5.3.2 Infiltration Bed

Description

An infiltration bed captures and temporarily stores stormwater runoff in a media bed that is located beneath an impervious surface or beneath an engineered layer of soil and vegetation. Infiltration beds capture and store stormwater runoff until it infiltrates into the subsurface below. The storage media may consist of clean-washed, open-graded stone aggregate, proprietary stormwater products, or perforated pipes set in a stone bed.

Infiltration beds are well suited for expansive level areas such as athletic fields, plazas, and pavement areas that are not suitable for a porous pavement surface (see Figures 5.3.2-1a and b). Infiltration beds can also be located under landscaped areas. Stormwater runoff from other portions of the site can be conveyed into the stormwater bed for management. If infiltration is not feasible or is limited, an infiltration bed can include an underdrain system for slow release. Infiltration beds can be designed to provide SOV, rate control, and water quality.

Figures 5.3.2-1a and b. An infiltration bed beneath a school athletic field provides stormwater management for the site and building while providing a level playfield area. Storm drain pipes convey roof runoff to the bed, and perforated pipes distribute the runoff through the bed. Small storms infiltrate while large storms discharge to the storm sewer at a mitigated flow rate.

BMP Functions Table

BMP	Applicability*	Volume Reduction	Water Quality	Peak Rate Reduction	Recharge	Runoff Temperature Mitigation	Heat Island	Habitat Creation	Maintenance Burden	Cost
Infiltration Bed	U/S/R	H	H	H	H	H	L	L	L	M

KEY: U = Urban; S = Suburban; R = Rural; H = High; M = Medium; L = Low

*Rating varies based on design considerations.

Key Design Features (See Figure 5.3.2-2)

- Often designed to capture volume of small storms and to provide peak rate control for larger storms.
- Often built to provide regional stormwater management.
- Clean-washed, open-graded stone storage bed with minimum of 40 percent void space.
- Additional storage may be achieved through the use of perforated pipes set in the stone bed or proprietary stormwater storage products.
- Surface material above bed may be pervious or impervious.
- Compacted fill material **may** be placed above bed.
- Level, uncompacted subgrade.
- Nonwoven geotextile at soil/stone interface, including top of bed to prevent soil movement into stormwater bed.
- Designed with method to convey water into stormwater bed.
- May include perforated pipe distribution network within bed.
- Sediment removal required for runoff from parking lots, roads, or other high pollutant source drainage areas.
- Always includes positive overflow.
- Should not place on compacted fill (fill with stone, as needed).
- When possible, place infiltration beds on upland soils.

Applications

- Athletic and recreational fields
- Parking lots and driveways where porous pavement is not appropriate or feasible
- Plazas and open spaces

- Below existing or proposed open space areas
- Beneath areas of fill material to achieve infiltration where major grade changes are required, such as on slopes
- Between impervious areas and downslope vegetation, such as woods or wetlands, where it is important to maintain soil moisture conditions after development

Advantages

- When used to provide volume reduction (SOV), may provide a Curve Number reduction and may reduce the peak rate requirements for the site.
- Well suited to directly receive “clean” roof runoff.
- Does not preclude use of the space (active recreation/parking).
- Can manage a significantly large quantity of runoff and function as a regional system.
- Effective for maintaining soil moisture conditions for downslope planting areas, wooded slopes, or wetlands.
- Flexible dimensions to fit conditions.
- Excellent retrofit capability (see Figure 5.3.2-5)
- Can be benched or terraced to accommodate slopes.
- Cost effective

Disadvantages

- High clogging potential if runoff from high sediment areas is not pretreated.
- Not visible and may be “forgotten.”
- Must be offset from foundations/basements.
- Infiltration requires suitable site conditions (i.e., adequate soil infiltration rate).

