Source: California Stormwater Manual

POLLUTANT REMOVAL Low = <30% Medium = 30-65% High = 65-100%			
	Low	Med	High
Suspended Solids			✓
Nitrogen		✓	✓
Phosphorous		✓	
Metals			✓
Bacteriological			✓
Hydrocarbons		✓	

Description: An infiltration trench is a long, narrow, rock-filled trench with no outlet that receives stormwater runoff. Runoff is stored in the void space between the stone aggregate and infiltrates through the bottom and into the soil matrix. Infiltration trenches can range from 3-12 feet deep, are backfilled with stone aggregate, and are lined with filter fabric. Underground trenches receive runoff through pipes or channels, whereas surface trenches collect sheet flow from the drainage area. Trenches should be designed to drain completely within 6-48 hours. Infiltration trenches perform well for removal of fine sediment and associated pollutants. Pre-treatment using buffer strips, swales, or detention basins is important for limiting amounts of coarse sediment entering the trench, which can clog and render the trench ineffective.

Typical uses: Residential subdivisions, high-density residential, ultra-urban areas, and parking lots.

Advantages:
- Appropriate for small sites with porous soils
- Infiltration trenches reduce runoff volume and filter pollutants
- Provide stream baseflow and recharge groundwater.
- As an underground BMP, trenches are unobtrusive and have little impact on site aesthetics

Limitations:
- Use should be restricted to small drainage areas – generally less than 5 acres
- Suitable for NRCS HSG-A/B soils; limited application in HSG-C soils; not recommended in HSG-D soils. Do not use with soil infiltration rates <0.5 inches/hour
- Seasonal high water table should be 4 feet below bottom of trench
- Susceptible to clogging by sediment – use upstream BMPs for sediment removal
- Restricted in karst areas
- Placement under paved surfaces or in industrial or commercial settings not recommended

Maintenance requirements:
- Remove sediment accumulation to ensure proper functioning
- Inspect for clogging – install an integrated observation well/piezometer to check water level
- Remove sediment from pre-treatment areas

A. Description

By diverting runoff into the soil, an infiltration trench not only treats the water quality volume, but also helps to preserve the natural water balance on a site and can recharge groundwater and preserve baseflow. Due to this fact, infiltration systems are limited to areas with highly porous soils where the water table and/or bedrock are located well below the bottom of the trench. In addition, infiltration trenches must be carefully sited to avoid the potential of groundwater contamination.

Infiltration trenches are not intended to trap sediment. Due to their high potential for failure, these facilities must only be considered for sites where upstream sediment control can be ensured. Pre-treatment using buffer strips, swales, or detention basins is important for limiting amounts of coarse sediment from entering the trench because it can clog the trench and render it ineffective. An example infiltration trench system is shown in Figure C5-S2- 1.

B. Stormwater management suitability

Infiltration trenches are designed primarily for reduction in stormwater runoff volume, but when integrated with other BMPs, they can achieve significant water quality improvement. Runoff volume control can be achieved for the water quality volume for smaller storm events up to the limits of the local infiltration capacity of the local soils. The runoff volume gradually infiltrates through the bottom and sides of the trench and into the subsoil, eventually reaching the water table. By diverting runoff into the soil, an infiltration trench not only treats the water quality volume, but also helps to preserve the natural water balance on a site, recharge groundwater, and preserve baseflow.

An infiltration trench may also be designed to capture and infiltrate the entire channel protection volume, Cpv, in either an offline or online configuration. For larger sites, or where only the WQv is diverted to the trench, another structural control must be used to provide Cpv extended detention. Infiltration trenches must be used in conjunction with another best management practice to provide overbank and extreme flood protection, if required.

C. Pollutant removal capabilities

Infiltration trenches can remove a wide variety of pollutants from stormwater through sorption (the action of soaking up or attracting substances), precipitation, filtering, and bacterial and chemical degradation. Pre-treatment areas up-gradient of the infiltration site are provided to remove a larger portion of the TSS and overall sediment load. Examples of some pre-treatment areas include grit chambers, water quality inlets, sediment traps, swales, and vegetated filter strips (SEWRPC 1991; Harrington 1989).

When used with pre-treatment areas, infiltration trenches can remove up to 80 percent of sediments, metals, coliform bacteria, and organic matter; and up to 60% of phosphorus and nitrogen (Schueler 1992). Biochemical oxygen demand (BOD) removal is estimated to be between 70-80%. Lower removal rates for nitrate, chlorides, and soluble metals should be expected. Undersized or poorly-designed infiltration trenches can reduce TSS removal performance. An infiltration trench is presumed to be able to remove 80% of the TSS load in typical urban post- development runoff when sized, designed, constructed, and maintained in accordance with the recommended specifications. In a situation where a removal rate is not deemed sufficient, additional controls may be put in place at the given site in a series or “treatment train” approach.

For additional information on monitoring BMP performance, see ASCE/EPA “Urban Stormwater BMP Performance Monitoring: A Guidance Manual for Meeting the National Stormwater BMP Database Requirements.”

Using washed aggregate and adding organic matter and loam to the subsoil may improve pollutant removal efficiencies. The addition of organic material and loam to the trench subsoil will enhance metals and nutrient removal through adsorption.

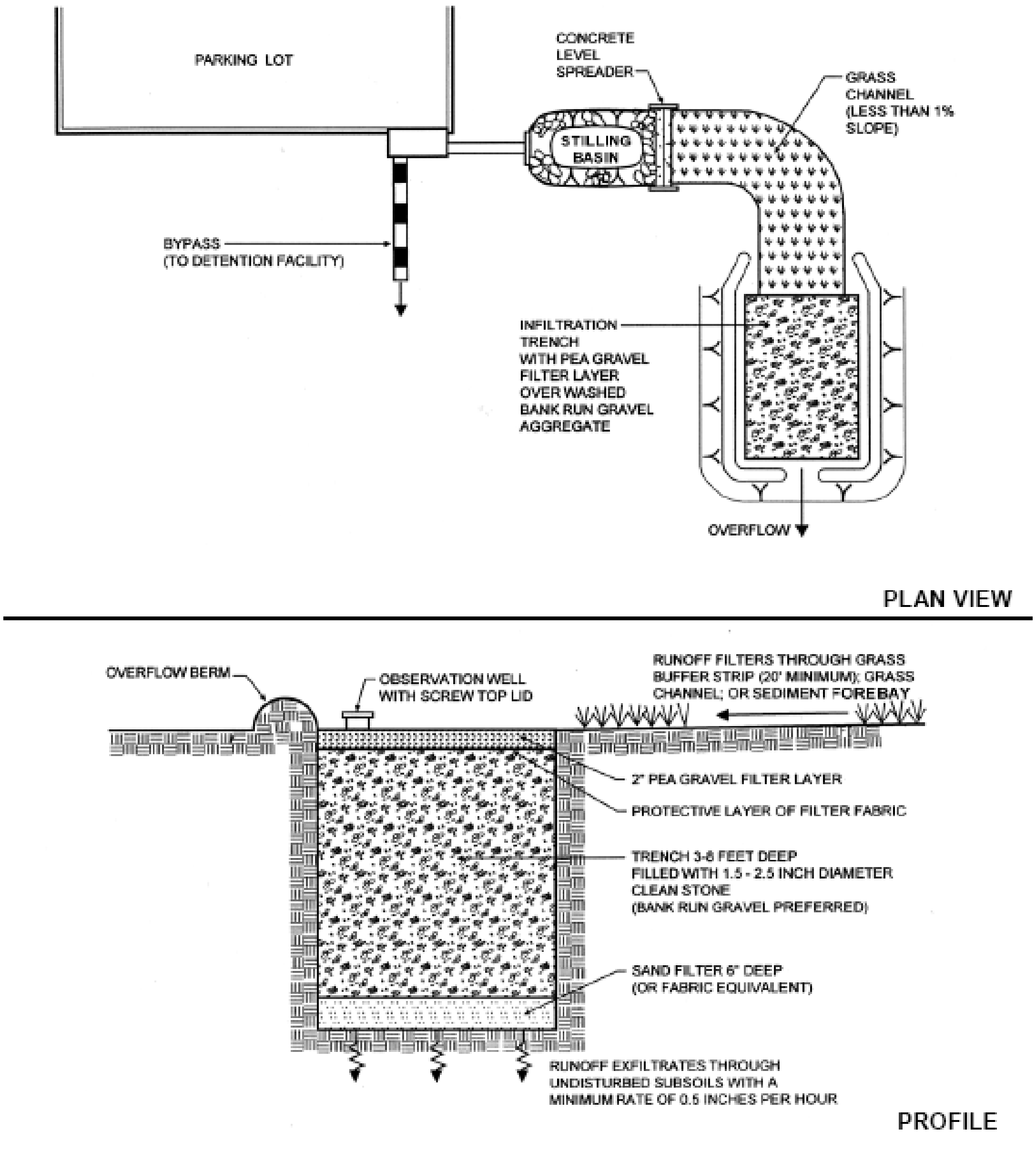

Figure C5-S2- 1: Example of an offline infiltration trench configuration
Source: Center for Watershed Protection

D. Application and feasibility

Infiltration trenches are generally suited for medium- to high-density residential, commercial, and institutional developments where the subsoil is sufficiently permeable to provide a reasonable infiltration rate and the water table is low enough to prevent groundwater contamination. They are applicable primarily for impervious areas where there are not high levels of fine particulates (clay/silt soils) in the runoff, and should only be considered for sites where the sediment load is relatively low.

