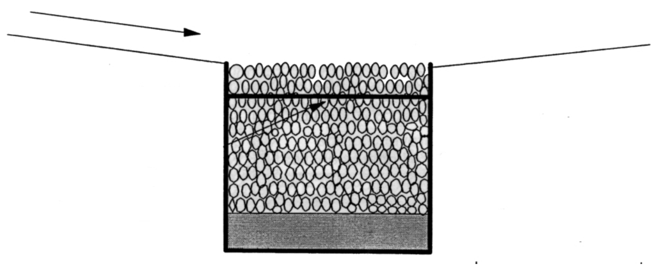
Infiltration Trenches



Description

Infiltration trenches are shallow (3- to 12-foot) excavations that are lined with filter fabric and filled with stone to create underground reservoirs for stormwater runoff from a specific design storm. The runoff gradually percolates through bottom and sides of the trench into the surrounding subsoil over a period of days. Infiltration trenches are typically implemented at the ground surface to intercept overland flows. Runoff can be captured by depressing the trench surface or by placing a berm at the down gradient side of the trench.

Infiltration trenches in this BMP Section refer to surface trenches that collect sheet flow from a few lots or properties as opposed to soakaway pits which are primarily used for a single lot application (see the On-Lot Infiltration BMP Section for information on this type of BMP).

Infiltration trenches require pretreatment of stormwater in order to remove as much of the suspended solids from the runoff as possible before it enters the trench. Pretreatment practices, such as grit chambers, swales with check dams, filter strips, or sediment fore-bays/traps should be a fundamental component of any BMP system relying on infiltration. Source controls should also be investigated (e.g., eliminate excessive sanding/salting practices). Public education with respect to street/driveway sediments should be provided in areas where an infiltration trench is proposed.

The design storm for an infiltration trench is typically a frequent, small storm such as the 1-year event. This provides treatment for the "first flush" of stormwater runoff. Infiltration trenches provide total peak discharge, runoff volume and water quality control for all storm events equal to or less than the design storm. This infiltration reduces the volume of runoff, removes many pollutants and provides stream baseflow and groundwater recharge.

Infiltration trenches have limited capabilities for controlling peak discharge for storms greater than the design storm. Because infiltra-

Purpose

	Water Quantity
Flow attenuation	◧
Runoff volume reduction	■

	Water Quality
Pollution prevention	
Soil erosion	N/A
Sediment control	N/A
Nutrient loading	N/A
Pollutant removal	
Total suspended sediment (TSS)	■
Total phosphorus (P)	■
Nitrogen (N)	■
Heavy metals	■
Floatables	◧
Oil and grease	◧
Other	
Fecal coliform	◧
Biochemical oxygen demand (BOD)	◧

■ Primary design benefit
◧ Secondary design benefit
□ Little or no design benefit

tion trenches will not significantly impact peak discharges of runoff, they are best used in conjunction with other BMPs; downstream detention is often still needed to meet peak runoff rate requirements.

Dissolved pollutants are effectively controlled for storm events less than the design storm, but these substances may not be removed from the runoff water as it infiltrates, and a portion could move to the groundwater. For this reason, the impact of infiltrated runoff on the groundwater should be considered, although in most cases, the magnitude of this impact is unknown. Chloride from road salt is an example of a soluble material that will not be removed during the infiltration process. Currently, there is much disagreement as to whether chlorides do, indeed, pose a significant threat to groundwater. A general guideline for groundwater protection is to design infiltration trenches with the bottom of the trench a minimum of 3 feet above the seasonally high groundwater table. This is consistent with the MPCA's guidelines for septic systems (MPCA, 2000). If the water table is too close to the ground surface, infiltration practices should not be used.

Figure 1 provides a schematic of a typical infiltration trench. Figures 2 and 3 illustrate two different examples of infiltration trench layouts- in a parking lot and in a median strip.