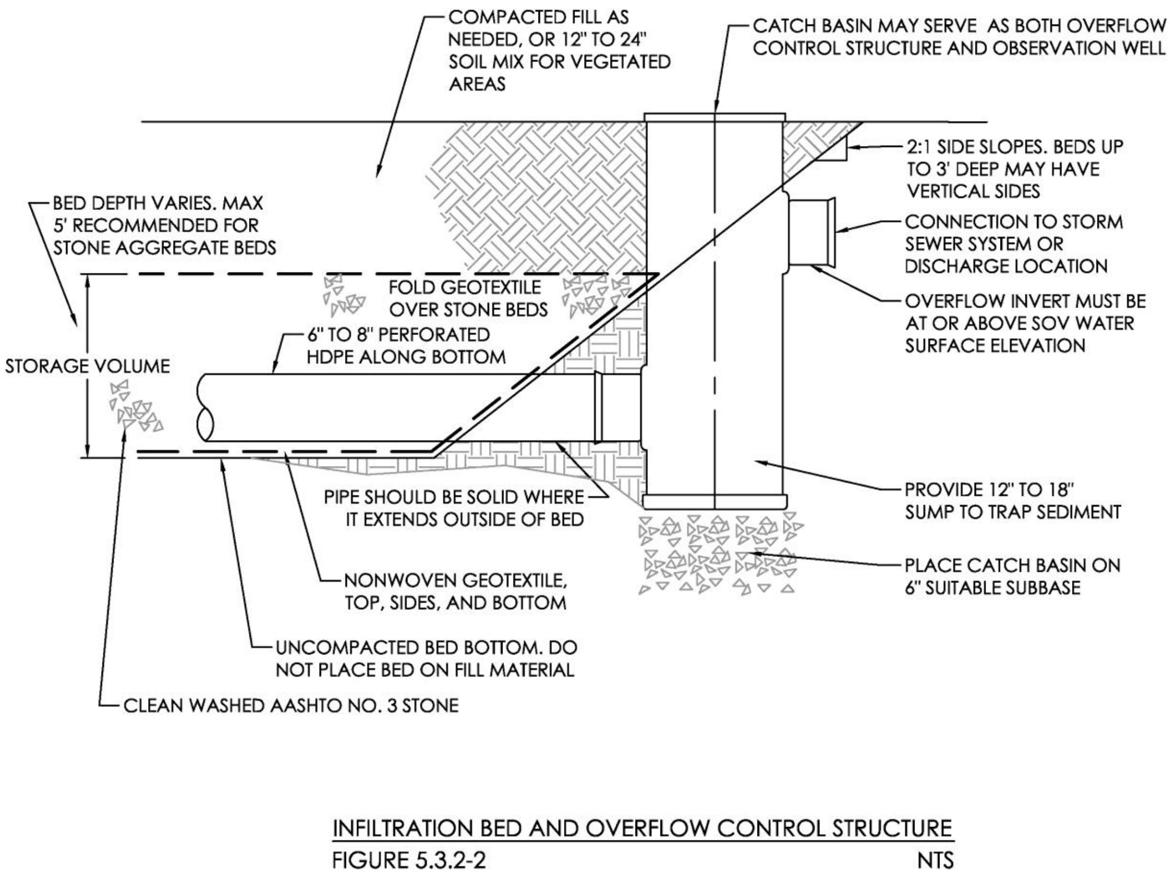

Figure 5.3.2-2. Infiltration bed cross-section. This cross-section shows an infiltration bed at the overflow structure. Runoff from the SOV fills the stormwater bed. In this example, the outflow pipe invert is at the top of the bed and serves to "back up" the water within the bed. Once the bed is full, larger storms discharge from the overflow pipe. A weir across an outflow pipe or within the outflow structure can also achieve the goal. The perforated pipe connection to the catch basin structure ensures that water will pass into the structure directly once the bed is full.

Applications

An infiltration bed can be "hidden" beneath a variety of surfaces such as athletic and other recreational fields, driveways, parking lots, and plazas. They are ideal in areas with limited space for stormwater management. Combining uses, such as integrating an infiltration bed into a design for a basketball court or rubber surface playground, can also be cost-effective.

Residential Infiltration Bed

Figures 5.3.2-3a and b. Infiltration beds were incorporated into standard asphalt driveways in this suburban residential development. Standard asphalt was chosen for ease of maintenance and to prevent homeowners from inadvertently "seal coating" porous pavement. Roof leaders convey runoff directly into beds. The sumped catch basin serves to connect the bed to the storm sewer and may also collect driveway and surface runoff. The roof leaders from the house include cleanouts.

