

Montgomery County RainScapes

Residential Permeable Pavement

What is permeable pavement?



Permeable pavement is an attractive, watershed-friendly way to capture and clean stormwater runoff, and is an important part of Montgomery County's RainScapes program. Permeable pavement is also a durable and environmentally sensitive alternative to conventional paving. Residential driveways that are permeable help advance the goal of using innovative natural approaches to reduce water pollution, stream channel erosion, and drainage problems caused by stormwater runoff. These driveways also provide functional amenities for homeowners.

Permeable pavement driveways catch and soak in rain that falls on the driveway surface, reducing or eliminating driveway runoff that would otherwise flow to a storm drain. They may also be used to capture runoff from adjacent impervious surfaces such as roofs, provided that the runoff does not have a high sediment load. Rainwater rapidly passes through the pavement surface and collects in a stone reservoir before soaking into the ground.

This guide focuses on permeable interlocking concrete pavers (PICP), which are made of high-strength solid concrete and have stone-filled openings that allow water to pass. The design standards in this guide are intended for use by qualified contractors in typical residential driveways and other small-scale installations generally pursued through the RainScapes program. Residential driveways designed according to these guidelines are intended for use by passenger vehicles, with occasional use by small trucks or moving vans.

Permeable Pavement FAQs

This guide provides detail on these and other questions:

- **How big can it be?** Permeable pavement can be used to replace all or part of the driveway.
- **How deep to dig?** The excavation depth is 15 inches typically, and more in some cases.
- **Where can permeable pavement be located?** Driveways are the most common location, but sidewalks, parking lots, and patios are also possible. Homeowners may choose to install permeable pavement to replace all or only part of an existing driveway.
- **Is every site suitable for a permeable driveway?** Some residential lots have challenges that go beyond the scope of this guidance, such as slow-draining soils, high water tables, driveways that slope toward houses, or steep slopes, requiring site-specific design by a professional.
- **How is permeable pavement maintained?** Residential permeable pavement driveways should be vacuumed with a heavy-duty wet/dry vacuum twice a year, usually in the spring and fall. Preventative maintenance is key to long-term performance. Sand, sediment, and plant material (leaves, grass clippings, etc.) must be kept off the permeable surface.
- **Is it ADA-accessible?** Most interlocking pavers are ADA compliant. Paver manufacturers can provide information on specific products.
- **Why replace the driveway?** In space-constrained lots that are too small for rain gardens, a permeable pavement driveway offers the best opportunity to capture and treat stormwater on site. The paver blocks also provide a unique and attractive design feature.

Where can permeable pavement go?

LOCATION

When planning a permeable pavement driveway, follow the requirements listed in Table 1. If all the requirements cannot be met, permeable pavement should not be installed at that location.

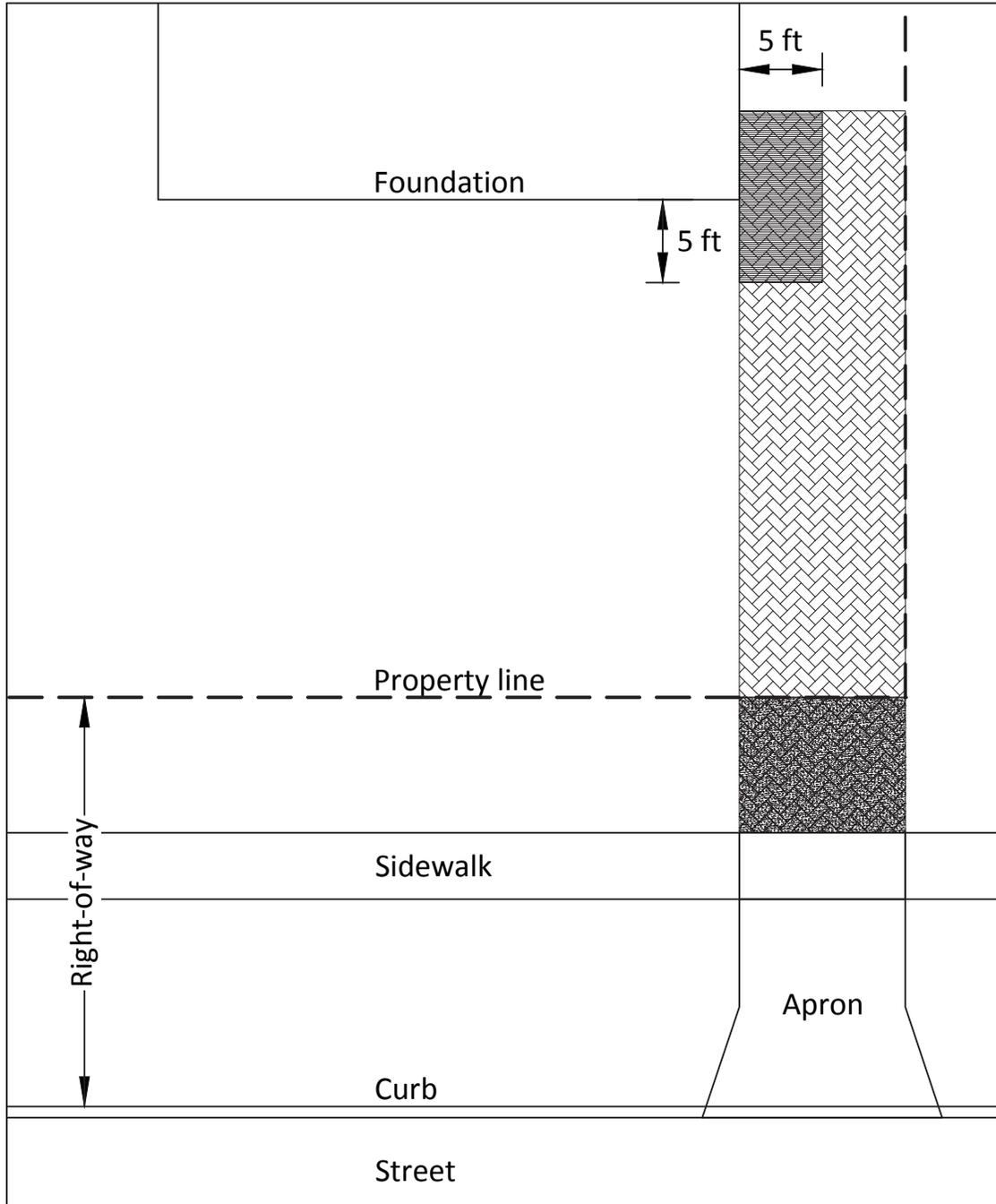
Table 1. Required design elements		
Setback	Distance	Reason
Foundation	A waterproof liner is required along any portion of the driveway perimeter within 10 feet of a foundation (Figures 1, 2, and 3).	Avoid possible water seepage into basements. See construction step 4 for details
Limit of installation	The permeable portion of the driveway must end at the right-of-way boundary (Figures 1, 2, and 3). For visual continuity, paver blocks with no subsurface storage may be installed up to the edge of the sidewalk, apron, or curbline - check with County staff.	Keep stormwater capture and treatment within private lots. Maintain consistent appearance and condition of sidewalks and driveway aprons. Conform with MCDOT ROW regulations.
Slopes	The driveway slope should not exceed 5%. The driveway must slope away from the house. Driveways that do not meet these criteria will need site-specific design by a professional.	Minimize runoff and ensure adequate infiltration into pavement surface
Trees	Do not disturb more than 25% of the critical root zone for any trees with a diameter at breast height (DBH) of eight inches or greater.	Reduce potential negative tree impacts from excavation
Utilities	Maintain a five-foot setback from sanitary sewer or water mains. Never install permeable pavement driveways over water, sewer, or gas mains. Look for private house connections.	Reduce the chance of infiltration into older pipes. Prevent the driveway from being disturbed if utility work is needed.
Water supply wells	Maintain a 100-foot setback from any water supply well.	Prevent infiltration into well
Septic systems	Maintain a 50-foot setback from any septic system component.	Prevent interference with septic system operation



Miss Utility

Always call Miss Utility (811) before digging. Calling before deciding on a permeable driveway design is recommended. Dig during the ticket timeframe, usually 10 days. It is advisable to have the ticket on hand while digging. Look for private house connections before digging. Verification of utility locations is the contractor's responsibility.

Figure 1. Plan view of permeable pavement driveway installation



Legend

 Install 5 foot wide perimeter liner if within 10 feet of a foundation, including garages	 Non-permeable pavers in ROW (no storage). Obtain County approval
 Permeable pavement area	Notes: 1. The driveway must slope away from the house. 2. Do not disturb the sidewalk or driveway apron.

Other important guidelines

SAGS

Permeable pavement should not be installed in driveways with a sag (low point) in the middle, unless the sag can be removed when reinstalling the driveway.

DITCHES AND SWALES

Permeable pavement is not recommended for driveways that receive concentrated flow from a ditch or swale because sediment deposition could occur. In addition, runoff from the ditch or swale could exceed the storage capacity of the permeable driveway.

UNPAVED AREAS

Do not install permeable pavement below areas with chronic erosion problems unless the eroded area can be permanently stabilized first. To reduce the chance of maintenance issues such as clogging, the amount of unpaved area draining to the permeable driveway should generally be kept to a minimum.

DRIVEWAY APRON

Do not use permeable pavement for the driveway apron. The driveway apron must be undisturbed or returned to its original condition to conform with Montgomery County right-of-way regulations.

