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# **APPENDIX B**

## **GUIDE TO STORM WATER BEST MANAGEMENT PRACTICES FOR WATER QUANTITY AND WATER QUALITY CONTROL**

\* This guide does not take the place of the City of Bowling Green storm water requirements. If developing within Bowling Green, please refer to the city manual for requirements. <https://www.bgky.org/stormwater/bmp>

## WARREN COUNTY STORM WATER GUIDE APPENDIX B

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## **B.1 INTRODUCTION**

Non-point source pollution is now responsible for up to eighty percent (80%) of pollution in waters of the U.S., which include streams, lakes, rivers, and wetlands. This is true, in part, due to significant reductions in direct discharges of pollutants by industry that have been achieved since passage of the Clean Water Act (CWA) of 1972. In urban areas, non-point source pollution occurs because storm water runoff collects impurities while passing over rooftops, streets, parking lots, landscaping and gutters. This polluted storm water runoff typically enters a storm drain system and is rapidly conveyed to a lake, stream or river. The percentage of impervious land cover in urban and suburban watersheds generally indicates the level of pollutant impact on receiving waters. In most cases, impervious cover in excess of thirty percent (30%) results in streams that are considered “degraded,” while impervious cover between ten and thirty percent (10%-30%) causes “impacts” on the receiving streams. Typical residential development results in approximately thirty-five percent (35%) of a watershed being impervious, which is more than enough to degrade the receiving waters. Realization of this fact is important, because healthy (non-impacted) streams are important for a healthy ecosystem, and a healthy ecosystem is important for all living creatures including people.

In Warren County the karst cave system has been utilized, often overly so, to manage storm water runoff. Utilization of karst for storm water management is not an exact science. It is often difficult to predict the exact pathways of underground streams and thus the impact of introducing increased runoff to downstream locations. We have also come to realize that the karst system has limits and see this in the form of basins that do not readily drain or may even surcharge when the cave system is full.

A second by-product of utilizing the karst for storm water drainage is the almost immediate introduction of contaminants into our water systems. Fertilizers and other chemicals that are used on lawns are carried directly into storm sewers then into basins and often into drywells and sinkhole boxes with no treatment. Ultimately these toxins travel into our ground water, streams lakes effecting wildlife and our source drinking water.

To protect our natural resources, the CWA of 1972, as amended in 1987, prohibits the discharge of pollutants to waters of the U.S. and mandates that storm water not be discharged unless it is in compliance with a National Pollutant Discharge Elimination System (NPDES) permit. Bowling Green and Warren County are responsible for ensuring that discharges of storm water from public storm water systems into waters of the state comply with CWA requirements. The implementation of the requirements contained in this manual will be a primary mechanism for accomplishing this objective.

Storm water management in Bowling Green/Warren County shall include management for quality as well as quantity (flood protection). This storm water appendix is intended as a guide only to provide information on the structural water quality and water quantity best management practices (BMPs).

Permanent water quality treatment measures described in this chapter should not be confused with erosion and sediment controls required during construction.

## **B.2 GENERAL DESIGN CRITERIA**

Storm water management in Bowling Green/Warren County shall include management for quality and quantity. This section provides the general design criteria for both.

### **B.2.1 Water Quantity Control**

Water quantity controls shall be implemented so that post-development peak discharges do not exceed pre-development discharges for those storms listed in *Table B.1*.

### **B.2.2 Water Quality Controls**

Research has indicated that capturing and treating eighty percent (80%) of the total annual runoff volume provides effective water quality treatment volume based on removal of particulates. Effective removal of solid particles in the runoff also provides for removal of significant amounts of nitrogen, phosphorus, and oil and grease. Ninety percent (90%) of the annual runoff seems to be a large volume, but the storm events that cumulatively produce this runoff volume in Warren County produce less than 1.0 inches of runoff each. Using historical rainfall records, typical soil parameters, and the SWMM model, the runoff depth necessary for eighty percent (80%) runoff capture was approximated as a function of percent impervious area. These values, which are shown in *Table B-1*, represent the water quality depth that shall be treated for each development. For example, a twenty (20)-acre development that is forty percent (40%) impervious has a water quality depth of 0.7 inches over the whole area (not just the impervious area), resulting in a water quality volume (WQV) of 50,820 cubic feet.

In addition to carrying pollutants, storm water runoff from developed areas increases the frequency and duration of bankfull flows in the receiving streams, causing increased erosion of the stream banks and further degradation of in-stream water quality. On-site infiltration designed for the increased runoff due to development is the preferred solution to this impact.

