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Best Management Practice Fact Sheet 7:
Permeable Pavement

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This fact sheet is one of a 15-part series on urban *stormwater management* practices.

Please refer to definitions in the glossary at the end of this fact sheet.
Glossary terms are *italicized* on first mention in the text. For a comprehensive list, see Virginia Cooperative Extension (VCE) publication 426-119, "Urban Stormwater: Terms and Definitions."

What Is Permeable Pavement?

Permeable pavement (PP) is a modified form of asphalt or concrete with a top layer that is *pervious* to water due to voids intentionally created during mixing. PPs include *pervious concrete, porous asphalt*, and *interlocking concrete pavers*. These materials are used as *stormwater treatment practices* in urban areas. They are used in place of traditionally *impervious surfaces* to allow *infiltration* and storage, thus reducing runoff (see figure 1).

Figure 1. Typical permeable pavement.
Source: Wetland Studies and Solutions Inc., Gainesville, Va., 2009. Photo by D. Sample.

Where Can Permeable Pavements Be Used?

Permeable pavements can be used in a variety of urban settings. They are particularly suited for low-traffic-load areas, parking areas, overflow parking areas, and for pedestrian traffic areas. PP is also used on certain highways to prevent *hydroplaning*. As a general rule, the layers under PP should have an infiltration rate exceeding a half an inch per hour.

PPs in high-traffic areas should be considered carefully. With more traffic, the pervious surface will receive increased wear, and is more likely to be clogged by *sediment* and need more frequent maintenance. In addition, high-traffic areas often have salt and sand applied to counter snow or ice. The salt can leach and cause groundwater contamination, and the sand can clog the pavement.

How Does Permeable Pavement Work?

These pavements consist of several layers, including the pervious top layer and underlying layers of gravel or stone that create a *stormwater* storage *reservoir* (see figure 2). The PP's depth and materials are determined by the amount of runoff storage and by concerns related to traffic. Permeable pavements provide stormwater management through temporary storage of runoff in the underground reservoir. Water leaves the reservoir by either infiltration or through an *underdrain* that discharges to a *stormwater conveyance system*.

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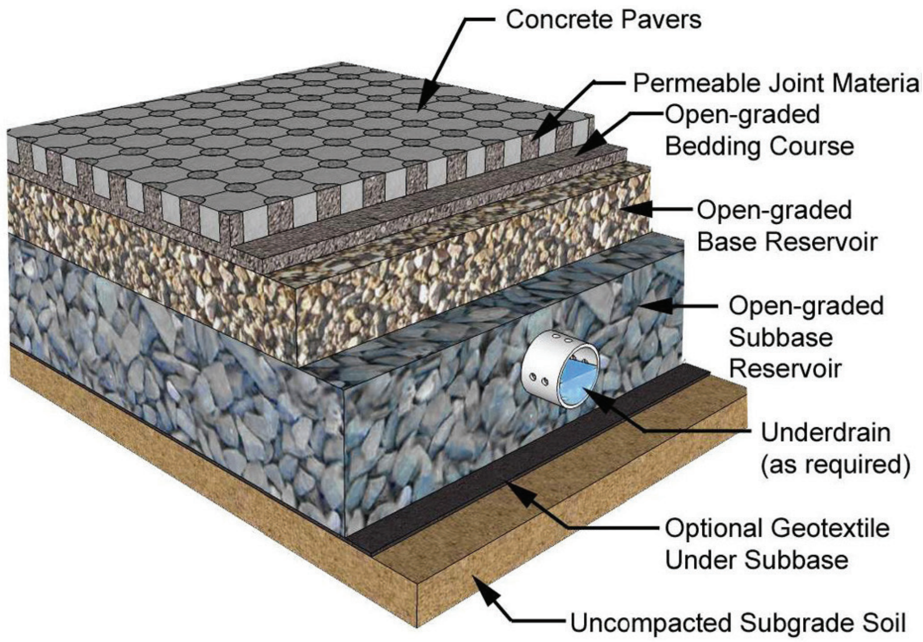

Figure 2. Profile of typical permeable pavement (Smith 2006).