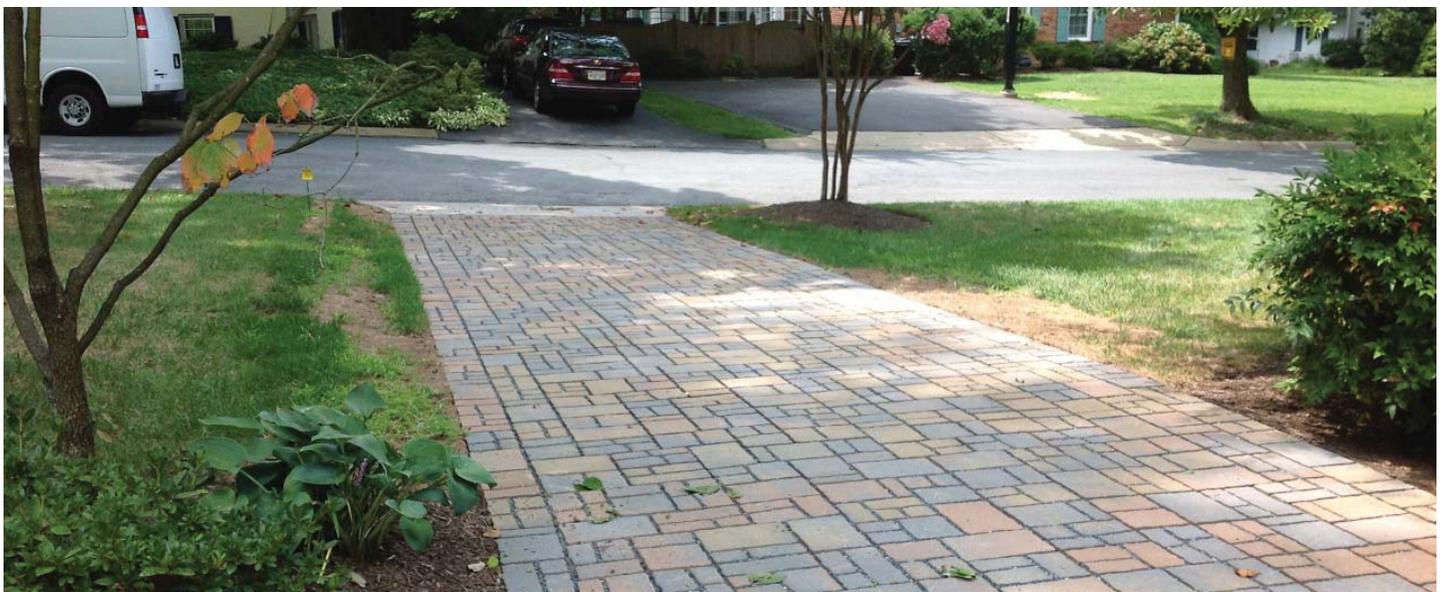
LONG DRIVEWAYS

Driveways that are longer than 15 feet and have a slope greater than 2% may need additional design to prevent water from accumulating at the low end – consult a design professional.

HEAVY VEHICLES

Driveways designed according to these guidelines are not intended to support recurring loads from tractor trailers or garbage trucks.

Non-typical applications, such as steep slopes, high water tables, and impermeable soils require consultation with a qualified designer/engineer. Specific design guidance may also be obtained from the Interlocking Concrete Pavement Institute (ICPI) and other relevant sources.



Testing the soil

For permeable pavement to function properly, water must be able to infiltrate into the soil under the driveway. Use a simple test pit to estimate the soil infiltration rate below the driveway, following all steps below. Perform the test in the late spring or fall, when the water content of soils may be higher. Avoid testing when the ground is frozen, very wet, or very dry.

To avoid disturbing the existing pavement, dig a test pit in the yard adjacent to the existing driveway. The test pit should be two feet from the driveway edge and approximately one foot wide. It should also be located near the low point of the drive (but within the lot line) because water stored in the permeable driveway will generally migrate in that direction.

The bottom of the test pit should match the bottom of the excavation because infiltration into the existing soil will occur at that depth. The test pit depth will typically be **15 inches**, based on the typical dimensions of the following components, the most important of which is the reservoir depth. Refer to the Sizing section for guidance on selecting the reservoir depth. Ensure that the test pit depth matches the dimensions for the actual design.

- Paver thickness (minimum 3½ inches)
- Bedding stone thickness (two inches recommended)
- Reservoir depth (typically 10 inches; see Sizing section)

Carefully examine the soil horizon near the bottom of the test pit to check for a shallow clay layer. If a clay layer is present, the test pit can be excavated further to try to reach a less restrictive soil layer. However, the ultimate excavation depth for the entire driveway should match the depth of the test pit. The depth of the driveway excavation will affect the cost of materials as well as disposal of excavated material.

Always saturate the soil prior to conducting the test. Fill the hole to the **top** with water. Let the water drain completely. Within twelve hours of draining, fill bottom **six inches** with water and start timing the drawdown period. If the drawdown time exceeds **24 hours**, permeable pavement is not recommended without consulting a professional for a site-specific design. It may be possible to capture driveway runoff in a rain garden.

These design guidelines are based on the assumption of adequate subgrade bearing capacity under saturated conditions. If there are concerns about the bearing capacity of the subgrade at the final excavation depth, contact a geotechnical engineer or qualified professional for further soil evaluation (e.g., dynamic cone penetrometer test).

Depth to groundwater

In low-lying areas, the seasonal high water table may be close to the surface. The bottom of the excavation must be 2 feet above the seasonal high water table to ensure sufficient protection for groundwater.

If a high water table is suspected, use a more specialized soil test, or request a soil map from the Natural Resources Conservation Service or the Maryland-National Capital Park and Planning Commission.

For more information visit:

The Maryland Natural Resources Conservation Service
www.md.nrcs.usda.gov

The Maryland-National Capital Park and Planning Commission
www.montgomeryplanning.org

The Natural Resource Conservation Service Web Soil Survey
<http://websoilsurvey.nrcs.usda.gov>

Design guidelines

EDGE RESTRAINTS

Edge restraints are essential to permeable driveway design and construction. Edge restraints must be present on all sides of the driveway to provide a rigid perimeter that prevents pavers from shifting horizontally. Edge restraints also help to ensure proper compaction of reservoir and bedding stone. Soil backfill is not an acceptable edge restraint.

Four options for edge restraints are possible. Additional information is provided in Table 2 and in the construction sequence.

1. A concrete curb, cast in place or precast, with a minimum four-inch width. The curb should extend at least nine inches below the finished driveway surface. This depth may include the thickness of a soldier or sailor course adhered to the top of the curb. The top of the curb may be below grade (recommended) or flush with the driveway surface (Figure 4).
2. Metal or plastic strip edging. The edging **must** be designed for use with pavers. Do not use landscape edging. The edging must be nailed into a dense-graded perimeter berm with a minimum top width of 12 inches (Figure 5).
3. A cut pavement edge, at least five inches thick, adjacent to the permeable driveway. Thinner pavement sections are not acceptable edge restraints. This option applies mainly to the edge at the existing sidewalk, driveway apron, or roadway.
4. The building foundation can also serve as an edge restraint, provided that the edge is straight, vertical, and at least five inches thick.

Table 2. Allowable edge restraint configurations

Edge restraint type	Concrete curb	Strip edging	Pavement edge	Foundation
Best location(s)	All sides	Left/right sides	Downslope end	At house
Required excavation width beyond paver edge, each side (in.)	4-8	7-8	0	0
Comment	May be preferable if driveway edge abuts property line.	Requires use of dense-graded berm for nailing strips in place.	Pavement thickness at cut edge must be at least five inches.	See construction step 4 for waterproofing measures near foundation.

OVERFLOW DESIGN

The storage capacity of the permeable driveway may be exceeded by very heavy rainfall or storms in quick succession. Excess flow must be directed to a suitable location using one of the approaches below.

- **Piped overflow** – If grades allow, excess flow may be diverted into an overflow pipe connected to a pop-up drain in the yard (Figures 2, 4, & 5; construction step 8). **The feasibility of this option depends on elevations on the lot.** The outflow pipe must have at least a 2% slope, and the rim of the pop-up drain must be at least 1½ inches lower than the top of the overflow pipe at the upstream end. The pop-up drain should be located within the lot line, in a location that provides positive drainage away from structures and toward existing, stable flow paths, such as swales or the street. The pop-up drain should generally be located at least two feet away from the driveway. Ensure that the pop-up drain will not drain back onto the driveway or create a nuisance condition such as erosion or flow onto a neighboring lot. Alternately, the overflow pipe may connect to an adjacent storm drain or inlet if a pipe stub currently exists.

- **Surface overflow** – If a piped overflow design is not feasible, the stone layers below the driveway may completely fill with water during heavy rain. Excess flow will run off the driveway surface, much like a conventional driveway. The stored water will draw down over time, and will also collect at the downslope end of the driveway. To reduce the potential for rutting at the downslope end, a waterproof liner and an additional layer of #2 stone must be installed in this portion of the reservoir (Figure 3; construction step 6).

SIZING PERMEABLE DRIVEWAYS

A permeable pavement surface captures rainfall that falls directly on it. Homeowners can also look for opportunities to increase runoff treatment by directing additional impervious area to the permeable driveway. Examples include rooftop, sidewalk, and non-permeable portions of the driveway. In order to ensure adequate performance and water quality treatment, the size of the additional contributing impervious area must be no more than **five times** the permeable pavement area. This requirement does not change based on the depth of the reservoir stone.

