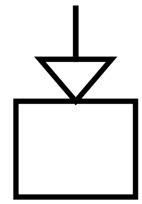
New Albany, Indiana
Stormwater Best Management Practices (BMPs)
Stormwater Pollution Treatment Practices (STPs)

STP-01

Activity: Infiltration Systems



IS

PLANNING CONSIDERATIONS:

Design Life:
N/A

Acreage Needed:
Minimal

Estimated Unit Cost:
N/A

Monthly Maintenance:
Negligible

Target Pollutants

Significant ♦ Partial ◈ Low or Unknown ◇

Sediment ♦ Heavy Metals ♦ Nutrients ♦ Oxygen Demanding Substances ♦ Toxic Materials ♦
Oil& Grease ♦ Bacteria & Viruses ♦ Floatable Materials ♦ Construction Waste ◇

Description

A majority of runoff from small storms is infiltrated into the ground rather than discharged to a surface water body through a family of systems. These acceptable systems include vaults, exfiltration trenches, dry wells and porous modular pavement grids. Along with these acceptable systems swales and filter strips can also achieve a limited degree of infiltration. SPP-06: Flow Diversion, Drains and Swales and STP-05: Biofilter Swales and Strips should also be reviewed.

Suitable Applications

- Where conditions are suitable, infiltration systems may be the preferred choice because stormwater is placed into the ground thereby reducing excess runoff and providing groundwater recharge (volume control).
- Need to achieve high level of particulate and dissolved pollutant removal.
- Suitable site soils and geologic conditions; low potential for long-term erosion in the catchments.
- Multiple management objectives (e.g., ground water recharge or runoff volume control).
- Retention basins are generally not preferred in this area (shallow bedrock conditions), thus they are not discussed in detail in this BMP. Small scale infiltration devices have a higher success potential if given local soil conditions promote such devices.
- Porous pavements are generally not preferred in this area due to durability problems. Porous modular paving grids are preferred in areas with light use traffic conditions

Activity: Infiltration Systems	STP-01

Suitable Applications (Continued)

- May not be suitable near drinking water wells, foundations, septic tanks, drain fields, or unstable slopes.

- Acceptable infiltration systems include:

  - Infiltration or exfiltration trench which is an underground chamber filled with rock, also called a rock well (Figure STP-01-1).
  - Dry well or "vertical" infiltration trench (Figure STP-01-2).
  - Concrete grid and modular pavement which are lattice grid structures with grassed, pervious material placed in the openings (Figure STP-01-3).

- Infiltration basins may be used if it can be demonstrated that soil, geology, and groundwater conditions are suitable and there is a permanent mechanism to perform maintenance (including funding requirements).

- Recommended minimum preconstruction infiltration rates have ranged from 0.25 to 4 inches per hour with a safety factor of 2.0 in the wet season water table condition. Drawdown should occur within 72 hours using the safety factor of 2.0.

- Not less than 3 feet separation from seasonal high ground water 4 to 8 feet in distance if soils are very coarse) and not less than 4 feet in separation from bedrock.

- Avoid steep (10%) slopes or other geologic conditions that would be made unstable by the infiltrating water.

- The degree of treatment achieved by infiltration is a function of the amount of stormwater that is captured and infiltrated over time (e.g. 80-95% of average annual volume).

- For basins and trenches, pretreat the stormwater to remove the floatables and settleable solids, particularly when placing these systems in finer soils. This can be accomplished using swales, filter inlets, or baffle boxes.

Design and Sizing Considerations

- These systems should be designed by a licensed professional civil engineer.

- Size the volume to capture 85-95% of the average annual runoff value.

- Pretreatment will be required in fine soils.

- Emergency overflow or bypasses for larger storms are required on all infiltration systems.

- Observation wells are required in trenches every 50 to 100 feet.

Design and Sizing Considerations (Continued)

- Infiltration Systems should be designed to capture no less than the "maximized storm runoff capture volume" of 80-95% TSS removal and drain over a 12-hour period. The maximized storm runoff capture volume can be calculated by:

$$V = (a \cdot C) \cdot P_6$$

where:

V = maximized capture volume determined using either the event capture ratio or the volume capture ratio as its basis, watershed in.;
a = regression constant from least-square analysis;
Event capture ratio: at least 1.109 for 12-hour drain time,
Volume capture ratio: at least 1.312 for 12-hour drain time (for approximately 85^{th} percentile runoff event – 82-88%).
C = watershed runoff coefficient.
P_6 = mean storm precipitation volume, watershed in.

To determine if the captured runoff volume can be percolated into the ground through the sides of the system, consider the percolation flow rate:

$$U = k \cdot I$$

where:

U = flow velocity ft/s;
k = saturated hydraulic conductivity ft/s; and
I = hydraulic gradient (wet season).

- Assume I = 1.0 if the bottom of the system is above the high seasonal groundwater level.

Maintenance

- Inspect the facility at least annually and after extreme events. If there is still water in the pond or trench 72 hours after a storm it is time to clean the facility.
- The primary objective of maintenance/inspection activities is to ensure that the infiltration facility continues to perform as designed and to substantially lengthen the required time interval between major rehabilitation.
- Frequent (at least twice per year) cleaning of porous pavement grids.
- Till infiltration surfaces when needed to restore the infiltration capacity and to control weed growth. Tilling should generally be accomplished using rotary tillers.
- Remove debris and sediment annually to avoid excessive concentrations of pollutants and loss of infiltrative capacity.

Sediment Removal

- A primary function of STPs is to collect sediments. The sediment accumulation rate is dependant on a number of factors including watershed size, facility sizing, construction upstream, industrial or commercial activities upstream, etc. The sediment contents should be identified before it is removed and disposed.

Activity: Infiltration Systems	STP-01

Maintenance (Continued)

- Some sediment may contain contaminants of which the Indiana Department of Environmental Management (IDEM) requires special disposal procedures. If there is any uncertainty about what the sediment contains or it is known to contain contaminants, then IDEM should be consulted and their disposal recommendations followed. The IDEM – Division of Water Pollution Control should be contacted. Generally, special attention or sampling should be given to sediments accumulated in facilities serving industrial, manufacturing or heavy commercial sites, fueling centers or automotive maintenance areas, large parking areas, or other areas where pollutants (other than “clean” soil) are suspected to accumulate and be conveyed via storm runoff.

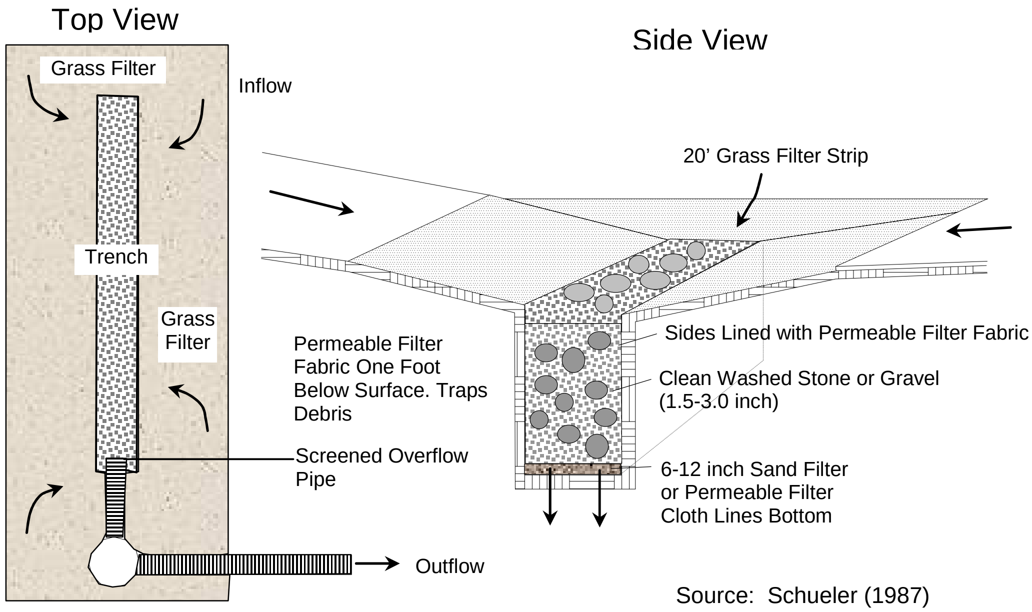
- Some sediment collected may be innocuous (free of pollutants other than “clean” soil) and can be used as fill material, cover or land spreading. It is important that this material not be placed in a way that will promote or allow resuspension in storm runoff. The sediment should not be placed within the high water level area of the STP, other BMP, creek, waterway, buffer, runoff conveyance device, or other infrastructure. Some demolition or sanitary landfill operators will allow the sediment to be disposed at their facility for use as cover. This generally requires that the sediment be tested to ensure that it is innocuous.

Inspection Checklist

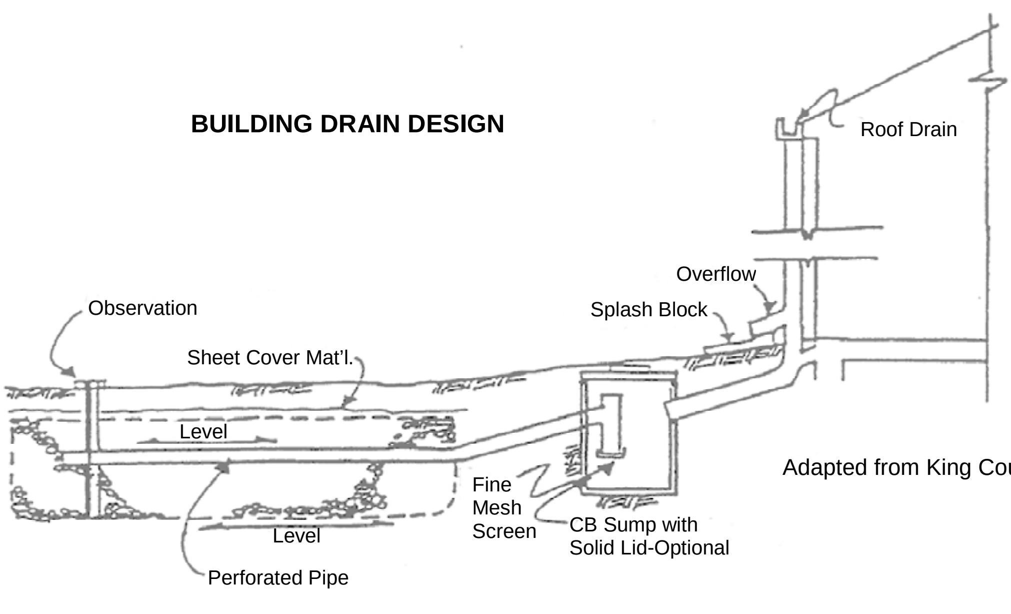
- ❑ Use of lighter equipment is used to minimize compaction.
  Note: If this prohibition is not feasible in particular situations, do not excavate the facility to final grade until after all construction is complete upstream.
- ❑ Infiltration surface is protected during construction.
- ❑ System is free of clogging, accumulation of metals, and ground water contamination during construction.
- ❑ System is not located on fill sites or steep slopes.

No significant risk for a hazardous chemical spill.

Activity: Infiltration Systems

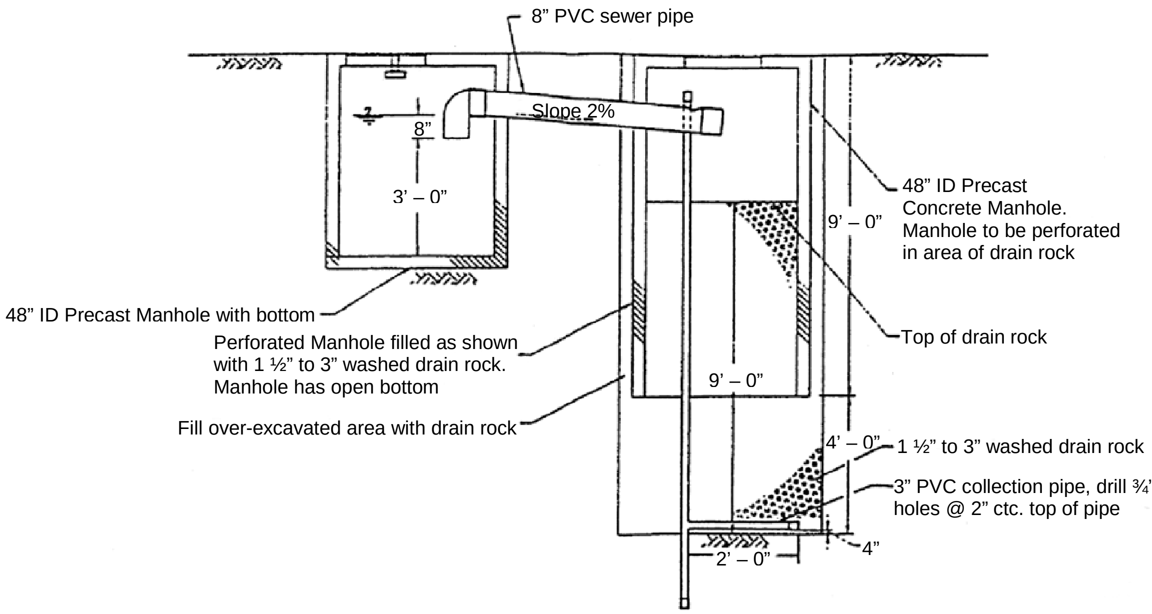


Source: Schueler (1987)

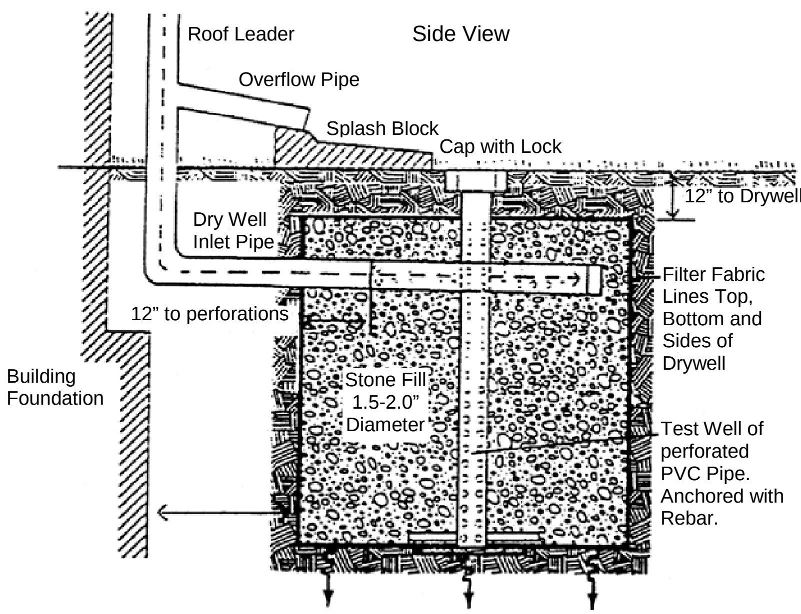


Adapted from King County

Figure STP-01-1
Infiltration Trench

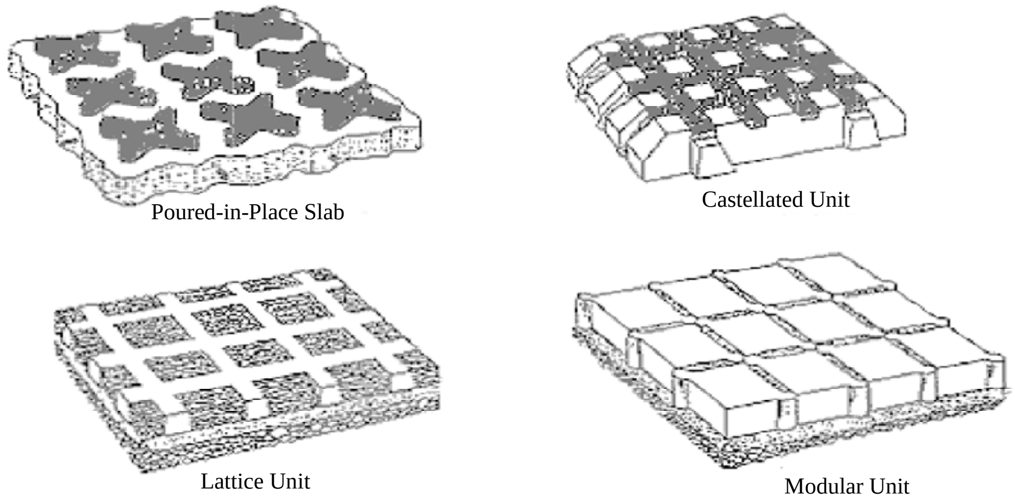


WITH PRETREATMENT



WITHOUT PRETREATMENT

Figure STP-01-2
Dry Well Configurations



Source: State of Florida

Figure STP -01-3
Grid and Modular Pavement Types

New Albany, Indiana
Stormwater Best Management Practices (BMPs)
Stormwater Pollution treatment Practices (STPs)

STP-02

Activity: Wet Detention Ponds

W

WDP

PLANNING CONSIDERATIONS:

Design Life:
Permanent

Acreage Needed:
Significant

Estimated Unit Cost:
Avg: $.50 per CF of Storage

Monthly Maintenance:
3% of Capital Costs

Target Pollutants

Significant ♦ Partial ◈ Low or Unknown ◊

Sediment ♦ Heavy Metals ♦ Nutrients ◈ Oxygen Demanding Substances ◈ Toxic Materials ♦
Oil& Grease ◈ Bacteria & Viruses ◈ Floatable Materials ♦ Construction Waste ◈

Description

A wet detention pond has a permanent water pool to treat incoming stormwater. A wet detention pond can be enhanced with a pretreatment sediment forebay, baffle box, or stormwater quality inlet. This management practice will provide a significant reduction in sediment, heavy metals, toxic materials, and floatable materials as well as partial reductions in the impacts due to nutrients, oxygen demanding substances, oil and grease, and bacteria and viruses.

Suitable Applications

- Need to achieve high level of particulate and some dissolved contaminant removal.
- Ideal for large, regional tributary areas.
- Multiple benefits of passive recreation (e.g., multi-purpose facilities, bird watching, wildlife habitat). See figure STP-02-9.

Design and Sizing Considerations

- These systems should be designed by a licensed professional civil engineer.
- Wet detention ponds should be designed as “off-line” structures to limit environmental impacts downstream when maintaining the facility. On-line facilities may be acceptable depending on specific site characteristics.

The major features of a wet detention pond are shown in Figures STP-02-1 and STP-02-2. It is essentially a small lake with rooted wetland vegetation along the perimeter. The permanent pool of water (below the weir crest, culvert, or inlet) provides a quiescent volume for continued settling of particulate contaminants and uptake of dissolved contaminants by aquatic plants between storms.

Activity: Wet Detention Ponds

Design and Sizing Considerations (Continued)

- The wetland vegetation is present to improve the removal of dissolved contaminants and to reduce the formation of algal mats. The "live" pool provides flood control, erosion control, and additional treatment benefits.
- The permanent pool should have a hydraulic residence time of at least 2 to 4 weeks.
- The maximum depth of the permanent pool is generally less than 12 feet, although greater depths are possible with artificial mixing or aerators at maximum depth. The objective is to avoid thermal stratification that could result in odor problems associated with anaerobic conditions. Gentle artificial mixing may be needed in small ponds because they are effectively sheltered from the wind.
- In industrial applications ground water or treated process water will have to be pumped into the facility to maintain the water level. The permanent pond could be allowed to dry during maintenance periods.
- The outlet of the facility should be restricted so as to detain a treatment design storm in a "live" pool on top of the permanent pool for 24 to 60 hours. The effect of restricting the outflow is to reduce the overflow rate during the storm reducing downstream erosion, flood control and slightly increasing the capture of settleable solids.
- Water quality detention ponds should be sized to collect the first flush of stormwater runoff. For this area, the first flush is generally the first 0.5 to 1.1 inches of runoff over the tributary area.
- About 10 to 25% of the surface area determined in the above procedure should be devoted to the forebay. The forebay can be distinguished from the remainder of the pond by one of several means: a lateral sill with rooted wetland vegetation, two ponds in series, differential pool depth, rock-filled gabions or retaining wall, or a horizontal rock filter placed laterally across the pond. A baffle box or water quality inlet(s) can be used in lieu of a forebay.

<u>Sizing the "Live" Pool</u>
The following two methods should be used to calculate the "live" pool volume. The most conservative (largest volume) should be selected.

- The recommended performance goal is at least 85 to 95% capture of the annual average runoff volume. The live pool may be calculated using long-term hourly hydrologic data and runoff capture simulation curves that consider a runoff coefficient for land use to determine a unit basin storage volume (v).

$$V_L = (A_T * v)/12$$

where: V_L = pond volume (acre-feet);
A_T = Total Tributary Area (acres); and
v = unit basin storage volume – taken from Figure STP-02-3 (0.5 to 1.1 inches)

Design and Sizing Conditions (Continued)

- Alternatively, the live pool portion of the wet pond can also be designed to capture the "maximized storm runoff capture volume," and drain over a 24-60 hour period. The maximized storm runoff capture volume can be calculated by:

$$V_L = (a \cdot C) \cdot P_6$$

where:

V_L = maximized capture volume determined using either the event capture ratio or the volume capture ratio as its basis, watershed in.;
a = regression constant from least-square analysis;
Event capture ratio: 1.299 for 24-hour drain time,
Volume capture ratio: 1.582 for 24-hour drain time (for approximately 85th percentile runoff event – 82-88%).
C = runoff coefficient
P_6 = mean storm precipitation volume, watershed in.

- Using this technique, the desired removal efficiency and land use characteristics can be applied to local hydrologic data to determine the optimal live pool volume. Note that A_T and the runoff coefficient selected can be modified to consider Directly Connected Impervious Area (DCIA) if the data is available.

- This live pool volume will add to the overall volume and will benefit the downstream waterways by reducing erosive velocities, providing flood control and an incremental increase in treatment.

Sizing the Permanent Pool

- Two methods are available for the sizing of the permanent pool portion of the wet detention ponds. One proposed on the removal of phosphorus (Florida, 1988; Maryland, 1986) It provides a detention time of 14 days based on the wettest month to allow sufficient time for the uptake of dissolved phosphorus by algae and the settling of fine solids where the particulate phosphorus tends to be concentrated. The following two methods should be used to calculate the permanent pool volume. The most conservative (largest volume) should be selected.

  Size the permanent pool portion of the wet pond using the wettest 14-day period using the following formula:

$$V_p = (CA_TR)/12$$

Where: V_p = permanent pool volume (acre-ft)
C = contributing area weighted average runoff coefficient
A_T = Total Tributary Area (acres)
R = 14 day wet season rainfall (inches)
= 2.04 inches

The second method predicts the removal of particulate contaminants only (USEPA, 1986). It relates the removal efficiency of suspended solids to pond volume. Using this method, the volume of the permanent pool may be calculated as follows:

$$V_P = V_{B/R}S_dA_i43560/12 = 10890S_dA_i$$

Design and Sizing Conditions (Continued)

where: V_P = permanent pool volume (ft^3)
$V_{B/R}$ = Ratio of Basin to Runoff Volume (Figure STP-02-7)
(a value of at least 4.0 should be used)
S_d = mean storm depth (inches)
A_i = impervious acres in the tributary watershed

For A_i the engineer may use directly connected impervious acres because it more correctly represents the area being treated and would allow a smaller facility. Although impervious area and directly connected impervious area are not the same, they are reasonable given the uncertainty of the methodology and expected pond performance.

- Wetland vegetation, occupying 25-50% of water surface area.
- Side slopes should be 6:1 (H:V) or flatter to provide a littoral shelf and safety bench from the side of the facility out to a point 2 to 3 feet below the permanent pool elevation. Side slopes above the littoral zone should be no steeper than 4:1 (H:V). Side slopes below the littoral zone can be 2:1 (H:V) to maximize permanent pool volumes where needed. A short (1.0 ft) drop-off can be constructed at the edge of the pond to control the potential breeding of mosquitoes.
- Skimmers – Facilities that receive stormwater from contributing areas with greater than 50 percent impervious surface or that are a potential source of oil and grease contamination must include a baffle, skimmer, and grease trap to prevent these substances from being discharged from the facility.
- The permanent pool may be excavated into bedrock for a wet or dry detention pond, but the cost may be prohibitive. Furthermore, if there is highly fractured bedrock or karst topography, then the modification of a detention pond should be carefully considered because it may not hold water and the additional water flow and/or weight could intensify karst activity.
- The interaction with other utilities must be considered as it may not be practical to develop a permanent pool in an area that is needed by another utility. Furthermore, the cost of designing around utilities or utility relocation must be considered.
- Access must be considered to account for maintenance crews and public interaction. Maintenance crews must have access to the site for proper maintenance. Ponds that are not designed with access for maintenance crews often become more of a nuisance than a beneficial part of a stormwater management program. It may also be desirable to encourage or discourage access for the public. Public education and recreation may be facilitated by access to the pond, provided public safety is sufficiently addresses. In some cases including some source land use conditions, however, it may be desirable to restrict public access such as in especially sensitive or dangerous areas.
- Design to minimize short-circuiting by including energy dissipaters on inlets, shape the pond with at least a 3:1 length to width ratio, and locate the inlets as far away from the outlet as possible. It should be noted that a length to width ratio of up to 7:1 is preferred. The inlet and outlet can be placed at the same end if baffling is installed to direct the water to the opposite end before returning to the outlet. If topography or aesthetics requires the pond to have an irregular shape, the pond area and volume should be increased to compensate for the dead spaces.

Design and Sizing Conditions (Continued)

- Except for very small facilities, include a forebay, baffle box, or stormwater quality inlet to facilitate maintenance. However, note that a forebay will require less frequent maintenance.
- Use side slopes of at least 4:1 (H:V) or flatter unless vertical retaining walls are used.
- To maintain the wet pool to the maximum extent possible, excessive losses by infiltration through the bottom must be avoided. Depending on the soils, this can be accomplished by compaction, incorporating clay into the soil, or an artificial liner.
- With earthen walls, place an antiseep collar around the outlet pipe.
- The outlet should incorporate an antivortex device if the facility is large (a 100-year storm must safely pass through or around the device).
- The sides of an earthen wall should be vegetated to avoid erosion. Drought tolerant groundcover species should be used if irrigation can not occur during the summer. See STP-04, Biofilters regarding recommended plant species.

