Chapter 7 - Infiltration and Bio-infiltration Treatment Facilities

7.1 Purpose

This Chapter provides site suitability, design, and maintenance criteria for infiltration treatment systems. Infiltration treatment Best Management Practices (BMPs) serve the dual purpose of removing pollutants (TSS, heavy metals, phosphates, and organics) from storm water and recharging aquifers.

A storm water infiltration treatment facility is an impoundment, typically a basin, trench, or bio-infiltration swale whose underlying soil removes pollutants from storm water. The infiltration BMPs described in this chapter include:

- BMP T7.10 Infiltration basins
- BMP T7.20 Infiltration trenches
- BMP T7.30 Bio-infiltration swales

Infiltration treatment soils must contain sufficient organic matter and/or clays to sorb, decompose, and/or filter storm water pollutants. Pollutant/soil contact time, soil sorptive capacity, and soil aerobic conditions are important design considerations.

The earlier sections of this Chapter provide information regarding site criteria, infiltration rates, site suitability, and guidance of a general nature for all of these BMPs. Later in the Chapter, detailed additional design criteria and considerations are provided for each specific BMP. Also, design requirements for infiltration facilities meeting Minimum Requirements #7: Flow Control, are not found in this Volume, but are found in Volume III.

7.2 Application

These infiltration and bio-infiltration treatment measures are capable of achieving the performance objectives cited in Chapter 3 for specific treatment menus. In general, these treatment techniques can capture and remove or reduce the target pollutants to levels that:

- Will not adversely affect public health or beneficial uses of surface and groundwater resources, and
- Will not cause a violation of groundwater quality standards
Infiltration treatment systems are typically installed:

- As off-line systems, or on-line for small drainages.
- As a polishing treatment for street/highway runoff after pretreatment for TSS and oil.
- As part of a treatment train.
- As retrofits at sites with limited land areas, such as residential lots, commercial areas, parking lots, and open space areas.
- With appropriate pretreatment for oil and silt control to prevent clogging. Appropriate pretreatment devices include a pre-settling basin, wet pond/vault, biofilter, constructed wetland, media filter, and oil/water separator.

An infiltration basin is preferred, where applicable, and where a trench or bio-infiltration swale cannot be sufficiently maintained.

7.3 General Considerations

Discussed below are several considerations common to infiltration and bio-infiltration treatment.

7.3.1 Site Characterization Criteria

One of the first steps in siting and designing infiltration treatment facilities is to conduct a characterization study. Information gathered during initial geotechnical investigations can be used for the site characterization. Some of the key data and issues to be characterized include the following:

**Surface Features Characterization:**

- Topography within 500 feet of the proposed facility.
- Anticipated site use (street/highway, residential, commercial, high-use site).
- Location of water supply wells within 500 feet of proposed facility.
- Location of groundwater protection areas and/or 1, 5 and 10-year time of travel zones for municipal well protection areas.
- A description of local site geology, including soil or rock units likely to be encountered, the groundwater regime, and geologic history of the site.

**Subsurface Characterization**

- Subsurface explorations (test holes or test pits) to a depth below the base of the infiltration facility of at least 5 times the maximum design depth of ponded water proposed for the infiltration facility,
- Test holes or test pits explorations shall be conducted during the wet season (December 1st through April 30th) to provide accurate groundwater saturation and groundwater information.
Continuous sampling (representative samples from each soil type and/or unit within the infiltration receptor) to a depth below the base of the infiltration facility of 2.5 times the maximum design ponded water depth, but not less than 6 feet.

- For basins, at least one test pit or test hole per 5,000 ft$^2$ of basin infiltrating surface (in no case less than two per basin).
- For trenches, at least one test pit or test hole per 50 feet of trench length (in no case less than two per trench).

Note: The depth and number of test holes or test pits and samples should be increased if, in the judgment of a licensed engineer with geotechnical expertise (P.E.) or other licensed professional acceptable to the City, the conditions are highly variable and such increases are necessary to accurately estimate the performance of the infiltration system. The exploration program may also be decreased if, in the opinion of the licensed engineer or other professional, the conditions are relatively uniform and the borings/test pits omitted will not influence the design or successful operation of the facility. In high water table sites the subsurface exploration sampling need not be conducted lower than two (2) feet below the groundwater table.

Prepare detailed logs for each test pit or test hole and a map showing the location of the test pits or test holes. Logs must include at a minimum, depth of pit or hole, soil descriptions, depth to water, presence of stratification.

Note: Logs must substantiate whether stratification does or does not exist. The licensed professional may consider additional methods of analysis to substantiate the presence of stratification that will significantly impact the design of the infiltration facility.

**Infiltration Rate Determination**

Determine the representative infiltration rate of the unsaturated vadose zone based on field infiltration tests and/or grain size/texture determinations. Field infiltration rates can be determined using the Pilot Infiltration Test (see PIT-Appendix V-B). Such site testing should be considered to verify infiltration rate estimates based on soil size distribution and/or texture. Infiltration rates may also be estimated based on soil grain-size distributions from test pits or test hole samples. This may be particularly useful where a sufficient source of water does not exist to conduct a pilot infiltration test. As a minimum, one soil grain-size analysis per soil stratum in each test hole shall be performed within 2.5 times the maximum design water depth, but not less than 6 feet.

