3.4 Post Construction Stormwater Control Fact Sheets (PTP)

Post Construction Stormwater Control Practices	3.4.5 **Infiltration Systems**
IS **Symbol** IS **TSS Reduction**: 90%	

Description

Infiltration systems are depressions with no outlet used to detain stormwater for a short period of time until it percolates into the groundwater table. Runoff flows into the system, is stored in the voids between stones and is slowly infiltrated through soil layers. As the stormwater penetrates the underlying soil, chemical, biological, and physical processes remove pollutants. Infiltration systems also provide groundwater recharge and preserve baseflow in nearby streams. Two types of infiltration systems that will be addressed here include: infiltration trenches and infiltration basins.

Applications

Infiltration systems can be used to manage stormwater runoff from urban areas, where they can be used to treat sheet flow from impervious areas. Infiltration systems are typically suitable for the following applications:

- Small drainage areas
- Impervious area runoff
- Offline systems
- Areas where removal of suspended solids, pathogens, metals, and nutrients is needed
- Areas determined appropriate by karst & geotechnical evaluations

Infiltration systems may fail due to improper siting, design, construction and/or maintenance. Infiltration systems are **not** suitable for the following applications:

- As an independent treatment mechanism
- Sites with steep slopes
- Sites where runoff from hot spot landuses that could contribute to groundwater contamination
- Sites that may cause water problems to downgrade properties.
- Sites with high sediment or pollutant loads
- Sites with high pesticide or pathogen levels
- Manufacturing or industrial sites
- Sites with combined sewer overflows are not suitable applications for this BMP

Infiltration systems should only be applied to stabilized drainage areas, as heavy sediment loads from construction areas will clog and disable the infiltration media. Likewise, they should not be used in areas where stormwater has the potential for high silt or clay content. High amounts of organic debris may also cause clogging for infiltration systems.

Infiltration systems should typically be designed for off-line use to capture the first flush of runoff. A diversion structure such as a flow splitter or weir may be necessary to separate and route the first flush to the infiltration system for water quality control, and route the remaining stormwater to a water quantity management device downstream. Infiltration systems are most effective when turbulent flow is minimized and the flow is spread uniformly across the filter media.

Infiltration Systems Variations

Infiltration Trench

Figure PTP-05- 1 Infiltration Trench
Source, Stormwater Managers Resource Center

An infiltration trench is a shallow excavated trench that is backfilled with a coarse stone aggregate allowing temporary storage of runoff in the void space of the material. Discharge of this stored runoff occurs through infiltration into the surrounding naturally permeable soil. An infiltration trench is ideal for linear applications, and is most effective when preceded by a pretreatment measure, such as a swale. Since these practices cannot be designed for stormwater quantity control, another measure must be included in the treatment train such as a stormwater pond.

For an infiltration trench, runoff is conveyed from the pretreatment practice into the trench where it is stored in the voids between pea gravel. Treatment occurs as water seeps through the soil. This practice requires verification of soil permeability and contributes to groundwater recharge. If used without proper pretreatment devices, the longevity of this practice may be less than 5 years. Therefore, infiltration trenches should not be constructed as an independent treatment mechanism. This practice is also not appropriate to serve hotspot landuse applications due to the propensity for groundwater contamination.

