LID-01 Permeable Paving Systems

1.0 Permeable Paving Systems

1.1 Description

Permeable Paving Systems are a best management practice that captures stormwater through voids in the pavement surface and filters water through an underlying aggregate reservoir. The reservoir typically allows water to infiltrate into the soil subgrade. The reservoir can also be designed to detain and release the water to a surface conveyance system if the underlying soil is not suitable for infiltration.

The purpose of permeable pavement is to control the quality and quantity of stormwater runoff while accommodating pedestrians, parking and possibly traffic. Permeable pavement reduces runoff volumes and pollutants. Permeable pavement is especially useful in existing urban development where the need to expand parking areas is hindered by lack of space needed for stormwater management. Permeable pavement is also useful in new developments with limited space where land costs are high, and when nutrient reductions or green building certification programs are desired.

1.2 Paving System Selection

Permeable Paving Systems can be divided into a four primary paving system types including Permeable Pavers, Pervious Concrete, Pervious Asphalt and Reinforced Grid Systems. See the proceeding sections for guidance with paving system selection.

1.2.1 Permeable Pavers

These include modular blocks of plastic, concrete or other material which have wide joints or openings that can be filled with soil, gravel, or grass. The most common form of permeable pavers are Permeable Interlocking Concrete Pavers (PICP) This may also include cast in place concrete grids or concrete grid pavers with openings that can be filled with permeable materials. The pavers are placed on a thin aggregate bedding layer over a thicker choker course and base beneath. The choker course and aggregate base provide uniform support, water storage and drainage.

<u>Advantages:</u> Well suited for plazas, patios, small parking areas and stalls, parking lots, parking lot roadways, and roadside parking stalls. Permeable Interlocking Concrete Pavers can be designed for larger loads and does not require curing time. As compared to Pervious Concrete and Pervious Asphalt, permeable pavers are easier and less costly to renovate if it becomes clogged. The Interlocking Concrete Pavement Institute offers a design guide, construction specifications, design software, and a Certified PICP Specialist Course for contractors.

<u>Disadvantages</u>**:** Permeable Interlocking Concrete Pavers often have the highest initial cost for materials and installation. Regular maintenance of permeable pavers may be higher than Pervious Concrete and Pervious Asphalt because of the need to refill the joints with aggregate after cleaning and the greater occurrence of weeds. Cast in place concrete grids or concrete grid pavers are intended for very limited vehicular traffic such as overflow parking, emergency access fire lanes, or median crossovers. Cast in place concrete grids or concrete grid pavers are not recommended for regularly used parking areas.

1.2.2 Pervious Concrete

Pervious Concrete is produced by reducing the fines in a conventional concrete mix with other materials to create interconnected void spaces for drainage. Pervious concrete has a coarser appearance than standard concrete although mixtures can be designed to provide a denser, smoother surface profile than traditional pervious concrete mixtures.

Advantages: While not as strong as conventional concrete pavement, Pervious Concrete provides adequate structural support, making it a good choice for travel lanes in parking lots in addition to parking areas, and roadside parking stalls The National Ready Mixed Concrete Association provides a contractor training and certification program. The American Concrete Institute publishes a construction specification and a report which provides guidance on structural, hydrological and hydraulic system and component design in addition to mix proportioning and maintenance.

Disadvantages**:** Mixing and installation must be done correctly or Pervious Concrete will not function properly. Pervious Concrete can be subject to surface raveling and deicing salt degradation if not designed and constructed properly. Restoring surface permeability after a significant loss of initial permeability may be difficult without removing and replacing the surface course for the affected area.

1.2.3 Pervious Asphalt

Pervious Asphalt is similar to conventional (impervious) asphalt except that less fine material is used in the mixture in order to provide for drainage. Pervious Asphalt has a courser appearance than conventional asphalt.

Advantages: While not as strong as conventional asphalt pavement, Pervious Asphalt offers sufficient structural strength for parking lots and roadside parking stalls. The National Asphalt Pavement Association (NAPA) provides a Design, Construction and Maintenance Guide for Porous Asphalt titled *Porous Asphalt Pavement for Stormwater Management.*

Disadvantages**:** Mixing and installation must be done correctly or Pervious Asphalt will not function properly. The owner, contractor and designer will ensure that standard asphalt is not placed in lieu of pervious asphalt. Asphalt sealants or overlays that eliminate surface permeability cannot be used. Restoring surface permeability after a significant loss of initial permeability may be difficult without removing and installing a portion of the surface course.