The infiltration rate is needed for routing and sizing purposes and for classifying the soil for treatment adequacy.
Soil Testing
At a minimum, soil characterization for each soil unit (soils of the same texture, color, density, compaction, consolidation and permeability) encountered shall include:

- Grain-size distribution (ASTM D422 or equivalent AASHTO specification).
- Textural class (USDA) (See Figure 7.1).
- Percent clay content (include type of clay, if known).
- Cation exchange capacity (CEC) and organic matter content for each soil type and strata. Where distinct changes in soil properties occur, to a depth below the base of the facility of at least 2.5 times the maximum design water depth, but not less than 6 feet. Consider if soils are already contaminated, thus diminishing pollutant sorptive capacity (for water quality design only).
- For soils with low CEC and organic content, deeper characterization of soils may be warranted (refer to Section 7.3.3 Site Suitability Criteria) (for water quality design only).
- Color/mottling.
- Variations and nature of stratification.

Infiltration Receptor
Infiltration receptor (unsaturated and saturated soil receiving the storm water) characterization should include:

- Installation of groundwater monitoring wells. Use at least three per infiltration facility, or three hydraulically connected surface and groundwater features. This will establish a three-dimensional relationship for the groundwater table, unless the highest groundwater level is known to be at least 50 feet below the proposed infiltration facility. The monitoring wells will:
  - Monitor the seasonal groundwater levels at the site during at least one wet season, and,
  - Consider the potential for both unconfined and confined aquifers, or confining units, at the site that may influence the proposed infiltration facility as well as the groundwater gradient. Other approaches to determine groundwater levels at the proposed site could be considered if pre-approved by the City of Tacoma, and,
  - Determine the ambient groundwater quality, if that is a concern.
- An estimate of the volumetric water holding capacity of the infiltration receptor soil. This is the soil layer below the infiltration facility and above the seasonal high-water mark, bedrock, hardpan, or other low permeability layer. This analysis should be conducted at a conservatively high infiltration rate based on vadose zone porosity, and the water quality runoff volume to be infiltrated. This, along with
an analysis of groundwater movement, will be useful in determining if there are volumetric limitations that would adversely affect drawdown.

- Depth to groundwater table and to bedrock/impermeable layers.
- Seasonal variation of groundwater table based on well water levels and observed mottling.
- Existing groundwater flow direction and gradient.
- Lateral extent of infiltration receptor.
- Horizontal hydraulic conductivity of the saturated zone to assess the aquifer’s ability to laterally transport the infiltrated water.
- Impact of the infiltration rate and volume at the project site on groundwater mounding, flow direction, and water table; and the discharge point or area of the infiltrating water. A groundwater mounding analysis should be conducted at all sites where the depth to seasonal groundwater table or low permeability stratum is less than 15 feet and the runoff to the infiltration facility is from more than one acre. The site professional can consider conducting an aquifer test, or slug test and the type of groundwater mounding analysis necessary at the site.

Note: A detailed soils and hydrogeologic investigation should be conducted if potential pollutant impacts to groundwater are a concern, or if the applicant is proposing to infiltrate in areas underlain by till or other impermeable layers. (Suggested references: “Implementation Guidance for the Ground Water Quality Standards”, Department of Ecology, publication 96-2, 1996, and, "Washington State Water Quality Guide," Natural Resources Conservation Service, W. 316 Boone Ave, Spokane, WA 99201-2348).

7.3.2 Design Infiltration Rate Determination

The representative site infiltration rate must be determined from soil test results, the stratification identified during the site characterization, and/or in-situ field measurements.

Infiltration rates for treatment can be determined using either a correlation to grain size distribution from soil samples, textural analysis, or by in-situ field measurements. Short-term infiltration rates up to 2.4 in./hr represent soils that typically have sufficient treatment properties. Long-term infiltration rates are used for sizing the infiltration pond based on maximum pond level and drawdown time. Long-term infiltration rates up to 2.0 inches per hour can also be considered for treatment if SSC-4 and SSC-6 are met, as defined in Section 7.3.3.

Historically, infiltration rates have been estimated from soil grain size distribution (gradation) data using the United States Department of Agriculture (USDA) textural analysis approach. To use the USDA textural analysis approach, the grain size distribution test must be conducted in accordance with the USDA test procedure (Soil Survey Manual, U.S. Department of Agriculture, October 1993, page 136). This manual only
considers soil passing the #10 sieve (2 mm) (U.S. Standard) to determine
percentages of sand, silt, and clay for use in Figure 7.1 (USDA Textural
Triangle). However, many soil test laboratories use the ASTM soil size
distribution test procedure (ASTM D422), which considers the full range
of soil particle sizes, to develop soil size distribution curves. The ASTM
soil gradation procedure must not be used with Figure 7.1.

