Section 3.7. 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:

- I-1 Infiltration Trench
- I-2 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 field *measured* soil infiltration rates are sufficient. To prevent possible groundwater contamination, infiltration should not be utilized at sites designated as stormwater hotspots.

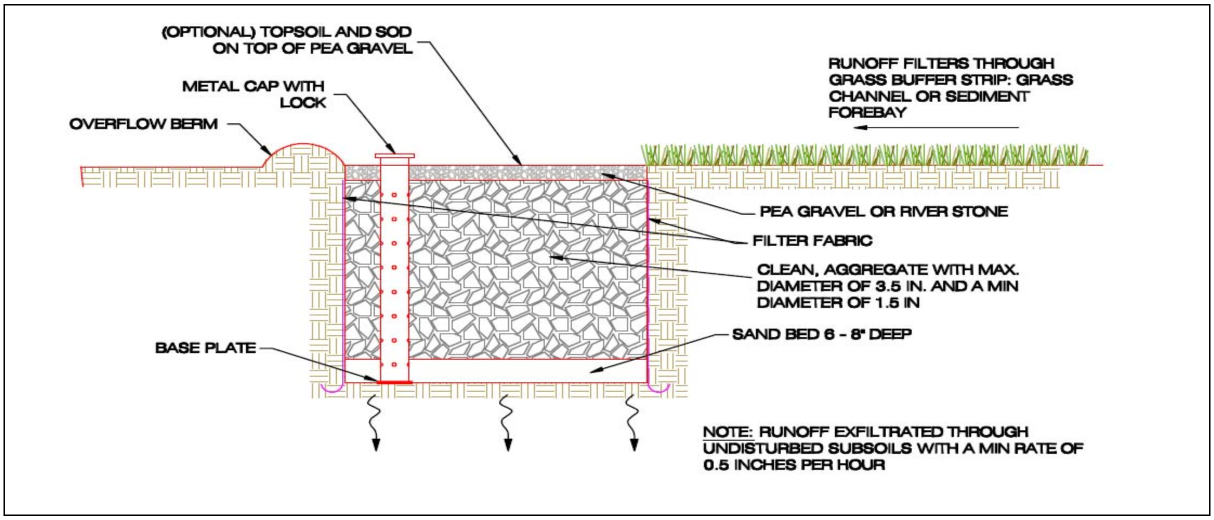

Figure 3.7.1. Example of an Infiltration Trench.

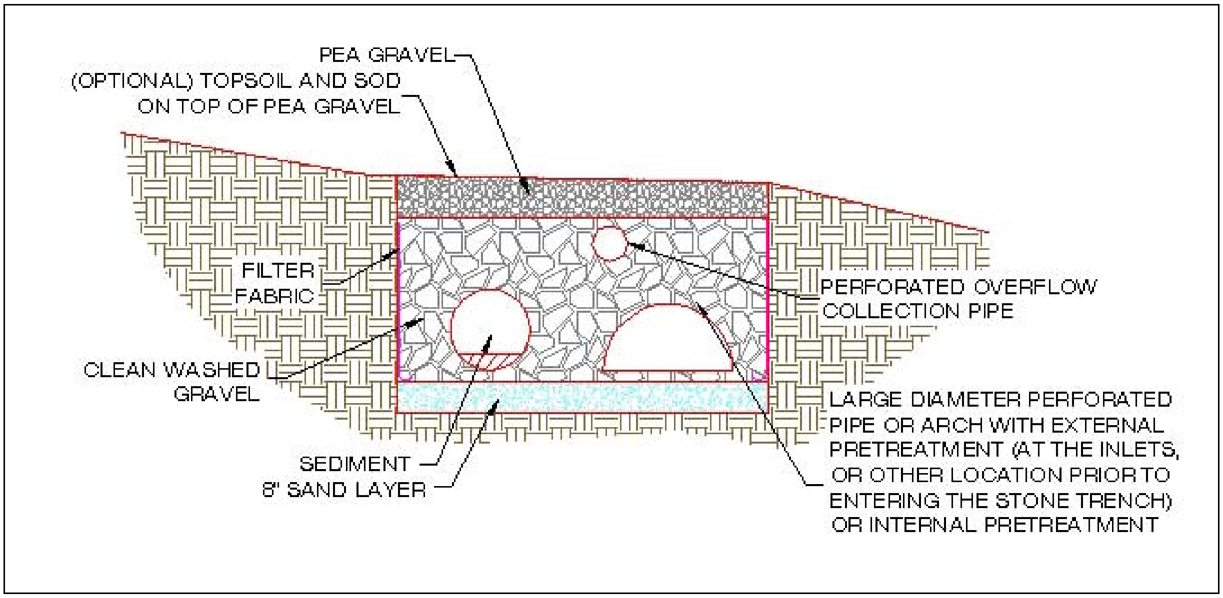

Figure 3.7.2. Infiltration Section with Supplemental Pipe Storage.

