

## 1.0 Stormwater Infiltration

**Definition:** Practices that capture and temporarily store the design storm volume before allowing it to infiltrate into the soil over a two day period. Design variants include:

- 1-A Infiltration Trench
- 1-B Infiltration Basin



Infiltration practices use temporary surface or underground storage to allow incoming stormwater runoff to exfiltrate into underlying soils. Runoff first passes through multiple pretreatment 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 are suitable for use in residential and other urban areas where *measured* soil permeability rates exceed 1 inch per hour. To prevent possible groundwater contamination, infiltration should not be utilized at sites designated as stormwater hotspots. Extraordinary care shall be taken to assure that long-term infiltration rates are achieved through the use of performance bonds, post construction inspection and long-term maintenance.

### 1.1 Infiltration Stormwater Credit Calculations

Infiltration practices receive 100% retention volume credit ( $R_v$ ) for the volume stored and infiltrated by the practice (**Table 1.1**). No additional pollutant removal credit is awarded.

**Table 1.1 Infiltration Performance Credits**

Runoff Reduction	
Retention Allowance	100%
RP <sub>v</sub>	100% of Retention Storage
C <sub>v</sub>	100% of Retention Storage
F <sub>v</sub>	100% of Retentions Storage
Pollutant Reduction	
TN Reduction	100% of Load Reduction
TP Reduction	100% of Load Reduction
TSS Reduction	100% of Load Reduction

The practice must be sized using the guidance detailed in *Section 1.5. Infiltration Design Criteria*

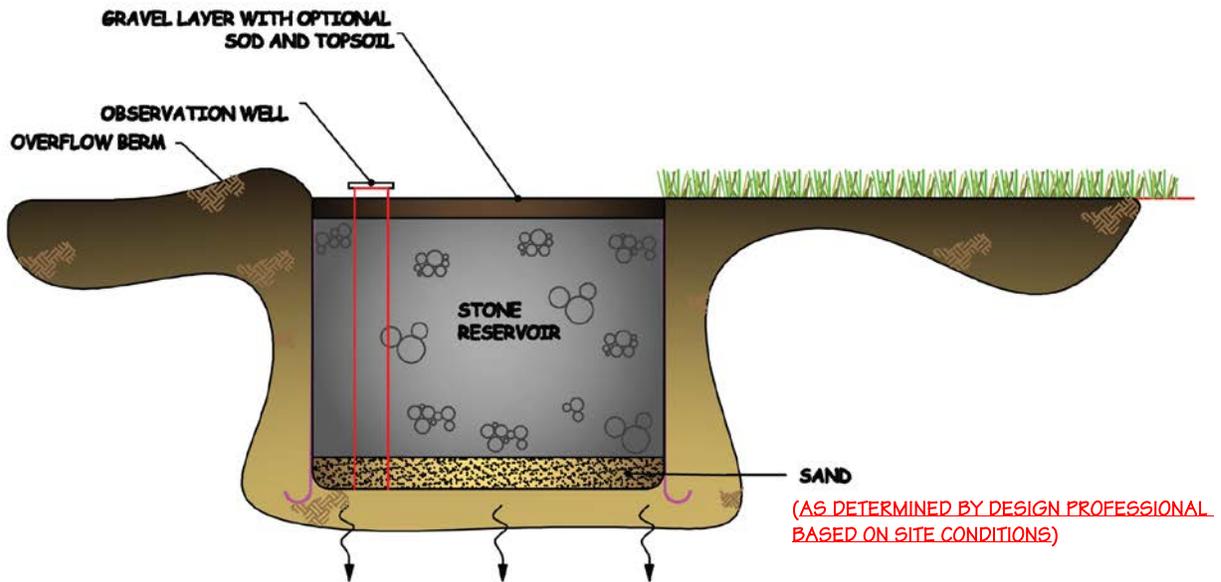


Figure 1.1. Infiltration Trench.