Infiltration Systems
Variations

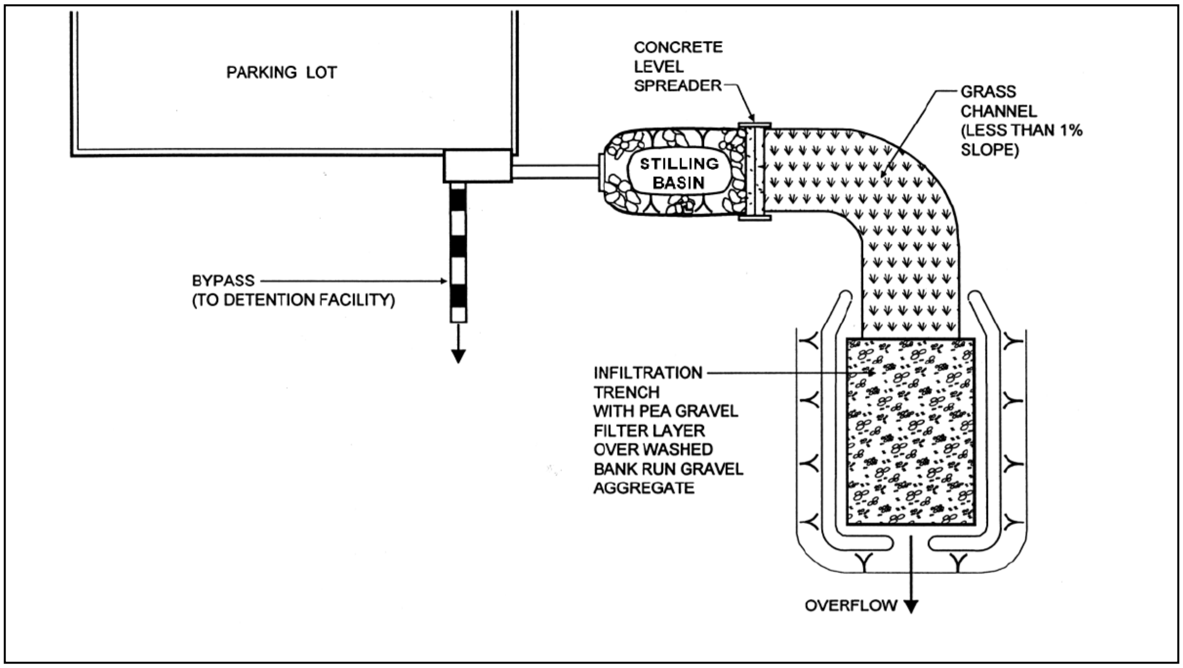


Figure PTP-05- 2 Infiltration Trench
Source: Maryland Stormwater Design Manual

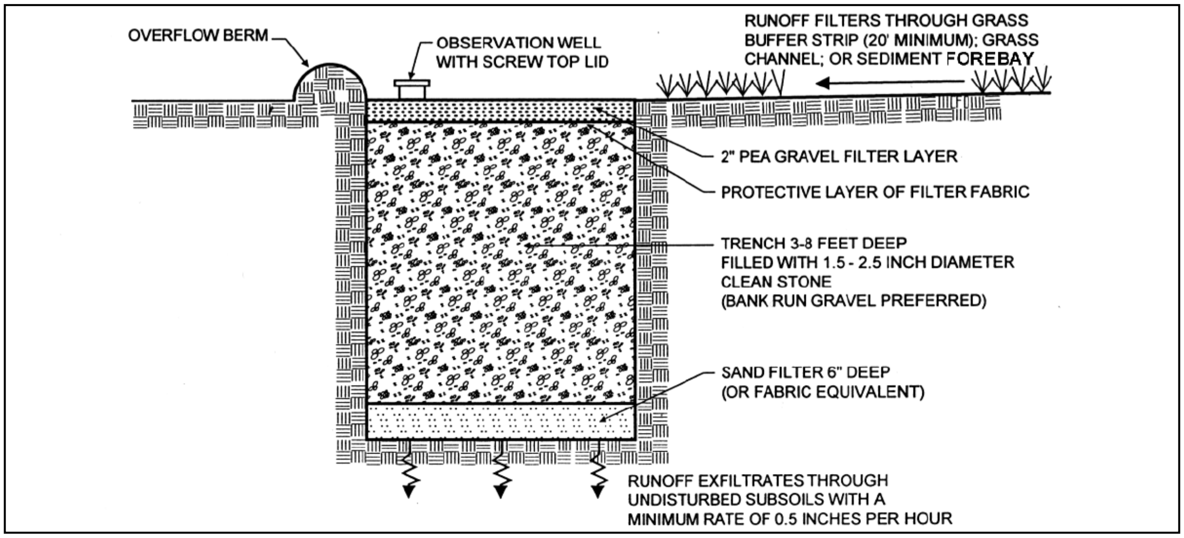


Figure PTP-05- 3 Infiltration Trench
Source: Maryland Stormwater Design Manual

Infiltration Systems Variations

Infiltration Basin

Figure PTP-05- 4 Infiltration Basin
Source, Stormwater Managers Resource Center

An infiltration basin is a natural or constructed impoundment that captures, temporarily stores and infiltrates the design volume of water over several days. In the case of a constructed basin, the impoundment is created by excavation or embankment. Like the infiltration trench, this practice is most effective when coupled with pretreatment practices such as grass filter strips or grass channels. This practice requires verification of soil permeability and has high maintenance requirements to prevent clogging. Although this practice does not utilize an outlet, a backup underdrain pipe is incorporated to relieve ponded water that has not infiltrated over long periods of time. Drawbacks to the use of infiltration basins are a high failure rate, and frequent maintenance to maintain soil permeability.

