G. BMPs to Achieve the Required Reductions in Pollutant Loading

BMP #1: Comly Avenue Dry Extended Detention Basin

The Borough established a 7,722 square foot dry extended detention basin along Comly Avenue. The drainage area to the basin is 15.87 acres within the Neshaminy Creek Drainage Area. The drainage area is composed of 4.49 acres of impervious area and 11.38 acres of pervious area. With a BMP effectiveness of 60% the dry extended detention basin has the following calculated pollutant load reductions.

Sediment: 6,763.59 lbs/year
Phosphorus: 7.92 lbs/year
Nitrogen: 67.86 lbs/year

BMP #2: Pine Street Infiltration Trench

The Borough established a 385 linear foot infiltration trench along South Pine Street. The drainage area to the basin is 11.56 acres within the Mill Creek Drainage area. The drainage area is composed of 4.86 acres of impervious area and 6.70 acres of pervious area. With a BMP effectiveness of 85% the infiltration trench has the following calculated pollutant load reductions.

Sediment: 9,101.61 lbs/year
Phosphorus: 14.20 lbs/year
Nitrogen: 75.27 lbs/year

BMP #3: Highland Avenue Infiltration Trench

The Borough is considering the construction of an infiltration trench along West Highland Avenue. The trench will span 135 feet with a width and depth of 8 feet and 6 feet respectively. The drainage area to the trench is 4.59 acres within the Neshaminy Creek Drainage Area. The drainage area is composed of 1.19 acres of impervious area and 3.40 acres of pervious area. The infiltration volume of the trench is 2,158 cubic feet, less than the volume of runoff required to meet the volume control guidelines in the simplified method. For this reason, the Chesapeake Bay Panel Adjustor Curve method was used to calculate the following reductions.

Sediment: 1,758 lbs/year
Phosphorus: 3 lbs/year
Nitrogen: 44 lbs/year

BMP #4: Station Avenue Infiltration Trench

The Borough is considering the construction of an infiltration trench along Station Avenue. The trench will span 100 feet with a width and depth of 8 feet and 6 feet respectively. The drainage area to the trench is 12.54 acres within the Neshaminy Creek Drainage Area. The drainage area is composed of 2.83 acres of impervious area and 9.71 acres of pervious area. The infiltration volume of the trench is 1,598 cubic feet, less than the volume of runoff required to meet the volume control guidelines in the simplified method. For this reason, the Chesapeake Bay Panel Adjustor Curve method was used to calculate the following reductions.

Sediment: 1,867 lbs/year
Phosphorus: 3 lbs/year
Nitrogen: 45 lbs/year

Neshaminy Creek Calculated Reductions

Neshaminy Creek Watershed			
BMP	TSS Reduction (lbs/year)	TP Reduction (lbs/year)	TN Reduction (lbs/year)
Comly Avenue (BMP #1)	6,763.59	7.92	67.86
Highland Avenue (BMP #3)	1,758	3	44
Station Avenue (BMP #4)	1,867	3	45
TOTALS	10,388.59	13.92	156.86
10% REDUCTION GOAL	10,378	10	120

Mill Creek Calculated Reductions

Mill Creek Watershed			
BMP	TSS Reduction (lbs/year)	TP Reduction (lbs/year)	TN Reduction (lbs/year)
Pine Street (BMP #2)	9,101.61	14.20	75.27
TOTALS	9,101.61	14.20	75.27
10% REDUCTION GOAL	7,326	7	69

REMINGTON & VERNICK ENGINEERS	
PROJECT:	Comly Avenue Extended Detention Basin
SUBJECT:	BMP CREDIT CALCULATIONS
SHEET:	1 OF 1 DATE: 8/27/2024
BY:	JMB
CHK'D:	

Drainage Area Name	Area (SF)	Impervious Area (SF)	Pervious Area (SF)
Comly Avenue	691,218.07	195,605.73	495,612.34

Soil Type
B

Drainage Area Name	Area (Ac.)	Impervious Area (Ac.)	Pervious Area (Ac.)
Comly Avenue	15.87	4.49	11.38

Drainge Area Name	Drainage Area (Ac.)	Impervious Area (Ac.)	Pervious Area (Ac.)	Impervious Sediment Loading Rate (lbs/acre)	Pervious Sediment Loading Rate (lbs/acre)	Pollutant Load TSS (lbs/year)
Comly Avenue	15.87	4.49	11.38	1,839.00	264.96	11,272.64

Drainage Area Name	Drainage Area (Ac.)	Impervious Area (Ac.)	Pervious Area (Ac.)	Impervious Nitrogen Loading (lbs/acre/year)	Pervious Nitrogen Loading (lbs/acre/year)	Pollutant Load TN (lbs/year)
Comly Avenue	15.87	4.49	11.38	23.06	20.72	339.30

Drainage Area Name	Drainage Area (Ac.)	Impervious Area (Ac.)	Pervious Area (Ac.)	Impervious Phosphorus Loading (lbs/acre/year)	Pervious Phosphorus Loading (lbs/acre/year)	Pollutant Load TP (lbs/year)
Comly Avenue	15.87	4.49	11.38	2.28	0.84	19.80

BMP Name	BMP Reduction	Sediment Reduction (lbs/year)
Comly Avenue	60.00%	**6,763.59**

BMP Name	BMP Reduction	Nitrogen Reduction (lbs/year)
Comly Avenue	20.00%	**67.86**

BMP Name	BMP Reduction	Phosphorus Reduction (lbs/year)
Comly Avenue	40.00%	**7.92**

REMINGTON & VERNICK ENGINEERS	
PROJECT:	S. Pine Street Infiltration Trenches (between 805 Pine and Manor)
SUBJECT:	BMP CREDIT CALCULATIONS
SHEET:	1 OF 1	DATE: 8/27/2024
BY:	AVS
CHK'D:	IK

Drainage Area Name	Area (SF)	Impervious Area (SF)	Pervious Area (SF)
S. Pine St Trench DA	503,547.00	211,564.39	291,982.61

Soil Type
B & C

Drainage Area Name	Area (Ac.)	Impervious Area (Ac.)	Pervious Area (Ac.)
S. Pine St Trench DA	11.56	4.86	6.70