Institutional Infiltration Bed

Figure 5.3.2-4. An infiltration bed beneath large athletic fields at Purdue University serves as a regional stormwater system for the campus. The two football practice fields are nearly 3 acres in area and capture runoff from the fields as well as nearly 10 acres of parking lots and roads. Runoff from parking lots and roads is pretreated with bioretention and vegetated swales before being discharged into the bed.

Landscaped Areas

Figure 5.3.2-5. This landscaped area is underlain by an infiltration bed. The bed receives runoff from the upslope impervious areas.

Urban Greening Infiltration Bed

Figure 5.3.2-6. This urban park plaza is built above an infiltration bed that completely underlies the plaza. Runoff is both piped into the bed from adjacent areas and is able to enter the bed through the porous pavers around the perimeter of the plaza.

Applicable Protocols and Specifications

The following Protocols and Specifications (see Appendices A through F) are applicable to infiltration beds and must be addressed:

- Protocol 1 Setbacks from Structures
- Protocol 2 Coordination with Other Utilities
- Protocol 3 Site Evaluation and Infiltration Testing

- Protocol 4 Infiltration System Design and Construction Guidelines
- Stormwater System Specifications
  - Aggregates and Drainage Layers
  - Pipes
  - Control Structures
  - Geotextiles
  - Impervious Liners and Waterproofing

Design Considerations for Infiltration Beds

Infiltration beds can be designed beneath various surfaces, from vegetated to impervious. They can be integrated into new development or as part of a retrofit project in both urban and suburban areas. The key design components for infiltration beds discussed below allow design flexibility to ensure maximum performance.

1. Location and Capture Area

Infiltration beds can be located:

- Close to the source of runoff to minimize the need for additional stormwater structures.
- As part of a “regional” or site stormwater management system, designed to capture runoff from a larger drainage area (see Figure 5.3.2-7).

In both instances, stormwater is conveyed into the bed via pipes or other measures.

Figure 5.3.2-7. This diagram of the athletic fields at Purdue indicates how runoff from streets and parking areas is directed through bioretention areas and vegetated swales before being directed to the infiltration bed. Overflow from the vegetated systems is piped into the bed in this "treatment train" approach.

<u>Slopes</u>

- Infiltration beds should not be constructed on fill material, because compacted fill will prevent infiltration.

- Where fill is required to achieve desired site grades, infiltration beds can be located beneath the compacted fill. This allows the bed to be constructed on native soil material (see Figure 5.3.2-8).
- The bed bottom must be level or with a slope less than 0.5 percent. If needed, the infiltration bed may be benched or terraced on slopes, similar to the examples for porous pavement (see Figure 5.3.2-9).

Figure 5.3.2-8. This supermarket parking lot required a level surface. Infiltration beds were placed at the native soil interface, beneath the fill material and parking lot.