Infiltration trenches can be used either to capture sheet flow from a drainage area or to function as an offline device. Due to the relatively narrow shape, infiltration trenches can be adapted to many different types of sites and can be utilized in retrofit situations. Unlike some other structural stormwater controls, they can easily fit into the margin, perimeter, or other unused areas of developed sites. Infiltration trenches capture and treat small amounts of runoff but do not control peak hydraulic flows. Infiltration trenches should be used in conjunction with another best management practice to provide both water quality control and peak flow control (Harrington 1989). Peak flow control is usually achieved with a slow release of the stormwater management volume through an orifice in the storage facility. As a result, the water quality volume will equal the stormwater detention area below the orifice, and must infiltrate to exit.

The applicability of infiltration trenches depends on native soils, slope, depth to water tables, depth to bedrock, size of drainage area, and proximity to wells, surface waters, and foundations. Trenches are generally suitable to sites with gentle slopes, permeable soils, deep bedrock, and deep groundwater. Excessive slope of the drainage area, fine-particle soil types, and proximate location of the water table and bedrock may prevent the use of infiltration trenches.

1. **General feasibility.**
   a. Suitable for Residential Subdivision Usage – yes
   b. Suitable for High Density/Ultra Urban Areas – yes
   c. Regional Stormwater Control – no

2. **Physical feasibility – physical constraints at project site.**
   a. **Drainage area.** 5 acres maximum.
   b. **Space required.** Will vary depending on the depth of the facility.
   c. **Site slope.** No more than 6% (for pre-construction facility footprint).
   d. **Minimum head.** Elevation difference needed at a site from the inflow to the outflow: 1 foot.
   e. **Minimum depth to water table.** Four feet recommended between the bottom of the infiltration trench and the elevation of the seasonally high water table.
   f. **Soils.** Infiltration rate greater than 0.5 in/hr required (typically HSG-A and B soils).
   g. **Other constraints/considerations.** Aquifer protection: no hotspot runoff allowed; meet setback requirements in design criteria.

E. Planning and design criteria

1. **Evaluation of the site.** Per the general criteria listed in C5-S1.

2. **Slope and drainage area.** The drainage area slope determines the velocity of the runoff and influences the amount of pollutants entrained in the runoff. Infiltration trenches work best when the up-gradient drainage area slope is less than 5% (Schueler, 1987). The down-gradient slope should be no greater than 15% to minimize slope failure and seepage. The slope of the surrounding area should be such that the runoff is evenly distributed as sheet flow as it enters the trench. Runoff can be captured by depressing the trench surface or by placing a berm at the down-gradient side of the trench. In general, infiltration trenches are suitable for drainage areas up to 5 acres. Supplemental BMPs should always be carefully considered. The drainage area must be fully developed and stabilized with vegetation before constructing an infiltration trench. High sediment loads from unstabilized areas will quickly clog the infiltration trench.

3. **Depth to water table and bedrock.** Land availability, the depth to bedrock, and the depth to the water table will determine whether the infiltration trench is located underground or at grade. Feasible sites should have a minimum of 4 feet to bedrock in order to reduce excavation costs. There should also be at least 4 feet below the trench to the water table to prevent potential groundwater problems.

4. **Minimum setbacks.** Stormwater easements may be necessary to accommodate setbacks. Recommended setbacks are as follows:
   a. Property line: 10 feet
   b. Building foundation: 25 feet
   c. Private well: 100 feet
   d. Public water supply well: 1,000 feet
   e. Septic system tank/leach field: 100 feet
   f. Surface waters: 100 feet

5. **Location and siting:**
   a. Infiltration trenches can be used to capture sheet flow or function as an offline device. They are suitable for medium- to high-density residential areas. Because of their narrow shape, they can be added to many different sites and retrofit situations. They easily fit into the margin, perimeter, or other unused areas of developed sites. Infiltration trenches are not suitable for sites that use or store chemicals or hazardous materials, unless diversion structures prevent hazards from entering the trench. The potential for spills can be minimized by

aggressive pollution prevention measures. Many municipalities and industries have developed comprehensive spill prevention control and countermeasure plans. These plans should be modified to include the infiltration trench and the contributing drainage area.

b. When used in an offline configuration, the WQv is diverted to the infiltration trench through the use of a flow splitter. Stormwater flows greater than the WQv are diverted to other controls or downstream, using a diversion structure or flow splitter.

c. To reduce the potential for costly maintenance and/or system reconstruction, it is strongly recommended that the trench be located in an open or lawn area, with the top of the structure as close to the ground surface as possible. Infiltration trenches should not be located beneath paved surfaces, such as parking lots.

d. The underlying soils must meet the soils screening criteria with an infiltration rate, *f*, of 0.5 in/hr or greater, as initially determined from NRCS soil textural classification; and subsequently confirmed by field geotechnical tests. The minimum geotechnical testing is one test hole per 5,000 square feet, with a minimum of two borings per facility (taken within the proposed limits of the facility). Infiltration trenches cannot be used in fill soils.

e. Infiltration trenches should have a contributing drainage area of 5 acres or less.

f. Infiltration trenches are designed for intermittent flow and must be allowed to drain and allow re-aeration of the surrounding soil between rainfall events. They must not be used on sites with a continuous flow from groundwater, sump pumps, or other sources. Trenches should be designed to drain completely within 6-72 hours. A shorter drain time of 48 hours is often used as a factor of safety in the design. A minimum drainage time of 6 hours will ensure satisfactory pollutant removal. The maximum drainage time is dependent on the precipitation zone. In Iowa, the average time between storm events is approximately 72 hours. Therefore, the trench should be designed to drain completely within a maximum of 72 hours.

g. The site assessment approach for stormwater infiltration sites is very similar to the site assessment used for the design of onsite wastewater treatment systems. In a soil/water infiltration system (SWIS) for septic tank effluent, the same concerns are considered as with seasonal high groundwater, depth to water table, and soil permeability. The typical loading rates for septic tank effluent in B soils would be on the order of 0.5-1.0 gal/day/ft^2 of infiltration surface. These are long-term loading rates and are based on the assumption that a bio-mat will eventually form at the soil/water interface.

6. **Cold weather considerations.** Climate can limit infiltration trench use. Winter sanding can clog an infiltration trench, and winter salting can increase the potential for chloride contamination of groundwater. Additionally, the trench surface may freeze, thereby preventing the runoff from entering the trench and allowing the untreated runoff to enter surface water. 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.

F. Physical specifications, geometry, and volume

1. A well-designed infiltration trench consists of:
   a. Excavated shallow trench backfilled with sand, coarse stone, and pea gravel; and lined with a filter fabric.
   b. Appropriate pre-treatment measures.
   c. One or more observation wells to show how quickly the trench dewaters or to determine if the device is clogged.
   d. A plan view and profile schematic for the design of an offline infiltration trench is shown in Figure C5-S2- 1. A schematic for an online infiltration facility is shown in Figure C5-S2- 2.

2. Physical specifications of an infiltration trench include:
   a. The required trench storage volume is equal to the WQv. For smaller sites, an infiltration trench can be designed with a larger storage volume to include the Cpv.

b. A trench must be designed to fully dewater the entire WQv within 24-48 hours after a rainfall event. The slowest infiltration rate obtained from tests performed at the site should be used in the design calculations.
c. Trench depths should be between 3 and 8 feet, to provide for easier maintenance. The width of a trench is usually less than 25 feet.
d. Broader, shallow trenches reduce the risk of clogging by spreading the flow over a larger area for infiltration.
e. The surface area required is calculated based on the trench depth, soil infiltration rate, aggregate void space, and fill time (assume a fill time of 2 hours for most designs).
f. The bottom slope of a trench should be flat across its length and width to evenly distribute flows, encourage uniform infiltration through the bottom, and reduce the risk of clogging.