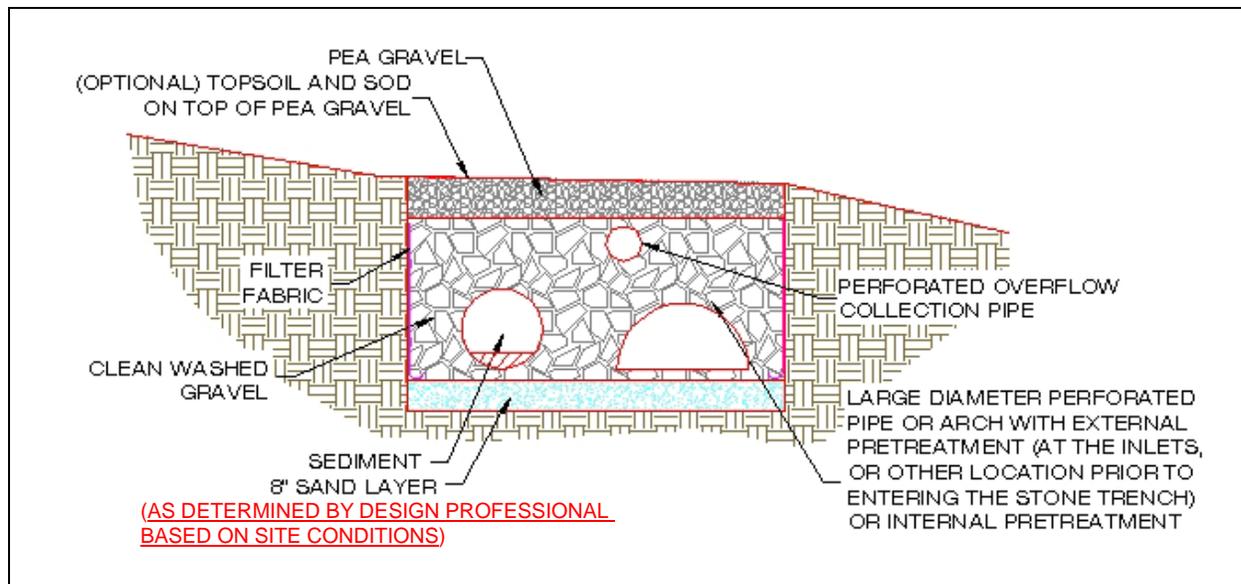


Figure 1.2. Infiltration Section with Supplemental Pipe Storage.