For example, if a homeowner installs 600 square feet of permeable pavement, up to 3,000 additional square feet of impervious area may be directed to the driveway. This may include paved areas that would naturally flow onto the permeable surface, or roof runoff from a downspout. If the contributing impervious area is significantly larger than five times the permeable pavement area, the permeable pavement area should be enlarged or the runoff should be partially or completely directed away from the driveway. Runoff from contributing impervious areas should be free of sediment.

In all cases, the permeable driveway must capture at least one inch of rain. If additional impervious area is directed to the driveway, the reservoir depth may need to be increased to ensure at least one inch of rainfall capture (Tables 3-5).

Typical permeable driveways with a 10-inch reservoir can capture approximately 400 or more square feet of additional impervious area.

LANDSCAPE DESIGN CONSIDERATIONS

- Installation of permeable pavement provides an opportunity to alter the driveway width. For instance, the driveway could be narrowed, with native vegetation planted along the edges.
- A variety of paver colors, shapes, and styles is available from different manufacturers.
- A soldier or sailor course can be laid along the edges of the driveway (Figure 4). Serving as a decorative border, soldier or sailor course pavers typically differ from those used in the rest of the driveway. Non-permeable pavers can be used. Soldier and sailor courses are laid perpendicular or parallel to the edge restraints, respectively, and the choice depends primarily on aesthetic preferences.
- Obtain several sample pavers before finalizing materials purchase.

Rainfall storage calculation

The amount of rainfall that can be captured and stored depends on the permeable pavement area, the depth of the stone reservoir, and the amount of additional impervious area that drains to the driveway. Tables 3-5 show rainfall capture for different reservoir depths. **The recommended reservoir depth for most installations is 10 inches.**

The permeable pavement area is based on the extent of the stone reservoir. The permeable pavement area **may not extend past the property line** (Figure 1). Site-specific factors may reduce the available permeable pavement area.

Residential permeable pavement driveways should be sized for 1.0 to 2.5 inches of rain. The minimum rain capture goal for a RainScapes Reward Rebate is 1.0 inch.

Using the rainfall storage tables

1. Estimate the available permeable pavement area based on property line location, edge restraint width (Table 2), and other location guidelines.
2. Measure the additional impervious area (e.g., roof) that can be directed to the permeable driveway. The roof drainage area to each downspout can be found by dividing the house footprint by the number of downspouts. The additional contributing impervious area should be no more than **five times** the permeable pavement area, as indicated by the blank cells in Tables 3-5.
3. Table 3 is the recommended starting point because it will meet the rainfall capture goal in many cases while minimizing the excavation depth.
4. Across the top of the table, find the number closest to the additional impervious area (if any) that drains to the driveway, not including the driveway itself. This may include roof and patio.
5. Look down the column. Find the number closest to the desired rainfall storage (at least 1.0 inch).
6. Look to the left side of the table to find the corresponding permeable pavement area.
7. If this permeable pavement area is larger than the available space, choose a smaller rainfall depth or repeat the process with a deeper reservoir.
8. Make a note of the final stone reservoir depth and permeable pavement area.

Example: Use Table 3 for a design with a 10-inch reservoir. This table shows that a permeable driveway with a 400 sq. ft. permeable pavement area and 200 sq. ft. of additional impervious area can capture 2.1 inches of rainfall.

Note: This rainfall capture calculation is conservative because it does not include drawdown into the underlying soil.

Table 3. Rainfall capture for 10 inch reservoir.

Inches of rain stored	Additional impervious area (square feet)					
	0	100	200	400	800	1200
100	3.2	1.6	1.1	0.6		
200	3.2	2.1	1.6	1.1	0.6	
300	3.2	2.4	1.9	1.4	0.9	0.6
400	3.2	2.5	2.1	1.6	1.1	0.8
600	3.2	2.7	2.4	1.9	1.4	1.1
800	3.2	2.8	2.5	2.1	1.6	1.3
1000	3.2	2.9	2.6	2.3	1.8	1.4
1200	3.2	2.9	2.7	2.4	1.9	1.6

Table 4. Rainfall capture for 20 inch reservoir.

Inches of rain stored	Additional impervious area (square feet)					
	0	100	200	400	800	1200
100	6.3	3.2	2.1	1.3		
200	6.3	4.2	3.2	2.1	1.3	
300	6.3	4.7	3.8	2.7	1.7	1.3
400	6.3	5.1	4.2	3.2	2.1	1.6
600	6.3	5.4	4.7	3.8	2.7	2.1
800	6.3	5.6	5.1	4.2	3.2	2.5
1000	6.3	5.7	5.3	4.5	3.5	2.9
1200	6.3	5.8	5.4	4.7	3.8	3.2

Table 5. Rainfall capture for 30 inch reservoir.

Inches of rain stored	Additional impervious area (square feet)					
	0	100	200	400	800	1200
100	9.5	4.7	3.2	1.9		
200	9.5	6.3	4.7	3.2	1.9	
300	9.5	7.1	5.7	4.1	2.6	1.9
400	9.5	7.6	6.3	4.7	3.2	2.4
600	9.5	8.1	7.1	5.7	4.1	3.2
800	9.5	8.4	7.6	6.3	4.7	3.8
1000	9.5	8.6	7.9	6.8	5.3	4.3
1200	9.5	8.7	8.1	7.1	5.7	4.7

Figure 2. Profile view along driveway centerline
Permeable driveway with piped overflow

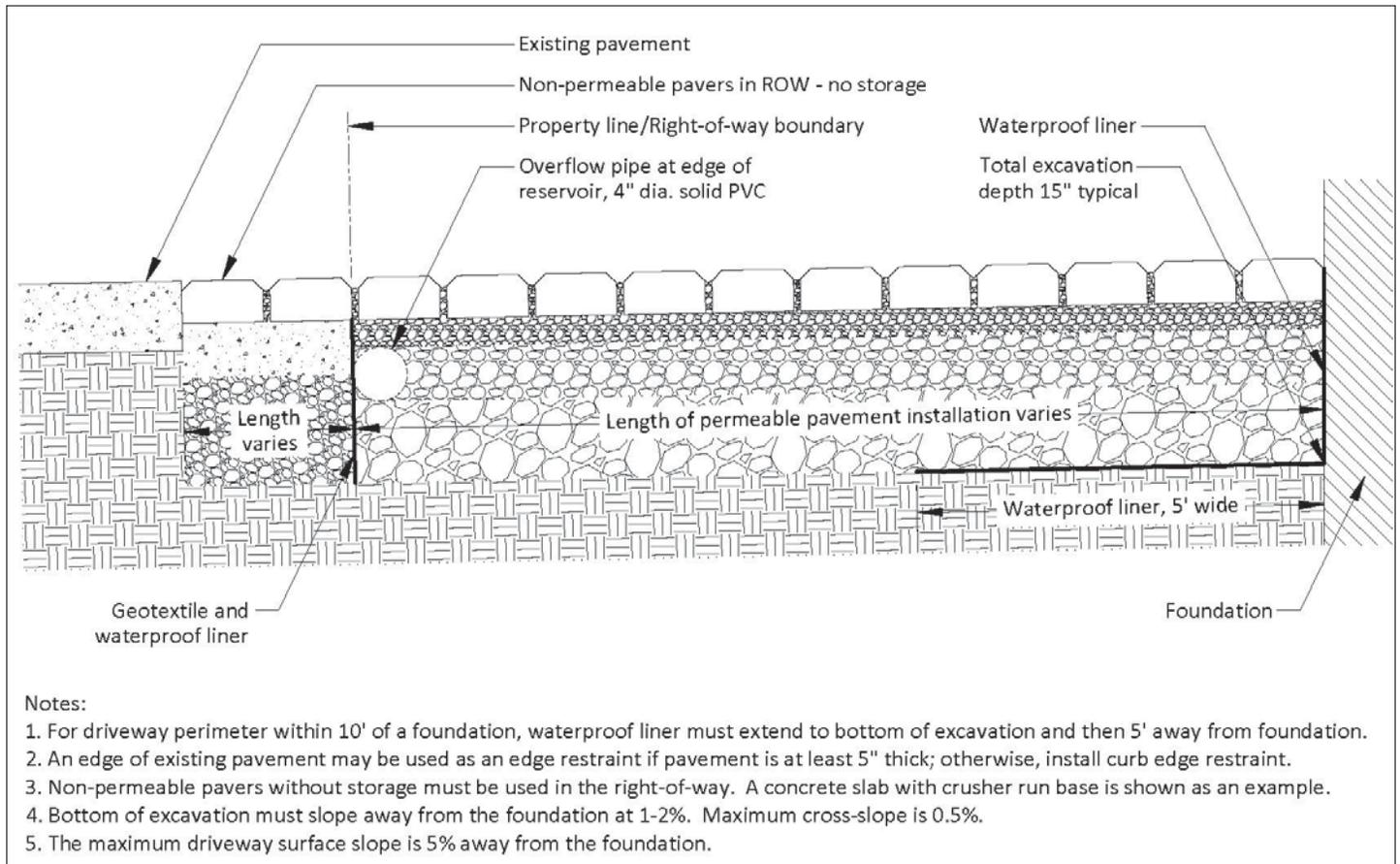
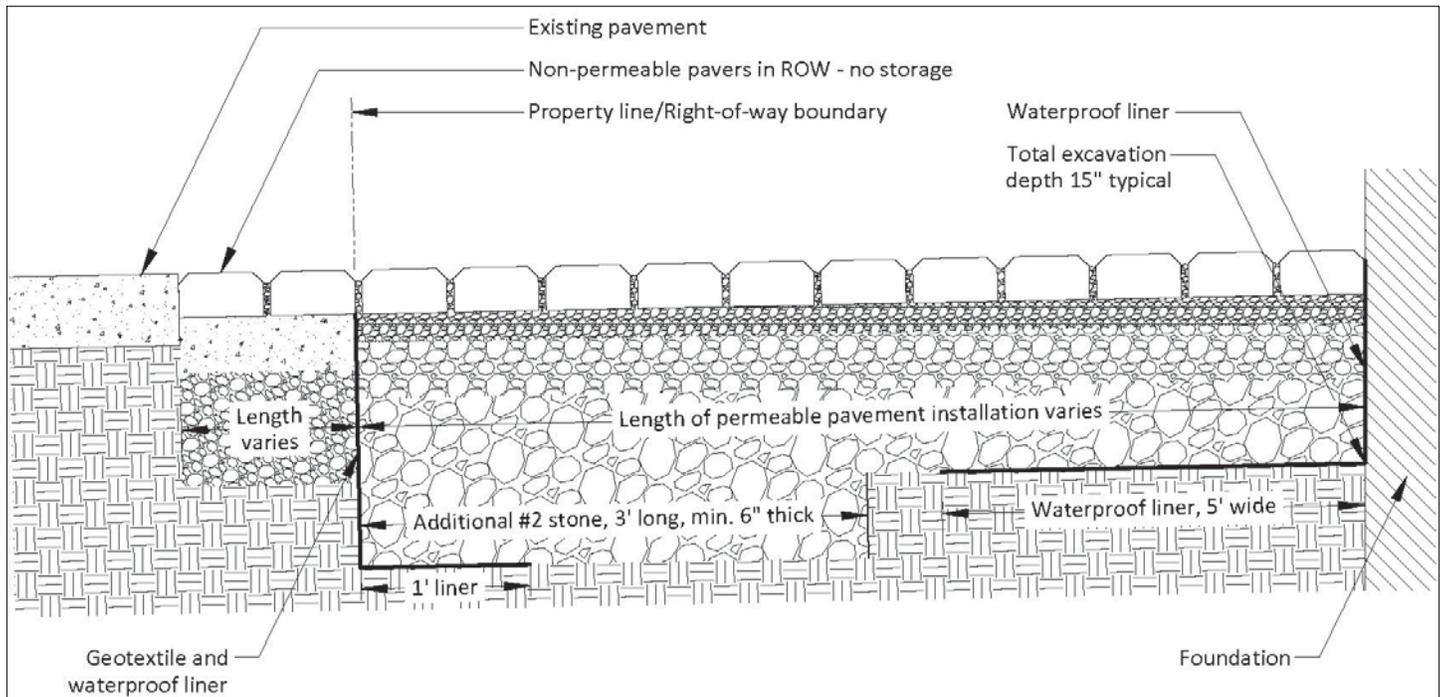