Three Methods for Determining Long-term Infiltration Rate for Sizing
the Infiltration Basin, Trench, or Swale

For designing the infiltration facility, the site professional should select
one of the three methods described below that will best represent the
long-term infiltration rate at the site. The long-term infiltration rate should
be used for routing and sizing the basin/trench for the maximum
drawdown time of 24 hours. It is suggested that Method 1 be used to
corroborate and compare the infiltration rate estimates of the other
methods, using the appropriate correction factors. Verification testing of
the completed facility is strongly encouraged using Site Suitability
Criterion (SSC) # 9.

Method 1 — USDA Soil Textural Classification

Table 7.1 correlates USDA soil texture and infiltration rates for
homogeneous soils. It is based on the correlation developed by Rawls,
et. al., with minor changes in the infiltration rates based on WEF/ASCE
(1998). The infiltration rates provided in Table 7.1 represent short-term
conservative rates for homogeneous soils, which should be used for
treatment soil suitability determinations. However, these rates do not
represent the effects of site variability and long-term clogging due to
siltation and biomass buildup in the infiltration facility.

To determine long-term infiltration rates, Ecology’s Technical Advisory
Committee (TAC) recommends that the short-term infiltration rates be
reduced as shown in Table 7.1. A correction factor of 2 to 4 is assigned,
depending on the soil textural classification. These correction factors
(CF) consider an average degree of long-term facility maintenance, TSS
reduction through pretreatment, and site variability in the subsurface
conditions (due to a deposit of ancient landslide debris, buried stream
channels, lateral grain size variability, etc. that affect homogeneity).

However, these correction factors could be reduced, subject to the
approval of the City of Tacoma, under the following conditions:

- For sites with little soil variability,
- Where there will be a high degree of long-term facility maintenance,
- Where specific, reliable pretreatment is employed to reduce TSS
  entering the infiltration facility.

In no case shall a correction factor less than 2.0 be used.

Correction factors higher than those provided in Table 7.1 should be
considered for situations where: long-term maintenance will be difficult to
implement; where little or no pretreatment is anticipated; or, where site
conditions are highly variable or uncertain. These situations require the
use of best professional judgment by the site engineer and the approval of the City. An operation and maintenance plan and a financial bonding plan may also be required by the City.

Method 2 — ASTM Gradation Testing at Full Scale Infiltration Facilities

As an alternative to Table 7.1, recent studies by Massmann and Butchart were used to develop long-term infiltration rates provided in Table 7.2. These studies compare infiltration measurements from full-scale infiltration facilities to soil gradation data developed using the ASTM procedure (ASTM D422). The data that forms the basis for Table 7.2 was from soils that would be classified as sands or sandy gravels. No data was available for finer soils. Therefore, Table 7.2 should not be used for soils with a $d_{10}$ size (10% passing the size listed) less than 0.05 mm (U.S. Standard Sieve).

The primary source of the data used by Massmann and Butchart was from Wiltsie (1998), who included limited infiltration studies only on Thurston County sites. However, Massmann and Butchart also included limited data from King and Clark County sites in their analysis. This table provides recommended long-term infiltration rates that have been correlated to soil gradation parameters using the ASTM soil gradation procedure.

Table 7.2 can be used to estimate long-term design infiltration rates directly from soil gradation data, subject to the approval of the local jurisdiction. As is true of Table 7.1, the long-term rates provided in Table 7.2 represent average conditions regarding site variability, the degree of long-term maintenance and pretreatment for Total Suspended Solids (TSS) control. The long-term infiltration rates in Table 7.2 may need to be decreased if the site is highly variable, or if maintenance and influent characteristics are not well controlled.

The infiltration rates provided in Tables 7.1 and 7.2 represent rates for homogeneous soil conditions. If more than one soil unit is encountered within 6 feet of the base of the facility, or 2.5 times the proposed maximum water design depth, use the lowest infiltration rate determined from each of the soil units as the representative site infiltration rate.

If soil mottling, fine silt or clay layers, which cannot be fully represented in the soil gradation tests, are present below the bottom of the infiltration pond, the infiltration rates provided in the tables will be too high and should be reduced. Based on limited full-scale infiltration data (Massmann and Butchart, 2000; Wiltsie, 1998), it appears that the presence of mottling indicates soil conditions that reduce the infiltration rate for homogeneous conditions by a factor of 3 to 4.

Method 3 - In-situ Infiltration Measurements or Pilot Infiltration Tests (PIT)

Where feasible, Ecology encourages in-situ infiltration measurements, using a procedure such as the Pilot Infiltration Test (PIT) described in Appendix V-B. Small-scale infiltration tests such as the EPA Falling Head
or double ring infiltrometer test (ASTM D3385-88) are not recommended unless modified versions are determined to be acceptable by Ecology or the City.

As with the previous methods, the infiltration rate obtained from the PIT shall be considered to be a short-term rate. To obtain long-term infiltration rates the short-term rates must be reduced by applying a total correction factor. The total correction factor is the sum of the partial correction factors, presented in Table 7.3, that account for site variability, number of tests conducted, degree of long-term maintenance, influent pretreatment/control, and potential for long-term clogging due to siltation and bio-buildup.

The typical range of partial correction factors to account for these issues based on TAC experience is summarized in Table 7.3. The range of partial correction factors is for general guidance only. The specific partial correction factors used shall be determined based on the professional judgment of the licensed engineer or other site professional considering all issues which may affect the long-term infiltration rate, subject to the approval of the City.