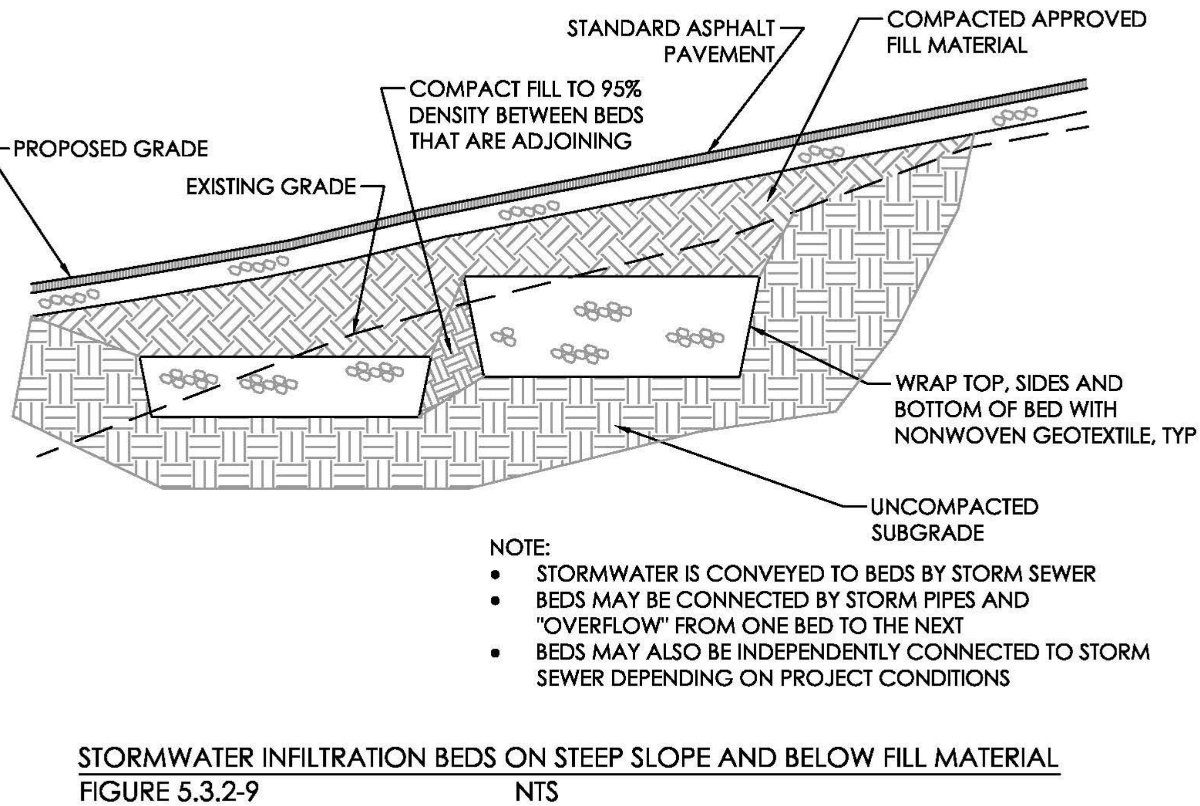

Figure 5.3.2-9. Cross-section of infiltration beds on slope and beneath fill material.

Drainage Area

- The type of land use in the drainage area must be carefully considered. Roof runoff is generally "clean" with regard to sediment and is ideal for discharge to an infiltration bed. Runoff from other areas such as parking lots must be treated with sediment-reduction measures (such as vegetated swales and filter strips) before runoff is discharged into the bed.
- Infiltration beds should not be used in hot spot areas where there is the potential for runoff with higher than average pollutant levels to enter the groundwater. Only the hot spot area is precluded from the infiltration bed; other portions of the site may be well-suited for infiltration bed use.

2. Entrance/Flow Conditions

Stormwater runoff must be conveyed into an infiltration bed, usually with storm sewer pipes. Pipes may end within and discharge directly into a small bed, or continue through the bed as a continuously perforated pipe to better distribute water in a large bed (see Figure 5.3.2-10).

If the surface of the bed is vegetated, adequate soil cover (a minimum of 12 to 24 inches) must be installed to support the proposed landscape vegetation. The soil cover can allow surface runoff to permeate through the soil and into the infiltration bed. An infiltration bed may be placed below compacted fill material and impervious surfaces. When a bed is placed below compacted fill, stormwater must be conveyed into the bed via pipes and structures.