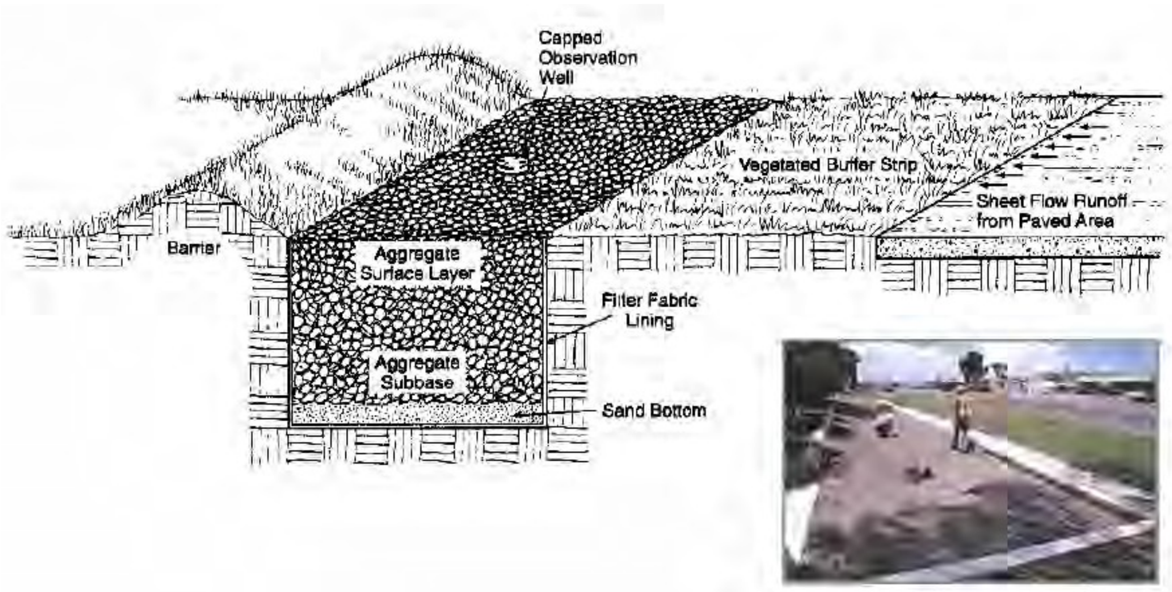

Figure C5-S2- 2: Example of an online infiltration trench configuration
Source: Georgia Stormwater Manual, 2000

3. Components of an infiltration trench (See Figure C5-S2- 3):
   a. **Aggregate.** The basic infiltration trench uses stone aggregate in the top of the trench to promote filtration. The stone aggregate is normally 1-3 inches in diameter, which provides a void space of ~35 percent (SEWRPC 1991; Harrington 1989; Schueler 1987). The stone aggregate should be washed to remove dirt and fines before placement in the trench. The aggregate should be non-crushed limestone or a river-run washed stone (often referred to as septic rock). A 4-6 inch layer of clean, washed, ASTM C33 medium aggregate concrete sand is placed on the bottom of the trench to encourage drainage and prevent soil compaction when the stone aggregate is added. The design can be modified by substituting pea gravel for stone aggregate in the top foot of the trench. The pea gravel should be #8 to ⅜-inch. The pea gravel improves sediment filtering and maximizes the pollutant removal in the top of the trench. 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. Infiltration trenches can also be modified by adding a layer of organic material (peat) or loam to the trench subsoil. This modification appears to enhance the removal of metals and nutrients through adsorption.

   b. **Sheet flow.** The trench surface may consist of stone or vegetation with inlets to evenly distribute the runoff entering the trench (SEWRPC 1991; Harrington 1989). A level spreader can be installed to create sheet flow (Harrington 1989).

   c. **Filter fabric.** The sides and bottom of the infiltration trench should be lined with filter fabric. The fabric should be placed around the walls and bottom of the trench, and 1 foot below the trench surface. The filter fabric should overlap each side of the trench in order to cover the top of the stone aggregate layer. The filter fabric prevents sediment in the runoff and soil particles from the sides of the trench from clogging the aggregate. Filter fabric placed 1 foot below the trench surface will maximize pollutant removal within the top layer of the trench and decrease the pollutant loading to the trench bottom, reducing the required frequency of maintenance.

d. **Observation well.** (See example schematics). An observation well allows monitoring of drainage. The observation well can be 4 to 6-inch diameter PVC pipe with a lockable cap. The well can either be 6 inches above-ground or flush with the ground, depending on the trench surface. It is anchored to a footplate at the bottom of the trench, and should be located near the longitudinal center of the infiltration trench. A visible floating marker should be provided to indicate the water level. The pipe should have a plastic collar with ribs to prevent rotation when removing the cap. The screw-top lid should be a cleanout with a locking mechanism or special bolt to discourage vandalism. The depth to the invert should be marked on the lid.

e. **Filter strip.** A vegetated buffer strip, 20-25 feet wide, is established adjacent to the infiltration trench to capture large sediment particles in the runoff. The buffer strip is installed immediately after trench construction using sod instead of hydroseeding (Schueler 1987). The buffer strip should be graded with a slope between 0.5 and 15% so that runoff enters the trench as sheet flow.

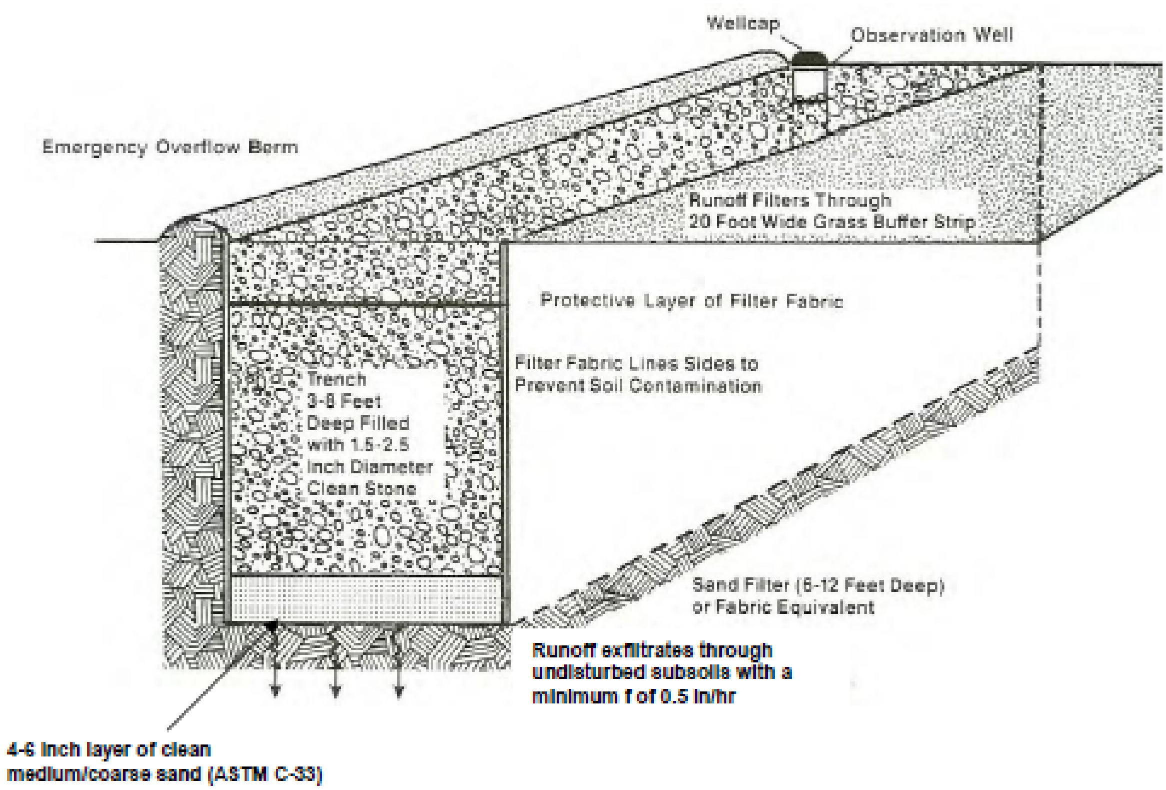

Figure C5-S2- 3: Components and configuration of an infiltration trench
Source: Adapted from Schueler, 1987

G. Design of infiltration trenches

The design of an infiltration trench is based on the textural class and nominal infiltration rate of the soils underlying the trench such that a feasible design is possible. The design of an infiltration trench is also based on the maximum allowable depth of the trench (d_{max} - ft). The maximum allowable depth should meet the following criteria:

Equation C5-S2- 1

$$d\_max = ((fT\_s)/n)/12$$

Where:
f = final infiltration rate of the trench area (in/hr)

T_s = maximum allowable storage time (hr)
n = porosity, volume voids/total volume (V_v/V_t) of the aggregate reservoir.

A nominal value for *n* of 0.32-0.35 is typical. This can be adjusted based on specific measurement for the aggregate specified. The maximum allowable storage time should be no greater than 72 hours. The maximum allowable depth for a site may also be limited by the depth to the water table.