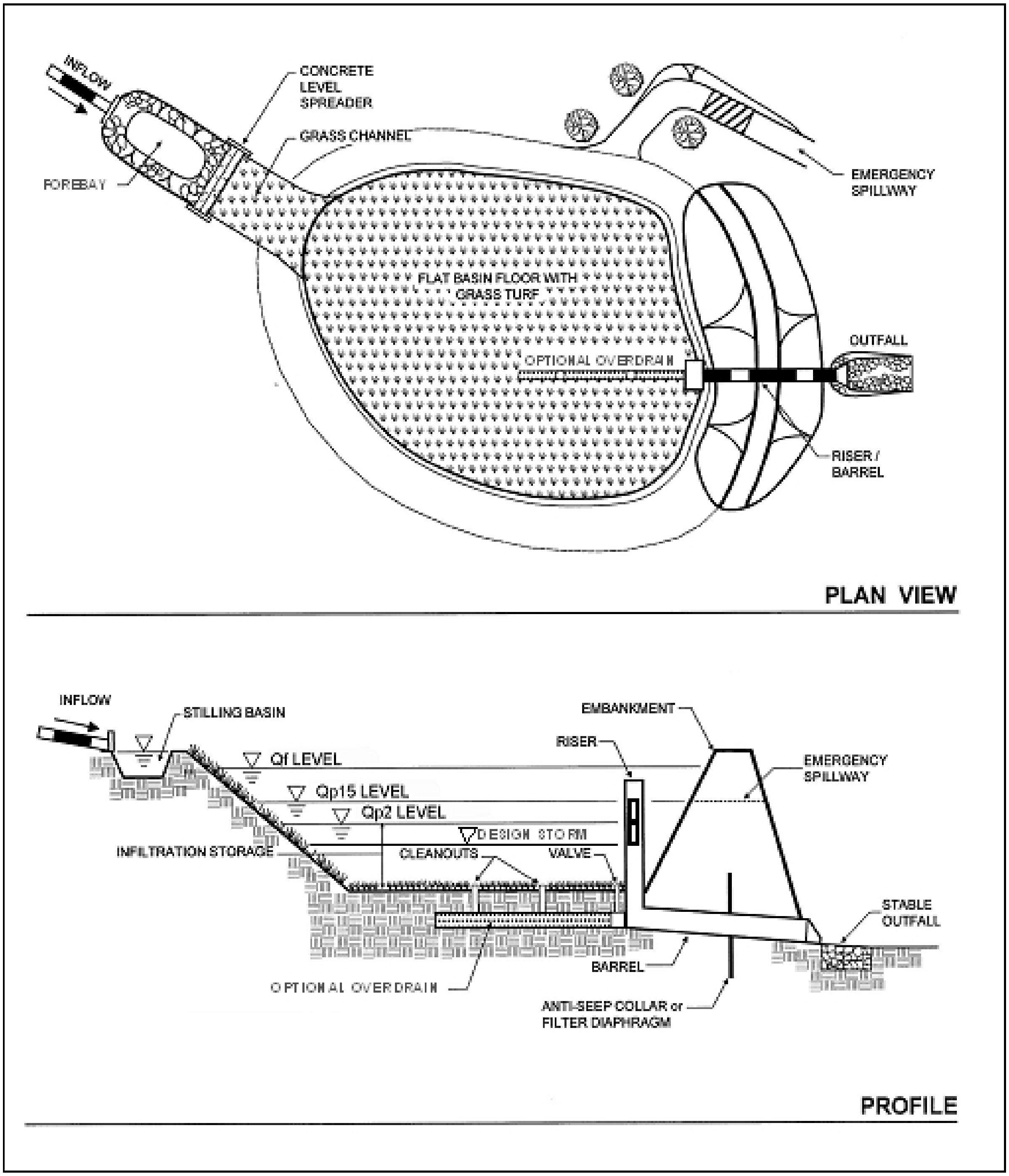

Figure 3.7.3. Example of an Infiltration Basin.