Figure 3. Profile view along driveway centerline
Permeable driveway with surface overflow



Notes:

1. For driveway perimeter within 10' of a foundation, waterproof liner must extend to bottom of excavation and then 5' away from foundation.
2. An edge of existing pavement may be used as an edge restraint if pavement is at least 5" thick; otherwise, install curb edge restraint.
3. Non-permeable pavers without storage must be used in the right-of-way. A concrete slab with crusher run base is shown as an example.
4. Bottom of excavation must slope away from the foundation at 1-2%. Maximum cross-slope is 0.5%.
5. The maximum driveway surface slope is 5% away from the foundation.
6. The additional 6" layer of #2 stone must span the full width of the excavation.

Figure 4. Cross-section at downslope end of driveway
Permeable driveway with concrete curb edge restraint and piped overflow

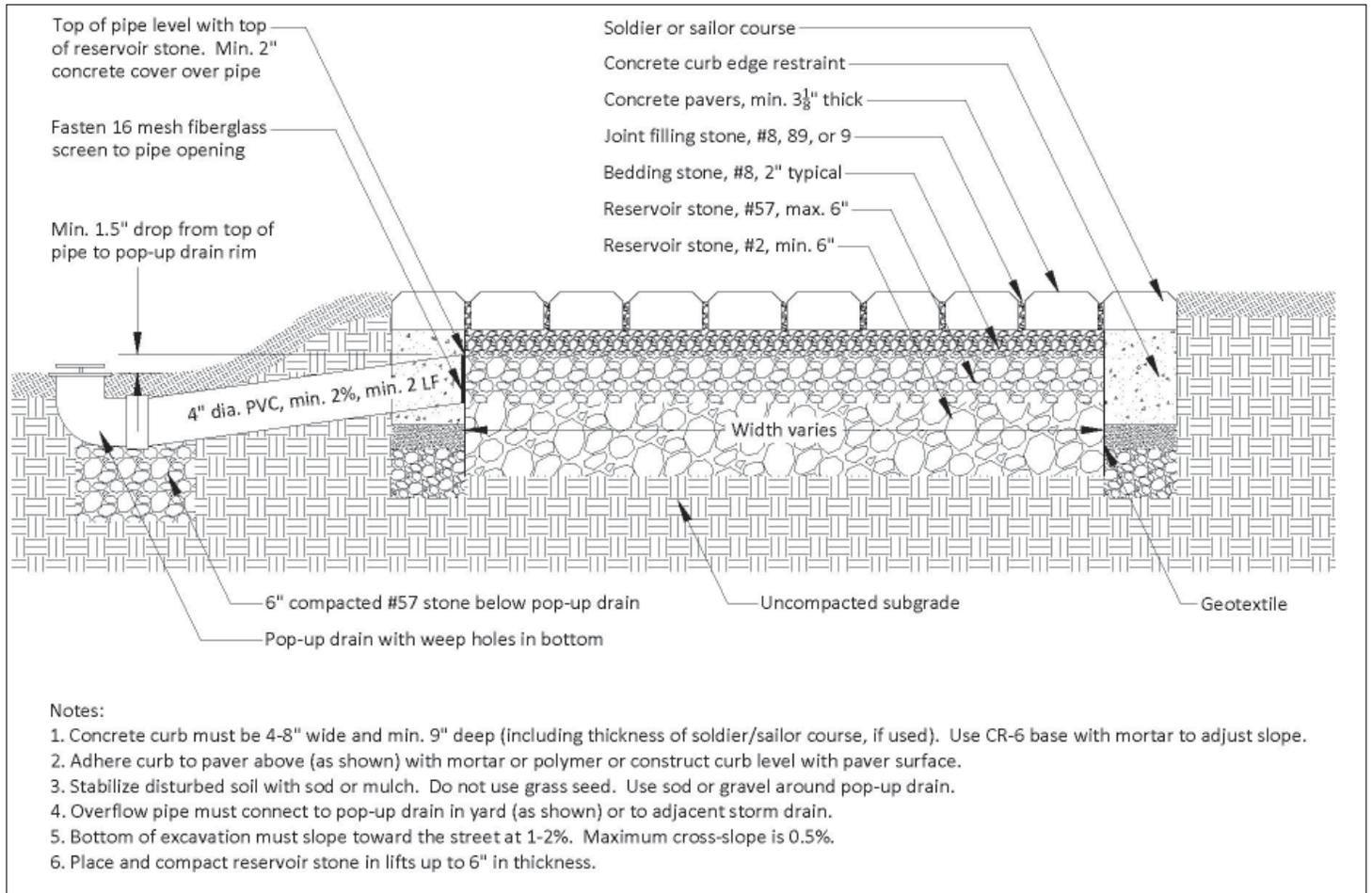
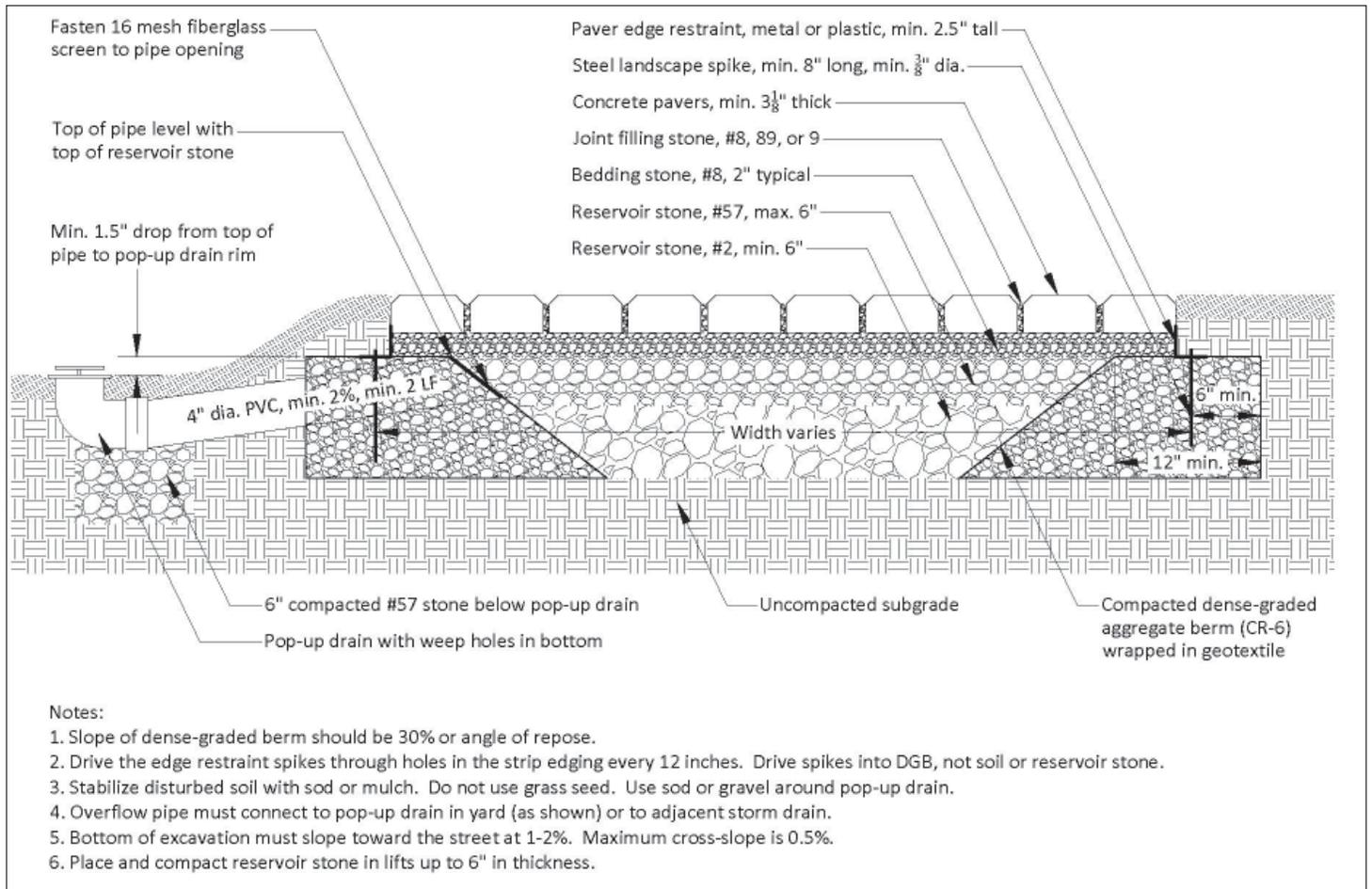


