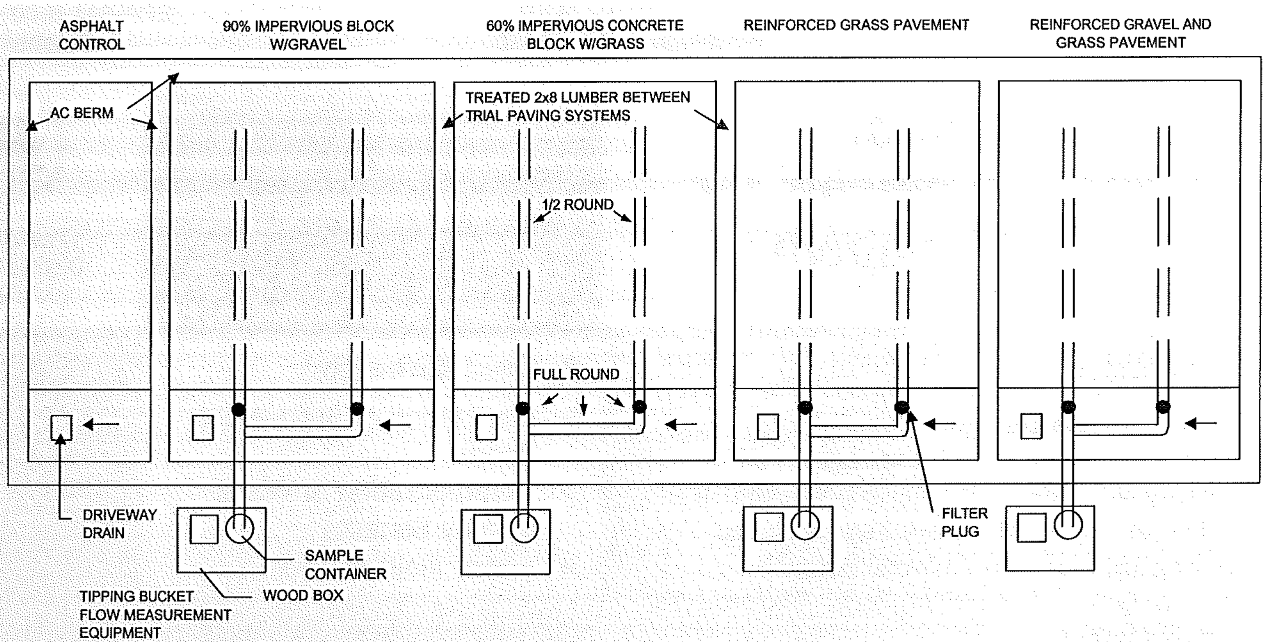


Figure 2. Schematic of the test facility showing treatments and runoff collection devices.

Project Summary and Benefits

The results of this study showed the following relationships:

- The use of permeable pavement systems dramatically reduced surface runoff volume and attenuated the peak discharge, as shown in Figure 3.
- Although there were significant structural differences between the systems, the hydrologic benefits were consistent.
- Storm characteristics and weather conditions influenced the hydrologic responses of the systems.
- Permeable pavement system types vary widely in cost and are more expensive than typical asphalt pavements. Cost comparisons between permeable pavement installations and conventional ponds or underground vaults are limited. However, the elimination of conventional systems and reduced life cycle and maintenance costs can result in significant cost savings over the long term.
- A significant contribution of permeable pavements is the ability to reduce *effective impervious area*, which has a direct connection with downstream drainage systems. This strategy of hydrologic and hydraulic disconnectivity can be used to control runoff timing, reduce runoff volume, and provide water quality benefits.

Contact Information

Derek Booth, Director
Center for Urban Water Resources Management
Box 352700
Roberts Annex 100
(206) 543-7923
dbooth@u.washington.edu

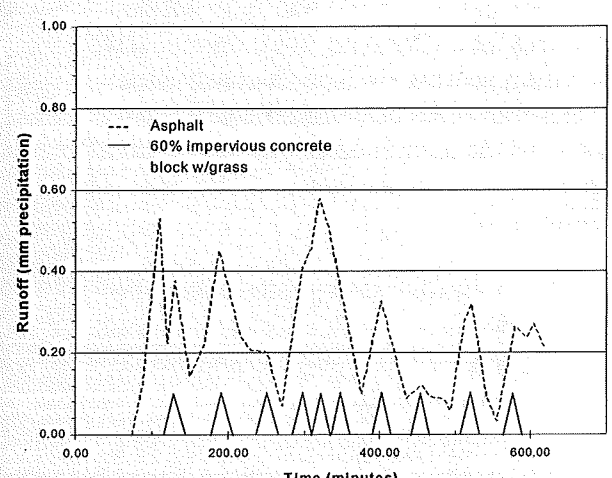


Figure 3. Runoff volumes from asphalt and permeable pavements.