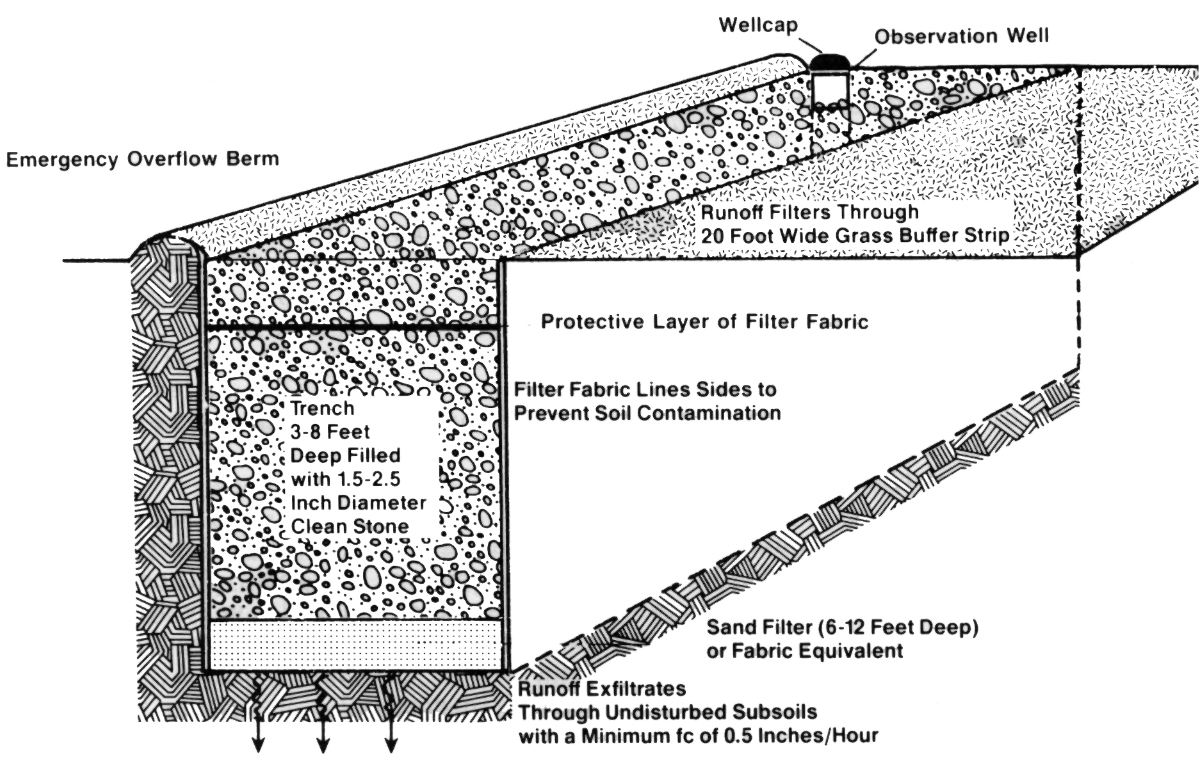


Figure 1: Typical Infiltration Trench Design
Source: Schueler, 1987.