**TABLE B-1**

**WATER QUALITY DEPTH VERSUS PERCENT IMPERVIOUS SURFACE**

<b>% Impervious Surface</b>	<b>Water Quality Depth (inches)</b>
<b>0 to 9</b>	<b>0</b>
<b>10</b>	<b>0.4</b>
<b>20</b>	<b>0.5</b>
<b>30 storm water</b>	<b>0.6</b>
<b>40</b>	<b>0.7</b>
<b>50</b>	<b>0.85</b>
<b>60</b>	<b>1.0</b>
<b>70</b>	<b>1.15</b>
<b>80</b>	<b>1.3</b>
<b>90</b>	<b>1.45</b>
<b>100</b>	<b>1.6</b>

Notes:

- 1) The Water Quality Volume (WQV) is the volume resulting from applying the prescribed Water Quality Depth to the drainage area to be developed.
- 2) For % impervious values between those given use linear interpolation.
- 3) Water quality controls are not required for sites that are less than ten percent (10%) impervious.

**B.3 BIORETENTION SYSTEMS**

Bioretention is a practice to treat storm water runoff using a conditioned planting soil bed and planting materials to filter runoff stored within a shallow depression. The method combines physical filtering and absorption with biological processes. The system consists of a structure to spread flow, a pretreatment filter strip or grass channel, a sand bed, pea gravel overflow curtain drain, a shallow ponding area, a surface organic layer of mulch, a planting soil bed, plant material, a gravel underdrain system, and an overflow system. *Figure B-1* shows a diagram of a bioretention system designed to receive runoff from a paved area.

**B.3.1 Applicability**

Bioretention systems are very effective for water quality treatment. Bioretention systems are particularly well suited for use in parking lot islands, roadside swales and median strips.

### **B.3.2 Design Criteria**

Size the area of the filter bed in accordance with the design WQV corresponding to the area draining to it. (See the next section for procedure)

Design the bioretention system to be on-line with an overflow catch basin, as shown in *Figure B-1*, to handle volumes exceeding the design WQV.

Design the bioretention system to have a longitudinal slope of 0 to 1 percent (0-1%).

Provide a pretreatment system composed of a pea gravel diaphragm and a grassed filter strip. The pea gravel diaphragm also serves as a flow spreader. Dimensions of the gravel diaphragm and grass filter strip shown in *Figure B.1* are minimums. When flow into a bioretention system is parallel to its long dimension (i.e., from a drainage swale), omit the gravel diaphragm shown in *Figure B.1* and provide a berm across the downstream end of the system to impede the flow. The top of the berm shall be level across the base of the bioretention system and be twelve to eighteen (12-18) inches high in the center.

Provide a planting soil bed with a minimum width of four (4) feet and a minimum depth of four (4) feet (including a twelve (12)-inch sand bed). The planting soil bed can be as wide as fifteen (15) feet. The area of the system is determined by the required area of the filter bed. The minimum length is fifteen (15) feet.

For widths greater than ten (10) feet, maintain at least a 2:1 length to width ratio.

Provide a pea gravel curtain drain, as shown in *Figure B.1*. The minimum width of the curtain drain is eight (8) inches.

Provide a two to three (2-3) inch thick mulch layer above the planting soil bed.

Grade the top of the planting soil bed to provide a shallow ponding area with a maximum depth of six (6) inches.

Provide an underdrain system of gravel and perforated pipe. Design the gravel bed to be at least eight (8) inches deep. Connect the underdrain to the storm drainage system or design it to daylight to a suitable non-erosive outfall.

### B.3.3 Design Procedures

Size the filter bed using the following equation:

$$A_f = V * (d_f) / [k * (h_f + d_f)(t_f)]$$

Where:

- $A_f$  = surface area of the sand filter bed (ft<sup>2</sup>)
- $V$  = treatment or infiltration volume (ft<sup>3</sup>)
- $D_f$  = planting bed depth (ft.)
- $k$  = coefficient of permeability for planting bed (ft. /day)
- $h_f$  = average height of water above the planting bed (ft);  $h_f = 0.5 * h_{max}$
- $t_f$  = time required for  $V$  to filter through the planting bed (days).

Note:

- $d_f$  = 4 feet (including sand filter) unless it is increased by designer
- $k$  = 0.5 feet/day (median value of a silt loam)
- $h_f$  =  $0.5 * h_{max} = 3$  inches = 0.25 feet
- $t_f$  = 3 days

Design the bioretention system to provide the minimum filter area required and to meet the design criteria.