Drainge Area Name	Drainage Area (Ac.)	Impervious Area (Ac.)	Pervious Area (Ac.)	Impervious Sediment Loading Rate (lbs/acre)	Pervious Sediment Loading Rate (lbs/acre)	Pollutant Load TSS (lbs/year)
Pine Street	11.56	4.86	6.70	1,839.00	264.96	10,707.77

Drainage Area Name	Drainage Area (Ac.	Impervious Area (Ac.)	Pervious Area (Ac.)	Impervious Nitrogen Loading (lbs/acre/year)	Pervious Nitrogen Loading (lbs/acre/year)	Pollutant Load TN (lbs/year)
Pine Street	11.56	4.86	6.70	23.06	20.72	250.89

Drainage Area Name	Drainage Area (Ac.	Impervious Area (Ac.)	Pervious Area (Ac.)	Impervious Phosphorus Loading (lbs/acre/year)	Pervious Phosphorus Loading (lbs/acre/year)	Pollutant Load TP (lbs/year)
Pine Street	11.56	4.86	6.70	2.28	0.84	16.70

BMP Name	BMP Reduction*	Sediment Reduction (lbs/year)
Pine Street	85.00%	**9,101.61**

BMP Name	BMP Reduction	Nitrogen Reduction (lbs/year)
Pine Street	30.00%	**75.27**

BMP Name	BMP Reduction	Phosphorus Reduction (lbs/year)
Pine Street	85.00%	**14.20**

PROJECT:	Highland Avenue Infiltration Trench
SUBJECT:	BMP CREDIT CALCULATIONS
SHEET:	1 OF 1 DATE: 8/27/2024
BY:	JMB
CHK'D:	

Drainage Area Name	Area (SF)	Impervious Area (SF)	Pervious Area (SF)
Highland Avenue	200,000.00	51,701.00	148,299.00

Soil Type
B

Drainage Area Name	Area (Ac.)	Impervious Area (Ac.)	Pervious Area (Ac.)
Highland Avenue	4.59	1.19	3.40

Drainge Area Name	Drainage Area (Ac.)	Impervious Area (Ac.)	Pervious Area (Ac.)	Impervious Sediment Loading Rate (lbs/acre)	Pervious Sediment Loading Rate (lbs/acre)	Pollutant Load TSS (lbs/year)
Highland Avenue	4.59	1.19	3.40	1,839.00	264.96	3,084.74

Drainage Area Name	Drainage Area (Ac.)	Impervious Area (Ac.)	Pervious Area (Ac.)	Impervious Nitrogen Loading (lbs/acre/year)	Pervious Nitrogen Loading (lbs/acre/year)	Pollutant Load TN (lbs/year)
Highland Avenue	4.59	1.19	3.40	23.06	20.72	97.91

Drainage Area Name	Drainage Area (Ac.)	Impervious Area (Ac.)	Pervious Area (Ac.)	Impervious Phosphorus Loading (lbs/acre/year)	Pervious Phosphorus Loading (lbs/acre/year)	Pollutant Load TP (lbs/year)
Highland Avenue	4.59	1.19	3.40	2.28	0.84	5.57

Infiltration Volume (CF)	Runoff Volume (CF)	Runoff Depth Captured per Impervious Acre (in)	Sediment Removal Percentage (From Expert Panel Curve)	Nitrogen Removal Percentage (From Expert Panel Curve)	Sediment Removal Percentage (From Expert Panel Curve)
2,157.84	20,554.00	0.50	57%	45%	54%

BMP Name	BMP Reduction	Sediment Reduction (lbs/year)
Highland Avenue	57.00%	**1,758**

BMP Name	BMP Reduction	Nitrogen Reduction (lbs/year)
Highland Avenue	45.00%	**44**

BMP Name	BMP Reduction	Phosphorus Reduction (lbs/year)
Highland Avenue	54.00%	**3**

PROJECT:	505 Station Avenue Infiltration Trench
SUBJECT:	BMP CREDIT CALCULATIONS
SHEET:	1 OF 1 DATE: 8/27/2024
BY:	JMB
CHK'D:	

REMINGTON & VERNICK ENGINEERS

Drainage Area Name	Area (SF)	Impervious Area (SF)	Pervious Area (SF)
Station Avenue	546,394.00	123,324.00	423,070.00

Soil Type
B

Drainage Area Name	Area (Ac.)	Impervious Area (Ac.)	Pervious Area (Ac.)
Station Avenue	12.54	2.83	9.71

Drainge Area Name	Drainage Area (Ac.)	Impervious Area (Ac.)	Pervious Area (Ac.)	Impervious Sediment Loading Rate (lbs/acre)	Pervious Sediment Loading Rate (lbs/acre)	Pollutant Load TSS (lbs/year)
Station Avenue	12.54	2.83	9.71	1,839.00	264.96	7,779.83

Drainage Area Name	Drainage Area (Ac.)	Impervious Area (Ac.)	Pervious Area (Ac.)	Impervious Nitrogen Loading (lbs/acre/year)	Pervious Nitrogen Loading (lbs/acre/year)	Pollutant Load TN (lbs/year)
Station Avenue	12.54	2.83	9.71	23.06	20.72	266.53

Drainage Area Name	Drainage Area (Ac.)	Impervious Area (Ac.)	Pervious Area (Ac.)	Impervious Phosphorus Loading (lbs/acre/year)	Pervious Phosphorus Loading (lbs/acre/year)	Pollutant Load TP (lbs/year)
Station Avenue	12.54	2.83	9.71	2.28	0.84	14.61

Infiltration Volume (CF)	Runoff Volume (CF)	Runoff Depth Captured per Impervious Acre (in)	Sediment Removal Percentage (From Expert Panel Curve)	Nitrogen Removal Percentage (From Expert Panel Curve)	Phosphorus Removal Percentage (From Expert Panel Curve)
1,598.40	20,554.00	0.16	24%	17%	21%

BMP Name	BMP Reduction	Sediment Reduction (lbs/year)
Station Avenue	24.00%	**1,867**

BMP Name	BMP Reduction	Nitrogen Reduction (lbs/year)
Station Avenue	17.00%	**45**

BMP Name	BMP Reduction	Phosphorus Reduction (lbs/year)
Station Avenue	21.00%	**3**

BMP 6.4.4: Infiltration Trench

An Infiltration Trench is a "leaky" pipe in a stone filled trench with a level bottom. An Infiltration Trench may be used as part of a larger storm sewer system, such as a relatively flat section of storm sewer, or it may serve as a portion of a stormwater system for a small area, such as a portion of a roof or a single catch basin. In all cases, an Infiltration Trench should be designed with a positive overflow.