Infiltration Trenches

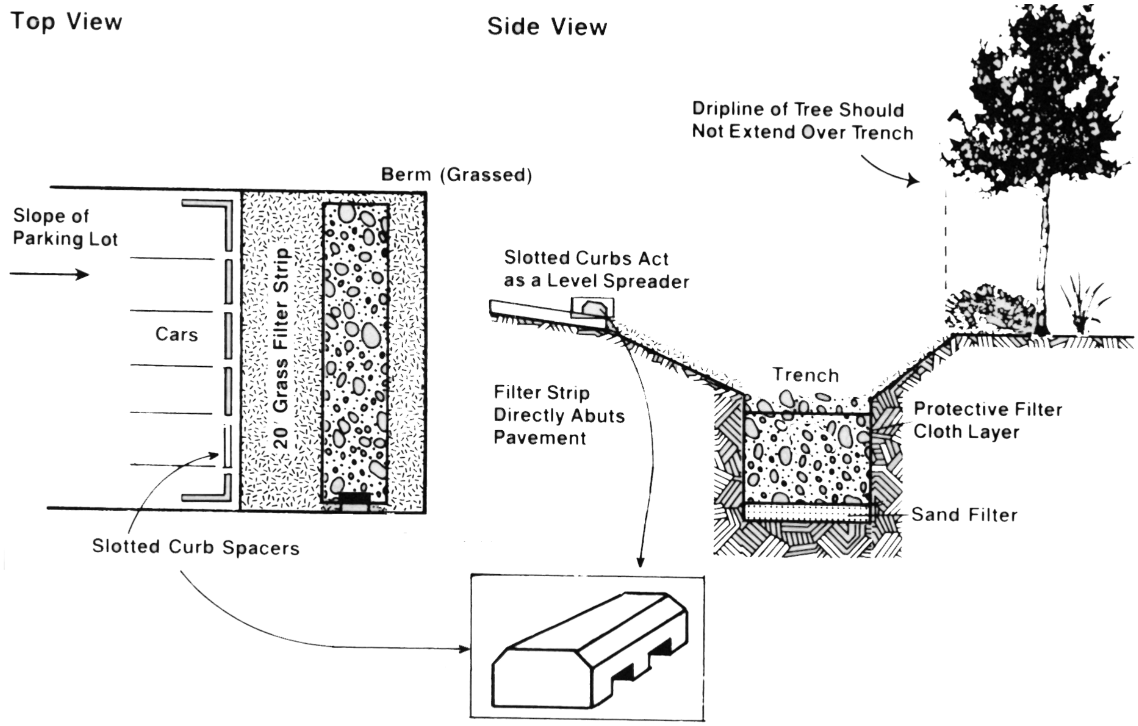


Figure 2: Parking Lot Perimeter Trench Design

Source: Schueler, 1987.

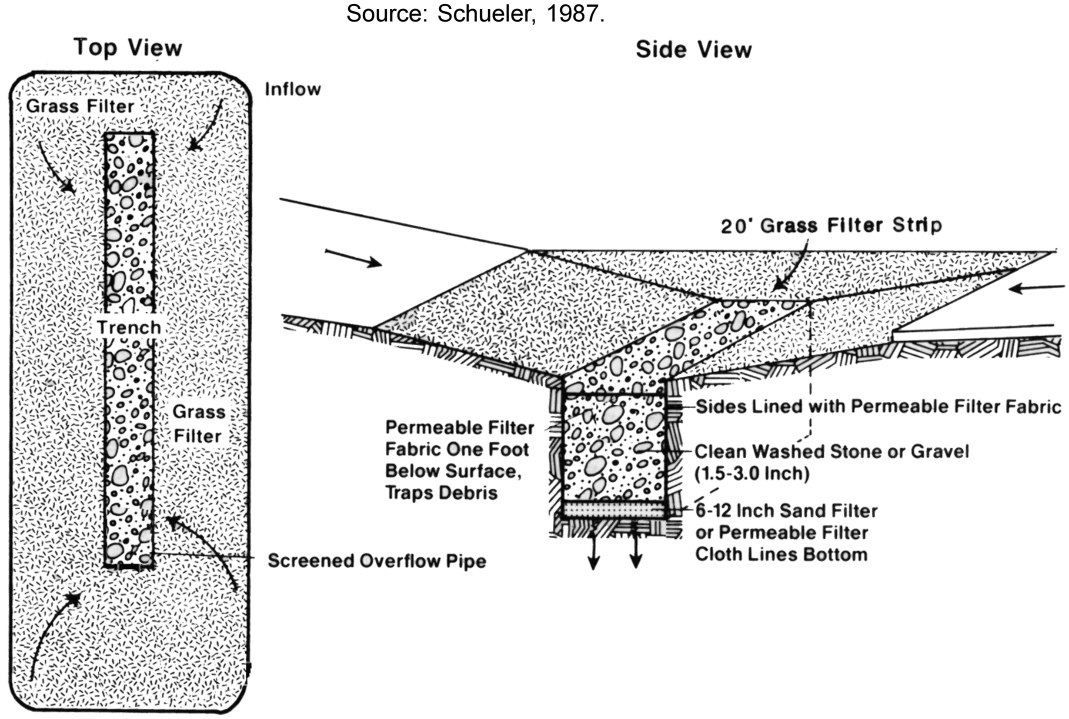


Figure 3: Median Strip Trench Design

Source: Schueler, 1987.