### B.3.4 Specifications

Provide planting soil with the following characteristics:

- pH of 5.2 to 7.0
- organic content of 1.5 to 4 percent
- magnesium of 35 pounds per acre minimum
- phosphorus (as  $P_2O_5$ ) of 75 pounds per acre minimum
- potassium (as  $K_2O$ ) at 85 pounds per acre minimum
- soluble salts less than 500 ppm
- clay content of 10 to 25 percent by volume
- silt content of 30 to 55 percent by volume
- sand content of 35 to 60 percent by volume
- free of stones, stumps, roots, or other woody material greater than 1 inch in diameter

Place planting soil in lifts of twelve to eighteen (12-18) inches and loosely compact or tamp lightly with backhoe bucket.

Provide shredded hardwood mulch aged at least two (2) months. Place mulch layer two to three (2-3) inches deep.

Provide clean river pea gravel for the curtain drain and diaphragm sized to meet ASTM D-448 size no. 6 with diameter ranging from one-eighth to one-fourth (1/8-1/4) inch.

Provide gravel for the underdrain sized to meet AASHTO M-43 with size range of one half to two (1/2-2) inches in diameter.

Provide PVC piping for the underdrain satisfying AASHTO M-278 standard for rigid schedule 40 pipe. Provide three-eighths (3/8) inch diameter perforations on six (6)-inch centers with four holes per row.

Plant a base of bioretention system (planting soil bed) in herbaceous ground cover and shrubs. Plant side slopes of bioretention system in herbaceous ground covers, vines and shrubs. Trees may also be used in the bioretention system. Use direct seeding for herbaceous varieties and nursery stock for vines, shrubs and trees.

Areas to be seeded with herbaceous varieties shall be roughened with a rake or similar tool. Seeding rates shall be a minimum of ten (10) pounds of seed mix per one thousand (1,000) square feet of area.

Bare root or containerized stock shall be planted at the same depth as planted in the nursery. The stock should be planted in a hole large enough to accommodate the root system when well spread. Shrubs and vines shall be planted at a minimum density of seventeen hundred (1,700) stems per acre (one stem per twenty-five (25) square feet at five (5) feet on center).

Select herbaceous species for the planting soil bed from the following list. Use a minimum of two species.

<u>Common Name</u>	<u>Scientific Name</u>
Barnyard grass	<i>Echinochloa crusgalli</i>
Switch Grass	<i>Panicum virgatum</i>
Swamp Milkweed	<i>Asclepias incarnate</i>
Giant Cane	<i>Arundinaria gigantea</i>
Jewelweed	<i>Impatiens capensis</i>
River Oats	<i>Chasmanthium latifolia</i>
Deertongue	<i>Panicum clandestinum</i>
Boneset	<i>Eupatorium perfoliatum</i>

Select herbaceous species for the side slopes also, select vines, shrubs and trees from the following list on page B.8 and B.9

### **SUGGESTED RIPARIAN SPECIES LIST**

The species on the list are only suggestions. Native species that are appropriate for a given site may be proposed.

<b>Tree Species</b>	<b>Scientific Name</b>
Pin Oak	<i>Quercus palustris</i>
Cherrybark Oak	<i>Quercus pagoda</i>
Bur Oak	<i>Quercus macrocarpa</i>
Swamp Chestnut Oak	<i>Quercus michauxii</i>
Shingle Oak	<i>Quercus imbricaria</i>
Northern Red Oak	<i>Quercus rubra</i>
Post Oak	<i>Quercus stellate</i>
Red Maple	<i>Acer rubrum</i>
Green Ash	<i>Fraxinus pennsylvanica</i>
Shellbark Hickory	<i>Carya laciniosa</i>
Blackgum	<i>Nyssa sylvatica</i>
American Elm	<i>Ulmus americana</i>
Eastern Cottonwood	<i>Populus deltoids</i>
Black Walnut	<i>Juglans nigra</i>
River Birch	<i>Betula nigra</i>
Yellow Poplar	<i>Liriodendron tulipifera</i>
Persimmon	<i>Diospyrus virginiana</i>
Ohio Buckeye	<i>Aesculus glabra</i>
Sugar Maple	<i>Acer saccharum</i>
Sycamore	<i>Plantanus occidentalis</i>
<b>Shrubs</b>	<b>Scientific Name</b>
Arrow-wood	<i>Viburnum dentatum</i>
American Plum	<i>Prunus americana</i>
Deciduous Holly	<i>Ilex decidua</i>
Gray Dogwood	<i>Cornus racemosa</i>
Silky Dogwood	<i>Cornus amomun</i>
Spicebush	<i>Lindera benzoin</i>
Sassafras	<i>Sassafras albinum</i>
American Elder	<i>Sambucus canadensis</i>
Button Bush	<i>Cephalanthus occidentalis</i>
River Cane	<i>Arundinaria gigantea</i>
Coralberry	<i>Symphoricarpos orbiculatus</i>