Key Design Elements

- Continuously perforated pipe set at a minimum slope in a stone filled, level-bottomed trench
- Limited in width (3 to 8 feet) and depth of stone (6 feet max. recommended)
- Trench is wrapped in nonwoven geotextile (top, sides, and bottom)
- Placed on uncompacted soils
- Minimum cover over pipe is as per manufacturer.
- A minimum of 6" of topsoil is placed over trench and vegetated
- Positive Overflow always provided

Deed restrictions recommended
Not for use in hot spot areas without pretreatment

Potential Applications

Residential: Yes
Commercial: Yes
Ultra Urban: Yes
Industrial: Yes
Retrofit: Yes
Highway/Road: Yes

Stormwater Functions

Volume Reduction: Medium
Recharge: High
Peak Rate Control: Medium
Water Quality: High

Water Quality Functions

TSS: 85%
TP: 85%
NO3: 30%

Other Considerations

- **Protocol 1. Site Evaluation and Soil Infiltration Testing** and **Protocol 2. Infiltration Systems Guidelines** should be followed, see Appendix C

Description

An Infiltration Trench is a linear stormwater BMP consisting of a continuously perforated pipe at a minimum slope in a stone-filled trench (Figure 6.4-1). Usually an Infiltration Trench is part of a **conveyance system** and is designed so that large storm events are conveyed through the pipe with some runoff volume reduction. During small storm events, volume reduction may be significant and there may be little or no discharge. All Infiltration Trenches are designed with a **positive overflow** (Figure 6.4-2).

An Infiltration Trench differs from an Infiltration Bed in that it may be constructed without heavy equipment entering the trench. It is also intended to convey some portion of runoff in many storm events.

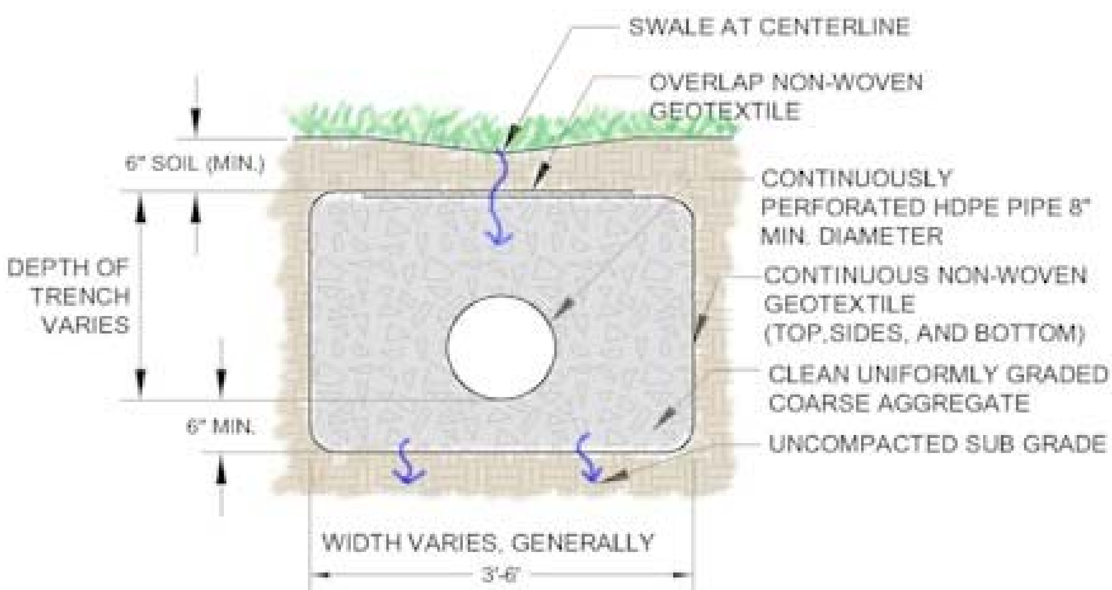


Figure 6.4-1

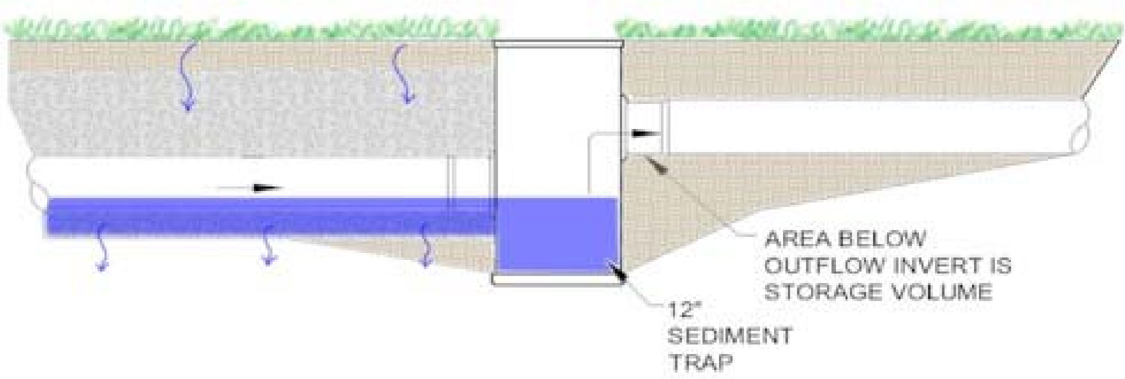


Figure 6.4-2

All Infiltration Trenches should be designed in accordance with Appendix C. Although the width and depth can vary, it is recommended that Infiltration Trenches be limited in depth to not more than six (6) feet of stone. This is due to both construction issues and Loading Rate issues (as described in the Guidelines for Infiltration Systems). The designer should consider the appropriate depth.