Infiltration Systems
Variations

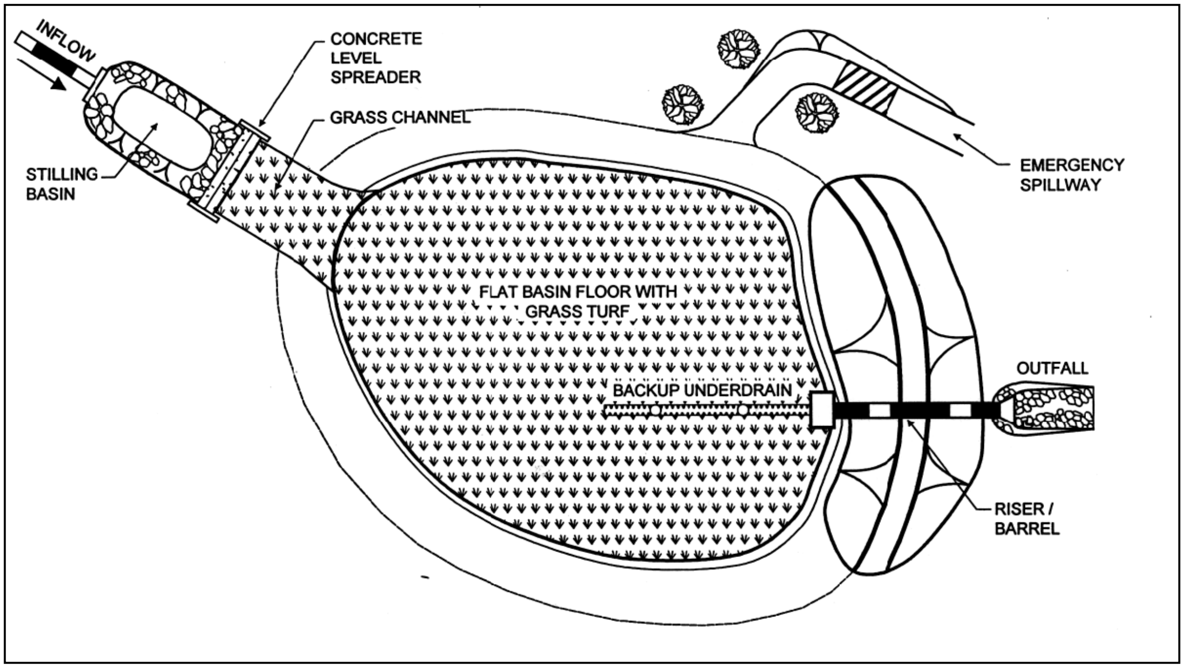


Figure PTP-05- 5 Infiltration Basin
Source: Maryland Stormwater Design Manual

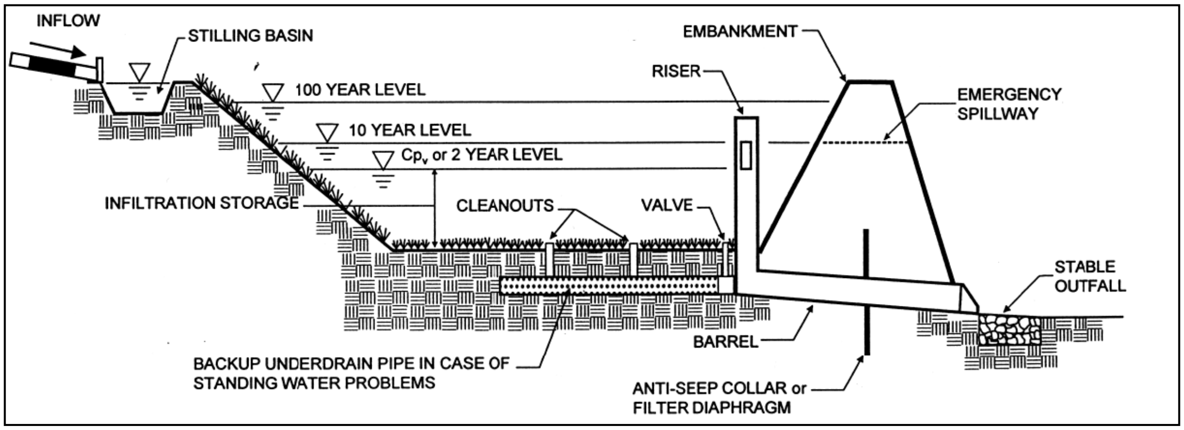


Figure PTP-05- 6 Infiltration Basin
Source: Maryland Stormwater Design Manual

Maintenance

When not properly maintained, infiltration systems have a high failure rate. Maintenance and inspections should be conducted regularly to ensure the long term functionality of the system. An observation well should be installed in trenches to determine how quickly it drains after a storm event and to observe sediment buildup.

As-Needed

- Replace pea gravel/topsoil and top surface filter fabric (when clogged).
- Mow grass filter strips and remove grass clippings.

Monthly

- Ensure that contributing area, practice and inlets are clear of debris.
- Ensure that the contributing area is stabilized.
- Remove sediment and oil/grease from pretreatment devices and outflow structures.
- Repair under cut and eroded areas at inflow and outflow structures.

Semi-Annual

- Check observation wells following 3 days of dry weather (failure to infiltrate within this time indicates clogging).
- Inspect pretreatment devices and diversion structures for sediment buildup and structural damage.
- Remove trees that start to grow in the vicinity of the infiltration system.

Annual

- Disc or aerate basin bottom. De-thatch basin bottom.

Every 5-Years

- Scrape basin bottom and remove sediment. Restore original cross-section and infiltration rate. Seed or sod to restore ground cover.
- If bypass capability is available, utilize to provide an extended dry period. This may allow the system to regain the infiltration rate in the short term.

Upon Failure

- Total rehabilitation of the system to maintain storage capacity.
- Excavate trench walls to expose clean soil.

Design Criteria

- The size of the drainage area typically dictates the type of infiltration system. Infiltration trenches have a maximum drainage area of 5 acres. Infiltration basins can work with drainage areas between 5 and 10 acres.