The following discussions are to provide guidance in determining the partial correction factors to apply in Table 7.3.

**Site variability and number of locations tested.** The number of locations tested must be capable of representing the subsurface conditions throughout the facility site. The partial correction factor used for this issue varies directly with the level of uncertainty for the occurrence of adverse subsurface conditions. If the range of uncertainty is low (for example, conditions are known to be uniform through previous exploration and site geological factors), one pilot infiltration test may be adequate to justify a partial correction factor at the low end of the range. If the level of uncertainty is high, due to highly variable site conditions or limited local testing data, a partial correction factor near the high end of the range may be appropriate. This might be the case where the site conditions are highly variable due to a deposit of ancient landslide debris, or buried stream channels. In these cases, even with many explorations and several pilot infiltration tests, the level of uncertainty may still be high.

**Degree of long-term maintenance to prevent siltation and bio-buildup.** The standard of comparison here is the long-term maintenance requirements provided in Section 4.6, and any additional requirements by the City. Full compliance with these requirements would be justification to use a partial correction factor at the low end of the range. If there is a high degree of uncertainty that long-term maintenance will be carried out consistently, or if the maintenance plan is poorly defined, a partial correction factor near the high end of the range may be justified.

**Degree of influent control to prevent siltation and bio-buildup.** A partial correction factor near the high end of the range may be justified under the following circumstances:
• If the infiltration facility is located in a shady area where moss or litter fall, buildup from the surrounding vegetation is likely and cannot be easily controlled through long-term maintenance.

• If there is minimal pre-treatment, and the influent is likely to contain moderately-high TSS levels.

If influent into the facility can be well controlled such that the planned long-term maintenance can easily manage siltation and biomass buildup, then a partial correction factor near the low end of the range may be justified.

The determination of long-term design infiltration rates from in-situ infiltration test data involves a considerable amount of engineering judgment. Therefore, when reviewing or determining the final long-term design infiltration rate, the City may consider the results of both textural analyses and in-situ infiltration tests results when available.

7.3.3 Site Suitability Criteria (SSC)

This section specifies the site suitability criteria that must be considered for siting infiltration treatment systems. When a site investigation reveals that any of the nine applicable criteria cannot be met, appropriate mitigation measures must be implemented so that the infiltration facility will not pose a threat to safety, health, and the environment.

For infiltration treatment, site selection and design decisions, a geotechnical and hydrogeologic report should be prepared by a qualified engineer with geotechnical and hydrogeologic experience. A comparable professional, acceptable to the City, may also conduct the work if it is under the seal of a registered Professional Engineer. The design engineer may utilize a team of certified or registered professionals in soil science, hydrogeology, geology, and other related fields.

The nine site suitability criteria are as follows:

**SSC-1 Setback Criteria**

Setback requirements are generally required by the City, uniform building code requirements, or state regulations. Where a conflict between setbacks occurs, the City shall require compliance with the most stringent of the setback requirements from the various codes/regulations.

*Below are conditions the soils professional must evaluate to determine the need for additional or more stringent setbacks not found in this manual.*

**The professional should evaluate:**

• Potential impacts to drinking water wells, septic tanks or drainfields, and springs used for public drinking water supplies. Infiltration facilities upgradient of drinking water supplies and within 1, 5, and 10-year time of travel zones must comply with Health Department...
requirements (Washington Wellhead Protection Program, DOH, 12/93).

- Potential impacts from roadways subject to deicers or herbicides which are likely to be present in the influent to the infiltration system.
- Potential impacts to all building foundations in the vicinity of the proposed infiltration facility. Recommend investigating all building foundations within 100 feet downslope and 20 feet upslope from the facility.
- Potential impacts to all property lines within 20 feet of the facility.
- Potential impacts to a Native Growth Protection Easement (NGPE); ≥20 feet.
- Potential impacts to the top of slopes >15% and within 50 feet.
- On-site and offsite structural stability due to extended subgrade saturation and/or head loading of the permeable layer, including the potential impacts to downgradient properties, especially on hills with known side-hill seeps.

**SSC-2 Ground Water Protection Areas**

A site is not suitable if the infiltrated storm water will cause a violation of Ecology’s Ground Water Quality Standards (see SSC-9 for verification testing guidance). The City shall be consulted for applicable pretreatment requirements and whether the site is located in an aquifer sensitive area, sole source aquifer, or a wellhead protection zone. See Volume I, Chapter 2 for geographic specific requirements.

**SSC-3 High Vehicle Traffic Areas**

Treatment infiltration BMPs may be considered for runoff from areas of industrial activity and the high vehicle traffic areas described below, if appropriate pretreatment (including oil removal) is provided to ensure that groundwater quality standards will not be violated and that the infiltration facility will not be adversely affected.

High Vehicle Traffic Areas are:

- Commercial or industrial sites subject to an expected average daily traffic count (ADT) ≥100 vehicles/1,000 ft² gross building area (trip generation); and
- Road intersections with an ADT of ≥ 25,000 on the main roadway, or ≥ 15,000 on any intersecting roadway.