1.2.4 Reinforced Grid Systems

Reinforced Grid Systems, often referred to as geocells, and consists of flexible plastic or metal interlocking units that infiltrate water through large openings filled with aggregate or topsoil and turf grass. Reinforced Grid Systems are well suited for emergency vehicle access over lawn areas or overflow parking. They are not approved for regularly used vehicular areas such as parking lots.

Advantages: Reduces expenses and maximizes lawn area.

Disadvantages**:** Reinforced Grid Systems have less structural strength than the other pavement course options, especially when used under saturated conditions. When covered with vegetation, it requires mowing, fertilization and watering. Overuse can kill the turf grass or create ruts from displaced aggregates.

1.3 Design Components

The Wearing Course or Surface Layer - provides strength for the designed traffic loads while maintaining adequate infiltration capacity for stormwater runoff. This course may be cast-in place concrete, asphalt, concrete and plastic pavers, and plastic or metal grid systems. These courses generally have very high initial infiltration rates. Ensure that clogging rates are accounted for in the system design. While this layer allows for the infiltration of storm flows and provides some water quality benefits, the wearing course cannot be allowed to become saturated from excessive water volume stored in the aggregate base layer. For backup infiltration capacity, an unpaved stone edge hydraulically connected to the aggregate base or an overflow outlet is installed.

The Aggregate Base or Storage Bed - provides a stable base for the paver, a highly permeable layer for the infiltration of storm water into the underlying soil or under-drain system, and a temporary reservoir for storage of water prior to exfiltration through the underlying soil or under-drain system. In concrete and asphalt systems this layer is typically composed of a larger aggregate with a smaller stone (leveling or choker course) between the wearing course and the larger stone base course. The choker course is needed to reduce rutting from construction traffic and to more evenly distribute the loading to the base material. Designs with partial or no exfiltration require under-drains. All installations are required to have an observation well installed at the furthest down slope area.

Ensure that the surrounding area is stabilized prior to installation. If the base course is being used for retention, the storage bed is excavated level to maximize infiltration across the entire area. If an under-drain is used, the bed is sloped to provide positive drainage at the desired rate for the under-drain. A non-woven filter fabric is installed along the bottom and sides of the excavation according to the manufacturer's specifications. Overlap adjacent strips at least 24 inches and secure fabric 4 feet outside of the storage bed. The aggregate is installed in 6 inch lifts and compacted to 95% modified proctor.

Subgrade – Analyze the subgrade conditions by a qualified geotechnical engineer for load bearing given the anticipated soil moisture conditions. A separation between the base course and the seasonal high water table of three feet is required.

1.3.1 General Design Requirements

The design of pervious pavements will depend on the application and location at each site. Locations where pervious pavements are not recommended include:

- Storm Water Hotspots, locations where concentrated pollutant spills are possible such as gas stations, and industrial chemical storage sites.
- Areas where maintenance is unlikely to be performed at appropriate intervals (residential and major roadways).
- In applications with no enforceable guidelines.
- Where heavy regular applications of sand are used for maintaining traction during winter.
- Areas with high seasonal groundwater or other conditions which create prolonged saturated conditions at or near the ground surface and within the pavement sections. Fill soils can become unstable when saturated.
- Locations where the estimated long term infiltration rate is less than 0.1 inch/hr.

1.3.2 Design Requirements

The use of pervious pavement, permeable pavers and grid systems is limited by slope conditions. Table 1, provides slope limitations for each BMP.

Table 1 – Slope limitations

BMP Type	Max. Slope
Pervious Asphalt	5%
Pervious Concrete	6%
Permeable Pavers	10%
Grid Systems	6%

In order to ensure adequate infiltration, it is important to estimate the long-term infiltration rate of the soil underlying a pervious pavement application. For small installations (patios, walkways, and driveways on individual lots) no infiltration field tests are necessary. However a soil grain size, texture analysis or soil pit excavation and infiltration tests may be prudent if highly variable soil conditions or seasonal high water tables are suspected. For large installations (parking lots, roadside parking stalls, and parking travel lanes) that include storage volume using base material below the surface, use the following methods to estimate the infiltration capacity of the underlying soil.

