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Drainage Letter

for:

1002 LLC

or Claremont Business Park, Filing 2, Lot 8
El Paso County, Colorado Springs, Colorado

Prepared for:
Hammers Construction, LLC.
1411 Woolsey Heights
Colorado Springs, CO 809151
Phone (719) 571-1599
Attn: Zack Crabtree

Prepared by:
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Dated:
September 29, 2017

El Paso County Project# PPR-17-046___

Table of Contents

CERTIFICATION STATEMENTS v

I. GENERAL LOCATION AND DRAINAGE DESIGN DESCRIPTION 2

A. **Purpose** 2

B. **Property Description** 2

C. **Existing Drainage Characteristics** 2

D. **Floodplain Statement** 2

E. Proposed Drainage Characteristics 2

F. Water Quality Provisions – Rain Garden 3

G. The Four-Step Process 3

H. Private Water Quality Facility – Cost Estimate 4

I. Drainage Fees 4

II. CONCLUSIONS 4

III. REFERENCES 4

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CERTIFICATION STATEMENTS

The attached drainage plan and report were prepared under my direction and supervision and are correct to the best of my knowledge and belief. Said drainage report has been prepared according to the criteria established by the County for drainage reports and said report is in conformity with the applicable master plan of the drainage basin. I accept responsibility for any liability caused by any negligent acts, errors or omissions on my part in preparing this report.

____

Todd Cartwright Date

Registered Professional Engineer

State of Colorado No. 33365

<u>Developer's Statement:</u>

I, the developer have read and will comply with all of the requirements specified in this drainage report and plan.

____

Hammers Construction

By: ____________________________________

Title: ____________________________________

Address: 1411 Woolsey Heights
Colorado Springs, CO 80915

<u>EL PAASO COUNTY:</u>

Filed in accordance with the requirements of the Drainage Criteria Manual, Volumes 1 & 2, El Paso County Engineering Criteria Manual and Land Development Code as amended.

______________________________________ ______________________

Jennifer Irvine, P.E.

County Engineer/ECM Administrator Date

Conditions:

I. General Location and Drainage Design Description

A. Purpose

The purpose of this letter is to show that there shall be no negative drainage effects associated with the proposed development of Lot 8 within the Claremont Business Park Filing 2, recorded 4/14/2010 under Reception No. 210713035 of the El Paso County Records. This final drainage letter is being submitted concurrently with the improvement construction plans proposing a light industrial building and the associated drivelines.

B. Property Description

The proposed project site is within the Northeast Quarter of Section 8, Township 14 South, Range 65 West of the 6th Principal Meridian. The site can be further described as 1415 Selix Grove. See also appendix a for a vicinity map. Lot 8 consists of approximately 0.4 acres and is currently vacant. The proposed project consists of all infrastructure typically associated with light industrial development. Most the site will consist of crushed asphalt, curb, lighting, and landscaping.

C. Existing Drainage Characteristics

The site is currently vacant with a relatively new roadway infrastructure and associated utilities with slopes ranging from 0-4% from northeast to southwest. Flows from the site run in a sheet-flow manner and drain to the northwest portion of the site, and then eventually outfalls to an existing storm sewer collection system at the northwest corner of Lot 8 and ultimately discharges to the East Fork Sand Creek.

D. Floodplain Statement

According to LOMR 06-08-B137P adjusted the FEMA FIRM map 08041C0752F, effective March 17, 1997, the site lies within Unshaded Zone X. Unshaded Zone X is identified as areas outside of 500-year flood.

E. Proposed Drainage Characteristics

Most the site will consist of asphalt, crushed asphalt, a building and, a Storm Water Quality Facility and landscaping. The subject site was previously analyzed within the Final Drainage Report (FDR) for Claremont Business Park Filing 2 prepared by Matrix Design Group approved 04/23/2007. Onsite Water Quality Control Volume (WQCV) is required but on-site storm water detention is not required per the FDR for Claremont Business Park Filling 2A.

The post-developed flows from Lot 8 shall be directed to a Storm Water Quality Facility (permeable pavement type), which is located along the western property line near Selix Grove. Flows also enter the permeable pavement near the northwestern portion of the site via curb and gutter. (1.3 cfs for the 5-yr and 2.5 cfs for the 100-yr). The Rational calculations were made knowing an existing hydraulic soil group (HSC) of type A (See Appendix C).

The remainder of lot 8 post development flows will exit the site to the north into Selix Grove (0.2 cfs for the 5-yr and 0.4 cfs for the 100-yr).

Flows that enter the permeable pavement system will infiltrate into the ground. Based on percolation test completed October 13, 2016 for an adjacent lot we anticipate a perc rate of 16-20 minutes per inch. Using the conservative 16.0 min/in for the 24.5 inches of permeable pavement storage the detention should drain in 6.4 hours.

Include the conversion calculation for the 311 in/hr to cfs to provide a quick comparison using similar units.

…eed to be conducted prior to construction to validate the design. The … a minimum of 25 minutes per inch to drain the pond in 8 hours.

F. **Water Quality Provisions – Permeable Pavement Detention**

The proposed permeable pavement system will be built per Urban Drainage and Flood Control recommendations (see Appendix B for additional information on the permeable pavement system). The volume provided by the permeable pavement system is approximately 353 cu-ft which exceeds the required Water Quality Control Volume of 352 cu-ft. This volume will have achieved in a 24.5-inch-deep reservoir. The size of the permeable pavement system is based on an impervious area of 91%, a drainage area of approximately 0.25 acres, and a runoff of 0.6-inches of precipitation per *El Paso County – Drainage Criteria Manual Volume 2*. See Appendix B for Design Procedure Form for permeable pavement system.

Pavestone permeable pavement is ASTM tested to receive water an infiltration rate of 311 inches of water per hour. This is more than the 100-storm runoff rate of 2.5 CFS. The infiltration test is included in Appendix B.

The permeable pavement is designed for the 100-year event. Storms in excess of the 100-year event will bypass the permeable pavement and enter Selix Grove and continue west to Sand Creek.

G. **Maintenance**

The permeable pavement will be maintained by the lot owner. Over time, the permeable pavement system with clog with dirt and will need to be cleaned. This will be observable by when the water infiltrates slower or puddles. Cleaning should follow Pavestone manufacturer procedures. Please refer to the attached maintenance instructions in Appendix B

H. **The Four-Step Process**

Per the Engineering Criteria Manual - Appendix 1, the four-step process was implemented for stormwater management:

Step 1: Employ Runoff Reduction Practices. Due to the small site, employing runoff reduction practices is not possible.

Step 2: Stabililze Drainageways. There are no stream channels onsite to stabilize.

Step 3: Provide Water Quality Capture Volume (WQCV). The WQCV is being provided by a Rain Garden located on the western edge of the property.

Step 4: Consider Need for Industrial and Commercial BMPs. The business use will not be producing any industrial or commercial hazards. In addition, due to the small-scale development of the site, no additional source controls are necessary.

Private Water Quality Facility – Cost Estimate

Private Water Quality Facility (permeable pavement system): $6,000

Drainage Fees

Since the property has already been platted, no drainage fees are required to be paid.

II. Conclusions

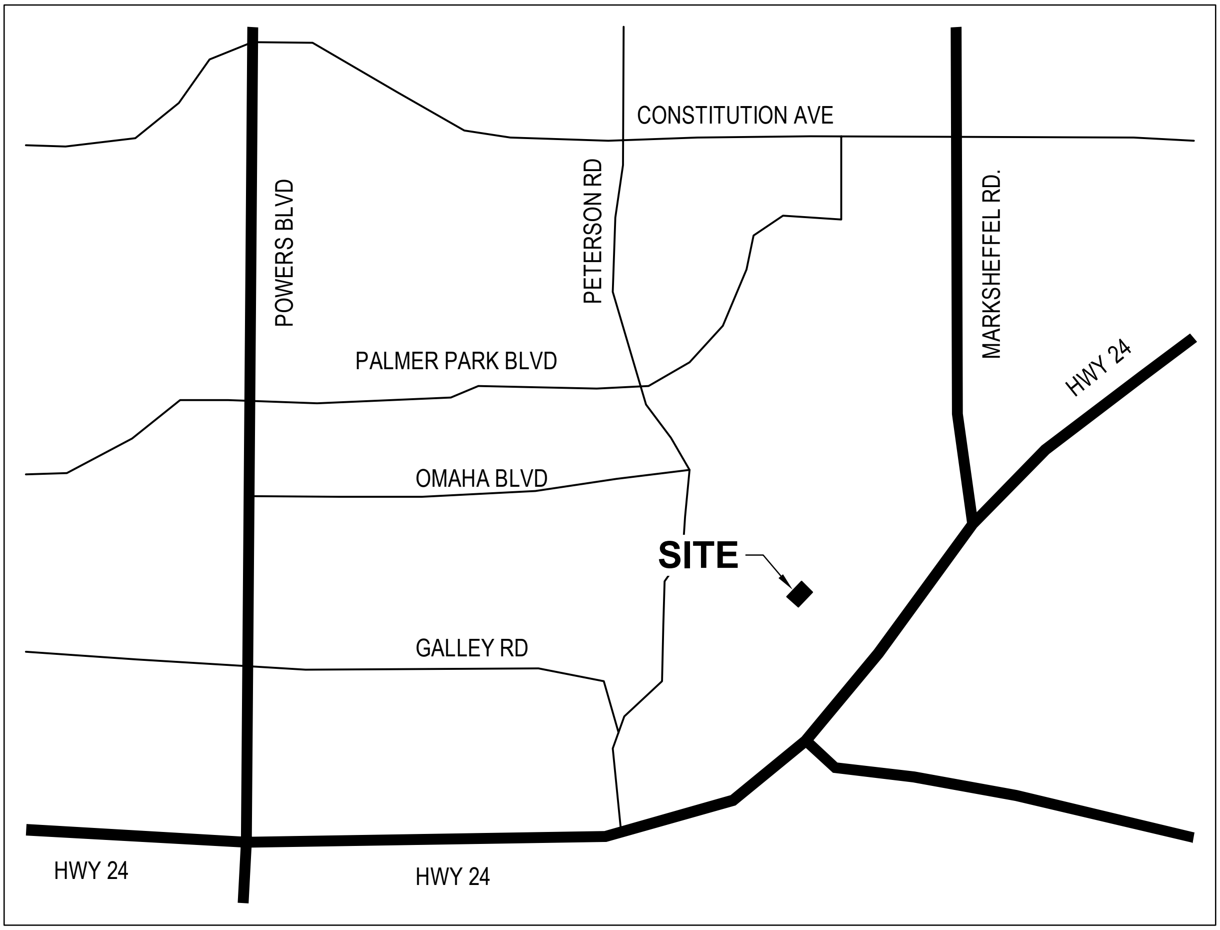
The proposed runoff patterns for the site have no negative drainage effects within Claremont Business Park Filing 2 or the surrounding area. The methodologies and drainage criteria used in the overall drainage design meet the current County DCM requirements. This drainage letter is in conformance with the Final Drainage Report for Claremont Business Park Filing 2.

III. References

1. *El Paso County Drainage Criteria Manual*, El Paso County, most recent version.
2. *Urban Storm Drainage and Criteria Manual, Urban Drainage and Flood Control District,* most recent version.
3. *Final Drainage Report for Claremont Business Park Filing No. 2, November 2006, by the* Matrix Design Group.

APPENDIX A

VICINITY MAP



VICINITY MAP
NTS

CBP F2, LOT 8
HAMMERS CONSTRUCITON

1415 SELIX GROVE
COLORADO SPRINGS, CO

FIGURE 1 - VICINITY MAP

Project No:	HCI 004.01
Drawn By:	TAC
Checked By:	TAC
Date:	09/27/17

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APPENDIX B

PERMEABLE PAVEMENT DESIGN INFORMATION
PERMEABLE PAVEMENT INFILTRATION RATE
PERMEABLE PAVEMENT MAINTENANCE INSTRUCTIONS

Description

Photograph PPS-1. The reservoir layer of a permeable pavement provides storage volume for the WQCV. Photo courtesy of Muller Engineering and Jefferson County Open Space.

The term *Permeable Pavement System*, as used in this manual, is a general term to describe any one of several pavements that allow movement of water into the layers below the pavement surface. Depending on the design, permeable pavements can be used to promote volume reduction, provide treatment and slow release of the water quality capture volume (WQCV), and reduce effective imperviousness. Use of permeable pavements is a common Low Impact Development (LID) practice and is often used in combination with other BMPs to provide full treatment and slow release of the WQCV. A number of installations within the UDFCD boundary have also been designed with an increased depth of aggregate material in order to provide storage for storm events in excess of the water quality (80th percentile) storm event. This requires some additional design considerations, which are discussed within this BMP Fact Sheet.

Site Selection

This infiltrating BMP requires consultation with a geotechnical engineer when proposed near a structure. In addition to providing the pavement design, a geotechnical engineer can assist with evaluating the suitability of soils, identifying potential impacts, and establishing minimum distances between the BMP and structures.

