VIRGINIA DEQ STORMWATER
DESIGN SPECIFICATION No. 8

INFILTRATION PRACTICES

VERSION 2.0
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SECTION 1: DESCRIPTION

Infiltration practices use temporary surface or underground storage to allow incoming stormwater runoff to exfiltrate into underlying soils. Runoff first passes through multiple pre-treatment mechanisms to trap sediment and organic matter before it reaches the practice. As the stormwater penetrates the underlying soil, chemical and physical adsorption processes remove pollutants. Infiltration practices have the greatest runoff reduction capability of any stormwater practice and are suitable for use in residential and other urban areas where *measured* soil permeability rates exceed 1/2 inch per hour. To prevent possible groundwater contamination, infiltration should not be used at sites designated as stormwater hotspots.

SECTION 2: PERFORMANCE

When used appropriately, infiltration has a very high runoff volume reduction capability, as shown in **Table 8.1**.

Table 8.1. Summary of Stormwater Functions Provided by Infiltration

Stormwater Function	Level 1 Design	Level 2 Design
Annual Runoff Volume Reduction (RR)	50%	90%
Total Phosphorus (TP) EMC Reduction[1] by BMP Treatment Process	25%	25%
Total Phosphorus (TP) Mass Load Removal	63%	93%
Total Nitrogen (TN) EMC Reduction[1] by BMP Treatment Process	15%	15%
Total Nitrogen (TN) Mass Load Removal	57%	92%
Channel and Flood Protection	• Use the Virginia Runoff Reduction Method (VRRM) Compliance Spreadsheet to calculate the Curve Number (CN) Adjustment ***OR*** • Design for extra storage (optional; as needed) on the surface or in the subsurface storage volume to accommodate larger storm volumes, and use NRCS TR-55 Runoff Equations [2] to compute the CN Adjustment.	

[1] Change in the event mean concentration (EMC) through the practice. The actual nutrient mass load removed is the product of the removal rate and the runoff reduction (RR) rate (see Table 1 in the *Introduction to the New Virginia Stormwater Design Specifications*).

[2] NRCS TR-55 Runoff Equations 2-1 thru 2-5 and Figure 2-1 can be used to compute a curve number adjustment for larger storm events, based on the retention storage provided by the practice(s).

Sources: CWP and CSN (2008), and CWP (2007)

Leadership in Energy and Environmental Design (LEED®). The LEED® point credit system designed by the U.S. Green Building Council (USGBC) and implemented by the Green Building Certification Institute (GBCI) awards points related to site design and stormwater management. Several categories of points are potentially available for new development and redevelopment projects. **Chapter 6** of the 2013 *Virginia Stormwater Management Handbook* (2nd Edition) provides a more thorough discussion of the site planning process and design considerations as related to Environmental Site Design and potential LEED credits. However, the Virginia Department of Environmental Quality is not affiliated with the USGBC or GBCI and any information on applicable points provided here is based only on basic compatibility. **Designers should research and verify scoring criteria and applicability of points as related to the specific project being considered through USGBC LEED resources.**

Table 8.2. Potential LEED® Credits for Infiltration[1]

Credit Category	Credit No.	Credit Description
Sustainable Sites	SS6.1	Stormwater Design: Quantity Control
Sustainable Sites	SS6.2	Stormwater Design: Quality Control

[1] Actual site design and/or BMP configuration may not qualify for the credits listed. Alternatively, the project may actually qualify for credits not listed here. Designers should consult with a qualified individual (LEED AP) to verify credit applicability.

SECTION 3: DESIGN TABLE

The major design goal for Infiltration is to maximize runoff volume reduction and nutrient removal. To this end, designers may choose to go with the baseline design (Level 1) or choose an enhanced design (Level 2) that maximizes nutrient and runoff reduction. To qualify for Level 2, the infiltration practice must meet all the design criteria shown in the right hand column of **Table 8.3**.

Table 8.3. Level 1 and Level 2 Infiltration Design Guidelines

Level 1 Design (RR:50; TP:25; TN:15)	Level 2 Design (RR:90; TP:25; TN:15)
<u>Sizing:</u> $T_v = [(Rv)(A)/12]$ – the volume reduced by an upstream BMP	<u>Sizing:</u> $T_v = [1.1(Rv)(A)/12]$ – the volume reduced by an upstream BMP
At least two forms of pre-treatment (see **Table 8.6**)	At least three forms of pre-treatment (see **Table 8.6**)
Soil infiltration rate 1/2 to 1 in./hr. (see **Section 6.1** & **Appendix 8-A**); number of tests depends on the scale (**Table 8.4**)	Soil infiltration rates of 1.0 to 4.0 in/hr (see **Section 6.1** & **Appendix 8-A**); number of tests depends on the scale (**Table 8.4**)
Minimum of 2 feet between the bottom of the infiltration practice and the seasonal high water table or bedrock (**Section 5**)	
T_v infiltrates within 36 to 48 hours (**Section 6.6**)	
Building Setbacks – see **Table 8.4**	
All Designs are subject to hotspot runoff restrictions/prohibitions	

SECTION 4: TYPICAL DETAILS

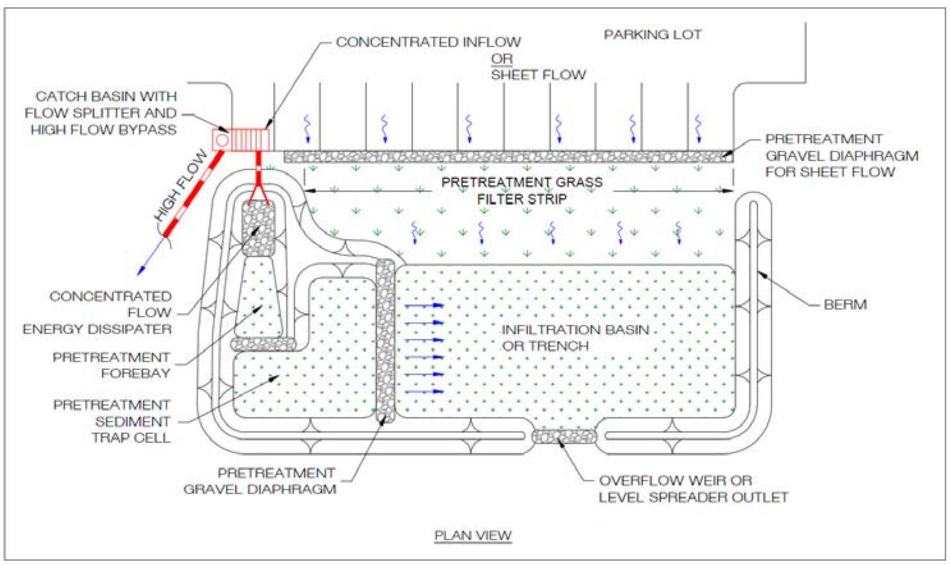

Figure 8.1A. Infiltration Trench or Basin Plan View with Concentrated Inflow and Sheet Inflow

