# Chapter 9 – Infiltration Basin

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9.1 Overview of Practice

Infiltration basins are impounding facilities which temporarily store surface runoff and infiltrate a designated portion of it into the soil strata.

Unlike infiltration trenches, infiltration basins may also serve as peak mitigation facilities. This is accomplished by providing “dry” storage above the designated infiltration volume. This dry, flood control volume is then released through a multi-stage riser and barrel system. Conceptually, an infiltration basin can be viewed as an extended dry detention basin whose water quality volume is infiltrated into the soil strata rather than released through a small orifice over a 30 hour period.

As shown in Table 1.1, the water quality volume of an infiltration trench can vary, and the anticipated pollutant removal performance of the trench varies as a function of this volume.
9.2 Site Constraints and Siting of the Facility

The designer must consider a number of site constraints in addition to the contributing drainage area’s impervious cover when an infiltration basin is proposed. These constraints are discussed as follows.

9.2.1 Minimum Drainage Area

The minimum drainage area contributing to an infiltration trench is not restricted. However, when contributing drainage areas are particularly small, infiltration trenches will often provide a more cost-effective option.

9.2.2 Maximum Drainage Area

The drainage area contributing runoff to an infiltration basin should be restricted to no more than 50 acres.

9.2.3 Site Slopes

Infiltration basins are suitable for installation on sites exhibiting slopes generally less than 20 percent. Infiltration basins should be located a minimum of 50 feet away from any slope steeper than 15 percent. When site slopes exceed 20 percent, alternative BMP measures should be considered. The floor slope of an infiltration basin should be as flat as practically possible in order to maximize the area upon which effective infiltration can occur.

9.2.4 Site Soils

When an infiltration basin is proposed the soil infiltration rate is of critical design importance. A subsurface analysis and permeability test is required. The required subsurface analysis should investigate soil characteristics to a depth of no less than three feet below the proposed bottom of the basin. Data from the subsurface investigation should be provided to the Materials Division early in the project planning stages to evaluate the feasibility of such a facility on native site soils.

The soil’s design infiltration rate should be measured when the soil is in a saturated condition. Soil infiltration rates which are deemed acceptable for infiltration trenches range between 0.52 and 8.27 inches per hour (DCR, 1999, Et Seq.). Infiltration rates falling within this range are typically exhibited by soils categorized as loam, sandy loam, and loamy sand.

Soils exhibiting a clay content of greater than 30 percent are unacceptable for infiltration facilities. Similarly, soils exhibiting extremely high infiltration rates, such as sand, should also be avoided. Table 9.1 presents typical infiltration rates observed for a variety of soil types. This table is provided as a reference only, and does not replace the need for a detailed site soil survey.
9.2 - Site Constraints and Siting of the Facility

### Table 9.1. Hydrologic Soil Properties Classified by Soil Texture

*(Virginia Stormwater Management Handbook, 1999, Et seq.)*

<table>
<thead>
<tr>
<th>Texture Class</th>
<th>Effective Water Capacity ($C_w$) (inch per inch)</th>
<th>Minimum Infiltration Rate ($I$) (inch per hour)</th>
<th>Hydrologic Soil Grouping</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand</td>
<td>0.35</td>
<td>8.27</td>
<td>A</td>
</tr>
<tr>
<td>Loamy Sand</td>
<td>0.31</td>
<td>2.41</td>
<td>A</td>
</tr>
<tr>
<td>Sandy Loam</td>
<td>0.25</td>
<td>1.02</td>
<td>B</td>
</tr>
<tr>
<td>Loam</td>
<td>0.19</td>
<td>0.52</td>
<td>B</td>
</tr>
<tr>
<td>Silt Loam</td>
<td>0.17</td>
<td>0.27</td>
<td>C</td>
</tr>
<tr>
<td>Sandy Clay Loam</td>
<td>0.14</td>
<td>0.17</td>
<td>C</td>
</tr>
<tr>
<td>Clay Loam</td>
<td>0.14</td>
<td>0.09</td>
<td>D</td>
</tr>
<tr>
<td>Silty Clay Loam</td>
<td>0.11</td>
<td>0.06</td>
<td>D</td>
</tr>
<tr>
<td>Sandy Clay</td>
<td>0.09</td>
<td>0.05</td>
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<tr>
<td>Silty Clay</td>
<td>0.09</td>
<td>0.04</td>
<td>D</td>
</tr>
<tr>
<td>Clay</td>
<td>0.08</td>
<td>0.02</td>
<td>D</td>
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</table>

#### 9.2.5 Depth to Water Table

Infiltration basins should not be installed on sites with a high groundwater table. Inadequate separation between the basin bottom and the surface of the water table may result in contamination of the water table. This potential contamination arises from the inability of the soil surrounding the trench to filter pollutants prior to their entrance into the water table. Additionally, a high water table may flood an infiltration basin during periods of high precipitation and/or runoff. A minimum separation distance of no less than two feet is required between the bottom of an infiltration basin and the surface of the *seasonally* high water table, with four or more feet of separation preferred. Unique site conditions may arise which require an even greater separation distance. The separation distance provided should allow the basin to empty completely within a maximum of 48 hours following a runoff producing event.