Variations

Infiltration Trenches generally have a vegetated (grassed) or gravel surface. Infiltration Trenches also may be located alongside or adjacent to roadways or impervious paved areas with proper design. The subsurface drainage direction should be to the downhill side (away from subbase of pavement), or located lower than the impervious subbase layer. Proper measures should be taken to prevent water infiltrating into the subbase of impervious pavement.

Infiltration Trenches may also be located down a mild slope by "stepping" the sections between control structures as shown in Figure 6.4-3. A level or nearly level bottom is recommended for even distribution.

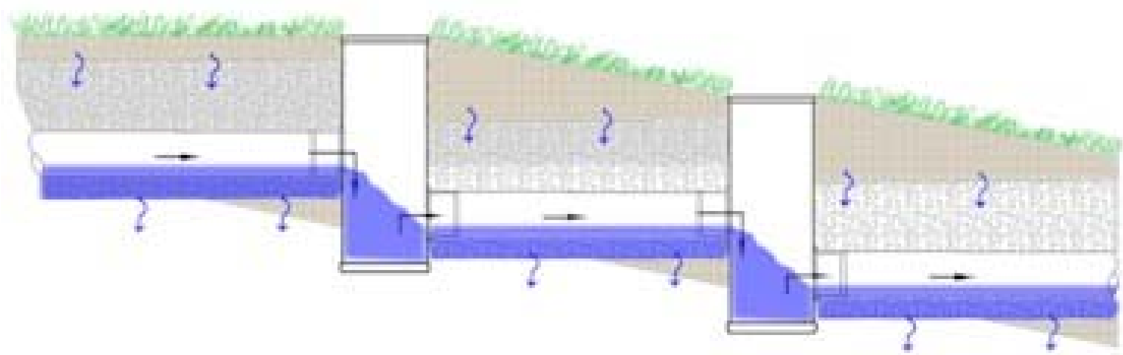
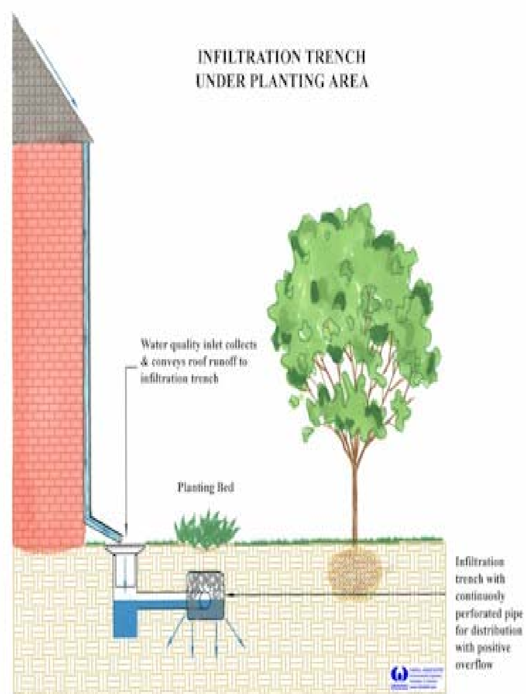


Figure 6.4-3

Applications

- **Connection of Roof Leaders**

Roof leaders may be connected to Infiltration Trenches. Roof runoff generally has lower sediment levels and often is ideally suited for discharge through an Infiltration Trench. A cleanout with sediment sump should be provided between the building and Infiltration Trench.



- **Connection of Inlets**

Catch Basins, inlets and area drains may be connected to Infiltration Trenches, however sediment and debris removal should be addressed. Structures should include a sediment trap area below the invert of the pipe for solids and debris. In areas of high traffic or areas where excessive sediment, litter, and other similar materials may be generated, a water quality insert or other pretreatment device is needed.

- **In Combination with Vegetative Filters**

An Infiltration Trench may be preceded by or used in combination with a Vegetative Filter, Grassed Swale, or other vegetative element used to reduce sediment levels from areas such as high traffic roadways. Design should ensure proper functioning of vegetative system.

- **Other Applications**

Other applications of Infiltration Trenches may be determined by the design professional as appropriate.

Design Considerations

1. Soil Investigation and Percolation Testing is required (see Appendix C, Protocol 2)
2. Guidelines for Infiltration Systems should be met (i.e., depth to water table, setbacks, Loading Rates, etc. See Appendix C, Protocol 1)
3. Water Quality Inlet or Catch Basin with Sump (see Section 6.6.4) recommended for all surface inlets, designed to avoid standing water for periods greater than the criteria in Chapter 3.
4. A continuously perforated pipe should extend the length of the trench and have a positive flow connection designed to allow high flows to be conveyed through the Infiltration Trench.
5. The slope of the Infiltration Trench bottom should be level or with a slope no greater than 1%. The Trench may be constructed as a series of "steps" if necessary. A level bottom assures even water distribution and infiltration.
6. Cleanouts or inlets should be installed at both ends of the Infiltration Trench and at appropriate intervals to allow access to the perforated pipe.
7. The discharge or overflow from the Infiltration Trench should be properly designed for anticipated flows.

Detailed Stormwater Functions

Infiltration Area

The Infiltration Area is the bottom area of the Trench*, defined as:

Length of Trench x Width of Trench = Infiltration Area (Bottom Area)

This is the area to be considered when evaluating the Loading Rate to the Infiltration Trench.
* Some credit can be taken for the side area that is frequently inundated as appropriate.

Volume Reduction Calculations

Volume = Depth* (ft) x Area (sf) x Void Space

*Depth is the depth of the water surface during a storm event, depending on the drainage area and conveyance to the bed.

Infiltration Volume = Bed Bottom Area (sf) x Infiltration design rate (in/hr) x Infiltration period* (hr) x (1/12)

*Infiltration Period is the time when bed is receiving runoff and capable of infiltration. Not to exceed 72 hours.

The void ratio in stone is approximately 40% for AASTO No 3. If the conveyance pipe is within the Storage Volume area, the volume of the pipe may also be included. All Infiltration Trenches should be designed to infiltrate or empty within 72 hours.

Peak Rate Mitigation Calculations
See Chapter 8 for Peak Rate Mitigation methodology which addresses link between volume reduction and peak rate control.

Water Quality Improvement
See Chapter 8 for Water Quality Improvement methodology which addresses pollutant removal effectiveness of this BMP.