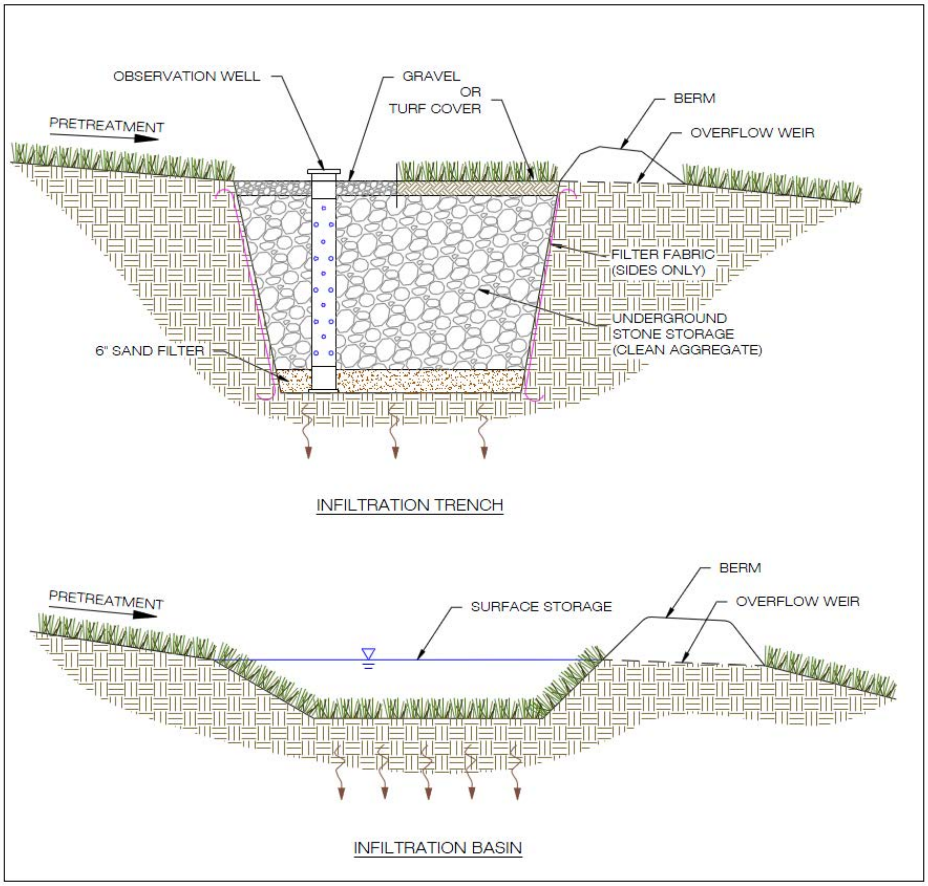

Figure 8.1B. Infiltration Trench or Basin Section View

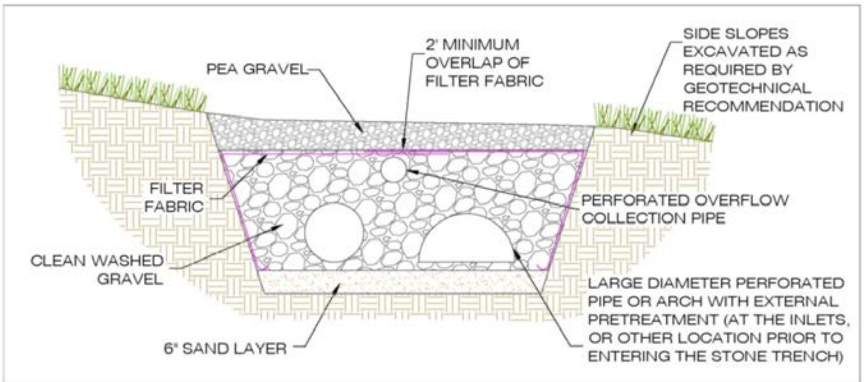

Figure 8.2A: Infiltration Section with Supplemental Pipe Storage

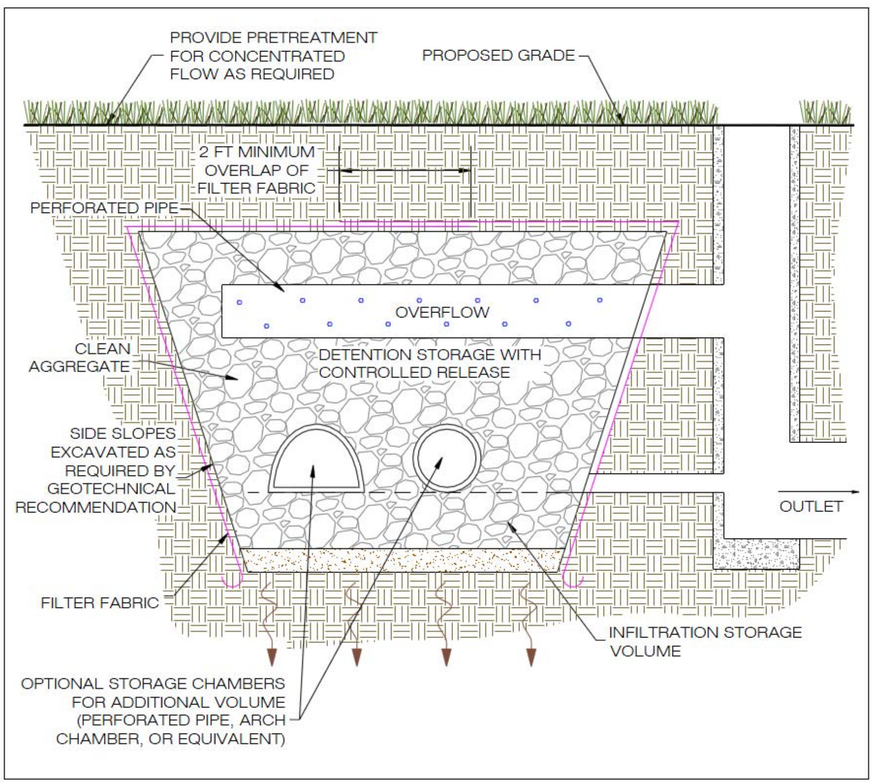

Figure 8.2B: Infiltration Combined with Detention (Channel and/or Flooding Protection)

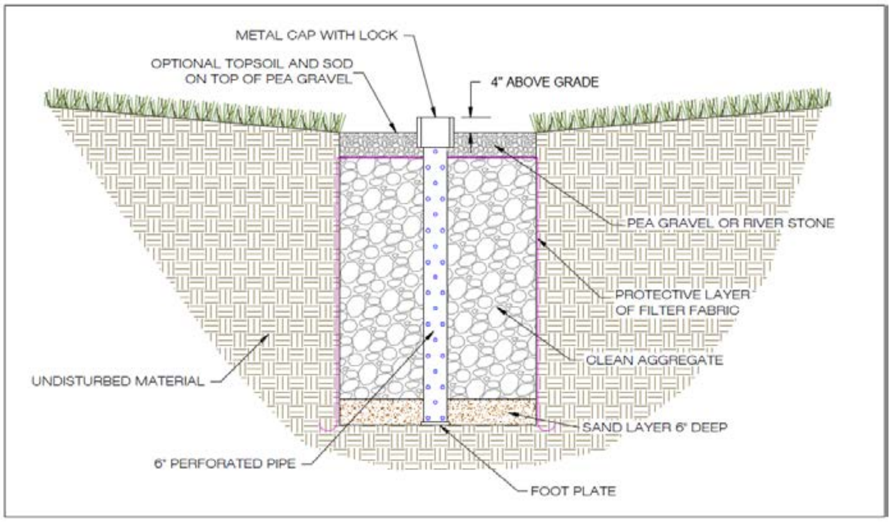

Figure 8.3: Observation Well

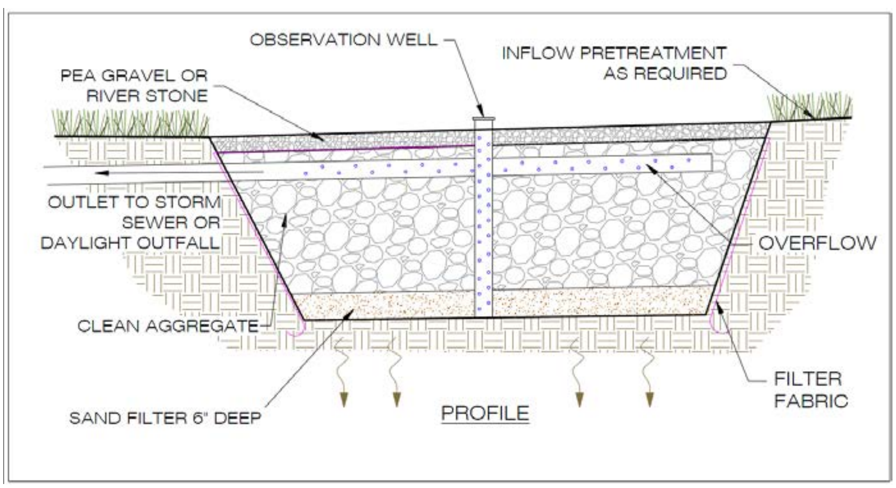

Figure 8.4: Typical Infiltration Trench

SECTION 5: PHYSICAL FEASIBILITY & DESIGN APPLICATIONS

Since infiltration practices have a very high runoff reduction capability, they should always be considered when initially evaluating a site. Designers should evaluate the range of soil properties during initial site layout and seek to configure the site to conserve and protect the soils with the greatest recharge and infiltration rates. In particular, areas of Hydrologic Soil Group A or B soils shown on NRCS soil surveys should be considered as primary locations for infiltration practices. At this point, designers should carefully identify and evaluate constraints on infiltration, as follows:

Contributing Drainage Area. The maximum contributing drainage area (CDA) to an individual infiltration practice should be less than 2 acres and as close to 100% impervious as possible. This specification covers three scales of infiltration practices (1) Micro-infiltration (250 to 2,500 sq. ft. of CDA), (2) small-scale infiltration (2,500 to 20,000 sq. ft. of CDA) and (3) conventional infiltration (20,000 to 100,000 sq. ft. of CDA). The design, pre-treatment and maintenance requirements differ, depending on the scale at which infiltration is applied (see **Table 8.4** below for a summary).