#### 9.2.6 Separation Distances

Infiltration basins should be located at least 20 feet down-slope and at least 100 feet up-slope from building foundations. Infiltration basins should not be located within 100 feet of any water supply well. Local health officials should be consulted when the implementation of an infiltration basin is proposed within the vicinity of a septic drainfield.

#### 9.2.7 Bedrock

A minimum of two feet of separation is required between the bottom of an infiltration basin and bedrock, with four feet or greater recommended.
9.2 - Site Constraints and Siting of the Facility

9.2.8 Placement on Fill Material

Infiltration basins should not be constructed on or nearby fill sections due to the possibility of creating an unstable subgrade. Fill areas are vulnerable to slope failure along the interface of the in-situ and fill material. The likelihood of this type of failure is increased when the fill material is frequently saturated, as anticipated when an infiltration BMP is proposed. Additionally, construction traffic and compaction activities will generally result in fill material exhibiting an infiltration rate below that which is desirable for an infiltration facility.

9.2.9 Karst

The concentration of runoff into an infiltration facility may result in the formation of flow channels. Such channels may lead to collapse in karst areas, and therefore the implementation of infiltration basins in known karst areas should be avoided.

9.2.10 Basin Location

When possible, infiltration basins should be placed in low visibility areas. When such a basin must be situated in a high profile area, care must be given to ensure that the facility empties completely within a 48 hour maximum. The location of an infiltration basin in a high visibility area places a great emphasis on the facility’s ongoing maintenance.

9.2.11 Existing Utilities

Infiltration basins should not be constructed over existing utility rights-of-way or easements. When this situation is unavoidable, permission to impound water over these easements must be obtained from the utility owner prior to design of the basin. When it is proposed to relocate existing utility lines, the costs associated with their relocation should be included in the overall basin construction cost.

9.2.12 Wetlands

When the construction of an infiltration basin is planned in the vicinity of known wetlands, the designer must coordinate with the appropriate local, state, and federal agencies to identify wetlands boundaries, their protected status, and the feasibility of BMP implementation in their vicinity.

9.2.13 Floodplains

The construction of infiltration basins within floodplains is strongly discouraged. When this situation is deemed unavoidable, critical examination must be given to ensure that the proposed basin remains functioning effectively during the 10-year flood event. The structural integrity and safety of the basin must also be evaluated thoroughly under 100-year flood conditions as well as the basin’s impact on the characteristics of the 100-year floodplain. When basin construction is proposed within a floodplain, construction and permitting must comply with all applicable regulations under FEMA’s National Flood Insurance Program.
9.3 General Design Guidelines

The following presents a collection of design issues to be considered when designing an infiltration basin for improvement of water quality.

9.3.1 Foundation and Embankment Material

Foundation data for the dam must be secured by the Materials Division to determine whether or not the native material is capable of supporting the dam while not allowing water to seep under the dam, as per Instructional and Informational Memorandum (IIM-LD-195) under “Post Development Stormwater Management”.

If the basin embankment height exceeds 15’, or if the basin includes a permanent pool, the design of the dam should employ a homogenous embankment with seepage controls or zoned embankments, or similar design in accordance with the Virginia Stormwater Management Handbook and recommendations of the VDOT Materials Division.

During the initial subsurface investigation, additional borings should be made near the center of the proposed basin when:

- Excavation from the basin will be used to construct the embankment
- There is a potential of encountering rock during excavation
- A high or seasonally high water table, generally two feet or less, is suspected

9.3.2 Outfall Piping

If the basin is equipped with a riser structure and outlet barrel, the pipe culvert under or through the basin embankment shall be reinforced concrete equipped with rubber gaskets. Pipe: Specifications Section 232 (AASHTO M170), Gasket: Specification Section 212 (ASTM C443).

A concrete cradle shall be used under the pipe to prevent seepage through the embankment. The cradle shall begin at the riser or inlet end of the pipe, and extend the pipe’s full length.