## **SUGGESTED RIPARIAN SPECIES LIST**

<b>Herbaceous Species</b>	<b>Scientific Name</b>
Rice cutgrass	<i>Leersia oryzoides</i>
Managrass	<i>Glyceria straita</i>
Spangle grass	<i>Chasmanthium latifolium</i>
Barnyard grass	<i>Echinochloa crus-galli</i>
Switchgrass	<i>Panicum virgatum</i>
Annual rye	<i>Secale cereal</i>
Wild rye	<i>Elymus virginicus</i>
Deertongue grass	<i>Panicum clandestinum</i>
Panic grass	<i>Panicum microcarpon</i>
Giant Cane Bambo	<i>Arundinaria gigantea</i>
Boneset	<i>Eupatorium perfoliatum</i>
Big Bluestem	<i>Andropogon gerardii</i>
Prairie cordgrass	<i>Spartina pectinata</i>
Water Plantain	<i>Alisma subcrodatum</i>
Common Milkweed	<i>Asclepias syriaca</i>
Beggar's Ticks	<i>Biden polyeps</i>
Canada Brome	<i>Bromus pubescens</i>
American Bellflower	<i>Campanula americana</i>
Frank's Sedge	<i>Carex frankii</i>
Sedge	<i>Carex granularis</i>
Shallow Sedge	<i>Carex lurida</i>
Hop Sedge	<i>Carex lupulina</i>
River Oats	<i>Chasmanthium latifolium</i>
Riverbank Wild rye	<i>Elymus riparius</i>
Downy Wild rye	<i>Elymus villosus</i>
Joe-pie Weed	<i>Eupatorium maculatum</i>
Fowl Manna Grass	<i>Glyceria striata</i>
Rush	<i>Juncus sp.</i>
Western Panic grass	<i>Panicum acuminatum</i>
Switchgrass	<i>Panicum virginica</i>
Foxglove Beardtongue	<i>Penstemon digitalis</i>
Leafcup	<i>Polymnia canadensis</i>
Brown-eyed Susan	<i>Rudbeckia triloba</i>
Dark Green Belrush	<i>Scirpus cyprinus</i>
Yellow Wingstem	<i>Verbesina alternafolia</i>
White Wingstem	<i>Verbesina virginica</i>

## **B.4 INFILTRATION SYSTEMS**

Infiltration practices and/or bioretention systems reduce the adverse impacts on the receiving waters that result from increasing the impervious area. This chapter describes several infiltration practices that can be used in many different situations. Many of the practices cannot function as the sole water quality infiltration and treatment device, but will provide significant “credits” toward reducing the magnitude of the runoff that must be detained and treated.

Infiltration practices include a variety of practices such as directing downspouts to grassed areas and using modular pavement. Infiltration practices also include swales, terraforming, infiltration, and vegetative filters. Terraforming is a term for special grading practices such as terracing and berming that are intended to promote infiltration. This section presents infiltration practices and describes the minimum requirements that must be met to obtain credits to reduce water quality treatment volumes.

The infiltration volume credit listed for each practice can be used to satisfy an equal amount of water quality volume.

### **B.4.1 Downspouts to Grass**

Discharging downspouts from roofs onto grassed yards encourages infiltration and reduces direct discharge to impervious areas such as driveways. The grass area shall be greater than or equal to the roof area.

#### ***Infiltration Credit***

When downspouts are discharged onto grass, the infiltration credit is 0.225 acre-feet per acre of roof area.

#### ***Design Criteria***

The lot must be graded so that the downspout discharge travels at least thirty (30) feet over grass before reaching a driveway, roadway, paved ditch or any other impervious conveyance.

### **B.4.2 Modular Pavement**

Modular pavement consists of strong structural materials, typically concrete, having regularly interspersed void spaces that are filled with pervious materials such as sand, gravel, or sod. These pavements can be used as driveways or as overflow parking in areas that are used less frequently than the main parking areas for civic, commercial and industrial facilities. Modular pavement can be used for any portion of parking up to that amount allowed by the Planning Commission.

#### ***Infiltration Credit***

Any area that is paved using modular pavement can be treated as pervious for purposes of calculating WQV and post-development peak runoff, as long as appropriate design criteria and construction specifications are satisfied.

### ***Design Criteria***

Large void spaces in modular pavement shall represent at least thirty percent (30%) of the total surface area of the pavement.

Voids shall be filled with silty soil and vegetated with permanent grass. If vegetation is inappropriate voids may be filled with sand or gravel, but the material shall be clean and uniform (poorly graded) to ensure high permeability.

### ***Construction Specifications***

Install all modular pavements following manufacturer's specifications.