3.7.1. 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 the U.S. Department of Agriculture's Natural Resources Conservation Service (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:

Underground Injection Control for Class V Wells. In order for an infiltration practice to avoid classification as a Class V well, which is subject regulation under the Federal Underground Injection Control (UIC) program, the practice must be wider than the practice is deep. If an infiltration practice is "deeper than its widest surface dimension" or if it includes an underground distribution system, then it will likely be considered a Class V injection well. Class V injection wells are subject to permit approval by the U.S. Environmental Protection Agency (EPA). For more information on Class V injection wells and stormwater management, designers should consult http://water.epa.gov/type/groundwater/uic/class5/comply_minrequirements.cfm for EPA's minimum requirements.

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. The 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 6%, although check dams or other devices may be employed to reduce the effective slope of the practice. 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%.

Minimum Hydraulic Head. Two or more feet of head may be needed to promote flow through 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.

Soils. 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 Appendix P. Native soils must have silt/clay content less than 40% and clay content less than 20%. Soils investigation must be performed by a qualified soils or geotechnical engineer. Soil boring locations should correspond to the location of the proposed infiltration device and should have a minimum of one boring for every 1,000 square feet of infiltration practice.

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 a sufficient infiltration rate exists.

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. 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 practice. Examples of typical setbacks are:

- 250 to 2,500 square feet = 5 feet if down-gradient from building; 25 feet if up-gradient.
- 2,500 to 20,000 square feet = 10 feet if down-gradient from building; 50 feet if up-gradient.
- 20,000 to 100,000 square feet = 25 feet if down-gradient from building; 100 feet if up-gradient.

All setbacks must be verified by a professional geotechnical engineer registered in the District of Columbia.

Proximity to Utilities. Interference with underground utilities should be avoided, if possible. When large site development is undertaken the expectation of achieving avoidance will be high. Conflicts may be commonplace on smaller sites and in the public right of way. Where conflicts cannot be avoided, the following guidelines shall be followed:

- Consult with each utility company on recommended offsets that will allow utility maintenance work with minimal disturbance to the stormwater Best Management Practice (BMP).
- Whenever possible, coordinate with utility companies to allow them to replace or relocate their aging infrastructure while BMPs are being implemented.
- BMP and utility conflicts will be a common occurrence in public right-of-way projects. However, the standard solution to utility conflict should be the acceptance of conflict provided sufficient soil coverage over the utility can be assured.
- Additionally, when accepting utility conflict into the BMP design, it is understood that the BMP will be temporarily impacted during utility maintenance but restored to its original condition.

Hotspots and High Loading Situations. Infiltration practices are not intended to treat sites with high sediment or trash or 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 Q.

On sites with existing contaminated soils, as indicated in Appendix P, infiltration is not allowed.

3.7.2. 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 off-line 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 stormwater retention volume (SWRv) 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 15-yr design storm.

3.7.3. 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:

- Grass channel
- Grass filter strip (minimum 20 feet and only if sheet flow is established and maintained)
- Forebay (minimum 25% of the design storm volume)
- Gravel diaphragm (minimum 1 foot deep and 2 feet wide and only if sheet flow is established and maintained)
- Sand filter cell (see Section 3.6)

If the basin serves a CDA greater than 20,000 sq. ft., a forebay or sand filter cell must be used for pretreatment.

A minimum pretreatment volume of at least 25% of the SWRv or design storm shall be provided prior to entry to an infiltration facility and can be provided in the form of a sedimentation basin, sump pit, grass channel, grass filter strip, plunge pool, or other measure.

If the infiltration rate for the underlying soils is greater than 2 inches per hour, a minimum pretreatment volume of at least 50% of the SWRv or design storm shall be provided prior to entry into an infiltration facility.

Exit velocities from the pretreatment chamber shall not be erosive (above 6 fps) during the 15-year design storm and flow from the pretreatment chamber should be evenly distributed across the width of the practice (e.g. using a level spreader).

3.7.4. Infiltration Design Criteria

Geometry. Where possible, infiltration practices should be designed to be wider than they are deep, to avoid classification as a class V injection well. For more information on Class V wells see http://water.epa.gov/type/groundwater/uic/class5/index.cfm.

Practice Slope. The bottom of an infiltration practice should be flat (i.e. 0% longitudinal and lateral slopes) to enable even distribution and infiltration of stormwater.