Permeable pavement systems provide an alternative to conventional pavement in pedestrian areas and lower-speed vehicle areas. They are not appropriate where sediment-laden runoff could clog the system (e.g., near loose material storage areas).

This BMP is not appropriate when erosive conditions such as steep slopes and/or sparse vegetation drain to the permeable pavement. The sequence of construction is also important to preserve pavement infiltration. Construction of the pavement should take place only after construction in the watershed is complete.

For sites where land uses or activities can cause infiltrating stormwater to contaminate groundwater, special design requirements are required to ensure no-infiltration from the pavement section.

Permeable Pavement	
Functions	
LID/Volume Red.	Yes
WQCV	Yes
WQCV+Flood Control	Yes
Fact Sheet Includes EURV Guidance	No
Typical Effectiveness for Targeted Pollutants[3]	
Sediment/Solids	Very Good[1]
Nutrients	Good
Total Metals	Good
Bacteria	Unknown
Other Considerations	
Life-cycle Costs[4]	High[2]

[1] Not recommended for watersheds with high sediment yields (unless pretreatment is provided).

[2] Does not consider the life cycle cost of the conventional pavement that it replaces.

[3] Based primarily on data from the International Stormwater BMP Database (www.bmpdatabase.org).

[4] Based primarily on BMP-REALCOST available at www.udfcd.org. Analysis based on a single installation (not based on the maximum recommended watershed tributary to each BMP).

Permeable pavements and other BMPs used for infiltration that are located adjacent to buildings, hardscape or conventional pavement areas can adversely impact those structures if protection measures are not provided. Wetting of subgrade soil underlying those structures can cause the structures to settle or result in other moisture-related problems. Wetting of potentially expansive soils or bedrock can cause those materials to swell, resulting in structure movements. In general, a geotechnical engineer should evaluate the potential impact of the BMP on adjacent structures based on an evaluation of the subgrade soil, groundwater, and bedrock conditions at the site. In addition, the following minimum requirements should be met:

- In locations where subgrade soils do not allow infiltration, the pavement section should include an underdrain system.
- Where infiltration can adversely impact adjacent structures, the filter layer should be underlain by an underdrain system designed to divert water away from the structure.
- In locations where potentially expansive soils or bedrock exist, placement of permeable pavement adjacent to structures and conventional pavement should only be considered if the BMP includes an underdrain designed to divert water away from the structure and is lined with an essentially impermeable geomembrane liner designed to restrict seepage.

Designing for Maintenance

Recommended ongoing maintenance practices for all BMPs are provided in the BMP Maintenance chapter of this manual. During design and construction, the following should be considered to ensure ease of maintenance over the long-term:

- Hold a pre-construction meeting to ensure that the contactor has an understanding of how the pavement is intended to function. Discuss the contractor’s proposed sequence of construction and look for activities that may require protection of the permeable pavement system.
- Ensure that the permeable pavement is protected from construction activities following pavement construction (e.g., landscaping operations). This could include covering areas of the pavement, providing alternative construction vehicle access, and providing education to all parties working on-site.
- Include an observation well to monitor the drain time of the pavement system over time. This will assist with determining the required maintenance needs. See Figure PPS-8.

Benefits

- Permeable pavement systems provide water quality treatment in an area that serves more than one purpose. The depth of the pavement system can also be increased to provide flood control.
- Permeable pavements can be used to reduce effective imperviousness or alleviate nuisance drainage problems.
- Permeable pavements benefit tree health by providing additional air and water to nearby roots.
- Permeable pavements are less likely to form ice on the surface than conventional pavements.
- Some permeable pavements can be used to achieve LEED credits.

Limitations

- Additional design and construction steps are required for placement of any ponding or infiltration area near or upgradient from a building foundation, particularly when potentially expansive soils exist. This is discussed in the design procedure section.
- In developing or otherwise erosive watersheds, high sediment loads can clog the facility.

- Call for construction fence on the plans around pervious areas where infiltration rates need to be preserved and could be reduced by compaction from construction traffic or storage of materials.

Example Construction Drawing Notes

- Excavation of subgrade shall not commence until after the pre-construction meeting.
- Subgrade shall be excavated using low ground pressure (LGP) track equipment to minimize over compaction of the subgrade. [1]
- Grading and compaction equipment used in the area of the permeable pavement should be approved by the engineer prior to use.
- Loose materials shall not be stored on the permeable pavement area.
- The contractor shall, at all times during and after system installation, prevent sediment, debris, and dirt from any source from entering the permeable pavement system.
- Placement of the wearing course shall be performed <u>after</u> fine grading and landscaping in adjacent areas is complete. If the wearing course becomes clogged due to construction activities, clean the surface with a vacuum machine to restore the infiltration rate after construction is complete.

[1] For partial and full infiltration sections only.

Design Procedure and Criteria

Note: This manual includes a variety of specific pavements, which are discussed and distinguished in supplemental BMP Fact Sheets T-10.1, T-10.2, etc. This BMP Fact Sheet outlines the design procedure and other design components and considerations that are common to all of the systems. Review of the supplemental Fact Sheets is recommended to determine the appropriate pavement for a specific site or use.

1. **Subsurface Exploration and Determination of a No-Infiltration, Partial Infiltration, or Full Infiltration Section**: Permeable pavements can be designed with three basic types of sections. The appropriate section will depend on land use and activities, proximity to adjacent structures and soil characteristics. Sections of each installation type are shown in Figure PPS-1.

   - **No-Infiltration Section**: This section includes an underdrain and an impermeable liner that prevents infiltration of stormwater into the subgrade soils. Consider using this section when any of the following conditions exist:

     - Land use or activities could contaminate groundwater if stormwater is allowed to infiltrate.
     - Permeable pavement is located over potentially expansive soils or bedrock that could swell due to infiltration and potentially damage the permeable pavement system or adjacent structures (e.g., building foundation or conventional pavement).

- **Partial Infiltration Section**: This section does not include an impermeable liner, and allows some infiltration. Stormwater that does not infiltrate is collected and removed by an underdrain system.

- **Full Infiltration Section**: This section is designed to infiltrate the water stored in the voids of the pavement into the subgrade below. UDFCD recommends a minimum infiltration rate of 2 times the rate needed to drain the WQCV over 12 hours.

Subsurface Exploration and Testing for all Sections: A geotechnical engineer should scope and perform a subsurface study. Typical geotechnical investigation needed to select and design the pavement system for handling anticipated traffic loads includes:

- Prior to exploration review geologic and geotechnical information to assess near-surface soil, bedrock and groundwater conditions that may be encountered and anticipated ranges of infiltration rate for those materials. For example, if the site is located in a general area of known shallow, potentially expansive bedrock, a no-infiltration section will likely be required. It is also possible that this BMP may be infeasible, even with a liner, if there is a significant potential for damage to the pavement system or adjacent structures (e.g., areas of dipping bedrock).

- Drill exploratory borings or exploratory pits to characterize subsurface conditions beneath the subgrade and develop requirements for subgrade preparation. Drill at least one boring or pit for every 40,000 ft^2, and at least two borings or pits for sites between 10,000 ft^2 and 40,000 ft^2. The boring or pit should extend at least 5 feet below the bottom of the base, and at least 20 feet in areas where there is a potential of encountering potentially expansive soils or bedrock. More borings or pits at various depths may be required by the geotechnical engineer in areas where soil types may change, in low-lying areas where subsurface drainage may collect, or where the water table is likely within 8 feet below the planned bottom of the base or top of subgrade. Installation of temporary monitoring wells in selected borings or pits for monitoring groundwater levels over time should be considered where shallow groundwater that could impact the pavement system area is encountered.

- Perform laboratory tests on samples obtained from the borings or pits to initially characterize the subgrade, evaluate the possible section type, and to assess subgrade conditions for supporting traffic loads. Consider the following tests: moisture content (ASTM D 2216); dry density (ASTM D 2936); Atterberg limits (ASTM D 4318); gradation (ASTM D 6913); swell-consolidation (ASTM D 4546); subgrade support testing (R-value, CBR or unconfined compressive strength); and hydraulic conductivity. A geotechnical engineer should determine the appropriate test method based on the soil type.

- For sites where a full infiltration section may be feasible, perform on-site infiltration tests using a double-ring infiltrometer (ASTM D 3385). Perform at least one test for every 160,000 ft^2 and at least two tests for sites between 40,000 ft^2 and 160,000 ft^2. The tests should be located near completed borings or pits so the test results and subsurface conditions encountered in the borings can be compared, and at least one test should be located near the boring or pit showing the most unfavorable infiltration condition. The test should be performed at the planned top of subgrade underlying the permeable pavement system, and that subgrade should be prepared similar to that required for support of the permeable pavement system.

- Be aware that actual infiltration rates are highly variable dependent on soil type, density and moisture content and degree of compaction as well as other environmental and construction influences. Actual rates can differ an order of magnitude or more from those indicated by infiltration or permeability testing. Selection of the section type should be based on careful assessment of the subsurface exploration and testing data.

2. **Required Storage Volume**: Provide the WQCV based on a 12-hour drain time.

- Find the required WQCV (watershed inches of runoff). Using the effective impervious area of the watershed area, use Figure 3-2 located in Chapter 3 to determine the WQCV based on a 12-hour drain time. The maximum recommended ratio for tributary impervious area to permeable pavement area is 2.0. Higher loading is not recommended, as it may increase the required maintenance interval.

- Calculate the design volume as follows:

$$V = \left[\frac{\text{WQCV}}{12}\right] A \qquad \text{Equation PPS-1}$$

  Where:

  A = watershed area tributary to the permeable pavement (ft^2)

  V = design volume (ft^3)

- Add flood control volume if desired. When designing for flood control volumes, provide an overflow that will convey runoff in excess of the WQCV directly into the reservoir. A gravel strip or inlet that is connected to the reservoir can provide this overflow.

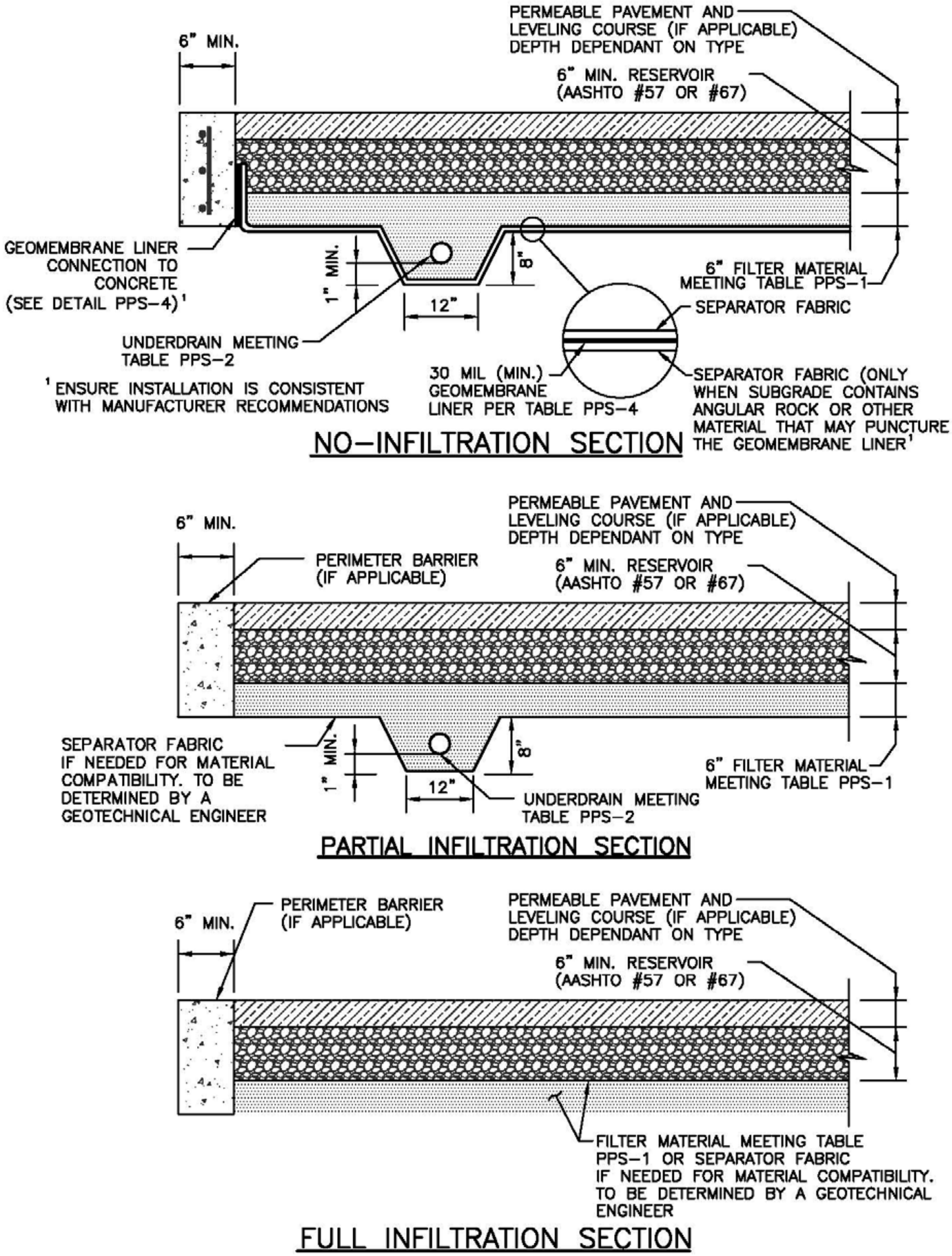


Figure PPS-1. Permeable Pavement Sections

3. **Depth of Reservoir**: The minimum recommended depth of AASHTO No. 57 or No. 67 coarse aggregate is 6 inches. Additional depth may be required to support anticipated loads or to provide additional storage, (i.e., for flood control). This material should have all fractured faces. UDFCD recommends that void storage be calculated only for the reservoir, assuming the aggregate filter layer is saturated. With the exception of porous gravel pavement, use a porosity of 40% or less for both No. 57 and No. 67 coarse aggregate. For porous gravel pavement use a porosity of 30% or less to account for reduced volume due to sediment. Porous gravel pavements typically allow greater sediment volumes to enter the pavement. See Figures PPS-2 and PPS-3 for alternative pavement profiles. Calculate available storage using equation PPS-2 for a flat subgrade installation, and PPS-3 for a sloped subgrade installation. These equations allow for one inch of freeboard. Flat installations are preferred as the design spreads infiltration evenly over the subgrade. For sloped subgrade installations, the increased storage depth located upstream of the lateral barrier (see step 7) can increase lateral movement (parallel to the flow barrier) of water into areas adjacent to the pavement section.