**SSC-4 Soil Infiltration Rate/Drawdown Time for Treatment**

*Infiltration Rates-Short-term and long-term:*

For treatment purposes the short-term soil infiltration rate should be 2.4 in./hour, or less, to a depth of 2.5 times the maximum design pond water
depth, or a minimum of 6 ft. below the base of the infiltration facility. This infiltration rate is also typical for soil textures that possess sufficient physical and chemical properties for adequate treatment, particularly for soluble pollutant removal (see SSC-6). It is comparable to the textures represented by Hydrologic Groups B and C. Long-term infiltration rates up to 2.0 inches/hour can also be considered, if the infiltration receptor is not a sole-source aquifer, and in the judgment of the site professional, the treatment soil has characteristics comparable to those specified in SSC-6 to adequately control the target pollutants.

The long-term infiltration rate should also be used for maximum drawdown time and routing calculations.

**Drawdown Time:**

It is necessary to empty the maximum ponded depth (water quality volume) from the infiltration basin within 24 hours from the completion of inflow to the storage pond in order to meet the following objectives:

- Restore hydraulic capacity to receive runoff from a new storm.
- Maintain infiltration rates.
- Aerate vegetation and soil to keep the vegetation healthy.
- Enhance the biodegradation of pollutants and organics in the soil.

**SSC-5 Depth to Bedrock, Water Table, or Impermeable Layer**

The base of all infiltration basins or trench systems shall be ≥ 5 feet above the seasonal high-water mark, bedrock (or hardpan) or other low permeability layer. A minimum separation of 3 feet may be considered if the groundwater mounding analysis, volumetric receptor capacity, and the design of the overflow and/or bypass structures are judged by the site professional to be adequate to prevent overtopping and to meet the site suitability criteria specified in this section.

**SSC-6 Soil Physical and Chemical Suitability for Treatment**

The soil texture and design infiltration rates should be considered along with the physical and chemical characteristics specified below to determine if the soil is adequate for removing the target pollutants. The following soil properties must be carefully considered in making such a determination:

- Cation exchange capacity (CEC) of the treatment soil must be ≥ 5 milliequivalents CEC/100 g dry soil (USEPA Method 9081). *Consider empirical testing of soil sorption capacity, if practicable.* Ensure that soil CEC is sufficient for expected pollutant loadings, particularly heavy metals. CEC values of >5 meq/100g are expected in loamy sands, according to Rawls, et al. Lower CEC content may be considered if it is based on a soil loading capacity determination for the target pollutants that is accepted by the City.

- Depth of soil used for infiltration treatment must be a minimum of 18 inches.
• Organic Content of the treatment soil (ASTM D 2974): Organic matter can increase the sorptive capacity of the soil for some pollutants. The site professional should evaluate whether the organic matter content is sufficient for control of the target pollutant(s).

• Waste fill materials should not be used as infiltration soil media nor should such media be placed over uncontrolled or non-engineered fill soils.

• Engineered soils may be used to meet the design criteria in this chapter and the performance goals in Chapters 3 and 4. Field performance evaluation(s), using acceptable protocols, would be needed to determine feasibility, and acceptability by the local jurisdiction. See also Chapter 12.

SSC-7 Cold Climate and Impact of Roadway deicers

• For cold climate design criteria (snowmelt/ice impacts) refer to D. Caraco and R. Claytor (1997).

• Potential impact of roadway deicers on potable water wells must be considered in the siting determination. Mitigation measures must be implemented if infiltration of roadway deicers can cause a violation of groundwater quality standards.

SSC-8 Verification Testing of the Completed Facility

Verification testing of the completed full-scale infiltration facility is recommended to confirm that the design infiltration parameters are adequate to manage the design volume and meet the pollutant capture objectives of the infiltrating soil. The site professional should determine the duration and frequency of the verification testing program for the potentially impacted groundwater. The groundwater monitoring wells installed during site characterization may be used for this purpose. Long-term in-situ drawdown and water quality monitoring for a two-year period would be preferable (see Volume III, Chapter 3, Section 3.2.6 – SSC-7).

7.3.4 General Information for Infiltration Basins, Trenches, and Bio-infiltration Swales

This section covers general design, construction, and maintenance criteria that apply to infiltration basins, trenches, and bio-infiltration swales.

Sizing Criteria

Size should be determined by one of the following methods:

1) Routing 91% of the runoff volume, as predicted by Western Washington Hydrology Model (WWHM) (or an approved, equivalent continuous runoff model) through the facility; or

2) Using the Simple Method, discussed below, that infiltrates the Water Quality Design Storm Volume within 24 hours.
**Off-line versus On-line Treatment**

Infiltration facilities for treatment can be located upstream or downstream of detention and can be off-line or on-line. For off-line facilities, the flow splitter should be designed to route the water quality design flow rate to the infiltration facility. Until a continuous runoff model is available that identifies the flow rate associated with 91% of the runoff volume, use:

- Estimate for that flow rate as identified in Chapter 4 for upstream facilities;
- 2-year return frequency flow rate for flows downstream of detention.

The storage pond above the infiltration surface should not overflow since all flows routed to it are at or below the water quality design flow rate.