- Sloped areas immediately adjacent to the bioretention system should be no greater than 15%.
- Both types of infiltration systems provide a 90% TSS reduction.
- Pretreatment by other BMPs is required for infiltration systems.
- The sides of infiltration trenches should be lined with a filter fabric that prevents soil piping but has greater permeability that the underlying soil.
- Sheet flow should enter the infiltration system perpendicular to its main axis, and channel flow should enter parallel to the main axis of the direction of flow.
- Underlying soils must be suitable for infiltration.
- Infiltration systems should be constructed with a minimum of 4 feet distance between its base and the seasonally high water table or bedrock to allow for infiltration to occur.
- If a site overlies karst geology, additional geotechnical investigation must be undertaken. The potential for groundwater contamination and sinkhole collapse must be evaluated.
- A porosity value "n" ($n=V_v/V_t$) of 0.40 should be used in the design of stone reservoirs for infiltration systems.
- Design infiltration systems to fully de-water the entire WQ_v within 48 hours after the storm event.
- A conveyance system shall be included in the design of all infiltration systems in order to ensure that excess flow is discharged at non-erosive velocities.
- A dense and vigorous vegetative cover should be established over the contributing pervious drainage area before runoff can be accepted into an infiltration system. Infiltration systems should not be constructed until the contributing drainage area has been completely stabilized.
- Infiltration systems should not be used for a sediment control device during the construction phase.
- Infiltration systems cannot be covered by an impermeable surface.
- Direct access should be provided to all infiltration practices for maintenance and rehabilitation.