Construction Sequence

1. Protect Infiltration Trench area from compaction prior to installation.
2. If possible, install Infiltration Trench during later phases of site construction to prevent sedimentation and/or damage from construction activity. After installation, prevent sediment laden water from entering inlets and pipes.
3. Install and maintain proper Erosion and Sediment Control Measures during construction.
4. Excavate Infiltration Trench bottom to a uniform, level uncompacted subgrade free from rocks and debris. Do NOT compact subgrade.
5. Place nonwoven geotextile along bottom and sides of trench*. Nonwoven geotextile rolls should overlap by a minimum of 16 inches within the trench. Fold back and secure excess geotextile during stone placement.
6. Install upstream and downstream Control Structures, cleanouts, etc.
7. Place uniformly graded, clean-washed aggregate in 8-inch lifts, lightly compacting between lifts.
8. Install Continuously Perforated Pipe as indicated on plans. Backfill with uniformly graded, clean-washed aggregate in 8-inch lifts, lightly compacting between lifts.
9. Fold and secure nonwoven geotextile over Infiltration Trench, with minimum overlap of 16-inches.
10. Place 6-inch lift of approved Topsoil over Infiltration Trench, as indicated on plans.
11. Seed and stabilize topsoil.
12. Do not remove Inlet Protection or other Erosion and Sediment Control measures until site is fully stabilized.
13. Any sediment that enters inlets during construction is to be removed within 24 hours.

(from left to right) Installation of Inlets and Control Structure; Non-woven Geotextile is folded over Infiltration Trench; Stabilized Site

(Clockwise from top left) Infiltration Trench is on downhill side of roadway; Infiltration Trench is installed; Infiltration Trench is paved with standard pavement material

Maintenance and Inspection Issues

- Catch Basins and Inlets should be inspected and cleaned at least 2 times per year.
- The vegetation along the surface of the Infiltration Trench should be maintained in good condition, and any bare spots revegetated as soon as possible.
- Vehicles should not be parked or driven on a vegetated Infiltration Trench, and care should be taken to avoid excessive compaction by mowers.

Cost Issues

The construction cost of infiltration trenches can vary greatly depending on the configuration, location, site-specific conditions, etc. Typical construction costs in 2003 dollars range from $4 - $9 per cubic foot of storage provided (SWRPC, 1991; Brown and Schueler, 1997). Annual maintenance costs have been reported to be approximately 5 to 10 percent of the capital costs (Schueler, 1987).

Specifications

The following specifications are provided for information purposes only. These specifications include information on acceptable materials for typical applications, but are by no means exclusive or limiting. The designer is responsible for developing detailed specifications for individual design projects in accordance with the project conditions.

1. Stone for infiltration trenches shall be 2-inch to 1-inch uniformly graded coarse aggregate, with a wash loss of no more than 0.5%, AASHTO size number 3 per AASHTO Specifications, Part I, 19th Ed., 1998, or later and shall have voids 40% as measured by ASTM-C29.

2. Non-Woven Geotextile shall consist of needled nonwoven polypropylene fibers and meet the following properties:

a. Grab Tensile Strength (ASTM-D4632)
b. Mullen Burst Strength (ASTM-D3786)
c. Flow Rate (ASTM-D4491)
d. UV Resistance after 500 hrs (ASTM-D4355) 70%
e. Heat-set or heat-calendared fabrics are not permitted
Acceptable types include Mirafi 140N, Amoco 4547, and Geotex 451.

3. Pipe shall be continuously perforated, smooth interior, with a minimum inside diameter of 8-inches. High-density polyethylene (HDPE) pipe shall meet AASHTO M252, Type S or AASHTO M294, Type S.

References

Brown and Schueler, *Stormwater Management Fact Sheet: Infiltration Trench.* 1997.

Schueler, T., 1987. *Controlling urban runoff: a practical manual for planning and designing urban BMPs*, Metropolitan Washington Council of Governments, Washington, DC

SWRPC, The Use of of Best Management Practices (BMPs) in Urban Watersheds, US Environmental Protection Agency,1991.

BMP 6.6.3: Dry Extended Detention Basin

A dry extended detention basin is an earthen structure constructed either by impoundment of a natural depression or excavation of existing soil, that provides temporary storage of runoff and functions hydraulically to attenuate stormwater runoff peaks. The dry detention basin, as constructed in countless locations since the mid-1970's and representing the primary BMP measure until now, has served to control the peak rate of runoff, although some water quality benefit accrued by settlement of the larger particulate fraction of suspended solids. This extended version is intended to enhance this mechanism in order to maximize water quality benefits.

The basin outlet structure must be designed to detain runoff from the stormwater quality design storm for extended periods. Some volume reduction is also achieved in a dry basin through initial saturation of the soil mantle (even when compacted) and some evaporation takes place during detention. The net volume reduction for design storms is minimal, especially if the precedent soil moisture is assumed as in other volume reduction BMPs.

Key Design Elements

- Evaluation of the device chosen should be balanced with cost
- Hydraulic capacity controls effectiveness
- Ideal in combination with other BMPs
- Regular maintenance is necessary including periodic sediment removal

Potential Applications

Residential: Yes
Commercial: Yes
Ultra Urban: Yes
Industrial: Yes
Retrofit: Yes
Highway/Road: Yes