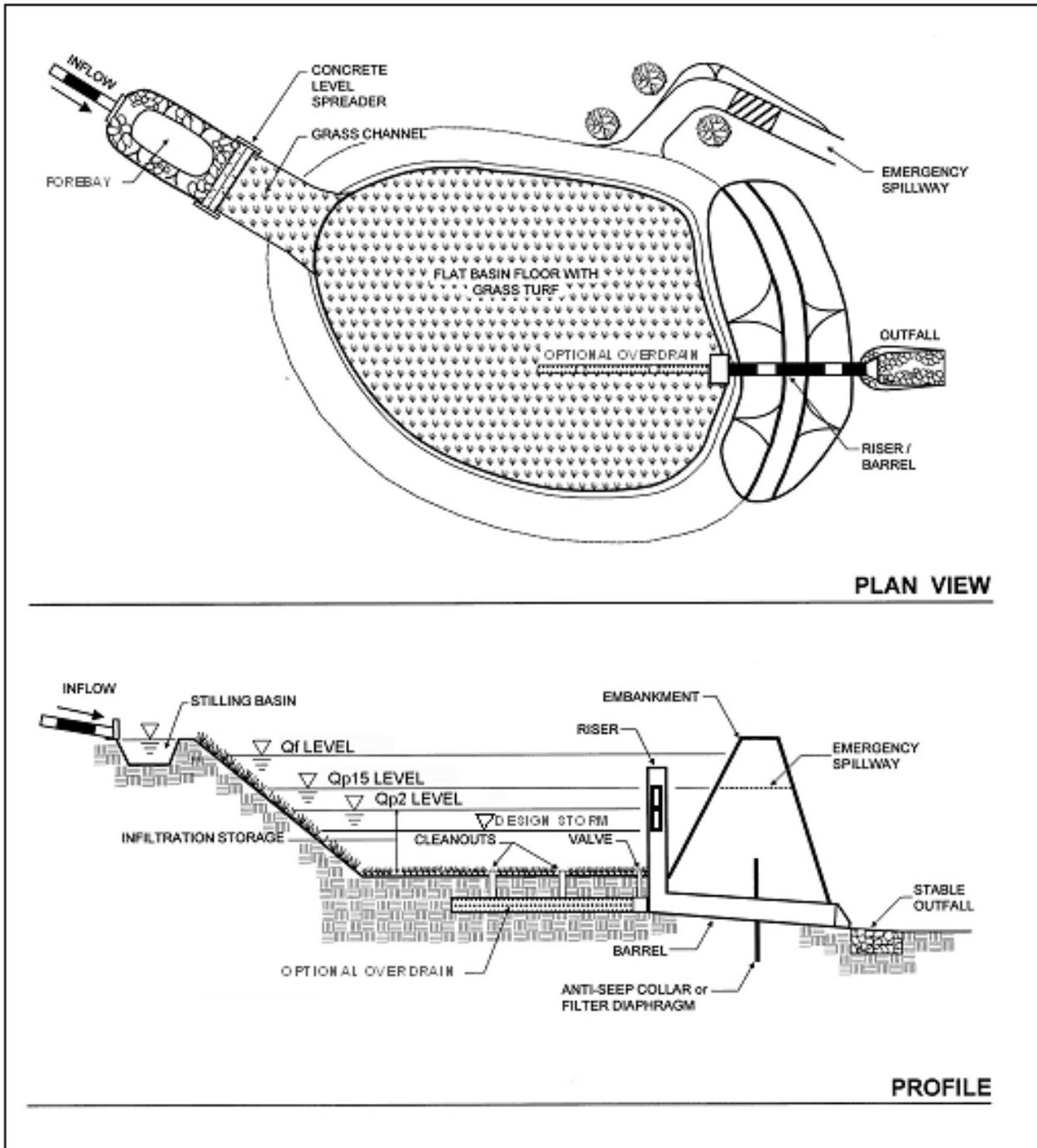


Figure 1.3. Infiltration Basin.

## 1.2 Infiltration Design Summary

Table 1.2 summarizes design criteria for infiltration practices, and Table 1.3 summarizes the materials specifications for these practices. For more detail, consult Sections 1.3 through 1.7. Section 1.8 describes practice construction and maintenance criteria.

**Table 1.2 Infiltration Design Summary**

	Basins	Trenches
Feasibility (Section 1.3)	<ul style="list-style-type: none"> <li>• Minimum soil infiltration of 1"/hr</li> <li>• Restrictions for treating hotspots, high loads, or dry weather flows</li> <li>• 2 foot separation from seasonal high groundwater for infiltration without underdrain</li> <li>• For infiltration with underdrain, invert of underdrain must be above seasonal high groundwater</li> <li>• Setbacks from wells, buildings and utilities</li> </ul>	
Conveyance (Section 1.4)	<ul style="list-style-type: none"> <li>• Must safely convey the Conveyance Event (Cv)</li> </ul>	
Pretreatment (Section 1.5)	<ul style="list-style-type: none"> <li>• 25% to 50% of retention volume in pretreatment, depending on soil infiltration rate</li> <li>• All runoff must be treated</li> <li>• Several pretreatment options may be used</li> </ul>	
Sizing (Maximum Depth) (Section 1.6)	$d_{\max} = \frac{1}{2}i \times t_d$	$d_{\max} = \frac{\left(\frac{1}{2}i \times t_d\right)}{\eta_r}$
	Maximum depth limits as well, based on practice size and CDA (See Table 1.4)	
Sizing (Surface Area) (Section 1.6)	$SA = Sv / (d + \frac{1}{2}i \times t_f)$	$SA = Sv / (\eta_r \times d + \frac{1}{2}i \times t_f)$
Variables:	$t_d$ = maximum drawn down time (days - 2) $i$ = field-verified infiltration rate for the native soils (ft./day) $\eta_r$ = available porosity of the stone reservoir (assume 0.4) $Sv$ = Retention volume treated by the practice $d$ = Infiltration depth (ft.) $t_f$ = Time to fill the infiltration facility (days – typically 2 hours, or 0.083 days)	
Geometry (Section 1.6)	<ul style="list-style-type: none"> <li>• Flat trench or basin bottom</li> <li>• 4:1 or flatter internal side slopes for basins</li> <li>• 2' or lower maximum ponding depth for basins</li> </ul>	<ul style="list-style-type: none"> <li>• Wider than they are deep to avoid injection well status</li> </ul>
Landscaping (Section 1.7)	Maintain vegetation in the buffers and practice drainage area to minimize erosion and debris	