   When used for vehicular traffic, a pavement design should be performed by a qualified engineer experienced in the design of permeable pavements and conventional asphalt and concrete pavements. The permeable pavement should be adequately supported by a properly prepared subgrade, properly compacted filter material and reservoir material.

   Reservoir aggregate should have all fractured faces. Place the aggregate in 6-inch (maximum) lifts, compacting each lift by using a 10-ton, or heavier, vibrating steel drum roller. Make at least four passes with the roller, with the initial passes made while vibrating the roller and the final one to two passes without vibration.

   - For flat or stepped installations (0% slope at the reservoir/subgrade interface):

     $$V = P\left[\frac{D-1}{12}\right]A$$ Equation PPS-2

     Where:

     V = volume available in the reservoir (ft^3)

     P = porosity, ≤0.30 for porous gravel, ≤0.4 for all other pavements using AASHTO No. 57 or No. 67 coarse aggregate in the reservoir

     D = depth of reservoir (in)

     A = area of the permeable pavement (ft^2)

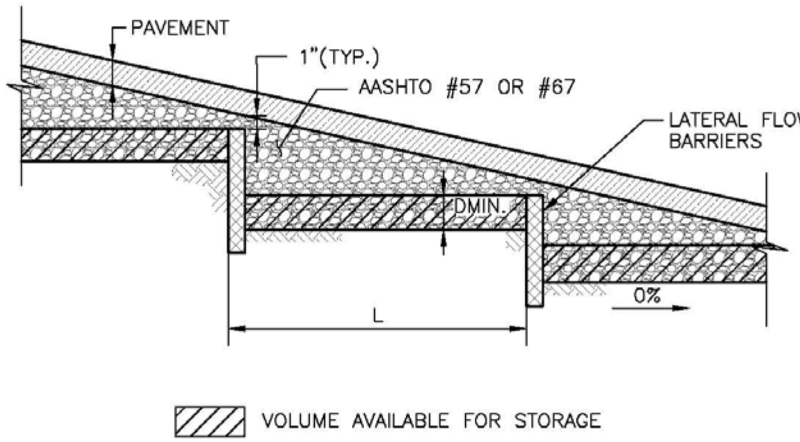


Figure PPS-2. Permeable Pavement Profile, Stepped Installation

- For sloped installations (slope of the reservoir/subgrade interface > 0%):

$$V = P\left[\frac{D - 6sL - 1}{12}\right]A \qquad \text{Equation PPS-3a}$$

While:

$$L < \frac{2\,\text{WQCV}}{sAP} \qquad \text{Equation PPS-3b}$$

Where:

V = volume available in the reservoir (ft^3)

P = porosity, ≤0.30 for porous gravel, ≤0.4 for all other pavements using AASHTO No. 57 or No. 67 coarse aggregate in the reservoir

s = slope of the reservoir/subgrade interface (ft/ft)

D = depth of the reservoir (in)

L = length between lateral flow barriers (see step 4) (ft)

A = area of the permeable pavement (ft^2)

WQCV = water quality capture volume (ft^3)

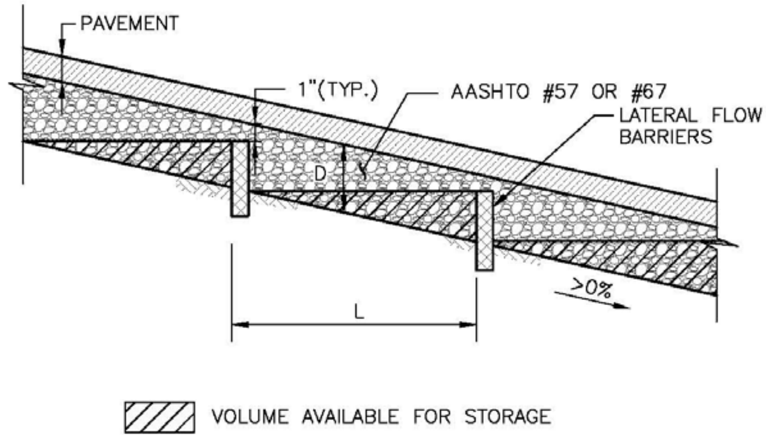


Figure PPS-3. Permeable Pavement Profile, Sloped Installation.

4. **Lateral Flow Barriers:** Construct lateral flow cutoff barriers using concrete walls or a 30 mil (minimum) PVC geomembrane. Lateral flow barriers should be placed parallel to contours (normal to flow). This will preserve the volume available for storage and ensure that stormwater will not resurface, washing out infill material. See Figure PPS-6 and Table PPS-4 when using a PVC geomembrane for this purpose. Also include a separator fabric, per Table PPS-3, between the geomembrane and all aggregate materials. Lateral flow barriers should be installed in all permeable pavement installations that have a reservoir/subgrade interface greater than 0%. Lateral flow barriers should be spaced, as necessary, to satisfy equations PPS-3a and PPS-3b. One exception is reinforced grass pavement. Infill washout is not a concern with reinforced grass pavement.

5. **Perimeter Barrier:** For all no-infiltration sections, provide a reinforced concrete barrier on all sides of the pavement system. Perimeter barriers may also be recommended for other permeable pavement installations depending on the type or use of the pavement. For PICP and concrete grid pavement, a barrier is required to restrain movement of the pavers or grids. Precast, cast-in-place concrete or cut stone barriers are required for commercial vehicular areas. For residential use and commercial pedestrian use, a metal or plastic edge spiked with 3/8-inch-diameter, 10-inch-long nails provides a less expensive alternative for edge restraint.

   For all pavements, consider the section beyond the permeable pavement when evaluating the perimeter design. The perimeter barrier helps force water into the underdrain and reduces lateral flow of water. Lateral flow can negatively impact the adjacent conventional pavement section, structure, or embankment (especially when the subgrade is sloped). Also consider material separation. Consider construction of the interface between the permeable pavement and the adjacent materials and how the design will prevent adjacent materials from entering the permeable pavement section. Depending on the soils, depth of pavement, and other factors, this may be achieved with fabric or may require a more formalized barrier.

   When a permeable pavement section is adjacent to conventional pavement, a vertical liner may be required to separate the reservoir of the permeable pavement system from dense-graded aggregates and soils within the conventional pavement. An impermeable linear can be used to provide this vertical barrier and separate these two pavement systems.

   <u>No-Infiltration Section:</u> For this type of section, the perimeter barrier also serves to attach the impermeable membrane. The membrane should extend up to the top of the filter layer and be firmly

attached to the concrete perimeter barrier using batten bars to provide a leak-proof seal. A nitrile-based vinyl adhesive can be used when the need for an impermeable liner is less critical. See Figures PPS-4 and PPS-5 for installation details. For ease of construction, including the placement of geotextiles, it is suggested that the barrier extend to the bottom of the filter layer.

Partial and Full Infiltration Section: The perimeter barrier for these sections also restricts lateral flow to adjacent areas of conventional pavement or other structures where excessive moisture and/or hydrostatic pressure can cause damage. When this is of particular concern, the perimeter barrier should be extended to a depth 12 inches or more below the underdrain. Otherwise, extend the barrier to the bottom of the filter layer.

6. **Filter Material and Underdrain System**: An aggregate filter layer and underdrain are required for all partial and no-infiltration sections. Without this filter layer, the section will not provide adequate pollutant removal. This is based on research performed by UDFCD monitoring sites with and without this component. A filter or separator fabric may also be necessary under the reservoir in a full infiltration section if the subgrade is not filter compatible with the reservoir material such that finer subgrade soils could enter into the voids of the reservoir.

   In previous versions of the USDCM, UDFCD recommended that the underdrain be placed in an aggregate drainage layer and that a geotextile separator fabric be placed between this drainage and the filter layer. This version of the USDCM replaces that fabric, which could more easily plug or be damaged during construction, with aggregate filter material that is filter-compatible with the reservoir, and a drainpipe with perforations that are filter-compatible with the filter material. This eliminates the need for a separator fabric between the reservoir and the underdrain layer. The filter material provided below should only be used with the underdrain pipe specified within this section.

   The underdrain should be placed below a 6-inch-thick layer of CDOT Class C filter material meeting the gradation in Table PPS-1. Extend the filter material around and below the underdrain as shown in Figure PPS-1.

   Provide clean-outs to allow inspection (by camera) of the drainpipe system during and after construction to ensure that the pipe was not crushed or disconnected during construction and to allow for maintenance of the underdrain.

   Use of Class C Filter material with a slotted PVC pipe that meets the slot dimensions provided in Table PPS-2 will eliminate the need for an aggregate layer wrapped geotextile fabric.

Design Opportunity

Pollutant removal occurs in the filter material layer of the section. The basic permeable pavement section may be considered with other wearing courses to provide water quality as long as:

- the filter layer is included in the section,
- the wearing course provides adequate permeability, and
- the new section does not introduce new pollutants to the runoff.

Table PPS-1. Gradation Specifications for Class C Filter Material (Source: CDOT Table 703-7)

Sieve Size	Mass Percent Passing Square Mesh Sieves
19.0 mm (3/4")	100
4.75 mm (No. 4)	60 – 100
300 µm (No. 50)	10 – 30
150 µm (No. 100)	0 – 10
75 µm (No. 200)	0 - 3

Table PPS-2. Dimensions for Slotted Pipe

Pipe Diameter	Slot Length[1]	Maximum Slot Width	Slot Centers[1]	Open Area[1] (per foot)
4"	1-1/16"	0.032"	0.413"	1.90 in^2
6"	1-3/8"	0.032"	0.516"	1.98 in^2

[1] Some variation in these values is acceptable and is expected from various pipe manufacturers. Be aware that both increased slot length and decreased slot centers will be beneficial to hydraulics but detrimental to the structure of the pipe.

Compact the filter layer using a vibratory drum roller or plate. The top of each layer below the leveling course must be uniform and should not deviate more than a ½ inch when a 10-foot straight edge is laid on its surface. The top of the leveling course should not deviate more than 3/8 inch in 10 feet.

7. **Impermeable Geomembrane Liner and Geotextile Separator Fabric:** For no-infiltration sections, install a 30 mil (minimum) PVC geomembrane liner, per Table PPS-4, on the bottom and sides of the basin, extending up at least to the top of the filter layer. Provide at least 9 inches (12 inches if possible) of cover over the membrane where it is attached to the wall to protect the membrane from UV deterioration. The geomembrane should be field-seamed using a dual track welder, which allows for non-destructive testing of almost all field seams. A small amount of single track and/or adhesive seaming should be allowed in limited areas to seam around pipe perforations, to patch seams removed for destructive seam testing, and for limited repairs. The liner should be installed with slack to prevent tearing due to backfill, compaction, and settling. Place CDOT Class B geotextile separator fabric, per Table PPS-3, above the geomembrane to protect it from being punctured during the placement of the filter material above the liner. If the subgrade contains angular rocks or other material that could puncture the geomembrane, smooth-roll the surface to create a suitable surface. If smooth-rolling the surface does not provide a suitable surface, also place the separator fabric between the geomembrane and the underlying subgrade. This should only be done when necessary because fabric placed under the geomembrane can increases seepage losses through pinholes or other geomembrane defects. Connect the geomembrane to perimeter concrete walls around the basin perimeter, creating a watertight seal between the geomembrane and the walls using a continuous batten bar and anchor connection (see Figure PPS-5). Where the need for the impermeable

membrane is not as critical, the membrane can be attached with a nitrile-based vinyl adhesive. Use watertight PVC boots for underdrain pipe penetrations through the liner (see Figure PPS-4).