Infiltration Trenches

Advantages

- Reduces the volume of runoff from a drainage area
- Can be very effective for removing fine sediment, trace metals, nutrients, bacteria, and oxygen-demanding substances (organics)
- Reduces downstream flooding and protects streambank integrity
- Reduces the size and cost of downstream stormwater control facilities and/or storm drain systems by infiltrating stormwater in upland areas
- Provides groundwater recharge and baseflow in nearby streams
- Reduces local flooding
- Appropriate for small sites (2 acres or less)
- Can be utilized where space is limited, due to their narrow dimensions

Limitations

- Potential failure due to improper siting, design and lack of maintenance, especially if pretreatment is not incorporated into the design.
- Depending on soil conditions, land use in the watershed and groundwater depth, a risk of groundwater contamination may exist.
- Not appropriate for industrial or commercial sites where the release of large amounts or high concentrations of pollutants is possible.
- Susceptible to clogging by sediment, resulting in frequent maintenance
- Requires frequent inspection and maintenance

Requirements

Design

Infiltration trench failure can be avoided with proper design, taking the following topics into consideration:

- Careful site selection (discussed further in the Site Sensitivity Analysis section)
- Treatment of sheet flow from a small drainage area
- Incorporation of pretreatment and a bypass for high flow events
- Good construction techniques that prevent smearing, over-compaction, and operation of the trench during the construction period.
- Performance of regular maintenance

All of these topics are discussed in further detail below.

Infiltration Trenches

Site Sensitivity Analysis

Before an infiltration system can be designed, a site sensitivity analysis must be performed. This evaluation may eliminate an infiltration practice from consideration because of soil characteristics or potential effects on groundwater. Because of varying geologic settings, a site evaluation needs to be tailored to the specific site conditions. A team approach to this evaluation is recommended where various disciplines such as engineering, hydrogeology and soil science are represented.

The applicability of infiltration trenches on a site depends on numerous site factors including, soils, slope, depth to water table, depth to bedrock or impermeable layer, contributing watershed area, land use, proximity to wells, surface waters, foundations, and others. Generally, infiltration trenches are suitable to sites with gentle slopes, permeable soils, relatively deep bedrock and groundwater levels, and a small contributing watershed area (less than 2 acres, ideally).

When performing a site evaluation, the following items should be considered:

- Runoff water quality: If runoff water will contain a significant concentration of soluble pollutants that could contaminate groundwater, an infiltration trench should not be used. Specifically, infiltration trenches are not recommended for industrial and commercial land uses where there is a high potential for groundwater contamination from chemical spills. In site specific cases where infiltration trenches are deemed acceptable for these land uses, the design must incorporate some form of upstream pretreatment.
- Degree of detail: The level of detail required for the study should be considered. For instance, a small structure receiving runoff from a roof top will not require as much detail as a structure serving a larger area and having a higher potential pollutant load.
- Geologic (groundwater) sensitivity: A site with a highly sensitive geology, such as one with a carbonate or surficial sand aquifer, may eliminate this practice from consideration.
- Depth to water table and bedrock: The seasonally high water table must be far enough below the bottom of the infiltration trench (at least 3 feet) to allow the structure to function hydraulically and to allow trapping and treatment of pollutants by the soil. Similarly, the bottom of the infiltration trench should be at least 3 feet from bedrock, although in the case of fractured bedrock, separations up to 10 feet may be required. This minimum separation distance is required to trap or treat pollutants before they reach the groundwater or bedrock and to maintain vegetation in the trench (MPCA, 2000).
- Frost line of the soil: The maximum effective depth of the trench should be located below the frost line to promote continued percolation of runoff water throughout the winter months. The maximum effective depth is defined as the depth to which the design volume of runoff actually fills the trench; trenches can be constructed to be deeper than they need to be to fit certain site characteristics or shallower if excess space is provided for storage.
- Proximity to drinking water wells and building foundations: Trenches should be located at least 150 feet away from drinking water wells to limit the possibility of groundwater contamination, and should be situated at least 10 feet down-gradient and 100 feet up-gradient from building foundations to avoid potential seepage problems.
- Soil percolation rate: The percolation rate of the soil must be great enough to drain the structure in a reasonable amount of time, generally 72 hours or less. Sites with clayey soils are not appropriate for infiltration trenches. Percolation rates are discussed in further detail below. If the percolation rate of the site's soils are not acceptable, the filtration family of BMP systems should be considered.