The infiltration trench is sized to accept the design volume that enters the trench (V_w) plus the volume of rain that falls on the surface of the trench (PA_t) minus the exfiltration volume (fTA_t) out of the bottom of the trench. Based on NRCS hydrograph analysis, the effective filling time for most infiltration trenches (T) will generally be less than two hours. The volume of water that must be stored in the trench (V_s) is defined as:

Equation C5-S2- 2

$$V_s = V_w + \left(\frac{P}{12}\right)(A_t) - \left(\frac{f}{12}\right)TA_t$$

Where:
V_w = water quality volume (WQv) or total runoff volume to be infiltrated (ft^3)
P = design rainfall event (in)
A_t = trench surface area (ft^2)
f = infiltration rate (in/hr)
T = fill time (hr)

For most design storm events, the volume of water due to rainfall on the surface area of the trench (PA_t) is small when compared to the design volume (V_w) of the trench, and may be ignored with little loss in accuracy to the final design. The volume of rainfall and runoff entering the trench can be defined in terms of trench geometry. The gross volume of the trench (V_t) is equal to the ratio of the volume of water that must be stored (V_w) to the porosity (*n*) of the stone reservoir in the trench.

V_s is also equal to the product of the depth (d_t-ft), the surface area (A_t-ft^2), and the porosity (n).

Equation C5-S2- 3

$$V_s = d_t \times A_t \times n$$

Combining Equation C5-S2- 1 and Equation C5-S2- 2 provides the following expression:

$$d_t \times A_t \times n = V_w + \left(\frac{P}{12}\right)(A_t) - \left(\frac{f}{12}\right)TA_t$$

Assuming the volume of water falling directly onto the trench area is negligible, then:

Equation C5-S2- 4

$$d_t \times A_t \times n = V_w - \left(\frac{f}{12}\right)TA_t$$

Because both dimensions, A_t and d_t, of the trench are unknown, the equation may be rearranged to determine the area of the trench (At) if the value of d_t is determined, based on either the location of the water table, or the maximum allowable depth of the trench (d_{max}):

Equation C5-S2- 5

$$A_t = \frac{V_w}{nd_t + \frac{fT}{12}}$$

H. Design procedures

Design plans should include a geotechnical evaluation that determines the feasibility of using an infiltration trench at the site (See Chapter 5, section 1).

1. **Step 1**. Compute runoff control volumes. Calculate the WQv, Cpv, Q_p, and the 100-year Q_f. See Chapter 3 for calculations.

2. **Step 2.** Determine if the development site and conditions are appropriate for the use of an infiltration trench. Confirm any local design criteria and check with local agencies to determine if there are any additional restrictions and/or surface water or watershed requirements that may apply. Consider any special site-specific design conditions, including:
   - Soil:
     - Soil type (USDA classifications)
     - Percent clay
     - Permeability
     - Assessment procedures
   - Depth to water table
   - Slope
   - Drainage area

3. **Step 3.** Compute the peak discharge rate for the water quality volume event. The peak rate of discharge for water quality design is needed for sizing of the offline diversion structure and piping.

   a. Using WQv (or total volume to be infiltrated), compute CN.
   b. Compute time of concentration using WinTR-55 method.
   c. Determine appropriate unit peak discharge from time of concentration.
   d. Compute Qwq from unit peak discharge, drainage area, and WQv.

4. **Step 4.** Size the flow diversion structure, if needed. A flow regulator (or flow splitter diversion structure) should be supplied to divert the WQv to the infiltration trench. Size low-flow orifice, weir, or other device to pass the Qwq.

5. **Step 5.** Size the infiltration trench:

   a. Determine the trench volume by assuming the WQv will fill the void space based on the computed porosity of the stone aggregate backfill (normally about 35%).

   b. A site-specific trench depth is calculated based on the soil infiltration rate, aggregate void space, and the trench storage time as described above (Harrington 1989). Compute the maximum allowable trench depth (d_{max}) from Equation C5-S2- 1. Select the trench design depth (d_t) based on the depth that is the required depth above the seasonal groundwater table, or a depth less than or equal to d_{max}, whichever results in the smaller depth. Trench depths are usually between 3-12 feet (SEWRPC 1991; Harrington 1989). However, a depth of 8 feet is most commonly used (Schueler 1987).

   c. Compute the trench surface area (A_t) for the particular soil type using Equation C5-S2- 4:

$$A_t = \frac{WQv}{nd_t + \frac{fT}{12}}$$

Where:
A_t = trench surface area, ft^2
WQv = water quality volume (or total volume to be infiltrated), ft^3
f = infiltration rate, in/hr
T = drain time (maximum time to dewater the entire WQv), hours

d. A minimum drainage time of 6 hours should be provided to ensure satisfactory pollutant removal in the infiltration trench (Schueler 1987). Although trenches are designed to provide temporary storage of stormwater, the trench should drain prior to the next storm event. For Iowa, the mean time between storm events is about 72 hours. Using a shorter drain time of 48 hours would provide a more conservative design.

e. In the event that the sidewalls of the trench must be sloped for stability during construction, the surface dimensions of the trench should be based on the following equation:

Equation C5-S2- 6

$$A_t = (L - Zd_t)(W - Zd_t)$$

Where L and W are the top length and width, and Z:1 is the trench side-slope ratio. The design procedure would begin by selecting a top width (W) that is greater than 2×*Zdt* for a specified slope (Z). The side slope ratio value will depend on the soil type and the depth of the trench. The top length (L) may then be determined as:

Equation C5-S2- 7

$$L = Zd_t + \frac{A_t}{W - Zd_t}$$

6. **Step 6**. Determine pre-treatment volume and design pre-treatment measures. Size pre-treatment facility to treat 25% of the water quality protection volume for offline configurations.

7. **Step 7.** Design spillway(s): Adequate stormwater outfalls should be provided for the overflow exceeding the capacity of the trench, ensuring non-erosive velocities on the downslope.

I. Inspection and maintenance requirements

Infiltration trenches, as with all BMPs, must have routine inspection and maintenance designed into the life performance of the facility. The principal maintenance objectives are to prevent clogging and groundwater contamination. Maintenance and inspection plans should be identified prior to establishment. Infiltration trenches and any pre-treatment BMPs should be inspected after large storm events to remove any accumulated debris or material. A more thorough inspection of the trench should be conducted annually. A summary of inspection and maintenance activities is provided in Table C5-S2- 1.

A record should be maintained of the dewatering time of an infiltration trench to determine if maintenance is needed. (Ponded water lasting more than 24 hours usually indicates that the trench is clogged). When vegetated buffer strips are used, they should be inspected for erosion or other damage after each major storm event. Trees and other large vegetation adjacent to the trench should also be removed to prevent damage to the trench.

Maintenance responsibility for an infiltration trench should be assigned to a responsible jurisdiction or authority through a legally binding and enforceable maintenance agreement completed as a condition of the site plan approval.

Table C5-S2- 1: Typical maintenance activities for infiltration trenches

Activity	Schedule
• Ensure the contributing drainage area, facility, and inlets are clear of debris. • Ensure that the contributing area is stabilized. • Remove sediment and oil/grease from pre-treatment devices, as well as overflow structures. • Mow grass filter strips as necessary. Remove grass clippings.	Monthly
• Check observation wells following three days of dry weather. Failure to percolate within this time period indicates clogging. • Inspect pre-treatment devices and diversion structures for sediment buildup and structural damage. • Remove trees that start to grow in the vicinity of the trench.	Semi-annual
• Replace pea gravel/topsoil and top surface filter fabric (when clogged).	As needed
• Perform total rehabilitation of the trench to maintain design storage capacity. • Excavate trench walls to expose clean soil.	Upon failure