Table 8.4. The Three Design Scales for Infiltration Practices

Design Factor	Micro-Infiltration	Small-Scale Infiltration	Conventional Infiltration
Impervious Area Treated	250 to 2,500 sq. ft.	2,500 to 20,000 sq. ft.	20,000 to 100,000 sq. ft.
Typical Practices	Dry Well French Drain Paving Blocks	Infiltration Trench Permeable Paving [1]	Infiltration Trench Infiltration Basin
Min. Infiltration Rate	1/2 inch/hour field verified		
Design Infil. Rate	50% of measured rate		
Observation Well	No	Yes	Yes
Type of Pre-treatment (see **Table 8.6**)	External (leaf screens, grass filter strip, etc)	Vegetated filter strip or grass channel, forebay, etc.	Pre-treatment Cell
Depth Dimensions	Max. 3-foot depth	Max. 5-foot depth	Max. 6-foot depth,
UIC Permit Needed	No	No	Only if the surface width is less than the max. depth
Head Required	Nominal: 1 to 3 feet	Moderate: 1 to 5 feet	Moderate: 2 to 6 feet
Underdrain Requirements?	An elevated underdrain only on marginal soils	None required	Back up underdrain
Required Soil Tests	Based on surface area of practice; minimum of one soil profile, one infiltration tests per location (**Appendix 8-A**)	Varies based on surface area of practice – Refer to **Table 8-A.2**.	Varies based on surface area of practice – Refer to **Table 8-A.2**.
Building Setbacks	10 feet down-gradient [2]	10 feet down-gradient 50 feet up-gradient	25 feet down-gradient 100 feet up-gradient

[1] Although permeable pavement is an infiltration practice, a more detailed specification is provided in Stormwater Design Specification No. 7.

[2] Note that the building setbacks are intended for simple foundations. The use of a dry well or french drain adjacent to an in-ground basement or finished floor area or any building should be carefully designed and coordinated with the design of the structure's water-proofing system (foundation drains, etc.), or avoided altogether.

Site Topography. Unless slope stability calculations demonstrate otherwise, infiltration practices should be located a minimum horizontal distance of 200 feet from down-gradient slopes greater than 20%. The average slope of the contributing drainage areas should be less than 15%.

Practice Slope. The bottom of an infiltration practice should be flat (i.e., 0% longitudinal slope) to enable even distribution and infiltration of stormwater, although a maximum longitudinal slope of 1% is permissible if an underdrain is employed. Lateral slopes should be 0%.

Minimum Hydraulic Head. The elevation difference needed to operate a micro-scale infiltration practice is nominal. However, 2 or more feet of head may be needed to drive small-scale and conventional infiltration practices.

Minimum Depth to Water Table or Bedrock. A minimum vertical distance of 2 feet must be provided between the bottom of the infiltration practice and the seasonal high water table or bedrock layer. The seasonal high water table (SHWT) is defined as the shallowest depth to free water that stands in an unlined borehole or where the soil moisture tension is zero for a significant period (more than a few weeks). Other factors that influence the determination of the SHWT include (but are not limited to) natural vegetation (overstory & understory), soil colors, soil mottles (an indicator of water-saturated anaerobic conditions), depth to the root zone (free standing water is the greatest impediment to root growth), and depth to the clay layer (hardpan). All of the above indicators may not be present in the soil.

Soils. Native soils in proposed infiltration areas must have a minimum infiltration rate (permeability or hydraulic conductivity per **Appendix 8-A**) of 1/2 inch per hour (typically Hydrologic Soil Group A and B soils meet this criterion). Initially, soil infiltration rates can be estimated from NRCS soil data, but they must be confirmed by an on-site infiltration evaluation.

Use on Urban Soils/Redevelopment Sites. Sites that have been previously graded or disturbed do not retain their original soil permeability due to compaction. Therefore, such sites are not good candidates for infiltration practices. In addition, *i*nfiltration practices should never be situated above fill soils.

Dry Weather Flows. Infiltration practices should not be used on sites receiving regular dry-weather flows from sump pumps, irrigation nuisance water, and similar kinds of flows.

Setbacks. Infiltration practices should not be hydraulically connected to structure foundations or pavement, in order to avoid harmful seepage. Setbacks to structures and roads vary based on the scale of infiltration (see **Table 8.1** above). At a minimum, conventional and small-scale infiltration practices should be located a minimum horizontal distance of 100 feet from any water supply well, 50 feet from septic systems, and at least 5 feet down-gradient from dry or wet utility lines.

High Loading Situations. Infiltration practices are *not* intended to treat sites with high sediment or trash/debris loads, because such loads will cause the practice to clog and fail.

Groundwater Protection. **Section 10** of this specification presents a list of potential stormwater hotspots that pose a risk of groundwater contamination. Infiltration of runoff from designated hotspots is highly restricted or prohibited.

Site-Specific Considerations. Infiltration practices can be applied to most land uses that have measured soil infiltration rates that exceed 1/2 inch per hour. However, there is no single infiltration application that fits every development situation. The nature of the actual design application depends on four key design factors, described below:

1. The first factor is the **Design Scale** at which infiltration will be applied:
   - **Micro-infiltration** is intended for residential rooftop disconnection, rooftop rainwater harvesting systems, or other small scale application (250 to 2,500 sq. ft. of impervious area treated);
   - **Small-scale infiltration** is intended for residential and/or small commercial applications that meet the feasibility criteria noted above; and
   - **Conventional infiltration** can be considered for most typical development and redevelopment applications and therefore has more rigorous site selection and feasibility criteria.

   Table 8.4 above compares the different design approaches and requirements associated with each infiltration scale.

2. The second key design factor relates to the **mode** (or method) of temporarily storing runoff prior to infiltration – either on the surface or in an underground trench. When storing runoff on the surface (e.g., an infiltration basin), the maximum depth should be no greater than 1 foot. However, if pre-treatment cells are used, a maximum depth of 2 feet is permissible if appropriate safety features are included. In the underground mode, runoff is stored in the voids of the stones, and infiltrates into the underlying soil matrix. Perforated corrugated metal pipe, plastic pipe, concrete arch pipe, or comparable materials can be used in conjunction with the stone to increase the available temporary underground storage. In some instances, a combination of filtration and infiltration cells can be installed in the floor of a dry extended detention (ED) pond.

3. The third design factor relates to the degree of **confidence that exfiltration can be maintained** over time, given the measured infiltration rate for the subsoils at the practice location and the anticipated land uses. This factor helps determine whether infiltration is an appropriate practice for the site. Alternative practices that provide comparable volume and pollutant reduction include bioretention, the dry swale, permeable pavement, etc., all of which can incorporate an underdrain.

4. The final factor is whether the infiltration practice will be designed as an **on-line or off-line facility**, as this determines the nature of conveyance and overflow mechanisms needed. Off-line practices are sized to only accept some portion of the treatment volume (*Tv*), and employ a flow splitter to safely bypass large storms. On-line infiltration practices may be connected to underground perforated pipes to detain the peak storm event, or have suitable overflows to pass the storms without erosion. On-line designs require careful design of the pre-treatment in order

to avoid the large flows from causing scour or turbulence within the practice that can lead to clogging.

SECTION 6: DESIGN CRITERIA

6.1. Defining the Infiltration Rate

Soil permeability is the single most important factor when evaluating infiltration practices. A field-verified minimum infiltration rate of *at least* 1/2 inch/hour is needed for the practice to work.

Projected Infiltration Rate. For planning purposes, the projected infiltration rate for the site can be estimated using the NRCS soil textural triangle for the prevailing soil types shown on the local NRCS Soil Survey. This data is used solely to locate portions of the site where infiltration may be feasible and to pinpoint where actual on-site infiltration tests will be taken to confirm feasibility.

Measured Infiltration Rate. On-site infiltration investigations should always be conducted to establish the actual infiltration capacity of underlying soils, using the methods presented in **Appendix 8-A**.

Design Infiltration Rate. Several studies have shown that ultimate infiltration rates decline by as much as 50% from initial rates, so designers should be very conservative and not attempt to use infiltration on questionable soils. To provide a factor of safety, the infiltration rate used in the design may be no greater than 50% of the measured rate.

6.2. Sizing of Infiltration Facilities

Several equations are needed to size infiltration practices. The first equations establish the maximum depth of the infiltration practice, depending on whether it is a surface basin (**Equation 8.1**)or underground reservoir (**Equation 8.2**).

Equation 8.1. Maximum Surface Basin Depth

$$d_{max} = \left({}^{1}\!/_{2}\, f \times t_d\right) / 12$$

Equation 8.2. Maximum Underground Reservoir Depth

$$d_{max} = (1/2\, f \times t_d) / (\eta \times 12)$$

Where:

d_{max} = maximum depth of the infiltration practice (feet)
f = measured infiltration rate (in./hr)
t_d = maximum drawn down time (normally 48 hours)
η = porosity of the stone reservoir (assume 0.4)

Designers should compare these results to the maximum allowable depths in **Table 8.5**, and use whichever value is *less* for subsequent design.