Figure 5. Cross-section at downslope end of driveway
Permeable driveway with strip edge restraint in dense-graded berm (DGB) and piped overflow



Construction



Miss Utility

Always call Miss Utility (811) before starting construction.

STEP 1. GENERAL CONSTRUCTION GUIDELINES

To ensure long-term performance of permeable pavement driveways, it is critical to follow good construction practices that control sediment, divert runoff, and minimize soil compaction.

a) Sequencing

- Install permeable pavement after any other site work has been completed. This will prevent accidental soil compaction and possible clogging from sediment.
- Do not install when the ground or stockpiled material is frozen or very wet. Spring or fall are best, when the ground has a moderate amount of moisture.

b) Soil protection

- All access for equipment, staging, and worker movement must have suitable ground protection. Acceptable methods include a mulch access path, wooden mats, and HDPE mats, following County standards.
- During construction, avoid disturbing or compacting the surrounding soil as much as possible, especially around healthy vegetation.
- Minimize the use of heavy equipment in the excavated area to avoid compacting the subsoil. Operate equipment at the sides of the excavation if feasible, or over installed base materials (e.g., reservoir stone).
- As much as possible, avoid walking on disturbed areas until they have been stabilized with mulch or sod.

c) Controlling runoff

- Secure a waterproof covering over any working surface during breaks in construction over eight hours, or if rain is imminent.
- Do not direct downspout flow to the driveway until permeable pavement installation is complete.
- Provide a splash pad in the driveway surface, if the downspout empties directly onto the pavement, in order to prevent joint washout.
- To control any remaining sources of sediment-laden runoff after the above measures have been taken, install temporary erosion control measures such as silt fences, temporary swales, or berms as appropriate.

d) Stockpiling

- Stockpile reservoir stone as close to the excavation as possible, or deposit directly into the excavated area.
- Keep stone stockpile away from standing water and from sources of sediment and debris. Stockpiled stone should be placed on pavement or geotextile to avoid sediment contamination.
- Do not use reservoir stone that is contaminated with sediment.

Photo documentation

Take photos to document all steps of the installation process to assist in rebate processing. Take photos of the basement before and after installation. Pay attention to any pre-existing water damage and/or foundation damage.

STEP 2. STAKEOUT

- a) Use stakes to mark the excavation area.
- b) The required excavation width is the sum of:
 - Final driveway width desired
 - Width needed for edge restraints on each side (Table 2)
- c) Offset stakes at least one foot outside the edge of the excavation to avoid disturbing stakes during construction.

STEP 3. CLEARING AND EXCAVATION

- a) Make a clean, straight saw cut in the existing pavement at all points where the pavers will touch existing pavement (e.g., sidewalk). Use a saw and blade appropriate for the material being cut.
- b) Inspect the thickness of the cut pavement section. If the existing pavement is less than five inches thick, it cannot be used as an edge restraint, and a concrete curb must be installed (Step 9b). Cut additional pavement to accommodate curbs as needed.
- c) Break up and remove the existing driveway with a jackhammer, sledgehammer and pry bar, or excavator blade.
- d) The required excavation depth is the sum of:
 - Paver thickness (minimum 3 $\frac{1}{8}$ inches)
 - Bedding stone thickness (two inches recommended)
 - Reservoir depth (typically 10 inches; see Sizing section)
- e) Excavate with mechanized equipment to the required width (Step 2) and depth. Hand dig within the dripline of any trees 12 inches DBH (diameter at breast height) or greater.
- f) For designs with surface overflow, excavate an additional six-inch depth at the downslope end of the reservoir (Step 6; Figure 3).
- g) Take care to minimize root impacts during excavation. Prune roots one inch in diameter or larger as needed.
- h) If reservoir stone cannot be installed immediately after excavation, either:
 - Excavate to the final depth, secure a waterproof covering over the excavation, and ensure that runoff does not enter from the sides; **or**
 - Leave six inches of soil in place without a covering and excavate to the final depth just prior to installing the reservoir stone.
- i) If the subgrade at the desired depth is unstable, unconsolidated, or contains large rocks or debris, excavate until stable subgrade is reached. Use #2 stone to fill the additional excavated volume and compact as described in Step 7. Do not use soil as fill.

- j) The bottom of the excavation **must slope away from the foundation** and toward the street. A 1% slope is preferable, but up to 2% is allowed. This slope must be provided regardless of the finished slope of the driveway surface. If site-specific conditions dictate that the bottom of the excavation has a slope greater than 2%, check dams may be needed to prevent water from accumulating at the low end – consult a design professional.
- k) The bottom of the excavation must not have a cross-slope that exceeds 0.5%.

STEP 4. GEOTEXTILE AND WATERPROOF LINER

- a) Geotextile should be placed on all vertical sides of the excavation. Do not place geotextile on the bottom of the excavation or any other horizontal surface, except when installing waterproof liners as noted below.
- b) Avoid wrinkles and folds in all geotextile and liner installation, and overlap a minimum of 24 inches at joints. Securely attach the geotextile and liner (if used) to the sides of the excavation following manufacturer specifications.
- c) A waterproof liner is required for any portion of the driveway perimeter **within 10 feet** of a foundation (Figures 1 - 3). Install geotextile as described above prior to installing the liner. The liner must extend vertically from the top of the pavers to the bottom of the excavation and then horizontally **five feet** away from the foundation.
- d) For designs with surface overflow, install a waterproof liner at the downslope end of the stone reservoir (Figure 3). Install geotextile as described above prior to installing the liner. The liner should extend vertically from the top of the pavers to the bottom of the excavation. Extend the liner horizontally one foot toward the house, following the bottom of the excavation and covering the entire excavated width.

Note: Steps 5 and 6 discuss installation of optional stone layers, dependent on design decisions regarding edge restraints and overflow. Although presented separately, both steps should occur in conjunction with the installation of reservoir stone (Step 7).

STEP 5. DENSE-GRADED BERM (ALTERNATE TO STEP 9B)

- a) If strip edge restraints are used, the required dense-graded berm (DGB) must be installed at the same time as the reservoir stone (Step 7).
- b) Keep DGB material separate from the reservoir stone at all times.
- c) Geotextile must be placed between the reservoir stone and the DGB to prevent migration of fines. Key in geotextile under DGB before placing the first lift (Figure 5).
- d) The DGB and geotextile should slope toward the edges of the driveway at approximately 30%, or the angle of repose.
- e) Install and compact six-inch lifts of DGB in conjunction with the adjacent reservoir stone. After compaction, the tops of the DGB and reservoir stone must be even.