Method 1: USDA Soil Textural Classification (Rawls survey) every 200 feet of road or every 5,000 ft^2

Method 2: ASTM D422 Gradation Testing at Full Scale Infiltration Facilities every 200 ft of road or 5,000 ft^2.

Method 3: Use small-scale infiltrometer tests every 200 feet of road or every 5,000 ft^2. These tests include the USEPA falling head or double ring infiltrometer tests (ASTM 3385-88). As these tests may not adequately measure variability of conditions in the test area they should be taken at several locations within the area of interest.

1.3.3 Pervious Asphalt Requirements

Table 2 – Pervious Asphalt Requirements

Design Component	Design Requirements & Considerations
The Wearing Course or Surface Layer	The top course is typically 2 to 4 inches thick. Permeable asphalt has similar strength and flow properties as conventional asphalt. Total void space is approximately 15-20%. The content of the asphalt cement ranges from 5.5 to 6.0 percent by weight dry aggregate. An elastomeric polymer can be added to reduce drain down. Also hydrated lime may be added at a rate of 1.0% by weight of the total dry aggregate to mixes using granite stone to prevent separation.
	The asphalt system is installed toward the end of construction activities to minimize sediment problems. Erosion and introduction of sediment is strictly controlled during and after construction. Test panels are recommended to determine asphalt cement grade and content compatibility with aggregate. In order to prevent rising water in the underlying aggregate base to saturate the pavement, a positive overflow will be installed.
The Aggregate Base or Storage	The minimum depth for structural support of this layer is 6 inches. The maximum depth is determined by the below grade storage volume. Aggregate base depths of 18 to 36 inches are common depending on storage needs. The coarse aggregate layer is 2.5 to 0.5 inch uniformly graded crushed (angular) thoroughly washed stone (AASHTO No. 3). The choker course is 1 to 2 inches in depth and consists of 1.5 inch to 0.0937 inch (No. 8 sieve) uniformly graded crushed washed stone for final grading of the base course. In applications with larger slopes, underground baffles may be used to make more efficient use of the storage layer. If baffles are used with an under-drain system, positive drainage to the under-drain will be provided along the baffles.
	Before installing the storage bed, stabilize the surrounding area to prevent runoff and sediment from entering the storage bed. A non-woven filter fabric is installed on the subsoil according to the manufacturer's specifications. Where the installation is adjacent to conventional paving surfaces, filter fabric is wrapped up the sides to the top of the base aggregate. Overlap adjacent strips of fabric at least 24 inches and secure 4 feet outside of the storage bed. Install the aggregate in maximum 8-inch lifts and lightly compact each lift. Install a 1 to 2-inch choker course evenly over the surface of the coarse aggregate layer. Filter fabric is folded over between the placement of the base and asphalt courses to protect installations from sediment inputs, and is trimmed when the site is fully stabilized.
Subgrade	After grading, ensure the existing subgrade is not compacted or subjected to excessive construction traffic. Immediately before base aggregate placement remove any accumulation of fine material from erosion with light equipment. Under-drains are required for soils where the estimated long-term infiltration rate is less than 0.5 in/hour. Ensure the draw-down time for the base does not exceed 24-hours.