Table 8.5. Maximum Depth (in feet) for Infiltration Practices

Mode of Entry	Scale of Infiltration		
	Micro Infiltration	Small Scale Infiltration	Conventional Infiltration
Surface Basin	1.0	1.5	2.0
Underground Reservoir	3.0	5.0	varies

Once the maximum depth is known, calculate the surface area needed for an infiltration practice using **Equation 8.3** or **Equation 8.4**:

Equation 8.3. Surface Basin Surface Area

$$SA = Tv_{BMP}/d + \left[\left((1/2)f \times t_f\right)/12\right]$$

Equation 8.4. Underground Reservoir Surface Area

$$SA = Tv_{BMP}/(\eta \times d) + \left[\left((1/2)f \times t_f\right)/12\right]$$

Where:

- SA = Surface area (ft²)
- Tv_{BMP} = Design volume for the BMP, e.g., treatment volume from the contributing drainage area plus any remaining volume from upstream runoff reduction practices (ft³)
- η = Porosity of stone reservoir (assume 0.4)
- d = Infiltration depth (maximum depends on the scale of infiltration and the results of **Equation 8.1** (ft.)
- f = Measured infiltration rate (in./hr)
- t_f = Time to fill the infiltration facility (typically 2 hours)

If the designer chooses to infiltrate less than the full *Tv* (e.g., through the use of micro-infiltration or small-scale infiltration), the runoff reduction rates shown in **Table 8.5** below must be directly prorated in the VRRM Compliance spreadsheet. To qualify for Level 2 runoff reduction rates, designers must provide 110% of the site-adjusted *Tv* (1.1**Tv*).

Commented [C1]: This table does not appear to be in this draft. Was this Table 8.4 in the original version, or perhaps Table 8.1 in this version? Or is there supposed to be a new/separate Table?

6.3. Soil Infiltration Rate Testing

Regardless of the scale of the infiltration application, perform at least one soil profile and one infiltration test per facility. The acceptable methods and the number of on-site soil explorations are outlined in **Appendix 8-A**.

6.4. Pre-treatment Features

Every infiltration practice must include multiple pre-treatment techniques, although the nature of pre-treatment practices depends on the scale at which infiltration is applied. The number, volume and type of acceptable pre-treatment techniques needed for the three scales of infiltration are provided in **Table 8.6**.

Table 8.6. Required Pre-treatment Elements for Infiltration Practices

Pre-treatment [1]	Scale of Infiltration		
	Micro Infiltration	Small-Scale Infiltration	Conventional Infiltration
Number and Volume of Pre-treatment Techniques Employed	**2** external techniques; no minimum pre-treatment volume required.	**3** techniques; **15%** minimum pre-treatment volume required (inclusive).	**3** techniques; **25%** minimum pre-treatment volume required (inclusive); at least **one** separate pre-treatment cell.
Acceptable Pre-treatment Techniques[2]	Leaf gutter screens Grass filter strip Upper sand layer Washed bank run gravel	Grass filter strip Grass channel Plunge pool Gravel diaphragm	Sediment trap cell Sand filter cell Sump pit Grass filter strip Gravel diaphragm
[1] A minimum of 50% of the runoff reduction volume must be pre-treated by a filtering or bioretention practice *prior* to infiltration *if* the site is a restricted stormwater hotspot			

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Note that conventional infiltration practices require pre-treatment of at least 25% of the *Tv*, including a surface pre-treatment cell capable of keeping sediment and vegetation out of the infiltration cell. All pre-treatment practices should be designed such that exit velocities are non-erosive for the two year design storm and evenly distribute flows across the width of the practice (e.g., using a level spreader).

6.5. Conveyance and Overflow

The nature of the conveyance and overflow to an infiltration practice depends on the scale of infiltration and whether the facility is on-line or off-line (**Table 8.7**). Where possible, conventional infiltration practices should be designed offline to avoid damage from the erosive velocities of larger design storms.

Table 8.7. Conveyance and Overflow Choices Based on Infiltration Scale

Conveyance and Overflow	Scale of Infiltration		
	Micro-Infiltration	Small-Scale Infiltration	Conventional Infiltration
Online Design	Discharge to a non-erosive pervious overland flow path designed to convey the 2-year design storm to the street or storm drain system.	An overflow mechanism such as an elevated drop inlet or flow splitter should be used to redirect flows to a non-erosive down-slope overflow channel or stabilized water course designed to convey the 10-year design storm.	
Off-line Design	Not Recommended	A flow splitter or overflow structure; design guidance in Claytor and Schueler (1996) and ARC (2001).	

6.6. Internal Geometry and Drawdowns

Runoff Reduction Volume Sizing. The proper approach for designing infiltration practices is to avoid forcing a large volume of runoff into a comparatively small area. Therefore, individual infiltration practices that are limited in size due to soil permeability and available space need not be sized to achieve the full *Tv* for the contributing drainage area, as long as other runoff reduction practices are applied at the site to meet the remainder of the *Tv*. The total *Tv* as computed using the VRRM Compliance spreadsheet must be accounted for

Infiltration Basin Restrictions. The maximum vertical depth to which runoff may be ponded over an infiltration area is 24 inches (i.e., infiltration basin). The side-slopes should be no steeper than 4H:1V, and if the basin serves a CDA greater than 20,000 sq. ft., a surface pre-treatment cell must be provided (this may be sand filter or dry sediment basin).

Rapid Drawdown. When possible, infiltration practices should be sized so that the target runoff reduction volume infiltrates within 36 hours to 48 hours, to provide a factor of safety that prevents nuisance ponding conditions.

Conservative Infiltration Rates. Designers should always use the design infiltration rate (safety factor of 2), rather than the measured infiltration rate, to approximate long term infiltration rates (see **Section 6.1** above).

Porosity. A value of 0.40 should be used in the design of stone reservoirs, although a larger value may be used if perforated corrugated metal pipe, plastic pipe, concrete arch pipe, or comparable materials are installed within the reservoir.

6.7. Landscaping and Safety

Infiltration trenches can be effectively integrated into the site plan and aesthetically designed with adjacent native landscaping or turf cover, subject to the following additional design considerations:

- Infiltration practices should *NEVER* be installed until all up-gradient construction is completed *AND* pervious areas are stabilized with dense and healthy vegetation.
- Vegetation associated with the infiltration practice buffers should be regularly mowed and maintained to keep organic matter out of the infiltration device and maintain enough native vegetation to prevent soil erosion from occurring.
- Infiltration practices do not pose any major safety hazards after construction. However, if an infiltration practice will be excavated to a depth greater than 5 feet, OSHA health and safety guidelines must be followed for safe construction practices.
- Infiltration trenches and basins with temporary ponding should not be designed to hold water greater than 1 foot deep. Deeper surface ponding (up to 2 feet maximum) may require safety provisions. .

Designers should always evaluate the nature of future operations to determine if the proposed site will be designated as a potential stormwater hotspot (see **Section 10.1**), and comply with the appropriate restrictions or prohibitions applicable to infiltration.

6.8. Maintenance Reduction Features

Maintenance is a crucial element that ensures the long-term performance of infiltration practices. The most frequently cited maintenance problem for infiltration practices is clogging of the surface stone by organic matter and sediment. The following design features can either minimize the risk of clogging or help to identify maintenance issues before they cause failure of the facility:

Pre-treatment Filter Strip of Low Maintenance Vegetation. Regular mowing of turf generates a significant volume of organic debris that can eventually clog the surface of an infiltration trench or basin when located in a turf area; similarly, mulch from landscaped areas can migrate into the infiltration facility. Landscaping vegetation adjacent to the infiltration facility should consist of low maintenance ground cover.

Observation Well. Small-scale and conventional infiltration practices should include an observation well, consisting of an anchored 6-inch diameter perforated PVC pipe fitted with a lockable cap installed flush with the ground surface, to facilitate periodic inspection and maintenance.

Filter Fabric. Geotextile filter fabric should not be installed along the bottom of infiltration practices. Experience has shown that filter fabric is prone to clogging, and a layer of coarse washed stone (choker stone) is a more effective substitute. However, permeable filter fabric must be installed on the trench sides to prevent soil piping. A layer of fabric may also be installed along the top of the practice to help keep organic debris or topsoil from migrating downward into the stone. Periodic maintenance to remove and replace this surface layer will be required to ensure that surface runoff can get into the infiltration practice.

Direct Maintenance Access. Access must be provided to allow personnel and equipment to perform non-routine maintenance tasks, such as practice reconstruction or rehabilitation. While a turf cover is permissible for micro- and small-scale infiltration practices, the surface should not be covered by an impermeable material, such as asphalt or concrete.