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.

Surface Stone. A 3-inch layer of clean, washed river stone or No. 8 or 89 stone should be installed over the stone layer.

Stone Layer. Stone layers must consist of clean, washed aggregate with a maximum diameter of 3.5 inches and a minimum diameter of 1.5 inches.

Underground Storage (optional). 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.

Overflow Collection Pipe (Overdrain). An optional overflow collection pipe can be installed in the stone layer 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 woven monofilament polypropylene geotextile fabric with a flow rate of > 100 gal./min./sq. ft. This layer should be applied only to the sides of the practice.

Material Specifications. Recommended material specifications for infiltration areas are shown in Table 3.7.1.

Table 3.7.1. Infiltration material specifications.

Material	Specification	Notes
Surface Layer (optional)	Topsoil and grass layer	
Surface Stone	Install a 3-inch layer of river stone or pea gravel.	This provides an attractive surface cover that can suppress weed growth.
Stone Layer	Clean, aggregate with a maximum diameter of 3.5 inches and a minimum diameter of 1.5 inches.	
Observation Well	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.
Overflow collection pipe (optional)	Use 4-inch or 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.	
Trench Bottom	Install a 6 to 8 inch sand layer (e.g. ASTM C 33, 0.02-0.04 inch)	
Filter Fabric (sides only)	Use woven monofilament polyprene geotextile with a flow rate of > 100 gal./min./sq. ft.	

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 achieve the full design storm volume (SWRv) 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 (see following page) 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 3.7.1) or trench with an underground reservoir (Equation 3.7.2).

Equation 3.7.1. Maximum Surface Basin Depth (for Infiltration Basins).

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

Equation 3.7.2. 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 (normally 1.5 to 2 days) (day)
η_r	=	Available porosity of the stone reservoir (assume 0.35)

These equations make 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 Appendix P.
- *Stone Layer Porosity.* A porosity value of 0.35 shall 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.
- *Rapid Drawdown.* Infiltration practices should be sized so that the target runoff reduction volume infiltrates within 72 hours, to prevent nuisance ponding conditions.

Designers should compare these results to the maximum allowable depths in Table 3.7.2 and use whichever value is *less* for subsequent design.

Table 3.7.2. Maximum facilitydepth (in feet) for infiltration practices.

Mode of Entry	Scale of Infiltration		
	Micro Infiltration (250 to 2,500 square feet)	Small Scale Infiltration (2,500 to 20,000 square feet)	Conventional Infiltration (20,000 to 100,000 square feet)
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 3.7.3 or Equation 3.7.4:

Equation 3.7.3. Surface Basin Surface Area (for Infiltration Basins).

$$SA = DesignStorm / (d + ½\, i \times t_f)$$

Equation 3.7.4. Underground Reservoir Surface Area (for Infiltration Trenches).

$$SA = DesignStorm / (\eta_r \times d + ½\, i \times t_f)$$

Where:

SA	=	Surface area (sq. ft.)
DesignStorm	=	SWRv or other design storm volume (cu. ft.) (e.g., portion of the SWRv)
η_r	=	available porosity of the stone reservoir (assume 0.35)
d	=	Infiltration depth (ft.) (maximum depends on the scale of infiltration and the results of **Equation 3.7.1 or 3.7.2**)
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)

The storage volume (Sv) captured by the infiltration practice is defined as the volume of water that is fully infiltrated through the practice (no overflow). Designers may choose to infiltrate less than the full design storm (SWRv). In this case, the design volume captured should be treated as the storage volume, Sv of the practice (see Section 3.7.7 Infiltration Stormwater Compliance Calculations). Sv can be determined by rearranging Equations 3.7.3 and 3.7.4 to yield Equations 3.7.5 and 3.7.6.

Equation 3.7.5. Storage Volume Calculation for Surface Basin Area (for Infiltration Basins).

$$Sv = SA \times (d + ½\, i \times t_f)$$

Equation 3.7.6. Storage Volume Calculation for Underground Reservoir Surface Area (for Infiltration Trenches).

$$Sv = SA \times (\eta_r \times d + ½\, i \times t_f)$$

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 within the stone aggregate layer, any perforated corrugated metal pipe, plastic pipe, concrete arch pipe, or comparable materials installed within the reservoir, expected infiltration, and any outlet structures used 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.