Ponds that serve smaller local site runoff do not offer as much recreational benefit as ponds serving larger regional runoff. Regional facilities can often be landscaped to offer recreational and aesthetic benefits. Jogging and walking trails, picnic areas, ball fields, and canoeing or boating are some of the typical uses. For example, portions of the facility used for flood control can be kept dry, except during floods, and can be used for exercise areas, soccer fields, or football fields. Wildlife benefits can also be provided in the form of islands or preservation zones, which allow a view of nature within the park schemes.

- The public's safety must be a foremost consideration. For the design of wet detention ponds, this usually takes place in the grading, fencing, landscaping, pipe cover, grating and signage. The most important design feature affecting public safety during a pond's operation is grading. The contours of the pond should be designed to eliminate "drop-offs". When possible, terraces or benches are used to transition into the permanent pool. Within the permanent pool, it is desirable to have a wet terrace 12 to 18 inches below the normal pool level. In some cases there is not sufficient room for grading of this type and the pond may require a perimeter fence.

<u>Outlet Design</u>

- Proper hydraulic design of the outlet is critical to achieving good performance of the detention basin. The two most common outlet problems that occur are: 1) the capacity of the outlet is too great resulting in partial filling of the basin and less than designed for drawdown time and 2) the outlet clogs because it is not adequately protected against trash and debris. To avoid these problems, two alternative outlet types are recommended for use: 1) V-notch weir, and 2) perforated riser. The V-notch weir will not clog as easily.

Design and Sizing Conditions (Continued)

Flow Control Using a "V" Notch Weir

- The outlet control "V" notch weir should be sized using the following formula (Merritt et.al., 1996).

$$Q = C_1 H^{5/2} \tan\left(\frac{\theta}{2}\right)$$

Where

θ = notch angle
H = head or elevation of water over the weir, ft
C_1 = discharge coefficient (see Figure STP-02-8)

The notch angle should be 20° or more. If calculations show that a notch angle of less than 20° is appropriate, then the outlet should be designed as a uniform width notch. This will generally necessitate some sort of floatables control such as a skimmer on the outlet or trash rack on the inlet.

Flow Control Using a Single Orifice

- The outlet control orifice should be sized using the following equation (GKY, 1989).

$$a = \frac{2A(H-H_o)^{0.5}}{3600CT(2g)^{0.5}} = \frac{(7x10^{-5})A(H-H_o)^{0.5}}{CT} \qquad (1)$$

where: a = area of orifice (ft^2)
A = average surface area of the pond (ft^2)
c = orifice coefficient
T = drawdown time of full pond (hrs.)
g = gravity (32.2 ft/sec^2)
H = elevation when the pond is full (ft)
H_o = final elevation when pond is empty (ft)

With a drawdown time of 40 hours the equation becomes:

$$a = \frac{(1.75x10^{-5})A(H-H_o)^{0.5}}{CT} \qquad (2)$$

TABLE - PERFORATED OUTLET RISER PIPE ORIFICES (Austin, 1988)

Riser Pipe	Vertical Spacing Between Rows (center to center)	Number of Perforations	Perforation Diameter
6 in.	2.5 in.	9 per row	1 in.
8 in.	2.5 in.	12	1 in.
10 in.	2.5 in.	16	1 in.

Design and Sizing Conditions (Continued)

Flow Control Using the Perforated Riser

For outlet control using the perforated riser as the outflow control, it is recommended that the procedure illustrated in STP-03-5 and 6. This design incorporates flow control for the small storms in the perforated riser but also provides an overflow outlet for large storms. If properly designed, the facility can be used for both water quality and drainage control by: 1) sizing the perforated riser as indicated for water quality control; 2) sizing the outlet pipe to control peak outflow rate from the 2-year storm; and 3) using a spillway in the pond berm to control the discharge from larger storms up to the 100-year storm.

Maintenance

- Remove floatables and sediment build-up.
- Correct erosion spots in banks.
- Check at least annually and after each extreme storm event. The facility should be cleaned of accumulated debris. The banks of surface ponds should be checked and areas of erosion repaired. Remove nuisance wetland species and take appropriate measures to control mosquitoes. Remove sediments if they are within 18 inches (45.7 cm) of an orifice plate.

Sediment Removal

- A primary function of STPs is to collect sediments. The sediment accumulation rate is dependant on a number of factors including watershed size, facility sizing, construction upstream, industrial or commercial activities upstream, etc. The sediment contents should be identified before it is removed and disposed.

Some sediment may contain contaminants of which the Indiana Department of Environmental Management (IDEM) requires special disposal procedures. If there is any uncertainty about what the sediment contains or it is known to contain contaminants, then IDEM should be consulted and their disposal recommendations followed. Generally, special attention or sampling should be given to sediments accumulated in facilities serving industrial, manufacturing or heavy commercial sites, fueling centers or automotive maintenance areas, large parking areas, or other areas where pollutants (other than “clean” soil) are suspected to accumulate and be conveyed via storm runoff.

Some sediment collected may be innocuous (free of pollutants other than “clean” soil) and can be used as fill material, cover or land spreading. It is important that this material not be placed in a way that will promote or allow resuspension in storm runoff. The sediment should not be placed within the high water level area of the STP, other BMP, creek, waterway, buffer, runoff conveyance device, or other infrastructure. Some demolition or sanitary landfill operators will allow the sediment to be disposed at their facility for use as cover. This generally requires that the sediment be tested to ensure that it is innocuous.

- Solids should be removed when 10 to 15% of the storage capacity has been lost.
- The pond’s success as a mechanism to benefit water quality is dependent on maintaining the permanent pool, skimmer devices, and inlet and outlet structures. This maintenance typically includes sediment, floatable, and debris removal from inlets, outlets and skimmers.
- Pond vegetation need to be trimmed or harvested as appropriate, grassy areas frequently mowed and repairs made to signage, walkways, picnic tables, or any other public recreation equipment.
- If both the operational aesthetic characteristics of a wet pond are not maintained, then it will be viewed as an eyesore and negative environmental impact even if it is functioning properly.

Activity: Wet Detention Ponds	STP-02

Inspection Checklist

- ❑ Concern for mosquitoes and maintaining oxygen in ponds.
- ❑ Cannot be placed on steep unstable slopes or on shallow fractured bedrock.
- ❑ Infeasible in very dense urban areas.
- ❑ For larger detention facilities, the structural integrity of the impounding embankment should also be considered. The embankment should be protected against catastrophic dam failure. Pending volume and depth, pond designs may require approval from IDEM or USACOE for various reasons including dam safety.
- ❑ May require permits from various regulatory agencies, e.g., IDEM, USACOE

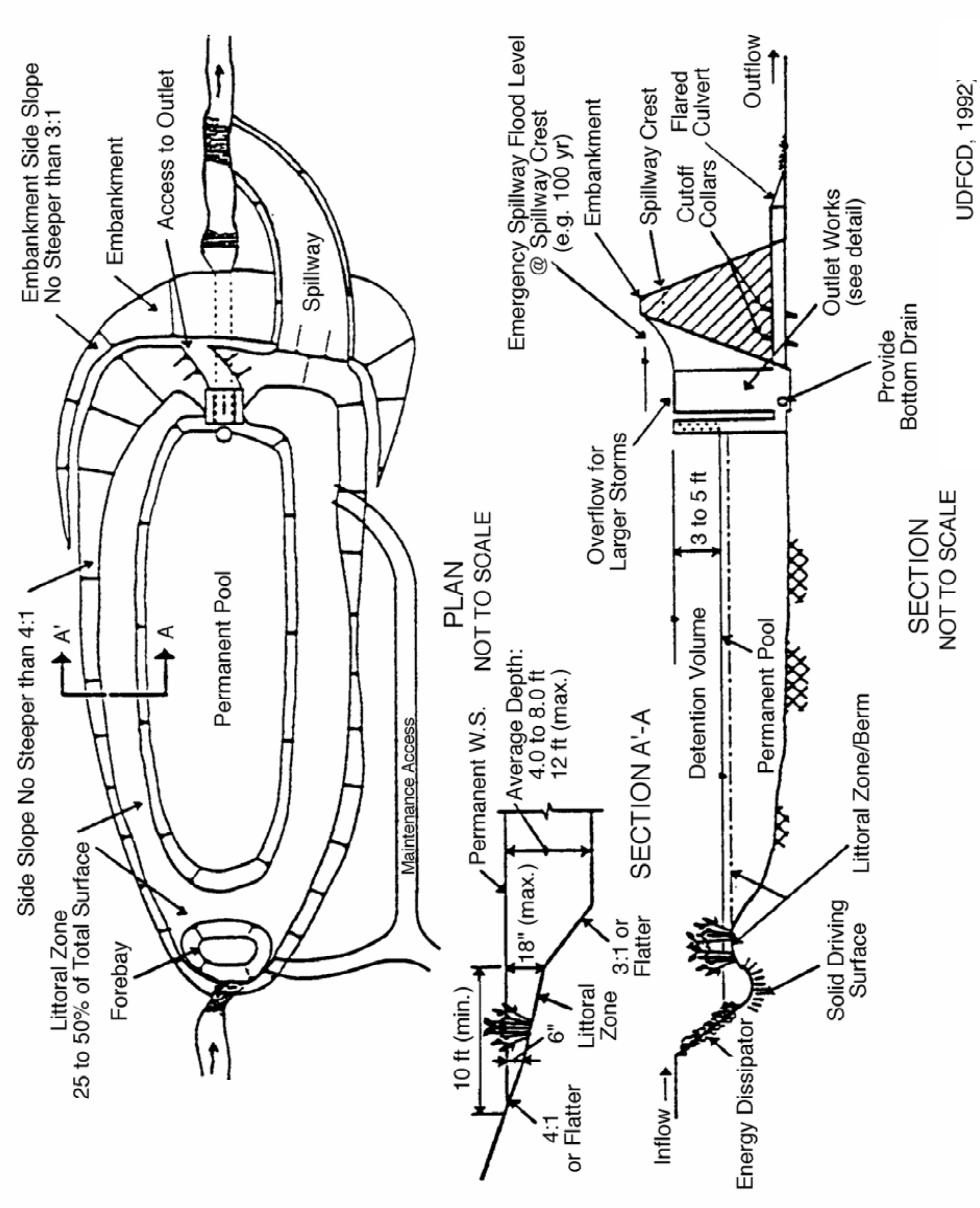


Figure STP-02-1
Wet Pond Layout

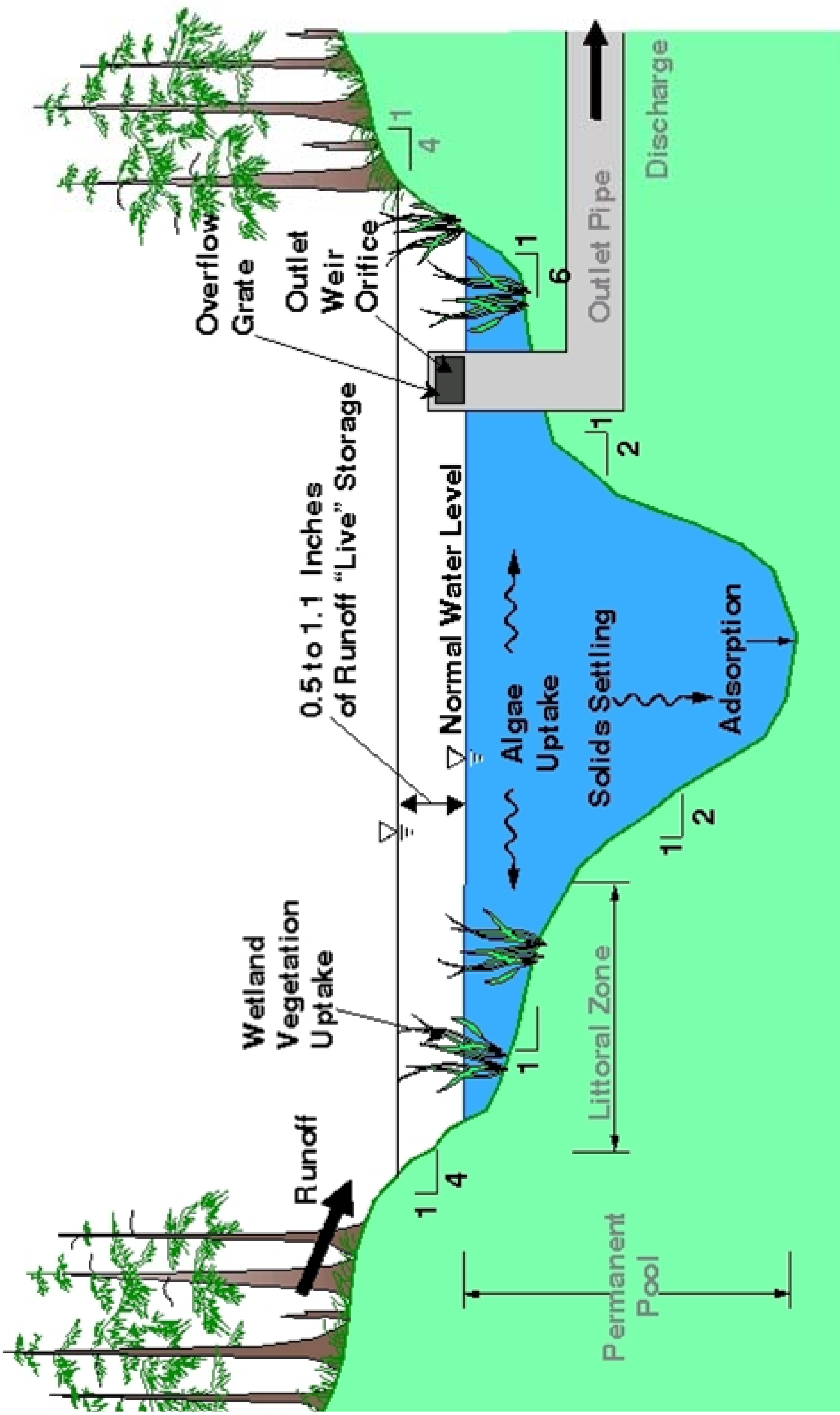
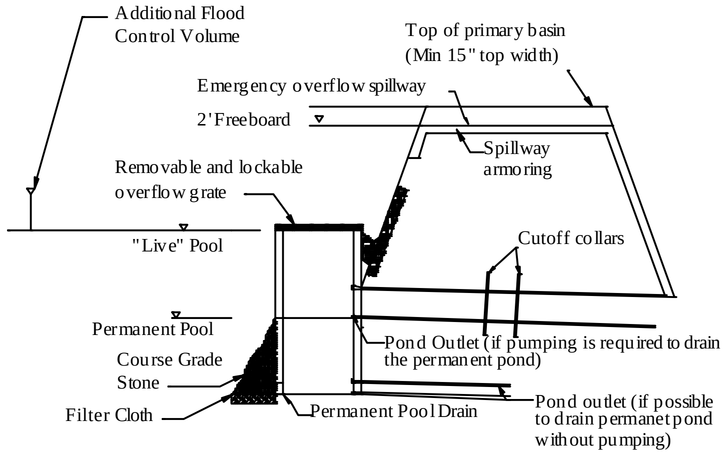


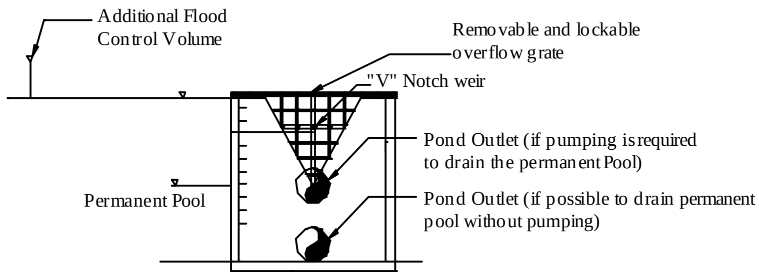
Figure STP-02-2
Wet Pond Layout

Source: City of Nashville, TN

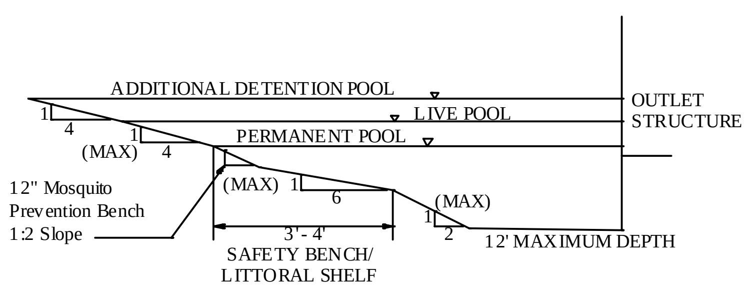
Activity: Wet Detention Ponds



SECTION OUTLET STRUCTURE
NTS

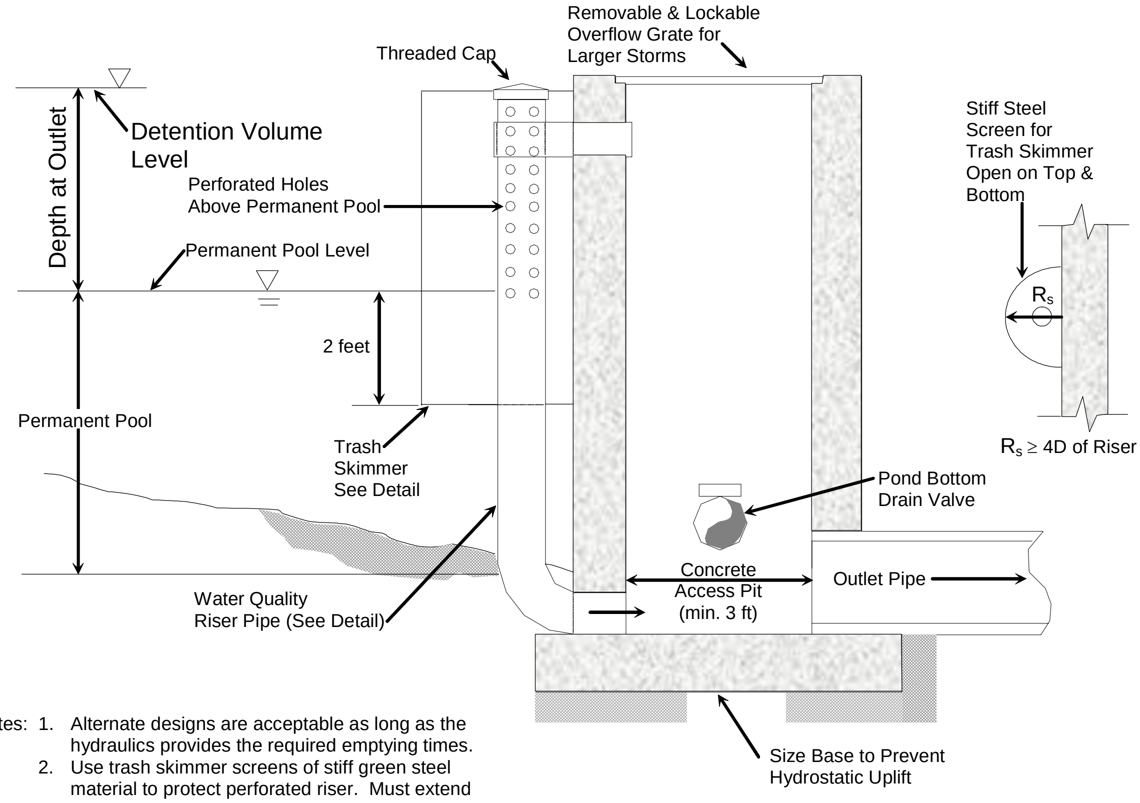


PROFILE OUTLET STRUCTURE
NTS



POND GRADING
NTS

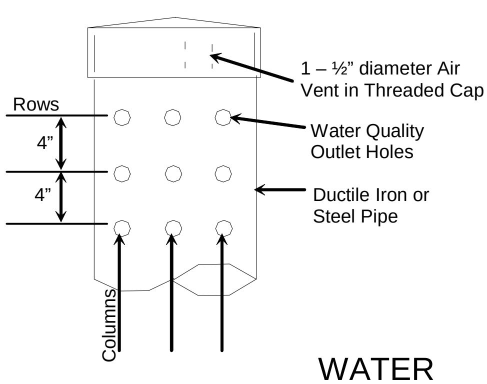
Figure STP-02-3
"V" Notch Weir Outlet Structure



Notes: 1. Alternate designs are acceptable as long as the hydraulics provides the required emptying times.
2. Use trash skimmer screens of stiff green steel material to protect perforated riser. Must extend from the top of the riser to 2 ft. below the permanent pool level.

OUTLET WORKS
NOT TO SCALE

Notes: 1. Minimum number of holes = 8
2. Minimum hole diameter = 1/8" Dia.



WATER QUALITY **RISER PIPE**

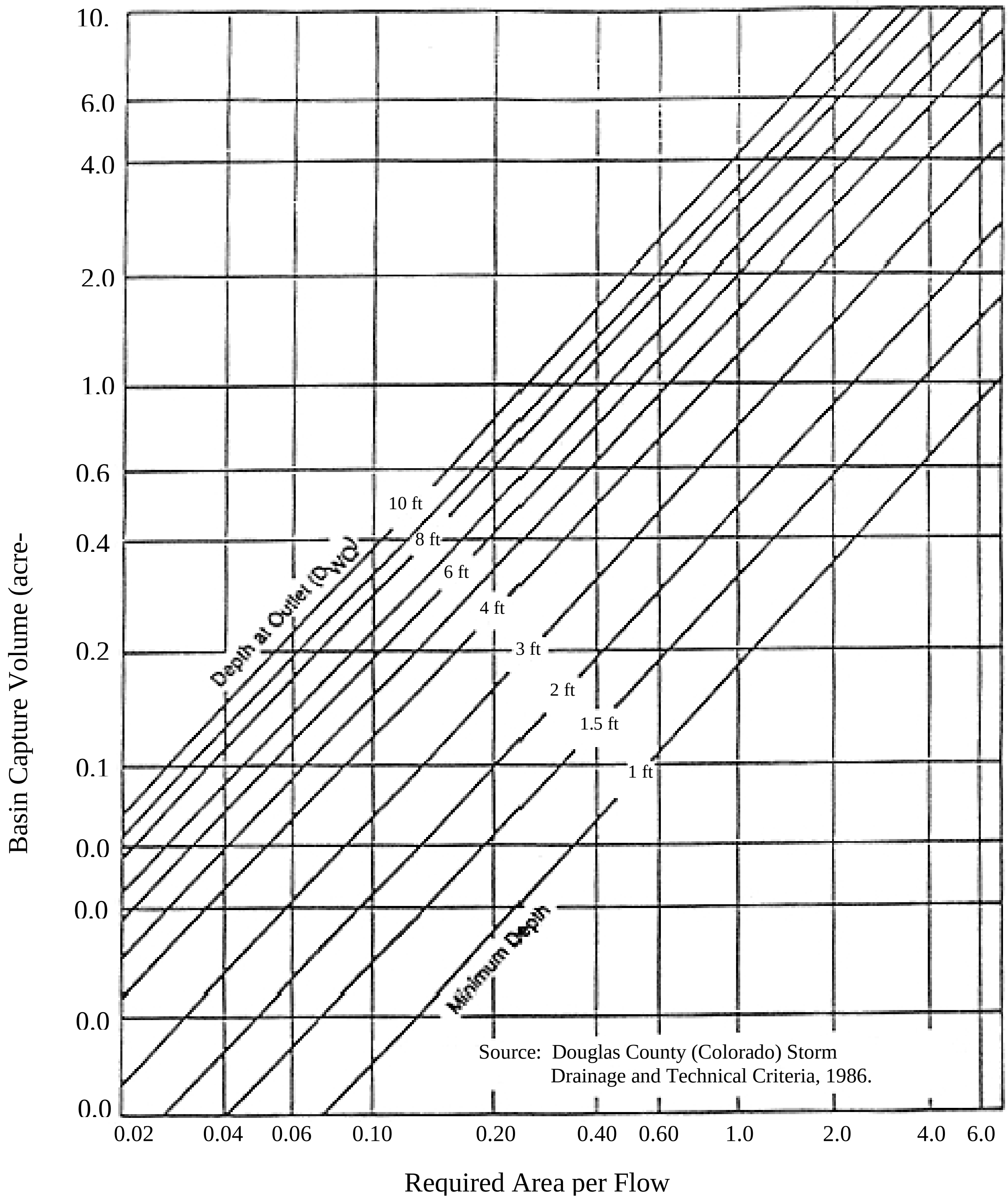
NOT TO SCALE

Maximum Number of Perforated Columns

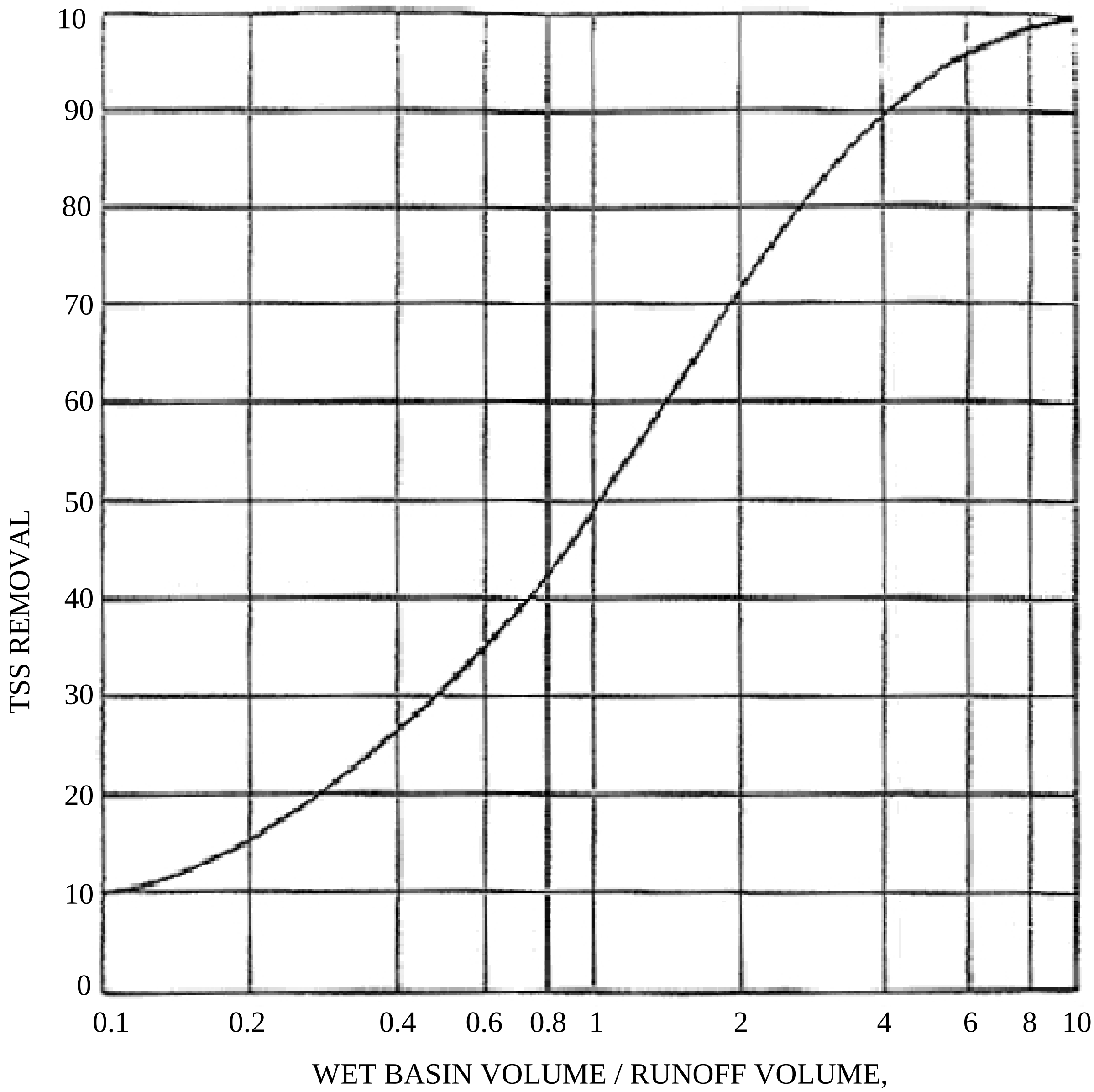
Riser Diameter (in.)	Hole Diameter, inches			
	¼"	½"	¾"	1"
4	8	8	-	-
6	12	12	9	-
8	16	16	12	8
10	20	20	14	10
12	24	24	18	12