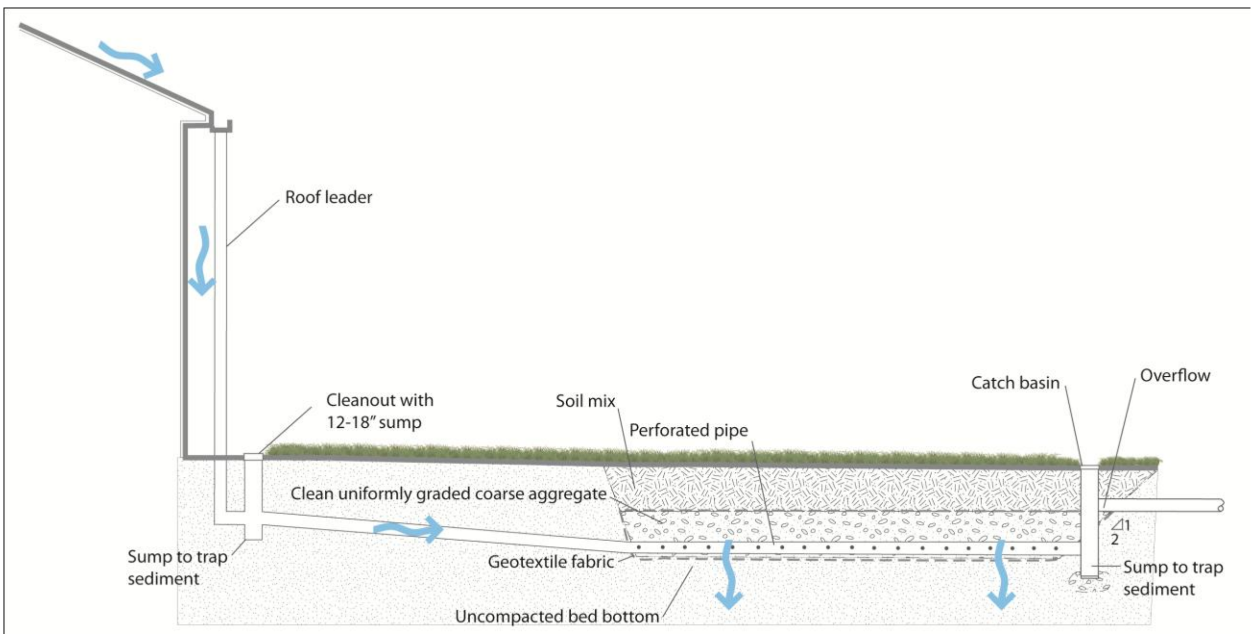

Figure 5.3.2-10. Conveyance of runoff into stormwater infiltration bed. Pipes may discharge directly into the bed or continue through the bed as a continuously perforated pipe.

3. Management of Sediment, Trash, and Debris

In areas of high sediment load, measures should be provided to prevent the movement of suspended material into the infiltration bed. Sediment can clog an infiltration bed and limit its functional lifespan.

- Roof runoff is generally lower in sediment and can be conveyed directly into a bed; however, a cleanout for roof leaders is required in the event that pipe clogging occurs.

- Runoff from roof areas that receive high amounts of leaf debris or other materials (such as deposition from equipment) should include sediment traps, or should be reconsidered. It may be preferable to discharge these roof areas to a vegetated swale or a filter strip prior to discharge into the bed.
- In areas of high trash or with specific concerns such as plastic shopping bags, entrance conditions should include a screen to prevent material from entering the infiltration bed. The designer must consider the site-specific conditions and adjacent land uses in each application.
- Water quality inserts or sumped inlets can reduce the amount of sediment from parking areas and low-traffic streets (see Figure 5.3.2-11). For high-traffic streets, the designer may wish to consider discharge to a vegetated system such as a filter strip or vegetated swale before discharge into the infiltration bed. Water quality inserts can also be used but must be maintained. Clogging of unmaintained inserts may result in ponding on the roadway. This potential hazard should be considered by the design engineer.

Figure 5.3.2-11. Water quality inserts can be used to reduce sediment and prevent trash from entering a stormwater infiltration bed. Water quality inserts require regular maintenance. (http://www.gaelwolf2.com/dnrec/trib_times_2004_4_catch_basin_inserts.htm, Aug. 24, 2012)

- If a large infiltration bed includes a perforated pipe distribution system, one or more cleanouts should be installed to allow access to the distribution pipes.

4. Storage and Stay-on-Volume

As shown on Figure 5.3.2-12, the **storage** capacity of an infiltration bed is measured as the volume **below** the lowest discharge invert (overflow).

Storage Volume (ft^3) =

Bed Length (ft) x Bed Width (ft) x Bed Depth (ft) Below Overflow Elevation x Void Ratio

Void ratios are generally:

- 0.40 for clean washed aggregate such as AASHTO No. 3
- 0.85 to 0.95 for manufactured storage units depending on manufacturer
- 1.0 for the interior volume in perforated pipes within the bed

The SOV is a function of the storage volume available for the 1-inch or 1.6-inch storm.