Table PPS-3. Physical Requirements for Separator Fabric[1]

Property	Class B		Test Method
	Elongation < 50%[2]	Elongation > 50%[2]	
Grab Strength, N (lbs)	800 (180)	510 (115)	ASTM D 4632
Puncture Resistance, N (lbs)	310 (70)	180 (40)	ASTM D 4833
Trapezoidal Tear Strength, N (lbs)	310 (70)	180 (40)	ASTM D 4533
Apparent Opening Size, mm (US Sieve Size)	AOS < 0.3mm (US Sieve Size No. 50)		ASTM D 4751
Permittivity, sec^{-1}	0.02 default value, must also be greater than that of soil		ASTM D 4491
Permeability, cm/sec	k fabric > k soil for all classes		ASTM D 4491
Ultraviolet Degradation at 500 hours	50% strength retained for all classes		ASTM D 4355

[1] Strength values are in the weaker principle direction
[2] As measured in accordance with ASTM D 4632

Table PPS-4. Physical Requirements for Geomembrane

Property	Thickness 0.76 mm (30 mil)	Test Method
Thickness, % Tolerance	±5	ASTM D 1593
Tensile Strength, kN/m (lbs/in) width	12.25 (70)	ASTM D 882, Method B
Modulus at 100% Elongation, kN/m (lbs/in)	5.25 (30)	ASTM D 882, Method B
Ultimate Elongation, %	350	ASTM D 882, Method A
Tear Resistance, N (lbs)	38 (8.5)	ASTM D 1004
Low Temperature Impact, °C (°F)	-29 (-20)	ASTM D 1790
Volatile loss, % max.	0.7	ASTM D 1203, Method A
Pinholes, No. Per 8 m^2 (No. per 10 sq. yds.) max.	1	N/A
Bonded Seam Strength, % of tensile strength	80	N/A

8. **Outlet**: The portion of the WQCV in each cell should be slowly released to drain in approximately 12 hours. An orifice at the outlet of the underdrain can be used for each cell to provide detention and slow release of the WQCV to offset hydromodification. Use a minimum orifice size of 3/8 inch to avoid clogging. If lateral walls are required, each cell should be considered a separate system and be

controlled independently. See Figure PPS-6 for underdrain system layout and outlet details showing a multi-cell configuration. Equations PPS-4 and PPS-5 can be used to determine the depth of the WQCV within the pavement section (based either on the stepped/flat installation shown in Figure PPS-2 or the sloped installation shown in Figure PPS-3) and Equation PPS-6 can be used to size the WQCV orifice. If the design includes multiple cells, these calculations should be performed for each cell substituting WQCV and V_{Total} with the volumes provided in each cell. The UD-BMP workbook available at www.udfcd.org can be used when multiple cells are similar in area. The workbook assumes that the WQCV is distributed evenly between each cell.

For calculating depth of the WQCV using a flat/stepped installation, see Figure PPS-2:

$$d = \frac{12\ \mathrm{WQCV}}{PA}$$ Equation PPS-4

Where:

d = depth of WQCV storage in the reservoir (in)

P = porosity, ≤0.30 for porous gravel, ≤0.4 for all other pavements using AASHTO No. 57 or No. 67 coarse aggregate in the reservoir

A = area of permeable pavement system (ft^2)

WQCV = water quality capture volume (ft^3)

For calculating depth of the WQCV using a sloped installation, see Figure PPS-3:

$$d = 6\left[\frac{2\ \mathrm{WQCV}}{PA}\right] + \mathrm{sL}$$ Equation PPS-5

Where:

d = depth of WQCV storage in the reservoir (in)

A = area of permeable pavement system (ft^2)

s = slope of the reservoir/subgrade interface (ft/ft)

L = length between lateral flow barriers (see step 4) (ft)

For calculating the diameter of the orifice for a 12-hour drain time (Use a minimum orifice size of 3/8 inch to avoid clogging.):

$$D_{12\text{ hour drain time}} = \sqrt{\frac{V}{1414\, y^{0.41}}}$$ Equation PPS-6

Where:

D = diameter of the orifice to drain a volume in 12 hours (in)

Y = distance from the lowest elevation of the storage volume (i.e. the bottom of the reservoir) to the center of the orifice (ft)

V = volume (WQCV or the portion of the WQCV in the cell) to drain in 12 hours (ft^3)

Additional Design Considerations

Subgrade Preparation

Partial Infiltration and Full Infiltration Installations: The subgrade should be stripped of topsoil or other organics and either excavated or filled to the final subgrade level. Unnecessary compaction or over-compaction will reduce the subgrade infiltration rate. However, a soft or loosely compacted subgrade will settle, adversely impacting the performance of the entire permeable pavement system. The following recommendations for subgrade preparation are intended to strike a balance between those competing objectives:

- For sites, or portions thereof, requiring excavation to the final subgrade level, compaction of the subgrade may not be needed, provided that loose materials are removed from the excavation, and a firm subgrade is provided for the support of the pavement system. A geotechnical engineer should observe the prepared subgrade. Local soft areas should be excavated and replaced with properly compacted fill. As an alternative to excavating and replacing material, stabilization consisting of geogrid and compacted granular fill material can be used to bridge over the soft area. Fill material should be free draining and have a hydraulic conductivity significantly higher than the subgrade soil. Fill is typically compacted to a level equivalent to 95% Standard Proctor compaction (ASTM D 698). The designer should specify the level of compaction required to support the pavement system.

- For sites (or portions thereof), requiring placement of fill above the existing subgrade to reach the final subgrade level, the fill should be properly compacted. Specify the hydraulic conductivity for the material that is to be placed. This should be at least one order of magnitude higher than the native material. If the type or level of compaction of fill material available for construction is different than that considered in design, additional testing should be performed to substantiate that the design infiltration rate can be met. However, additional infiltrometer testing may not be necessary, provided that it can be demonstrated by other means that the compacted fill material is more permeable than that considered for design.

- Low ground pressure (LGP) track equipment should be used within the pavement area to limit over-compacting the subgrade. Wheel loads should not be allowed.

No-Infiltration Sections: Unless otherwise indicated by the geotechnical engineer, the subgrade for this section should be scarified and properly compacted to support the liner and pavement system. A level of compaction equivalent to 95% of the Standard Proctor density (ASTM D 698) is typically used. The designer should specify the level of compaction. No-infiltration sections should be smooth rolled with a roller compactor, and the prepared subgrade surface should be free of sharp objects that could puncture the liner. Both the designer and the liner installer should inspect the subgrade for acceptance prior to liner placement.

Filter and Reservoir Layer Compaction

Filter material placed above the prepared subgrade should be compacted to a relative density between 70% and 75% (ASTM D4253 and ASTM D4254) using a walk-behind vibratory roller, vibratory plate compactor or other light compaction equipment. Do not over-compact; this will limit unnecessary infiltration into the underlying subgrade. The reservoir layer may not be testable for compaction using a method based on specified density (e.g., nuclear density testing). The designer should consider a method specification (e.g., number of passes of a specified vibratory compactor) for those materials. The number of passes appropriate is dependent on the type of equipment and depth of the layer.