Requirements
Design (continued)

- Size of the tributary drainage area: Although infiltration trenches were originally designed to accommodate larger drainage areas, the monitoring which has been undertaken to-date indicates that large scale infiltration is not feasible. One of the main problems with centralized infiltration trenches is that water from a large area is expected to infiltrate into a relatively small area. This does not reflect the natural hydrologic cycle and generally leads to problems (groundwater mounding, clogging, compaction). For these reasons, the contributing drainage area to any individual infiltration trench should be restricted to 2 acres or less.

General Design Considerations

Design Volume

Infiltration trench systems infiltrate a portion of the runoff from a rain event (usually the first flush or up to the first inch) while the remaining runoff bypasses the infiltration trench. The design infiltration volume can be calculated in many ways. Ultimately, the magnitude of the design infiltration volume depends on local authorities' practices and requirements.

Duration of Ponding

Trenches should be designed to provide a detention time of 6 to 72 hours. A minimum drainage time of 6 hours should be provided to ensure satisfactory pollutant removal in the infiltration trench (Schueler, 1987; SEWRPC, 1991). Although trenches may be designed to provide temporary storage of stormwater, the trench should drain prior to the next storm event. The drainage time will vary by precipitation zone. In Minnesota, the average time between storm events is estimated to be 72 hours. Therefore, the depth of the infiltration trench should be adjusted so that maximum drain time (based on the soil permeability at the site) is 72 hours for the total design infiltration volume.

Site Soil Permeability

The soils of a prospective site are an important consideration when determining the suitability for an infiltration trench. County soil surveys are useful for preliminary screening of a site for soil infiltration rate. The Natural Resource Conservation Service (formerly the Soil Conservation Service) hydrologic classifications for different soil types can be found in the National Engineering Handbook (NRCS, 1972) or on the NRCS' website at www.wcc.nrcs.usda.gov/water/quality/common/neh630/4content.html.

Permeability, also called "percolation rate" or "hydraulic conductivity", as opposed to infiltration rate, should be used to define the rate at which runoff can seep into the bottom and sides of an infiltration trench. Typically, the permeability of a soil is much higher than infiltration rate, and can be estimated by referencing an NRCS (formerly SCS) Soil Survey Report.

A geologic investigation of the site, however, is always preferable. Several methods of measuring soil permeability have been developed. The most commonly used test is the falling head percolation test. This method is described in detail in:

- Annual Book of ASTM Standards, 1998, Section 4, Vol 4.09, Soil and Rock (II): Designation D 5084-90, Standard Test Method for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter, pp 62-69.
- *Onsite wastewater Treatment and Disposal Systems Design Manual.* 1980. EPA, pp 39-49.

Infiltration Trenches

A minimum of two borings should be taken for each infiltration trench. Trenches over 100 feet in length should include at least one additional sample for each 50 foot increment. Borings should be taken at the actual location of the proposed infiltration trench to identify localized soil conditions.

The designer should use their best judgement to determine if the slowest or average measured percolation rate in the proposed trench area should be used for the design of the trench.

Where feasible, larger-scale of measurements of permeability are encouraged, using a procedure such as the Pilot Infiltration Test described in the State of Washington's Stormwater Management Manual (Washington State Department of Ecology, 1999). This document is currently available on the internet at www.ecy.wa.gov. This type of procedure can avoid some of the error associated with smaller-scale tests and can provide an indication of the longer-term infiltration rate that better represents the future conditions of the site.

Trench Volume and Configuration

The volume and surface area of an infiltration trench relate to the design volume of runoff entering the trench from the contributing watershed and the permeability of the soil below the trench. In addition, since the infiltration trench is filled with stone, only the space between the stone (hereafter called the void space in the storage media) is available for runoff storage.

The length and width of the trench will largely be determined by the characteristics of the site in question (topography, size and shape). The dimensions of the trench will also depend on the path of influent water. If stormwater is conveyed to the trench as uniform sheet flow, the length of the trench perpendicular to the flow direction should be maximized. If stormwater is conveyed as channel flow, the length of trench parallel to the direction of flow should be maximized.