**Table 1.3. Infiltration Material Specifications**

Material	Specification	Notes
<b>Surface Layer (optional)</b>	Topsoil and grass layer	
<b>Stone Layer</b>	Clean, aggregate with a maximum diameter of 2.5 inches and a minimum diameter of 0.5 inches (Delaware #3).	
<b>Observation Well</b>	Install a vertical 6-inch Schedule 40 PVC perforated pipe, with a lockable cap and anchor plate	Install one per 50 feet of length of infiltration practice, minimum 1 well per practice
<b>Overflow collection pipe (optional)</b>	Use 4-inch or 6-inch rigid schedule 40 PVC pipe, with 3/8" perforations at 6 inches on center	
<b>Filter Fabric (sides only)</b>	Use polypropylene geotextile with a flow rate of > 110 gallons/min./sq. ft. (e.g., GD-II)	

### 1.3 Infiltration Feasibility Criteria

Infiltration practices have very high storage and retention capabilities when sited and designed appropriately. 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. Additional information about soil and infiltration are described in more detail later in this section. During initial design phases, designers should carefully identify and evaluate constraints on infiltration, as follows:

**EPA Requirements for Class V Injection Wells.** Certain types of practices in this category may be classified as a Class V Injection Wells, which are subject to regulations under the Federal Underground Injection Control (UIC) program. In general, if the facility allows stormwater runoff to come in direct contact with groundwater it would meet this criterion. Facilities with a minimum 2' vadose zone separation from the groundwater table would not meet the criterion. Designers are advised to contact the DNREC Groundwater Discharges Section for additional information regarding UIC regulations and possible permitting requirements.

**Contributing Drainage Area.** To be most effective minimize the contributing drainage area (CDA). The CDA should be as close to 100% impervious as possible to minimize organic capping and maintenance concerns. The facility specific design, pretreatment and maintenance requirements will differ depending on the size of the infiltration practice.

**Site Topography.** Infiltration shall not be located on slopes greater than 5%. Further, 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%.

**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 for systems without an underdrain. The minimum vertical distance of 2 feet is relaxed for systems with an underdrain; the design invert of the underdrain must be set such that the seasonal high groundwater does not encroach into system through the underdrain.

**Soils.** Native soils in proposed infiltration areas must have a minimum infiltration rate of 1 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 designers must verify soil permeability by using the on-site soil investigation methods provided in the Soil Investigation Procedures. Soils investigation must be performed by a qualified soils or geotechnical engineer.

**Use on Urban Fill Soils/Redevelopment Sites.** Sites that have been previously graded or disturbed do not typically retain their original soil permeability due to compaction. Therefore, such sites are often not good candidates for infiltration practices unless the geotechnical investigation shows that the soil infiltration rate exceeds 1.0 in/hr.

**Dry Weather Flows.** Infiltration practices should not be used on sites receiving regular dry-weather flows from sump pumps, irrigation water, chlorinated wash-water, or other non-stormwater flows.

**Setbacks.** To avoid the risk of seepage, Infiltration facilities should not be hydraulically connected to structure foundations. The designer should check to ensure footings and foundations of adjacent buildings do not encroach within an assumed 4:1 phreatic zone drawn from the maximum design water elevation in the Infiltration facility. The setback for buildings from Table 1.4 can be used in lieu of a phreatic zone analysis. Setbacks from wells and septic systems shall meet minimum separation distances in accordance with Department regulations. The setbacks in Table 1.4 can be used in lieu of a site specific determination.

~~**Setbacks.** Infiltration practices should not be hydraulically connected to structure foundations or pavement, in order to avoid harmful seepage. Setbacks to structures vary based on the size of the infiltration facility:-~~

**Table 1.4 Minimum Setbacks**

Size of Infiltration Facility	Minimum Setback			
	Structure is Up-Grade	Structure is Down-Grade	Septic System	Well
250 to 2,500 square feet	5'	25'	100'	150'
2,500 to 20,000 square feet	10'	50'	100'	150'
20,000 to 100,000 square feet	25'	100'	100'	150'

**Proximity to Utilities.** No Infiltration facility shall be built within five feet horizontally of an existing underground utility without prior authorization from the utility owner. A proposed underground utility may be built within five feet, horizontally, of an infiltration facility as long as protective measures are in place accounting for future maintenance of the underground utility and meeting the design requirements of the utility owner.