9.3.3 Principal Spillway Design

The basin outlet should be designed in accordance with Minimum Standard 3.02 of the Virginia Stormwater Management Handbook, (DCR, 1999, Et Seq.). The primary control structure (riser or weir) should be designed to operate in weir flow conditions for the full range of design flows. If this is not possible, and orifice flow regimes are anticipated, the outlet must be equipped with an anti-vortex device, consistent with that described in Minimum Standard 3.02.

The principal spillway should be equipped with a low flow orifice to permit draining of the facility in the event the infiltration surface becomes clogged and runoff cannot be infiltrated. This low flow orifice should remain plugged as long as the facility is infiltrating runoff at the rate for which it was designed.
9.3.4 **Embarkment**

The top width of the embankment should be a minimum of 10’ in width to provide ease of construction and maintenance. Positive drainage should be provided along the embankment top.

The embankment slopes should be no steeper than 3H:1V to permit mowing and other maintenance.

9.3.5 **Embarkment Height**

A basin embankment may be regulated under the Virginia Dam Safety Act, Article 2, Chapter 6, Title 10.1 (10.1-604 Et seq.) of the Code of Virginia and Dam Safety Regulations established by the Virginia Soil and Water Conservation Board (VS&WCB). An infiltration basin embankment may be excluded from regulation if it meets any of the following criteria:

- is less than six feet in height
- has a capacity of less than 50 acre-feet and is less than 25 feet in height
- has a capacity of less than 15 acre-feet and is more than 25 feet in height
- will be owned or licensed by the Federal Government

When an embankment is not regulated by the Virginia Dam Regulations, it must still be evaluated for structural integrity when subjected to the 100-year flood event.

9.3.6 **Fencing**

Per Instructional and Informational Memorandum (IIM-LD-195) under General Subject “Post Development Stormwater Management,” fencing is typically **not required or recommended** on most VDOT detention facilities. However, exceptions do arise, and the fencing of a dry extended detention facility may be needed. Such situations include:

- Ponded depths greater than 3’ and/or excessively steep embankment slopes
- The basin is situated in close proximity to schools or playgrounds, or other areas where children are expected to frequent
- It is recommended by the VDOT Field Inspection Review Team, the VDOT Residency Administrator, or a representative of the City or County who will take over maintenance of the facility

“No Trespassing” signs should be considered for inclusion on all detention facilities, whether fenced or unfenced.
9.3.7 Design Infiltration Rate
To provide a factor of safety, and to account for the decline in performance as the facility ages, the soil infiltration rate upon which a basin design is founded should be one-half the infiltration rate obtained from the geotechnical analysis (DCR, 1999, Et Seq.).

9.3.8 Maximum Storage Time
Infiltration basins should be designed to empty completely within 48 hours following a runoff producing event.

9.3.9 Runoff Pretreatment
Infiltration basins should be preceded by a pretreatment facility. Roadways and parking lots may produce runoff with high levels of sediment, grease, and oil. These pollutants can potentially clog the pore space in the basin floor, thus reducing its infiltration and pollutant removal performance. Suitable pretreatment practices include vegetated buffer strips, sediment forebays, and proprietary water quality inlets. At a minimum, each basin inflow point should be equipped with a sediment forebay. Individual forebay volumes should range between 0.1 and 0.25 inches over the outfall’s contributing impervious area with the sum of all forebay volumes not less than 10 percent of the total WQV.

All infiltration basins that receive surface runoff as sheet flow should be equipped with a vegetated buffer strip at least 20 feet wide.

9.3.10 Discharge Flows
All basin outfalls must discharge into an adequate receiving channel as defined by Regulation MS-19 in the Virginia Erosion and Sediment Control Handbook, (DCR, 1992, Et seq.). Existing natural channels conveying pre-development flows may be considered receiving channels if they satisfactorily meet the standards outlined in the VESCH MS-19. Unless unique site conditions mandate otherwise, receiving channels should be analyzed for overtopping during conveyance of the 10-year runoff producing event and for erosive potential under the 2-year event.
9.4 Design Process

Many of the design elements in an infiltration basin are identical to those of a dry extended detention basin. These elements include estimation of flood control storage volumes, design of a multi-stage riser, storage indication (reservoir) routing, emergency spillway design, riser buoyancy calculations, and the design of sediment forebays. For those design items, the reader is referred to Chapter 2 – Dry Extended Detention Basin.

This section presents the design steps exclusive to infiltration basins serving as water quality BMPs. The pre and post-development runoff characteristics are intended to replicate stormwater management needs routinely encountered during linear development projects. The hydrologic calculations and assumptions presented in this section serve only as input data for the detailed BMP design steps. Full hydrologic discussion is beyond the scope of this report, and the user is referred to Chapter 4 of the Virginia Stormwater Management Handbook (DCR, 1999, Et Seq.) for expanded hydrologic methodology.