Hole Diameter (in.)	Area (in.^{2})
1/8	0.013
1/4	0.049
3/8	0.110
1/2	0.196
5/8	0.307
3/4	0.442
7/8	0.601
1	0.785

Figure STP-02-4
Perforated Riser Pipe Outlet Structure



STP-02-5
Water Quality Outlet Sizing: Extended Detention Basin
(40-hour Drain Time of Capture Volume)



Source: FHWA

Figure STP-02-6
TSS Removal Efficiency
Versus V_B/V_R Ratio

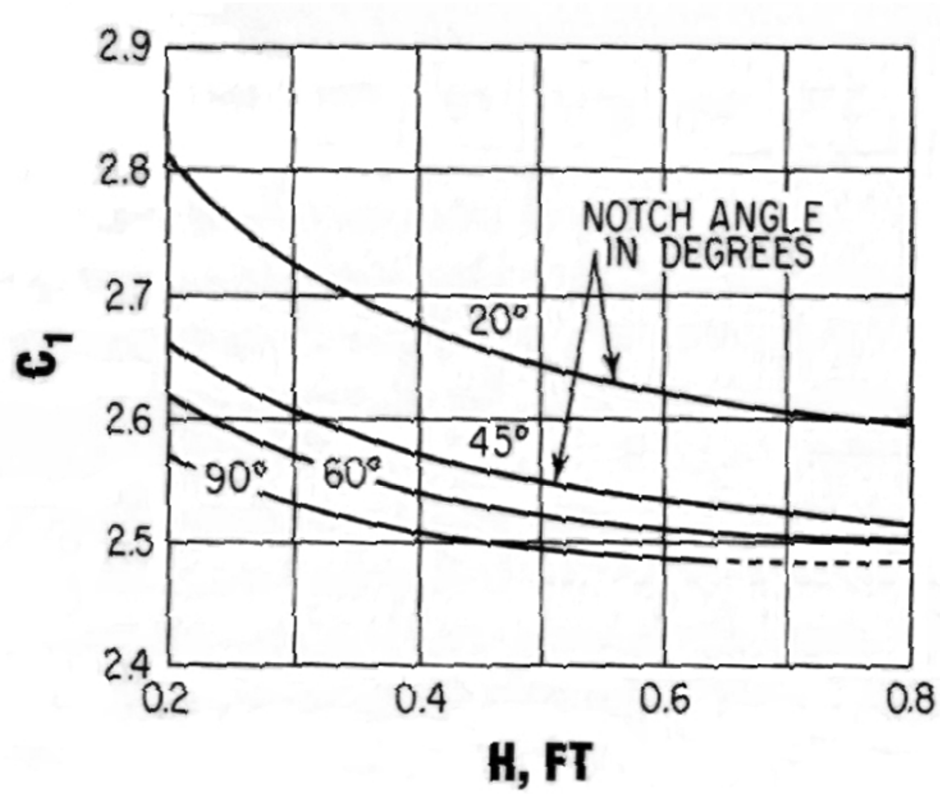


Figure STP-02-7
Sharp -Crested "V" Notch Weir Discharge Coefficients

New Albany, Indiana
Stormwater Best Management Practices (BMPs)
Stormwater Pollution treatment Practices (STPs)

STP-03

Activity: Dry Detention Ponds

D

DDP

PLANNING CONSIDERATIONS:

Design Life:
Permanent

Acreage Needed:
Significant

Estimated Unit Cost:
Avg: $.50 per CF of Storage

Monthly Maintenance:
3% of Capital Costs

Target Pollutants

Significant ♦ Partial ◈ Low or Unknown ◇

Sediment ♦ Heavy Metals ♦ Nutrients ◈ Oxygen Demanding Substances ◈ Toxic Materials ◈
Oil& Grease ◈ Bacteria & Viruses ◇ Floatable Materials ◈ Construction Waste ◇

Description

Extended detention ponds are dry between storms. During a storm the pond fills. A bottom outlet releases the stormwater slowly to provide time for sediments to settle. This management practice is likely to provide a significant reduction in sediments and heavy metals as well as a partial reduction in nutrients, toxic materials, floatable materials, oxygen demanding substances, and oil and grease.

Suitable Applications

- Objective is to remove only particulate pollutants (soluble pollutants are not intended to be removed).
- Use where lack of water prevents the use of wet ponds, wetlands or biofilters.
- Use where shallow wet ponds or wetlands would cause unacceptable mosquito conditions.
- Multiple benefits for passive recreation during dry periods (multi-purpose facilities, ball fields, picnicking etc.).
- The quality of the runoff and the intent of the basin should be considered. If the basin is being considered for highly soluble pollutant removal such as nutrients, then a wet detention pond is preferred over a dry detention pond.

Activity: Dry Detention Ponds

STP-03

Suitable Applications (Continued)

- Dry detention ponds and vaults may be particularly appropriate to areas where dry weather base flow cannot be used to maintain water levels, as is required for wet ponds and constructed wetlands. These systems are suitable for essentially any size tributary area from an individual commercial development to a large residential area. Surface ponds are less expensive to construct, but underground vaults may be appropriate in commercial developments. Use of concrete retaining walls will reduce the space required by a pond. The basic elements of a dry detention basin are illustrated in Figures STP-03-1 and 2. Additional details are provided in Figures STP 3-3 through 10.

- Dry ponds provide lower removal efficiency for dissolved pollutant parameters than wet ponds and constructed wetlands.

Design and Sizing Considerations

- These systems should be designed by a licensed professional civil engineer.

- Dry detention ponds should be designed as “off-line” structures to limit environmental impacts downstream when maintaining the facility. On-line facilities may be acceptable depending on specific site characteristics.

- Pond volume is sized to capture 85-95% of theoretical annual volume of the runoff. Generally, the pond is sized to capture and “treat” at least the “first flush” volume.

- Drawdown time of 24 to 48 hours.

- A shallow pond with large surface area performs better than a deep pond with the same volume. Design to minimize short-circuiting by including energy dissipaters on inlets, shape the pond with at least a 3:1 length to width ratio, and locate the inlets as far away from the outlet as possible. It should be noted that a length to width ratio of up to 7:1 is preferred. The inlet and outlet can be placed at the same end if baffling is installed to direct the water to the opposite end before returning to the outlet. If topography or aesthetics requires the pond to have an irregular shape, the pond area and volume should be increased to compensate for the dead spaces.
    - Place energy dissipaters at the entrance to minimize bottom erosion and re-suspension.
    - Vegetate side slopes and bottom to the maximum extent practical.
    - If side erosion is particularly severe, consider soil stabilization, armoring or lastly paving.
    - If floatables are a problem, protect outlet with trash rack, skimmer at inlet, or other device.

Activity: Dry Detention Ponds

Design and Sizing Considerations (Continued)

- Do not locate on fill sites or on or near steep slopes if it is expected that much of the water will exit through the bottom, or modify the bottom to prevent excessive infiltration.
- Embankment freeboard of at least 2 feet.
- Side slopes of at least 4:1 (H:V) unless vertical retaining walls are used.
- Provide dedicated access to the basin bottom (minimum 4:1 (H:V)) for maintenance vehicles.
- With a riser structure, include an anti-vortex device and a debris barrier.
- Skimmers – Facilities that receive stormwater from contributing areas with greater than 50 percent impervious surface or that are a potential source of oil and grease contamination must include a baffle, skimmer, and grease trap to prevent these substances from being discharged from the facility.
- The interaction with other utilities must be considered as it may not be practical to develop a permanent pool in an area that is needed by another utility. Furthermore, the cost of designing around utilities or utility relocation must be considered.

Access must be considered to account for maintenance crews and public interaction. Maintenance crews must have access to the site for proper maintenance. Ponds that are not designed with access for maintenance crews often become more of a nuisance than a beneficial part of a stormwater management program. It may also be desirable to encourage or discourage access for the public. Public education and recreation may be facilitated by access to the pond, provided public safety is sufficiently addresses. In some cases, however, it may be desirable to restrict public access such as in especially sensitive or dangerous areas.

- Include a forebay to facilitate maintenance.
- With earthen walls, place an antiseep collar (or collars) around the outlet pipe.
- The outlet should incorporate an antivortex device if the facility is large (A 100-year storm must safely pass through or around the device).
- The sides of an earthen wall should be vegetated to avoid erosion. Drought tolerant groundcover species should be used if irrigation can not occur during the summer. See STP-04, Biofilters regarding recommended plant species.
- Ponds that serve smaller local site runoff do not offer as much recreational benefit as ponds serving larger regional runoff. Regional facilities can often be landscaped to offer recreational and aesthetic benefits. Jogging and walking trails, picnic areas, ball fields, and canoeing or boating are some of the typical uses. For example, portions of the facility used for flood control can be kept dry, except during floods, and can be used for exercise areas.

Activity: Dry Detention Ponds

Design and Sizing Considerations (Continued)

- The public's safety must be a foremost consideration. For the design of dry detention ponds, this usually takes place in the grading, fencing, landscaping, pipe cover, grating and signage. The most important design feature affecting public safety during a pond's operation is grading. The contours of the pond should be designed to eliminate "drop-offs". When possible, terraces or benches are used to transition into the permanent pool. Within the permanent pool, it is desirable to have a wet terrace 12 to 18 inches below the normal pool level. In some cases there is not sufficient room for grading of this type and the pond may require a perimeter fence.
- Provide bypass or pass through capabilities for 100-year storm.

<u>Pond Sizing</u>

- Water quality requirements for detention ponds should be sized to collect the first flush of stormwater runoff; and release it over a 24- to 48-hour period. For this region, the first flush is generally the first 0.5 to 1.0 inches of runoff depending on the density and percent imperviousness of the land use.

The following two methods should be used to calculate the "live" pool volume. The most conservative (largest volume) should be selected.

- The recommended performance goal is 85 to 95%.
- The live pool portion of the dry pond can also be designed to capture the "maximized storm runoff capture volume," and drain over a 24-60 hour period. The maximized storm runoff capture volume can be calculated by:

$$V_L = (a \cdot C) \cdot P_6$$

where:

V_L = maximized capture volume determined using either the event capture ratio or the volume capture ratio as its basis, watershed in.;
a = regression constant from least-square analysis;
Event capture ratio: 1.299 for 24-hour drain time,
Volume capture ratio: 1.582 for 24-hour drain time (for approximately 85^{th} percentile runoff event – 82-88%).
C = Contributing area weighted runoff coefficient
P_6 = mean storm precipitation volume, watershed in..

Refer to ASCE Manual and Report on Engineering Practices No. 87 for additional information on this technique.

- Using this technique, the desired removal efficiency and land use characteristics can be applied to local hydrologic data to determine the optimal live pool volume. Note that A_T and the runoff coefficient selected can be modified to consider Directly Connected Impervious Area (DCIA) if the data is available.
- The live pool volume will benefit the downstream waterways by reducing erosive velocities, providing stormwater quality benefit, and some flood control.

Activity: Dry Detention Ponds

Design and Sizing Considerations (Continued)

- To achieve an equivalent pollutant capture percentage as a wet pond, 85 to 95 percent of the runoff must be captured and detained. Capture volumes over 95 percent are generally not cost effective. Therefore it is recommended that an average capture volume of 90 percent be used for determining the detention basin size required. Because of the possibility of re-suspension of materials during extreme storms, consideration should be given to placing the basin off-line. That is, it should have a bypass for the extreme events. Bypassing larger events will also allow the bed load earned by the storm and is necessary for beach replenishment to move downstream.
- A drawdown time of 24 to 48 hours is recommended in order to settle out the finer clay particles as stated above; however, 24 hours can be used if it can be demonstrated that this rate will remove 90% of the solids.
- About 10 to 25% of the surface area determined in the above procedure should be devoted to the forebay. The forebay can be distinguished from the remainder of the pond by one of several means: a lateral sill with rooted wetland vegetation, two ponds in series, differential pool depth, rock-filled gabions or retaining wall, or a horizontal rock filter placed laterally across the pond.

Outlet Design

- Proper hydraulic design of the outlet is critical to achieving good performance of the detention basin. The two most common outlet problems that occur are: 1) the capacity of the outlet is too great resulting in partial filling of the basin and less than designed for drawdown time and 2) the outlet clogs because it is not adequately protected against trash and debris. To avoid these problems, two alternative outlet types are recommended for use: 1) V-notch weir, and 2) perforated riser. The V-notch weir will not clog.
- Three different approaches can be used to control the outflow. One is to use a “V” notch weir. One is to use a single orifice outlet with or without the protection of a riser pipe. Lastly, a perforated riser itself may be used for discharge control. These approaches are presented below.
- Flow Control Using a “V” Notch Weir
- The outlet control “V” notch weir should be sized using the following formula (Merritt et.al., 1996).

$$Q = C_1 H^{5/2} \tan\left(\frac{\theta}{2}\right)$$

Where

θ = notch angle
H = head or depth of water over weir, ft
C_1 = discharge coefficient (see Figure STP-03-9)

Design and Sizing Considerations (Continued)

The notch angle should be 20º or more. If calculations show that a notch angle of less than 20º is appropriate, then the outlet should be designed as a uniform width notch. This will generally necessitate some sort of floatables control such as a skimmer on the outlet or trash rack on the inlet.

Flow Control Using a Single Orifice

The outlet control orifice should be sized using the following equation (GKY, 1989).

$$a = \frac{2A(H-H_o)^{0.5}}{3600CT(2g)^{0.5}} = \frac{(7x10^{-5})A(H-H_o)^{0.5}}{CT}$$

where: a = area of orifice (ft²)
- A = average surface area of the pond (ft²)
- c = orifice coefficient
- T = drawdown time of full pond (hrs.)
- g = gravity (32.2 ft/sec²)
- H = elevation when the pond is full (ft)
- H_o = final elevation when pond is empty (ft)

With a drawdown time of 40 hours the equation becomes:

$$a = \frac{(1.75x10^{-6})A(H-H_o)^{0.5}}{C}$$

Care must be taken in the selection of “c”: 0.60 is most often recommended and used. However, based on actual tests GKY (1989) recommends the following:

c = 0.66 for thin materials, that is, the thickness is equal to or less than orifice diameter
c = 0.80 when the material is thicker than the orifice diameter

Drilling the orifice into an outlet structure that is made of concrete can result in considerable impact on the coefficient, as does the beveling of the edge. The experiments by GKY (1989) were with sharp edged orifices.

Design and Sizing Considerations (Continued)

- Additional steps may be necessary to be certain that the small storms, which represent the majority of pollution, are effectively treated. One approach would be to check the design analysis to determine if the facility takes 24-48 hours to drain when half full. If not, either modify the design to achieve this objective, or install a two orifice outlet. The lower outlet is sized to drain a half-full facility in 24 hours. The second orifice is placed at the mid-water elevation and is sized in combination with the lower orifice to drain the entire facility in 48 hours. Another approach is to install the outlet about one foot above the bottom of the pond (essentially enlarging the micropool area). This lower area will dry up between storms and will capture much of the volume of small storms and improving pollutant removal.

- To prevent clogging of an orifice and the bottom orifices of the riser pipe, wrap the bottom three rows of orifices with geotextile fabric and a cone of one to three inch rock. The holes in the riser pipe should not be modified to achieve a 48-hour drawdown time.

TABLE - PERFORATED OUTLET RISER PIPE ORIFICES (Austin, 1988)

Riser Pipe	Vertical Spacing Between Rows (center to center)	Number of Perforations	Perforation Diameter
6 in.	2.5 in.	9 per row	1 in.
8 in.	2.5 in.	12	1 in.
10 in.	2.5 in.	16	1 in.

Flow Control Using the Perforated Riser

For outlet control using the perforated riser as the outflow control, it is recommended that the procedure illustrated in Figures STP-03-5, 6 and 7. This design incorporates flow control for the small storms in the perforated riser but also provides an overflow outlet for large storms. If properly designed, the facility can be used for both water quality, flood, and erosion control by: 1) sizing the perforated riser as indicated for water quality control; 2) sizing the outlet pipe to control peak outflow rate from the 2-year storm; and 3) using a spillway in the pond berm to control the discharge from larger storms up to the 100-year storm.

Maintenance

- Check outlet regularly for clogging and remove any debris.

- Check banks and bottom of surface basin for erosion and correct as necessary.

- Remove sediment when accumulation reaches 6 inches, or if re-suspension is observed or probable. Sediment may be permitted to accumulate deeper than 6 inches if there is a permanent marker indicating the depth where sediment needs to be removed, and that mark has not been met.

Maintenance (Continued)

Sediment Removal

- A primary function of STPs is to collect sediments. The sediment accumulation rate is dependant on a number of factors including watershed size, facility sizing, construction upstream, industrial or commercial activities upstream, etc. The sediment contents should be identified before it is removed and disposed.
- Some sediment may contain contaminants of which the Indiana Department of Environmental Management (IDEM) requires special disposal procedures. If there is any uncertainty about what the sediment contains or it is known to contain contaminants, then IDEM should be consulted and their disposal recommendations followed. Generally, special attention or sampling should be given to sediments accumulated in facilities serving industrial, manufacturing or heavy commercial sites, fueling centers or automotive maintenance areas, large parking areas, or other areas where pollutants (other than "clean" soil) are suspected to accumulate and be conveyed via storm runoff.
- Some sediment collected may be innocuous (free of pollutants other than "clean" soil) and can be used as fill material, cover or land spreading. It is important that this material not be placed in a way that will promote or allow re-suspension in storm runoff. The sediment should not be placed within the high water level area of the STP, other BMP, creek, waterway, buffer, runoff conveyance device, or other infrastructure. Some demolition or sanitary landfill operators will allow the sediment to be disposed at their facility for use as cover. This generally requires that the sediment be tested to ensure that it is innocuous.
- Check at least annually and after each extreme storm event. The facility should be cleaned of accumulated debris. The banks of surface ponds should be checked and areas of erosion repaired. Remove nuisance wetland species and take appropriate measures to control mosquitoes. Remove sediments if they are within 18 inches of an orifice plate.
- The pond's success as a mechanism to benefit water quality is dependent on maintaining the permanent pool, skimmer devices, and inlet and outlet structures. This maintenance typically includes sediment, floatable, and debris removal from inlets, outlets and skimmers.
- Pond vegetation need to be trimmed or harvested as appropriate, grassy areas frequently mowed and repairs made to signage, walkways, picnic tables, or any other public recreation equipment.
- If both the operational aesthetic characteristics of a dry pond are not maintained, then it will be viewed as an eyesore and negative environmental impact even if it is functioning properly.

Activity: Dry Detention Ponds	STP-03

Inspection Checklist

- ❑ Make sure the outlet is installed as designed. Special attention should be given to the elevations of each outlet geometry change, shape of the various weirs or orifices, and installation of cut-off collars in embankments.
- ❑ Require more frequent maintenance then wet ponds.
- ❑ Inability to vegetate banks and bottom may result in erosion and pollutant re-suspension.
- ❑ Limitation of the orifice diameter may preclude use in small watersheds.
- ❑ Pending their volume and depth basin designs may require approval from State Division of Safety of Dams. Generally, any embankment 15 ft or taller must meet special requirements. For larger detention facilities, the structural integrity of the impounding embankment should also be considered. The embankment should be protected against catastrophic dam failure. Pending volume and depth, pond designs may require approval from IDEM, or USACOE for various reasons including dam safety.
- ❑ Dry detention ponds require a large surface area (0.5 to 3% of the contributing drainage area) to provide sufficient pond volume for settling of sediment.
- ❑ If upstream erosion is not properly controlled, dry detention ponds can be maintenance intensive with respect to sediment removal, nuisance odors, and insects (i.e., mosquitoes), etc.
- ❑ Dry detention ponds require a differential elevation between inlets and outlets and thus, may be limited by terrain.
- ❑ May require permits from various regulatory agencies, e.g., IDEM, USACOE.