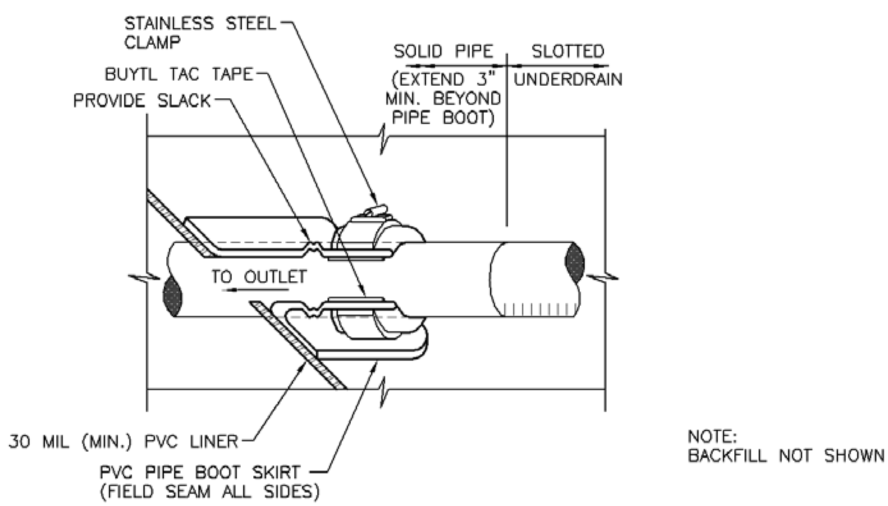


Figure PPS-4. Geomembrane Liner/Underdrain Penetration Detail

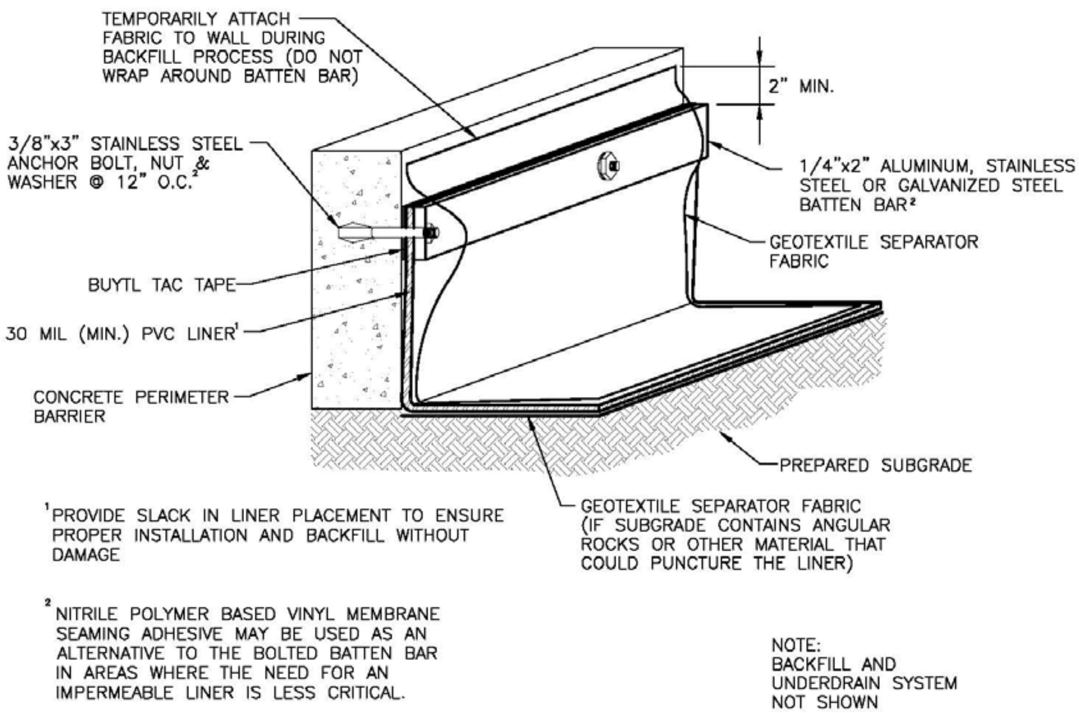


Figure PPS-5. Geomembrane Liner/Concrete Connection Detail

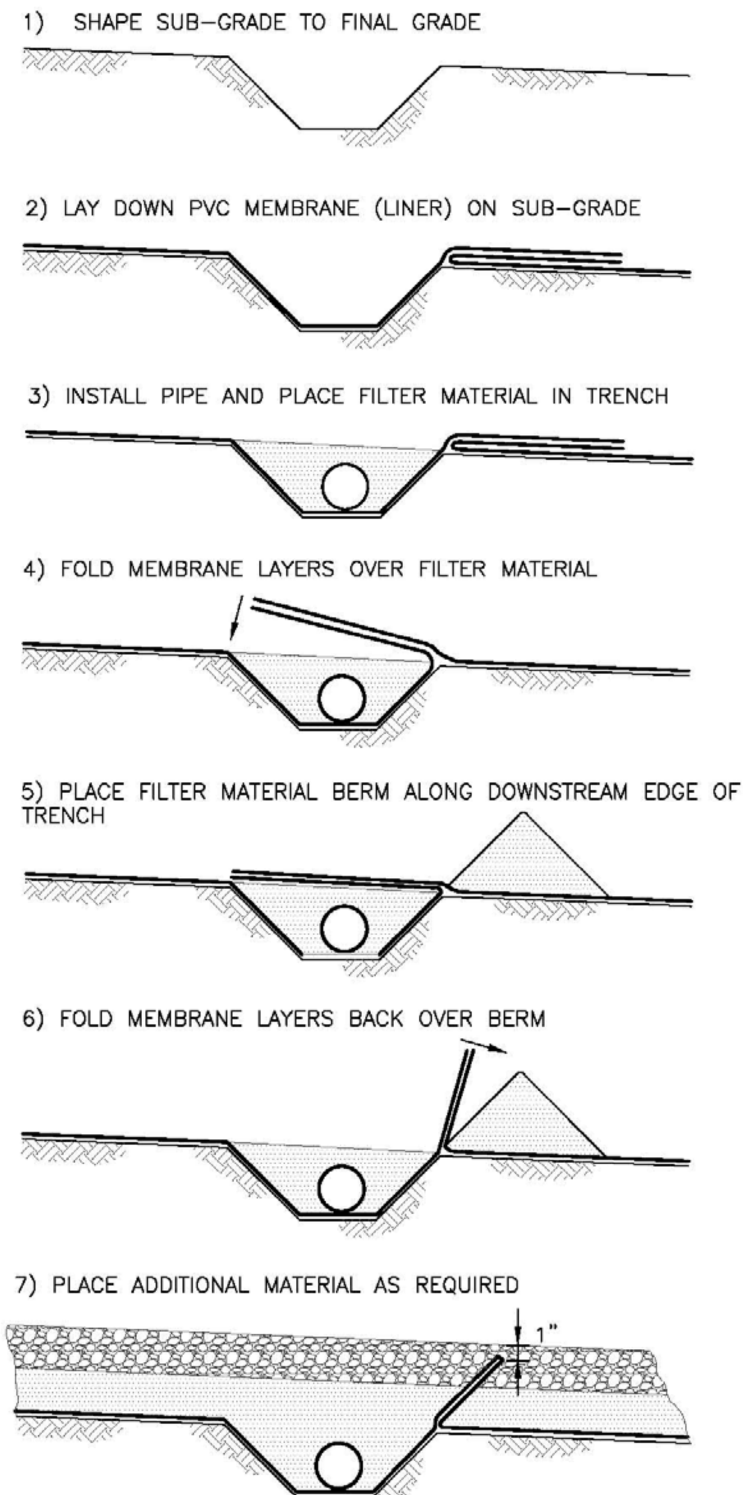


Figure PPS-6. Lateral Barrier Installation

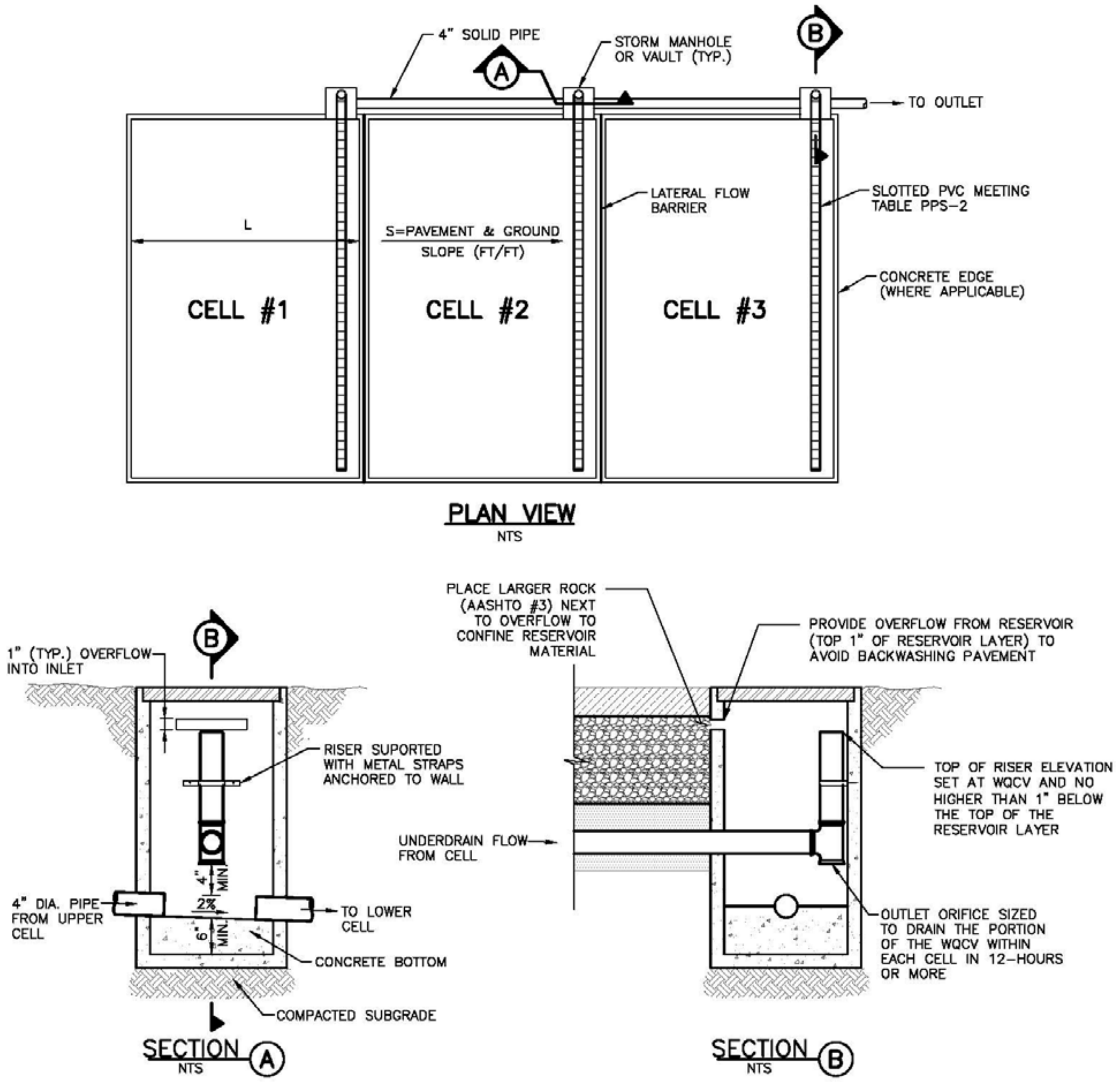
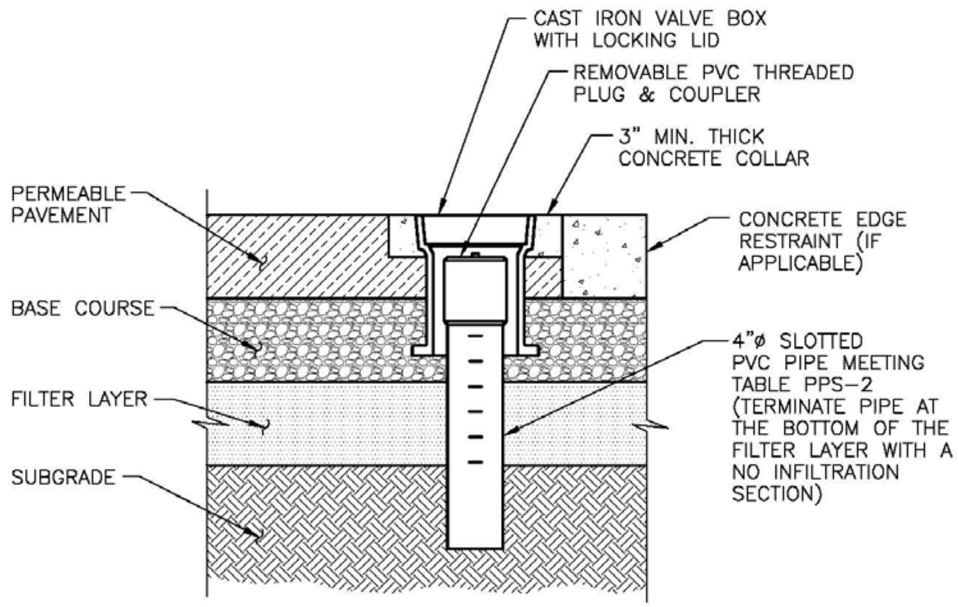
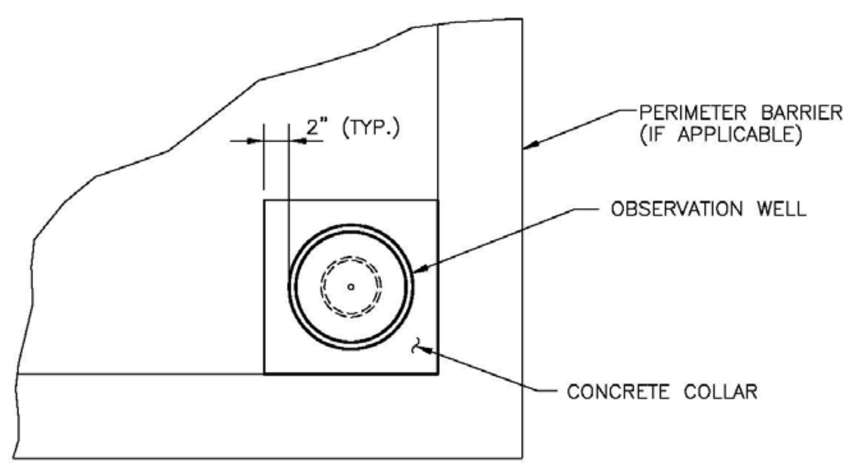


Figure PPS-7. Underdrain System Layout and Outlet Details



SECTION



PLAN

Figure PPS-8. Observation Well

Construction Considerations

Proper construction of permeable pavement systems requires measures to preserve natural infiltration rates (for full and partial infiltration sections) prior to placement of the pavement, as well as measures to protect the system from the time that pavement construction is complete to the end of site construction. Supplemental Fact Sheets on the specific pavements provide additional construction considerations. The following recommendations apply to all permeable pavement systems:

- When using an impermeable liner, ensure enough slack in the liner to allow for backfill, compaction, and settling without tearing the liner.
- Provide necessary quality assurance and quality control (QA/QC) when constructing an impermeable geomembrane liner system, including, but not limited to fabrication testing, destructive and non-destructive testing of field seams, observation of geomembrane material for tears or other defects, and air lace testing for leaks in all field seams and penetrations. QA/QC should be overseen by a professional engineer. Consider requiring field reports or other documentation from the engineer.
- Keep mud and sediment-laden runoff away from the pavement area.
- Temporarily divert runoff or install sediment control measures as necessary to reduce the amount of sediment run-on to the pavement.
- Cover surfaces with a heavy impermeable membrane when construction activities threaten to deposit sediment onto the pavement area.

Design Example

The *UD-BMP* workbook, designed as a tool for both designer and reviewing agency is available at www.udfcd.org. This section provides a completed design form from this workbook as an example.

Design Procedure Form: Permeable Pavement Systems (PPS)

Sheet 1 of 2

Designer: G. Frazer
Company: BMP Inc.
Date: November 29, 2010
Project: Shops at 56th Ave.
Location: SE corner of 56th Ave. and 83rd St.

1. Type of Permeable Pavement Section

A) What type of section of permeable pavement is used?
(Based on the land use and activities, proximity to adjacent structures and soil characteristics.)

Choose One
- ○ No Infiltration
- ● Partial Infiltration Section
- ○ Full Infiltration Section

B) What type of wearing course?

Choose One
- ● PICP
- ○ Concrete Grid Pavement
- ○ Pervious Concrete
- ○ Porous Gravel

2. Required Storage Volume

A) Effective Imperviousness of Area Tributary to Permeable Pavement, I_a — I_a = 65.0 %

B) Tributary Area's Imperviousness Ratio ($I = I_a / 100$) — i = 0.650

C) Tributary Watershed Area
(including area of permeable pavement system) — A_{Total} = 55,000 sq ft

D) Area of Permeable Pavement System
(Minimum recommended permeable pavement area = 13491 sq ft) — A_{PPS} = 15,000 sq ft

E) Impervi... Tributary Ratio
(Co... ...uos Area / Per... ...e Pavement ... — R... = 1.7

F) W... r Quality Capture Volume (... CV) ...sed on 12-... ...ain Time
(W... ...0.8 * (0.91 * i³ - 1.1... ...² + 0.7... ...i) / 12) * A... ...) — WQ... = 932 cu ft

G) Is flood control vo... ...e being ...

Cho...
- ● Y...
- ○ N...

Provide overfl... to carry runoff directly into the reserv... layer to ensure use ...ontr... ...s of infiltration rates.

H) Total Volume Needed — V_{Total} = 6,340 cu ft

3. Depth of Reservoir

A) Minimum Depth of Reservoir
(Minimum recommended depth is 6 inches) — D_{min} = 18.0 inches

B) Is the slope of the reservoir/subgrade interface equal to 0%?

Choose One
- ● YES- Flat or Stepped Installation
- ○ NO- Sloped Installation

C) Porosity (Porous Gravel Pavement $\leq$ 0.3, Others $\leq$ 0.40) — P = 0.40

D) Slope of the Base Course/Subgrade Interface — S = ______ ft / ft

E) Length Between Lateral Flow Barriers — L = ______ ft

F) Volume Provided Based on Depth of Base Course
Flat or Stepped: $V = P * ((D_{min-1})/12) * Area$
Sloped: $V = P * [(D_{min} - (D_{min} - 6*SL-1)) / 12] * Area$ — V = 8,500 cu ft

4. Lateral Flow Barriers

A) Type of Lateral Flow Barriers

Choose One
- ○ Concrete Walls
- ○ PVC geomembrane installed normal to flow
- ● N/A- Flat installation
- ○ Other (Describe):

B) Number of Permeable Pavement Cells — Cells = 1

5. Perimeter Barrier

A) Is a perimeter barrier provided on all sides of the pavement system?
(Recommeded for PICP, concrete grid pavement, or for any no-infiltration section.)