To prevent premature clogging and/or failure, modular pavements shall not be placed into service until the entire contributing surface drainage area has been completely stabilized.

Clearly mark the planned area for modular pavement to prevent heavy equipment from compacting the underlying soils.

Excavate the subgrade soil using equipment with tracks or oversized tires to minimize compaction.

### **B.4.3 Swales**

Swales are typically vegetated parabolic or trapezoidal channels with a large width to depth ratio that are used for conveying storm water runoff. Swales can act both as vegetated filters and infiltration practices because they tend to slow runoff rates and allow for both particle settling and storm water infiltration. Swales are encouraged wherever they can be used as an alternative to narrower, deeper channels that tend to convey flow at higher velocities. Swales are especially effective in reducing water quality impacts when used for roadside drainage instead of the traditional curb inlet/storm sewer system. In this application, curb cuts are used instead of drop inlets in the gutter. See *Figure B.2*.

Swales can be even more effective when constructed using berms or infiltration beds to encourage additional ponding and infiltration. These cases are discussed in subsequent sections.

### ***Infiltration Credits***

When swales are used, the infiltration credit is 0.25 acre-feet per acre of swale. To obtain this credit, the area draining to the swale must be at least three (3) times the area of the swale considering that the swale itself is part of the drainage area.

To calculate the area of the swale, the width will be the average water surface width corresponding to the flowrate associated with the 100-year storm.

#### ***Design Criteria***

To be considered a swale, a channel must have a width to depth ratio of at least 6:1, have a bed slope of not greater than four percent (4%), and be vegetated. When swales are used for roadside drainage, curb cuts shall be provided no less frequently than on per each one hundred (100) feet of curb.

Drop inlets in swales shall be spaced no closer than once per each three hundred (300) feet in order to obtain the infiltration credit.

Grassed channels that do not satisfy the design criteria to be considered swales may be given an infiltration credit only for the channel bottom, if the bed slope does not exceed four percent (4%).

#### **B.4.4 Bermed Swales**

A bermed swale or infiltration swale is a grassed swale constructed with berms or swale blocks across the swale to impound shallow pools of water, slowing flow and providing additional opportunities for particle settling and storm water infiltration.

#### ***Infiltration Credit***

Infiltration credit for a bermed swale is calculated in the same manner as the credit for a swale, except that the calculated infiltration credit can be increased by fifty percent (50%) of the water volume that can be impounded by the berms.

#### ***Design Criteria***

Swale blocks or earthen berms built across the swale shall be constructed with a two (2)-inch diameter PVC pipe through the berm to prevent long-term ponding of water.

Berms shall be no taller than eight (8) inches and spaced no closer than sixty (60) feet.

Drop inlets in swales shall be spaced no closer than once per each three hundred (300) feet in order to obtain the infiltration credit.

Grassed channels that do not satisfy the design criteria to be considered swales may be given an infiltration credit only for the channel bottom, if the bed slope does not exceed four (4) percent.

#### **B.4.5 Biofiltration Swales**

A biofiltration swale is a version of a bioretention system without the pipe underdrain system. This practice encourages infiltration from the swale bottom, through a planting bed, to the underlying soil. *See Figure B.3*

### ***Infiltration Credit***

Infiltration credit for a biofiltration swale is 0.50 acre-feet per acre of swale plus one hundred percent (100%) of the volume of the ponded water, when designed according to the following criteria.

If biofiltration swales are designed consistent with the procedures for bioretention systems, the infiltration credit equals the design treatment volume.

### ***Design Criteria***

Biofiltration swales shall be designed to have the following characteristics:

- trapezoidal or parabolic shape
- bottom width of 2 feet
- side slopes no steeper than 3:1
- longitudinal slope of 1 to 2 percent (up to 4 percent slope can be used with berms constructed as required for bermed swales)
- length, width, depth, and slope necessary to provide surface storage of the design volume with a maximum ponded depth of 18 inches.
- vegetated in accordance with requirements for vegetated channels with grass lining
- capacity to convey the 100-year design storm with at least 6 inches of freeboard
- A soil bed 36 inches deep having the width of the swale bottom

Plan the soil bed to consist of soils that have a permeability of at least 0.5 feet per day (USCS soils ML, SM, or SC). If native soils do not satisfy this criterion, a prepared soil bed can be designed.

An alternative to the above criteria is to size the filter bed (i.e., planting soil bed) for a biofiltration swale consistent with a bioretention system. Then the infiltration credit would be calculated in the same manner as the credit for bioretention.

### **B.4.6 Terraforming**

Terraforming is a term for special grading practices such as terracing and berming that are intended to promote infiltration. Bermed swales are a special case of terraforming. Terraforming can range from a small depression in permeable soil to an extensive series of bermed terraces. A simple example is given in *Figure B.4*.