Activity: Dry Detention Ponds

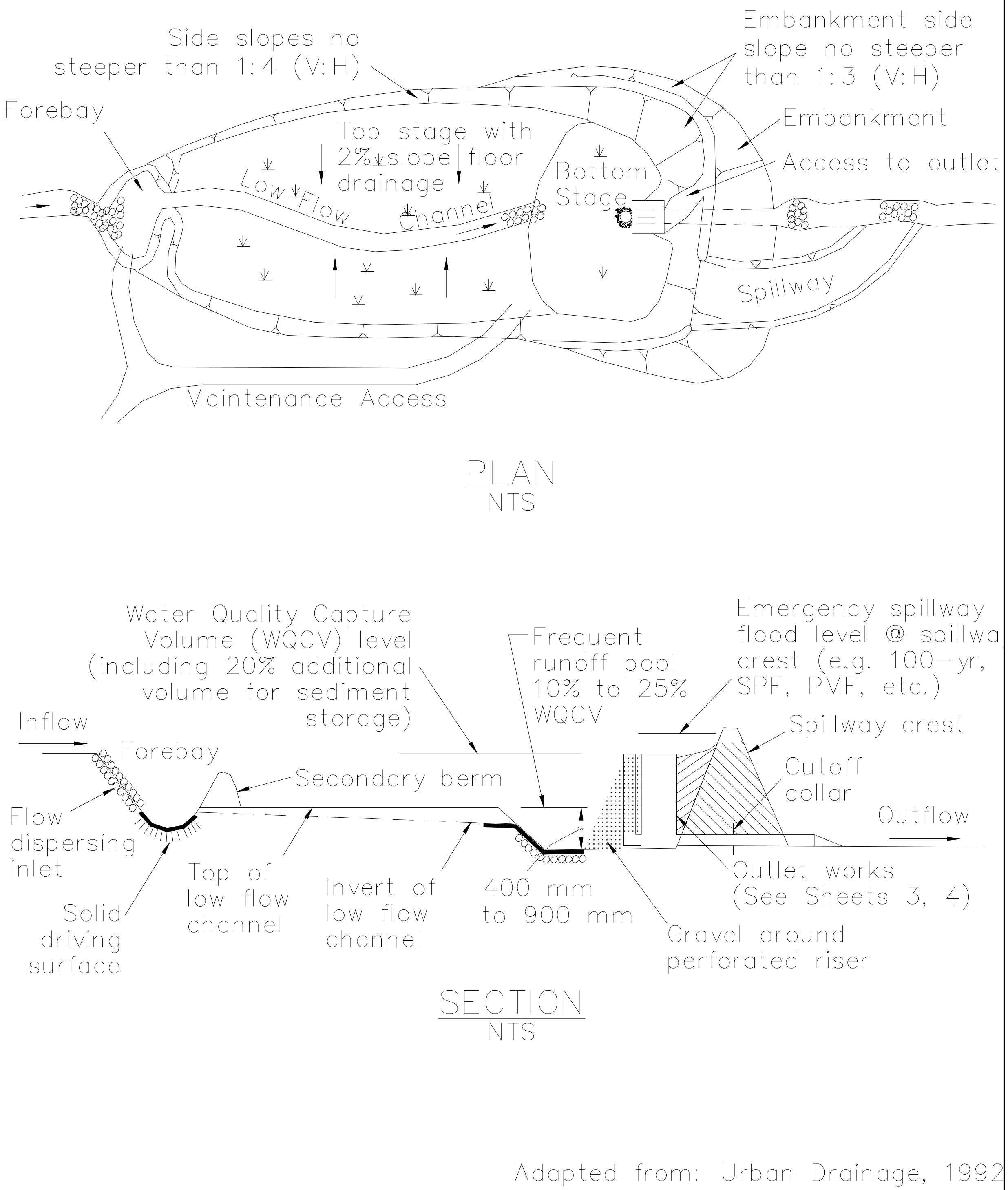
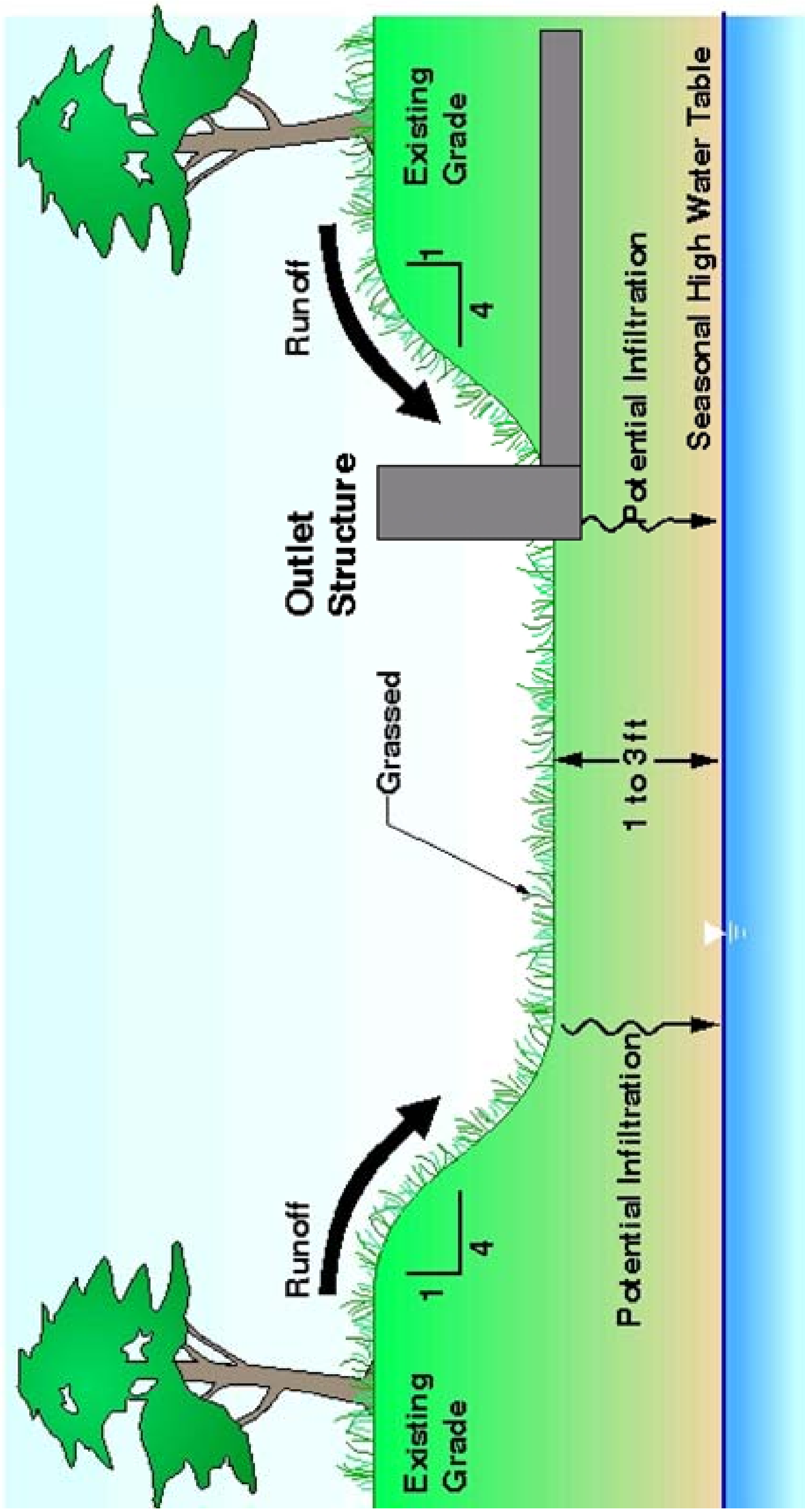
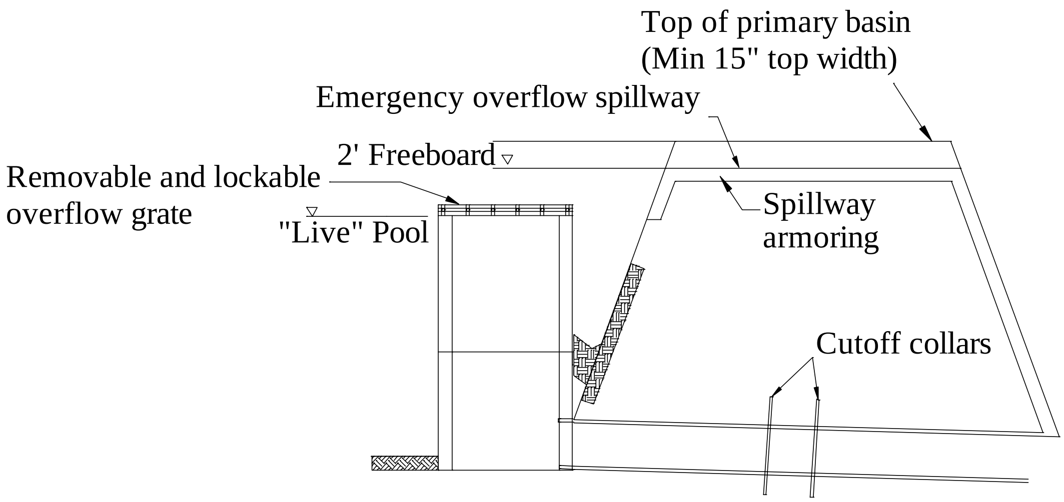


Figure STP-03-1
Dry Detention Pond Layout



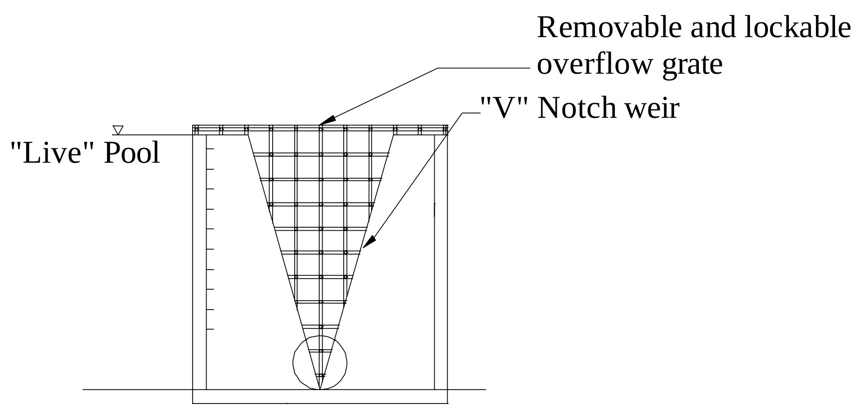
Source: City of Nashville

Figure STP-03-2
Dry Detention Pond Layout



SECTION OUTLET STRUCTURE

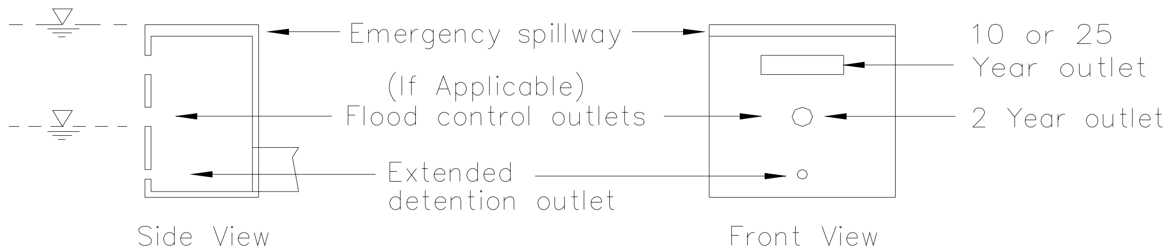
NTS



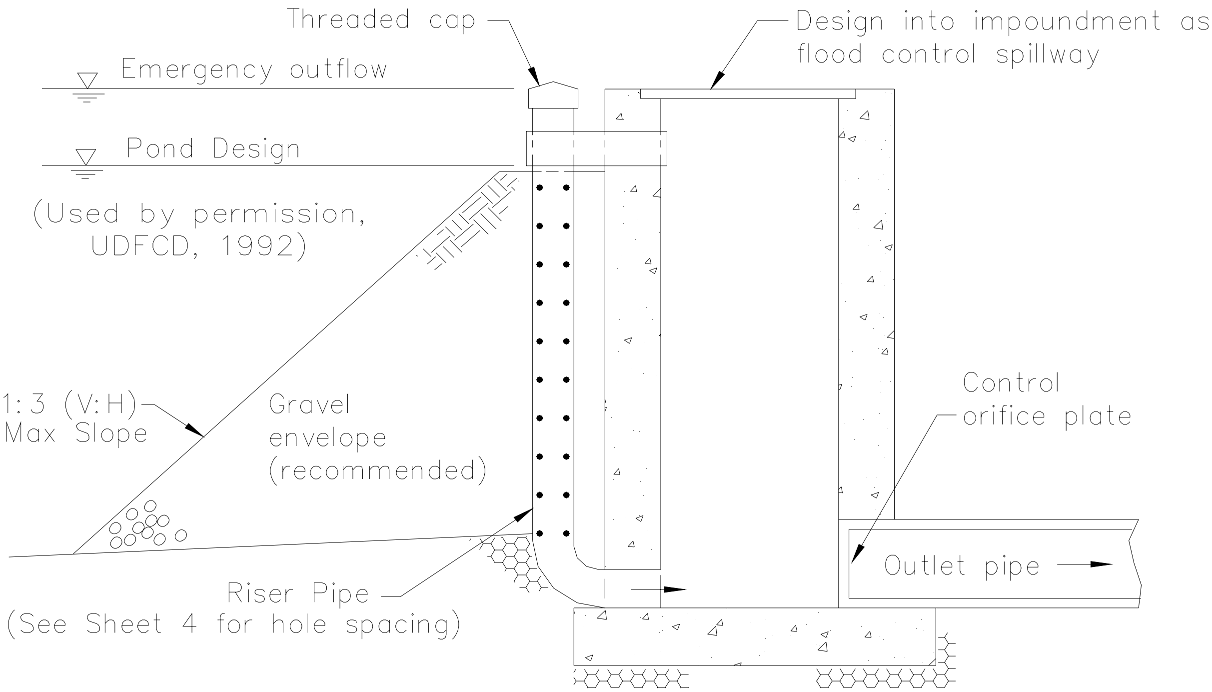
PROFILE OUTLET STRUCTURE

NTS

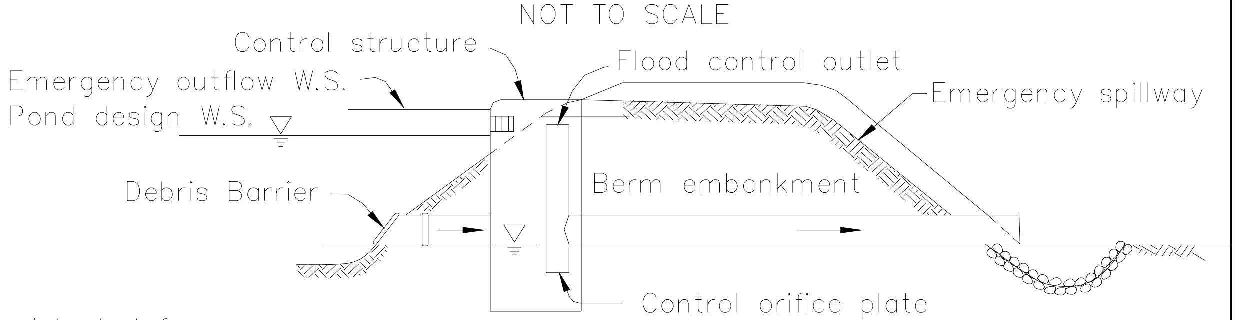
Figure STP-03-3
“V” Notch Weir Outlet Structure



CONCRETE STRUCTURE
NOT TO SCALE



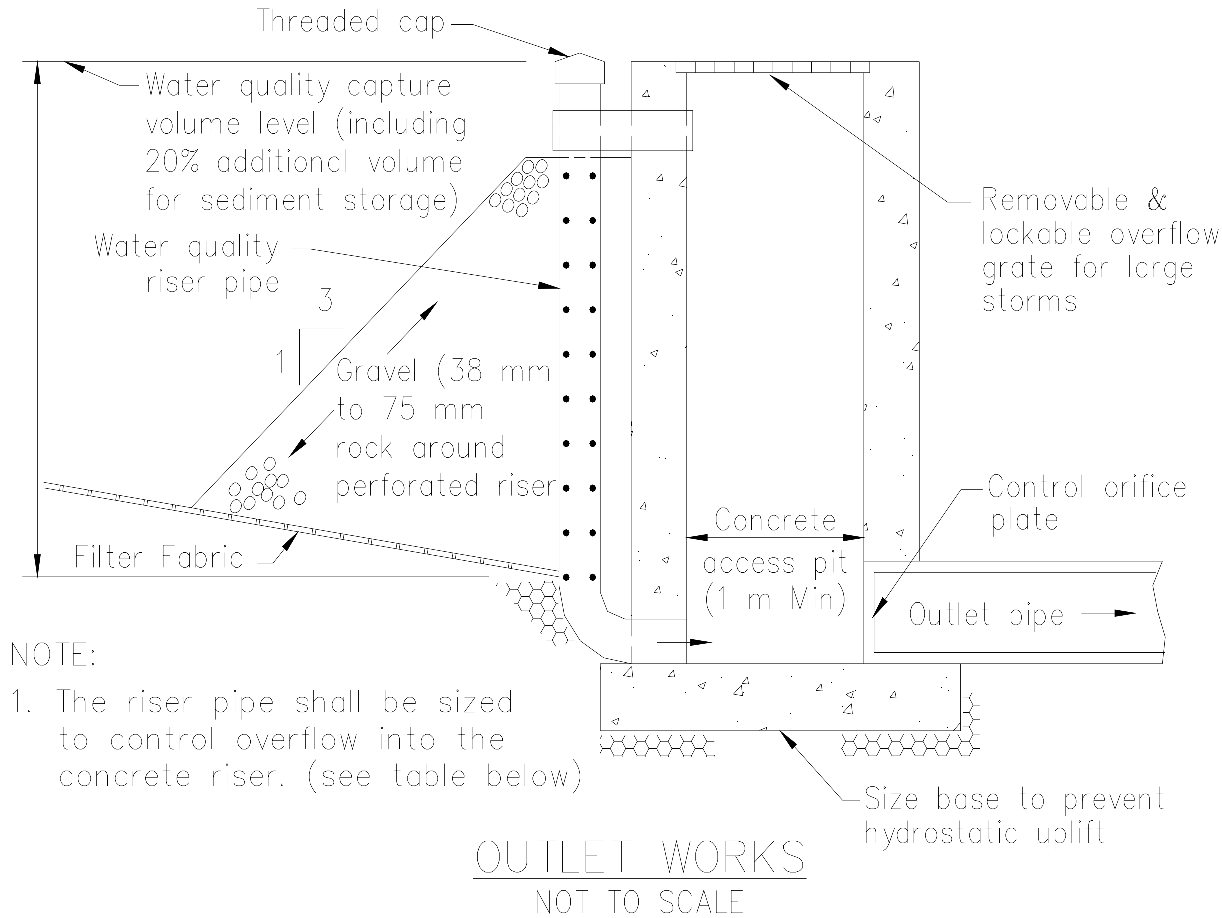
RISER PIPE
NOT TO SCALE



Adapted from:
Douglas County, CO

CONTROL MANHOLE
NOT TO SCALE

Figure STP-03-4
Other Outlet Structures



Perforated Outlet Riser Pipe Orifices (Austin, 1988)			
Riser Pipe Diameter	Vertical Spacing Between Rows (center to center)	Number of Perforations	Perforation Diameter
150 mm	64 mm	9 per row	25 mm
200 mm	64 mm	12 per row	25 mm
250 mm	64 mm	16 per row	25 mm

Figure STP-03-5
Riser Pipe Sizing

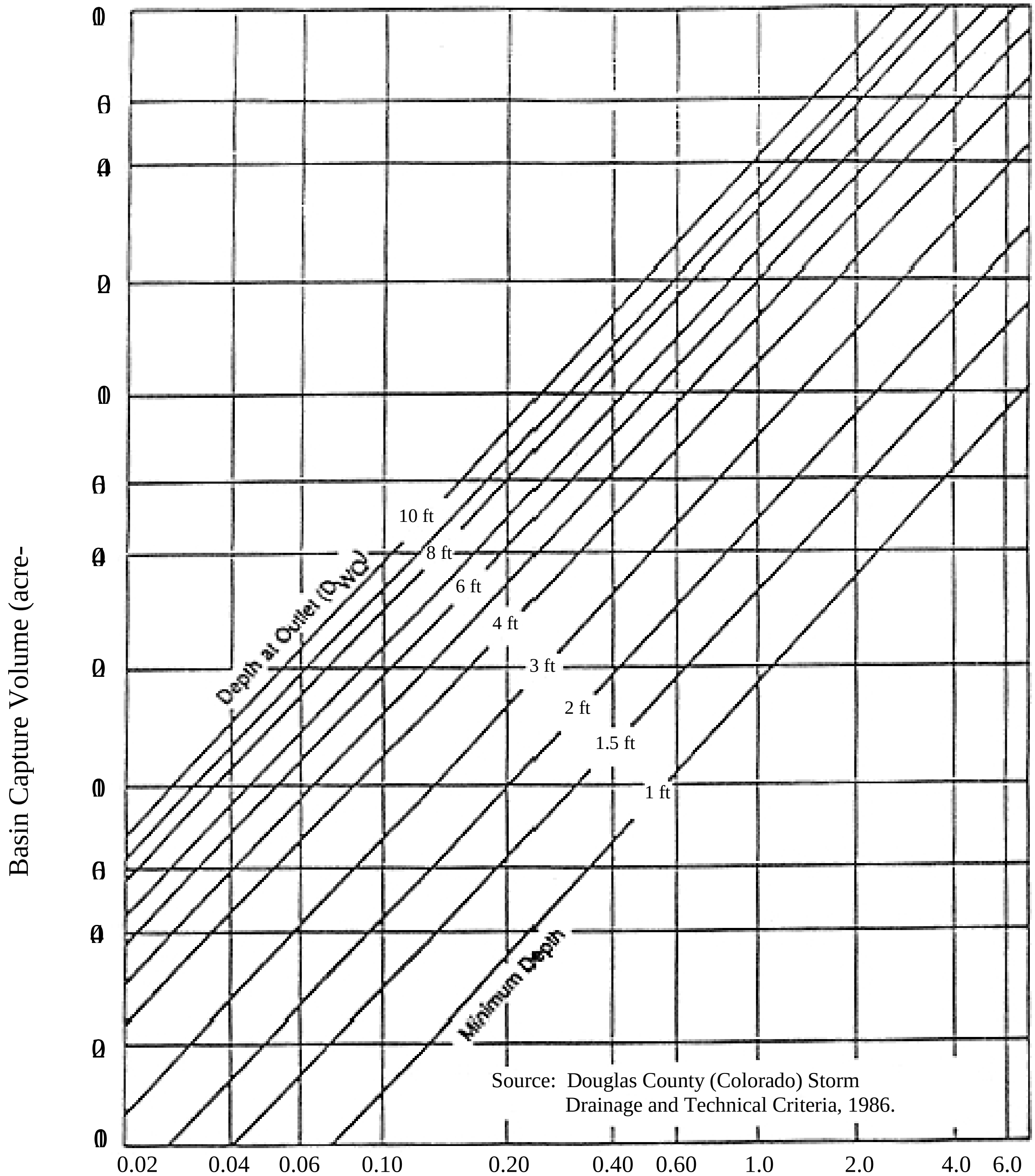
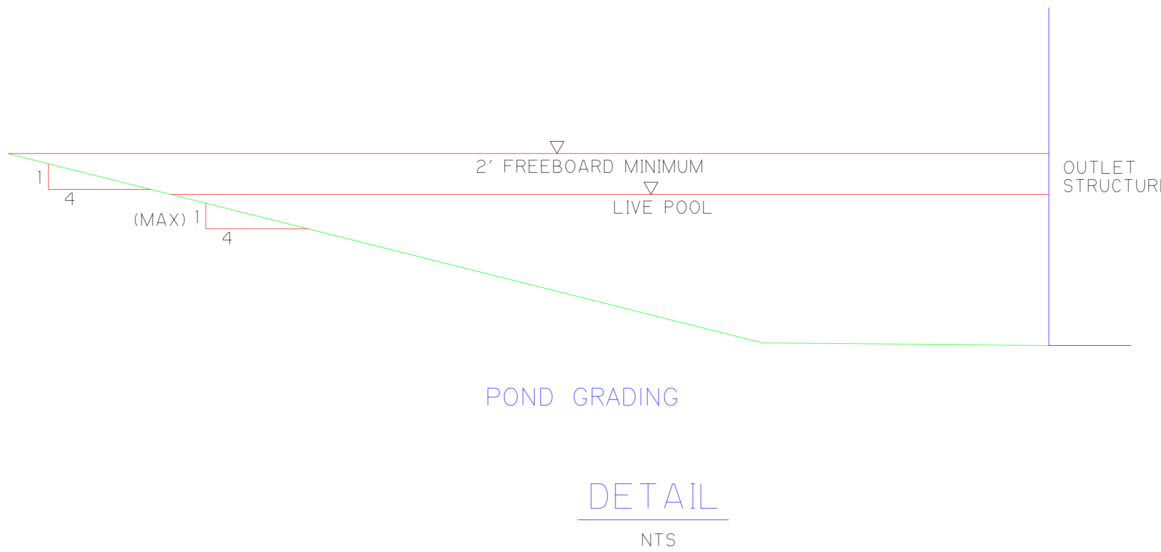


Figure STP-03-6
Perforated Riser Pipe Sizing
(Dry Detention Pond with 40-hour Drain Time of Capture Volume)



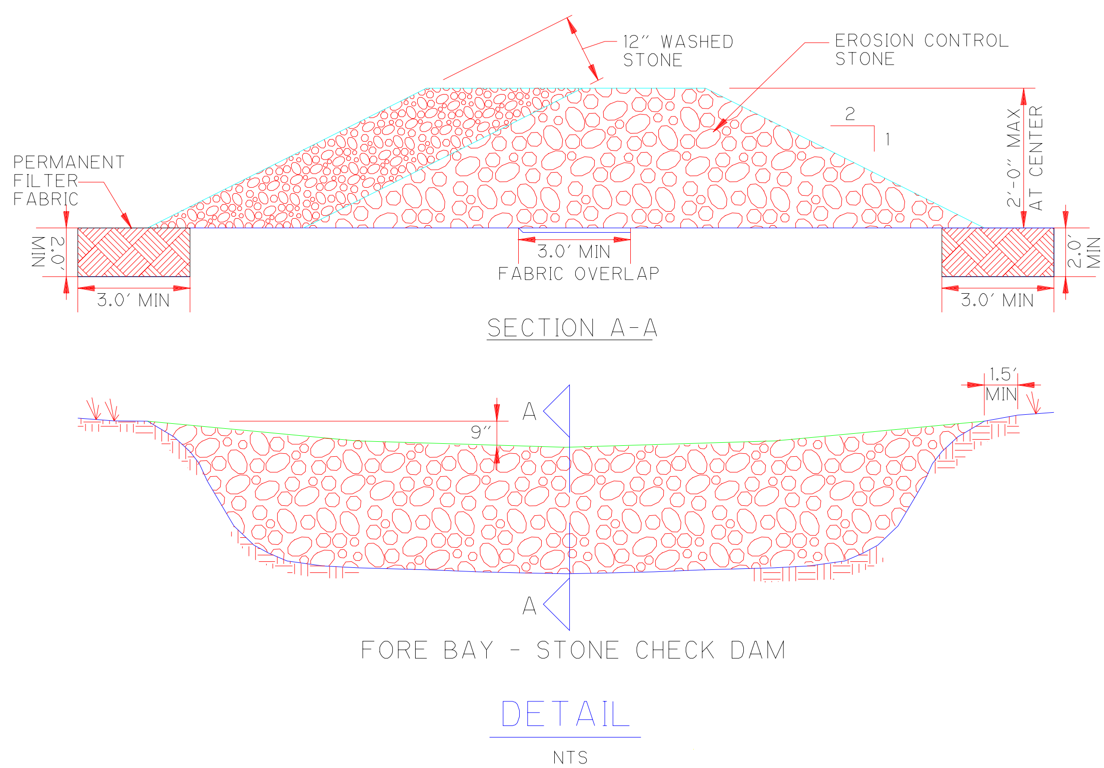


Figure STP-03-7
Dry Detention Pond Layout Details

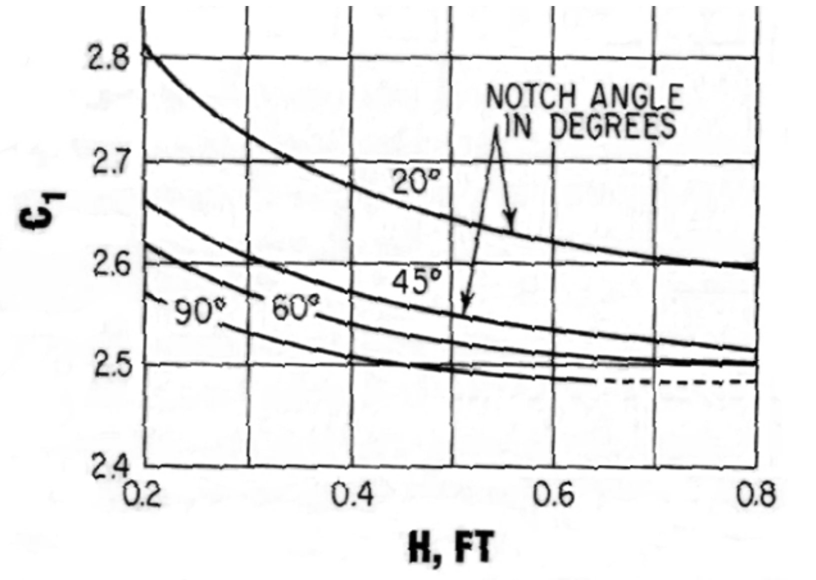


Figure STP-03-8
Sharp-Crested "V" Notch Weir Discharge Coefficients

Activity: Constructed Wetlands

PLANNING CONSIDERATIONS:

Acreage Needed: Significant

Estimated Unit Cost: Avg: $.50 per CF of Storage

Monthly Maintenance: 3% of Capital Costs

CW

Target Pollutants

Significant ♦ Partial ◈ Low or Unknown ◊

Sediment ♦ Heavy Metals ♦ Nutrients ♦ Oxygen Demanding Substances ♦ Toxic Materials ♦
Oil& Grease ♦ Bacteria & Viruses ◊ Floatable Materials ♦ Construction Waste ◊

Description

Constructed wetlands have a significant percentage of the facility covered by wetland vegetation. This management practice is likely to provide significant reductions in sediment, nutrients, heavy metals, toxic materials, floatable materials, oxygen demanding substances, oil and grease, as well as a partial reduction in bacteria and viruses.