**Hotspots and 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. Infiltration practices should be avoided at potential stormwater hotspots that pose a risk of groundwater contamination. For a list of potential stormwater hotspot operations, consult *Appendix 4*.

#### 1.4 Infiltration Conveyance Criteria

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. Where possible, conventional infiltration practices should be designed offline to avoid damage from the erosive velocities of larger design storms. If runoff is delivered by a storm drain pipe or along the main conveyance system, the infiltration practice shall be designed as an off-line practice. Pretreatment shall be provided for storm drain pipes systems discharging directly to infiltration systems.

**Off-line infiltration:** Overflows can either be diverted from entering the infiltration practice or dealt with via an overflow inlet. Optional overflow methods include the following:

- Utilize a low-flow diversion or flow splitter at the inlet to allow only the design volume to enter the facility. This may be achieved with a weir or curb opening sized for the target flow, in combination with a bypass channel. Using a weir or curb opening helps minimize clogging and reduces the maintenance frequency (further guidance on determining the peak flow rate will be necessary in order to ensure proper design of the diversion structure).
- Use landscaping type inlets or standpipes with trash guards as overflow devices.

**On-line infiltration:** An overflow structure should always be incorporated into on-line designs to safely convey larger storms through the infiltration area. The following criteria apply to overflow structures:

- An overflow mechanism such as an elevated drop inlet or overflow weir should be used to direct high flows to a non-erosive down-slope overflow channel, stabilized water course, or storm sewer system designed to convey the Conveyance Event (Cv).

#### 1.5 Infiltration Pretreatment Criteria

Every infiltration system shall have pretreatment mechanisms to protect the long term integrity of the infiltration rate. One of the following techniques must be installed to pretreat 100% of the inflow in every facility:

- Vegetated Channel (see *Specification 8. Vegetated Channel*)
- Grass Filter Strip (see *Specification 9. Sheet flow to Open Space*)
- Forebay (minimum 25% of the retention volume)
- Sand Filter (see *Specification 12. Stormwater Filtering Systems*)
- Proprietary Practices (see Specification 15. Proprietary Practices)
- Catch Basin Sumps (min. 2'; residential streets and site drainage only)

A minimum pretreatment volume of at least 25% of the design retention volume shall be provided for any infiltration facility which serves a CDA greater than 20,000 sq. ft.

Exit velocities from the pretreatment shall be non-erosive (typically above 4 fps) during the largest design storm that is connected to the facility and flow from the pretreatment chamber should be evenly distributed across the width of the practice (e.g., using a level spreader).

## 1.6 Infiltration Design Criteria

**Facility Slope.** The bottom of an infiltration facility should be flat (i.e., 0% longitudinal and lateral slopes) to enable even distribution and infiltration of stormwater, however the bottom may be stepped internally per design specifications.

**Infiltration Basin Geometry:** The maximum vertical depth to which runoff may be ponded over an infiltration basin is 24 inches. The side-slopes should be no steeper than 4H:1V

**Surface Cover (optional):** Designers may choose to install a layer of topsoil and grass above the infiltration practice.

**Stone Layer:** Stone layers must consist of clean, washed aggregate with a maximum diameter of 2.5 inches and a minimum diameter of 0.5 inches (Delaware #3 stone).

**Underground Storage (optional):** In the underground mode, runoff is stored in the voids of the stones, and infiltrates into the underlying soil matrix. Plastic, concrete, or comparable material structures 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 *See Specification 12. Detention Practices.*

**Overflow Collection Pipe:** An optional overflow collection pipe can be installed to convey collected runoff from larger storm events to a downstream conveyance system.

**Trench Bottom:** To protect the bottom of an infiltration trench from intrusion by underlying soils, a sand layer must be used. The underlying native soils should be separated from the stone layer by a 6 to 8 inch layer of coarse sand (e.g., ASTM C 33, 0.02-0.04 inch).