Stormwater Functions

Volume Reduction: Low
Recharge: None
Peak Rate Control: High
Water Quality: Low

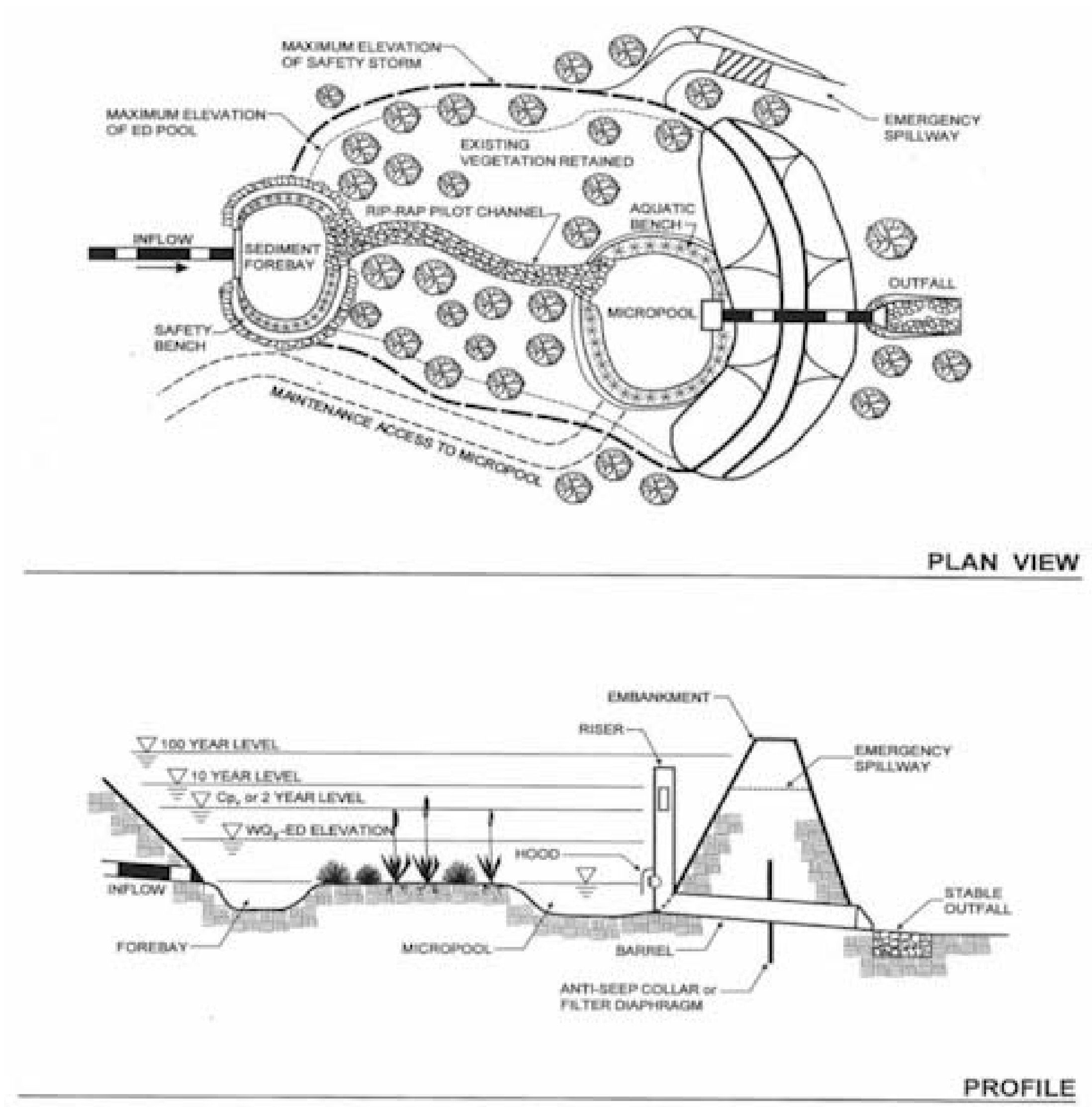
Water Quality Functions

TSS: 60%
TP: 40%
NO3: 20%

Description

Dry extended detention basins are surface stormwater structures which provide for the temporary storage of stormwater runoff to prevent downstream flooding impacts. Water quality benefits may be achieved with extended detention of the runoff volume from the water quality design storm.

- The primary purpose of the detention basin is the attenuation of stormwater runoff peaks.
    - Detention basins should be designed to control runoff peak flow rates of discharge for the 1 year through 100 year events.
    - Inflow and discharge hydrographs should be calculated for each selected design storm. Hydrographs should be based on the 24-hour rainfall event.



- Basins should be designed to provide water quality treatment storage to capture the computed runoff volume of the water quality design storm.
    - Detention basins should have a sediment forebay or equivalent upstream pretreatment. The forebay should consist of a separate cell that is offline (so as to not resuspend sediment, formed by an acceptable barrier and will need periodic sediment removal.

- A micropool storage area should be designed where feasible for the extended detention of runoff volume from the water quality design storm.
- Flow paths from inflow points to outlets should be maximized.

Variations

Sub-surface extended detention

Extended detention storage can also be provided in a variety of sub-surface structural elements, such as underground vaults, tanks, large pipes or other structural media placed in an aggregate filled bed in the soil mantle. All such systems are designed to provide runoff peak rate mitigation as their primary function, but some pollutant removal may be included. Regular maintenance is needed, since the structure must be drained within a design period and cleaned to assure detention capacity for subsequent rainfall events. These facilities are usually intended for space-limited applications and are not intended to provide significant water quality treatment.

- Underground vaults are typically box shaped underground stormwater storage facilities constructed of reinforced concrete, while tanks are usually constructed of large diameter metal or plastic pipe. They may be situated within a building, but the use of internal space is frequently not cost beneficial.
  - Storage design and routing methods are the same as for surface detention basins.
  - Underground vaults and tanks do not provide water quality treatment and should be used in combination with a pretreatment BMP.

- Underground detention beds can be constructed by excavating a subsurface area and filling with uniformly graded aggregate for support of overlying land uses.
  - This approach may be used where space is limited but subsurface infiltration is not feasible due to high water table conditions or shallow soil mantle.
  - As with detention vaults and tanks, this facility provides minimal water quality treatment and should be used in combination with a pretreatment BMP.
  - It is recommended that underground detention facilities not be lined to allow for even minimal infiltration, except in the case where toxic contamination is possible.

Applications

- **Low Density Residential Development**
- **Industrial Development**
- **Commercial Development**
- **Urban Areas**

Design Considerations

1. **Storage Volume, Depth and Duration**

   a. Extended detention basins should be designed to mitigate runoff peak flow .rates.b. An emergency outlet or spillway which is capable of conveying the spillway design flood (SDF) should be included in the design. The SDF is usually equal to the 100-year design flood
   c. Extended detention basins should be designed to treat the runoff volume produced by the water quality design storm.

d. Extended Detention Basins are designed to achieve a specified detention time. Details on the detention time are outlined in Chapter 3.
e. The lowest elevation within an extended dry detention basin should be at least 2 feet above the seasonal high water table. If high water table conditions are anticipated, then the design of a wet pond, constructed wetland or bioretention facility should be considered.