6.9. Infiltration Material Specifications

The basic material specifications for infiltration practices are outlined in **Table 8.8** below.

Table 8.8. Infiltration Material Specifications

Material	Specification	Notes
Stone	Clean, aggregate with a maximum diameter of 3.5 inches and a minimum diameter of 1.5 inches (VDOT No. 1 Open-Graded Coarse Aggregate) or the equivalent.	
Observation Well	Install a vertical 6-inch Schedule 40 PVC perforated pipe, with a lockable screw cap and anchor plate.	Install one per 50 feet of length of infiltration the practice.
Trench Bottom	Install a 6 to 8 inch sand layer (VDOT Fine Aggregate, Grade A or B)	
Trench Surface Cover	Install a 3-inch layer of river stone or pea gravel. Turf is acceptable when there is subsurface inflow (e.g., a roof leader).	This provides an attractive surface cover that can suppress weed growth.
Buffer Vegetation	Keep adjacent vegetation from forming an overhead canopy above infiltration practices, in order to keep leaf litter, fruits and other vegetative material from clogging the stone.	
Filter Fabric (sides only)	Use non-woven polyprene geotextile with a flow rate of > 110 gallons/min./sq. ft. (e.g., Geotex 351 or equivalent).	
Choking Layer	Install a 2- to 4-inch layer of choker stone (typically #8 or # 89 washed gravel) over the underdrain stone.	
Overflow Collection Pipe (where needed)	Use 6-inch rigid schedule 40 PVC pipe, with 3/8" perforations at 6 inches on center, with each perforated underdrain, installed at a slope of 1% for the length of the infiltration practice.	Install non-perforated pipe with one or more caps, as needed.

SECTION 7: REGIONAL & SPECIAL CASE DESIGN ADAPTATIONS

7.1. Karst Terrain

Conventional infiltration practices **should not be used** in karst regions due to concerns about sinkhole formation and groundwater contamination. Micro- or small-scale infiltration areas are permissible **only if** geotechnical studies indicate there is at least 4 feet of vertical separation between the bottom of the infiltration facilities and the underlying karst layer *AND* an impermeable liner and underdrain are used. In many cases, bioretention is a preferred stormwater management alternative to infiltration in karst areas.

7.2. Coastal Plain

The flat terrain, low head and high water table of many coastal plain sites can constrain the application of conventional infiltration practices. However, such sites are still suited for micro-scale and small-scale infiltration practices. Designers should maximize the surface area of the infiltration practice, and keep the depth of infiltration to less than 24 inches plus the groundwater separation. Where soils are extremely permeable (more than 4.0 inches per hour), shallow bioretention is a preferred alternative. Where soils are more impermeable (i.e., marine clays with less than 0.5 inches per hour), designers may prefer to use a constructed wetland practice.

7.3. Steep Terrain

Forcing conventional infiltration practices in steep terrain can be problematic with respect to slope stability, excessive hydraulic gradients and sediment delivery. Unless slope stability calculations demonstrate otherwise, it is generally recommended that infiltration practices should be located a minimum horizontal distance of 200 feet from down-gradient slopes greater than 20%. Micro-scale and small-scale infiltration can work well, as long as their smaller up-gradient and down-gradient building setbacks are satisfied.

7.4. Cold Climate and Winter Performance

Infiltration practices can be designed to withstand more moderate winter conditions. The main problem is caused by ice forming in the voids or the subsoils below the practice, which may briefly result in nuisance flooding when spring melting occurs. The following design adjustments are recommended for infiltration practices installed in higher elevations:

- The bottom of the practice should extend below the frost line.
- Infiltration practices are not recommended at roadside locations that are heavily sanded and/or salted in the winter months (to prevent movement of chlorides into groundwater and prevent clogging by road sand).
- Pre-treatment measures can be oversized to account for the additional sediment load caused by road sanding (up to 40% of the *Tv*).
- Infiltration practices must be set back at least 25 feet from roadways to prevent potential frost heaving of the road pavement.

7.5. Linear Highway Sites

Infiltration practices can work well for linear highway projects, where soils are suitable and can be protected from heavy disturbance and compaction during road construction operations.

SECTION 8: CONSTRUCTION

8.1. Construction Sequence

The following is a typical construction sequence to properly install infiltration practices. The sequence may need to be modified to reflect the scale of infiltration, site conditions, and whether or not an underdrain needs to be installed.

Infiltration practices are particularly vulnerable to failure during the construction phase for two reasons. First, if the construction sequence is not followed correctly, construction sediment can clog the practice. In addition, heavy construction can result in compaction of the soil, which can then reduce the soil's infiltration rate. For this reason, a careful construction sequence needs to be followed. Ideally, the infiltration practice should be outside the limits of disturbance.

During site construction, the following steps are absolutely critical:

- Avoid excessive compaction by delineating the area of the proposed practice and preventing construction equipment and vehicles from traveling over the proposed location.

- Keep the infiltration practice “off-line” until construction is complete. Prevent sediment from entering the infiltration site by using super silt fence, diversion berms or other means. In the erosion and sediment (E&S) control plan, indicate the earliest time at which stormwater runoff may be directed to a conventional infiltration basin The E&S control plan must also indicate the specific methods to be used to temporarily keep runoff from the infiltration site.
- Infiltration practice sites should never serve as the sites for temporary sediment control devices (e.g., sediment traps, etc.) during construction.
- Upland drainage areas need to be completely stabilized with a thick layer of vegetation prior to commencing excavation for an infiltration practice, as verified by the local erosion and sediment control inspector/program.

8.2. Installation

The actual installation of an infiltration practice is done using the following steps:

1. Excavate the infiltration practice to the design dimensions *from the side***,** using a backhoe or excavator. The floor of the pit should be completely level, but equipment should be kept off the floor area to prevent soil compaction.

2. Correctly install filter fabric on the trench sides. Large tree roots should be trimmed flush with the sides of infiltration trenches to prevent puncturing or tearing of the filter fabric during subsequent installation procedures. When laying out the geotextile, the width should include sufficient material to compensate for perimeter irregularities in the trench and for a 6-inch minimum overlap at the top of the trench. The filter fabric itself should be tucked under the sand layer on the bottom of the infiltration trench. Stones or other anchoring objects should be placed on the fabric at the trench sides, to keep the trench open during windy periods. Voids may occur between the fabric and the excavated sides of a trench. Natural soils should be placed in all voids, to ensure the fabric conforms smoothly to the sides of excavation.

3. Scarify the bottom of the infiltration practice, and spread 6 inches of sand on the bottom as a filter layer.

4. Anchor the observation well(s), and add stone to the practice in 1-foot lifts.

5. Use sod to establish a dense turf cover for at least 10 feet on each side of the infiltration practice to reduce erosion and sloughing. If the vegetation is seeded instead, use native grasses primarily due to their adaptability to local climates and soil conditions.

8.3. Construction Inspection

Inspections are needed during and immediately after construction to ensure that the infiltration practice is built in accordance with the approved design and this specification. Qualified individuals should use detailed inspection checklists to include sign-offs at critical stages of construction, to ensure that the contractor’s interpretation of the plan is consistent with the designer’s intentions. An example construction phase inspection checklist for Infiltration practices is provided at the end of this specification. Inspection during the following key points during construction will help insure successful performance:

- Check elevations of the excavation invert. Ensure that the soil at the bottom of the infiltration facility has not has smeared by the excavation equipment. The bottom soil should be scarified with the teeth of the backhoe bucket.
- Installation of the bottom 6-inch sand filter layer and the initial layer of stone prior to placement of any storage components.
- Top cover of pea gravel or turf as required on plans.
- Stabilization of adjacent pre-treatment filter strips and the contributing drainage area prior to bringing infiltration area into service.

Upon final inspection and acceptance, the GPS coordinates should be logged for all infiltration practices and submitted for entry into the local BMP maintenance tracking database.

SECTION 9: MAINTENANCE

9.1. Maintenance Agreements

The Virginia Stormwater Management regulations specify the circumstances under which a maintenance agreement must be executed between the owner and the VSMP Authority and sets forth inspection requirements, compliance procedures if maintenance is neglected, notification of the local program upon transfer of ownership, and right-of-entry for local program personnel.

- When micro-scale or small-scale infiltration practices are installed on private residential lots, homeowners will need to (1) be educated about their routine maintenance needs, (2) understand the long-term maintenance plan, and (3) be subject to a deed restriction, drainage easement or other mechanism enforceable by the VSMP Authority to ensure that infiltrating areas are not converted or disturbed.
- The mechanism should, if possible, grant authority for local agencies to access the property for inspection or corrective action.