Choose One
- ● YES
- ○ NO

Design Procedure Form: Permeable Pavement Systems (PPS)

Sheet 2 of 2

Designer: G. Frazer
Company: BMP Inc.
Date: November 29, 2010
Project: Shops at 56th Ave.
Location: SE corner of 56th Ave. and 83rd St.

6. Filter Material and Underdrain System	
A) Is the underdrain placed below a 6-inch thick layer of CDOT Class C filter material?	Choose One (●) YES ( ) NO ( ) N/A
B) Diameter of Slotted Pipe (slot dimensions per Table PPs-2)	Choose One (●) 4-inch ( ) 6-inch
C) Distance from the Lowest Elevation of the Storage Volume (i.e. the bottom of the base course to the center of the orifice)	y = 3.8 ft
7. Impe... embrane Liner a... eotextile Sep... Fabric	
A) ... there a minimum 30 mil thic... pe... able PVC g... brane ... r on the bottom and sides ... the ba..., extendin... o t... e top of t... urse?	...se One ( ) ...ES (●) ...O
B) ...T Class ... parat... abric	...se One ( ) ...laced above the liner ( ) Placed above and below the liner
8. Outlet (Assumes each cell has similar area, subgrade slope, and length between lateral barriers (unless subgrade is flat). Calculate cells individually where this varies.)	
A) Depth of WQCV in the Reservoir (Elevation of the Flood Control Outlet)	D_{WQCV} = 1.86 inches
B) Diameter of Orifice for 12-hour Drain Time (Use a minimum orifice diameter of 3/8-inches)	$D_{Orifice}$ = 0.62 inches

Notes:

CONSTRUCTION TESTING SCIENCES

Construction Testing Sciences
P.O. Box 824483, Dallas, TX 75382-4483
Phone: 214.703.8911
www.ctsciences.com

Report of Permeability Testing

Client: Pavestone
Project: Eco-Priora Permeable Pavers
Project No.: 101026

Report No.: 10076
Date of Service: 06/08/11

Construction Testing Sciences (CTS) was retained by Pavestone to perform permeability testing on Eco-Priora Permeable Pavers utilizing ASTM Size No. 9 crushed stone aggregate joint infill material. The purpose of this testing was to determine the rate of water flow through the paver joints.

Test Mockup

A mockup frame, measuring 23 1/4" x 28" inside, was constructed with screen material secured to the bottom of the frame. The frame was placed over expanded metal so as not to inhibit the flow of water. The Eco-Priora pavers, which consist of one size, were then placed inside the frame in a staggered joint pattern. The perimeter of the mockup was sealed with silicone sealant and allowed to cure. The ASTM Size No. 9 crushed limestone aggregate was then placed in the paver joints and consolidated. A diffuser was placed approximately eight inches above the mockup to provide even dispersion of water. A 300 gallon elevated water tank was used to provide the water supply. While running each test, a constant supply of water was supplied to the tank to maintain constant flow.

Test Results

Testing was conducted maintaining a 0.5" head of water above the top surface of the pavers. The level of head water was established, maintained for approximately 30 seconds, and the rate of flow was determined. This procedure was performed a total of five times. The average flow rate was determined and is reported below.

Head Water (Inches)	Rate of Flow (Inches per Hour)
0.5	311

STATE OF TEXAS
KENNETH L. BOWNDS
76345
LICENSED
PROFESSIONAL ENGINEER

6/8/11

Kenneth L. Bownds, P.E.

10.3 Aquatic Plant Harvesting

Harvesting plants will permanently remove nutrients from the system although removal of vegetation can also resuspend sediment and leave areas susceptible to erosion. For this reason, UDFCD does not recommend harvesting vegetation as routine maintenance. However, aquatic plant harvesting can be performed if desired to maintain volume or eliminate nuisances related to overgrowth of vegetation. When this is the case, perform this activity during the dry season (November to February). This can be performed manually or with specialized machinery.

Photograph 6-4. This broom sweeper will only remove debris from the pavement surface. Broom sweepers are not designed to remove solids from the void space of a permeable pavement. Use a vacuum or regenerative air sweeper to help maintain or restore infiltration through the wearing course.

If a reduction in cattails is desired, harvest them annually, especially in areas of new growth. Cut them at the base of the plant just below the waterline, or slowly pull the shoot out from the base. Cattail removal should be done during late summer to deprive the roots of food and reduce their ability to survive winter.

10.4 Sediment Removal

If the channel becomes overgrown with plants and sediment, it may need to be graded back to the original design and revegetated. The frequency of this activity is dependent on the site characteristics and should not be more than once every 10 to 20 years.

11.0 Permeable Pavement Systems

The key maintenance objective for any permeable pavement system is to know when runoff is no longer rapidly infiltrating into the surface, which is typically due to void spaces becoming clogged and requiring sediment removal. This section identifies key maintenance considerations for various types of permeable pavement BMPs.

11.1 Inspection

Inspect pavement condition and observe infiltration at least annually, either during a rain event or with a garden hose to ensure that water infiltrates into the surface. Video, photographs, or notes can be helpful in measuring loss of infiltration over time. Systematic measurement of surface infiltration of pervious concrete, Permeable Interlocking Concrete Pavers (PICP), concrete grid pavement, and porous asphalt[1] can be accomplished using ASTM C1701 Standard Test Method for Infiltration Rate of In Place Pervious Concrete.

[1] Porous asphalt is considered a provisional treatment BMP pending performance testing in Colorado and is not included in this manual at the present time.

11.2 Debris Removal, Sweeping, and Vacuuming

- **All Pavements:** Debris should be removed, routinely, as a source control measure. Typically, sites that require frequent sweeping already plan for this activity as part of their ongoing maintenance program. For example, a grocery store may sweep weekly or monthly. Depending on the season, city streets also may have a monthly plan for sweeping. This is frequently performed with a broom sweeper such as the one shown in Photo 6-4. Although this type of sweeper can be effective at removing solids and debris from the surface, it will not remove solids from the void space of a permeable pavement. Use a vacuum or regenerative air sweeper to help maintain or restore infiltration. If the pavement has not been properly maintained, a vacuum sweeper will likely be needed.

- **PICP, Concrete Grid Pavements (with aggregate infill), Pervious Concrete, and Porous Asphalt[1]:** Use a regenerative air or vacuum sweeper after any significant site work (e.g., landscaping) and approximately twice per year to maintain infiltration rates. This should be done on a warm dry day for best results. Do not use water with the sweeper. The frequency is site specific and inspections of the pavement may show that biannual vacuuming is more frequent than necessary. After vacuuming PICP and Concrete Grid Pavers, replace infill aggregate as needed.

11.3 Snow Removal

In general, permeable pavements do not form ice to the same extent as conventional pavements. Additionally, conventional liquid treatments (deicers) will not stay at the surface of a permeable pavement as needed for the treatment to be effective. Sand should not be applied to a permeable pavement as it can reduce infiltration. Plowing is the recommended snow removal process. Conventional plowing operations should not cause damage to the pavements.

- **PICP and Concrete Grid:** Deicers may be used on PICP and grid pavers; however, it may not be effective for the reason stated above. Sand should not be used. If sand is accidently used, use a vacuum sweeper to remove the sand. Mechanical snow and ice removal should be used.

- **Pervious Concrete:** Do not use liquid or solid deicers or sand on pervious concrete. Deicers can damage the concrete and sand will reduce infiltration. Mechanical snow and ice removal should be used.

- **Porous Asphalt[2]:** Use liquid or solid deicers sparingly; mechanical snow and ice removal is preferred. Do not apply sand to porous asphalt.

11.4 Full and Partial Replacement of the Pavement or Infill Material

- **PICP and Concrete Grid:** Concrete pavers, when installed correctly, should have a long service life. If a repair is required, it is frequently due to poor placement of the paver blocks. Follow industry guidelines for installation and replacement after underground repairs.

  If surface is completely clogged and rendering a minimal surface infiltration rate, restoration of surface infiltration can be achieved by removing the first ½ to 1 inch of soiled aggregate infill

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[2] Porous asphalt is considered a provisional treatment BMP pending performance testing in Colorado and is not included in this manual at the present time.

material with a vacuum sweeper. After cleaning, the openings in the PICP will need to be refilled with clean aggregate infill materials. Replacement of the infill is best accomplished with push brooms.

- **Porous Gravel:** Remove and replace areas of excessive wear or reduced infiltration as needed. The frequency is dependent on site characteristics including site uses, vegetation, and materials.
- **Pervious Concrete:** Partial replacement of pervious concrete should be avoided. If clogged, power washing or power blowing should be attempted prior to partial replacement because saw cutting will cause raveling of the concrete. Any patches should extend to existing isolated joints. Conventional concrete may be used in patches, provided that 90 percent of the original pervious surface is maintained.
- **Reinforced Grass:** Remove and replace the sod cover as needed to maintain a healthy vegetative cover or when the sod layer accumulates significant amount of sediment (i.e., >1.5 inches). Maintenance and routine repairs should be performed annually, with sod replacement approximately every 10 to 25 years. When replacing sod, use a high infiltration variety such as sod grown in sandy loam.
- **Porous Asphalt[3]:** Conventional asphalt may be used in patches, provided that 90 percent of the original permeable surface is maintained.

12.0 Underground BMPs

Maintenance requirements of underground BMPs can vary greatly depending on the type of BMP. Frequent inspections (approximately every three months) are recommended in the first two years in order to determine the appropriate interval of maintenance for a given BMP. This section provides general recommendations for assorted underground BMPs. For proprietary devices, the manufacturer should provide detailed maintenance requirements specific for the BMP.

12.1 Inspection

- **All Underground BMPs:** Inspect underground BMPs at least quarterly for the first two years of operation and then twice a year for the life of the BMP, if a reduced inspection schedule is warranted based on the initial two years. Specifically look for debris that could cause the structure to bypass water quality flows. Strong odors may also indicate that the facility is not draining properly. Inspection should be performed by a person who is familiar with the operation and configuration of the BMP.
- **Inlet Inserts:** Inspect inlet inserts frequently; at a minimum, inspect after every storm event exceeding 0.6 inches. Removal of flow blocking debris is critical for flood control.

12.2 Debris Removal, Cartridge Replacement, and Vacuuming

- **All Underground BMPs:** Follow the manufacturer's recommended maintenance requirements and remove any flow blocking debris as soon as possible following inspection.

[3] Porous asphalt is considered a provisional treatment BMP pending performance testing in Colorado and is not included in this manual at the present time.

APPENDIX C

HYDRAULIC CALCULATIONS:

1) RATIONAL CALCULATIONS – PROPOSED CONDITION
2) DESIGN CALULATIONS FOR PERMEABLE PAVEMENT

Hammers Construction - 1002 LLC
Project# HCI004
Area Runoff Coefficient Summary - PROPOSED

			DEVELOPED			UNDEVELOPED			WEIGHTED	
BASIN	TOTAL AREA		AREA	C_5	C_{100}	AREA	C_5	C_{100}	C_5	C_{100}
	(SF)	(Acres)	(Acres)			(Acres)				
P-1	13,418	0.31	0.28	0.90	0.95	0.03	0.25	0.35	***0.84***	***0.90***
P-2	3,986	0.09	0.02	0.90	0.95	0.07	0.25	0.35	***0.39***	***0.48***

% Impervious										
P-1		0.3	0.28	100%		0.03	0%			91%
P-2		0.1	0.02	100%		0.07	0%			22%
Total Area =		0.40	0.30	100%		0.10	0%			75%

Calculated by: ____________
Date: ____________
Checked by: ____________

Hammers Construction - 1002 LLC
Project# HCI004
Area Drainage Summary - PROPOSED

		WEIGHTED		OVERLAND				STREET / CHANNEL FLOW					T_t	CA		INTENSITY		TOTAL FLOW	
BASIN	AREA TOTAL	C_5	C_{100}	C_5	Length	Height	T_C	Grass/ Paved	Length	Slope	Velocity	T_t	TOTAL	CA_5	CA_{100}	I_5	I_{100}	Q_5	Q_{100}
	(Acres)	* For Calcs See Runoff Summary			(ft)	(ft)	(min)		(ft)	(%)	(fps)	(min)	(min)			(in/hr)	(in/hr)	(c.f.s.)	(c.f.s.)
P-1	**0.31**	0.84	0.90	0.25	10	1	2.4 0.0 0.0	Paved	210	0.5%	1.4	2.6 0.0 0.0	5.0 IIN 5 USE	0.26	0.28	5.0	9.1	**1.3**	**2.5**
P-2	**0.09**	0.39	0.48	0.25	10	1	2.4 0.0 0.0	Paved	150	0.5%	1.4	1.8 0.0 0.0	5.0 IIN 5 USE	0.04	0.04	5.0	9.1	**0.2**	**0.4**