Suitable Applications

- Need to achieve high level of particulate and some dissolved contaminant removal.
- Ideal for large, regional tributary areas.
- Multiple benefits of passive recreation and wildlife.
- Although natural wetlands are being used to treat stormwater, regulatory agencies do not favor this use, except as a final "polishing" step after treatment by one or more of the treatment control BMPs presented in this manual. Constructed wetlands, in contrast, are built specifically for treating stormwater runoff. They are not wetlands created as mitigation for the loss of natural wetlands. Consequently, there is no intention to replicate the complete array of ecological functions of a wetland (e.g., the presence of wildlife), although it can be done. A constructed wetland is generally one of better aesthetics than the treatment systems. It is likely that constructed wetlands will be used only in very large industrial sites, but small facilities with concrete retaining walls to conserve space will also likely be effective.

STP-04

Activity: Constructed Wetlands

Design and Sizing Considerations

- These systems should be designed by a licensed professional civil engineer.
- Suitable soils for wetland vegetation.
- Surface area equal to at least 1% and preferably 2% of the tributary watershed. Surface area greater than about 1 or 2% of the tributary watershed is not justified, given the uncertainty of any improvement in performance with the increase in size.
- A Forebay, baffle box, or other stormwater quality inlets are often required to remove floatable debris and course sediments.
- The simplest form of a constructed wetland includes a basin with a forebay and wetland vegetation area. The deeper forebay (3 to 6 feet) traps floatables and the larger settleable solids, facilitating maintenance as well as protecting the wetland vegetation. Alternatively, a detention pond may be placed before the wetland, to remove settleable solids and to protect the wetland from extreme increases in water elevation. The wetland vegetation is placed in a shallow pool that extends laterally across the basin. Construction of low flow channels through emergent vegetation can cause stormwater to short circuit through channels rather than through the wetland vegetation.
- Placing rooted wetland species through the majority of the facility adds to the cost, in comparison to a wet pond. However, it is believed by many practitioners that the vegetation improves performance. Placing the vegetation across the facility improves settling of particulates and uptake of dissolved contaminants. As the constructed wetland is shallower than a wet pond, there may be better contact between the water and soil which may be the primary remover of dissolved phosphorus and metals.
- The vegetation reduces the effect of wind which can cause significant short-circuiting in a wet pond. Water loss in a wetland may not be greater and possibly less than a wet pond. Evapo-transpiration from the plants will be greater in a wetland but evaporation from the water surface may be less because the dense vegetation eliminates the effect of the wind. The net result may be a slower rate of water loss. Conceivably a constructed wetland could be made smaller than a wet pond, given the benefits of the vegetation.
- Relying on volunteer plants to cover the vegetated area will delay complete coverage for several years and may allow the invasion of undesirable species or dominance by one or two species such as cattails which tend to flourish in disturbed conditions. Complexity is promoted by varying water depth through the vegetated area rather than keeping the depth uniform.
- Using gravel as the substrate may be a suitable approach in small facilities. Because the gravel is lacking in nutrients certain emergent species will take their nutrients from the water (Thut, 1988). See Reddy and Smith (1988). Harvesting may also be more practical with this approach.

Design and Sizing Considerations (Continued)

- Of particular concern in many areas will be mosquitoes. Thick stands of emergent vegetation provide an ideal breeding habitat. If Gambusia (mosquito fish) are introduced into the facility the design must include a deep pool area where the fish can reside during the dry season. The forebay can serve this function.

- The facility can be sized using the same procedure outlined for Wet Detention Ponds, STP-02. However, inasmuch as a wetland is shallower than a wet pond, sizing the wetland for the same V_b/V_r as a wet pond requires considerably more surface area. Given the likely advantages of a constructed wetland over a wet pond, some may consider this to be an unreasonable penalty. It is therefore recommended that the surface area of the constructed wetland not exceed that which would be determined for a wet pond.

- Additional design considerations include:
- Have 25% to 50% (forebay and afterbay) 3 to 6 ft. deep, and remaining area 6 in. to 24 in. deep or as appropriate for the wetland species selected. This geometry should provide satisfactory conditions for wetland wildlife (Adams et al., 1983).
- Side slopes of at least 4:1 (H: V) to a water depth of 2 ft. except on very small facilities where retaining walls may be used to conserve space. If retaining walls are used, the area must be fenced for safety.
- Access for maintenance vehicles to the forebay, the outlet, and around the perimeter.
- Freeboard of at least 2 feet.
- With earthen contained facilities, install an antiseep collar on the outlet pipe.
- The soils must be suitable for wetland vegetation. If necessary, organic soils (18 to 24 in.) must be imported to the site.
- The soil must have an affinity for phosphorus. Soils with aluminum and iron are best. Soils saturated with phosphorus or a metal specie may cause the concentrations of these contaminants to increase in the overlying water.
- Minimize short-circuiting by placing energy dissipaters at the inlet, and by having a high length to width ratio.
- Short-circuiting must be minimized by using a generally rectangular or irregular shaped configuration with a length to width ratio of at least 3:1 to 7:1 and by placing the inlet and outlet at opposite ends. The inlet and outlet can be placed at the same end if baffling (islands) is installed to direct the water to the opposite end before returning to the outlet. If topography or aesthetics requires the wetland to have an irregular shape, the wetland area and volume should be increased to compensate for the dead spaces. Energy dissipaters and entrance baffles will spread the water laterally across the facility.
- Minimize water loss by infiltration through the wetland bottom.
- Supplemental water may be needed to avoid loss of rooted vegetation during the dry period.

Design and Sizing Considerations (Continued)

- To maintain the wet pool to the maximum extent possible excessive losses by infiltration through the bottom must be avoided. Depending on the soils, this can be accomplished by compaction, incorporating clay into the soil, or an artificial liner. Wetland vegetation species have evolved to handle the stress of seasonal variations in water availability. However, during the dry season there must be sufficient water to avoid complete desiccation of plant roots. Consequently, constructed wetlands are infeasible in areas where there is a lack of either a base flow or near-surface ground water during the dry season. Supplemental water such as pumped ground water and treated process wastewater may have to be used.

- Constructed wetlands may not need antivortex and trash rack devices on their outlets like a wet pond because of the rooted vegetation. See STP-02, Wet Detention Ponds regarding inlet design. Design concepts for outlet devices are discussed in STP-02 and 3, Detention Ponds. See Josselyn (1982) regarding wetland plant considerations. Establishing wetland vegetation initially may be difficult and require multiple plantings.

- Another consideration is the regulatory implications of removing accumulated material from constructed wetlands. Some actions will require a 404 or other permit. At present, constructed wetlands are excluded from this requirement (Ritchie, 1992).

Maintenance

- Remove foreign debris and sediment build-up.

- Areas of bank erosion should be repaired.

- Remove nuisance species.

- Check at least annually and after each extreme storm event.

- Clean deposits from the forebay when a loss of capacity is significant, probably every 3 to 5 years depending on the land use, or when the concentrations of toxicants in the sediments are reaching a level of concern. If baffle boxes are used instead of a forebay, it will require annual inspection. If a stormwater quality inlet(s) is used, then it will require inspections every 6 months.

Sediment Removal

- A primary function of STPs is to collect sediments. The sediment accumulation rate is dependant on a number of factors including watershed size, facility sizing, construction upstream, industrial or commercial activities upstream, etc. The sediment contents should be identified before it is removed and disposed.

- Some sediment may contain contaminants of which the Indiana Department of Environmental Management (IDEM) requires special disposal procedures. If there is any uncertainty about what the sediment contains or it is known to contain contaminants, then IDEM should be consulted and their disposal recommendations followed. Generally, special attention or sampling should be given to sediments accumulated in facilities serving industrial, manufacturing or heavy commercial sites, fueling centers or automotive maintenance areas, large parking areas, or other areas where pollutants (other than “clean” soil) are suspected to accumulate and be conveyed via storm runoff.

Activity: Constructed Wetlands

Maintenance (Continued)

- Some sediment collected may be innocuous (free of pollutants other than "clean" soil) and can be used as fill material, cover or land spreading. It is important that this material not be placed in a way that will promote or allow resuspension in storm runoff. The sediment should not be placed within the high water level area of the STP, other BMP, creek, waterway, buffer, runoff conveyance device, or other infrastructure. Some demolition or sanitary landfill operators will allow the sediment to be disposed at their facility for use as cover. This generally requires that the sediment be tested to ensure that it is innocuous.

- There is some question as to whether annual harvesting of rooted vegetation is either practical or effective at reducing seasonal losses of nutrients and prolonging the life of the facility (USEPA, 1988). The benefits of harvesting may depend upon the wetland specie (Suzuki, T. et al., 1991). Placing rooted vegetation in gravel beds rather than soil may make harvesting practical. If harvesting is to be done, it should occur twice per season, in the early summer when nutrient content in the plant material is at its peak, and in the fall before plant dormancy. Given the significant role of the bottom soil in removing metals and phosphorus its replacement may be required, although, probably not more frequently than once every few decades. Cleaning the forebay more frequently is important as noted above.

Inspection Checklist

- Concern for mosquitoes.
- Cannot be placed on steep unstable slopes.
- Need base flow to maintain water level.
- Not feasible in densely developed areas.
- Nutrient release may occur during winter.
- Overgrowth can lead to reduced hydraulic capacity.
- Regulatory agencies may limit water quality to natural wetlands.
- Establishing wetland vegetation may be difficult.
- Wetlands are generally shallower than wet ponds and result in larger area requirements.
- Costs for providing supplemental water may be prohibitive.

Activity: Biofilter, Swales and Strips

BF

BF

PLANNING CONSIDERATIONS:

Design Life:
Permanent

Acreage Needed:
Varies

Estimated Unit Cost:
Avg: $100 per LF
Range: $50-$150 per LF

Monthly Maintenance:
10% of Installation

Target Pollutants		
Significant ♦	Partial ◈	Low or Unknown ◊

Sediment ♦ Heavy Metals ♦ Nutrients ◈ Oxygen Demanding Substances ◈ Toxic Materials ♦
Oil& Grease ♦ Bacteria & Viruses ◊ Floatable Materials ◈ Construction Waste ◊

Description

There are two types of biofilters: swales and filter strips. A swale is a vegetated channel that treats concentrated flow. A filter strip treats sheet flow and is placed parallel to the contributing surface. This management practice is likely to provide a significant reduction in sediment, heavy metals, toxic materials, oil and grease and partial reductions in nutrients, floatable materials, and oxygen demanding substances.

Suitable Applications

- Biofilters are often used in conjunction with other stormwater management practices.
- Biofilters are often placed along or serve parking lots. See Figure STP-05-2 for an illustration of how swales draining to slightly raised inlets can be used as pretreatment.
- Performance somewhat less than wet ponds and constructed wetlands.
- Limited to treating a few acres.
- Minimizing DCIA (directly connected impervious areas) involves ensuring that as much runoff as possible from impervious areas is routed over relatively large pervious areas and, in some cases, choosing an alternative surface to pavement or concrete that allows for some degree of infiltration. Figure STP-05-3 is an illustration of an example parcel that has been modified to convert a portion of the DCIA into non-directly connected impervious area by rerouting the roof gutters over the lawn (properly graded between houses) and to convert a portion of the DCIA to pervious area by using a porous surface.

Activity: Biofilter, Swales and Strips

Suitable Applications

- Landscaped swales can be used around parking lots, houses, and other structures. The swales will provide pretreatment and also provide conveyance to larger secondary or primary stormwater management systems.

- Connections from the curbs to roadside swales can be provided to route street flow to grass-lined swales before discharge to the secondary or primary stormwater management system. Since roadway runoff may contain a greater pollutant load than runoff from most other surfaces, providing swale pretreatment of roadway runoff will reduce pollutant loads to the regional ponds and improve the overall efficiency of the BMP treatment train. The swale space required for pretreatment of roadway runoff in roadside swales can be incorporated into green space requirements and be used to enhance the aesthetics of the roadways.

Design and Sizing Considerations

- These systems should be designed by a licensed professional civil engineer.

- A biofilter swale is a vegetated channel that looks similar to, but is wider than, a ditch that is sized only to transport flow. The biofilter swale must be wider to maintain low flow velocities and to keep the depth of the water below the height of the vegetation up to a particular design event. A filter strip is placed along the edge of the pavement (its full length if possible). The pavement grade must be such as to achieve sheet flow to the maximum extent practical along the strip.

- The type of filter strip discussed here is not to be confused with the natural vegetated buffer strip used in residential developments to separate the housing from a stream.

- Properly designed swales are useful for proper grading around houses as well as detention / retention prior to discharge into a secondary or primary system. Fill from the shallow swale area may be used elsewhere on the property to improve the grading plan. Landscaped swales would typically be 0.5 to 1.0 foot deep and should have side slopes no steeper than 4:1 (H:V), with side slopes of 6:1 (H:V) or greater being less noticeable and more attractive.

- Grass-lined swales may be constructed around parking lots and commercial centers as recessed planters for landscaping. The swales could be part of the landscaping and would incorporate raised inlets (4 to 6 inches) into the design, which will allow for the initial 0.25 inch retention volume for pretreatment. Although groundwater tables in the developable area are generally within 1 to 2 feet of the surface, recovery times for retention volumes of approximately 0.25 inches should be sufficiently small to allow the use of limited retention. Minimum infiltration rates of 0.1 inch/ hour are expected, allowing a relatively quick drawdown. Swales incorporated within commercial areas can enhance aesthetics and be used as credit towards green space and landscaping requirements. Figure STP-05-2 shows an example of a landscaped swale with a raised inlet. These landscaped swales use runoff to water plants and improve aesthetics.

Design and Sizing Conditions (Continued)

- The connections between the curb and the swale can be implemented in two ways. The first method is to provide regularly spaced flumes in the curb as the connection to the swale. This method would be less expensive and will be aesthetically appealing (Figure STP-05-4). Another way is to provide a 4- to 6-inch diameter pipe approximately every 200 feet between the curb and the swale. This method may provide better erosion control at the edge of the curb by preventing flowing water over the interface of the curb and the swale. The disadvantage to this method is the potential for clogging, and thus the requirement for increased maintenance, in these small pipes.

- The problem of spreading the flow across the width of the swale may limit its use to tributary catchments of only a few acres.

- The length of pavement prior to the filter strip should not exceed a few hundred feet to avoid channelization of large aggregates of runoff along the pavement before it reaches the pavement edge. To avoid channelization, care must be taken during construction to make sure that the cross-section of the biofilter is level and that its longitudinal slope is even. Channelization will reduce the effective area of the biofilter used for treatment and may erode the grass because of excessive velocities.

- The design engineer must determine the width of a swale using Manning's Equation and the 2-year rainfall intensity appropriate to the site. An n value of 0.20 to 0.24 is recommended depending on the expected height of the turf (dependent upon mowing frequency). The design engineer must also calculate the peak flow of the 100-year event to determine the depth of a swale to convey flood flows. Since a width using an "n" of 0.20 is generally wider than what is required of a grass lined channel, channel stability should not be of concern. It is generally not necessary to have a bypass for the extreme events because the minimum width specification limits erosive velocities if there is a relatively gentle slope. If erosion at extreme events is of concern, consider the above concepts to minimize erosion. The design engineer can make the swale wider than determined in the above step, with a corresponding shortening of the swale length to obtain the same surface area. However, there is a practical limitation on how wide the swale can be and still be able to spread the flow across the swale width.

- Splitting the flow into multiple inlets and/or placing a flow spreader near the storm inlet should be incorporated into the design. A concept that may work is to place a level 2" x 12" timber or equivalent concrete, aluminum or gravel structure across the width of the swale 8-15 feet from the pipe outlet. Place gravel between the outlet and the timber, to within 2 inches or so of the top of the timber. Place large rock immediately near the outlet to dissipate the flow energy: the rock also may help distribute the flow.

- Residence time for "maximized" captured runoff should be at least 5 minutes. See STP-01 for discussion of "maximized" capture runoff. Use a runoff coefficient of C=1.0 assuming complete runoff and no infiltration.

Activity: Biofilter, Swales and Strips

Design and Sizing Conditions (Continued)

- The maximum velocity should be no more than 0.9 ft/sec.
- Maximum bottom width of 8 ft unless level spreaders are installed frequently (every 50 feet).
- Average depth of flow should be no more than 1.0 in. and maximum depth should be no more than 3 in. for grass or approximately 2 in. below the height of the shortest wetland plant species in the biofilter. Furthermore, the maximum flow depth should be no greater than one-third of the gross or emergent wetland vegetation height for infrequently moved swales or greater than one-half of the vegetation height for regularly mowed swales.
- The minimum width for a swale is determined by Manning's Equation.
- Minimum length of a swale is 100 feet unless level spreaders are used at least every 50 feet or as necessary to prevent flow channelizations.
- Minimum length of a filter strip is 10 feet
- Maximum length without a level spreader is 80 feet for a filter strip or swale.
- The longitudinal slope must not exceed 5%.
- Use a flow spreader and energy dissipater at the entrance of a swale.
- Good soils are important to achieve good vegetation cover.
- WEF Manual of Practice No. 23 / ASCE Manual and Report on Engineering Practice No. 87 (1998) should be consulted for additional guidance on the design, construction, and maintenance of biofilters.

Maintenance

- Achieve sheet flow with filter strips.
- The facility should be checked annually for signs of erosion, vegetation loss, and channelization of the flow.
- The grass should be mowed when it reaches a height of 8 inches. Allowing the grass to grow taller may cause it to thin and become less effective. The clippings should be bagged and removed.
- Keep all level spreaders even (level) and free of debris.
- Mow grass covered biofilters regularly to promote growth and pollutant uptake. Remove cuttings and dispose of properly (preferably through composting).

Activity: Biofilter, Swales and Strips

STP-05

Maintenance (Continued)

- Remove sediment by hand with a flat-bottomed shovel during dry periods.
- Remove only the amount of sediment necessary to restore hydraulic capacity, leaving as much of the vegetation in place as possible. Reseed or plug any damaged turf or vegetation.
- Eventually, sufficient sediment will be trapped that the entire biofilter will need to be removed with sediment and reconstructed to begin a new cycle of stormwater quality control.

Sediment Removal

- A primary function of STPs is to collect sediments. The sediment accumulation rate is dependant on a number of factors including watershed size, facility sizing, construction upstream, industrial or commercial activities upstream, etc. The sediment contents should be identified before it is removed and disposed.
- Some sediment may contain contaminants of which the Indiana Department of Environmental Management (IDEM) requires special disposal procedures. If there is any uncertainty about what the sediment contains or it is known to contain contaminants, then IDEM should be consulted and their disposal recommendations followed. Generally, special attention or sampling should be given to sediments accumulated in facilities serving industrial, manufacturing or heavy commercial sites, fueling centers or automotive maintenance areas, large parking areas, or other areas where pollutants (other than "clean" soil) are suspected to accumulate and be conveyed via storm runoff.
- Some sediment collected may be innocuous (free of pollutants other than "clean" soil) and can be used as fill material, cover or land spreading. It is important that this material not be placed in a way that will promote or allow resuspension in storm runoff. The sediment should not be placed within the high water level area of the PTP, other BMP, creek, waterway, buffer, runoff conveyance device, or other infrastructure. Some demolition or sanitary landfill operators will allow the sediment to be disposed at their facility for use as cover. This generally requires that the sediment be tested to ensure that it is innocuous.
- The grass should be mowed no shorter than 3 inches.

Inspection Checklist

- ☐ Poor performance occurs when the swale or filter strip is undersized, or when runoff is allowed to channelize in the swale or filter strip.
- ☐ Cannot be placed on steep slopes.
- ☐ Proper maintenance required to maintain health and density of vegetation.

COLD TOLERANCE (winter color persistance)

High
- Creeping bentgrass
- Kentucky bluegrass
- Red fescue
- Colonial bentgrass
- Highland bentgrass
- Perennial ryegrass
- Tall fescue
- Weeping alkaligrass
- Dichondra
- Zoysiagrass
- Common bermudagrass
- Hybrid bermudagrass
- Kikuyugrass
- Seashore paspalum
- St. Augustinegrass

Low

HEAT TOLERANCE

High
- Zoysiagrass
- Hybrid bermudagrass
- Common bermudagrass
- Seashore paspalum
- St. Augustinegrass
- Kikuyugrass
- Tall fescue
- Dichondra
- Creeping bentgrass
- Kentucky bluegrass
- Highland bentgrass
- Perennial ryegrass
- Colonial bentgrass
- Weeping alkaligrass
- Red fescue

Low

MOWING HEIGHT ADAPTATION

High cut
- Tall fescue
- Red fescue
- Kentucky bluegrass
- Perennial ryegrass
- Weeping alkaligrass
- St. Augustinegrass
- Common bermudagrass
- Dichondra
- Kikuyugrass
- Colonial bentgrass
- Highland bentgrass
- Zoysiagrass
- Seashore paspalum
- Hybrid bermudagrass
- Creeping bentgrass

Low Cut

DROUGHT TOLERANCE

High
- Hybrid bermudagrass
- Zoysiagrass
- Common bermudagrass
- Seashore paspalum
- St. Augustinegrass
- Kikuyugrass
- Tall fescue
- Red fescue
- Kentucky bluegrass
- Perennial ryegrass
- Highland bentgrass
- Creeping bentgrass
- Colonial bentgrass
- Weeping alkaligrass
- Dichondra

Low

MAINTENANCE COST AND EFFORT

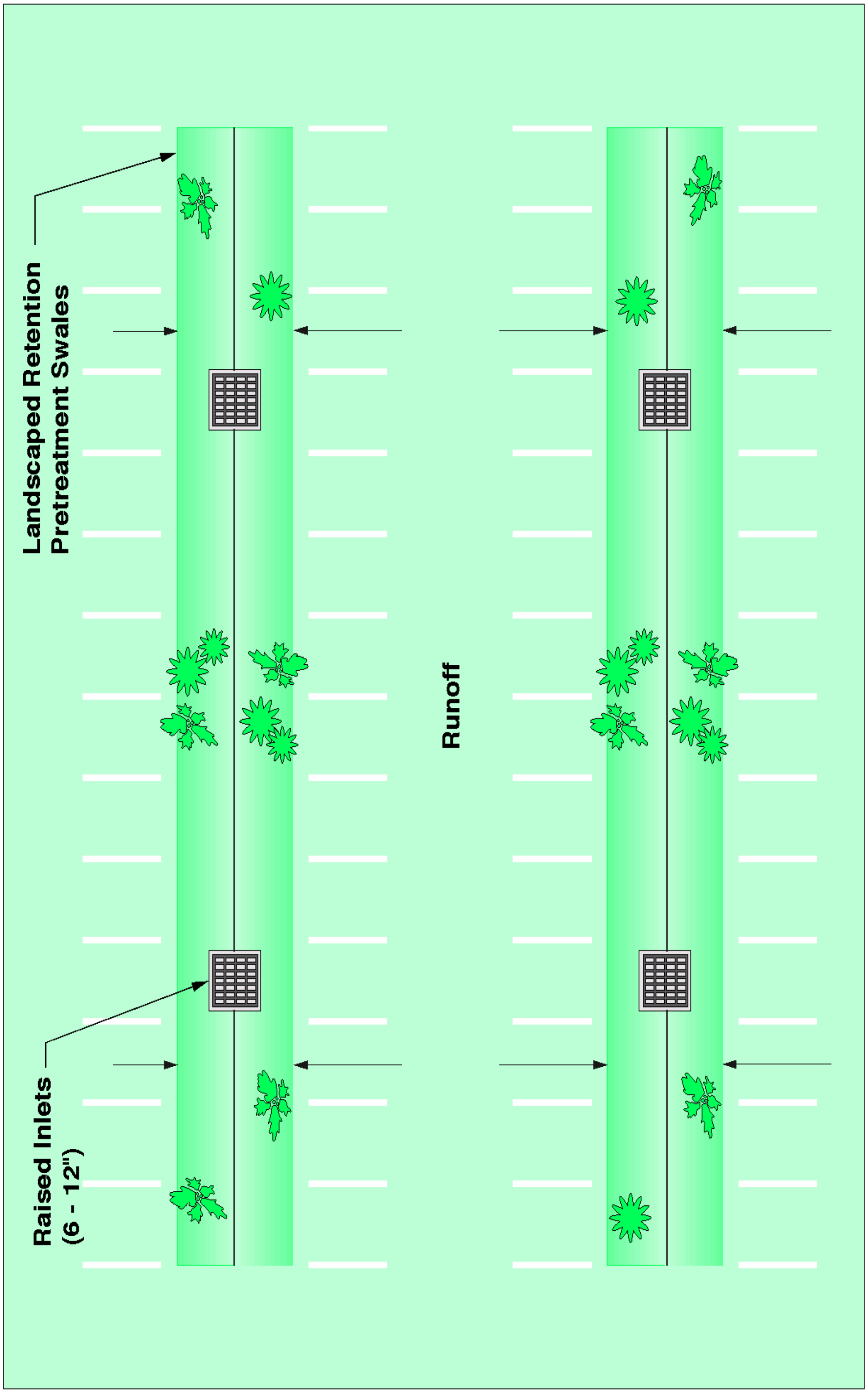
High
- Creeping bentgrass
- Dichondra
- Hybrid bermudagrass
- Kentucky bluegrass
- Colonial bentgrass
- Seashore paspalum
- Perennial ryegrass
- St. Augustinegrass
- Highland bentgrass
- Zoysiagrass
- Tall fescue
- Common bermudagrass
- Kikuyugrass

Low

Note: Consult *Landscaping with Native Plants – Middle Tennessee Central Basin and Highland Rim,* Tennessee Exotic Pest Plant Council, May 1998.