3.7.5. Infiltration Landscaping Criteria

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 not be installed until all up-gradient construction is completed and pervious areas are stabilized with dense and healthy vegetation, unless the practice can be kept off-line so it receives no runoff until construction and stabilization is complete.
- Vegetation associated with the infiltration practice buffers should be regularly maintained to limit organic matter in the infiltration device and maintain enough vegetation to prevent soil erosion from occurring.

3.7.6. 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:

1. Avoid excessive compaction by preventing construction equipment and vehicles from traveling over the proposed location of the infiltration practice.
2. 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 control plan, indicate the earliest time at which stormwater runoff may be directed to a conventional infiltration basin. The erosion and sediment control plan must also indicate the specific methods to be used to temporarily keep runoff from the infiltration site.
3. Infiltration practice sites should never serve as the sites for temporary sediment control devices (e.g. sediment traps, etc.) during construction.
4. 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. The floor of the pit should be completely level, but equipment should be kept off the floor area to prevent soil compaction.
2. 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, 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 Inspections. Inspections are 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. An example construction phase inspection checklist for infiltration practices can be found in Appendix L.

3.7.7. 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.

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. Access must be provided to allow personnel and heavy equipment to perform non-routine maintenance tasks, such as practice 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 a dedicated and routine maintenance inspection schedule with clear guidelines and schedules, as shown in Table 3.7.3 below. Where possible, facility maintenance should be integrated into routine landscaping maintenance tasks.

Table 3.7.3. 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. Perform spot-reseeding if where needed. ▪ Remove sediment and oil/grease from inlets, pre-treatment devices, flow diversion structures, and 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.	Semi-annual inspection
▪ Clean out accumulated sediments from the pre-treatment cell.	Annually

It is highly recommended that annual site inspections be performed for infiltration practices to ensure the practice performance and longevity of infiltration practices. An example maintenance inspection checklist for infiltration systems can be found in Appendix M.

A declaration of covenants that includes all maintenance responsibilities to ensure the continued stormwater performance for the BMP is required. The declaration of covenants specifies the property owner's primary maintenance responsibilities, and authorizes DDOE staff to access the property for inspection or corrective action in the event the proper maintenance is not performed. The declaration of covenants is attached to the deed of the property. An example form is provided at the end of Chapter 5 though variations will exist for scenarios where stormwater crosses property lines. The covenant is between the property and the District Government. It is submitted through the Office of the Attorney General (OAG). All SWMPs have a maintenance agreement stamp that must be signed for a building permit to proceed. A maintenance schedule must appear on the SWMP. Additionally, a maintenance schedule is required in schedule c of the declaration of covenants.

Covenants are not required on government properties, but maintenance responsibilities must be defined through a partnership agreement or a memorandum of understanding.

Waste material from the repair, maintenance, or removal of a BMP or land cover change shall be removed, and the maintenance contractor shall submit a written report to DDOE within forty-eight (48) hours after disposing of the waste material. The report shall include:

(a) The name, address, phone number, and business license number of the contractor transporting the waste materials;
(b) Date of removal;
(c) The address of the BMP;
(d) Type of BMP serviced;
(e) Amount and type of waste material removed;
(f) The name and location of the facility where the waste material was disposed of; and
(g) A sworn statement that disposal was in compliance with applicable federal and District law.

3.7.8. Infiltration Stormwater Compliance Calculations

Infiltration practices receive 100% retention value for the amount of storage volume (Sv) provided by the practice (Table 3.7.4). No additional pollutant removal is awarded.

Table 3.7.4. Infiltration retention value and pollutant removal.

Retention Value	= *Sv*
Additional Pollutant Removal	N/A*

* No additional pollutant removal is awarded since the practice retains 100% of the storage volume

The practice must be sized using the guidance detailed in Section 3.7.4. Infiltration Design Criteria.

Infiltration practices also contribute to peak flow reduction. This contribution can be determined in several ways. One method is to subtract the Sv or Retention Value from the total runoff volume for the 2-year, 15-year, and 100-year storms. The resulting reduced runoff volumes can then be used to calculate a Reduced Natural Resource Conservation Service (NRCS) Curve Number for the site or drainage area. The Reduced Curve Number can then be used to calculate peak flow rates for the various storm events. Other hydrologic modeling tools that employ different procedures may be used as well.

3.7.9. References

Virginia DCR Stormwater Design Specification No. 8: Bioretention Version 1.8. 2010.