The appropriate bottom area of the trench can be calculated using the equation shown below. This equation assumes that all of the infiltration occurs through the bottom of the trench.

$$A = 12V / (P\ n\ t)$$

where A = bottom area of the trench (ft^2)

V = runoff volume to be infiltrated

P = percolation rate of surrounding native soil (in/h)

n = void space fraction in the storage media (0.4 for clear stone)

t = retention time (maximum of 72 hours)

Trench depths are usually between 3 and 12 feet (SEWRPC, 1991, Harrington, 1989). A site specific, maximum effective trench depth can be calculated based on the soil percolation rate, aggregate void space, and the trench storage time (Harrington, 1989).

$$D = P * t / (n * 12)$$

Where D= depth of the trench, in feet

P = percolation rate of surrounding existing soil (in/hr)

t = retention time (maximum of 72 hours)

n = void space fraction in the storage media (0.4 for clear stone)

Infiltration Trenches

Requirements

Design (continued)

Infiltration trenches can be constructed to be deeper than they need to be to fit certain site characteristics. The maximum effective depth is defined as the depth to which the design volume of runoff actually fills the trench.

Filter Fabric

The sides and bottom of the infiltration trench should be lined with geotextile fabric (filter fabric). Also, there can be a layer of nonwoven filter fabric 6 to 12 inches below the ground surface to prevent suspended solids from clogging the majority of the storage media. It should be recognized, however, that there may be a need to frequently replace this filter fabric layer depending on the volume of suspended solids transported to the trench.

The filter fabric material must be compatible with the surrounding soil textures and application purposes. The cut width of the filter fabric must have sufficient material for a minimum 12-inch overlap. When overlaps are required between rolls, the upstream roll must lap a minimum of two feet over the downstream roll to provide a shingled effect. The bottom of the infiltration trench can be covered with a six to twelve inch layer of clean sand in place of filter fabric.

Storage Media

The basic infiltration trench design utilizes stone aggregate in the top of the trench to provide storage. The trench should be filled with clean, washed stone with a diameter of 1.5 to 3 inches. This aggregate size provides a void space of 40 percent (SEWRPC, 1991, Harrington, 1989, Schueler, 1987).

This design can be modified by substituting pea gravel for stone aggregate in the top 0.3 meter (1 foot) of the trench. The pea gravel improves sediment filtering and maximizes the pollutant removal in the top of the trench.

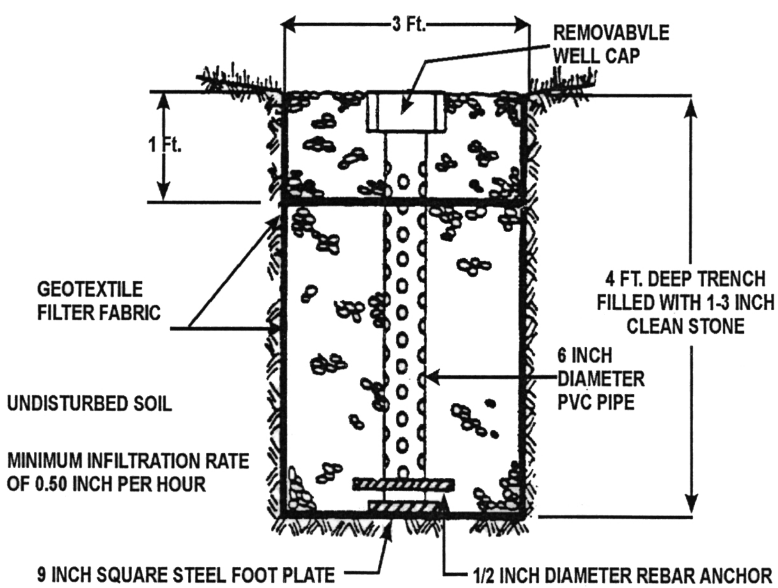


Figure 4: Observation Well Details

Source: SWRPC, 1991.

Infiltration Trenches

When the modified trenches become clogged, they can generally be restored to full performance by removing and replacing only the pea gravel layer, without replacing the lower stone aggregate layers.

It should be noted that while stone is the most common form of storage media in infiltration trenches, there are suppliers that manufacture precast infiltration storage media. These alternative storage media solutions are generally acceptable and should be reviewed and implemented on a case by case basis until there is adequate research/experience with their performance.

Observation Well:

An observation well located at the center of the trench is recommended to monitor water drainage from the system. The well can be a 4 to 6 inch diameter PVC pipe, which is anchored vertically to a foot plate at the bottom of the trench as shown in Figure 4 . This well should have a lockable above-ground cap.