Design Components

- **Site** – Infiltration systems may fail due to improper siting, design, construction and/or maintenance.
  - Soils
    - To be suitable for infiltration, underlying soils should have an infiltration rate of 0.52 inches per hour or greater. Initially, soil infiltration rates can be determined from NRCS soil textural classification and subsequently confirmed by field geotechnical tests.
      - The recommended geotechnical testing is one test hole per 5000 square feet, with a minimum of two borings per facility (taken within the proposed limits of the facility).
    - Soils should have a clay content of less than 20% and a silt/clay content of less than 40%.
    - Infiltration systems should not be located in fill soils.
  - Setbacks
    - 50 feet (horizontally) from 20% or greater slopes
    - 100 feet (horizontally form any water supply well
    - 10 feet down gradient from dry wells
    - 25 feet down gradient from structures
- **Pretreatment** – to ensure the long term effectiveness of infiltration systems, preventative measures should be taken to minimize clogging. Pretreatment is generally most effective when multiple BMPs are placed in series.
  - Before entering an infiltration system, stormwater should first enter a pretreatment practice sized to treat a minimum of 25% of the WQ_v.
    - If the infiltration rate of the underlying soils in the infiltration system treatment area exceeds 2 inches per hour, a pre-treatment practice capable of treating a minimum of 50% of the WQ_v should be used.
    - If the infiltration rate of the underlying soils in the infiltration system treatment area exceeds 5 inches per hour a pre-treatment practice capable of treating 100% of the WQ_v should be used.
  - To prevent cogging and preserve the long term integrity of the infiltration system treatment area infiltration rate, the following pretreatment BMPs/techniques should be used (at least three per trench and two per basin):
    - Grass filter strips/Grass channel
    - Swale
    - Plunge pool
    - Forebay
    - Bottom sand layer
    - Upper sand layer (6" minimum) with filter fabric at the sand/gravel interface
    - Use of washed bank run gravel as aggregate

Design Components

- To protect groundwater from possible contamination, runoff from designated hotspot land uses or activities should not be infiltrated without proper pretreatment to remove hydrocarbons, trace metals, or toxicants.

- Exit velocities from pretreatment systems should be non-erosive and flows should be evenly distributed across the width of the practice.

Treatment

Design infiltration trenches to handle the WQ_v. Stormwater associated with the larger rainfall events should bypass the infiltration trench.

- Conveyance System
  - A flow splitter or diversion structure should be provided to divert the WQ_v to the infiltration system and the larger flows bypass unless the infiltration system is sized for water quality treatment.
  - When a flow splitter or diversion structure is not used the contributing drainage area for the infiltration system should be limited to the appropriate size given the variation, and an overflow should be provided within the system to pass part of the WQ_v to a stabilized watercourse or storm drain.
  - A natural overland flow path may be used for stormwater runoff exceeding the capacity of the infiltration system. However, it should be evaluated for concentrated flow that may cause erosion. If computed flow velocities do not exceed the non-erosive threshold, the overflow may be accommodated by natural topography.

- Infiltration Trenches – range from 2 to 10 feet deep and less than 25 feet wide, with a maximum of 3:1 (H:V) side slopes. The bottom of the infiltration trench should be flat, in order to enable even distribution and infiltration of stormwater. The longitudinal slope may vary from 0% to 1%, while the lateral slopes should be held at 0%. Fill the infiltration trench with a 6" layer of sand and coarse stone aggregate. Install filter fabric to separate the sand layer and coarse aggregate. Infiltration trenches are less conducive to site aesthetics.
  - Observation Well – install an anchored 6 inch diameter perforated PVC pipe with a lockable cap in infiltration trenches to monitor the water level and drawdown time. The pipe should be flush with the bottom of the trench.

- Infiltration Basins – range from 3 to 12 feet deep with a maximum of 3:1 (H:V) side slopes. The bottom of infiltration basin should be flat, in order to enable even distribution and infiltration of stormwater. The longitudinal slope may vary from 0% to 1%, while the lateral slopes should be held at 0%. Infiltration basins should be integrated into the site planning process and aesthetically designed as attractive green space planted with native vegetation.

- Outlet – it is recommended that infiltration systems include dewatering methods in the event of failure. This can be done with an underdrain system that accommodates drawdown. Infiltration basins that are designed for water quality should have a multistage outlet and emergency spillway

Design Procedures

Compute The following design procedures apply to infiltration trenches and infiltration basins.

Step 1 – Compute runoff control volumes.

- Calculate the Water Quality Volume (WQ_v).

Step 2 – Determine if the development site conditions are appropriate for the use of an infiltration trench.

- Type of development?
- Permeable subsoils?
- Low water table?
- Low sediment load?
- Karst area?

Step 3 – Confirm design criteria and applicability

- Consider any special site-specific design conditions/criteria (Additional Site-Specific Design Criteria and Issues).

Step 4 – Size flow diversion structure, if needed

- A flow regulator (or flow splitter diversion structure) should be supplied to divert the WQ_v to the infiltration trench.
- Size low flow orifice, weir, or other device to pass Q_{wq}.