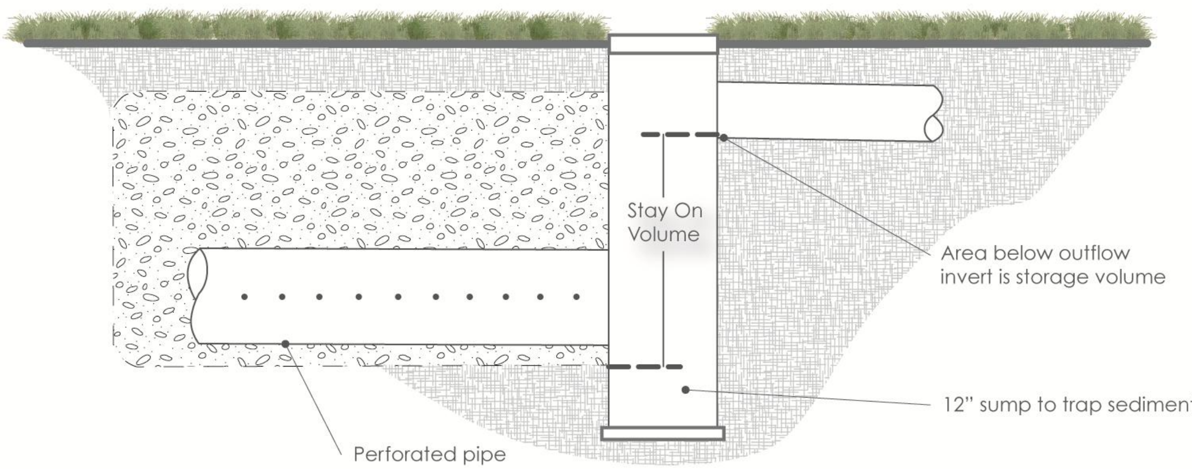

Figure 5.3.2-12. Storage capacity of stormwater infiltration bed is estimated below the overflow elevation.

5. Area and Dimensions

The size and area of an infiltration bed are a function of the drainage area that will discharge into the bed. For infiltration systems, it is important **not** to concentrate too much stormwater in one location for management. This can lead to accelerated clogging from sediment, high water depths that may compress soils, and soils that do not dry out between storms (and change structure). It also provides soil/water contact for water quality improvement. A basic rule-of-thumb is to design an infiltration bed with a surface area (footprint) that is a ratio of the impervious and compacted pervious areas that drain to it. The amount of rainfall volume must also be considered. The following ratios based on design rainfall depth can be used to estimate the surface area of a subsurface infiltration bed:

<u>1-inch Rainfall</u>

1:10 ratio of infiltration bed surface area to impervious drainage area

1.6-inch Rainfall

1:8 ratio of infiltration bed surface area to impervious drainage area

The land use type draining into an infiltration bed should be considered in bed area design. It is **strongly** discouraged that beds receiving runoff from high-sediment areas such as streets and high-use parking lots exceed the recommended ratios. The recommended ratios can be increased when managing runoff from clean roof areas, especially in areas with high (greater than 1 inch per hour) infiltration rates. “Clean” and “dirty” runoff should not be mixed if possible, although this is not always feasible.

The bed depth of water storage is primarily determined by the rainfall depth managed and the loading ratio, and influenced to a lesser extent by the infiltration rate. **There is no specific limit on the maximum width or length of an infiltration bed. However, designers are discouraged from designing excessively deep infiltration beds (greater than 5 feet for the SOV capacity), even in areas with high infiltration rates, because of concerns that the pressure at greater water depths may compact or alter the underlying soil.** There is no depth limit on non-infiltrating, slow-release beds.

Beds can be designed for short-term, deeper water depths during the larger, and less frequent, peak rate storm events if necessary to provide peak rate mitigation.

Proprietary products may be used as storage media and as a substitute for stone subbase; however, all products must be approved by the City. A number of modular subsurface, plastic, interlocking storage units provide higher void space and comparable structural stability as AASHTO No. 3, but may be more costly (see Figures 5.3.2-13).