Source: US EPA, 1999

J. Example schematics

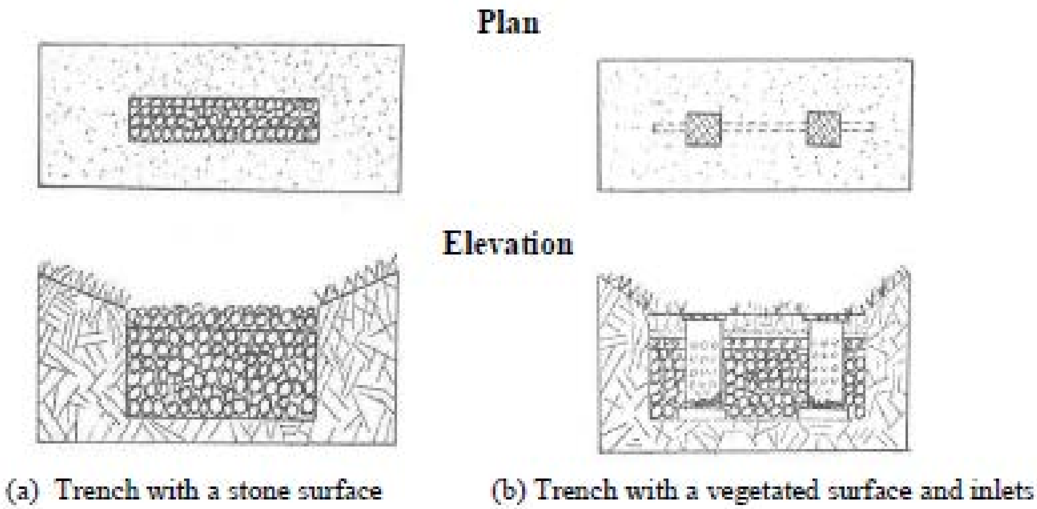

Figure C5-S2- 4: Types of infiltration trenches
Source: Schueler, 1987

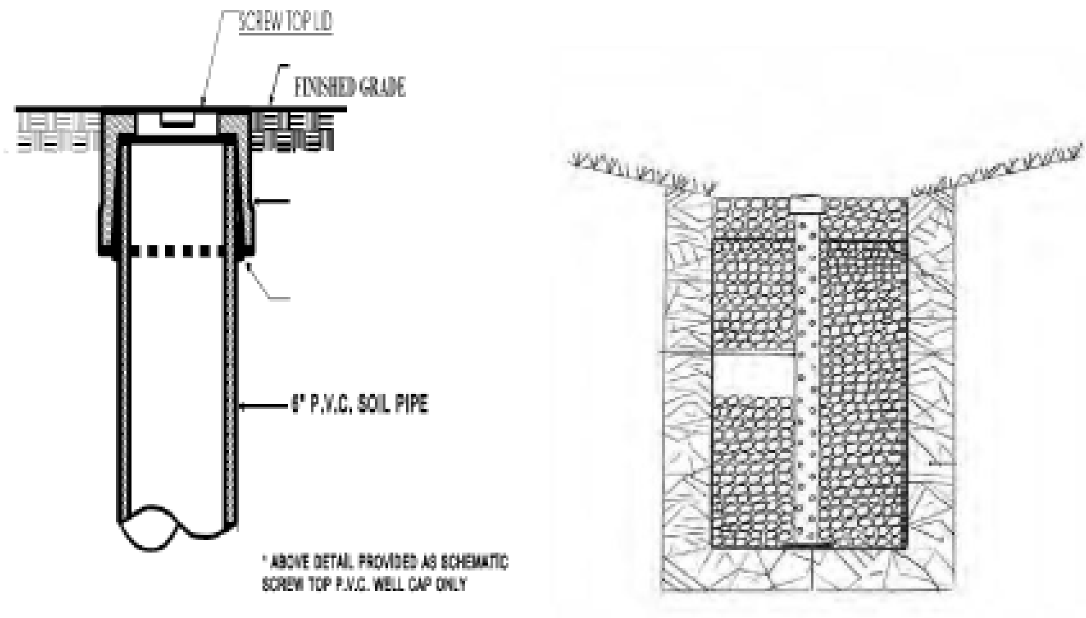

Figure C5-S2- 5: Example observation well and access lid
Source: Adapted from Maryland WRA

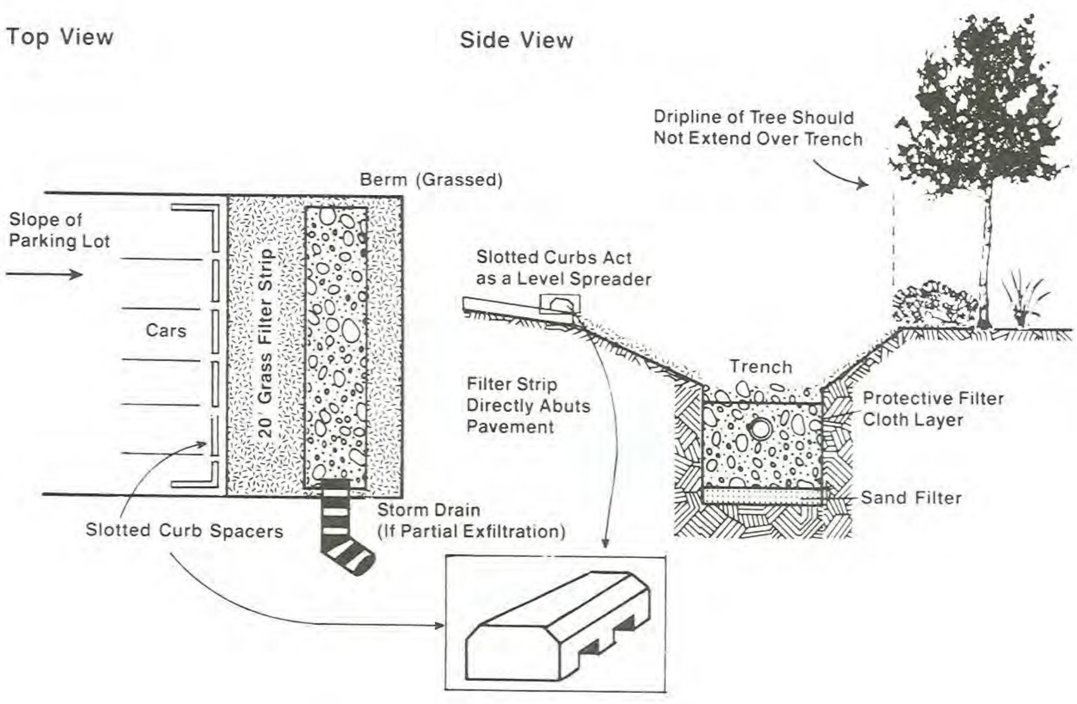

Figure C5-S2- 6: Commercial trench design – parking lot
Source: MWCOG, 1987

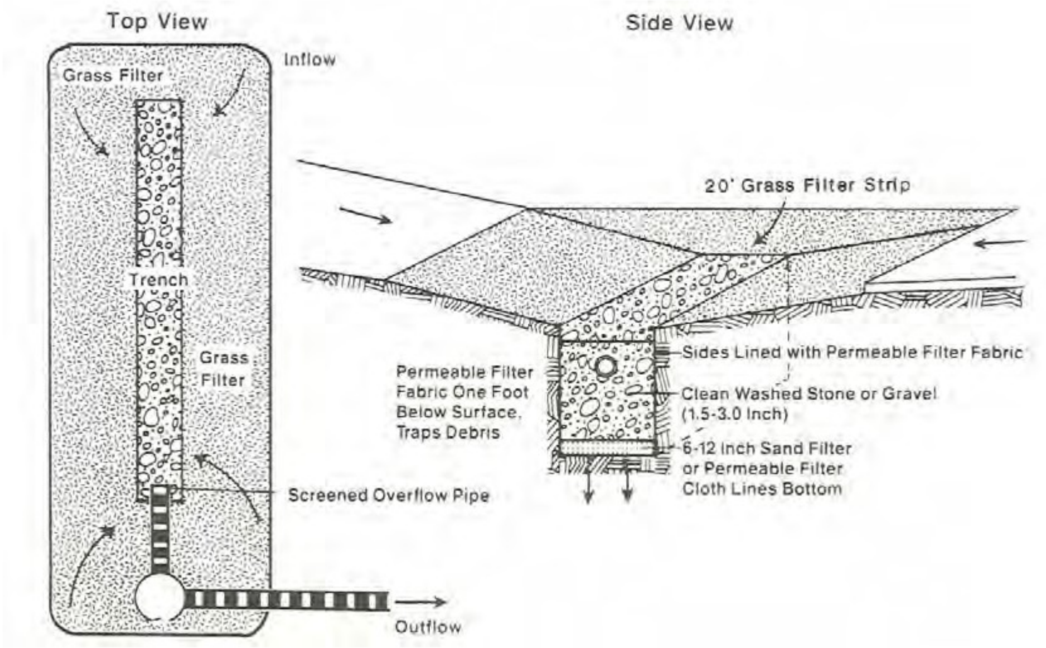

Figure C5-S2- 7: Median strip design – multiple lane street/highway
Source: MWCOG, 1987