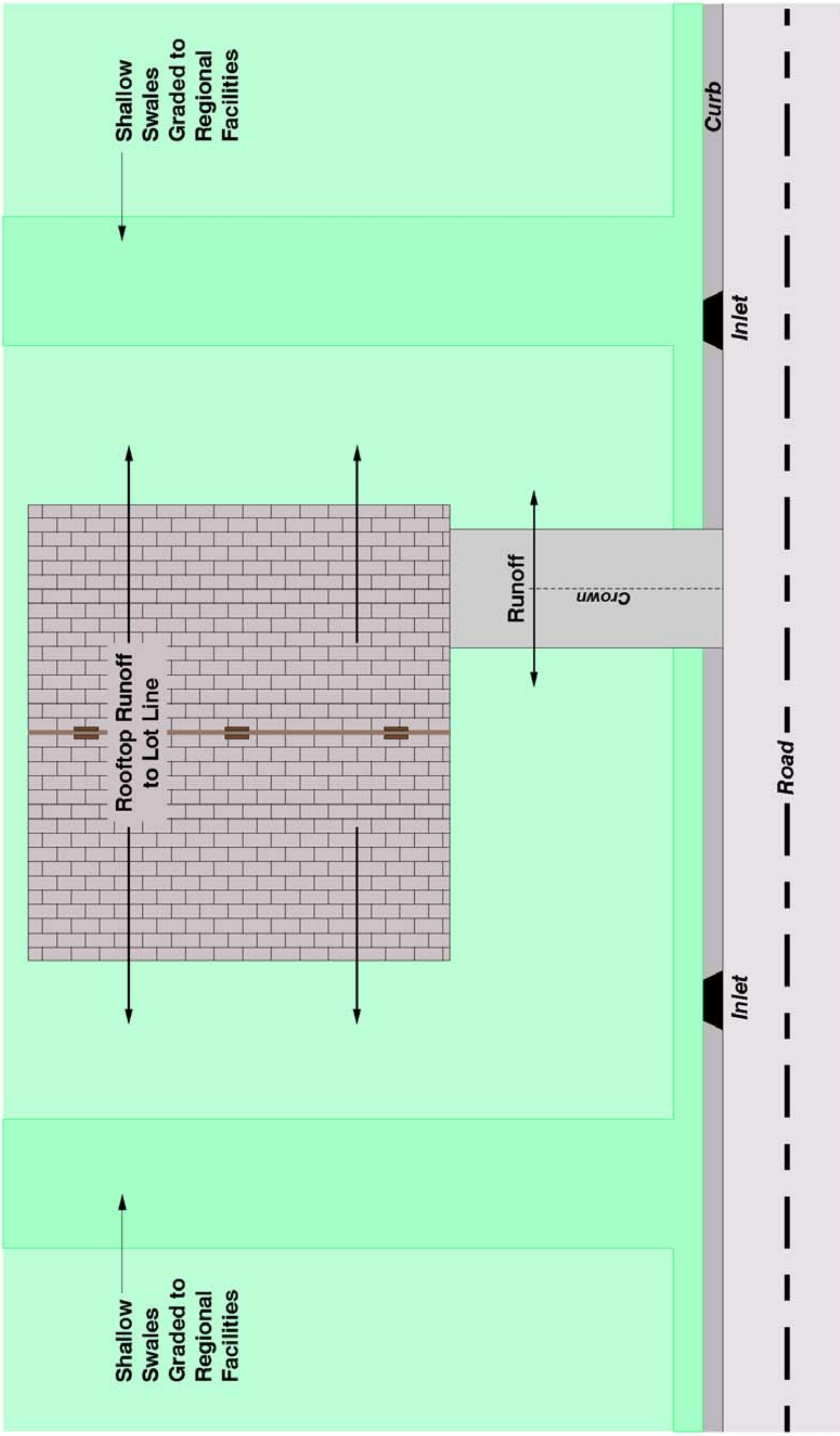
FIGURE STP-05-1
TURF GRASS SPECIES

Activity: Biofilter, Swales and Strips



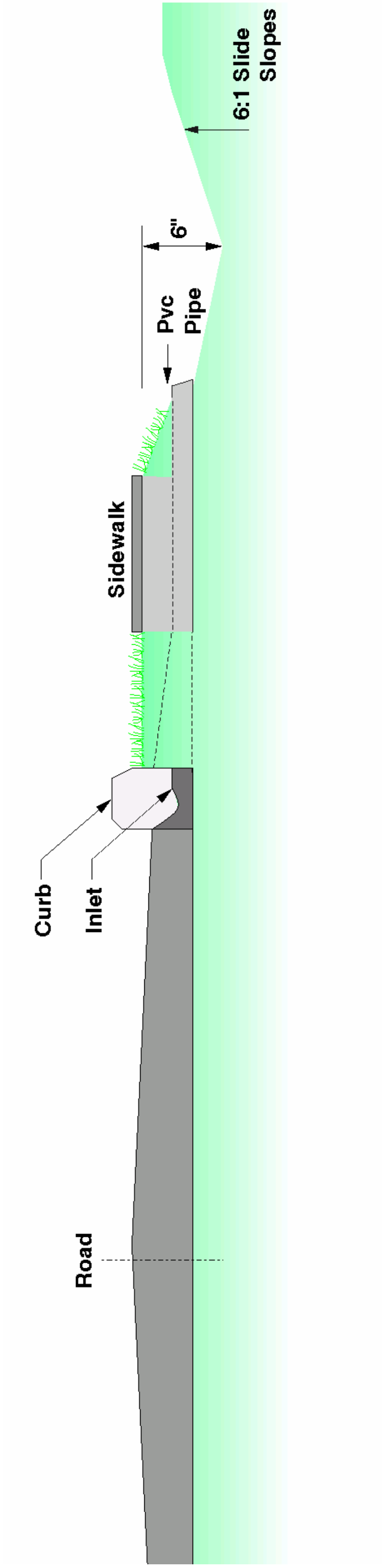
Source: City of Nashville

Figure STP-05-2
Landscaped Retention Pretreatment Swales
With Raised Inlets



Source: City of Nashville

Figure STP-05-3
Landscaped Retention Pretreatment Swales
With Raised Inlets



Source: City of Nashville

Figure STP-05-4
Roadside Swalse

New Albany, Indiana
Stormwater Best Management Practices (BMPs)
Stormwater Pollution treatment Practices (STPs)

STP-06

Activity: Media Filtration/Media Filters and Water Quality Inlets

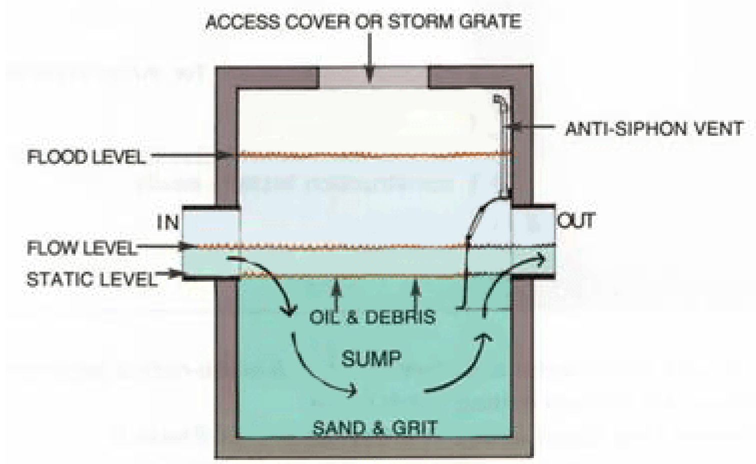
PLANNING CONSIDERATIONS:

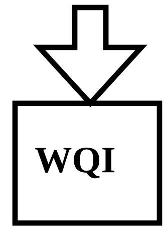
Design Life:
Permanent

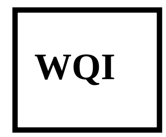
Acreage Needed:
Minimal

Estimated Unit Cost:
N/A

Monthly Maintenance:
N/A







Target Pollutants

Significant ♦ Partial ◈ Low or Unknown ◊

Sediment ♦ Heavy Metals ◊ Nutrients ◊ Oxygen Demanding Substances ◊ Toxic Materials ◊
Oil& Grease ◊ Bacteria & Viruses ◊ Floatable Materials ◊ Construction Waste ◊

Description

Consists of a settling basin followed by a filter. The most common filter media is sand; some use peat/sand or filter cloth, sorbent materials and other commercial available mixtures. This management practice is likely to create a significant reduction in sediment, heavy metals, oil and grease, and floatable materials and partial reductions in nutrients, toxic materials, and oxygen demanding substances, and bacteria and viruses. It is important that these systems “dry out” between storm events to allow oxidation of pollutants.

This BMP fact sheet discusses general uses of filters and separators in the form of simple catch basin inserts to complex multi-chambered and multi-staged filters. The practices presented in STP-07: Oil/Water Separators should also be reviewed.

Some of the systems presented in this BMP fact sheet represent or are similar to commercially available products. This fact sheet is not intended to demonstrate a preference by the Engineering Department toward a particular manufacturer. However, this fact sheet does describe the types of products known to be available, the Engineering Department’s understanding of their suitability and general effectiveness.

Suitable Applications

- The various systems discussed in this fact sheet should be selected based on the targeted constituents, site area constraints, cost and frequency of maintenance, and inspection requirements. Many of the systems are readily available in a variety of layouts through commercial vendors.

Activity: Media Filtration/Media Filters and Water Quality Inlets	STP-06

Suitable Applications (Continued)

- One of the most important selection criteria that must be evaluated is the ability to bypass or convey large storm events without damaging the system, exceeding design flow capacity or re-suspending collected pollutants. See figure STP-06-1.

  - Another very important selection criterion is consideration of long-term inspection and maintenance resources. If there is not a plan to regularly inspect and maintain the selected system on a long-term basis, and a fiscal guarantor that the required maintenance resources will be available for the life of the system, then the system should not be installed. If these types of systems are not periodically inspected, cleaned, and otherwise maintained, they will fail and could result in more intense impacts to stormwater quality than if they were not installed at all.
  - Can be placed underground.
  - Some systems are suitable for individual developments and small tributary areas up to about 100 acres.
  - Some water quality inlets (or separators) can be used as pretreatment for filters, ponds, wetlands or biofilters.
  - May require less space than other treatment control BMPs.
  - Sand or cartridged media filters may be particularly suitable for industrial sites because they can be located underground and industrial facilities generally have the resources to routinely inspect and maintain the systems.
  - Sand and cartridged media filtration systems are suitable for commercial or other dense / highly impervious land uses provided there is a plan and sufficient resources to inspect and maintain the systems.

- Separators and separator / filter systems are suitable for smaller catchments including parking and roadways where sediment, trash, or other debris may collect.

- Some separators and separator / filter systems have some success in capturing oil and grease. However, it should be noted that these systems generally require more frequent inspection and maintenance. If the systems can be easily inspected and maintained, then they are suitable for small catchments in parking lots and roadways. It should be noted that in areas frequently receiving oil and grease oil / water separator system, as discussed in STP-07, should be considered.

- The most experience to date is with surface facilities shown conceptually in Figure STP-06-2 with a sand media. It can be used on catchments up to 50 acres.

Suitable Applications (Continued)

- Two other systems are most suitable for small catchments of a few acres. An underground "linear" filter (Figure STP-06-3) that accepts sheet flow from adjacent pavement. It, therefore, may be ideal for industrial applications. An underground design, the vault sand filter (Figure STP-06-3), may also be ideal for industrial developments. It accepts concentrated flow.

- Both underground systems presented in STP-06-3 require a pretreatment device such as a wet vault or other separation system as illustrated in Figures STP-06-4 through 8. It is essentially a conventional gravity separator but without the appropriate geometric configuration. They have been found to be generally ineffective because the recommended size (200 to 400 ft^3/acre of tributary area) is too small. To be effective, a water quality inlet must have the surface area and volume that is similar to that of conventional separators. They may exhibit odor problems during the summer because of the lack of bacterial degradation of accumulated organic matter and the lack of re-aeration of the wet pool. Some facilities have been observed to have odor, but it has been noticeable only when the system is opened for inspection.

- The concepts illustrated in Figures STP-06-8, 9, and 10 can be inserted into catch basins. They should only be used where maintenance staff is available to check the filters frequently and where local flooding will not occur if the filters clog.

Design and Sizing Conditions

- These systems should be designed by a licensed professional civil engineer.

- The filtered separator systems are designed to be most effective under small or medium sized flows such as the "first flush". They generally are not effective under flooding conditions. Furthermore, some systems can be damaged or pollutants resuspended if operating under high flow or flooding conditions. To prevent overloading filter and separation systems, there should be a mechanism to bypass or divert large flows. Some commercially available systems have a high flow bypass built into the "device". Other systems, especially sand filters, must have a separate bypass or diversion device upstream. A diversion weir in a manhole is illustrated in Figure STP-06-1.

- Must be dry between events.

- Spread flow across filter in a way that minimizes pollutant resuspension and prevents damage to the system.

- It is preferable to place filters "off-line" with a diversion weir or catch basin to protect from extreme events.

Design and Sizing Conditions (Continued)

Determine the volume of the pretreatment unit

To size the pretreatment basin or water quality inlet, refer to the sizing methods for dry or wet detention (STP-02, 03). With the sand or carbrided media filter, the pretreatment basin need not be as efficient as a full size system. The pretreatment system, however, should be large enough to provide a removal efficiency that avoids rapid clogging of the filter. It is suggested that the volume of a wet vault be such as to achieve a removal efficiency of 50 to 75% of TSS.

The volume of a pretreatment unit can be decreased by reducing the drawdown time, which results in a lower but acceptable removal efficiency. The facility volume can be determined from STP-03 Dry Detention using a drawdown time of 24 hours.

Determining the size of Commercial Products

When using commercial products such as water quality inlets (separators and/or filters) the manufacturer's recommendations should be considered in the product sizing and applicability. Special attention should be given to high flow bypass or diversion requirement to ensure pollutants are not resuspended and that the systems' media will not be damaged or displaced.

Determining the surface area of a sand filter

The following equation is derived from the City of Austin (1988) for a maximum (full pretreatment basin) filtration time of 24 hours:

Filter area (ft^2) = $3630 S_u AH/K(D+H)$

where:

- S_u = unit storage (inches-acre) (See STP-02 or 03)
- A = area in acres draining to facility
- H = depth (ft) of the sand filter
- D = average water depth (ft) over the filter taken to be one-half the difference between the top of the filter and the maximum water surface elevation
- K = filter coefficient recommended as 3.5 (Austin)

Equation (1) is appropriate for the filter media size of 0.02 to 0.04 inches in diameter. The filter area must be increased if a smaller media is used (see Austin, Texas (1988)).

Configuring a surface sand filter (City of Austin concept).

Additional design criteria for the settling basin (Austin, 1988):

- For the outlet use a perforated riser pipe, as described in STP-02 or 03, Detention.
- Size the outlet orifice for a 24-hour drawdown.

Activity: Media Filtration/Media Filters and Water Quality Inlets	STP-06

Design and Sizing Conditions (Continued)

- Energy dissipater at the inlet to the settling basin.
- Trash rack at outlets to the filter.
- Vegetate slopes to the extent possible (see Vegetated Biofilters).
- Access ramp (4:1 (H:V) or less) for maintenance vehicles.
- One foot (0.3 m) of freeboard.
- Length to width ratio of at least 3:1 and preferably 5:1.
- Sediment traps at inlet to reduce resuspension.
- Additional design criteria for the filter:
- Use a flow spreader (Figure STP-06-2).
- Safety factor of 2.0.
- Filter cloth on top.
- Dry out time required.
- Use clean sand 0.02- to 0.04-inch (5 to 10 mm) diameter.
    - Some have placed geofabric on sand surface to facilitate maintenance.
    - Under drains (Figure STP-06-2).
    - Schedule 40 PVC.
    - 4 inch diameter.
    - 3/8-inch perforations placed around the pipe, with 6-inch space between each perforation cluster.
    - Maximum 10-foot spacing between laterals.
    - Minimum grade of 1/8" per foot.
    - Or other considerations recommended by the manufacturer of the water quality inlet.

Configuring a linear filter

Take the volume for the pretreatment unit and the filter area identified above and configure into a structure similar to that shown in Figure STP-06-3. The structural design in Figure STP-06-3 assumes traffic loads over the filter. The structure can be less robust if it is located along the edge of the pavement, away from traffic. Other recommendations (Shaver, 1991):

- Depth of sand 18"
- Diameter of the outlet pipe should be 6" or less; use multiple outlets if necessary

Design and Sizing Conditions (Continued)

The filter must be positioned relative to the pavement in a manner that evenly distributes the flow as it enters the sedimentation chamber. Pavement design and construction is therefore critical.

Configuring a wet vault filter

Similarly the volume of the wet vault and filter area are configured into a rectangular unit similar to that shown in Figure STP-06-3. Other considerations for the wet vault include:

- A length to width ratio of at least 3:1 to minimize short-circuiting.
- Baffles to reduce entrance velocities and to retain floatables.
- Access ports to facilitate maintenance.
- Depth of the wet pool of at least 3 feet but not more than 10 feet.

Catch basin insert

- The catch basin insert filter may be ideal for industrial sites as it can be placed in existing catch basins, and therefore may avoid the need for an "end-of-pipe" facility. The system is illustrated in Figure STP-06-8, 9, and 10. It consists of a series of trays or sorbent roles/tubes. The top tray is a sediment trap. Filter material is placed in the lower trays. Of several materials examined, the most suitable appears to be household fiberglass insulation. Limited tests indicate over 90% removal of metals and oil (McPherson, 1992). As the insert requires frequent attention it should only be used where a maintenance person is located on-site. The insert should have a bypass along one side should the filter material clog and is hydraulically designed so as to not compromise the primary purpose of a catch basin, to get stormwater into the drain system.

Maintenance

- Inspect filter systems at least twice annually or more often if watershed is excessively erosive. Clean or replace any media as needed to prevent clogging.
- Inspect separation systems at least quarterly or more often if there is a higher potential for sediment or debris accumulation.
- Inspect semiannually, and after major storms.
    - Sediment should be removed from the settling basin when 4 inches accumulates and from the filter when ½ inch accumulates, or when there is still water in the basin or over the filter 40 hours after the storm. Remove floatables.

Maintenance (Continued)

Sediment Removal

A primary function of STPs is to collect sediments. The sediment accumulation rate is dependant on a number of factors including watershed size, facility sizing, construction upstream, industrial or commercial activities upstream, etc. The sediment contents should be identified before it is removed and disposed.

Some sediment may contain contaminants of which the Indiana Department of Environmental Management (IDEM) requires special disposal procedures. If there is any uncertainty about what the sediment contains or it is known to contain contaminants, then IDEM should be consulted and their disposal recommendations followed Generally, special attention or sampling should be given to sediments accumulated in facilities serving industrial, manufacturing or heavy commercial sites, fueling centers or automotive maintenance areas, large parking areas, or other areas where pollutants (other than "clean" soil) are suspected to accumulate and be conveyed via storm runoff.

Some sediment collected may be innocuous (free of pollutants other than "clean" soil) and can be used as fill material, cover or land spreading. It is important that this material not be placed in a way that will promote or allow resuspension in storm runoff. The sediment should not be placed within the high water level area of the STP, other BMP, creek, waterway, buffer, runoff conveyance device, or other infrastructure. Some demolition or sanitary landfill operators will allow the sediment to be disposed at their facility for use as cover. This generally requires that the sediment be tested to ensure that it is innocuous.

- ➢ Failure to clean the filter regularly may result in the need to replace the entire media because of penetration of fines into the filter.
- ➢ It is more cost effective for pollutant removal over the long term to clean the filter fabric on top regularly as recommended.
- ➢ If there are open space areas in the tributary that are erosive or if construction is occurring, more frequent cleaning will be necessary.
- ➢ It will likely be necessary to replace the filter media after construction activity has ceased and the soils are stabilized.

Inspection Checklist

- ➢ Filter and separation systems may require more frequent maintenance than most of the other BMPs.
- ➢ These systems will contribute to a large head loss that may require special consideration in the hydraulic design of the overall stormwater collection system.
- ➢ Dissolved pollutants are not captured by sand.
- ➢ Potential for severe clogging or reduced pollutant removal efficiencies in filter systems if there are exposed soil surfaces upstream.