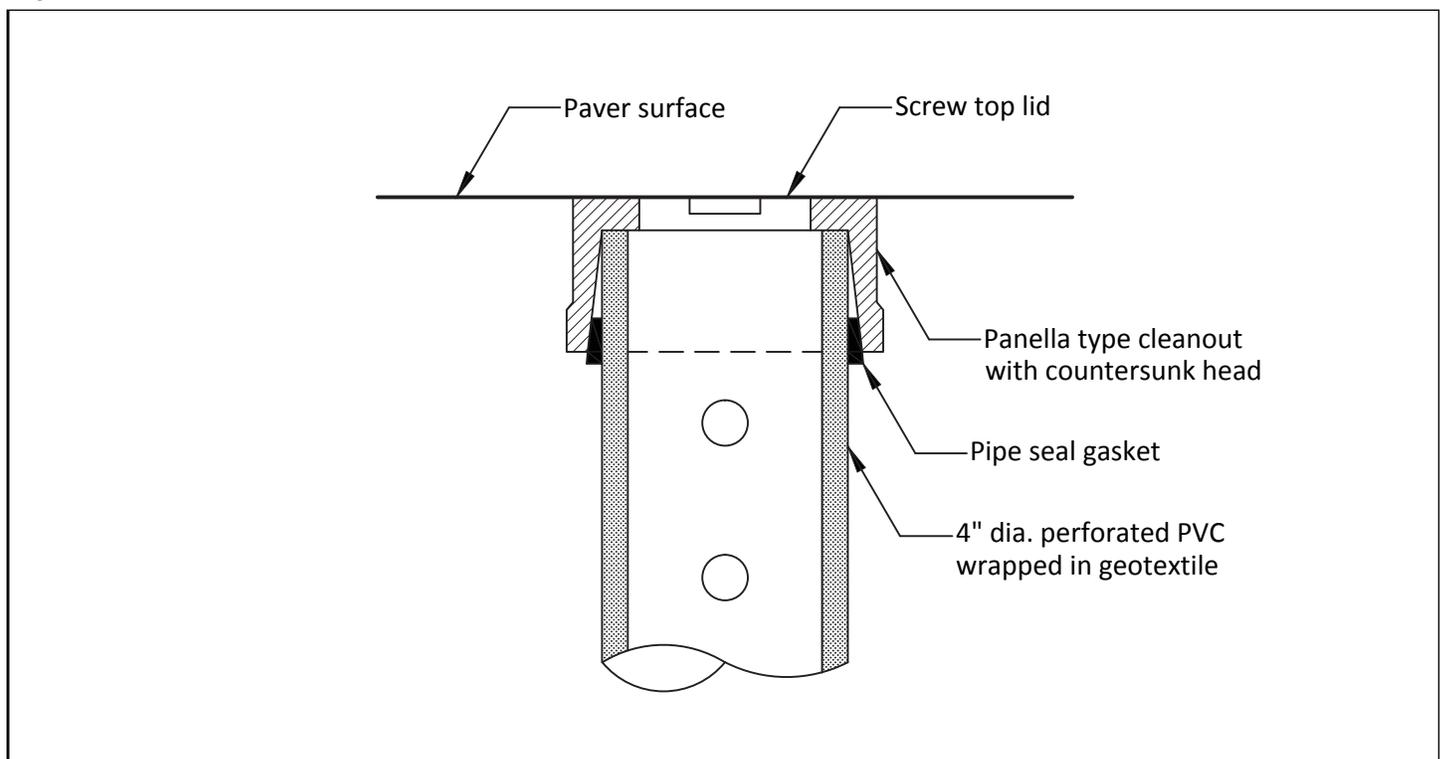
STEP 6. SURFACE OVERFLOW (ALTERNATE TO STEP 8)

- a) Driveways with surface overflow require an additional six-inch layer of #2 stone below the reservoir. This area of additional #2 stone is three feet long, must span the full excavated width, and is located at the downslope end of the reservoir (Figure 3). The extra layer of stone provides additional stability.
- b) Prior to installing the reservoir stone (Step 7), place and compact the six-inch layer of #2 stone in the area described in Step 6a and shown in Figure 3.

Observation well

Prior to installing reservoir stone, an observation well may be installed at the low end of the driveway at discretion of the owner or contractor (Figure 6).

Figure 6. Observation well detail



STEP 7. RESERVOIR STONE

- a) Use a hoe, heavy-duty rake, or the backhoe bucket teeth to scarify (roughen) the top six inches of the existing soil at the bottom of the excavated area.
- b) The reservoir stone thickness is typically 10 inches but may be greater in some cases; see the Sizing section.
- c) Do not re-use any base course stone from the existing driveway. The reservoir stone must consist only of a bottom layer of #2 stone and a top layer of #57 stone. Follow the guidance in Table 6 for the thickness of each stone layer.
- d) Place and spread the reservoir stone in lifts up to six inches in thickness. (Shorter lifts can be used at the contractor's discretion.) Level each lift by raking. Moisten each lift prior to compaction.
- e) Compact each lift using a walk-behind vibratory plate compactor with a minimum centrifugal compaction force of 13,500 lb. The compactor should be equipped with a compaction indicator. A walk-behind roller providing equivalent compaction may also be used at the contractor's discretion.
 - Make at least two passes in each direction, for a total of four passes minimum.
 - Compact the stone until the compaction indicator shows that compaction is complete; move to next area and repeat. If a compaction indicator is not available, compact the stone until there is no visible movement.
 - Do not crush the stone.
- f) The variation in the final surface elevation of the reservoir stone must not exceed ½ inch over 10 feet. As needed, rake or add stone and repeat the compaction process.

Table 6. Thickness of reservoir stone layers

Stone layer	10" reservoir	20" reservoir	30" reservoir
#57 (top)	4 inches	6 inches	6 inches
#2 (bottom)	6 inches	14 inches	24 inches

STEP 8. PIPED OVERFLOW (ALTERNATE TO STEP 6)

- a) Install reservoir stone and, if used, the dense-graded berm (Steps 5 and 7).
- b) The overflow pipe should just touch the edge of the stone reservoir, but not overlap it (Figures 4 and 5).
- c) The top of the overflow pipe must be level with the top of the reservoir stone.
- d) For strip edge restraints with a dense-graded berm (DGB), carefully remove enough DGB material to install the pipe. Cut the end of the overflow pipe to follow the side slope of the DGB (Figure 5).
- e) Secure a fiberglass screen around the opening of the overflow pipe prior to installing the pipe.
- f) Locate the position of the pop-up drain. The rim of the pop-up drain must be at least 1½ inches below the top of the upstream end of the overflow pipe (Figures 4 and 5).
- g) Excavate the desired locations for the overflow pipe and pop-up drain.
- h) Place and compact six inches of #57 stone below the pop-up drain.
- i) Install the overflow pipe from the edge of the stone reservoir to the pop-up drain location. The minimum pipe slope is 2%.
- j) Drill several holes in the bottom of the pop-up drain to allow complete drawdown of water in the pipe.
- k) Confirm pop-up drain elevation and pipe slope to ensure positive drainage. Connect the pop-up drain to the overflow pipe. Backfill around the overflow pipe and pop-up drain. Stabilize the area with sod or gravel. Do not use grass seed.

STEP 9A. STRIP EDGING IN DENSE-GRADED BERM (ALTERNATE TO STEP 9B)

- a) The dense-graded berm (DGB) is installed simultaneously with the reservoir stone (Steps 5 and 7) prior to installation of strip edging.
- b) Use steel landscape spikes to secure edge restraints to the DGB. **Do not** drive spikes into reservoir stone.
- c) Position the edge restraints so that spikes are driven at least six inches from the outside edge of the DGB.
- d) Every 12 inches, drive one spike through holes in the strip edging and into the DGB.
- e) The slope of the strip edge restraints must match the driveway slope.
- f) To minimize the need to cut the pavers, lay a temporary row of pavers across the width of the driveway after installing the first edge restraint. Use the position of the paver at the far side to guide the placement of the other edge restraint.

STEP 9B. CURB EDGE RESTRAINT (ALTERNATE TO STEP 9A)

- a) Crusher run aggregate (CR-6) should be used as the base for either cast in place curbs or precast curbs.
- b) The top of the curb may be below grade (recommended) or flush with the driveway surface (Figure 4).
- c) Curbs must be four to eight inches wide.
- d) The curb should extend at least nine inches below the finished driveway surface. This depth may include the thickness of a soldier or sailor course adhered to the top of the curb (Figure 4).
- e) Set up stringlines across the length and width of the driveway to assist in curb placement.
- f) If using an overflow pipe, pour the curb around the pipe, or cut a precast curb to allow the pipe to pass through it. Within the curb width, provide at least a two-inch cover of concrete above the top of the pipe.
- g) For precast curbs, lay a one- to three-inch thick haunch of concrete on the CR-6 base for the curb. Adjust the slope of each section of precast curb after placement as needed, while concrete haunch is still workable.
- h) The slope of the curb edge restraints must match the driveway slope.

STEP 10. BEDDING STONE

- a) All edge restraints must be installed before placing bedding stone (#8 stone).
- b) If a mechanical screed is not used, hand-screed the bedding stone as specified below.
 - Lay two to three metal screed rails parallel to the length of the driveway. The thickness of the screed rails must match the thickness of the bedding stone; two inches is recommended. The screed rails should be at least one foot inside the driveway from the edge restraints. The maximum width between any two screed rails should not exceed six feet.
 - Place bedding stone on top of the reservoir stone and screed rails. Moisten bedding stone, then spread with a rake.
 - Screed the bedding stone to a uniform depth of two inches by pulling a straight board (e.g., a straight 2 x 4) across the screed rails. The surface of the bedding stone should be level after screeding.
 - Carefully remove screed rails and fill the remaining grooves with bedding stone.
 - The variation in the surface elevation of the bedding stone must not exceed $\frac{3}{8}$ inch over a 10-foot straightedge.
- c) Avoid any pedestrian or vehicular traffic on screeded material before installing pavers.
- d) Do not compact the bedding stone directly. This layer will be compacted when compacting the pavers (Step 12).