9.2. Maintenance Inspections

Annual site inspections are critical to the performance and longevity of infiltration practices, particularly for small-scale and conventional infiltration practices. Maintenance of infiltration practices is driven by annual inspections that evaluate the condition and performance of the practices, including the following:

- The drawdown rate should be measured at the observation well for three days following a storm event in excess of 1/2 inch in depth. If standing water is still observed in the well after three days, this is a clear sign that that clogging is a problem.
- Check inlets, pre-treatment cells, and any flow diversion structures for sediment buildup and structural damage. Note if any sediment needs to be removed.
- Inspect the condition of the observation well and make sure it is still capped.
- Check that no vegetation forms an overhead canopy that may drop leaf litter, fruits and other vegetative materials that could clog the infiltration device.

- Evaluate the vegetative quality of the adjacent grass buffer and perform spot-reseeding if the cover density is less than 90%.
- Generally inspect the upland contributing drainage area for any controllable sources of sediment or erosion.
- Look for weedy growth on the stone surface that might indicate sediment deposition or clogging.
- Inspect maintenance access to ensure it is free of woody vegetation, and check to see whether valves, manholes and/or locks can be opened and operated.
- Inspect internal and external infiltration side slopes for evidence of sparse vegetative cover, erosion or slumping, and make necessary repairs immediately.

Based on inspection results, specific maintenance tasks will be triggered. Example maintenance inspection checklists for infiltration practices can be accessed in Appendix C of Chapter 9 of the *Virginia Stormwater Management Handbook* (2010)

9.3. Ongoing Maintenance

Effective long-term operation of infiltration practices requires a dedicated and routine maintenance inspection schedule with clear guidelines and schedules, as shown in **Table 8.9** below. Where possible, facility maintenance should be integrated into routine landscaping maintenance tasks.

Table 8.9. Typical Maintenance Activities for Infiltration Practices

Maintenance Activity	Schedule
• Replace pea gravel/topsoil and top surface filter fabric (when clogged). • Mow vegetated filter strips as necessary and remove the clippings.	As needed
• Ensure that the contributing drainage area, inlets, and facility surface are clear of debris. • Ensure that the contributing drainage area is stabilized. • Remove sediment and oil/grease from pre-treatment devices, as well as from overflow structures. • Repair undercut and eroded areas at inflow and outflow structures.	Quarterly
• Check observation wells 3 days after a storm event in excess of 1/2 inch in depth. Standing water observed in the well after three days is a clear indication of clogging. • Inspect pre-treatment devices and diversion structures for sediment build-up and structural damage. • Remove trees that start to grow in the vicinity of the infiltration facility.	Semi-annual inspection
• Clean out accumulated sediments from the pre-treatment cell.	Annually

SECTION 10: COMMUNITY & ENVIRONMENTAL CONCERNS

10.1. Designation of Stormwater Hotspots

Stormwater hotspots are operations or activities that are known to produce higher concentrations of stormwater pollutants and/or have a greater risk for spills, leaks or illicit discharges. **Table 8.10** presents a list of potential land uses or operations that may be designated as a **stormwater hotspot**. It should be noted that the actual hotspot generating area may only occupy a portion of the entire proposed use, and that some "clean" areas (such as rooftops) can be diverted away to another infiltration or runoff reduction practice. Communities should carefully review development proposals to determine if any future operation, on all or part of the site, will be designated as a potential stormwater hotspot. Based on this designation, one or more design responses are required, as shown below:

1. ***Stormwater Pollution Prevention Plan (SWPPP)***. The SWPPP, required as part of a VPDES industrial activity or a municipal stormwater permit, outlines pollution prevention and treatment practices that will be implemented to minimize polluted discharges from the on-going operations of the facility. (NOTE: This is different from the SWPPP required as part of regulated construction activities.) Other facilities or operations that are not classified as industrial activities (SIC Codes) are not required to have an Industrial VPDES permit, but may still be designated as potential stormwater hotspots by the local review authority, as part of their local stormwater ordinance (these are shown in the shaded areas of **Table 8.10**). It is recommended that these facilities include an addendum to their stormwater plan that details the pollution prevention practices and employee training measures that will be used to reduce contact of pollutants with rainfall or snowmelt.

2. ***Restricted Infiltration***. A minimum of 50% of the total *Tv* must be treated by a filtering or bioretention practice prior to any infiltration. Portions of the site that are not associated with the hotspot generating area should be diverted away and treated by another acceptable stormwater management practice.

3. ***Infiltration Prohibition.*** The risk of groundwater contamination from spills, leaks or discharges is so great at hotspot sites that infiltration of stormwater or snowmelt is ***prohibited*****.**

Table 8.10. Potential Stormwater Hotspot and Site Design Responses

Potential Stormwater Hotspot Operation	SWPP Required?	Restricted Infiltration	No Infiltration
Facilities w/NPDES Industrial permits	Yes	■	■
Public works yard	Yes		✓
Ports, shipyards and repair facilities	Yes		✓
Railroads/ equipment storage	Yes		✓
Auto and metal recyclers/scrapyards	Yes		✓
Petroleum storage facilities	Yes		✓
Highway maintenance facilities	Yes		✓
Wastewater, solid waste and composting facilities	Yes		✓
Industrial machinery and equipment	Yes	✓	
Trucks and trailers	Yes	✓	
Airfields	Yes	✓	
Aircraft maintenance areas	Yes		✓
Fleet storage areas	Yes		✓
Parking lots (40 or more parking spaces)	No	✓	
Gas stations	No		✓
Highways (2500 ADT)	No	✓	
Construction business (paving, heavy equipment storage and maintenance	No	✓	
Retail/wholesale vehicle/ equipment dealers	No	✓	
Convenience stores/fast food restaurants	No	✓	
Vehicle maintenance facilities	No		✓
Car washes	No		✓
Nurseries and garden centers	No	✓	
Golf courses	No	✓	
Note: For a full list of potential stormwater hotspots. please consult Schueler et al (2004)			
Key: ■ = depends on facility; ✓ = criterion applies			

10.2. Other Environmental and Community Issues

The following is a list of several other community and environmental concerns that may also arise when infiltration practices are proposed:

Nuisance Conditions. Poorly designed infiltration practices can create potential nuisance problems such as basement flooding, poor yard drainage and standing water. In most cases, these problems can be minimized through proper adherence to the setback, soil testing and pre-treatment requirements outlined in this specification.

Mosquito Risk. Infiltration practices have some potential to create conditions favorable to mosquito breeding, if they clog and have standing water for extended periods.

Groundwater Injection Permits. Groundwater injection permits are required if the infiltration practice is deeper than the longest surface area dimension of the practice (EPA, 2008). Designers should investigate whether or not a proposed infiltration practice is subject to ~~a~~ state or local groundwater injection permit requirements.

Sample Construction Inspection Checklist for Infiltration Practices: The following checklist provides a basic outline of the anticipated items for the construction inspection of Infiltration Practices. The users of this information may wish to incorporate these items into a VSMP Authority Construction Checklist format consistent with the format used for erosion and sediment control and BMP construction inspections.

☐ Pre-construction meeting with the contractor designated to install the infiltration practice has been conducted.

☐ Subsurface investigation and soils report supports the placement of an infiltration practice in the proposed location.

☐ Impervious cover has been constructed/installed and area is free of construction equipment, vehicles, material storage), etc.

☐ Area of infiltration practice has not been impacted during construction.

☐ All pervious areas of the contributing drainage areas have been adequately stabilized with a thick layer of vegetation and erosion control measures have been removed.

☐ Stormwater has been diverted around the area of the infiltration practice and perimeter erosion control measures to protect the facility during construction have been installed. .

☐ Excavation of the infiltration practice has achieved proper grades and the required geometry for the subsurface infiltration trench or the surface infiltration basin without compacting the bottom of the excavation.

☐ **Certification of Excavation Inspection**: Inspector certifies the successful completion of the excavation steps listed above.

☐ For infiltration trenches, placement of filter fabric, as required, on the side slopes.

☐ Bottom of trench has been scarified.

☐ Six-inch filter layer of sand placed on the trench bottom

☐ Observation well installed.

☐ Remaining stone aggregate placed (not dumped) in 6-inch lifts.

☐ Top surface of infiltration practice in accordance with approved plans.

☐ All erosion and sediment control practices have been removed.

☐ Follow-up inspection and as-built survey/certification has been scheduled.

☐ GPS coordinates have been documented for all infiltration practices on the parcel.

SECTION 11: REFERENCES

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APPENDIX 8-A

INFILTRATION and SOIL TESTING

Introduction

The goals of Runoff Reduction and compliance with the Virginia Stormwater Management Program (VSMP) Regulations on new and re-development are based on having a practical understanding of the soil conditions and their hydrologic response characteristics. This is especially important in the initial layout and design of the site development infrastructure: strategically locating impervious cover over soils with low permeability (Hydrologic Soil Groups C and D), directing runoff to soils that are highly permeability (Hydrologic Soil Groups A and B), and selecting appropriate runoff reduction BMPs.