Figures 5.3.2-13(a and b) This “on-line” infiltration bed is constructed of “RainStore” units to increase storage capacity. This bed was installed as a retrofit to reduce downstream erosion and flooding.

6. Overflow and Peak Rate

All infiltration beds must provide a safe way for water to exit the system when large storms generate more stormwater runoff than the bed can hold. The inclusion of a positive overflow route ensures that flooding risks and related property damage are minimized. The positive overflow route is often in the form of a modified inlet box with an internal weir plate, or simply an overflow pipe at an invert higher than the bottom of the infiltration bed. This maximizes the volume managed by the bed, while providing sufficient cover for overflow pipes. When water overtops the weir, it discharges via a pipe to the storm sewer or to another approved discharge point.

The overflow structure can be designed to function as a detention rate control structure for peak rate control, and can be modeled or evaluated as a detention system. Temporarily higher effective water depths are acceptable during large storm events managed for peak rate control. The catch basins can be used as overflow structures in large storms, and as rate control structures in larger storm events if the bed is constructed with sufficient capacity.

The minimum allowable diameter of an overflow pipe is 12 inches unless otherwise approved by the City.

<u>Peak Rate Control and Infiltration Credit</u>

For the purposes of site peak rate control, the designer may adjust the Curve Number value based on the volume managed by both the SOV and the infiltration volume that occurs during a portion of a 24-hour storm event. This allows the designer to account for runoff that was captured by applying LID, and to develop a representative lower Curve Number. This procedure is described in Chapter 7.

When adjusting the Curve Number, the infiltration volume can be estimated as the infiltration that occurs during the first 12 hours of a 24-hour design storm. This will ensure that estimated infiltration volumes are not greater than the actual volume captured within the BMP.

Infiltration Volume (ft^3) = Bioretention Bottom Area (ft^2) x Infiltration Rate (in/hr) x 1/12 x 12 hours

7. Freeboard

Infiltration beds can be designed without freeboard and be allowed to completely fill provided that other conditions, such as adjacent pavement subbase, are considered. Because infiltration beds often serve as peak rate detention facilities, they are often designed with additional capacity above the SOV storage volume. The designer should always confirm that an infiltration bed will not surcharge, but has adequate capacity for conveyance of large events.

8. Underdrain

An underdrain system is used to ensure that water moves through the system when the native soil infiltration rate is not high enough to empty the bed of water, or if the bed is underlain by an impervious liner and designed only for slow release. Underdrain systems should discharge to the existing stormwater system or to a location approved by the City. Underdrain systems must be included in the design if the native soil infiltration rate is less than 0.1 inch per hour, or if the bed is designed for slow release. See Protocol 3 for the infiltration testing procedure and Protocol 4 for infiltration system guidelines.

9. Waterproofing

In some instances, infiltration beds may be designed to infiltrate, but there may be concerns about impacts on adjacent structures such as basements, or impacts on the subbase of adjacent paved surfaces. For all subsurface infiltration beds, the designer must evaluate the impact of the system on adjacent structures and utilities as defined in Protocol 1, Setbacks from Structures and Protocol 2, Coordination with Other Utilities. The liner, if applied, must meet the guidelines provided in the Stormwater Specification. In many situations, a partial liner (i.e., one side of a bed) will adequately protect structures.

Utility pipes or conduits may pass through the bed if required, but the designer is encouraged to avoid utility crossings if possible. Where a new or existing utility passes through a stormwater bed, a waterstop should be installed along the utility as it exits the bed to prevent movement of water along the utility bedding material.

10. Water Quality/Total Suspended Solids

Infiltration beds that can capture and manage the required SOV through infiltration are considered to meet all water quality requirements. Infiltration beds that are under drained but can capture the required water quality volume as defined in Chapter 7 are also considered to provide water quality treatment. See Chapter 7 for additional discussion, and the Infiltration Bed Worksheet for calculations.

Sizing Calculations Worksheet for Subsurface Infiltration Beds

(Link to Worksheet)

Construction Considerations

Infiltration beds can be installed:

1. Early in the construction process, but should not receive **any** site runoff until site construction is complete and site stabilization has occurred. Runoff should be directed around the completed infiltration bed until site stabilization has occurred. Sediment-laden water should not be allowed to enter infiltration beds. The designer must consider stormwater management during construction.