STEP 11. PAVERS

- a) Install pavers immediately after placing and screeding the bedding stone (Step 10).
- b) Moisten the bedding stone before placing pavers.
- c) A string level or laser level may be used to guide paver placement and ensure levelness across the driveway width.
- d) Chalk lines on the screeded bedding stone can be used to maintain straight joint and paver alignment. If needed, the joint width can be varied within the manufacturer's tolerance to maintain a straight alignment.
- e) Install the soldier or sailor course, if used. These pavers may be placed flush against an edge restraint (e.g., strip edging or exposed concrete curb), or may be adhered to the top of a concrete curb (Figure 4).
- f) To improve stability and reduce chipping, where possible use uncut pavers where the permeable driveway meets the edge of existing pavement.
- g) Use a wet saw with a dust collection system to cut pavers. A block splitter may be used if a rougher-looking cut is acceptable. The cut faces must be vertical. Take care to control dust, especially to avoid staining installed pavers. Wet-cut pavers must be washed clean of slurry before installing. Do not install any paver that has been cut to less than one-third of its original size.
- h) Pavers should be placed hand-tight and match the pattern specified by the manufacturer. Do not hit or twist.
- i) Take pavers from alternating pallets to evenly distribute texture and color.
- j) Every few rows, make sure pavers are aligned and adjust as necessary.
- k) Prior to compaction, pavers should be $\frac{3}{4}$ inch higher than adjacent sidewalks or curbs.

STEP 12. PAVER COMPACTION

- a) Fill joints between pavers by sweeping in washed aggregate joint filling stone (#8, 89, or 9 as appropriate). **Do not use sand, polysand or stone screenings.**
- b) Sweep away loose stone on the pavement surface before compacting.
- c) Seat the pavers using a walk-behind vibratory plate compactor with a centrifugal compaction force of 5,000-7,000 lb. Make at least two passes in each direction, for a total of four passes minimum. Remove and replace any cracked pavers; refill joints and compact.
- d) After compacting, sweep in additional joint filling stone as needed. Sweep away loose stone on the pavement surface. Compact pavers at least once in each direction. Repeat filling and compacting until joint stone is within $\frac{1}{4}$ inch of the pavement surface.
- e) After finishing paver compaction, the variation in the driveway surface must not exceed $\frac{3}{8}$ inch over a 10-foot straight-edge.
- f) The difference in height between adjacent pavers should not exceed $\frac{1}{8}$ inch.
- g) After compaction, pavers should be $\frac{1}{4}$ to $\frac{3}{8}$ inch higher than adjacent sidewalks or curbs to allow for minor settlement.

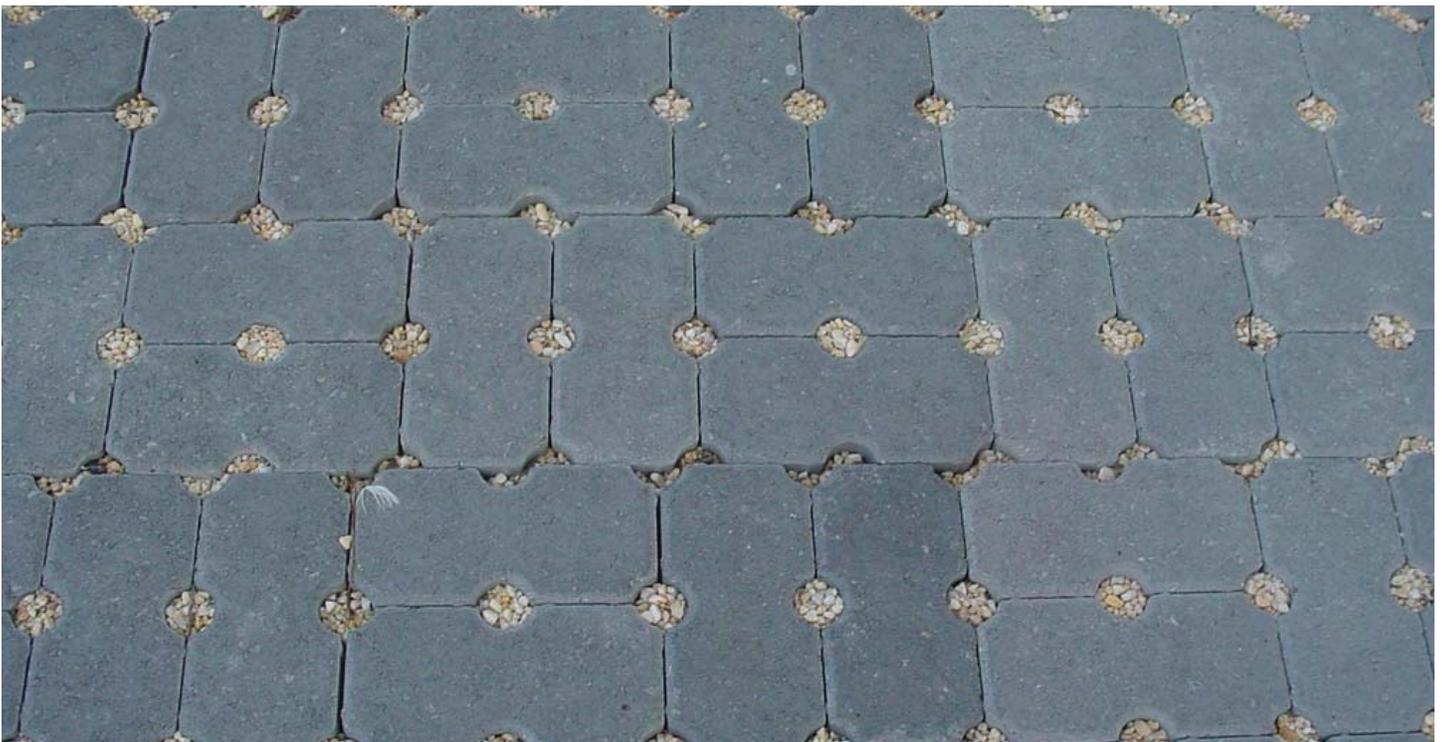
STEP 13. COMPLETION

- a) Backfill around the edges of the driveway with excavated soil. Any disturbed areas that drain onto the permeable pavement surface **must be stabilized immediately** with sod, mulch, or erosion control matting.
- b) Trim and remove any geotextile or waterproof liner that remains exposed after backfilling.
- c) Stockpile approximately 20 replacement pavers in an appropriate covered location.
- d) Seal all joints at existing impervious pavement.
- e) Save a sack of joint filling stone for future maintenance activities.

Common installation problems



Failing edge restraint caused by improper product and installation



Poorly aligned pavers

Maintenance

Routine maintenance is key to long-term performance. It is strongly recommended that homeowners and/or contractors follow the maintenance guidelines below.

ROUTINE INSPECTION AND CLEANING

- a) Several times a year, watch the driveway during moderate to heavy rainfall to observe whether water runs off the driveway surface. If installed, an observation well can also be used to track the drawdown time after rainfall ends. Vacuuming is recommended if most water appears to run off or remains on the driveway surface after the rain ends.
- b) Every spring and fall, vacuum the driveway with a heavy-duty wet/dry vacuum to remove accumulated sediment and maintain permeability. Use a flat nozzle (e.g., gulper or floor nozzle). Refill joint filling stone as needed. This task can also be performed by a contractor.
- c) For designs with piped overflow, inspect the pop-up drain for clogging every month and after major storms.
- d) Do not pressure-wash the driveway because sediment will be driven deeper into the joints, reducing permeability.
- e) Efflorescence is a naturally-occurring whitish powder in concrete materials. It will wear away over time. If it persists after several months, a commercial cleaning product may be used.