2. **Dry Extended Detention Basin Location**

   a. Extended detention basins should be located down gradient of disturbed or developed areas on the site. The basin should collect as much site runoff as possible, especially from the site's impervious surfaces (roads, parking, buildings, etc.).
   b. Extended detention basins should not be constructed on steep slopes, nor should slopes be significantly altered or modified to reduce the steepness of the existing slope, for the purpose of installing a basin.
   c. Extended detention basins should not worsen the runoff potential of the existing site by removal of trees for the purpose of installing a basin.
   d. Extended detention basins should not be constructed in areas with high quality and/or well draining soils, which are adequate for the installation of BMPs capable of achieving stormwater infiltration.
   e. Extended detention basins should not be constructed within jurisdictional waters, including wetlands.

3. **Basin Sizing and Configuration**

   a. Basins should be shaped to maximize the length of stormwater flow pathways and minimize short-circuited inlet-outlet systems. Basins should have a minimum width of 10 feet. A minimum length-to-width ratio of 2:1 is recommended to maximize sedimentation.
   b. Irregularly shaped basins are encouraged and appear more natural.
   c. If site conditions inhibit construction of a long, narrow basin, baffles constructed from earthen berms or other materials can be incorporated into the pond design to "lengthen" the stormwater flow path. Care should be taken to ensure the design storage capacity is provided after baffle installation.
   d. Low flow channels, if required, should always be vegetated with a maximum slope of 3 percent to encourage sedimentation. Alternatively, other BMPs may be considered such as wet ponds, constructed wetlands or bioretention.

4. **Embankments**

   a. Embankments should be less than 15 feet in height and should have side slopes no steeper than 3:1 (H:V).
   b. The basin should have a minimum freeboard of 1 foot above the SDF elevation.

5. **Inlet Structures**

   a. Inlet structures to basin should not be submerged at the normal pool depth.
   b. Erosion protection measures should be utilized to stabilize inflow structures and channels.

6. **Outlet Design**

   a. In order to meet designs storm requirements, dry extended detention basins should have a multistage outlet structure. Three elements are typically included in this design:
      1. A low-flow outlet that controls the extended detention and functions to slowly release the water quality design storm.
      2. A primary outlet that functions to attenuate the peak of larger design storms.
      3. An emergency overflow outlet/spillway
   b. The primary outlet structure should incorporate weirs, orifices, pipes or a combination of these to control runoff peak rates for required design storms. Water quality storage should be provided below the invert of the primary outlet. When routing basins, the low-flow outlet should be included in the depth-discharge relationship.
   c. Energy dissipaters are to be placed at the end of the primary outlet to prevent erosion. If the basin discharges to a channel with dry weather flow, care should be taken to minimize tree clearing along the downstream channel and to reestablish a forested riparian zone between the outlet and natural channel. Where feasible, a multiple orifice outlet system is preferred to a single pipe.
   d. The orifice should typically be no smaller than 2.5 inches in diameter. However, the orifice diameter may be reduced to 1 inch if adequate protection from clogging is provided.
   e. The hydraulic design of all outlet structures should consider any tailwater effects of downstream waterways.
   f. The primary and low flow outlet should be protected from clogging by an external trash rack.

7. **Sediment Forebay**

   a. Forebays should be incorporated into the extended detention design. The forebay storage volume is included for the water quality volume requirement.
   b. Forebays should be vegetated to improve filtering of runoff, to reduce runoff velocity, and to stabilize soils against erosion. Forebays are typically constructed as shallow marsh areas and should adhere to the following design criteria:
      1. It is recommended that forebays have a minimum length of 10 feet.
      2. Storage should be provided to trap the anticipated sediment volume produced over a period of 2 years.
      3. Forebays should be protected from the erosive force of the inflow to prevent resuspension of previously collected sediment during large storms (typically constructed offline).

8. **Vegetation and Soils Protection**
    a. Care should be taken to prevent compaction of in situ soils in the bottom of the extended detention basin in order to promote healthy plant growth and to encourage infiltration. If soils compaction is not prevented during construction, soils should be restored as discussed in BMP 6.7.3 – Soils Amendment & Restoration.
    b. It is recommended that basin bottoms be vegetated in a diverse native planting mix to reduce maintenance needs, promote natural landscapes, and increase infiltration potential. Vegetation may include trees, woody shrubs and meadow/wetland herbaceous plants.
    c. Woody vegetation should not be planted on the embankments or within 25 feet of the emergency overflow spillway.
    d. Meadow grasses or other deeply rooted herbaceous vegetation is recommended on the interior slope of embankments.
    e. Fertilizers and pesticides should not be used.

9. **Special Design Considerations**
    a. Ponds that have embankments higher than 15 feet, have a drainage of more than 100 acres or will impound more that 50 acre-feet of runoff during the high-water condition will be regulated as dams by PADEP. The designer shall consult Pennsylvania Chapter 105 to determine which provisions may apply to the specific project in question.
    b. Extended detention ponds should not be utilized as recreation areas due to health and safety issues. Design features that discourage access are recommended.

Detailed Stormwater Functions

Peak Rate Mitigation

Inflow and discharge hydrographs should be calculated and routed for each design storm. Hydrographs should be based on a 24-hour rainfall event.

Water Quality Improvement

Water quality mitigation is partially achieved by retaining the runoff volume from the water quality design storm for a minimum prescribed period as specified in Chapter 3. Sediment forebays should be incorporated into the design to improve sediment removal. The storage volume of the forebay may be included in the calculated storage of the water quality design volume.

Construction Sequence

1. Install all temporary erosion and sedimentation controls.
    a. The area immediately adjacent to the basin must be stabilized in accordance with the PADEP's *Erosion and Sediment Pollution Control Program Manual* (2000 or latest edition) prior to basin construction.
2. Prepare site for excavation and/or embankment construction.
    a. All existing vegetation should remain if feasible and should only be removed if necessary for construction.
    b. Care should be taken to prevent compaction of the basin bottom.
    c. If excavation is required, clear the area to be excavated of all vegetation. Remove all tree roots, rocks, and boulders only in excavation area
3. Excavate bottom of basin to desired elevation (if necessary).
4. Install surrounding embankments and inlet and outlet control structures.
5. Grade subsoil in bottom of basin, taking care to prevent compaction. Compact surrounding embankment areas and around inlet and outlet structures.
6. Apply and grade planting soil.
7. Apply geo-textiles and other erosion-control measures.
8. Seed, plant and mulch according to Planting Plan
9. Install any anti-grazing measures, if necessary.