Pretreatment:

Infiltration trenches are susceptible to high failure rates due to clogging from sediments, and therefore require pretreatment of stormwater in order to remove as much of the suspended solids from the runoff as possible before it enters the trench. Pretreatment, such as grit chambers, swales with check dams, filter strips, or sediment forebays/traps should be a fundamental component of any BMP system relying on infiltration. Even when infiltrating rooftop runoff, it is a practical decision to implement some form of pretreatment to remove sediments, leaf litter, and debris. This pretreatment will help to ensure the proper functioning of the infiltrating facility and allow for longer periods between maintenance. When designed properly, pretreatment devices should remove 25 to 30 percent of sediment loads. Figure 2 and 3 show an infiltration trench with pretreatment in the form of a grass filter strip.

Designs for infiltration trenches should emphasize accessibility and ease of maintenance.

Bypass:

A bypass system should be implemented for all infiltration trenches. A bypass flow path should be incorporated in the design of an infiltration trench to convey high flows around the trench.

The overland flow path of surface runoff exceeding the capacity of the infiltration trench should be evaluated to preclude erosive concentrated flow. If computed flow velocities do not exceed the non-erosive threshold, overflow may be accommodated by natural topography.

Groundwater Mounding:

Calculations to determine groundwater mounding (local elevation of the water table as a result of infiltrated surface water) may be necessary in cases where slope stability is a concern, and/or a high water table is encountered. A hydrogeologist should be consulted with respect to the potential for groundwater mounding in these areas. The results from groundwater mounding calculations should be regarded as an indication of the mounding potential rather than as an accurate representation of the actual mounding depth.

Requirements

Design (continued)

Cold Weather Considerations:

Consideration should be given to the operation of infiltration trenches during the winter period. Winter sanding of roads can clog an infiltration trench without adequate pretreatment, and winter salting will increase the potential for the chloride contamination of groundwater.

In cold climates, the trench surface may freeze, thereby preventing the runoff from entering the trench and allowing the untreated runoff to enter surface water. The surrounding soils may also freeze, reducing the percolation of the water into the soils and groundwater. However, recent studies indicate that if properly designed and maintained, infiltration trenches can operate effectively in colder climates. By keeping the trench surface free of compacted snow and ice, and by ensuring that part of the trench is constructed below the frost line, the performance of the infiltration trench during cold weather will be greatly improved.

If infiltration practices are used as a stand-alone, all-season water quality treatment facility, then oversizing (to account for reduced percolation) and/or extended pretreatment should be considered. Doubling the storage volume for surface infiltration devices is recommended. Redundant pretreatment (more than one pretreatment device in series) is recommended for all infiltration facilities receiving runoff from roads.

Sequencing

Care should be taken during construction to minimize the risk of premature failure of the infiltration trench. This failure is caused by the deposition of sediments from disturbed, unstabilized areas. This can be minimized or avoided by proper sequencing.

- Ideally, construction of the infiltration trench should take place after the site has been stabilized.
- Diversion berms or silt fence should be placed around the perimeter of the infiltration trench during all phases of construction. Sediment and erosion controls should be used to keep runoff and sediment away from the infiltration trench.
- Heavy equipment should not operate on the surface location where the infiltration trenches are planned. Soil compaction will adversely effect the performance of the trench, and infiltration trench sites should be roped off and flagged. During excavation and trench construction, only light equipment such as backhoes or wheel and ladder type trenchers should be used to minimize compaction of the surrounding soils.
- During and after excavation, all excavated materials should be placed downstream, away from the infiltration trench, to prevent redepositing during runoff events.

Construction

Experience has shown that the longevity of infiltration practices is strongly influenced by the care taken during construction. The construction sequence and specifications for each infiltration practice must be precisely followed.

- Infiltration trenches should not be used as temporary sediment traps during construction.

Infiltration Trenches

- Infiltration trenches will only operate as designed if they are constructed properly. There are three main rules that must be followed during the construction of an infiltration trench :

  1) Trenches should be constructed at the end of development construction

  2) Smearing of the soil at the interface with the trench bottom and sides must be avoided. Smearing of the trench bottom can be corrected by raking or rototilling.