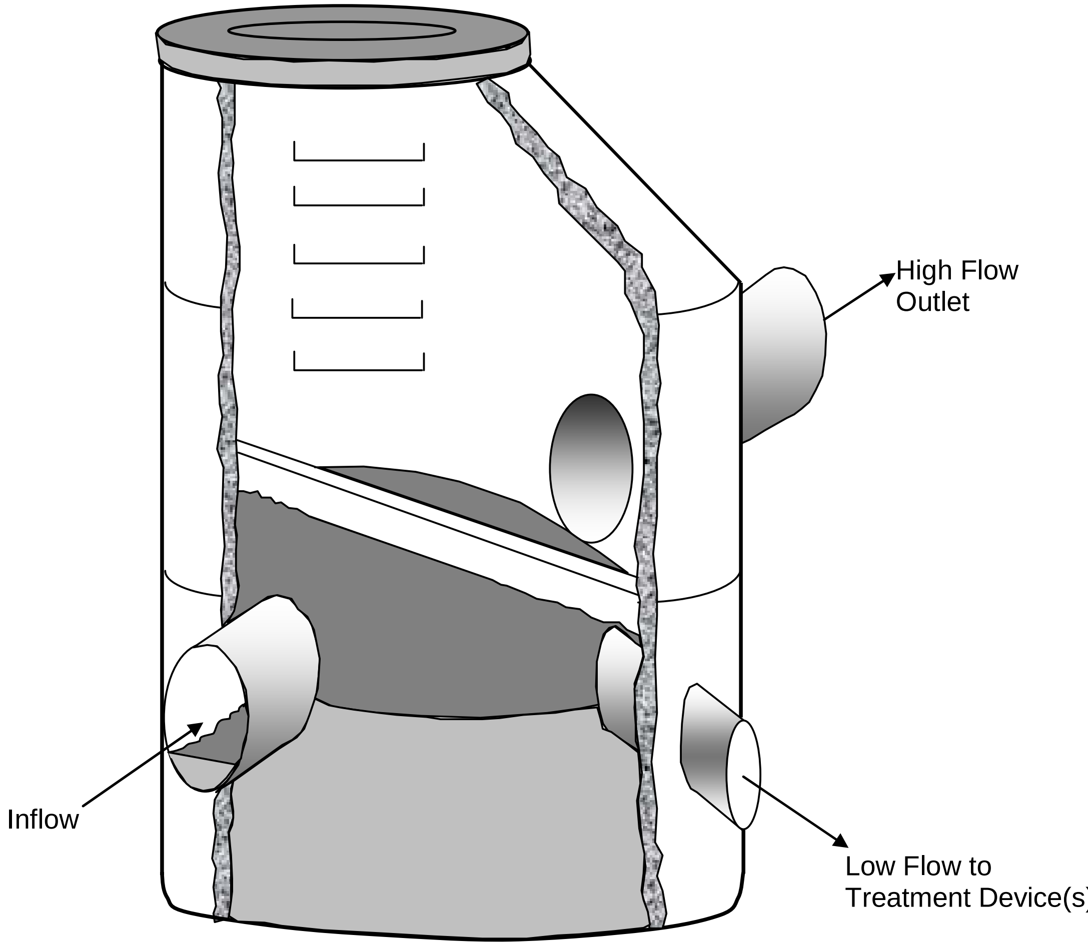


Figure STP-06-1
Stormwater High Flow Bypass

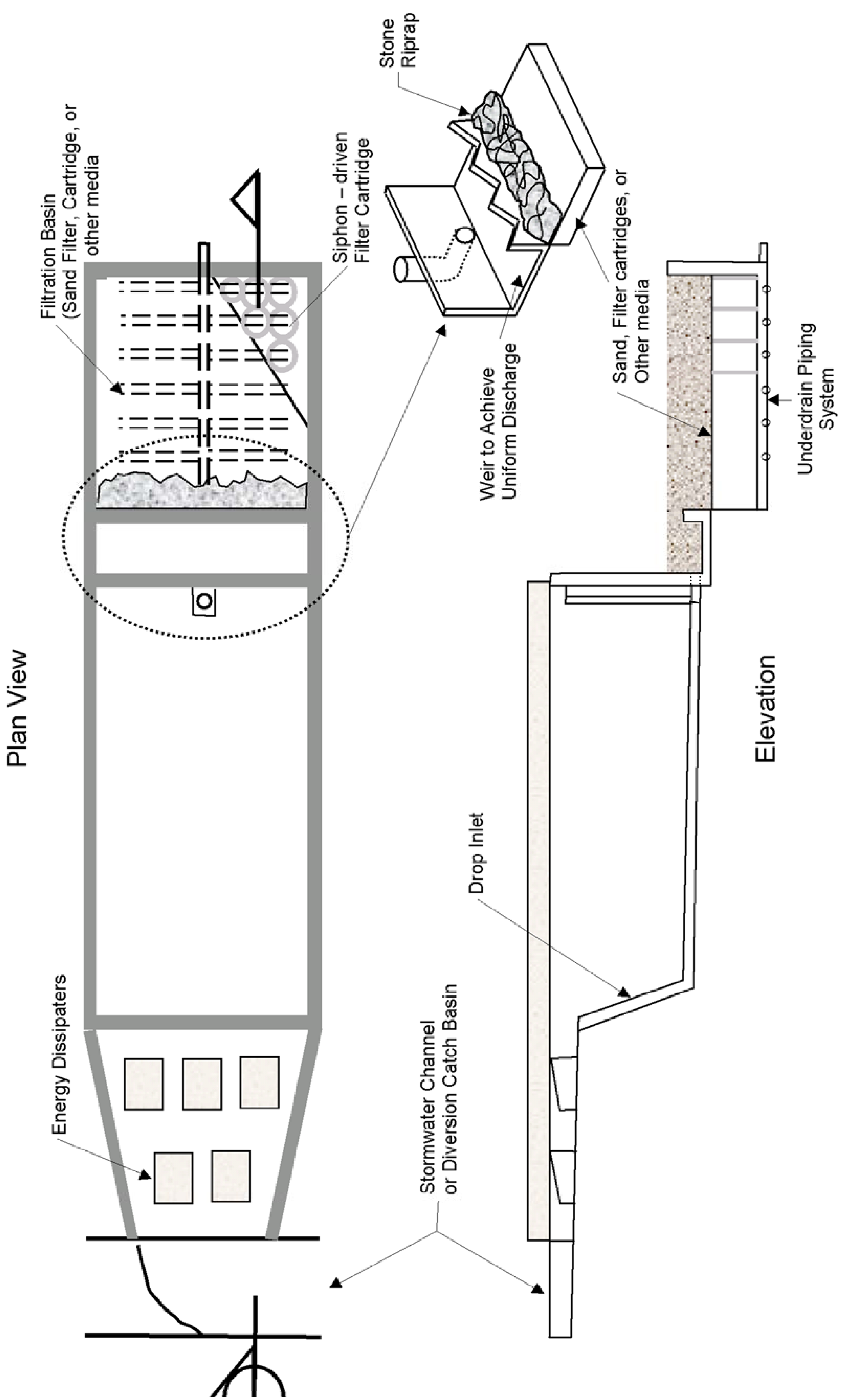
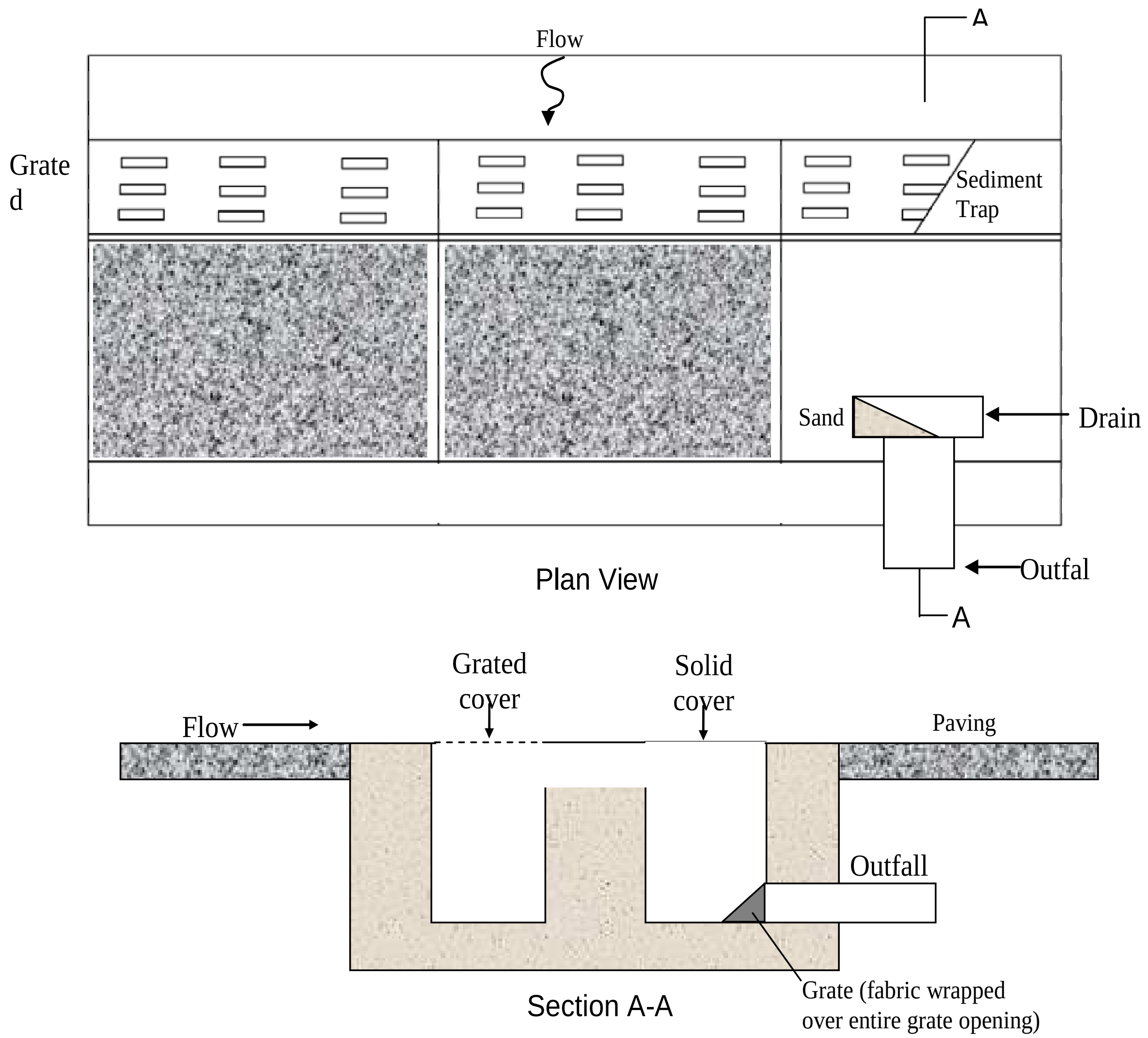
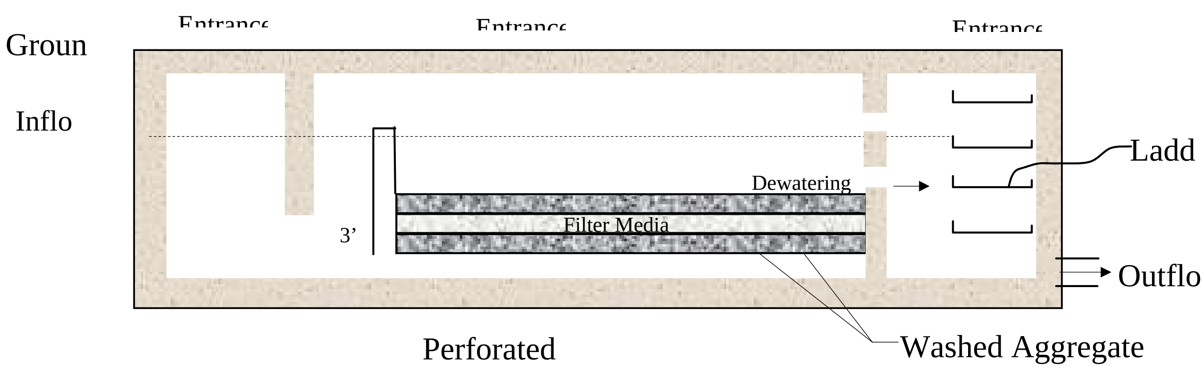


Figure STP-06-2
Multistage Sand Filter Layout

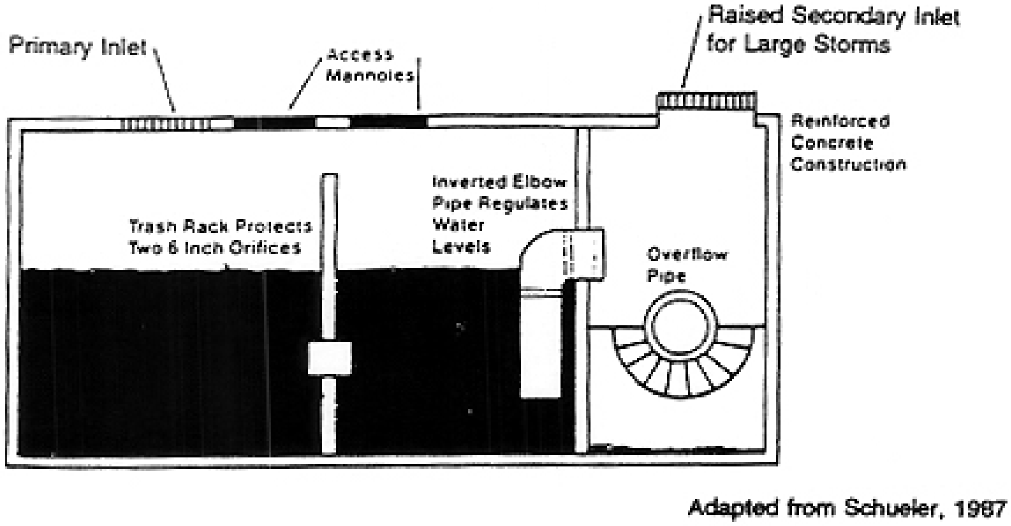


LINEAR SAND FILTER



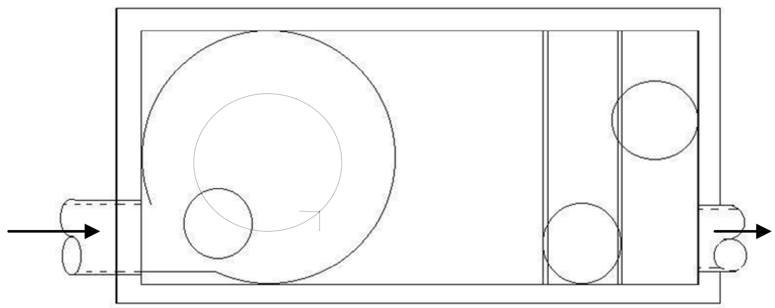
VAULT SAND FILTER

Figure STP-06-3
Midsize Media Filter System Layouts

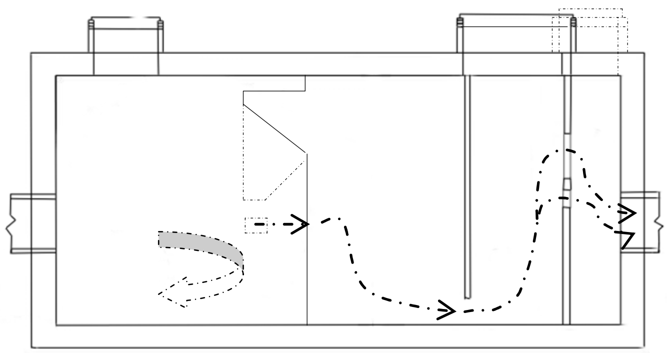


NOTE:
1. Size as conventional separator.
2. Design outlet orifice in elbow to limit outflow to the design rate for the unit.

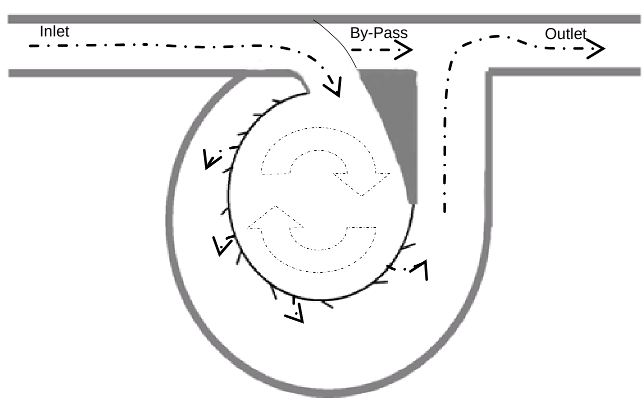
Figure STP-06-4
Horizontal Trash and Debris Separator



Swirl Deflector Plan View

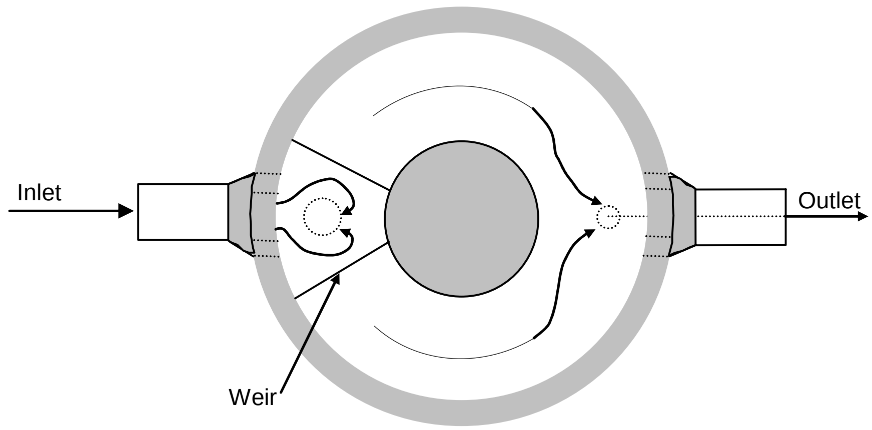


Swirl Deflector Elevation View



Continuous Deflection Plan View

Figure STP-06-5
Swirl / Continuous Deflection Separators



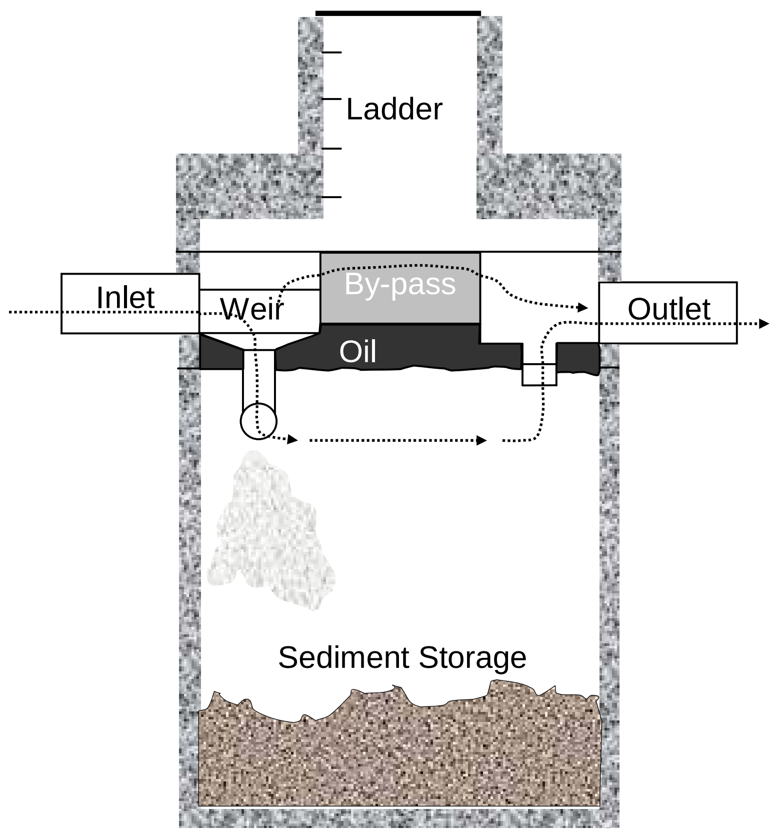


Figure STP-06-6
Separator / Filter
(Manhole Insert)

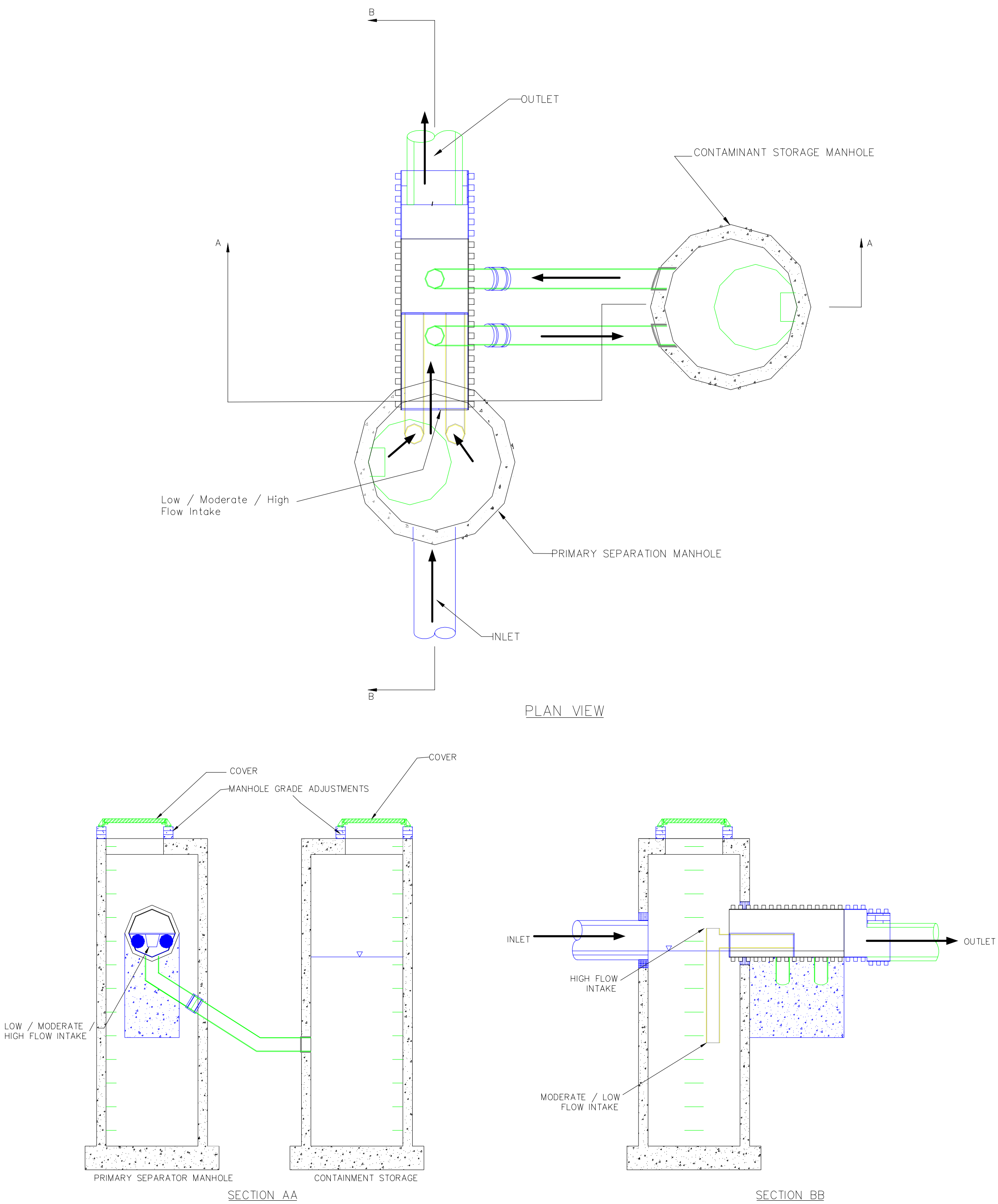
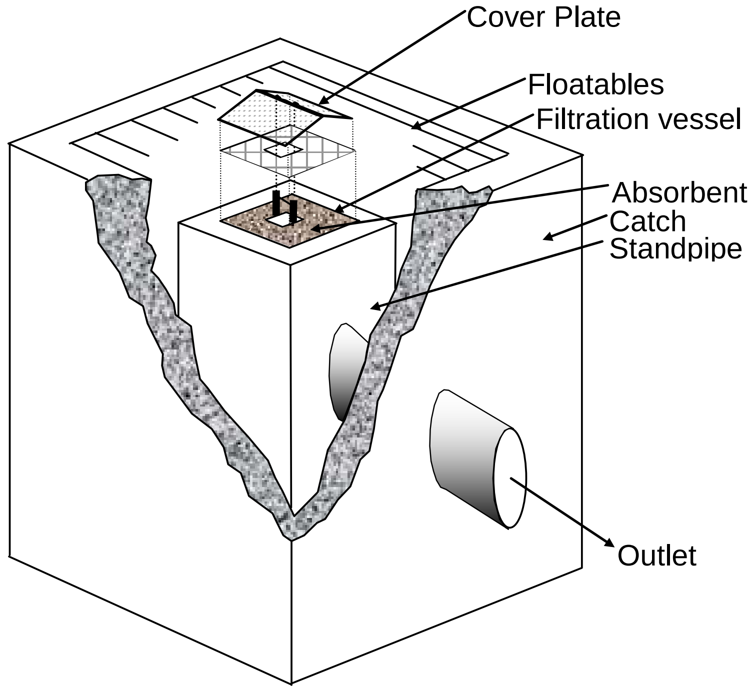


Figure STP-06-7
Dual Tank System
(Separator)



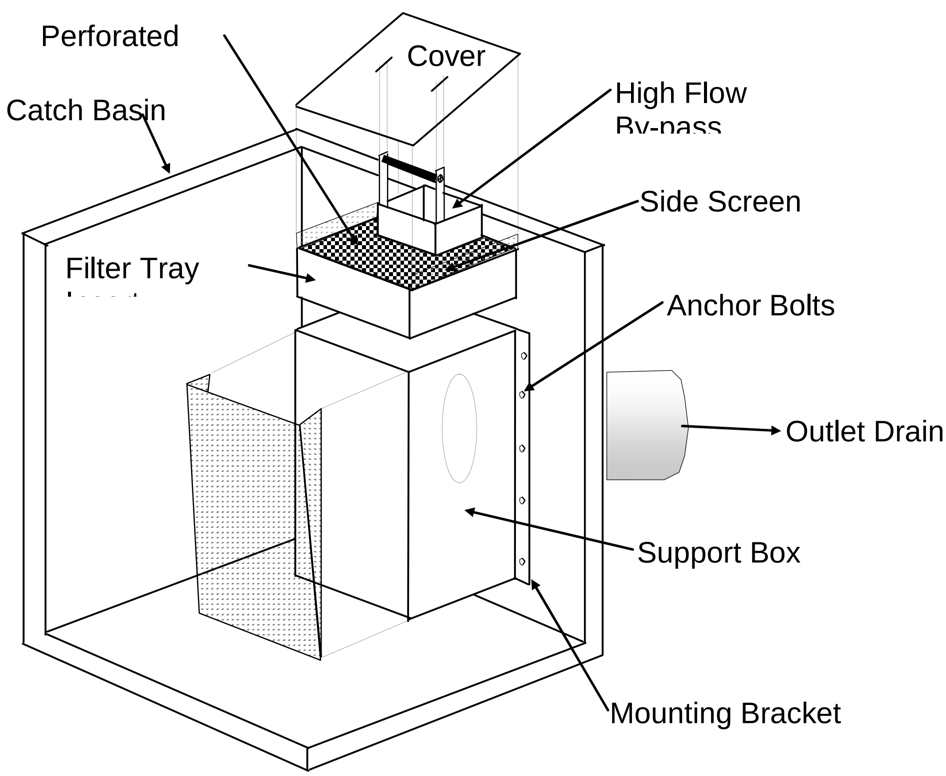


Figure STP-06-8
Catch Basin Insert Filters

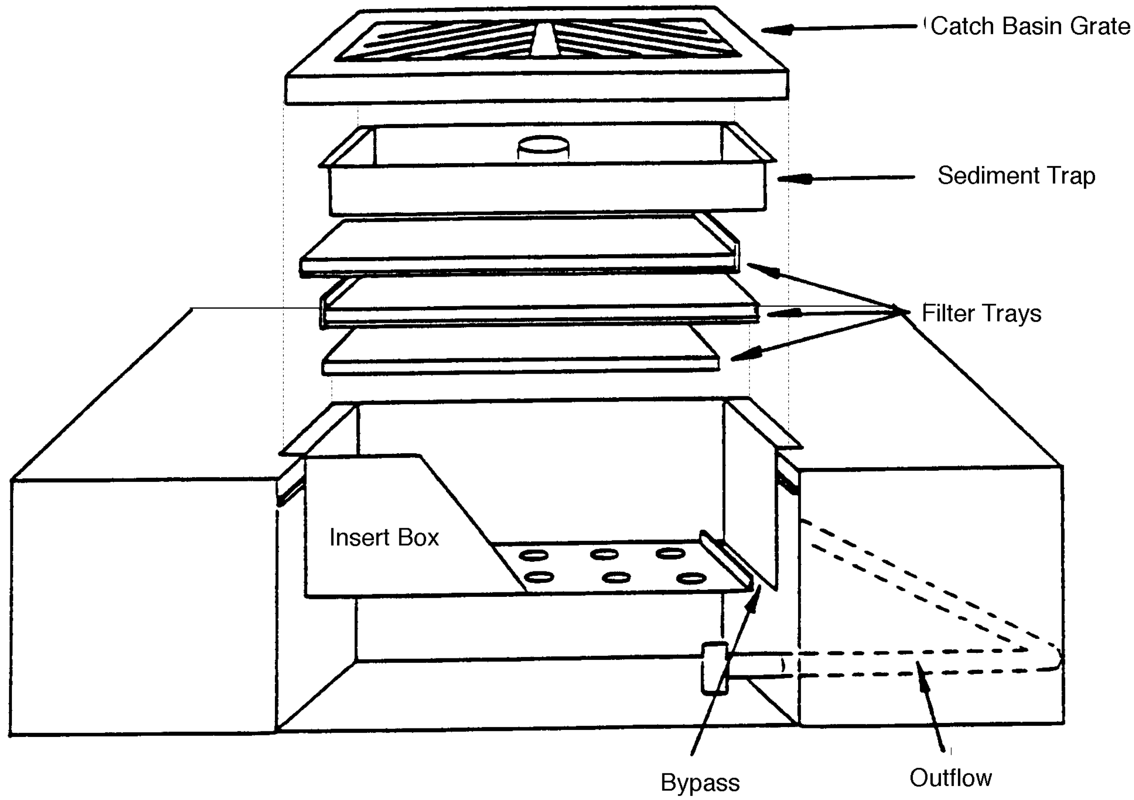


Figure STP-06-9
Grate Inlet Filter
(With Trays)