Maintenance Issues

Maintenance is necessary to ensure proper functionality of the extended detention basin and should take place on a quarterly basis. A basin maintenance plan should be developed which includes the following measures:

- All basin structures expected to receive and/or trap debris and sediment should be inspected for clogging and excessive debris and sediment accumulation at least four times per year, as well as after every storm greater than 1 inch.
    - Structures include basin bottoms, trash racks, outlets structures, riprap or gabion structures, and inlets.
- Sediment removal should be conducted when the basin is completely dry. Sediment should be disposed of properly and once sediment is removed, disturbed areas need to be immediately stabilized and revegetated.
- Mowing and/or trimming of vegetation should be performed as necessary to sustain the system, but all detritus should be removed from the basin.
    - Vegetated areas should be inspected annually for erosion.
    - Vegetated areas should be inspected annually for unwanted growth of exotic/invasive species.
    - Vegetative cover should be maintained at a minimum of 95 percent. If vegetative cover has been reduced by 10%, vegetation should be reestablished.

Cost Issues

The construction costs associated with dry extended detention basins can range considerably. One recent study evaluated the cost of all pond systems (Brown and Schueler, 1997). Before adjusting for inflation from 1997, the cost of dry extended detention ponds can be estimated with the equation:

$$C = 12.4V^{0.760}$$

Where:

C = Construction, Design and Permitting Cost
V = Volume needed to control the 10-year storm (cubic feet)
Using this equation, a typical construction costs (1997) are:
$ 41,600 for a 1 acre-foot pond
$ 239,000 for a 10 acre-foot pond
$ 1,380,000 for a 100 acre-foot pond

Dry extended detention basins utilizing highly structural design features (rip-rap for erosion control, etc.) are more costly than naturalized basins. There is an installation cost savings associated with a natural vegetated slope treatment which is magnified by the additional environmental benefits provided. Long-term maintenance costs are reduced when more naturalized approaches are utilized due to the ability of native vegetation to adapt to local weather conditions and a reduced need for maintenance, such as mowing and fertilization.

Normal maintenance costs can be expected to range form 3 to 5 percent of the construction costs on an annual basis.

These costs don't include the cost or value of the property.

Specifications

The following specifications are provided for information purposes only. These specifications include information on acceptable materials for typical applications, but are by no means exclusive or limiting. The designer is responsible for developing detailed specifications for individual design projects in accordance with the project conditions.

1. **Site Preparation**
   a. All excavation areas, embankments, and where structures are to be installed shall be cleared and grubbed as necessary, but trees and existing vegetation should be retained and incorporated within the dry detention basin area where possible.
   b. Where feasible, trees and other native vegetation should be protected. A minimum 10-foot radius around the inlet and outlet structures can be cleared to allow construction.
   c. Any cleared material should be used as mulch for erosion control or soil stabilization.
   d. Care should be taken to prevent compaction of the bottom of the reservoir. If compaction should occur, soils should be restored and amended.

2. **Earth Fill Material & Placement**
   a. The fill material should be taken from approved designated excavation areas. It should be free of roots, stumps, wood, rubbish, stones greater than 6 inches, or other

objectionable materials. Materials on the outer surface of the embankment must have the capability to support vegetation.

b. Areas where fill is to be placed should be scarified prior to placement. Fill materials for the embankment should be placed in maximum 8-inch lifts. The principal spillway should be installed concurrently with fill placement and not excavated into the embankment.

c. The movement of the hauling and spreading equipment over the site should be controlled. For the embankment, each lift should be compacted to 95% of the standard proctor. Fill material should contain sufficient moisture so that if formed in to a ball it will not crumble, yet not be so wet that water can be squeezed out.

3. **Embankment Core**
   a. The core should be parallel to the centerline of the embankment as shown on the plans. The top width of the core should be at least four feet. The height should extend up to at least the 10-year water elevation or as shown on the plans. The side slopes should be 1 to 1 or flatter. The core should be compacted with construction equipment, rollers, or hand tampers to assure maximum density and minimum permeability. The core should be placed concurrently with the outer shell of the embankment.
4. **Structure Backfill**
   a. Backfill adjacent to pipes and structures should be of the type and quality conforming to that specified for the adjoining fill material. The fill should be placed in horizontal layers not to exceed four inches in thickness and compacted by hand tampers or other manually directed compaction equipment. The material should fill completely all spaces under and adjacent to the pipe. At no time during the backfilling operation should driven equipment be allowed to operate closer than four feet to any part of the structure. Equipment should not be driven over any part of a concrete structure or pipe, unless there is a compacted fill of 24 inches or greater over the structure or pipe.
   b. Structure backfill may be flowable fill meeting the requirements of the PADOT Standard Specifications for Construction. Material should be placed so that a minimum of 6 inches of flowable fill should be under (bedding), over and, on the sides of the pipe. It only needs to extend up to the spring line for rigid conduits. Average slump of the fill material should be 7 inches to assure flowability of the mixture. Adequate measures should be taken (sand bags, etc.) to prevent floating the pipe. When using flowable fill all metal pipe should be bituminous coated. Adjoining soil fill should be placed in horizontal layers not to exceed 4 inches in thickness and compacted by hand tampers or other manually directed compaction equipment.
   c. Refer to Chapter 220 0f PennDot Pub. 408 (2000).

5. **Rock Riprap**
   a. Rock riprap should meet the requirements of Pennsylvania Department of Transportation Standard Specifications.

6. **Stabilization**
   a. All borrow areas should be graded to provide proper drainage and left in a sightly condition. All exposed surfaces of the embankment, spillway, spoil and borrow areas, and berms should be stabilized by seeding, planting and mulching.

7. **Operation and Maintenance**
   a. An operation and maintenance plan in accordance with Local or State Regulations will be prepared for all basins. As a minimum, a dam and inspection checklist should be included as part of the operation and maintenance plan and performed at least annually.

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