1.3.4 Pervious Concrete Requirements

Table 3 – Pervious Concrete Requirements

Design Component	Design Requirements & Considerations
The Wearing Course or Surface Layer	Typically 4 to 12 inches thick depending upon design loads. Permeable concrete is approximately 70 to 80 percent of the unit weight of conventional concrete and uses Portland cement type I or II conforming to ASTM C 150 or Type IP or IS conforming to ASTM C 595. The void space is 15 to 20% according to ASTM C 138 with a water cement ratio of 0.27-0.35, and an aggregate to cement ratio of 4:1 to 4.5:1. Admixtures including water reducing/retarding admixture (ASTM C 494 Type D) and hydration stabilizer (ASTM C 494 Type B), and fiber mesh may be used. Use potable water. Permeable concrete is similar to conventional concrete without the fine aggregate (sand component).
	Use the cement mix within 1 hour after water is introduced and within 90 minutes if an admixture is used and the temperature of the mix does not exceed 90° Fahrenheit. Base aggregate is wetted to improve the working time of the cement. A mechanical or manual screen can be used to level concrete at ½ inch above a form. The surface is covered with a 6-mil plastic and a static drum roller used for final compaction (roller should provide approx. 10 psi vertical force). Cover the Cement with plastic within 20 minutes and it remains covered for a minimum curing time of 7 days with no truck traffic for 10 days. Do not use high frequency vibrators as they can seal the surface of the concrete. Placement widths do not exceed 15 feet unless the contractor can demonstrate competence to install greater widths. Shrinkage associated with drying is less than that of conventional concrete. A conservative design can include control joints at 60-ft spacing cut to ¼ of the pavement thickness.
	The following tests are conducted to ensure proper performance i. Have the contractor place and cure two test panels covering a minimum of 225 ft^2 at the required thickness to demonstrate that specified unit weights and permeability can be achieved on site. The test panels have two cores taken from each panel in accordance with ASTM C 42 at least 7 days after placement. ii. Untrimmed cores measured for thickness (ASTM C 42), within ¼ inch of specified thickness iii. Cores trimmed and measured for unit weight (ASTM C 140), within 5 lbs/ft^3 of design specification iv. Void Structure tested (ASTM C 138) providing an infiltration rate greater than underlying soil If the test panel meets the requirements, the panel can be left in place as part of the completed installation. Collect and sample material once per day to measure unit weight per ASTM C 172 and C 29.
The Aggregate Base or Storage	The minimum depth for structural support of this layer is 6 inches. The maximum depth is determined by the below grade storage volume. Aggregate base depths of 18 to 36 inches are common depending on storage needs. The coarse aggregate layer is 2.5 to 0.5 inch uniformly graded crushed (angular) thoroughly washed stone (AASHTO No. 3). The choker course is 1 to 2 inches in depth and consists of 1.5 inch to 0.0937 inch (No. 8 sieve) uniformly graded crushed washed stone for final grading of the base course. In applications with larger slopes, underground baffles may be used to make more efficient use of the storage layer. If baffles are used with an under-drain system, positive drainage to the under-drain will be provided along the baffles.

	Before installing the storage bed, the surrounding area is stabilized to prevent runoff and sediment from entering the storage bed. A non-woven filter fabric is installed on the subsoil according to the manufacturer's specifications. Where the installation is adjacent to conventional paving surfaces, filter fabric is wrapped up the sides to the top of the base aggregate. Overlap adjacent strips of fabric at least 24 inches and secure 4 feet outside of the storage bed. Install the aggregate in maximum 8-inch lifts and lightly compact each lift. Install a 1 to 2-inch choker course evenly over the surface of the coarse aggregate layer. Filter fabric is folded over between the placement of the base and asphalt courses to protect installations from sediment inputs, and is trimmed when the site is fully stabilized.
Subgrade	After grading, do not compact the existing subgrade or subject it to excessive construction traffic. Immediately before base aggregate placement remove any accumulation of fine material from erosion with light equipment and scarify the soil to a minimum depth of 6 inches. The estimated long-term infiltration rate may be as low as 0.1 inch/hour. Install under-drains for soils with lower infiltration rates to prevent prolonged saturated conditions at or near the ground surface within the pavement section.

1.3.5 Permeable Paver Requirements

Table 4 – Permeable Paver Requirements

Design Component	Design Requirements & Considerations
The Wearing Course or Surface Layer	Design specifications for these systems are generally provided by the manufacturer. These systems provide adequate infiltration and load bearing capacity for the application. Directing surface flows to these systems from adjacent areas is not recommended without pretreatment
The Aggregate Base or Storage	The minimum thickness for the aggregate base for aggregate or plastic pavers depends on anticipated loadings, soil type and storm water storage requirements. Follow the Interlocking Concrete Paver Institute or the manufacturer's provided guidelines for base thickness when available. Typical depths range from 6 to 22 inches though larger depths may be used if greater storage capacity is desired. The minimum base depth for pedestrian and bicycle applications is 6 inches. An ASTM No. 57 crushed aggregate or similar is recommended for the coarse layer while a 3-inch layer of ASTM No. 8 is recommended for the choker course.
	Stabilizer the surrounding area prior to installation of the aggregate base. If the base course is being used for retention, the storage bed is excavated level to maximize infiltration across the entire area. If an under-drain is used, the bed is sloped to provide positive drainage at the desired rate for the under-drain. A non-woven filter fabric is installed along the bottom and sides of the excavation according to the manufacturer's specifications. Where the installation is adjacent to conventional practices, the fabric is wrapped up the sides to the top of the base aggregate. Install the No. 57 aggregate in 4 to 6 inch lifts compacting with at least 4 passes of a 10-ton steel drum roller. Initial passes can be with vibration but the final two will be static. Install the choker course in a similar manner. Ensure both courses are moist to facilitate compaction.
Subgrade	Under-drains are required for soils where the estimated long-term infiltration rate is less than 0.5 in/hour. Ensure the draw-down time for the base does not exceed 24-hours. For vehicle traffic areas, grade and compact the subgrade to 95 percent modified proctor density (ASTM D 1557). For pedestrian areas, compact to 95 percent standard proctor density (ASTM D698). The majority of soils in Greenville County will not retain useful infiltration rates when compacted and will require the use of under-drains.