2. The stormwater bed may be constructed after site construction is substantially complete and site stabilization has occurred. During construction of the site, areas reserved for infiltration beds **must** be protected and should be fenced or barricaded to prevent the movement of equipment over the proposed infiltration area. This is similar in practice and intent to protecting an onsite septic system disposal field from vehicle compaction.

The excavated capacity of an infiltration bed may be used as a temporary sediment trap/stormwater measure during construction. The bottom elevation during use as a sediment measure should be a minimum of 1 foot higher than the final infiltration bed bottom elevation. At the time of conversion from a sediment measure to an infiltration bed, any sediment and the remaining 1 foot of material should be removed for construction of the infiltration bed.

Construction Sequence Example

Step 1 Excavate and Prepare Subgrade

a. Do **not** compact or subject pervious pavement locations to excessive construction equipment traffic during construction. Protect areas from vehicular traffic during construction with construction fence, silt fence, compost sock, or other means acceptable to the City (see Figure 5.3.2-13, which shows a construction area delineated with construction fence to keep vehicular traffic isolated).
b. If alternate storage media is used in lieu of stone aggregate, provide a suitable stone subbase and do **not** compact bed bottom.
c. Infiltration beds can be installed at any time during the construction process provided that sediment-laden runoff is prevented from entering the bed. Do not allow runoff from any disturbed areas in the drainage area to discharge into the bed until these areas have been stabilized.
d. Remove fine materials and/or surface ponding in the graded bottom, caused by erosion, with light equipment and scarify the underlying soils to a minimum depth of 6 inches with a York rake or equivalent by light tractor.
e. Construct earthen berms (if used) between infiltration beds by excavating the beds and leaving existing material in place between the beds as a “berm.”
f. Bring subgrade of infiltration bed to line, grade, and elevations indicated on the plans. Fill and lightly regrade any areas damaged by erosion, ponding, or traffic compaction. All infiltration beds shall be level grade on the bottom (not greater than 0.5 percent slope).
g. Halt excavation and notify engineer immediately if evidence of sinkhole activity, unanticipated bedrock or groundwater conditions, or other site conditions that may affect infiltration bed design or performance are encountered.

Step 2 Install Overflow Structure and Other Stormwater Structures

a. Place the stormwater overflow structure on suitable subgrade to prevent settling (i.e., compacted subgrade and compacted suitable subbase material). Install overflow structure, inlet pipes, curbs, and other stormwater structures as appropriate before placement of stone storage bed.
b. Close and secure all inlets, pipes, trench drains, and other structures to prevent runoff from entering the infiltration bed before completion and site stabilization.
c. Maintain drainage overflow pathways during construction, while the infiltration bed is closed, to provide for drainage during storm events.
d. Infiltration bed conditions should be observed by the design engineer, following excavation and grading and prior to placement of geotextile and aggregate materials, to confirm that construction requirements have been met. Documentation must be provided to the City (see Appendix I).

Step 3 Install Infiltration Bed

a. Place geotextile and bed aggregate immediately after approval of subgrade preparation and installation of structures. Geotextile shall be placed in accordance with the manufacturer's standards and recommendations. Overlap adjacent strips of geotextile a minimum of 16 inches.
b. Place clean (washed), uniformly graded aggregate or other storage media in the bed in maximum 8-inch lifts. Spread the aggregate with equipment running over the aggregate and pushing toward bare soil. Lightly compact each aggregate layer while keeping construction equipment off the bed bottom as much as possible.
c. Following placement of storage media, place geotextile over the **top** of the bed to prevent soil movement into the bed. Place and secure geotextile to prevent soil movement through the overlap areas.
d. Place soil or other material above the storage bed.

Operations and Maintenance

All properly designed and installed subsurface infiltration beds will require annual maintenance, although they require less maintenance than other BMPs.

- Inspect and clean all inlets and catch basins biannually.
- Confirm that standing water does not remain in the bed after more than 96 hours without precipitation.
- Clean any pipes of connections that contain debris using a vacuum system. Do not wash material and debris into the bed.