### ***Infiltration Credit***

The infiltration credit for terraforming is 0.25 acre-feet per acre of area terraformed plus one hundred percent (100%) of the impounded water.

### **B.4.7 Infiltration Basins**

Infiltration basins may be used in locations that have at least five (5) feet of soil, with a permeability of at least 0.5 inches per hour underlying the device. The underlying five (5) feet of soil must also be above the seasonal high water table.

If soils do not meet the permeability requirement, they can be modified by mixing sand and gravel in the top five (5) feet of the soil underlying the device. If native soils are to be modified with sand or gravel, provide a design that shows the depth of soil to be modified and the total quantity of gravel or soil to be added. Include soil test data documenting the permeability of the soils before and after modification.

If desired, large infiltration basins can be designed much like an extended detention pond for storm peak control. The outlet structure and detention storage volumes are designed to be above the level needed to store the design WQV. The difference is that an infiltration basin does not have an extended detention outlet. Instead, the WQV is allowed to infiltrate into the soils underlying the basin. If the infiltration basin is not intended for peak flow control, it shall be designed so that volumes exceeding the WQV can discharge through an overflow weir or pipe. For small excavated basins of less than one-fourth (1/4) acre, volumes exceeding the WQV may be allowed to overflow onto the ground surface without use of an overflow structure, if proper erosion control measures are implemented.

The infiltration credit for an infiltrated basin is simply the volume designed to be impounded before overflow or discharge to a spillway.

### ***Design Criteria***

Test soils prior to designing an infiltration basin to ensure that the site is capable of infiltration. Obtain a minimum of three (3) soil test borings or test pits to verify that the soil is at least five (5) feet deep below the base elevation and has a permeability of at least 0.5 inch per hour.

Design the floor of the basin to be as flat as possible to promote infiltration. Provide side slopes not greater than 3:1 (h:v).

Provide a sediment forebay at the inlet to the basin with a depth of at least four (4) feet and a volume of at least ten percent (10%) of the WQV.

Size the basin to store the design WQV before discharging through the peak flow control outlet. If the basin is intended only for water quality treatment, design an outlet that allows volumes in excess of the WQV to discharge to a surface water conveyance.

If a base flow will be discharged into the infiltration basin, design a low flow orifice to allow base flow to pass through.

Adjust the storage depth so that the basin will completely drain the WQV in seventy-two (72) hours.

When using an infiltration basin for peak flow control, provide a minimum of one (1) foot of freeboard above the 100-year design storm high water elevation.

Impoundment depths shall not exceed fifteen (15) feet and storage volumes shall not exceed twenty-five (25) acre-feet.

Design earthen embankments with side slopes not steeper than 3:1 (horizontal to vertical).

Design basins to be placed outside the receiving stream except when a basin is designed as a regional detention basin and Warren County Public Works has approved its use as a regional basin.

Reserve adequate access from public or private right-of-way by establishing a maintenance easement. Design the access to be at least ten (10) feet wide, with a slope not greater than 5:1 (h:v). Design the access way to connect to the embankment so that equipment can access the top of the embankment on a slope not greater than 5:1 (h:v).

Provide a minimum twenty-five (25)-foot wide buffer strip between the basin and the nearest lot. Landscape the buffer strip with low-maintenance native grasses, shrubs and trees. Provide a landscaping plan for the basin and the buffer. Objectives of landscaping include improving the appearance for adjacent residents and providing wildlife habitat.

### ***Specifications***

Embankment, outlet and emergency spillway specifications are consistent with those for detention basins.

Excavate the basin with light equipment having tracks or over-sized tires to minimize compaction of the underlying soils. After the basin is excavated to the final design depth, deeply till the basin floor with a rotary tiller or disc harrow to restore infiltration rates. After tilling, apply a leveling drag.

Establish vegetation immediately after achieving final grade and preparing the infiltration bed. Stabilize the floor of the basin with a dense cover of water-tolerant herbaceous species consistent with requirements of bioretention systems.

### **B.4.8 Vegetated Filter Strips**

A vegetated filter is a practice that relies upon the use of vegetation to filter out sediment and other pollutants from storm water runoff. These filters also provide an opportunity for storm water runoff to infiltrate. Vegetated filters can be used as water quality devices. Vegetated filters can be used for small subareas of a larger development in order to reduce the total volume to be treated by other devices in the development.

A filter strip is a practice that relies upon sheet flow across the entire width of the vegetated area. The vegetation is typically grass; however, other ground cover can be used if it provides for dense vegetation. Filter strips are typically used at the edge of a parking lot or other paved surface.