*Note: An emergency overflow should still be included in the design. See Chapter 4 for flow splitter design details.*

For on-line infiltration facilities, the storage pond should be sized to restrict the total amount of overflow to 9% of the total runoff volume of the long-term time series or less depending on the design objective.

*Note: Refer to Volume III for overflow structure design details.*

**Method of Design and Sizing Criteria Procedure**

- **Simple Method**
  
  \[ A_{inf} = \frac{A_t Q_d}{F t} \]

  \( A_{inf} \) = Bottom surface area of infiltration facility  
  \( A_t \) = tributary drainage area  
  \( Q_d \) = the runoff depth for the 6-month, 24-hour storm, estimated using the SCS (NRCS) Curve Number Equations approach detailed in Volume III, Chapter 2.  
  \( F \) = long-term infiltration rate  
  \( t \) = 24 hours maximum drawdown time

- **Continuous Runoff Method**
  
  Refer to Chapter 8 for sizing sand filters using the Continuous Runoff Model Sizing Method. The only difference for sizing an infiltration facility is that the infiltration rate is a function only of surface area and ponded hydraulic head does not play a role. The long-term infiltration rate, as determined in Section 7.3.2 is multiplied by the horizontal surface area of an infiltration bed to obtain a volumetric infiltration rate that is input to the WWHM as a stage-storage-discharge table.

  *Note: Horizontal surface area changes with stage if the sidewalls are sloped.*

- **Control of Side-Wall Seepage**
  
  Typically, side-wall seepage is not a concern if seepage occurs through the same stratum as the bottom of the facility. However, for engineered soils or for soils with very low permeability, the potential to bypass the treatment soil through the side-walls may be significant. In
those cases, the side-walls must be lined, either with an impervious liner or with at least 18 inches of treatment soil, to prevent seepage of untreated flows through the side walls.

• **Construction Criteria**
  
  - **Excavation** - Initial excavation should be conducted to within 1-foot of the final elevation of the floor of the infiltration facility. Final excavation to the finished grade should be deferred until all disturbed areas in the upgradient watershed have been stabilized or protected. The final phase of excavation should remove all accumulated sediment. After construction is completed, prevent sediment from entering the infiltration facility by first conveying the runoff water through an appropriate pretreatment system such as a pre-settling basin, wet pond, or sand filter.
  
  - **Infiltration facilities** should generally not be used as temporary sediment traps during construction. If an infiltration facility is to be used as a sediment trap, it must not be excavated to final grade until after the upgradient drainage area has been stabilized. Any accumulation of silt in the basin must be removed before putting it in service.
  
  - **Traffic Control** - Relatively light-tracked equipment is recommended for excavation to avoid compaction of the floor of the infiltration facility. The use of draglines and trackhoes should be considered. The infiltration area should be flagged or marked to keep equipment away.

• **Maintenance Criteria**

  Provision should be made for regular and perpetual maintenance of the infiltration basin/trench, including replacement and/or reconstruction of the treatment infiltration medium. Maintenance should be conducted when water remains in the basin or trench for more than 24 hours or overflows the basin/pond. Adequate access for O&M must be included in the design of infiltration basins and trenches. An Operation and Maintenance Plan, approved by the City, should ensure maintaining the desired efficiency of the infiltration facility.

  Debris/sediment accumulation - Removal of accumulated debris/sediment in the basin/trench should be conducted every 6 months or as needed to prevent clogging, or when water remains in the pond for greater than 24 hours.

  The treatment soil should be replaced or amended as needed to ensure maintaining adequate treatment capacity.

• **Verification of Performance**

  During the first 1-2 years of operation, verification testing as specified in SSC-9 is strongly recommended, along with a maintenance program that achieves expected performance levels. Operating and maintaining groundwater monitoring wells is also strongly encouraged.
7.4 Best Management Practices (BMPs) for Infiltration and Bio-infiltration Treatment

The three BMPs discussed below are recognized currently as effective treatment techniques using infiltration and bio-infiltration. Selection of a specific BMP should be coordinated with the Treatment Facility Menus provided in Chapter 3.
BMP T7.10 Infiltration Basins

Description:
Infiltration basins are typically earthen impoundments with a grass cover, as shown schematically in Figure 7.2. - Example Infiltration Basin/Pond.

Additional Design Criteria specific for Basins
- The slope of the basin bottom should not exceed 3% in any direction.
- Treatment infiltration basins must have sufficient vegetation established on the basin floor and side slopes to prevent erosion and sloughing of the sideslopes and to provide additional pollutant removal. Erosion protection of inflow points to the basin must also be provided (e.g., riprap, flow spreaders, energy dissipaters). Select suitable vegetative materials for the basin floor and side slopes to be stabilized. Refer to Chapter 9 for recommended vegetation.
- A minimum of 1-foot of freeboard is recommended when establishing the design water depth at the long-term infiltration rate. Freeboard is measured from the rim of the infiltration facility to the maximum ponding level or from the rim down to the overflow point.
- A non-erodible outlet or spillway must be established at a proper elevation to discharge overflow. Ponding level, drawdown time, and storage volume are calculated from that reference point.