Some water quality improvement occurs through filtration in the reservoir layers. PPs are efficient for removal of sediments, *nutrients*, and some metals. However, sediment clogs the pores of these systems, leading to failure. Periodic vacuuming of the surface is necessary to remove sediments and restore the function of the system.

Limitations

- PPs have very specific maintenance requirements. Failure to perform these tasks will result in loss of runoff reduction capability.
- PPs should be limited to areas of low traffic. High-traffic areas require more careful engineering design and higher maintenance.
- The gravel reservoir must extend below the *frost line* to reduce the risk of *frost heave*.
- PPs should be used in places where snow or ice will not be cleared frequently due to the possible damage by salt, sand, and snowplows.
- The preferred contributing drainage area should be an impervious surface.

Maintenance

Routine Maintenance (monthly)

- Check pavement for clogging. Is stormwater infiltrating or running off? Vacuum the pavement as needed.
- An observation well is typically installed to monitor the storage reservoir to make sure it empties between storms.
- Manage the surrounding landscape areas to reduce erosion and runoff of debris and sediment onto the PP.

Nonroutine Maintenance (as needed)

- Inspect the PP for deterioration or damage from vehicular traffic.
- Avoid resealing, which is often used to renew asphalt pavements. This will render the PP effectively impervious to runoff and defeat its purpose.

Performance

PPs are effective at removing multiple pollutants from stormwater runoff. A typical PP is expected to reduce total phosphorus (TP) and total nitrogen (TN) by approximately 60 percent on a mass load basis, accounting for the runoff reduction in the practice. In more advanced designs, the PP has more filtration layers to provide a longer *residence time*. Advanced PP designs can improve the reduction of TP and TN to 80 percent on a mass load basis, accounting for runoff reduction (VA-DCR 2011).

Expected Cost

PPs are relatively expensive stormwater treatment practices when compared to other alternatives. A preliminary estimate of the average cost of PPs was approximately $15 per ft^2 of surface area, which is normally limited to a 2:1 ratio of impervious surface to pervious (Washington State Department of Ecology, & Herrera Environmental Consultants, 2012). The annual maintenance cost depends on the frequency of vacuuming, which is based on individual site conditions and sweeping. Since PPs allow land to be used for alternative purposes, such as parking, the cost of land is not included in this analysis.

Additional Information

The Virginia departments of Conservation and Recreation (VA-DCR) and Environmental Quality (VA-DEQ) are the two state agencies that address nonpoint source pollution. The VA-DCR oversees agricultural conservation; VA-DEQ regulates stormwater through the Virginia Stormwater Management Program.

Additional information on best management practices can be found at the Virginia Stormwater BMP Clearinghouse website at https://www.swbmp.vwrrc.vt.edu/ (Permanent link: https://perma.cc/WC5L-KCZ8). The BMP Clearinghouse is jointly administered by the VA-DEQ and the Virginia Water Resources Research Center.

Online Resources

Charles River Watershed Association –https://www.crwa.org/hs-fs/hub/311892/file-642204292-pdf/Our_Work_/Blue_Cities_Initiative/Resources/Stormwater_BMPs/CRWA_Permeable_Pavement.pdf

Interlocking Concrete Pavement Institute – www.icpi.org

Low Impact Development Center – http://www.lid-stormwater.net/permpavers_benefits.htm (Permanent link: https://perma.cc/KK8A-QM9N)

National Ready Mixed Concrete Association – www.perviouspavement.org

North Carolina State University – https://stormwater.bae.ncsu.edu/research-projects/permeable-pavement/ (Permanent link: https://perma.cc/JN43-K95P)

Virginia Stormwater BMP Clearinghouse – https://www.swbmp.vwrrc.vt.edu/ (Permanent link: https://perma.cc/WC5L-KCZ8)

Companion Virginia Cooperative Extension Publications

Daniels, W., G. Evanylo, L. Fox, K. Haering, S. Hodges, R. Maguire, D. Sample, et al. 2011. *Urban Nutrient Management Handbook*. Edited by M. Goatley. VCE Publication 430-350.

Fox, L., et al. 2018. *Stormwater Management for Homeowners Fact Sheet 3: Permeable Pavement*. VCE Publication SPES-11P.

Gilland, T., L. Fox and M. Andruczyk, 2018. *Urban Water-Quality Management - What Is a Watershed?* VCE Publication 426-041.