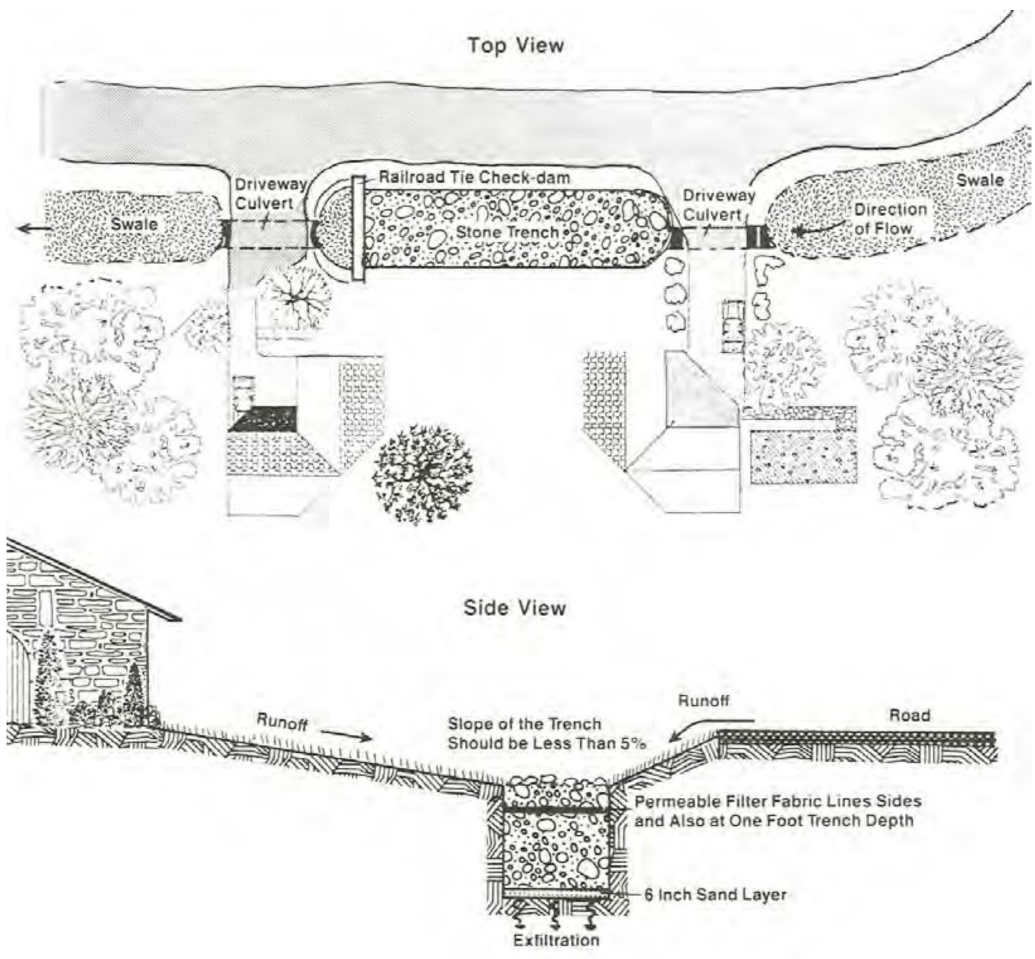

Figure C5-S2- 8: Swale/trench design (residential application)
Source: MWCOG, 1987

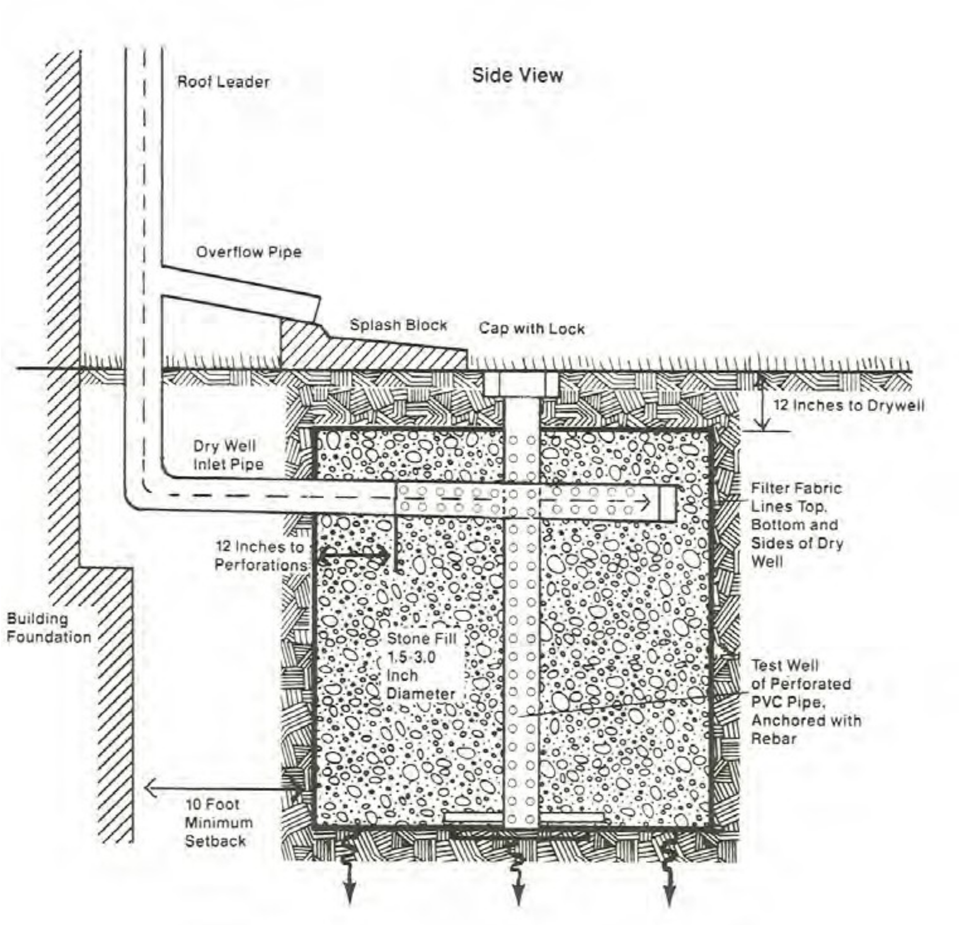

Figure C5-S2- 9: Infiltration: dry well design
Source: MWCOG, 1987

K. Design example

Infiltration Trench

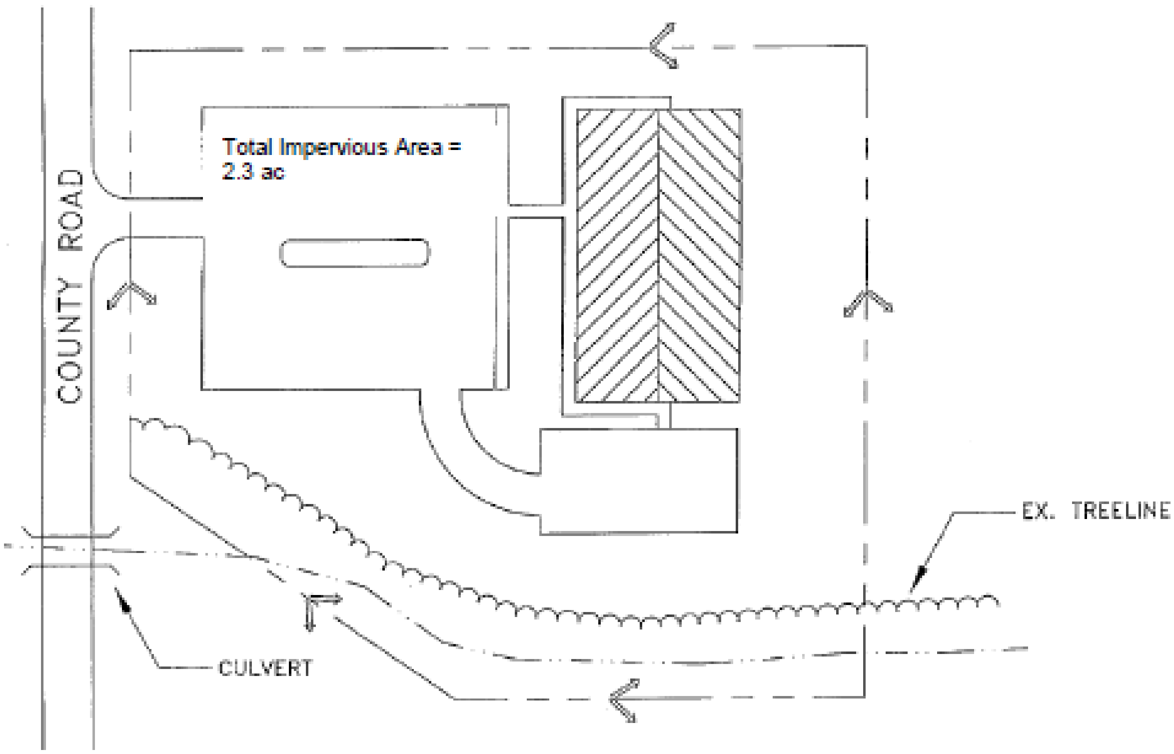

Figure C5-S2- 10: Infiltration design example site plan

Table C5-S2- 2: Bucketsville, IA Community Center; Marshould County, IA

Base Site Data	Hydrologic Data		
Total site drainage area (A) = 4 ac		Pre-	Post-
Impervious area = 2.3 ac; I = 2.2/4 = 57.5%	CN	68	84
Soils: HSG B (loam)	T_c	0.32	0.18

This example is focused on the design of an infiltration trench to meet the water quality treatment requirements for the site. Cpv and Q_p are not addressed in this example, other than determination for preliminary storage volume and peak discharge requirements. The Cpv and Q_p requirements will be handled by another set of downstream BMPs. Infiltration trenches provide water quality treatment (WQv) and recharge volume (Rev). Flows in excess of the WQv will be bypassed. The bypassed flow will be conveyed downstream and combined with other off-site flows in a conventional detention basin for Q_p control.