Maintenance Criteria Specific for Basins
- Maintain basin floor and side slopes to promote dense turf with extensive root growth. This enhances infiltration, prevents erosion and consequent sedimentation of the basin floor, and prevents invasive weed growth. Bare spots are to be immediately stabilized and revegetated.
- Vegetation growth should not be allowed to exceed 18 inches in height. Mow the slopes periodically and check for clogging and erosion.
- Seed mixtures should be the same as those recommended in Chapter 9. The use of low-growing, stoloniferous grasses will permit long intervals between mowing. Mowing twice a year is generally satisfactory. Fertilizers should be applied only as necessary and in limited amounts to avoid contributing to the pollution problems, including groundwater pollution. Consult the local extension agency for appropriate fertilizer types, including slow release fertilizers, and application rates.
BMP T7.20 Infiltration Trenches

Description:
Infiltration trenches are generally at least 24 inches wide, and are backfilled with a coarse stone aggregate, allowing for temporary storage of storm water runoff in the voids of the aggregate material. Stored runoff then gradually infiltrates into the surrounding soil. The surface of the trench can be covered with grating and/or consist of stone, gabion, sand, or a grassed covered area with a surface inlet. Perforated rigid pipe of at least 8-inch diameter can also be used to distribute the storm water in a stone trench. Trench configurations by Schueler (Figures 7.3 – 7.8) with inlet filter strips and/or 6-12 inches bottom sand layers are shown.

Due to accessibility and maintenance limitations infiltration trenches must be carefully designed, constructed and maintained.

Additional Design Criteria specific for Trenches
- Slope - The slope of the trench bottom should not exceed 3% in any direction.
- Access Port - Consider including an access port or open or grated top for accessibility to conduct inspections and maintenance.
- Backfill Material - The aggregate material for the infiltration trench should consist of a clean aggregate with a maximum diameter of 3 inches and a minimum diameter of 1.5 inches. Void space for these aggregates should be in the range of 30 percent to 40 percent.
- Filter Fabric - Protective permeable geotextile filter fabric should line the top and sides of the trench from one foot below the aggregate surface. The bottom sand or removable permeable fabric layer is optional.
- Overflow Channel - A non-erosive overflow channel or path, leading to a stabilized watercourse, should be provided at the 24-hour drawdown level.
- Observation Well - An observation well should be installed at the lower end of the infiltration trench to check for water levels, drawdown time, and to show the impact of sediments. Figure 7.9 illustrates observation well details. A typical observation well consists of a perforated PVC pipe, 4 to 6 inches in diameter, constructed flush with the ground elevation. For larger trenches a 12-36 inch diameter well can be installed to facilitate maintenance operations, such as pumping out the sediment. The top of the well should be capped, or covered with an ordinary drainage grate.
- Surface Cover - A stone-filled trench can be placed under a porous or impervious cover to conserve space.

Construction Criteria Specific for Trenches
- Trench Preparation - Excavated materials must be placed away from the trench sides to enhance trench wall stability. Care should also be
taken to keep this material away from slopes, neighboring property, sidewalks and streets. It is recommended that this material be covered with plastic (see Erosion/Sediment Control Measures in Volume II).

- Stone Aggregate Placement and Compaction - The stone aggregate should be placed in lifts and compacted using plate compactors. As a rule of thumb, a maximum loose lift thickness of 12 inches is recommended. The compaction process ensures geotextile conformity to the excavation sides, thereby reducing potential piping and geotextile clogging, and settlement problems.

- Potential Contamination - Prevent natural or fill soils from intermixing with the stone aggregate. All contaminated stone aggregate must be removed and replaced with uncontaminated stone aggregate.

- Overlapping and Covering - Following the stone aggregate placement, the geotextile must be folded over the stone aggregate to form a 12-inch minimum longitudinal overlap. When overlaps are required between rolls, the upstream roll should overlap a minimum of 2 feet over the downstream roll in order to provide a shingled effect.

- Voids Behind Geotextile - Voids between the geotextile and excavation sides must be avoided. Removing boulders or other obstacles from the trench walls eliminates one source of such voids. Natural soils should be placed in these voids at the most convenient time during construction to ensure geotextile conformity to the excavation sides. Soil piping and geotextile clogging, and possible surface subsidence will be avoided by this remedial process.

- Unstable Excavation Sites - Vertically excavated walls may be difficult to maintain in areas where the soil moisture is high or where soft or cohesionless soils predominate. Trapezoidal, rather than rectangular, cross-sections may be needed.

**Maintenance Criteria Specific for Trenches**

- Sediment buildup in the top foot of stone aggregate or the surface inlet should be monitored on the same schedule as the observation well.
BMP T7.30 Bio-infiltration Swale

Description

Bio-infiltration swales, also known as Grass Percolation Areas, combine grassy vegetation and soils to remove storm water pollutants by percolation into the ground. Their pollutant removal mechanisms include filtration, soil sorption, and uptake by vegetative root zones.

In general, bio-infiltration swales are used for treating storm water runoff from roofs, roads and parking lots. Flows greater than design flows are typically overflowed to the subsurface through an appropriate conveyance facility, or an overflow channel to storm water.