Accurately identifying the Hydrologic Soil Group (HSG) of the existing soils is also an important first design step in computing the design *Tv* and appropriate runoff reduction credit. More importantly, drainage area runoff computations using the Natural Resources Conservation Service (NRCS) methodology require knowledge of a soil's HSG, particularly for soils with pervious land covers.

1. Site Evaluation – Initial Screening

The initial screening of the on-site soils should be conducted in conjunction with a Natural Resources Inventory (**Chapter 6**). This exercise should identify basic soil characteristics related to stormwater management, such as the Hydrologic Soil Groups (HSG), as well as other features relevant to construction activities (e.g. erosion and sediment control). Also, the initial screening should identify where more detailed soil investigation and field determinations may be needed to refine the limits of the different HSGs as defined in the soil survey, or where field conditions indicate different characteristics than those indicated in the survey. This is especially important on sites with previously disturbed soils. The designer could assume the impacted soils are HSG D; however as has been found in many retrofit situations, the disturbed soils may be sufficiently permeable to support infiltration. A site evaluation as described in Section 2 below can identify the actual soil texture and permeability.

The initial screening should also include the identification of locations deemed suitable for infiltration BMPs and therefore further detailed geotechnical investigations. In general, designers should evaluate the potential for multiple small infiltration practices rather than relying on fewer large scale infiltration practices. Experience in other jurisdictions indicates that larger infiltration practices with correspondingly large contributing drainage areas experience maintenance problems due to excessive hydraulic loading (CWP 2009). Multiple smaller infiltration practices will also be less likely to have groundwater mounding problems.

Therefore, the initial screening should be broad in terms of soil types across the site, yet also detailed enough to advise the efficient implementation of more detailed soils and subsurface investigation.

NOTE: *Designers must be aware of the proposed earthwork for the final development layout when conducting the initial screening. Areas of cut and/or fill must be carefully evaluated for structural stability in addition to any precautions with regard to stormwater management designs. Infiltration or infiltration sumps located in the vicinity of fill has the potential to compromise the stability of the fill section by creating a slip-plane.*

*If the designer is not be aware of the final grading plan when developing a stormwater concept plan, he/she must coordinate the stormwater BMP type and placement with the site designer to ensure that the final locations are investigated and a licensed or otherwise qualified professional (as described in **Section X** of this Appendix) has conducted a geotechnical exploration and provided design recommendations. These recommendations must be included in the final geotechnical report as well as the stormwater management design report.*

2. Site Evaluation – Soil Characterization and Hydrologic Soil Groups

In accordance with NRCS recommendations, a soil's HSG is typically determined through information available in the NRCS Soil Survey. Detailed information can be found in local USDA NRCS Soil Surveys or online at the USDA NRCS Data Mart (http://soildatamart.nrcs.usda.gov). A listing of HSGs for Virginia soils is also included in Appendix 11-B of the *Virginia Stormwater Management Handbook* (2nd Edition, 2013). However, at certain locations, the Soil Survey does not have sufficient information to determine the HSG, or it has been mapped as Urban Land with an assumed default HSG D. It is also possible that direct soil observations or tests may indicate that a soil's HSG is different than that which is provided by the Soil Surveys due to mapping errors or the soil having been altered through cuts, fills or other disturbances.

In all cases, the designer should evaluate the existing soils to ensure a proper HSG designation for calculating the *Tv*, as well as any other construction related soil suitability limitations. The following guidance is intended to:

i) Assist in verifying the mapped soils,
ii) In cases where it has been determined that there are errors in mapping, assist in determining the soil characteristics, and
iii) Identify the applicability of the soils for certain infiltration practices by field verifying the permeability or infiltration rate of the soils.

Soils are grouped into Hydrologic Soils Groups A, B, C, or D based on similarities in certain characteristics:

- soil texture and structure;
- depth to a restrictive layer: (i.e. soil morphological characteristics which restrict the vertical movement of water including but not limited to abrupt textural boundaries, fragipan, bedrock, dense or cemented soils);
- depth to water table;
- hydraulic conductivity or transmission rate of water; and
- degree of swelling when saturated.

Terminology Alert: *In order to help designers work through the various elements of soil science related to BMP selection and stormwater design, the following provides basic definitions of some of the more common terms:*

Soil infiltration: the rate at which stormwater enters the soil. Infiltration is influenced by soil structure, compaction, organic matter, moisture content, and other physical characteristics at the soil surface. The design infiltration rate is usually expressed as a constant value, but the actual infiltration rate will be proportional to the hydraulic head or gradient.

Soil permeability – the rate at which stormwater flows through the soil.

NOTE: ***Infiltration* and *Permeability* are often used interchangeably in many reference materials.**

Soil Hydraulic Conductivity: the hydraulic conductivity (K) of a given soil can be related to its infiltration and permeability. The rate at which water enters the soil, *infiltration*, under optimal conditions, starts very fast and then declines and eventually approaches a constant rate of entry. This constant rate of infiltration is sometimes called the soil's *permeability*, but is technically defined as the *saturated hydraulic conductivity* (*Ksat*). In almost all cases, reference to an infiltration rate implies this long-term constant rate (permeability or Ksat). (Jarrett, 2008).

The property that is most limiting to water movement or the hydraulic conductivity generally determines the soil's hydrologic group. (USDA NRCS, May 2007)

For example, in terms of soil texture, Group C soil includes silt loam and sandy clay loam and is typically between 20 percent and 40 percent clay and less than 50 percent sand. There are some overlaps where the texture classes may include a range of sand-silt-clay fractions in one HSG and the same texture name with a slightly different fraction in a different HSG. For example, soils having clay, silty clay, or sandy clay texture (typically grouped in HSG D) may be placed in Group C if they are well aggregated, of low bulk density, or contain greater than 35 percent rock fragments.

Equally important are the defining physical characteristics of the group: the depth to a restrictive layer or water table, and saturated hydraulic conductivity. For Group C, the depth to any water impermeable layer is greater than 20 inches, and the depth to the water table is greater than 24 inches. Soils that are deeper than 40 inches to a restriction or water table are in Group C if the saturated hydraulic conductivity of all soil layers within 40 inches of the surface is less than 0.57 inches per hour (but exceeds 0.06 inches per hour). The saturated hydraulic conductivity in the least transmissive layer between the surface and 20 inches is between 0.14 in/hr and 1.42 in/hr.

In very general terms, water transmission through C soils is *somewhat* restricted, and they have moderately high runoff potential when thoroughly wet. A general definition of the HSG is provided:

Group A. Soils with low runoff potential. Soils having high infiltration rates even when thoroughly wetted and consisting chiefly of deep well drained to excessively well-drained sands or gravels and have a high rate of water transmission.

Group B. Soils having moderate infiltration rates even when thoroughly wetted and consisting chiefly of moderately deep to deep, moderately well drained to well drained soils with moderately fine to moderately coarse textures and have a moderate rate of water transmission .

Group C. Soils having slow infiltration rates even when thoroughly wetted and consisting chiefly of soils with a layer that impedes downward movement of water, or soils with moderately fine to fine textures and have a slow rate of water transmission.

Group D. Soils with high runoff potential. Soils having very slow infiltration rates even when thoroughly wetted and consisting chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material and have a very low rate of water transmission.

NOTE: *Readers are encouraged to refer to* ***National Engineering Handbook Chapter 7: Hydrologic Soil Groups****, and the* ***USDA Soil Survey Manual, Chapter 3*** *for detailed guidance on the application of soil classification criteria for determining the hydrologic group of a particular soil based on the characteristics observed and recorded from the soil profile pits and soil borings: soil texture, bulk density, depth to water table (or other restrictive layer), and if available, the saturated hydraulic conductivity.*

"Restrictions" in the soil profile are defined in the 1996 National Soil Survey Handbook and include, but are not limited to the presence of bedrock, dense material, fragipans, and ortsteins. The seasonally high water table is based on either observed saturation or redoxomorphic features. The presence and depth of these restrictions must be included in the soil logs.

The lead investigator should evaluate the available soil survey information and compare it with site visit observations to determine if the soil exploration is needed to more accurately identify and locate the hydrologic soil groups on the site. **Table 8A.1** provides guidelines for the number of soil test pits and soil borings for identifying and classifying soils on a development site. (**Section 3** below provides additional information on the procedures for soil borings and profile pits for the general purposes of identifying the hydrologic soil groups or hydraulic conductivity tests at specific locations).