1. **Step 1.** Compute runoff control volumes from unified sizing criteria.

   a. Compute WQv:
   $R_v = 0.05 + (57.5)(0.009) = 0.57$
   $WQv = \frac{(1.25in)(R_v)(A)}{12}$
   $= (1.25)(0.57)(4.0)\left(\frac{1ft}{12in}\right)(43{,}560\, ft^2/ac)$
   $= 10{,}345 ft^3 = 0.237 ac\text{-}ft$

   b. Compute stream channel protection volume, (Cpv):

      1) Use WinTR-55 to compute the pre- and post-development peak runoff rates for the 1-year, 24-hour

duration storm.

Condition	**CN**	**Q_1** inches	**Q_1** cfs	**Q_{25}** cfs	**Q_{100}** cfs
Pre-developed	68	0.5	0.6	6.0	9.0
Post-developed	84	1.9	5.5	17.0	22.0

2) Use WinTR-55 to compute channel protection storage volume:
   a) $q_u = 600\, csm/in$
   b) $\frac{q_o}{q_i} = 0.04$
   c) $\frac{V_s}{V_r} = 0.683 - 1.43\left(\frac{q_o}{q_i}\right) + 1.64\left(\frac{q_o}{q_i}\right)^2 - 0.804\left(\frac{q_o}{q_i}\right)^3$
   d) $V_s = CPv\ and\ V_r = volume\ of\ runoff\ in\ inches$
   e) $\frac{V_s}{V_r} = 0.64$
   f) $V_s = CPv = 0.64(1.9in)\left(\frac{1}{12}\right)(4ac) = 0.405ac - ft = 17{,}646ft^3$
   g) $CPv\ of\ 17{,}756ft^3\ to\ be\ released\ over\ 24\ hours$:
   h) $\frac{17{,}656ft^3}{24hr \times 3600sec/hr} = 0.2cfs(average\ release\ rate\ for\ CPv)$

c. Determine overbank protection flood protection volume (Q_{p25}).
   1) Use WinTR-55 for analysis of Q_5 to Q_{100} runoff volume in inches and respective peak rates.
   2) For a Q_{in} of 17 cfs and an allowable Q_{out} of 6 cfs, the V_s necessary for 25-year control is 0.52 ac-ft or 22,677 ft^3 under a developed CN of 84.

d. Compute WQv peak discharge (Q_{wq}) from Chapter 3, section 6 and Modified NRCS WinTR-55 procedure.
   1) $WQv = 10{,}345ft^3 = 0.237ac - ft$
   2) $CN = \frac{1000}{\left[10+5P+10Q_a-10\left(Q_a{}^2+1.25Q_aP\right)^{0.5}\right]}$

      $P = rainfall\ depth\ for\ water\ quality\ storm - 1.25inches$
      $Q_a = runoff\ volume, inches\ (equal\ to\ P \times R_v) = (1.25)(0.57) = 0.712in$
   3) $CN = 1000/[10 + 5(1.25in) + 10(0.71in) - 10[(0.71in)^2 + 1.25(0.71in)(1.25in)]^{0.5}$
      CN = 93.8 Use CN = 94
   4) Use T_c = 0.18 hour

d. Compute Q_{wq} using WinTR-55 using modified CN and T_c:
   1) WinTR-55 results for *modified* CN = 94 and T_c = 0.18 hr: For 1.25-inch rainfall, q_u = 622.89 csm/in
   2) Q_{wq} = 3.89 cfsec

e. Compute 1-year, 2-year, and 10-year peak discharge using conventional WinTR-55 procedure:
   1) For 57.5% impervious, B soils, CN=98 for impervious and CN=64 for open space
   2) CN = 84
   3) Use T_c = 0.18 hr
   4) WinTR-55 results (runoff and peak discharge summary):

Design storm event	Runoff volume (inches)	Peak discharge, Q (cfs)	Unit discharge, q_u (csm/in)
1-year	1.018	5.57	891.69
2-year	2.187	11.94	1910.82
10-year	2.897	15.7	2511.58
25-year	4.095	21.9	3504.19
50-year	4.754	25.25	4040.43
100-year	5.706	30.04	4806.93

2. **Step 2.** Determine if the development site and conditions are appropriate for using an infiltration trench. Site specific data:
   - Soil: loam
   - Infiltration rate: 0.8 in/hr
   - Ground elevation at BMP: 1020
   - Seasonally high water table: 1008
   - Stream invert: 1006
   - Soil slopes: 1.2%

3. **Step 3.** Confirm design criteria and applicability.

Infiltration Feasibility	
Criteria	**Status**
Infiltration rate (*f*) greater than or equal to 0.5 in/hr.	Infiltration rate is 0.8 in/hr. OK.
Soils have a clay content of less than 20% and a silt/clay content of less than 40%.	Loam soil at this site meets both criteria.
Infiltration cannot be located on slopes greater than 6% or in fill soils.	Slope is 1.2%; not fill soils. OK.
Hotspot runoff should not be infiltrated.	Not a hotspot land use. OK.
Infiltration is prohibited in karst topography.	Not in karst. OK.
The bottom of the infiltration facility must be separated by at least 4 feet vertically from the seasonally high water table.	Elevation of seasonally high water table: 1008 feet. Elevation of BMP location: 1020 feet. The difference is 12 feet. The trench can be up to 8 feet deep. OK.
Infiltration facilities must be located 100 feet horizontally from any water supply well.	No water supply wells nearby. OK.
Maximum contributing area generally less than 5 acres. (Optional)	4 acres. OK.
Setback 25 feet down-gradient from structures.	50 feet straight-line distance between the parking lot and the tree line. OK if the trench is 25 feet wide or narrower.

4. **Step 4.** Size the infiltration trench.

   a. Use Equation C5-S2- 4.
      1) $A_t = WQv/(nd_t + fT/12)$
      2) $A_t - area\ of\ trench, ft^2$
      3) WQv = volume to be stored/infiltrated, ft^3
         n = porosity
         F = infiltration rate, in/hr
         T = fill time
         d_t = depth of trench, ft

4) Assume that: n = 0.34
f = 0.8 in/hr
T_s = maximum storage time = 72 hours

$$d_{max} = \left(\frac{fT_s}{n}\right)/12 = \left[\frac{(0.8)(72.0)}{0.34}\right]/12 = 14.2ft$$

However, maximum depth for this site will be 8 ft due to water table

b. $A_t = (10{,}345ft^3/[(0.34)(8ft) + (0.8)(2.0)/12] = 3{,}635ft^2$

c. For a width, W, of 25 feet, determine the length, L:
L ft = 3,635 ft/25 ft = 145 ft

Assume that ⅓ of the runoff from the site drains to Point A and ⅔ drains to Point B. Use an L-shaped trench in the corner of the site (see Figure C5-S2- 11 for a site plan view). The surface area of the trench is proportional to the amount of runoff it drains (e.g., the portion draining from Point A is half as large as the portion draining Point B).

5. **Step 5.** Size the flow diversion structures.

a. Since two entrances are used, two flow diversions are needed. For the entire site: Q_{25} = 21.9 cfs
b. Peak flow for WQv = 3.89 cfs (step 3).
c. For the first diversion (Point A):

1) Assume peak flow equals ⅓ of the value for the entire site. Thus, $Q_{25} = \frac{21.9}{3} = 7.3cfs$. Peak flow for $WQv = \frac{3.89}{3} = 1.3cfs$

2) Size the low-flow orifice to pass 1.3 cfs with 1.5 feet of head using the orifice equation.
$Q = CA(2gh)^{1/2}; 1.3cfs = 0.6A(2 \times 32.2fps^2 \times 1.5ft)^{1/2}$
$A = 0.22ft^2; d = 0.53ft$; use 8-inch pipe with 8-inch gate valve

3) Size the 25-year overflow weir crest at 1022.5 feet.
Use a concrete weir to pass the 25-year flow (7.3-1.3 = 6 cfs). Assume 1 foot of head to pass this event. Size using the weir equation.
$Q = CLH^{1.5}$
$L = Q/(CH^{1.5})$
L = 6 cfs/ $(3.1)(1)^{1.5}$ = 1.93 ft; use 2 feet (see Figure C5-S2- 12)