SEDIMENT AND VEGETATION

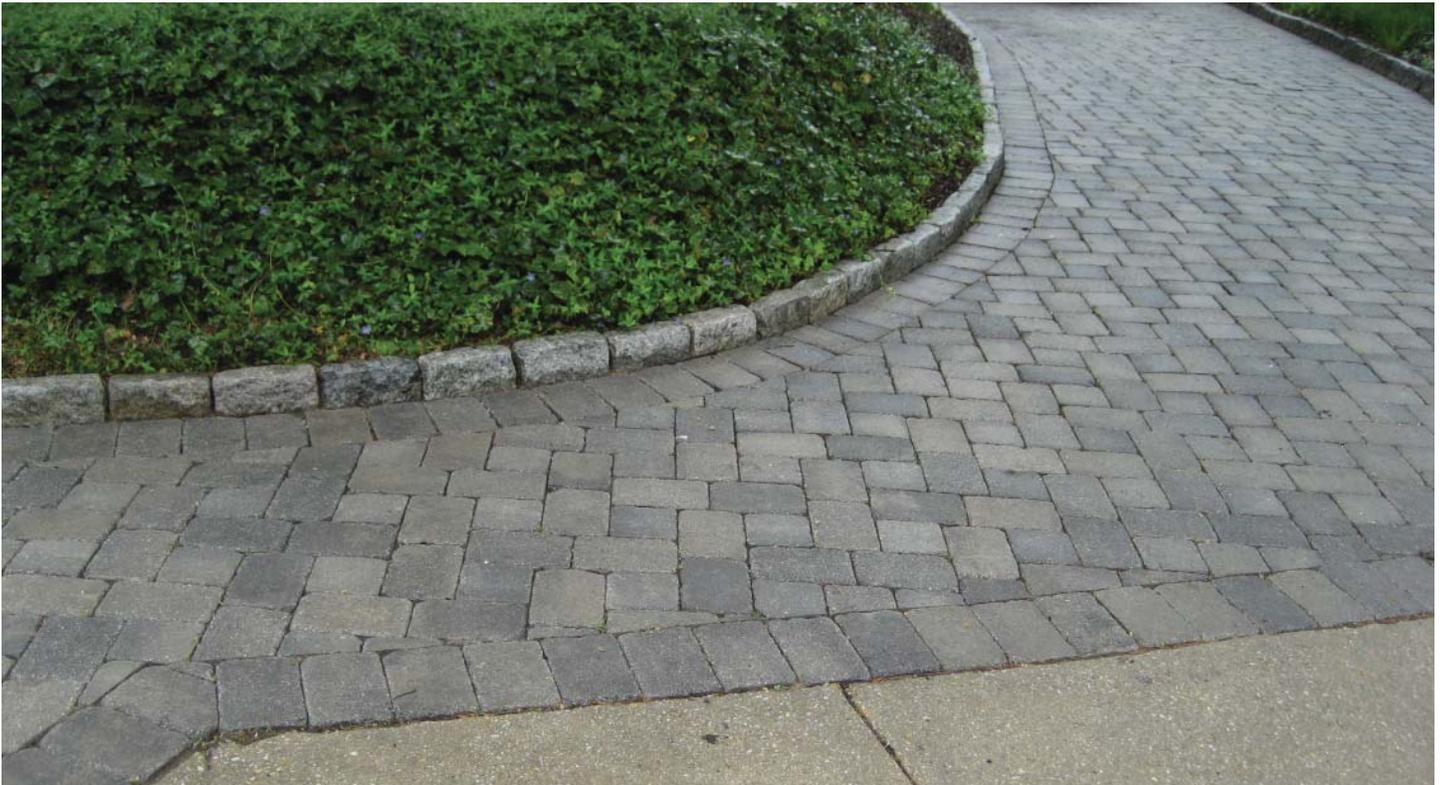
- a) Any pervious areas that drain onto the permeable pavement surface must be non-erodible. Maintain grass, mulch, or vegetative cover to prevent erosion. Immediately stabilize and repair disturbed areas by applying sod, planting and mulching, or placing temporary erosion control matting.
- b) If downspout flow is directed to the permeable driveway, inspect and clean contributing gutters at least once annually, after leaves drop in late fall. Spring inspection and cleaning may also be warranted. Check for erosion from downspout flows.
- c) Carefully pull weeds to minimize disruption to the stone between the joints. Refill joint filling stone as needed. A weed torch can be used for weeds that cannot easily be pulled. If weeds are persistent, use horticultural vinegar, an effective non-selective herbicide which does not have residual effects. As a last resort, spot-treat with a herbicide that is approved for use in streams and wetlands and has a low residual (e.g., Accord, Rodeo).

WINTER MAINTENANCE

- a) **Do not apply sand.** Apply salt sparingly. Joint filling stone or bedding stone can be lightly applied in place of sand if addition traction is desired. These materials can be obtained from local stone yards or landscape suppliers. Washed #8 or #9 stone is an acceptable grit to use on PICP.
- b) Snowblowers will not dislodge joint filling stone between pavers.
- c) Avoid piling snow on permeable pavement.

CONTRACTOR MAINTENANCE ACTIVITIES

- a) For annual vacuuming of larger driveways, use a vacuum filter street sweeper. A conventional wet/dry vacuum should be sufficient for most driveways, however. Do not use wet sweeping equipment. Replenish joint filling stone to the surface of the pavers as needed. Verify surface permeability after vacuuming (ASTM C1701 can be used).
- b) If excessive pavement settlement (greater than one inch) occurs, remove all pavers within one foot of the depressed area. Fill the depression with bedding stone (#8 stone) so that prior to compaction, the replaced pavers are $\frac{1}{4}$ inch above the elevation of the surrounding driveway surface. Ensure that the bedding stone surface is level. Replace pavers, maintaining existing spacing. Repeat paver compaction procedure.



Materials and equipment

EQUIPMENT

- $\frac{3}{4}$ ton pickup truck or larger
- Lightweight, wide-tracked mini excavator or backhoe loader
- Trailer for excavator
- For compacting reservoir stone: Walk-behind reversible vibratory plate compactor; approx. 60 Hz; min. 13,500 lb (60 kN) centrifugal compaction force, equipped with a compaction indicator. A walk-behind roller providing equivalent compaction may also be used at the contractor's discretion.
- For seating pavers: Walk-behind reversible vibratory plate compactor; 75-90 Hz; min. 5,000 lb (22 kN) centrifugal compaction force; max. 7,000 lb (31 kN)
- Circular saw for cutting existing pavement
- For cutting pavers: Wet saw with a dust collection system, or a block splitter
- #2 shovel
- Flat headed shovel
- Dirt tamper
- Wheelbarrow
- String level or laser level
- Chalk line
- Tarp to cover stone prior to installation
- Hose and water source
- Ground protection matting
- Forms for edging
- 2 lb. sledge for driving spikes

LABOR

- Foreman
- Equipment operator
- Paver installation crew

PAVERS

- Pavers must conform to ASTM C 936 (Standard Specification for Solid Interlocking Concrete Paving Units).
- The minimum paver thickness is $3\frac{1}{8}$ inches (80 mm).
- Pavers must have a surface open area of 5 to 15%, inclusive.
- Interlocking pavers with integrated spacers must be used in order to provide the greatest strength and stability. Pavers should be specifically designed for use in permeable applications.
- Consult the manufacturer's installation instructions for acceptable ranges of joint widths between pavers, typically $\frac{1}{2}$ inch or less.

EDGE RESTRAINTS

- Strip edge restraints must be specifically designed for use with concrete pavers. Do not use wood or general landscape edging.
- Strip edge restraints should be at least 2½ inches tall (e.g., Asphalt Edge or equivalent), in order to contain a two-inch bedding stone layer and provide ½ inch overlap with pavers.
- Landscape spikes must be at least eight inches long, with a diameter of ⅜ inch.
- All concrete curbs must be at least four inches wide and nine inches deep (six inches deep if a soldier or sailor course is adhere to the top of the curb).
- If a soldier or sailor course will be adhered to the top of a concrete curb edge restraint, appropriate mortar must be supplied.

STONE

- All stone (except for crusher run aggregate) must be open-graded crushed stone with 90% fractured faces and must be washed and free of soil, foreign material, and particles passing the No. 200 sieve. Do not use limestone screenings, sand, or rounded gravel or stone.
- Bedding stone: Washed ASTM #8 gradation
- Joint filling stone: Washed ASTM #8, 89, or 9 gradation, to fit within the joint width of the selected pavers. Test pavers and joint filling stone for compatibility before purchasing materials. Do not use sand, or stone gradations smaller than #9.
- Reservoir stone: Washed ASTM #57 and #2 gradation
- Dense-graded berm (if used): Crusher run aggregate (CR-6)

GEOTEXTILE AND WATERPROOF LINER

- Geotextile: Non-woven, Maryland State Highway Administration Class PE, Type I or approved equivalent
- Waterproof liner (if needed): Minimum 30 mil thickness. PVC, HDPE, or EPDM rubber

PIPED OVERFLOW (IF USED)

- Overflow pipe: Four-inch diameter schedule 40 solid (non-perforated) PVC. Do not use SDR pipe or corrugated HDPE.
- Pop-up drain and adapters as needed to connect to overflow pipe
- 16 mesh fiberglass screen and fasteners to cover opening of overflow pipe

NOTE ON OTHER PAVEMENT TYPES

- The function of the stone reservoir is the same in all types of permeable pavement. For other permeable pavement systems, such as porous asphalt or pervious concrete, please consult manufacturer and industry specifications.

References

- **Montgomery County RainScapes Program:** <http://www.montgomerycountymd.gov/rainscapes>
- **Montgomery County RainScapes Manuals:** <http://www6.montgomerycountymd.gov/dectmpl.asp?url=/content/dep/water/rainmanuals.asp>
- ICPI University Curricula: <http://www.icpi.org/curriculum>
- Maryland Standards and Specifications for Soil Erosion and Sediment Control. Maryland Department of the Environment, 2011. <http://www.mde.state.md.us/programs/Water/StormwaterManagementProgram/SoilErosionandSedimentControl/Documents/2011%20ESC%20Standards%2005232011%20web%20version.pdf>
- Permeable Design Pro Software. Interlocking Concrete Pavement Institute. <http://www.icpi.org/node/1298>
- Tree Protection in the Right of Way. Montgomery County Department of Permitting Services, June 2011 <http://permittingervices.montgomerycountymd.gov/DPS/pdf/TreeProtection.pdf>
- Web Soil Survey. Natural Resources Conversation Service. <http://websoilsurvey.nrcs.usda.gov>

For Montgomery County RainScapes projects, this guide should take precedence over external resources when there are discrepancies in guidance.

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 240-773-3556 TTY