**Filter Fabric:** Use a geotextile fabric with a flow rate of > 110 gal./min./sq. ft. (e.g., Delaware GD-II).

**Material Specifications:** Recommended material specifications for infiltration areas are shown in Table 1.3 in Section 1.2.

**Practice Sizing:** The proper approach for designing infiltration practices is to avoid forcing a large amount of infiltration into a small area. Therefore, individual infiltration practices that are limited in size due to soil permeability and available space need not be sized to capture the entire design volume for the contributing drainage area, as long as other stormwater treatment practices are applied at the site to meet the remainder of the design storm volume.

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 1.1**) or trench with an underground reservoir (**Equation 1.2**).

**Equation 1.1. Maximum Surface Basin Depth (for Infiltration Basins)**

$$d_{\max} = \frac{1}{2}i \times t_d$$

**Equation 1.2. Maximum Underground Reservoir Depth (for Infiltration Trenches)**

$$d_{\max} = \frac{\left(\frac{1}{2}i \times t_d\right)}{\eta_r}$$

Where:

- $d_{\max}$  = maximum depth of the infiltration practice (feet)
- $i$  = field-verified infiltration rate for the native soils(ft./day)
- $t_d$  = maximum drawn down time (days - 2)
- $\eta_r$  = available porosity of the stone reservoir (assume 0.4)

This equation makes the following design assumptions:

- *Conservative Infiltration Rates.* For design purposes, the field-tested subgrade soil infiltration rate ( $i$ ) is divided by 2 as a factor of safety to account for potential compaction during construction and to approximate long term infiltration rates. On-site infiltration investigations should always be conducted to establish the actual infiltration capacity of underlying soils, using the methods presented in the Soil Investigation Procedures.
- *Stone Layer Porosity.* A porosity value of 0.4 shall be used in the design of stone reservoirs, although a larger value may be used if underground retention chambers are installed within

the reservoir.

- *Rapid Drawdown*. Infiltration practices should be sized so that the target runoff reduction volume infiltrates within 48 hours, to prevent nuisance ponding conditions.

**Equation 1.3. Surface Basin Surface Area (for Infiltration Basins)**

$$SA = Sv / (d + 1/2 i \times t_f)$$

**Equation 1.4. Underground Reservoir Surface Area (for Infiltration Trenches)**

$$SA = Sv / (\eta_r \times d + 1/2 i \times t_f)$$

Where:

$SA$	=	Surface area (sq. ft.)
$Sv$	=	Design retention volume treated by the practice
$\eta_r$	=	available porosity of the stone reservoir (assume 0.4)
$d$	=	Infiltration depth (ft.) (maximum depends on the scale of infiltration and the results of <b>Equation 1.1 or 1.2</b> )
$i$	=	field-verified infiltration rate for the native soils (ft/day)
$t_f$	=	Time to fill the infiltration facility (days – typically 2 hours, or 0.083 days)

Infiltration practices can also be designed to address, in whole or in part, the detention storage needed to comply with channel protection and/or flood control requirements. The designer can model various approaches by factoring in storage chambers within the stone aggregate layer and expected infiltration as part of the design. Routing calculations can also be used to provide a more accurate solution of the peak discharge and required storage volume.

## 1.7 Infiltration Landscaping Criteria

Infiltration trenches can be effectively integrated into the site plan and aesthetically designed with adjacent native landscaping or turf cover. Vegetation associated with the infiltration practice buffers should be regularly mowed with clippings removed and maintained to keep organic matter out of the infiltration device and maintain enough vegetation to prevent soil erosion from occurring.

## 1.8 Infiltration Construction Sequence

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.

During site construction, the following steps are absolutely critical:

- Avoid compaction by preventing construction equipment and vehicles from traveling over the proposed location of the infiltration practice using “Sensitive Area Protection” guidelines during construction.
- Infiltration trenches should remain “off-line” until construction is complete to prevent construction sediment from clogging the stone reservoir layer. Prevent sediment from entering the infiltration site by using silt fence, diversion berms or other means. In the erosion and sediment control plan, indicate the earliest time at which stormwater runoff may be directed to an infiltration trench. The erosion and sediment control plan must also indicate the specific methods to be used to temporarily keep runoff from the infiltration facility.
- Infiltration basins should not serve as the sites for temporary sediment control devices (e.g., sediment traps, etc.) during construction unless extensive design and construction methods are employed to protect the infiltration facilities’ ability to infiltrate. Examples of these design considerations are the need to remove choking sediment from the facility, tilling the basin, and performing additional geological site investigations to determine that the infiltration rate has been maintained.
- Upland drainage areas need to be completely stabilized with a thick layer of vegetation prior to commencing excavation for an infiltration practice.