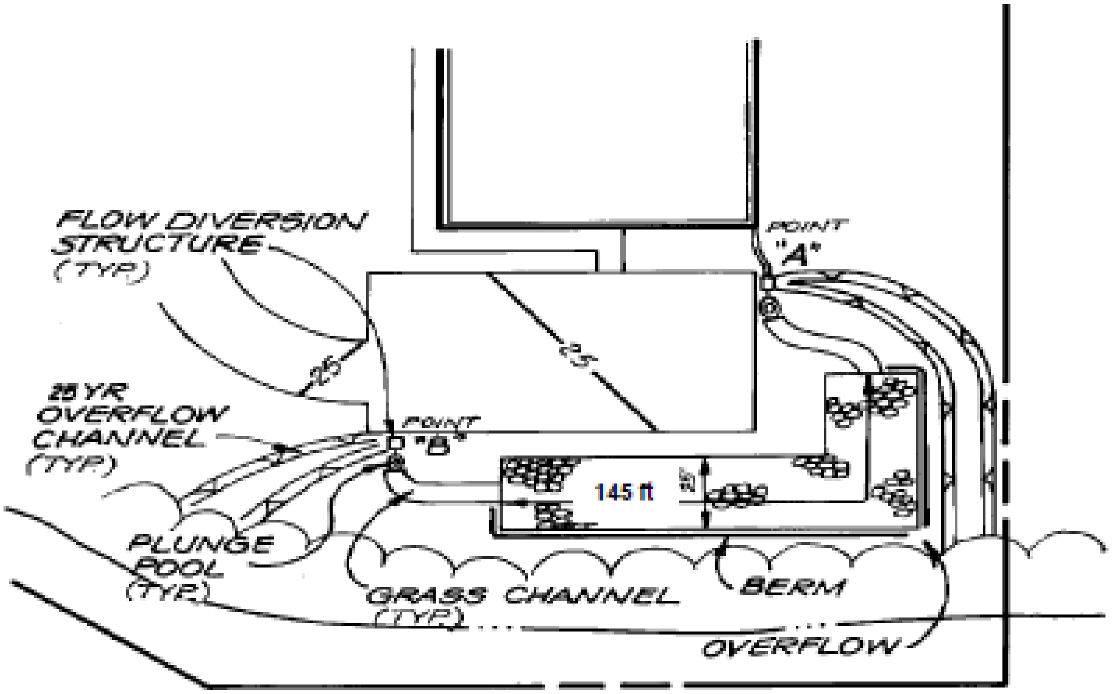

Figure C5-S2- 11: Infiltration trench site plan

d. Size the second diversion (Point B) using the same techniques.
   1) Peak flow equals ⅔ of the value for the entire site. Thus: Q_{25} = (21.9)(0.67) = 14.7 cfs Peak flow for WQv = (3.89)(0.67) = 2.6 cfs
   2) Size the low-flow orifice to pass 2.6 cfs with 1.5 ft of head using the orifice equation.
      $Q = CA(2gh)^{1/2};\ 2.6cfs = 0.53(2 \times 32.2fps^2 \times 1.5ft)^{1/2}$
      $A = 0.44ft^2; d = 0.75ft$; use 10-inch pipe with 10-inch gate valve

e. Size the 25-year overflow weir crest at 22 feet. Use a concrete weir to pass the 25-year flow (14.7 – 2.6 = 12.1 cfs). Assume 1 foot of head to pass this event. Size using the weir equation.
   $Q = CLH^{1.5}$;
   $L = Q/(CH^{1.5})$
   $L = 12.1\ cfs/(3.1)(1)^{1.5} = 3.9$ ft; use 4 ft (see Figure C5-S2- 12)

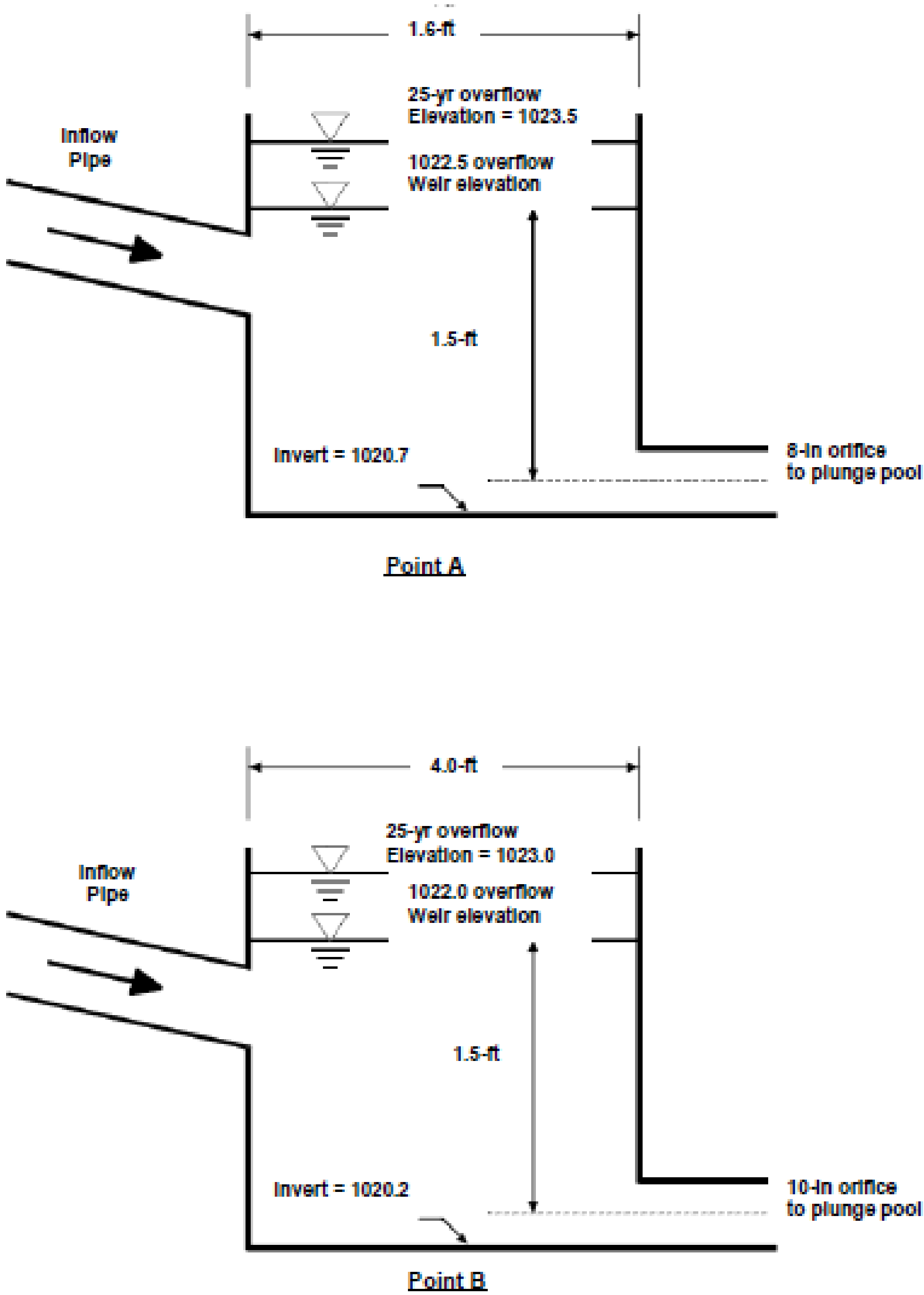

Figure C5-S2- 12: Weir elevation sizing

6. **Step 6.** Size pre-treatment volume and design pre-treatment measures. As a rule of thumb, size pre-treatment to treat 25% of the WQv. Therefore, treat 10,345 ft^3 x 0.25 = 2,586 ft^3. For pre-treatment, use a pea-gravel filter with a geotextile filter fabric, a plunge pool, and a grass channel.

   a. **Pea gravel filter.** The pea gravel filter layer covers the entire trench with 2 inches of material (see Figure C5-S2- 11). Assuming a porosity of 0.32, the water quality treatment volume in the pea gravel filter layer is: $WQv_{(filter)}$ = (0.32)(2 in)(1/12)(3635 ft^2) = 194 ft^3.

   b. **Plunge pools.** Use a 5-ft x 10-ft plunge pool at Point A and a 10-ft x 10-ft plunge pool at Point B with average depths of 2 feet. $WQv_{(pool)}$ = (10 ft)(10 ft + 5 ft)(2 ft) = 300 ft^3

c. **Grass channel.** The WQv for the grass channel needs to treat the remaining volume (2,586- 194-300)ft^3 = 2092- ft^3

Use the procedure in Chapter 9 to design the grass channels:

a. The channel at Point A should treat ⅓ of 2092 ft^3 or 698 ft^3.

b. Assume a trapezoidal channel with a 4-foot channel bottom, 3:1 side slope, and a Manning's n of 0.15. Use a 1% longitudinal slope.

c. Use a peak discharge of 1.3 cfs (Peak flow for ⅓ of the WQv).

d. Compute velocity: V=0.5 fps.

e. To retain the ⅓ of WQv (3,448 ft^3) for 10-minutes, the length would be 300 feet. Since the swale only needs to treat 25% of the WQv minus the treatment provided by the plunge pool and the gravel layer, or 698 ft^3, the length is pro-rated to reflect this reduction.

   Therefore, adjust the length: L = (300 ft) (698 ft^3/3448 ft^3) = 60.7 feet. **Use 60 feet.**
   Size the channel at Point B in a similar manner for the ⅔ of WQv.