1.3.6 Grid Systems

Table 5 – Grid System Requirements

Design Component	Design Requirements & Considerations
The Wearing Course or Surface Layer	Design specifications for these systems are generally provided by the manufacturer. These systems provide adequate infiltration and load bearing capacity for the application. Directing surface flows to these systems from adjacent areas is not recommended without pretreatment.
The Aggregate Base or Storage	The minimum thickness of this layer depends on anticipated loadings, underlying soil type and storage requirements. A typical minimum depth for driveways, alleys and parking lots is 4 to 6 inches. Increased depths can be used to increase storage capacity. The base aggregate is made up of a sandy gravel material typical for road base construction.
Subgrade	After grading, do not compact the existing subgrade or subject it to excessive construction traffic. Immediately before base aggregate placement remove any accumulation of fine material from erosion with light equipment. Under-drains are required for soils where the estimated long-term infiltration rate is less than 0.5 in/hour. The draw-down time for the base will not exceed 24-hours.

1.4 General Construction Requirements

Porous pavements are specialty applications and are installed by contractors who have been trained and have experience with the type of pavement being used. If the installation contractor does not have adequate experience they will retain a qualified consultant to monitor the production, handling and placement of the porous pavement.

Avoid the introduction of sediment and runoff from surrounding unpaved areas where possible to prevent clogging of the pavement pore spaces. When this is unavoidable, use pre-treatment practices to allow for filtering or settling of sediments before the runoff reaches the porous pavement. Use filter fabric between the underlying soil and the base course of the pavement to prevent fines from migrating up into the base. Ensure that muddy vehicles do not drive on the base material or surface layer during construction. This is especially true of fine soils such as those found in Greenville County. Under-drains are required in these applications where the long-term infiltration rate of the underlying soil is less than 0.1 inch/hr. These precautions enhance the operation and extend the operational life of the pavement.

1.4.1 Site Preparation

Do not begin construction on permeable pavement until acceptable conditions are present. This includes the following items:

- Pervious surfaces are graded and do not discharge to the permeable pavement, except for instances when this is unavoidable, such as redevelopment projects.
- Impervious areas that drain to the permeable pavement are completed.
- Areas of the site adjacent to the permeable pavement are stabilized with vegetation, mulch, straw, seed, sod, fiber blankets or other appropriate cover in order to prevent erosion and possible contamination with sediments.
- Construction access to other portions of the site is established so that no construction traffic passes through the permeable pavement site during installation. Install barriers or fences as needed.
- The forecast calls for a window of dry weather to prevent excess compaction or smearing of the soil subgrade while it is exposed.
- All permeable pavement areas are clearly marked on the site.

1.4.2 Excavation and Subgrade Preparation

Clear and excavate the area for pavement and base courses while protecting and maintaining subgrade infiltration rates using following these steps:

- Excavate in dry subgrade conditions and avoid excavating immediately after storms without a sufficient drying period.
- Do not allow equipment to cross the pavement area after excavation has started.
- Operate excavation equipment from outside the pavement area or from unexcavated portions of the area using an excavation staging plan.
- Use equipment with tracks rather than tires to minimize soil compaction when equipment on the subgrade surface is unavoidable.
- Dig the final 9 to 12 inches by using the teeth of the excavator bucket to loosen soil and do not smear the subgrade soil surface. Final grading or smoothing of the subgrade will be done by hand if possible.
- Minimize the time between excavation and placement of the aggregate.
- Ensure the final subgrade slope does not exceed 0.5%. Inspect and verify the subgrade slope before proceeding.