**Infiltration 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.
2. Install geotextile per design 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 per design.
4. Anchor the observation well(s), and add stone to the practice in 1-foot lifts.
5. Use sod, where applicable to establish a dense turf cover for at least 10 feet around the sides of the infiltration practice, to reduce erosion and sloughing.

**Construction Review.** Review is needed during 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.

## 1.9 Infiltration Maintenance Criteria

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 stone by organic matter and sediment. The following design features can minimize the risk of clogging:

**Stabilized CDA.** Infiltration systems may not receive runoff until the entire contributing drainage area has been completely stabilized, unless a design and construction method can be shown to remove all clogging sediment prior to site completion.

**Observation Well.** 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.

**No Filter Fabric on Bottom.** Avoid installing geotextile filter fabric along the bottom of infiltration practices. Experience has shown that filter fabric is prone to clogging. However, permeable filter fabric must be installed on the trench sides to prevent soil piping.

**Direct Maintenance Access.** Infiltration systems must be covered by a common open space to allow inspection and maintenance. Access must be provided to allow personnel and heavy equipment to perform non-routine maintenance tasks, such as reconstruction or rehabilitation. While a turf cover is permissible for small-scale infiltration practices, the surface must never be covered by an impermeable material, such as asphalt or concrete.

Effective long-term operation of infiltration practices requires an Operation and Maintenance Plan, including maintenance inspection schedule with clear guidelines and schedules, as shown in **Table 1.5** below. Where possible, facility maintenance should be integrated into routine landscaping maintenance tasks.

**Table 1.6. Typical maintenance activities for infiltration practices**

Maintenance Activity	Schedule
<ul style="list-style-type: none"> <li>• Replace topsoil and top surface filter fabric (when clogged).</li> <li>• Mow vegetated filter strips as necessary and remove the clippings.</li> </ul>	As needed
<ul style="list-style-type: none"> <li>• Ensure that the contributing drainage area, inlets, and facility surface are clear of debris.</li> <li>• Ensure that the contributing drainage area is stabilized. Perform spot-reseeding if where needed.</li> <li>• Remove sediment and oil/grease from inlets, pre-treatment devices, flow diversion structures, and overflow structures.</li> <li>• Repair undercut and eroded areas at inflow and outflow structures.</li> </ul>	Quarterly
<ul style="list-style-type: none"> <li>• 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.</li> <li>• Inspect pre-treatment devices and diversion structures for sediment build-up and structural damage.</li> <li>• Remove trees that start to grow in the vicinity of the infiltration facility that may drop leaf litter, fruits and other vegetative materials that could clog the infiltration device.</li> </ul>	Semi-annual inspection
<ul style="list-style-type: none"> <li>• Clean out accumulated sediments from the pre-treatment cell.</li> </ul>	Annually

An Operation and Maintenance Plan for the project will be approved by DNREC or the Delegated Agency prior to project closeout. The Operation and Maintenance Plan will specify the property owner's primary maintenance responsibilities and authorize DNREC or Delegated Agency staff to access the property for maintenance review or corrective action in the event that proper maintenance is not performed. Infiltration facilities that are, or will be, owned and maintained by a joint ownership such as a homeowner's association must be located in common areas, community open space, community-owned property, jointly owned property, or within a recorded easement dedicated to public use.

Operation and Maintenance Plans should clearly outline how vegetation in the Infiltration facility and its buffer will be managed or harvested in the future. Periodic mowing of the Infiltration facility is required, unless it is managed as a meadow (mowing every other year) or forest. The maintenance plan should schedule a cleanup at least once a year to remove trash and debris.

Maintenance of an Infiltration facility is driven by annual maintenance reviews that evaluate the condition and performance of the Infiltration facility. Based on maintenance review results, specific maintenance tasks may be required.

### 1.10 References

No references.