  3) Compaction of the trench storage media and surrounding soils during construction must be minimized

- Before the development site is graded, the area of infiltration trench should be roped off to prevent heavy equipment from compacting the underlying soils.
- Light earth-moving equipment should be used to excavate the infiltration trench. Use of heavy equipment causes compaction of the soils beneath the trench floor and side slopes, resulting in reduced percolation capacity.

Maintenance

Maintenance is required for the proper operation of infiltration trenches as it is with all BMPs. Plans for infiltration trenches should identify owners, parties responsible for maintenance, and an inspection and maintenance schedule.

- The use of pretreatment BMPs will significantly minimize maintenance requirements of the trench itself. Removing accumulated sediment from a sump pit or a vegetated swale is considerably less difficult and less costly than rehabilitating a trench. Eventually, the infiltration trench should be rehabilitated, but this time span is relative to the effective performance of the trench. With appropriate design and aggressive preventive maintenance, this rehabilitation may not be necessary for a decade or more.
- Once the trench has gone online, inspections should occur after every major storm for the first few months to ensure proper stabilization and function. Water levels in the observation well should be recorded over several days to check trench drainage.
- After the first few months of operation, the infiltration trench should be inspected at least twice per year. Important items to check for include: accumulated sediment, leaves and debris in the pretreatment device, clogging of inlet and outlet pipes and ponded water both inside and on the surface of the infiltration trench.
- When ponding occurs at the surface or in the trench, corrective maintenance is required immediately.
- Clogging in trenches occurs most frequently on the surface. Grass clippings, leaves, and accumulated sediment should be removed routinely from the surface of the trench. If the clogging appears only to be at the surface, it may be necessary to remove and replace the first layer of stone aggregate and the filter fabric.
- Ponded water inside the trench (as visible from the observation well) after 24 hours or several days after a storm event often indicates that the bottom of the trench is clogged, indicating a percolation failure from the bottom. In this case, all of the stone aggregate and filter fabric or media must be removed. Accumulated sediment should be stripped from the trench bottom. At this point the bottom may be scarified or tilled to help induce infiltration. New fabric and clean stone aggregate should be refilled.
- Pretreatment devices associated with trenches should be inspected and cleaned at least twice a year, and ideally every other month.

Infiltration Trenches

Sources

1. Center for Watershed Protection. 2001. "Infiltration Trenches" fact sheet in Stormwater Manager's Resource Center. www.stormwatercenter.net. Ellicott City, MD.
2. Harrington, B.W. 1989. *Design and Construction of Infiltration Trenches in Design of Urban Runoff Quality Control*. American Society of Civil Engineers.
3. Massachusetts Dept. of Environmental Protection. 1997. Stormwater Management. Volume Two: Stormwater Technical Handbook. Boston.
4. Minnesota Pollution Control Agency. 2000. Protecting Water Quality in Urban Areas: Best Management Practices for Dealing with Storm Water Runoff from Urban, Suburban and Developing Areas of Minnesota. St. Paul.
5. National Resources Conservation Service (SCS). 1972. *National Engineering Handbook, Section 4: Hydrology.* Washington D.C.
6. Ontario Ministry of the Environment. 1999. *Stormwater Management Planning and Design Manual.* Draft Final Report. Toronto.
7. Southeastern Wisconsin Regional Planning Commission (SEWRPC). 1991. *Costs of Urban Nonpoint Source Water Pollution Control Measures*. Technical Report No. 31.
8. Schueler, Tom. 1987. *Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs.* Metropolitan Washington Council of Governments, Washington D.C.
9. U.S. Environmental Protection Agency. 1980. Onsite Wastewater Treatment and Disposal Systems. US EPA Report number EPA 625/1-80-012.
10. U.S. Environmental Protection Agency. 1999. PA *Preliminary Data Summary of Urban Storm Water Best Management Practices*. Report EPA-821-R-99-012.
11. U.S. Environmental Protection Agency. 1999. Storm Water Management Fact Sheet. US EPA report numbers EPA-832-F-99-001 through EPA-843-F-99-050.
12. Washington State Department of Ecology, Water Quality Program. 1999. *Stormwater Management in Washington State. Volume V: Runoff Treatment BMPs*. Olympia.