After verifying the subgrade slope, scarify, rip or trench the soil subgrade surface (while the soil is dry) of infiltrating pavement systems to maintain the soil's pre-disturbance infiltration rate. To scarify the pavement, use backhoe bucket's teeth to rake the surface of the subgrade. To rip the subgrade, use a subsoil ripper to make parallel rips 6 to 9 inches deep spaced 3 feet apart along the length of the permeable pavement excavation. In silty or clayey soils, place clean coarse sand over the ripped surface to keep it free-flowing. The sand layer should be adequate to fill the rips.

An alternative to scarification and ripping is trenching. When trenching, install parallel trenches 12 inches wide by 12 inched deep along the length of the permeable pavement excavation. Excavate trenches every 6 feet (measured from center to center of each trench) and fill with ½ in. of clean course sand and 11½ in. of ASTM No. 67 aggregate. Ripped or trenched (uncompacted) soil subgrade can settle after aggregate base and surface course installation and compaction. Therefore, base compaction requires special attention to means and methods in the construction specifications and during construction inspection to minimize future settlement from ripped or trenched soil subgrades.

1.4.3 Subgrade Soil Test for Infiltration

Perform infiltration testing as specified in Section 1.3.2

1.4.4 Place Geotextiles and Geomembrane (If Applicable)

If using geotextiles or geomembranes, follow the manufacturer's recommendations for the appropriate overlap between rolls of material. Secure geotextile or geomembrane so it will not move or wrinkle when placing aggregate.

1.4.5 Place Catch Basin, Observation Wells, and Underdrain System

Place catch basins and observation wells according to the design plans and verify that the elevations are correct. If an upturned elbow design is used, then the underdrains are placed first. In such case, verify the following:

- Elevations of the underdrains and upturned elbows are correct.
- Dead ends of pipe underdrains are closed with a suitable cap placed over the end and held firmly in place.
- Portions of the underdrain system are within 1-foot of the outlet structure are solid and not perforated.

1.4.6 Place Aggregate Base

Inspect all aggregates to insure they are clean, free of fines and conform to the plans and specifications. If aggregates delivered to the site cannot be immediately placed into the excavation, stockpile the aggregate on an impervious surface, geotextile, or on an impervious material to keep the aggregate free of sediment. If aggregate becomes contaminated with sediment, replace it with clean materials.

Before placing the aggregate base, remove any accumulation of sediments on the finished soil subgrade. Use light, tracked equipment. If the excavated subgrade surface is subjected to rainfall before placement of the aggregate base, excavate the resulting surface crust to at least an additional 2 inches of depth, raked or scarified to break up the crust. For sites with an impermeable liner or geotextiles, remove any accumulated sediments and check placement. Check slopes and elevations on the soil subgrade and the finished elevation of base (after compaction) or bedding materials to ensure they conform to the plans and specifications.

Spread all aggregate (not dump) by a front-end loader or from dump trucks depositing from near the edge of the excavated area or resting directly on deposited aggregate piles. Moisten and spread the washed stone without driving on the soil subgrade. Be careful not to damage under-drains and their fittings, catch basins, or observation wells during compaction. Follow compaction recommendations by the permeable pavement manufacturer or from industry guidelines. Be sure that corners, areas around utility structures and observation wells, and transition areas to other pavements are adequately compacted. Do not crush aggregates during compaction as this generates additional fines that may clog the soil subgrade.

1.4.7 Install Curb Restraints and Pavement Barriers

Install edge restraints and barriers between permeable and impervious pavement per the design plans.

1.4.8 Install Surface Layer

The bedding and pavement course installation procedures depend on the permeable pavement surface. It is important to follow the specifications and manufacturer’s installation instructions. Install the bedding course in accordance with manufacturer or industry guide specifications. Improper bedding materials or installation can cause significant problems in the performance of the pavers and stone jointing materials between them.

If constructing a PICP pavement, use a contractor that holds a PICP Specialist Certificate from the Interlocking Concrete Pavement Institute. A list of contractors can be obtained from the Interlocking Concrete Pavement Institute.

1.5 Site Protection

It is preferable to have the permeable pavement installed at the end of the site construction timeline. If that is not possible, protect the permeable pavement until project completion. Route construction access through other portions of the site so that no construction traffic passes through or over the permeable pavement site. Install barriers or fences as needed.