The following design example entails the construction of a small interchange and new section of two lane divided highway in Williamsburg. The total project site, including right-of-way and all permanent easements, consists of 24.8 acres. Pre and post-development hydrologic characteristics are summarized below in Table 9.2. Initial geotechnical investigations reveal a soil infiltration rate of 1.84 inches per hour with site soils classified as Hydrologic Soil Group B.

<table>
<thead>
<tr>
<th></th>
<th>Pre-Development</th>
<th>Post-Development</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Area (acres)</td>
<td>24.8</td>
<td>24.8</td>
</tr>
<tr>
<td>Land Cover</td>
<td>Unimproved Grass Cover</td>
<td>11.2 acres impervious cover</td>
</tr>
<tr>
<td>Impervious Percentage</td>
<td>0</td>
<td>45</td>
</tr>
</tbody>
</table>

Table 9.2. Hydrologic Characteristics of Example Project Site

Step 1. Compute the Required Water Quality Volume

The project water quality volume is a function of the developed impervious area, and is computed as follows:

\[ WQV = \frac{IA \times \frac{1}{12} \text{in}}{2} \]

\[ IA = \text{Impervious Area (ft}^2\text{)} \]

The project site in this example is comprised of a total drainage area of 24.8 acres. The total impervious area within the site is 11.2 acres. Therefore, the water quality volume is computed as follows:
The impervious cover within the project site is less than 67 percent of the total project site. Therefore, the infiltration basin will be sized to treat the computed water quality volume of 20,328 cubic feet.

**Step 2. Compute the Design Infiltration Rate**

The design infiltration rate, $f_d$, is computed as one-half the infiltration rate obtained from the required geotechnical analysis. For the given site conditions, the design infiltration rate is computed as:

$$f_d = 0.5 f = (0.5) \left( \frac{1.84 \text{ in}}{\text{hr}} \right) = 0.92 \frac{\text{in}}{\text{hr}}$$

**Step 3. Compute the Maximum Ponded Depth of Infiltration Volume**

The basin must be designed such that it is completely empty within a maximum of 48 hours following a runoff producing event. To ensure compliance with this requirement, the maximum ponding depth for the infiltration (treatment) volume is computed by the following equation:

$$d_{\text{max}} = f_d \times T_{\text{max}}$$

$d_{\text{max}}$ = maximum allowable basin depth (ft)
$f_d$ = design infiltration rate (in/hr)
$T_{\text{max}}$ = maximum allowable drain time (48 hours)

The maximum allowable ponding depth is therefore computed as:

$$d_{\text{max}} = \left( \frac{0.92 \text{ in}}{\text{hr}} \right) \left( \frac{1 \text{ ft}}{12 \text{ in}} \right) (48 \text{ hr}) = 3.68 \text{ ft}$$
Step 4. Compute the Minimum Allowable Basin Surface Area

Employing Darcy’s Law, and assuming one-dimensional flow through the bottom of the basin, we can compute the minimum allowable surface area of the basin floor by the following equation:

\[ S_{A_{\text{min}}} = \frac{WQV}{(f_d)(T_{\max})} \]

- \( S_{A_{\text{min}}} \) = minimum basin bottom surface area (ft²)
- \( WQV \) = treatment volume (ft³)
- \( f_d \) = design infiltration rate (in/hr)
- \( T_{\max} \) = maximum allowable drain time (48 hours)

The minimum allowable basin floor area is computed as follows:

\[ S_{A_{\text{min}}} = \frac{20,328 \text{ ft}^3}{0.92 \text{ in/hr} \left(\frac{1 \text{ ft}}{12 \text{ in}}\right)(48 \text{ hr})} = 5,524 \text{ ft}^2 \]

Step 5. Size the Basin Based on Site-Specific Parameters

In order to reduce the amount of required right-of-way acquisition, the surface area of a structural BMP is minimized during the design process. However, minimization of surface area may require a BMP depth that is either impractical or, in the case of an infiltration facility, violates design parameters. The following design approach attempts to minimize the surface area of the basin while meeting restrictions on ponding depth.

The minimum allowable basin floor area was previously computed as 5,524 ft². This is the minimum basin area that, when considering a factor of safety, will ensure that the basin empties within a maximum of 48 hours. In practice, the actual configuration of an infiltration basin will be dictated largely by topography and other site-specific constraints. The final design may require multiple iterations to provide the required treatment volume. In this design, we will consider a basin of rectangular orientation, with a 2.5:1 length to width ratio. A schematic illustration of this basin configuration is shown in Figure 9.2.