Sample, D., et al. 2011-2012. Best Management Practices Fact Sheet Series 1-15. VCE Publications 426-120 through 426-134.

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Smith, D. 2012. *Permeable Interlocking Concrete Pavements Manual: Selection, Design, Construction, Maintenance*. 4th Edition. Herndon, Va.: Interlocking Concrete Pavement Institute. Virginia Department of Conservation and Recreation (VA-DCR). 2011.

Virginia Department of Environmental Quality (VA DEQ). 2011. *Virginia DCR Stormwater Design Specification No. 7: Permeable Pavement*, Version 1.8. https://www.swbmp.vwrrc.vt.edu/wp-content/uploads/2017/11/BMP-Spec-No-7_PERMEABLE-PAVEMENT_v1-8_03012011.pdf.

Washington State Department of Ecology and Herrera Environmental Consultants. *PugetSound Stormwater BMP Cost Database*. 2012.

Glossary of Terms

Best management practice (BMP) – Any treatment practice for urban lands that reduces pollution from stormwater. BMPs can be either a physical structure or a management practice. A similar, but different, set of BMPs are used to mitigate agricultural runoff.

Detention time – See residence time**.**

Erosion – A natural process by either physical processes, such as water or wind, or chemical means that moves soil or rock deposits from one source and transports it to another. Excessive erosion is considered an environmental problem that is very difficult to reverse.

Filtration – A treatment process that removes pollutants by straining, sedimentation, and similar practices.

Frost heave – When water in the soil freezes and expands, causing upward movement of the soil.

Frost line – The depth at which groundwater freezes above and remains liquid below.

Groundwater contamination – The presence of unwanted chemical compounds in groundwater. In the case of infiltrative stormwater treatment, it would normally refer to dissolved compounds, such as nitrates. It could possibly include unwanted bacteria.

Hydroplaning – Occurs when a wheeled vehicle loses traction and control when driving over wet roads. The surface of the tire is actually separated from the roadway surface by a thin layer of water.

Impervious surfaces – Hard surfaces that do not allow infiltration of rainfall into them; not pervious.

Infiltration – The process by which water (surface water, rainfall, or runoff) enters the soil.

Interlocking concrete pavers – Small pieces of concrete designed to attach to other similar pieces to form a contiguous pavement. They typically have a small amount of pervious space between them. Some of these pavers are permeable, but not all.

Nutrients – Substances required for growth of all biological organisms. When considering water qualities, the nutrients of greatest concern in stormwater are nitrogen and phosphorus, because they are often limiting in downstream waters. Excessive amounts of these substances are pollution and can cause algal blooms and dead zones to occur in downstream waters.

Permeable pavement – A modified form of asphalt or concrete with a top layer that is pervious to water due to voids within the mix design.

Pervious – A ground surface that is porous and allows infiltration into it.

Pervious concrete – A permeable pavement material consisting of concrete in which the fine materials are left out of the mix. The concrete pavement thus contains voids that allow water to pass through.

Porous asphalt – A permeable material that uses an asphaltic binder, which is semipermeable, because the smaller aggregates are left out of the process. Therefore, the final asphalt pavement allows water to pass through it.

Reservoir – A place where water is stored; in permeable pavement, it is the underground gravel layer where excess stormwater is stored.

Residence time – The average time it takes water to travel through a treatment system such as permeable pavers. Residence time can also be called *detention time*.

Sediment – Soil, rock, or biological material particles formed by weathering, decomposition, and erosion. In water environments, sediment is transported across a *watershed* via streams.

Stormwater – Water that originates from impervious surfaces during rain events; often associated with urban areas. Also called runoff.

Stormwater conveyance system – Means by which stormwater is transported in urban areas.

Stormwater treatment practice – A type of best management practice that is structural and reduces pollution in the water that runs through it.

Underdrain – A perforated pipe in the bottom of a treatment practice, such as bioretention or permeable pavement, designed to collect water that does not infiltrate native soils.

Watershed – A unit of land that drains to a single "pour point." Boundaries are determined by water flowing from high elevations to the pour point. The pour point is the point of exit from the watershed, or where the water would flow out of the watershed if it were turned on end.