- If this is not possible, protect the pavement per the construction documents.
- Protection techniques include mats, plastic sheeting, barriers to limit access, or moving the stabilized construction entrance
- Schedule street sweeping during and after construction to prevent sediment from accumulating on the pavement.

1.6 Maintenance

Permeable Paving Systems require maintenance to provide long term functioning. A majority of the maintenance efforts involve efforts to prevent the surface from clogging. Consider long term maintenance when using permeable paving systems

Permeable Paving System	Maintenance Requirements
Pervious Asphalt and Concrete	Clean surfaces using suction and sweeping, or high-pressure wash and suction. Hand held pressure washers are effective for cleaning void spaces and are appropriate for smaller areas. Smaller utility cuts can be repaired with conventional pavers is desired.
Permeable Pavers	Do not use washing. Only suction and sweeping is used when debris are dry. Pavers can be removed individually and replaced during utility work. Replace broken pavers to prevent structural instability.
Grid Systems	Remove and replace top course aggregate if clogged or contaminated using vacuum trucks or other techniques. Remove and replace broken grid segments where three or more adjacent grid cells are broken or damaged. Replenish the top course aggregate as needed.

1.6.1 Preventive Maintenance

The following list of preventive maintenance guidelines is required for Permeable Paving Systems.

- Clean the surface with portable blowers frequently, especially during the fall and spring to remove leaves and pollen before they irreversibly reduce the pavement's surface permeability.
- Do not stockpile soil, sand, mulch or other materials on the permeable pavement.
- Do not wash vehicles parked on the permeable pavement.
- Place tarps to collect any spillage from soil, mulch, sand or other materials transported over the pavement.
- Cover stockpiles of soil near the permeable pavement.
- Bag grass clippings or direct them away from the permeable pavement.
- Do not blow materials onto the permeable pavement from adjacent areas.
- Do not apply sand during winter storms.
- Immediately remove any material deposited onto the permeable pavement during maintenance activities.
- Remove large materials by hand. Remove smaller organic material using a hand-held blower machine.
- Remove weeds growing in the joints of pavers by spraying them with a systemic herbicide such as glyphosate and then return within the week to pull them by hand.

1.6.2 Surface Cleaning

At a minimum, surface cleaning is required when runoff pools or puddles for extended periods longer than 24-hrs. Owners are required to clean pervious concrete and pervious asphalt systems once annually, but more frequent cleanings are recommended, because surface infiltration is very difficult to restore after it has become clogged, and surface replacement is expensive.

The three main types of street cleaners are: mechanical, regenerative air and vacuum. Vacuum or regenerative air street sweepers are required because they are effective at cleaning the pore spaces in the pavement surface.

Mechanical sweepers are the most common. Mechanical sweepers come in various sizes for cleaning pedestrian or vehicular pavements, and generally do not use a vacuum. Mechanical sweepers employ brushes that initially move litter toward the machine center and lift trash onto a conveyor belt for temporary storage inside the machine. The brush bristles can penetrate some pavers, but not other types of permeable pavement. For other pavement types, mechanical sweepers may be used for removing trash, leaves, and other organic material, but the mechanical sweeper is not likely to be effective in removing sediment.

Regenerative air cleaners are the second most common. Regenerative air cleaners work by directing air at a high velocity within a confined box the rides across the pavement. The uplift from the high velocity effectively loosens dust and other fine particles on and near the pavement surface and lifts them into a hopper at the back of the truck. This equipment removes surface-deposited sediments from all pavement types. This equipment is recommended for regular preventive maintenance for permeable pavement.

Vacuum street cleaners are the least common and most expensive. Vacuum street cleaners apply a strong vacuum to a relatively narrow area that lifts particles both at and below the surface of the pavement. Vacuum sweepers have demonstrated the ability to suction 3 to 4 inches of gravel from PICP and have the ability to restore infiltration to some pavements that have been neglected.

1.7 References

NCDENR Stormwater BMP Manual, Chapter 18 Permeable Pavement, Chapter Revised 10-16-12

Pennsylvania Stormwater Best Management Practices Manual, Section 6 Comprehensive Stormwater Management: Structural BMPs. January 2005.

Virginia DCR Stormwater Design Specification No. 7, Permeable Pavement, Version 1.8. March 1, 2011.