Step 5 – Size infiltration system.

- The area of the trench can be determined from the following equation:

$$A = (WQ_v) / (nd + kT/12)$$

Where:

A = Surface Area

WQ_v = Water Quality Volume (or total volume to be infiltrated)

n = porosity

d = trench depth (feet)

k = percolation (inches/hour)

T= Fill Time (time for the practice to fill with water), in hours

- A porosity value n = 0.32 should be used. All infiltration systems should be designed to fully dewater the entire WQ_v within 48 hours after the rainfall event. A fill time T=2 hours can be used for most designs.

Design Procedures

- Infiltration Basins should be sized according to the following:
  - Determine the depth of the infiltration basin.

    $D = i \times t$

    Where:

    i = infiltration rate, (in/hr)

    t = maximum drawdown time, (hr)
  - Determine the Effective Infiltration Area of the infiltration basin.

    $A = WQ_v/D$

    Where:

    A = effective infiltration area at the bottom of the practice, (ft^2)

    WQv = Water Quality volume, (ft^3)

    D = maximum depth of practice, (ft)
  - Determine the dimensions of the infiltration basin.

    Design the infiltration basin with a 2:1 length to width ratio at the bottom.
  - Determine the volume of the infiltration basin.

    $V = [(A_1+A_2) / 2] \times D$

    Where:

    A_1 = Area at bottom of infiltration basin, (ft^2)

    A_2 = Area at top of infiltration basin, (ft^2)

    D = Depth of infiltration basin, (ft)

Step 6 –Determine pretreatment volume and design pretreatment measures.

- A pretreatment practice should be sized to treat a minimum of 25% of the WQ_v.
  - If the infiltration rate of the underlying soils exceeds 2 inches per hour a pre-treatment practice capable of treating a minimum of 50% of the WQv should be used.
  - If the infiltration rate of the underlying soils exceeds 5 inches per hour a pre-treatment practice capable of treating 100% of the WQv should be used.

Step 7 – Design underdrains, emergency spillway.

- An underdrain system with a drawdown valve should be provided to dewater an infiltration basin for maintenance.
- Infiltration basins that are designed for water quality should have a multistage outlet and emergency spillway.

STEP 8 – Prepare vegetation and landscaping plan

- A landscaping plan for infiltration system should be prepared to indicate how the infiltration system will be stabilized and established with vegetation. The appropriate grass species and wetland plants should be chosen based on the site location, soil type, and hydric conditions.

Design Procedures

STEP 9 – Complete the Design Summary Table.

Design Parameter	**Required Size**	**Actual Size**
Infiltration System Type		
WQ_v		
Pretreatment Type		
Pretreatment Size, V		
Infiltration Rate		

Example Design

Proposed development of an undeveloped site into an office building and associated parking.

<u>Base Data</u> Total Drainage area = 5.0 ac Site Area = 3.54 ac Soils Type "C" ***Pre-Development*** Impervious Area = 0 ac; or I = 0% Meadow (CN = 71) ***Post-Development*** Impervious Area = 1.72 ac; or I = 1.72/3.54 = 49% Open Space, Fair (CN = 79) Paved parking lots, roofs, driveways, etc. (CN =98)	**<u>Hydrologic Data</u>** Pre Post CN 71 89 **WQ_v Depth** = 1.1 in **<u>Precipitation</u>** I_{WQ} 2.45 in/hr 2yr, 24hr 3.54 in 25yr, 24hr 5.88 in 100yr, 24hr 7.43 in

Example Design

This example focuses on the design of an infiltration basin to meet the water quality control requirements. This example design focuses on water quality volume (WQ_v) control only. However, similar design procedures would be used to design for the other water quantity control requirements.

Problem: Design an infiltration basin for this site. Infiltration basins provide 90% TSS reduction. Therefore, not other water quality treatment BMPs will be needed for this site. The total drainage area to the pond is 5 acres, which includes offsite drainage.