### ***Design Criteria***

Design a filter strip to have a width matching the width of the area draining to the filter.

Design a filter strip to have a smooth transition with the area draining to it so that sheet flow can be developed across the filter.

Design filter strips to have a minimum slope of two percent (2%) and a maximum slope of six percent (6%).

Provide a dense turf or other comparable vegetated ground cover over the whole filter area.

When the contributing area draining to the filter strip is impervious, do not allow the overland flow length of the impervious surface to exceed seventy-five (75) feet.

When the contributing area draining to the filter strip is pervious, do not allow the overland flow length of the contributing surface to exceed one hundred fifty (150) feet.

### ***Infiltration Credit***

The infiltration credit for vegetated filters is 0.075 acre-feet per acre of filter.

## **B.5 SAND AND ORGANIC FILTERS**

In general usage, storm water filters are a diverse group of techniques for treating storm water quality with each using some sort of filtering media such as sand, soil, gravel, peat, compost or vegetation. Filters will include systems with a designed filter bed composed of sand, gravel, compost or peat and an outlet to the storm water drainage system or a receiving stream. Systems described in this section include surface sand filters, underground sand filters, perimeter sand filters and organic filters.

### **B.5.1 Applicability**

Filters can be used for water quality treatment, but are not appropriate for peak flow (quantity) control.

### **B.5.2 General Design Criteria**

Design criteria in this section apply to all filtration devices in this section.

Provide a pretreatment cell to allow sedimentation prior to the filter bed and reduce clogging.

Locate inlet and outlet structures at extreme ends of the pretreatment cell.

Design the pretreatment or sedimentation cell to have a minimum depth of three (3) feet to minimize resuspension and turbulence.

Design the bottom of the pretreatment cell to be nearly level to facilitate sedimentation.

Design the surface area of the pretreatment cell (in square feet) to be at least 0.0081 times the WQV (in cubic feet) for areas with seventy-five percent (75%) or more impervious surface. For areas with less than seventy-five percent (75%) impervious surface, design the surface area of the pretreatment cell (in square feet) to be at least 0.066 times the WQV (in cubic feet). The order of magnitude difference in the two factors derives from the fact that areas with higher percentages of impervious surface (i.e., seventy-five percent (75%) or more) tend to have a greater proportion of coarse-grained sediments, which have a higher settling velocity.

Size the pretreatment cell with a minimum length to width ratio of 2:1.

The length to width ratio of the pretreatment cell can be less than 2:1 if baffles are provided to obtain a flow length equivalent to or greater than would be obtained with a 2:1 ratio.

Design each filtering device for a capture or storage volume equal to or greater than three-fourths (3/4) times the WQV.

Design filtration systems to be off-line by using a flow-splitter or other device to divert flows in excess of the WQV around the filtration systems.

Provide sufficient access to the device for construction and maintenance. Provide an access ramp with a maximum slope of ten percent (10%) for vegetated ramps, fifteen percent (15%), if the slope is stabilized with crushed stone, or twenty-five percent (25%) if paved.

Construct exposed piping and accessories out of durable, strong materials to avoid susceptibility to damage by vandalism.

Provide access manholes and/or grates to underground and below grade structures for each subsurface chamber. Provide manhole diameters of at least thirty (30) inches to meet confined space access criteria. Place manhole steps to allow maintenance personnel easy access to structure bottoms. Provide a five (5)-foot minimum height clearance (from the top of the sand layer to the bottom of slab) for all fixed permanent

underground structures. Provide lifting rings or other suitable elements to lift and replace structure top slabs.

Construct the underground sand filter with a dewatering gate valve located just above the top of the sand filter bed. Should the filter bed and/or underdrain system clog completely, the gate valve can be opened to dewater the filter chamber for needed maintenance.

### **B.5.3 Surface Sand Filter**

A surface sand filter is shown in *Figure B-5*. This system is constructed of reinforced concrete with a pretreatment (sedimentation) chamber and a filter bed chamber with a sand filter and underdrain system. *Figure B-5* also shows a flow diversion chamber at the inlet end of the structure.

The filter bed has an eighteen (18)-inch to twenty four (24)-inch sand layer which traps or strains pollutants before runoff is collected in an underdrain system (gravel and perforated pipe) and conveyed to the receiving stream, channel or pipe. The filter bed surface may have sand or grass cover.

Surface sand filters are open at the top, which provides easy access for maintenance, but renders these unsuitable in areas easily accessible to the general public, especially small children. Control access to surface sand filters by enclosing them in an eight (8)-foot chain link fence. Such a configuration is most suitable to industrial and warehousing facilities rather than commercial/retail establishments where aesthetic impact is significant. Even for industrial sites, consider proximity to residential areas and other locations frequented by children. In some locations, an eight (8)-foot fence may not provide adequate protection.