![Figure 9.1. Schematic Basin Orientation](image)
The dimensions of the basin floor can then be approximated by solving the following expression:

\[
W \times 2.5W = 5,524 \text{ ft}^2 \\
W = 47.0 \text{ ft} \\
L = 117.5 \text{ ft}
\]

The volume above the basin floor that is allocated to infiltration can be approximated by the following equation:

\[
V = \left( \frac{A_1 + A_2}{2} \right) d
\]

\( V \) = infiltration (treatment) volume (ft\(^3\))
\( A_1 \) = surface area of basin floor (5,524 ft\(^2\))
\( A_2 \) = surface area above the basin floor allocated to infiltration
\( d \) = incremental depth between \( A_1 \) and \( A_2 \)

Based on a trapezoidal approximation, the surface area, \( A_2 \), can be expressed as a function of depth, \( d \):

\[
A_2 = [47.0 + (2)(d)(Z)] \times [117.5 + (2)(d)(Z)]
\]

\( Z \) = basin side slopes (ZH:1V)

In this example, we will consider that the basin side slopes are 3H:1V. The updated \( A_2 \) expression then becomes:

\[
A_2 = [47.0 + (2)(d)(3)] \times [117.5 + (2)(d)(3)]
\]

A total infiltration volume of 20,328 ft\(^3\) must be provided above the surface of the basin floor. At this point, the designer can construct a plot of storage versus depth by employing the above equation for \( A_2 \) in the previous expression for volume, \( V \). This plot is shown in Figure 9.2.
The plot indicates that the infiltration volume of 20,328 ft$^3$ is provided at an approximate depth of 2.8 feet above the basin floor. This estimate can be verified as follows:

\[ A_2 = [47.0 + (2)(2.8)(3)] \times [117.5 + (2)(2.8)(3)] = 8,568 \text{ ft}^2 \]

The total storage volume provided above the permanent pool is then computed as:

\[ V = \left( \frac{5,524 + 8,568}{2} \right)2.8 = 19,729 \text{ ft}^3 \]

The volume is less than the required storage volume of 20,328 ft$^3$, and therefore must be increased. The calculation is repeated for a ponded infiltration depth of 2.9 feet.

\[ A_2 = [47.0 + (2)(2.9)(3)] \times [117.5 + (2)(2.9)(3)] = 8,688 \text{ ft}^2 \]

The total storage volume provided above the permanent pool is then computed as:

\[ V = \left( \frac{5,524 + 8,688}{2} \right)2.9 = 20,607 \text{ ft}^3 \]

The infiltration volume provided at a ponded depth of 2.9 feet exceeds (slightly) the minimum treatment volume of 20,328 ft$^3$ and is therefore acceptable. Additionally, the
Infiltration volume is provided at a depth that is less than the maximum allowable depth of 3.68 feet. Therefore, it can be anticipated that the basin will empty completely within the maximum allowable time of 48 hours.

At this point, the remaining design process largely mimics that of a Dry Extended Detention facility. Flood control storage can be provided in the facility beginning at 2.9 feet above the basin floor (the upper limit of the infiltration volume). The remaining design elements include estimation of flood control storage volumes, design of a multi-stage riser, storage indication (reservoir) routing, emergency spillway design, riser buoyancy calculations, and the design of sediment forebays. For those design items, the reader is referred to Chapter 2 – Dry Extended Detention Basin.

**Step 6. Landscaping**

Infiltration basins must exhibit a dense vegetative cover before any stormwater runoff is directed to the facility. Careful attention must be given to the types of vegetation selected for the basin floor and embankment. The vegetative species must be selected based on their inundation tolerance and the anticipated frequency and depth of inundation. The designer is referred to the Virginia Erosion and Sediment Control Handbook (DCR, 1992, Et seq.) for recommendations of specific vegetative species based on the facility’s geographic location. Generally, low-growing stoloniferous grasses are good candidates for infiltration facilities as they permit long intervals between mowing, thus minimizing the frequency of traffic on the surface of the facility.

Maintenance of the facility’s vegetative cover is essential to the long-term performance of the facility. A dense vegetative stand enhances infiltration, minimizes surface erosion, and deters invasive and detrimental vegetative species. Any bare spots on the surface of the facility should be re-seeded immediately.

The use of fertilizers should be minimized and avoided completely if practically possible. Excessive use of fertilizers on highly permeable soil may lead to groundwater contamination. Reference the Virginia Erosion and Sediment Control Handbook (DCR, 1992, Et seq.) for recommendations on appropriate fertilizer types and minimum effective application rates.