Calculated by: ____________
Date: ____________
Checked by: ____________

Design Procedure Form: Permeable Pavement Systems (PPS)

UD-BMP (Version 3.06, November 2016)

Designer: 1002 LLC
Company:
Date: December 5, 2017
Project:
Location:

1. Type of Permeable Pavement Section	
A) What type of section of permeable pavement is used? (Based on the land use and activities, proximity to adjacent structures and soil characteristics.)	Choose One: ○ No Infiltration; ○ Partial Infiltration Section; ◉ Full Infiltration Section
B) What type of wearing course?	Choose One: ◉ PICP; ○ Concrete Grid Pavement; ○ Pervious Concrete; ○ Porous Gravel
2. Required Storage Volume	
A) Effective Imperviousness of Area Tributary to Permeable Pavement, I_a	I_a = 89.0 %
B) Tributary Area's Imperviousness Ratio ($I = I_a / 100$)	i = 0.890
C) Tributary Watershed Area (including area of permeable pavement system)	A_{Total} = 13,418 sq ft
D) Area of Permeable Pavement System (Minimum recommended permeable pavement area = 4132 sq ft)	A_{PPS} = 450 sq ft
E) Impervious Tributary Ratio (Contributing Imperviuos Area / Permeable Pavement Ratio)	R_T = 25.6 — IMPERVIOUS TRIBUTARY RATIO EXCEEDS 2.0
F) Water Quality Capture Volume (WQCV) Based on 12-hour Drain Time ($WQCV = (0.8 * (0.91 * i^3 - 1.19 * i^2 + 0.78 * i) / 12) * Area$)	WQCV = 352 cu ft
G) Is flood control volume being added?	Choose One: ○ YES; ◉ NO
H) Total Volume Needed	V_{Total} = ___ cu ft
3. Depth of Reservoir	
A) Minimum Depth of Reservoir (Minimum recommended depth is 6 inches)	D_{min} = 24.5 inches
B) Is the slope of the reservoir/subgrade interface equal to 0%?	Choose One: ◉ YES- Flat or Stepped Installation; ○ NO- Sloped Installation
C) Porosity (Porous Gravel Pavement ≤ 0.3, Others ≤ 0.40)	P = 0.40
D) Slope of the Base Course/Subgrade Interface	S = ___ ft / ft
E) Length Between Lateral Flow Barriers	L = ___ ft
F) Volume Provided Based on Depth of Base Course Flat or Stepped: $V = P * ((D_{min-1})/12) * Area$ Sloped: $V = P * [(D_{min} - (D_{min} - 6*SL-1)) / 12] * Area$	V = 353 cu ft
4. Lateral Flow Barriers	
A) Type of Lateral Flow Barriers	Choose One: ○ Concrete Walls; ○ PVC geomembrane installed normal to flow; ◉ N/A- Flat installation; ○ Other (Describe):
B) Number of Permeable Pavement Cells	Cells = 1
5. Perimeter Barrier	
A) Is a perimeter barrier provided on all sides of the pavement system? (Recommeded for PICP, concrete grid pavement, or for any no-infiltration section.)	Choose One: ◉ YES; ○ NO

Design Procedure Form: Permeable Pavement Systems (PPS)

Designer: 1002 LLC
Company:
Date: December 5, 2017
Project:
Location:

6. Filter Material and Underdrain System	
A) Is the underdrain placed below a 6-inch thick layer of CDOT Class C filter material?	Choose One: ○ YES ○ NO ◉ N/A
B) Diameter of Slotted Pipe (slot dimensions per Table PPs-2)	Choose One: ○ 4-inch ○ 6-inch
C) Distance from the Lowest Elevation of the Storage Volume (i.e. the bottom of the base course to the center of the orifice)	y = ______ ft
7. Impermeable Geomembrane Liner and Geotextile Separator Fabric	
A) Is there a minimum 30 mil thick impermeable PVC geomembrane liner on the bottom and sides of the basin, extending up to the top of the base course?	Choose One: ○ YES ◉ NO
B) CDOT Class B Separator Fabric	Choose One: ○ Placed above the liner ○ Placed above and below the liner
8. Outlet (Assumes each cell has similar area, subgrade slope, and length between lateral barriers (unless subgrade is flat). Calculate cells individually where this varies.)	
A) Depth of WQCV in the Reservoir (Elevation of the Flood Control Outlet)	D_{WQCV} = ______ inches
B) Diameter of Orifice for 12-hour Drain Time (Use a minimum orifice diameter of 3/8-inches)	$D_{Orifice}$ = ______ inches

Notes:

APPENDIX D

1) NRCS Soil Study
2) FEMA FIRMETTE

United States Department of Agriculture

NRCS

Natural Resources Conservation Service

A product of the National Cooperative Soil Survey, a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local participants

Custom Soil Resource Report for

El Paso County Area, Colorado

September 27, 2017

Preface

Soil surveys contain information that affects land use planning in survey areas. They highlight soil limitations that affect various land uses and provide information about the properties of the soils in the survey areas. Soil surveys are designed for many different users, including farmers, ranchers, foresters, agronomists, urban planners, community officials, engineers, developers, builders, and home buyers. Also, conservationists, teachers, students, and specialists in recreation, waste disposal, and pollution control can use the surveys to help them understand, protect, or enhance the environment.

Various land use regulations of Federal, State, and local governments may impose special restrictions on land use or land treatment. Soil surveys identify soil properties that are used in making various land use or land treatment decisions. The information is intended to help the land users identify and reduce the effects of soil limitations on various land uses. The landowner or user is responsible for identifying and complying with existing laws and regulations.

Although soil survey information can be used for general farm, local, and wider area planning, onsite investigation is needed to supplement this information in some cases. Examples include soil quality assessments (http://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/) and certain conservation and engineering applications. For more detailed information, contact your local USDA Service Center (https://offices.sc.egov.usda.gov/locator/app?agency=nrcs) or your NRCS State Soil Scientist (http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/contactus/?cid=nrcs142p2_053951).

Great differences in soil properties can occur within short distances. Some soils are seasonally wet or subject to flooding. Some are too unstable to be used as a foundation for buildings or roads. Clayey or wet soils are poorly suited to use as septic tank absorption fields. A high water table makes a soil poorly suited to basements or underground installations.

The National Cooperative Soil Survey is a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local agencies. The Natural Resources Conservation Service (NRCS) has leadership for the Federal part of the National Cooperative Soil Survey.

Information about soils is updated periodically. Updated information is available through the NRCS Web Soil Survey, the site for official soil survey information.

The U.S. Department of Agriculture (USDA) prohibits discrimination in all its programs and activities on the basis of race, color, national origin, age, disability, and where applicable, sex, marital status, familial status, parental status, religion, sexual orientation, genetic information, political beliefs, reprisal, or because all or a part of an individual's income is derived from any public assistance program. (Not all prohibited bases apply to all programs.) Persons with disabilities who require alternative means for communication of program information (Braille, large print, audiotape, etc.) should contact USDA's TARGET Center at (202) 720-2600 (voice and TDD). To file a complaint of discrimination, write to USDA, Director, Office of Civil Rights, 1400 Independence Avenue, S.W., Washington, D.C. 20250-9410 or call (800) 795-3272 (voice) or (202) 720-6382 (TDD). USDA is an equal opportunity provider and employer.

Contents

Preface.......... 2
Soil Map.......... 5
Soil Map.......... 6
Legend.......... 7
Map Unit Legend.......... 8
Map Unit Descriptions.......... 8
El Paso County Area, Colorado.......... 10
28—Ellicott loamy coarse sand, 0 to 5 percent slopes.......... 10
References.......... 12

Soil Map

The soil map section includes the soil map for the defined area of interest, a list of soil map units on the map and extent of each map unit, and cartographic symbols displayed on the map. Also presented are various metadata about data used to produce the map, and a description of each soil map unit.

Soil Map

Map Scale: 1:403 if printed on A landscape (11" x 8.5") sheet.

Meters: 0, 5, 10, 20, 30

Feet: 0, 15, 30, 60, 90

N

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 13N WGS84

MAP LEGEND

Area of Interest (AOI)
- Area of Interest (AOI)

Soils
- Soil Map Unit Polygons
- Soil Map Unit Lines
- Soil Map Unit Points

Special Point Features
- Blowout
- Borrow Pit
- Clay Spot
- Closed Depression
- Gravel Pit
- Gravelly Spot
- Landfill
- Lava Flow
- Marsh or swamp
- Mine or Quarry
- Miscellaneous Water
- Perennial Water
- Rock Outcrop
- Saline Spot
- Sandy Spot
- Severely Eroded Spot
- Sinkhole
- Slide or Slip
- Sodic Spot
- Spoil Area
- Stony Spot
- Very Stony Spot
- Wet Spot
- Other
- Special Line Features

Water Features
- Streams and Canals

Transportation
- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background
- Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:24,000.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: El Paso County Area, Colorado
Survey Area Data: Version 14, Sep 23, 2016

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Jun 3, 2014—Jun 17, 2014

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

El Paso County Area, Colorado (CO625)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
28	Ellicott loamy coarse sand, 0 to 5 percent slopes	0.3	100.0%
Totals for Area of Interest		**0.3**	**100.0%**

Map Unit Descriptions

The map units delineated on the detailed soil maps in a soil survey represent the soils or miscellaneous areas in the survey area. The map unit descriptions, along with the maps, can be used to determine the composition and properties of a unit.

A map unit delineation on a soil map represents an area dominated by one or more major kinds of soil or miscellaneous areas. A map unit is identified and named according to the taxonomic classification of the dominant soils. Within a taxonomic class there are precisely defined limits for the properties of the soils. On the landscape, however, the soils are natural phenomena, and they have the characteristic variability of all natural phenomena. Thus, the range of some observed properties may extend beyond the limits defined for a taxonomic class. Areas of soils of a single taxonomic class rarely, if ever, can be mapped without including areas of other taxonomic classes. Consequently, every map unit is made up of the soils or miscellaneous areas for which it is named and some minor components that belong to taxonomic classes other than those of the major soils.

Most minor soils have properties similar to those of the dominant soil or soils in the map unit, and thus they do not affect use and management. These are called noncontrasting, or similar, components. They may or may not be mentioned in a particular map unit description. Other minor components, however, have properties and behavioral characteristics divergent enough to affect use or to require different management. These are called contrasting, or dissimilar, components. They generally are in small areas and could not be mapped separately because of the scale used. Some small areas of strongly contrasting soils or miscellaneous areas are identified by a special symbol on the maps. If included in the database for a given area, the contrasting minor components are identified in the map unit descriptions along with some characteristics of each. A few areas of minor components may not have been observed, and consequently they are not mentioned in the descriptions, especially where the pattern was so complex that it was impractical to make enough observations to identify all the soils and miscellaneous areas on the landscape.

The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The objective of mapping is not to delineate pure taxonomic classes but rather to separate the landscape into landforms or landform segments that have similar use and management requirements. The delineation of such segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, however, onsite investigation is needed to define and locate the soils and miscellaneous areas.

An identifying symbol precedes the map unit name in the map unit descriptions. Each description includes general facts about the unit and gives important soil properties and qualities.

Soils that have profiles that are almost alike make up a *soil series*. Except for differences in texture of the surface layer, all the soils of a series have major horizons that are similar in composition, thickness, and arrangement.

Soils of one series can differ in texture of the surface layer, slope, stoniness, salinity, degree of erosion, and other characteristics that affect their use. On the basis of such differences, a soil series is divided into *soil phases*. Most of the areas shown on the detailed soil maps are phases of soil series. The name of a soil phase commonly indicates a feature that affects use or management. For example, Alpha silt loam, 0 to 2 percent slopes, is a phase of the Alpha series.

Some map units are made up of two or more major soils or miscellaneous areas. These map units are complexes, associations, or undifferentiated groups.

A *complex* consists of two or more soils or miscellaneous areas in such an intricate pattern or in such small areas that they cannot be shown separately on the maps. The pattern and proportion of the soils or miscellaneous areas are somewhat similar in all areas. Alpha-Beta complex, 0 to 6 percent slopes, is an example.

An *association* is made up of two or more geographically associated soils or miscellaneous areas that are shown as one unit on the maps. Because of present or anticipated uses of the map units in the survey area, it was not considered practical or necessary to map the soils or miscellaneous areas separately. The pattern and relative proportion of the soils or miscellaneous areas are somewhat similar. Alpha-Beta association, 0 to 2 percent slopes, is an example.

An *undifferentiated group* is made up of two or more soils or miscellaneous areas that could be mapped individually but are mapped as one unit because similar interpretations can be made for use and management. The pattern and proportion of the soils or miscellaneous areas in a mapped area are not uniform. An area can be made up of only one of the major soils or miscellaneous areas, or it can be made up of all of them. Alpha and Beta soils, 0 to 2 percent slopes, is an example.