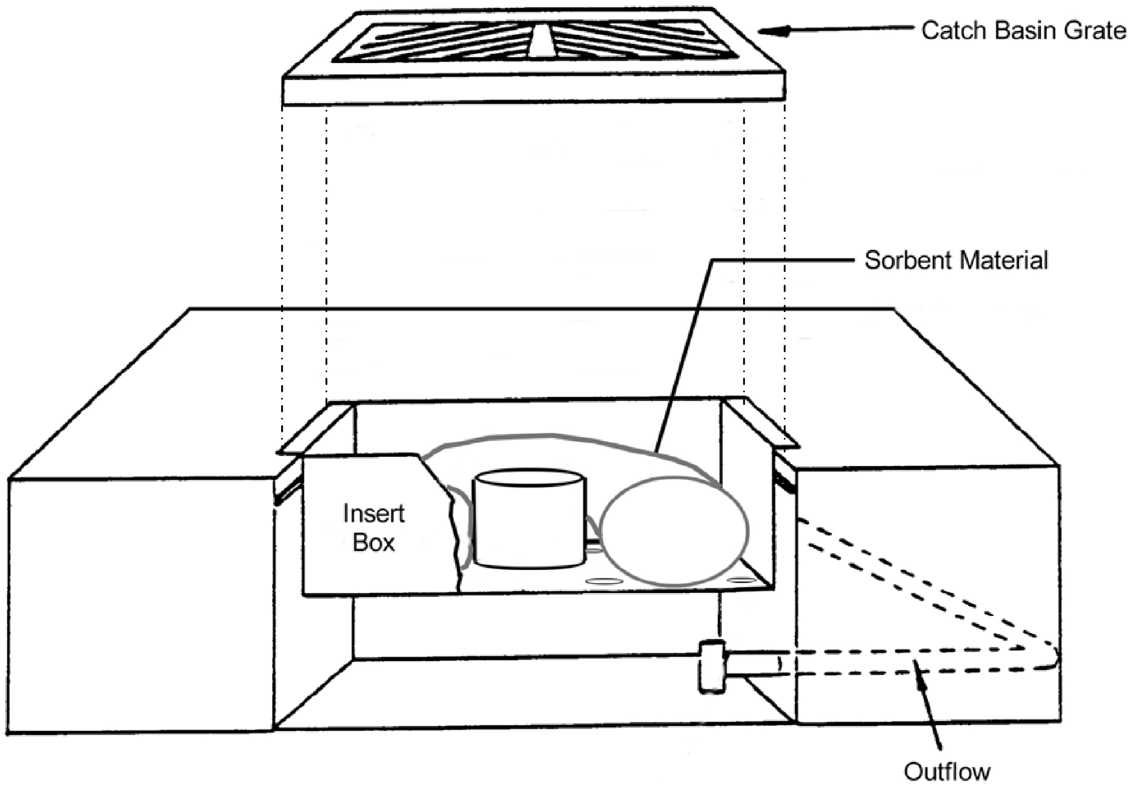


Figure STP-06-10
Grate Inlet Filter
(With Sorbent Material)

	New Albany, Indiana **Stormwater Best Management Practices (BMPs)** **Stormwater Pollution treatment Practices (STPs)**	STP-07
	Activity: Oil/Water Separation	

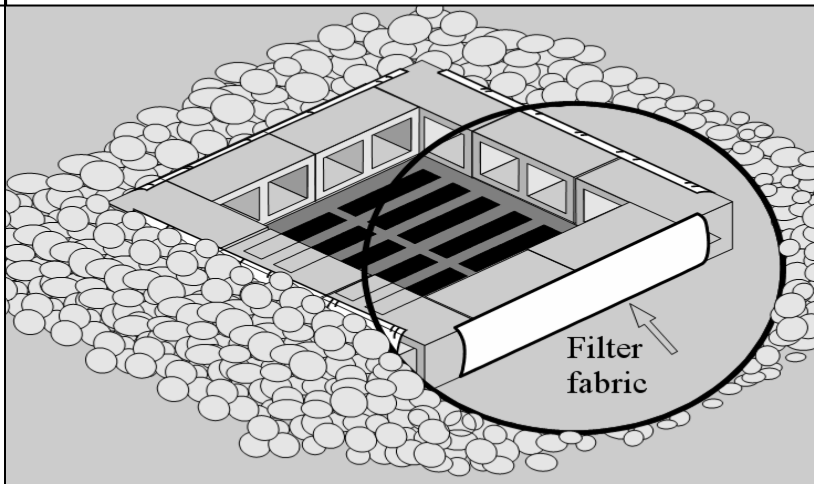
PLANNING CONSIDERATIONS:

Design Life:
1 yr

Acreage Needed:
Minimal

Estimated Unit Cost:
N/A

Monthly Maintenance:
N/A



Oil
Water

O/W

Target Pollutants

Significant ♦ Partial ◈ Low or Unknown ◊

Sediment ♦ Heavy Metals ◊ Nutrients ◊ Oxygen Demanding Substances ◊ Toxic Materials ◊
Oil& Grease ♦ Bacteria & Viruses ◊ Floatable Materials ♦ Construction Waste ◊

Description

Oil/water separators are designed to remove one specific group of contaminants: petroleum compounds and grease. However, separators will also remove floatable debris and settleable solids. Two general types of oil/water separators are used: conventional gravity separator and the coalescing plate interceptor (CPI). This management practice is likely to create a significant reduction in the impacts of floatable materials and oil and grease as well as partial reductions in the impacts of sediment, nutrients, heavy metals, toxic materials, and oxygen demanding substances.

This BMP fact sheet discusses oil/water separators. Other systems can be used in conjunction with or as a simpler alternative to the complex design, inspection, operation and maintenance requirements of oil/water separators. STP-06: Media Filtration/Media Filters and Water Quality Inlets should also be reviewed.

Suitable Applications

- The various systems discussed in this fact sheet should be selected based on the targeted constituents, site area constraints, cost and frequency of maintenance and inspection requirements. Many of the systems are readily available in a variety of layouts through commercial vendors.

- One of the most important selection criteria that must be evaluated is the ability to bypass or convey large storm events without damaging the system, exceeding design flow capacity or resuspending collected pollutants.

Activity: Oil/Water Separation

Suitable Applications (Continued)

- Another very important selection criteria is consideration of long-term inspection and maintenance resources. If there is not a plan to regularly inspect and maintain the selected system on a long-term basis, and a fiscal guarantor that the required maintenance resources will be available for the life of the system, then the system should not be installed. If these types of systems are not periodically inspected, cleaned and otherwise maintained, they will fail and could result in more intense impacts to stormwater quality than if they were not installed at all.

- Applicable to situations where the concentration of oil and grease related compounds will be abnormally high and source control cannot provide effective control.

- The general types of businesses where this situation is likely are truck, car, and equipment maintenance and washing businesses, as well as a business that performs maintenance on its own equipment and vehicles. Public facilities where separators may be required include marine ports, airfields, fleet vehicle maintenance and washing facilities, and mass transit park-and-ride lots.
- Conventional separators are capable of removing oil droplets with diameters equal to or greater than 150 microns. A CPI separator should be used if smaller droplets must be removed.

- Oil/water separators will be needed for a few types of industrial sites where activities result in abnormal amounts of petroleum products lost to exposed pavement, either by accidental small spills or normal dripping from the vehicle undercarriage (gas stations, auto shops, etc.)

- Separators may also be advisable where an area is heavily used by mobile equipment such as loading wharfs at marine ports. Limited data indicates oil/water separators can reduce the oil/grease concentration below 10 mg/l.

- The sizing of separators is based upon the rise rate velocity of oil droplets and rate of runoff. However, with the exception of stormwater from oil refineries there are no data describing the characteristics of petroleum products in urban stormwater that are relevant to design: either oil density and droplet size to calculate rise rate or direct measurement of rise rates.

Design and Sizing Conditions

- These systems should be designed by a licensed professional civil engineer.

- Sizing related to anticipated influent oil concentration, water temperature and velocity, and the effluent goal. To maintain reasonable separator size, it should be designed to bypass flows in excess of “first flush”. The bypass mechanism should be designed to minimize potential for captured pollutants from being “washed out” or resuspended under flows in excess of the “first flush”.

Design and Sizing Conditions (Continued)

- It is known that a significant percentage of the petroleum products are attached to the fine suspended solids and therefore are removed by settling not flotation. Consequently, the performance of oil/water separators is uncertain.
- The basic configurations of the two types of separators are illustrated in Figure STP-07-1. With small installations, a conventional gravity separator has the general appearance of a septic tank, but is much longer in relationship to its width. Larger facilities have the appearance of a municipal wastewater primary sedimentation tank. The CPI separator contains closely spaced plates which enhance the removal efficiency. In effect, to obtain the same effluent quality a CPI separator requires considerably less space than a conventional separator. The angle of the plates to the horizontal ranges from 0° (horizontal) to 60°, although 45° to 60° is the most common. The perpendicular distance between the plates typically ranges from 0.75 to 1 in. The stormwater will either flow across or down through the plates, depending on the plate configuration.

Design of Conventional Separators

The sizing of a separator is based upon the calculation of the rise rate of the oil droplets using the following equation:

$$V_p = 1.79(d_p - d_c)d^2 \times 10^{-8}/n \qquad (1)$$

where: V_p = rise rate (ft/second)
n = absolute viscosity of the water (poises)
d_p = density of the oil (gm/cc)
d_c = density of the water (gm/cc)
d = diameter of the droplet to be removed (microns)

A water temperature must be used to select the appropriate values for water density and viscosity from Table STP-07-1. The engineer should use the expected temperature of the stormwater during the December-January period. There are no data on the density of petroleum products in urban stormwater but it can be expected to lie between 0.85 and 0.95. To select the droplet diameter the engineer must identify an efficiency goal based on an understanding of the distribution of droplet sizes in stormwater. However, there is no information on the size distribution of oil droplets in urban stormwater. Figure STP-07-2 is a size and volume distribution for stormwater from a petroleum products' storage facility. The engineer must also select a design influent concentration, which carries considerable uncertainty because it will vary widely within and between storms.

To illustrate Equation 1: if the effluent goal is 10 mg/l and the design influent concentration is 50 mg/l, a removal efficiency of 80% is required. From Figure STP-07-2: this efficiency can be achieved by removing all droplets with diameters 90 microns or larger. Using a water temperature of 10°C gives a water density of 0.998. Using an oil density of 0.898, the rise rate for a 90 micron droplet is 0.0011 feet per second.

Design and Sizing Conditions (Continued)

It is generally believed that conventional separators are not effective at removing droplets smaller than 150 microns. Theoretically, a conventional separator can be sized to remove a smaller droplet but the facility may be so large as to make the CPI separator more cost effective:

Sizing conventional Separator

$$D = (Q/2V)^{0.5}$$

Where: D = depth, which should be between 3 and 8 feet.
Q = design flow rate (cfs)
V = allowable horizontal velocity which is equal to 15 times the design oil rise rate but not greater than 0.05 ft/s

Application of the Conventional Oil/Water Separator

Assume that a conventional oil/water separator is to be used to treat runoff from a 1/2 acre parking lot. Assume further it is to be sized to treat runoff from a rainfall rate of 0.50 inches/hr (which translates to a runoff rate of 0.50 cfs/acre when the area is 100 percent impervious).

Using the example above, the computed Vp is 0.0011 ft/sec (3.4×10^{-4} m/s). Using Equation 2, V = 15 x 0.0011 = 0.0165 ft/sec (5.0×10^{-3} m/s) which is less than 0.05 ft/sec (1.5×10^{-2} m/s); thus,

D = (Q/2V)0.05 = (1/2 x 0.05/(2 x 0.0165)) x 0.05
D = 3.8 ft

L = VD/Vp = 0.0165 x 3.8/0.0011
L = 57 ft

W = Q/(VD) = 0.25/(0.0165 x 3.8)
W = 4.0 ft , since W is less than 2 x D, increase width to W = 3.8 x 2 = 7.6 ft.

Thus, a conventional oil/water separator sized to capture runoff from a 0.5 in/hr (1.3 cm/hr) rainfall on a 1/2 acre parking lot would be:

D = 3.8 ft
W = 7.6 ft
L = 57 ft

Sizing CPI separator

Manufacturers can provide packaged separator units for flows up to several cubic feet per second. For larger flows, the engineer must size the plate pack and design the vault. Given the great variability of separator technology among manufacturers with respect to plate size, spacing, and inclination, it is recommended that the design engineer consult vendors for a plate package that will meet the engineer's criteria. Manufacturers typically identify the capacity of various standard units.

Design and Sizing Conditions (Continued)

The engineer can size the facility using the following procedure. First identify the expected plate angle, H (as degrees), and calculate the total plate area required,

$$A(ft^2).\ A = Q/V_p \cos(H) \qquad (3)$$

However, the engineer's design criteria must be comparable to that used by the manufacturer in rating its units. CPI separators are not 100% hydraulically efficient; ranging from 0.35 to 0.95 depending on the plate design (Aquatrend, undated). If the engineer wishes to incorporate this factor, divide the result from Equation 3 by the selected efficiency.

- Select spacing, S, between the plates, usually 0.75 to 1.5 inches.
- Identify reasonable plate width, W, and length, L.
- Number of plates, N = A/WL.
- Calculate plate volume, $P_v(ft^3)$.

$$P_V = (\underline{NS} / 12 + L \cos(H))(WL \sin(H)) \qquad (4)$$

- Add a foot (0.3 m) beneath the plates for sediment storage.
- Add 6" to 12" above the plates for water clearance so that the oil accumulates above the plates.
- Add one foot for freeboard.
- Add a forebay for floatables and distribution of flow if more than one plate unit is needed.
- Add after bay for collection of the effluent from the plate pack area.
- For larger units include device to remove and store oil from the water surface.
- Horizontal plates require the least plate volume to achieve a particular removal efficiency. However, settleable solids will accumulate on the plates complicating maintenance procedures. The plates may be damaged by the weight when removed for cleaning. The plates should be placed at an angle of 45° to 60° so that settleable solids slide to the facility bottom. Experience shows that even with slanted plates some solids will "stick" to the plates because of the oil and grease. Placing the plates closer together reduces the plate volume. However, if debris is expected such as twigs, plastics, and paper, select a larger plate separation distance. Or install ahead of the plates a trash rack and/or screens with a diameter somewhat smaller than the plate spacing.

Activity: Oil/Water Separation

STP-07

Inspection Checklist

- It is known that a significant percentage of the petroleum products are attached to the fine suspended solids and therefore are removed by settling not flotation. Consequently, the performance of oil/water separators is uncertain.
- The design loading rate for oil/water separators is low, therefore, they can only be cost-effectively sized to detain and treat nuisance and low flows (small storm or first flush events). Sizing to accommodate an average to large storm results in a large sized facility and is not economical and often not feasible.
- Undersizing or conveying flows in excess of the first flush for small catchments can result in poor performance or resuspension of collected pollutants.
- Oil/water separators require frequent periodic maintenance for the life of the structure.

Table STP-07-1
Water Viscosities & Densities

Temperature		Absolute Viscosity		Density of pure water in air	
°C	°F	(Poises)	(slugs/ft.sec)	(gm/cc)	(lbs/ft^3)
0	32.0	0.017921	0.00120424	0.999	62.351
1	33.8	0.017343	0.00116338	0.999	62.355
2	35.6	0.016728	0.00112407	0.999	62.358
3	37.4	0.016191	0.00108799	0.999	62.360
4	39.2	0.015674	0.00105324	1.000	62.360
5	41.0	0.015188	0.00102059	0.999	62.360
6	42.8	0.014728	0.00098968	0.999	62.359
7	44.6	0.014284	0.00095984	0.999	62.357
8	46.4	0.013860	0.00093135	0.999	62.354
9	48.2	0.013462	0.00090460	0.999	62.350
10	50.0	0.013077	0.00087873	0.999	62.345
11	51.8	0.012713	0.00085427	0.999	62.339
12	53.6	0.012363	0.00084870	0.999	62.333
13	55.4	0.012028	0.00080824	0.999	62.326
14	57.2	0.011709	0.00078681	0.999	62.317
15	59.0	0.011404	0.00076631	0.999	62.309
16	60.8	0.011111	0.00074662	0.999	62.299
17	62.6	0.010828	0.00072761	0.999	62.289
18	64.4	0.010559	0.00070953	0.999	62.278
19	66.2	0.010299	0.00069206	0.999	62.266
20	68.0	0.010050	0.00067533	0.998	62.254

Activity: Oil/Water Separation

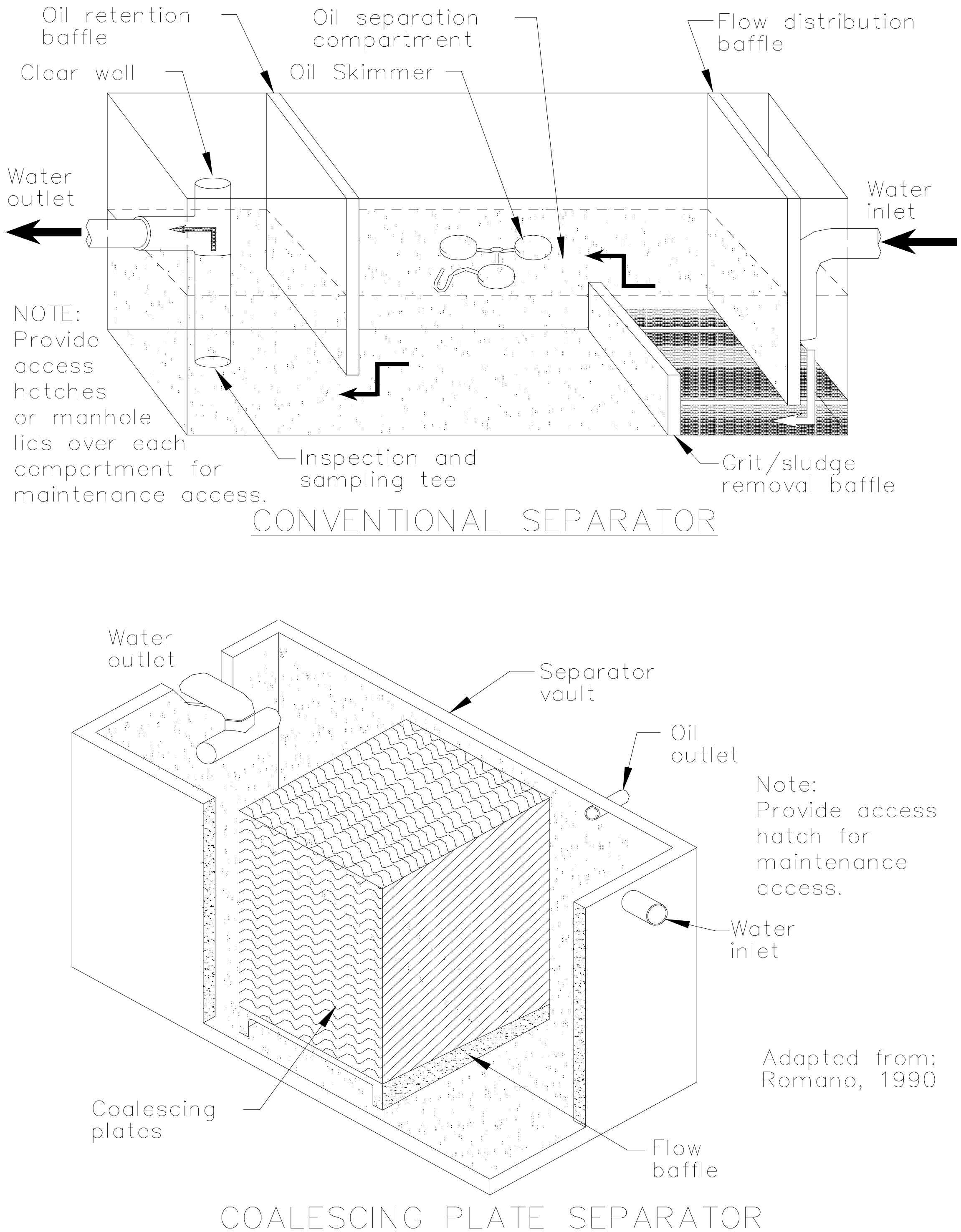


Figure STP-07-1
Oil/Water Separator Types

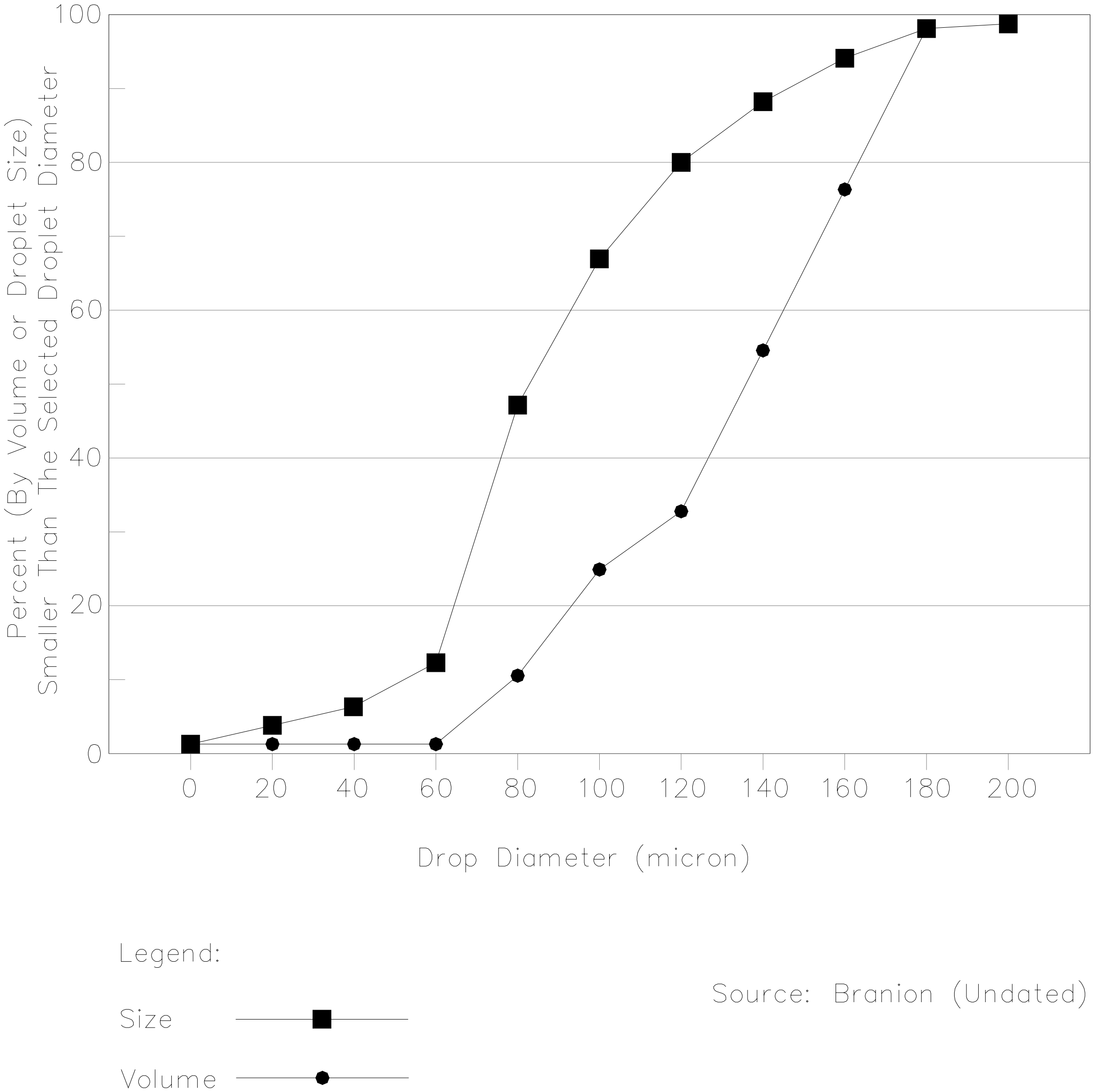


Figure STP-07-2
Particle Size, Capture, Distribution and Volume

New Albany, Indiana
Stormwater Best Management Practices (BMPs)
Stormwater Pollution treatment Practices (STPs)

STP-08

Activity: Multiple Systems

PLANNING CONSIDERATIONS:

Design Life:
N/A

Acreage Needed:
N/A

Estimated Unit Cost:
N/A

Monthly Maintenance:
N/A

Target Pollutants

Significant ♦ Partial ◊ Low or Unknown ◊

Sediment ♦ Heavy Metals ♦ Nutrients ♦ Oxygen Demanding Substances ♦ Toxic Materials ♦
Oil& Grease ♦ Bacteria & Viruses ◊ Floatable Materials ♦ Construction Waste ♦

Description

A multiple treatment system uses two or more of the preceding BMPs in series. This management practice is likely to create significant reductions in sediment, floatable materials, nutrients, heavy metals, toxic materials, oxygen demanding substances, oil and grease, and partial reductions in bacteria and viruses.

Suitable Applications

- Need to protect particularly sensitive stream or various site uncertainties warrant staged treatment.
- Enhanced reliability.
- Optimum use of the site.
- Generally less expensive to maintain more, but more effective.

Design and Sizing Conditions

- These systems should be designed by a licensed professional civil engineer.
- Refer to individual treatment control BMPs, SPP and STP sections.

Maintenance

- Refer to individual treatment control BMP's, SPP and STP sections.

STP-08

Activity: Multiple Systems

Inspection Checklist

Available space.

- ❑ Multiple systems may occur in series or by stacking vertically. Multiple systems that have been tried or that appear to be feasible are presented below:
- ❑ High flow bypass manhole, gate, weir or orifice above a forebay, pond, filter, oil/water separator, swale, or water quality manhole/insert. This is preferred for all stormwater quality systems to ensure that flows in excess of the design flow do not damage the system or resuspend collected pollutants.
- ❑ Dry detention above wet detention pond: recommended by several practitioners because of the uncertainty about the performance of wet ponds.
- ❑ Wet detention pond above media filter: desirable because settleable solids that can quickly clog media filters are removed.
- ❑ Dry detention basin – media filter: settling basin is needed to avoid excessive maintenance on the sand filter.
- ❑ Wet or dry detention basin – media filter – wetland: for a larger system draining to an especially sensitive water body.
- ❑ Wet detention pond – wetland: where an unusually high loading of sediment is expected, a full size wet pond, rather than just a forebay in the wetland, may be desirable to minimize the amount of sediment reaching the wetland where it would be more costly to remove.
- ❑ Biofilter – wet or dry detention pond: used frequently to enhance reliability or as an alternative to a forebay.
- ❑ Forebay (or baffle box) – wet or dry detention: collection of floatable debris and coarse sediment reduces frequency of detention pond cleanout while making debris and sediment removal easier.
- ❑ Biofilter – infiltration trench: for pretreatment of the stormwater before it enters an infiltration system.
- ❑ Oil/water separator – wetland or biofilter: the oil/water separator is used to protect the vegetated treatment system where high concentrations of oil may frequently occur.