Additional Design Criteria Specific for Bio-infiltration Swales

- Use the same sizing guidance, off-line and on-line guidance, and design procedures as in Section 7.3.4.
- Drawdown time for the maximum ponded volume: 24 hours max.
- Swale bottom: flat with a longitudinal slope less than 1%.
- The maximum ponded level: 6 inches.
- Treatment soil to be at least 18 inches thick with a CEC of at least 5 meq/100 gm dry soil, organic content of at least 1%, and sufficient target pollutant loading capacity. The design soil thickness may be reduced to as low as 6 inches if appropriate performance data demonstrates that the vegetated root zone and the natural soil can be expected to provide adequate removal and loading capacities for the target pollutants. The design professional should calculate the pollutant loading capacity of the treatment soil to estimate if there is sufficient treatment soil volume for an acceptable design period (see Criteria for Assessing the Trace Element Removal Capacity of Biofiltration Systems, Stan Miller, Spokane County, June 2000).
- Other combinations of treatment soil thickness, CEC, and organic content design factors can be considered if it is demonstrated that the soil and vegetation will provide a target pollutant loading capacity and performance level acceptable to the local jurisdiction.
- The treatment zone depth of 6 inches or more should contain sufficient organics and texture to ensure good growth of the vegetation.
- The treatment soil infiltration rate should not exceed 1-inch per hour for a treatment zone depth of 6 inches relying on the root zone to enhance pollutant removal. The Site Suitability Criteria in Section 7.3.3 must also be applied; if a design soil depth of 18 inches is used then a maximum infiltration rate of 2.4 inches per hour is applicable.
- Native or adapted grass should be used.
- Pretreatment of debris, gross TSS, and oil & grease to prevent the clogging of the treatment soil and/or growth of the vegetation, where necessary.
• Identify pollutants, particularly in industrial and commercial area runoff, that could cause a violation of Ecology's groundwater quality standards (Chapter 173-200 WAC). Include appropriate mitigation measures (pretreatment, source control, etc.) for those pollutants.
Table 7.1
Recommended Infiltration Rates
Based on USDA Soil Textural Classification

<table>
<thead>
<tr>
<th>*Short-Term Infiltration Rate (in./hr)</th>
<th>Correction Factor, CF</th>
<th>Estimated Long-Term (Design) Infiltration Rate (in./hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clean sandy gravels and gravelly sands (i.e., 90% of the total soil sample is retained in the #10 sieve)</td>
<td>20</td>
<td>2</td>
</tr>
<tr>
<td>Sand</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>Loamy Sand</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Sandy Loam</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Loam</td>
<td>0.5</td>
<td>4</td>
</tr>
</tbody>
</table>

** Not recommended for treatment
*** Refer to SSC-4 and SSC-6 for treatment acceptability criteria

Table 7.2
Alternative Infiltration Rates Based on ASTM Gradation Testing

<table>
<thead>
<tr>
<th>D₁₀ Size from ASTM D422 Soil Gradation Test (mm)</th>
<th>Estimated Long-Term (Design) Infiltration Rate (in./hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 0.4</td>
<td>9*</td>
</tr>
<tr>
<td>0.3</td>
<td>6.5*</td>
</tr>
<tr>
<td>0.2</td>
<td>3.5*</td>
</tr>
<tr>
<td>0.1</td>
<td>2.0**</td>
</tr>
<tr>
<td>0.05</td>
<td>0.8</td>
</tr>
</tbody>
</table>

* Not recommended for treatment
** Refer to SSC-4 and SSC-6 for treatment acceptability criteria

Table 7.3
Correction Factors to be Used With In-Situ Infiltration Measurements to Estimate Long-Term Design Infiltration Rates

<table>
<thead>
<tr>
<th>Issue</th>
<th>Partial Correction Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site variability and number of locations tested</td>
<td>CFᵥ = 1.5 to 6</td>
</tr>
<tr>
<td>Degree of long-term maintenance to prevent siltation and bio-buildup</td>
<td>CFₘ = 2 to 6</td>
</tr>
<tr>
<td>Degree of influent control to prevent siltation and bio-buildup</td>
<td>CFᵢ = 2 to 6</td>
</tr>
</tbody>
</table>

Total Correction Factor (CF) = CFᵥ + CFₘ + CFᵢ
Figure 7-1 USDA Textural Triangle

Note: Shaded area applicable for design of infiltration BMPs

Source: USDA (reproduced with permission)
Figure 7-2  Example Infiltration Basin/Pond

Source: King County (reproduced with permission)
Figure 7-3  Parking Lot Perimeter Trench Design

Source: Schueler (reproduced with permission)

Figure 7-4  Infiltration Trench System

Source: Schueler (reproduced with permission)
Figure 7-5 Median Strip Trench Design

Source: Schueler (reproduced with permission)

Figure 7-6 Oversized Pipe Trench Design

Source: Schueler (reproduced with permission)
Slope of the Trench
Should be less than

Figure 7-7 Swale/Trench Design

Source: Schueler (reproduced with permission)

Figure 7-8 Underground Trench with Oil/Grit Chamber

Source: Schueler (reproduced with permission)
Figure 7-9 Observation Well Details

Source: King County (reproduced with permission)