Step 1 – Compute runoff control volumes

Total Site WQ_v:

$$WQ_v = [(P\ R_v)(A)]/12$$

Where:

P = 1.1 inches

$R_v = 0.05 + 0.009(I)$

I = 49

$R_v = 0.05 + 0.009(49) = 0.491$

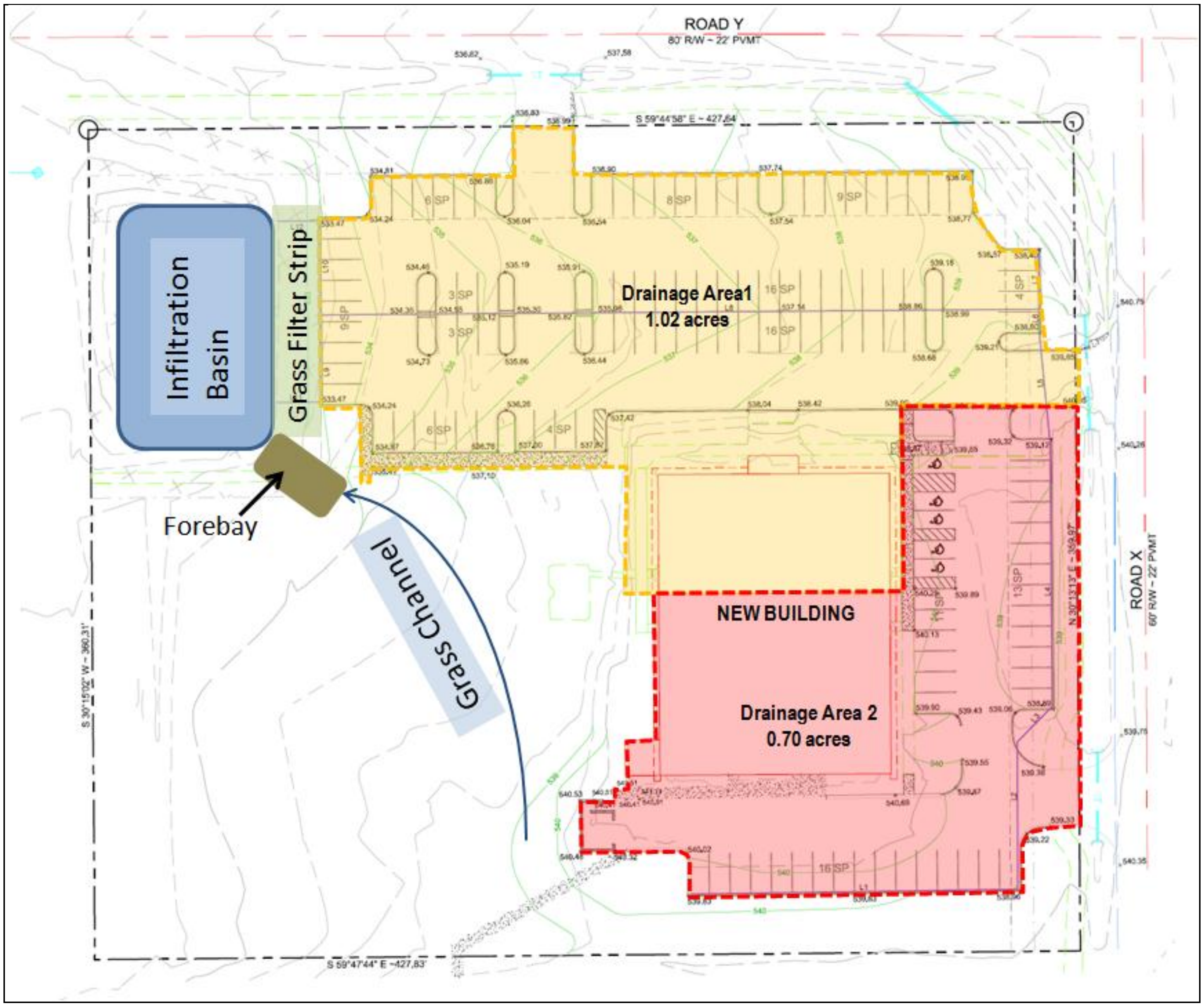
A = 1.72 acres

WQ_v = (1.1in x 0.491 x 1.72ac)/12 = 0.077 acre-ft = 3373 ft^3

Step 2 – Determine if the development site conditions are appropriate for the use of an infiltration trench.

- The landuse for the development is not considered a hotspot landuse.
- High levels of pesticides, sediment, and other pollutant loads are not anticipated.
- Based upon soil borings, the high water table level is 15 feet below the ground surface, and the clay content is 12%. The silt/clay content is 38%.
- Geotechnical reports found no active karst features on the site.
- There are no water supply or dry wells within 100 ft.