Table 8A.1. Soil Explorations Required for Hydrologic Soil Group Classification

Mapping unit or DA size		
< 0.5 ac	**> 0.5 ac; < 2.0 ac**	**> 2 ac**
1 Soil Profile Pit 1 Soil Boring	1 Soil Profile Pit 4 Soil Borings	1 additional Soil Profile Pit[1] 2 additional Soil Borings[1]

[1] For each additional 2 acres

3. Site Evaluation – Soil Testing for Infiltration BMPs

Where infiltration of runoff into the existing soil strata is part of the selected BMP runoff reduction strategy, the designer must determine the actual soil permeability through field tests. The failure of stormwater infiltration devices is often attributed to an inaccurate estimation of the design infiltration rate and/or depth to the seasonal high water table or other limiting layer. There are also numerous examples of infiltration BMP failures attributed to a lack of sediment control or other protections during construction, or inadequate runoff pre-treatment and long term maintenance. However, those deficiencies are addressed through better design, construction, and operation and maintenance guidance. The purpose of this guidance is to provide clear expectations for the number and type of soil tests required in order to ensure that the individual infiltration practice is appropriate for specific site location.

The goals of the soil tests are to establish detailed information on groundwater conditions and physical characteristics of the soil to determine the suitability of the soil for a stormwater infiltration BMP. Soil testing will include soil profile test pits or soil borings, and infiltration tests. At a minimum, any stormwater practice that requires confirmation of soil conditions and depth to groundwater or bedrock should include one soil profile and two infiltration tests (if required).

Table 8A.2 Number of Soil Profiles and Infiltration Tests Required

Area of Practice	# of Soil Profile Explorations	# of Infiltration (Permeability) Tests
Up to 2,500 ft^2	1	2*
2,500 ft2 to 5,000 ft^2	2	3
5,000 ft2 to 7,500 ft^2	2	4
7,500 ft2 to 10,000 ft^2	2	5
Greater than 10,000 ft^2	Add 1 soil profile and 2 infiltration tests for each additional 5,000 ft^2 of practice	
Linear practices should add 1 additional soil profile for each 100 linear feet of practice, and 1 additional infiltration test for each additional 50 linear feet of practice. *Micro scale applications with a small footprint (<500 ft^2), such as a downspout disconnection (Design Specification No. 1) require only one infiltration test per location.		

The depth of soil profiles and infiltration tests should extend no less than four feet below the invert of the bottom of the BMP, or a depth of two times the maximum potential water depth in the BMP below the proposed surface of the BMP, whichever is greater. Sampling should occur from a depth two feet above the proposed facility invert to the full depth of the boring. The initial profile and infiltration test should be located centrally in the practice footprint, with additional explorations located equal distant and representative of the practice footprint.

Data recorded in each reference soil profile should be compared to the soil profile described in the adjacent soil exploration(s) to confirm consistency. Where soil and/or groundwater properties vary significantly between soil explorations, additional soil profiles or infiltration tests should be conducted as necessary to resolve such differences and accurately characterize the soils in the area of interest.

The location of the soil explorations must be shown on a legible site plan/map that:

- Is drawn to scale or fully dimensional.
- Illustrates the location of the infiltration devices.
- Shows the location of all pits and borings.
- Shows distance from infiltration devices to wetlands, or other sensitive features.

Soil Profiles

The documentation of soil profiles should include a soil log prepared for each soil profile pit and/or soil boring in accordance with ASTM D 1452 Practice for Soil Investigation and Sampling Auger Borings, and a description of all soil horizons encountered according to the Unified Soil Classification System (USCS) per ASTM D-2488 (Description and Identification of Soils Visual-Manual Procedure) and USDA textural classification. In addition, results from Dynamic Cone Penetrometer (DCP) [ASTM Special Technical Publication #399] test or Standard Penetration Test (SPT) [ASTM D1586-99] results should be provided. The soil boring log should, at a minimum, include the following:

a. elevation of the existing ground surface and elevations of permeability test locations;
b. the depth and thickness of each soil horizon and the depth to the substratum;
c. the dominant matrix or background and mottle colors, abundance, size, and contrast using the Munsell system of classification for hue, value and chroma;
d. the appropriate textural class as shown on the USDA textural triangle;
e. the volume percentage of coarse fragments larger than two (2) millimeters in diameter;
f. soil structure, particle sizes, and shape;
g. the soil moisture condition, using standard USDA classification terminology;
h. the depth and occurrence of soil restrictions including, but not limited to, abrupt textural boundaries likely to restrict the movement of water, fragipans, dense materials, bedrock, and ortstein;
i. the depth to the seasonally high ground water level, either perched or regional;
j. any observed seepage or saturation; and
k. elevation of the seasonally high groundwater table[1].

[1]The Seasonally High Water Table (SHWT) elevation is required to ensure that the proposed bottom of the stormwater practice meets the minimum separation distance to the groundwater. Determination of the SHWT elevation should be determined in accordance with the guidance provided in **Section 4** of this appendix.

Infiltration Field Tests (required)

Permeability tests (otherwise also referred to as infiltration tests or hydraulic conductivity tests) must be conducted at the most restrictive layer between the bottom elevation of the proposed infiltration BMP and a depth of 4 feet below the bottom, or two times the maximum potential water depth in the BMP, whichever is greater. For example, permeability tests for a bioretention basin that is proposed to be 4 feet in depth with a maximum potential water depth of 4.5 feet should be conducted at the most restrictive layer between a depth of 4 feet and the greater of 7 feet or two times the water depth, or 9 feet, below the surface.

Where stormwater infiltration BMPs are in proximity to fractured bedrock, there should be a minimum of two feet of soil between the bottom of the infiltration BMP and the bedrock. Where the permeability rate of the bedrock is critical to the function of the basin, the design engineer should demonstrate that appropriate testing methods (such as a Basin Flood Test) are used to establish the permeability rates of the infiltration BMP.

The number of permeability tests for fractured bedrock should be no less than the tests required for permeability in the soil.

The following tests are acceptable for use in determining soil infiltration rates. Other tests may be allowed at the discretion of the local plan approving authority. The Geotechnical Report should include a detailed description of the test method and published source references:

- Tube Permeameter Method (ASTM D 2434);
- Double-Ring Infiltrometer (ASTM D 3385);
- Basin flooding test for bedrock; or
- other constant head permeability tests that use in-situ conditions and accompanied by a recognized published source reference.

All soil evaluations, including test profile pits, soil borings, and permeability tests should be conducted under the supervision of a licensed Soil Scientist or other licensed professional acceptable to the authority having jurisdiction.

4. Seasonally High Water Table

The following guidance is excerpted from Testing Guidelines for Infiltration Facilities published by the Fairfax County Public Works and Environmental Services and represents comprehensive guidance on accurately determining the seasonally high water table elevation. VSMP Authorities, especially those in Virginia's coastal plain, may elect to incorporate guidance specific to the local conditions.

Determination of the SHWT should be performed during the months of November through May. SHWT determination by direct observation of the groundwater level should not be performed during the months of June through October unless the value of the Palmer Drought Severity Index (PDSI) is equal to or greater than 2.0 (i.e., wet). If the value of the PDSI is less than 2.0 (i.e., near normal or drier), the determination of SHWT by direct observation and testing conducted during the months of June through October may be used for preliminary design only. Final design should then be based on a confirmatory investigation performed during the months of November through May (or anytime of the year when the PDSI is equal to or greater than 2.0). Weekly values of the PDSI are available online from the National Weather Service Climate Prediction Center (http://www.cpc.ncep.noaa.gov/products/monitoring_and_data/drought.shtml)

The SHWT may be determined using soil morphology throughout the year by a certified professional registered in Virginia, with training and experience in soil morphology (certified professional soil scientist, professional wetland delineator or professional geologist). Professional engineers registered in Virginia with experience in the field of geotechnical engineering may also be certified to determine the SHWT provided that they have successfully completed training on Soil Morphology deemed to be acceptable to the VSMP Authority. (Classes are offered by the

Northern Virginia Soil and Water Conservation District (NVSWCD) http://www.fairfaxcounty.gov/nvswcd/ ; comparable classes may be offered in other regions of Virginia.)

Evaluation of the SHWT using soil morphology should be based on low chroma colors, mottles and redoximorphic features of the soil. Unlike other types of field tests which may be performed by an individual under the responsible charge of the registered professional, this evaluation must be performed by the registered/certified professional personally. If the registered/certified professional performing the evaluation determines that a follow-up confirmatory field measurement of the SHWT is required, or if required by the VSMP Authority, the follow-up evaluation should be performed when the Palmer Drought Severity Index (PDSI) is equal or greater than 2.0 or anytime during the months of November through May. Additional information on the use of soil morphology is available in these publications: *Soil Morphology as an Indicator of Seasonal High Water Tables* by Peter C. Fletcher, USDA-NRCS, and Peter L.M. Veneman, University of Massachusetts, and *Soil Wetness and Morphological Relations* by Dr. David Linbo, North Carolina State University.

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