Some surveys include *miscellaneous areas*. Such areas have little or no soil material and support little or no vegetation. Rock outcrop is an example.

El Paso County Area, Colorado

28—Ellicott loamy coarse sand, 0 to 5 percent slopes

Map Unit Setting

National map unit symbol: 3680
Elevation: 5,500 to 6,500 feet
Mean annual precipitation: 13 to 15 inches
Mean annual air temperature: 47 to 50 degrees F
Frost-free period: 125 to 145 days
Farmland classification: Not prime farmland

Map Unit Composition

Ellicott and similar soils: 85 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Ellicott

Setting

Landform: Flood plains, stream terraces
Landform position (three-dimensional): Tread
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Sandy alluvium

Typical profile

A - 0 to 4 inches: loamy coarse sand
C - 4 to 60 inches: stratified coarse sand to sandy loam

Properties and qualities

Slope: 0 to 5 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Somewhat excessively drained
Runoff class: Very low
Capacity of the most limiting layer to transmit water (Ksat): High to very high (5.95 to 19.98 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: Frequent
Frequency of ponding: None
Available water storage in profile: Low (about 4.1 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 7w
Hydrologic Soil Group: A
Ecological site: Sandy Bottomland LRU's A & B (R069XY031CO)
Other vegetative classification: SANDY BOTTOMLAND (069AY031CO)
Hydric soil rating: No

Minor Components

Fluvaquentic haplaquoll

Percent of map unit:
Landform: Swales
Hydric soil rating: Yes

Other soils

Percent of map unit:
Hydric soil rating: No

Pleasant

Percent of map unit:
Landform: Depressions
Hydric soil rating: Yes

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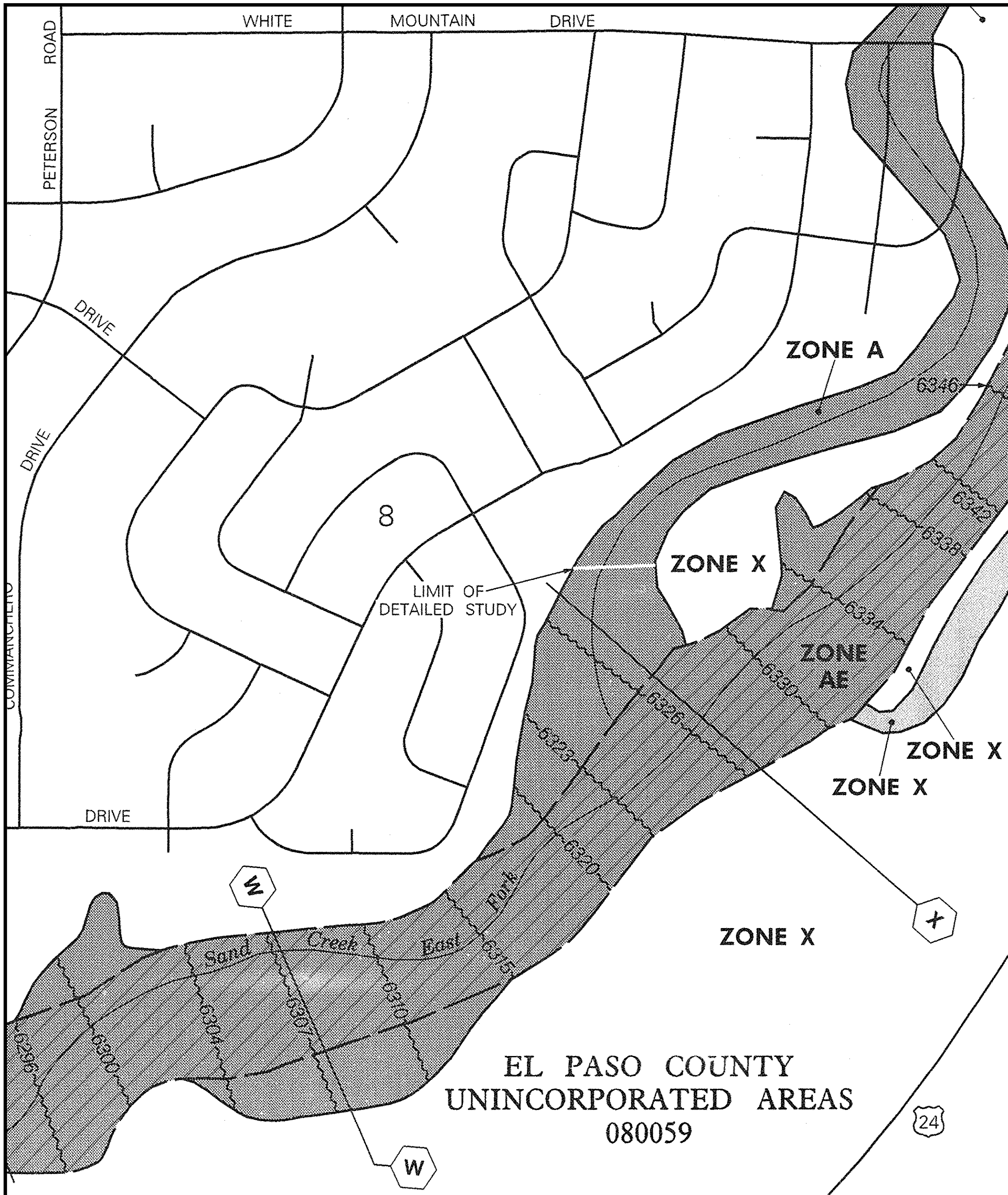
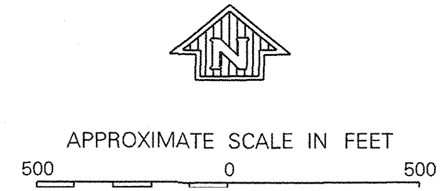




NATIONAL FLOOD INSURANCE PROGRAM

FIRM

FLOOD INSURANCE RATE MAP

EL PASO COUNTY, COLORADO AND INCORPORATED AREAS

PANEL 752 OF 1300
(SEE MAP INDEX FOR PANELS NOT PRINTED)

CONTAINS:

COMMUNITY	NUMBER	PANEL	SUFFIX
COLORADO SPRINGS, CITY OF	080060	0752	F
EL PASO COUNTY, UNINCORPORATED AREAS	080059	0752	F

MAP NUMBER
08041C0752 F

EFFECTIVE DATE:
MARCH 17, 1997

Federal Emergency Management Agency

APPENDIX E

Drainage Map

GRADING LEGEND

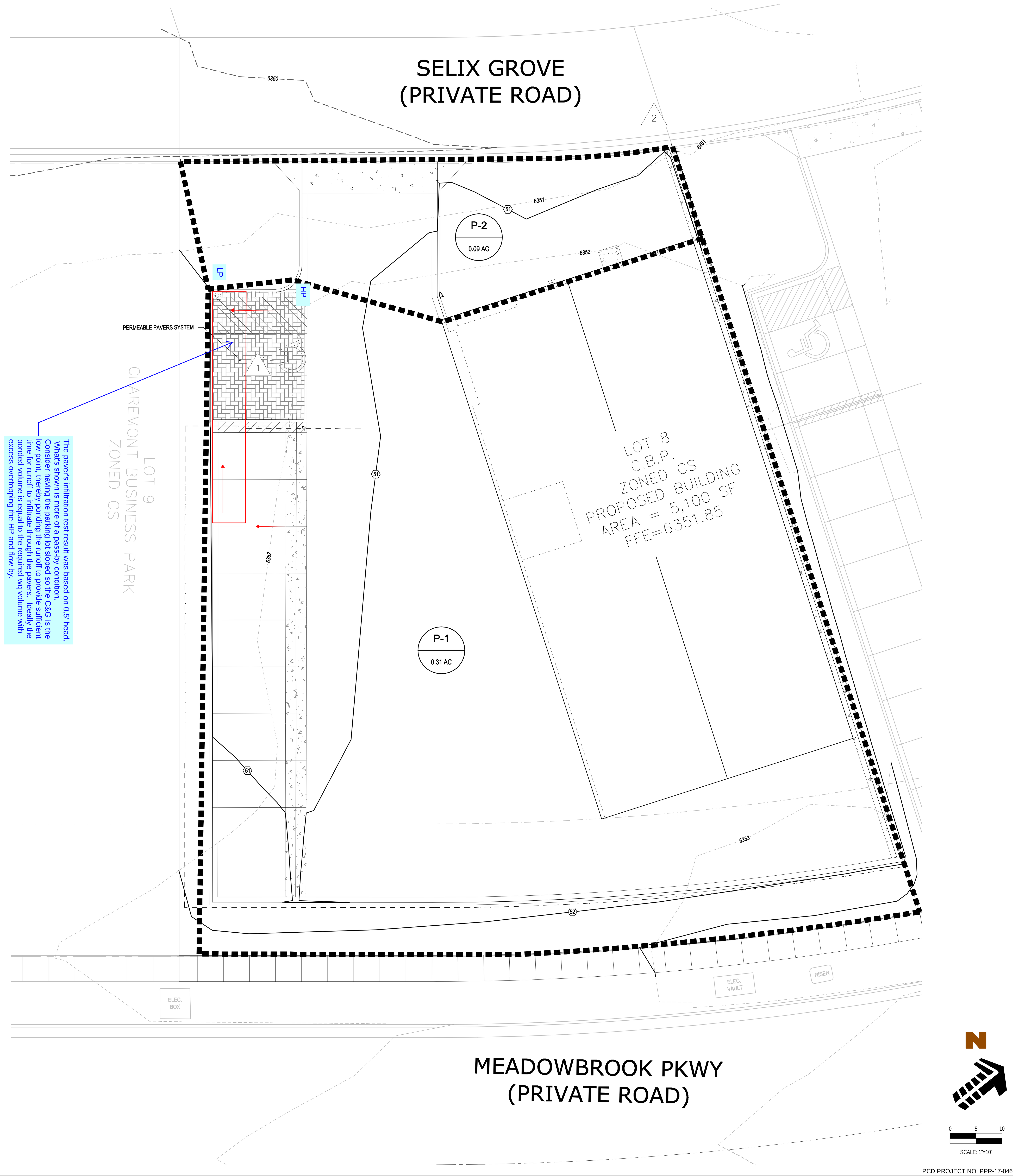
6334	EXISTING CONTOUR
6340	PROPOSED MAJOR CONTOUR
41	PROPOSED MINOR CONTOUR
	MAJOR BASIN BOUNDARY LINE
	PROPOSED STORM SEWER
	FLOW ARROW
X.X%	SLOPE
BW	BOTTOM OF WALL
FFE	FINISHED FLOOR
FG	FINISH GRADE
GB	GRADE BREAK
TW	TOP OF WALL
55.00	FINISHED GRADE ELEVATION
P-1	BASIN DESIGNATION
0.10 AC	BASIN AREA (ACRES)
1	DESIGN POINT

RUNOFF SUMMARY

DP	Q5 (CFS)	Q100 (CFS)
1	1.3	2.5
2	0.2	0.4

RAIN GARDEN BMP SUMMARY

WQCV REQUIRED = 320 CF
WQCV PROVIDED = 345 CF
WQCV DEPTH = 2.0 ft
INFILTRATION RATE = 17.9 MIN/INCH



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HAMMERS CONSTRUCTION
QUALITY COMMERCIAL CONSTRUCTION SINCE 1963

NOT FOR CONSTRUCTION

PROPOSED DRAINAGE MAP

CBP, F2 - LOT #8

1415 SELIX GROVE
COLORADO SPRINGS, CO

#	Date	Issue / Description	Init.
00	12/05/17	AGENCY SUBMITTAL	TAC

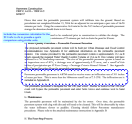
Project No:	HCI004.1
Drawn By:	
Checked By:	TAC
Date:	DECEMBER 2017

PROPOSED DRAINAGE MAP

PR

Markup Summary

dsdlaforce (8)



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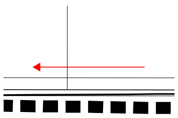
Author: dsdlaforce

Include the conversion calculation for the 311 in/hr to cfs to provide a quick comparison using similar units.



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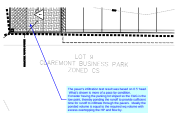

Subject: Callout
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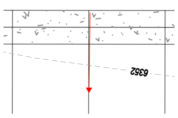
Author: dsdlaforce

The paver's infiltration test result was based on 0.5' head. What's shown is more of a pass-by condition.
Consider having the parking lot sloped so the C&G is the low point, thereby ponding the runoff to provide sufficient time for runoff to infiltrate through the pavers. Ideally the ponded volume is equal to the required wq volume with excess overtopping the HP and flow by.



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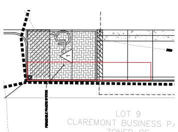

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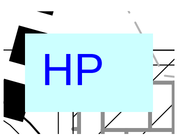

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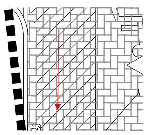
HP



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LP

todd_cartwright (2)

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SAMPLE

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SAMPLE