Example Design



Step 3 – Confirm design criteria and applicability

- Underlying soils on this site have an infiltration rate of 0.6 in/hr.
- A sediment forebay will be included and designed for 25% of WQ_v
- A grass lined channel will convey runoff from drainage area 2 to the forebay and infiltration basin. A flow diversion will be incorporated into the channel design to bypass larger storm events. The infiltration basin is only being designed for stormwater quality.
- A grass filter strip will provide pretreatment for drainage area 1.

Step 4 – Size flow diversion structure, if needed

Since the infiltration basin will only treat the water quality volume, a diversion structure will be placed in the grass channel to bypass the flows in excess of WQ_v to the water quality treatment BMP.

Example Design

Step 5 – Size infiltration basin.

- The infiltration basin will have 3H:1 side slopes.
- Determine the depth of the infiltration basin.

  $D = i \times t$

  Where:

  i = infiltration rate, (in/hr)

  t = maximum drawdown time, (hr)

  D = (0.6 in/hr) x (48 hr) = 28.8 in = 2.4 ft

- Determine the Effective Infiltration Area of the infiltration basin.

  $A = WQ_v/D$

  Where:

  A = effective infiltration area at the bottom of the practice, (ft^2)

  WQ_v = Water Quality volume, (ft^3)

  D = maximum depth of practice, (ft)

  A = (3373 ft^3) / (2.4 ft) = 1406 ft^2

- Determine the dimensions of the infiltration basin.

  Design the infiltration basin with a 2:1 length to width ratio at the bottom. The basin will be 54 ft long and 27 ft wide. The top and bottom dimensions are generally the same.

- Determine the volume of the infiltration basin.

  $V = [(A_1+A_2) / 2] \times D$

  Where:

  A_1 = Area at bottom of infiltration basin, (ft^2)

  A_2 = Area at top of infiltration basin, (ft^2)

  D = Depth of infiltration basin, (ft)

- V = [(1458 ft^2 + 1458 ft^2) / 2] x 2.4 ft = **3499.2 ft^3 > 3373** ft^3✓

Example Design

Step 6 –Determine pretreatment volume and design pretreatment measures.

- A sediment forebay will be added at the end of the grass channel prior to the WQ_v entering the Infiltration Basin.
- Determine WQ_v conveyed by grass channel.

$$WQ_v = [(P\ R_v)(A)]/12$$

Where:

P = 1.1 inches

$R_v = 0.05 + 0.009(I)$

I = 49

$R_v = 0.05 + 0.009(49) = 0.491$

A = 0.70 acres for DA2

WQ_v = (1.1in x 0.491 x 0.70ac)/12 = 0.032 acre-ft = 1394 ft^3

- Verify percentage of WQ_v.

$\%WQ_v$ pretreated = (1394 ft^3 / 3373 ft^3) x 100 = 41.3% > 25% ✓

- Determine Area of the forebay. Set the forebay depth at 3 ft

A = V/D

Where:

A = Area of forebay, (ft^2)

V = Pretreatment Volume, (ft^3)

D = Depth of forebay (ft^3)

A = (1394ft^3) / (3 ft) = 465 ft^2

- Determine the dimensions of the forebay.

Design the forebay with a 2:1 length to width ratio at the bottom. The forebay will be 31 ft long 15 ft wide, and 3ft deep, which is 1395 ft^3 in storage provided.

Step 7 – Design underdrains, emergency spillway.

- An underdrain system with a 6-inch perforated PVC pipe surrounded by a 12-inch thick gravel layer should be used. The 6-in perforated pipe should be connected to a drawdown valve.
- This infiltration basin is designed to treat the water quality volume only with higher flows bypassing the basin. An emergency spillway is not required.

STEP 8 – Prepare vegetation and landscaping plan

- The infiltration basin will have a grass lining.

Example Design

Step 9 –Complete the Design Summary Table.

Design Parameter	**Required Size**	**Actual Size**
Infiltration System Type	Basin	
WQ_v	3373 ft3	
Pretreatment Type	Pretreatment 1: grass filter strip: no design Pretreatment 2: forebay (25% WQv): 1394 ft^3	Pretreatment 1: no design Pretreatment 2: 1395 ft^3
Pretreatment Size, V	3373 ft^3	3499.2 ft^3
Infiltration Rate	0.6 in/hr	0.6 in/hr