#### ***Design Procedures***

Size the pretreatment chamber in accordance with design criteria in section B.5.2

Size the area of the filter bed using the following equation:

$$A_f = WQV \cdot (d_f) / [k \cdot (h_f + d_f) \cdot (t_f)]$$

Where:

$A_f$  = surface area of the sand filter bed (ft<sup>2</sup>)

WQV = water quality treatment volume (ft<sup>3</sup>)

$d_f$  = sand filter bed depth (ft)

$k$  = coefficient of permeability for sand bed (ft/day)

$h_f$  = average height of water above the sand bed (ft);  $h_f = 0.5 \cdot h_{max}$

$t_f$  = time required for the WQV to filter through the sand bed (days).

Note:

- Set  $d_f$  such that  $1.5 \text{ feet} \leq d_f \leq 2 \text{ feet}$
- $h_f$  can vary depending on the site conditions, but six feet is the maximum value.
- Use 1.7 days (i.e., 40 hours) for the filter bed draw-down time ( $t_f$ ).
- Use  $k = 3.5 \text{ ft/day}$ .

Design the underdrain system beneath the filter bed to be at least six (6) inches deep, with at least two (2) inches of gravel over drain pipes and pipe slopes of at least one-half percent (0.5%).

Design the underdrain system to ensure that the flow through rate of the filter bed is controlled by the filter media rather than the underdrain system.

Calculate the minimum volume which must be stored within the device as  $V_{\min} = 0.75 \text{ (WQV)}$ .

Compute the water volume within the filter bed as  $V_f = A_f * 0.35 * (d_f + d_u)$ , where  $d_f$  is the depth of the sand bed and  $d_u$  is the depth of the gravel underdrain. The constant 0.35 represents the porosity of the sand and gravel. *Figure 10-6* provides an illustration of the parameters used for calculating storage volume.

Compute the temporary storage volume above the filter bed as  $V_{f - \text{temp}} = 2 * h_f * A_f$ .

Compute the remaining volume required for the pretreatment chamber as  $V_s = V_{\min} - (V_f + V_{f - \text{temp}})$ . Check that  $V_s$  is approximately 50 percent of  $V_{\min}$ . If it is not, decrease  $h_f$  and re-compute. Note that changing  $h_f$  will change the computed  $A_f$ .

Calculate the height in the pretreatment chamber,  $h_s$ , as  $h_s = V_s / A_s$ .

Check that  $h_s$  is greater than  $2 * h_f$  and  $h_s$  is greater than three (3) feet. If not, adjust  $h_f$  and repeat computation.

Design a junction box flow splitter with either a pipe or weir overflow to the storm water system. Set the invert of the overflow to the elevation of the design water level in the pretreatment chamber. Design the overflow to convey the peak discharge anticipated from the 10-year storm.

Design the structural concrete components in accordance with design loads and site soil conditions.

### ***Specifications***

Select sand to meet AASHTO M-6 or ASTM C-33 requirements for medium aggregate concrete sand with size range of 0.02 to 0.04 inches.

Select underdrain gravel to meet AASHTO classification M-43 with size range of one-half (0.5) to two (2) inches.

Select geotextile fabric to have a minimum puncture strength of one hundred twenty-five (125) pounds (ASTM D-751), minimum mullen burst strength of four hundred (400)

psi (ASTM D-117), and minimum tensile strength of three hundred (300) pounds (ASTM D-1682). Geotextile fabric shall have an opening size equivalent to U.S. sieve size #80 and shall provide a minimum flow rate of one hundred twenty-five (125) gallons per minute per square foot.

Select underdrain piping to meet AASHTO M-278 requirements for Schedule 40 PVC pipe. Provide three-eighths (3/8)-inch perforations on six (6)-inch centers with four (4) holes per row.

Construct the base of the sand filter structure on undisturbed soil or rock. If disturbed soil must be used as a base, recompact it to ninety-five percent (95%) of maximum standard dry density in six (6)-inch compacted lifts.

Do not allow runoff to enter the sand filter bed until the upstream drainage area is completely stabilized and site construction is completed. The sedimentation pond may serve as a temporary sediment control pond during site construction with the provision that overflows will bypass the filtration bed.

Construct the top of the filter bed completely level.

Store materials which might be damaged during construction (such as perforated PVC piping, geotextiles, etc.) in a safe location and handle carefully.

Construct overflow weirs, multiple orifices and flow distribution slots completely level to ensure adequate distribution of design flows.

Construct the main collector pipe for underdrain systems at a minimum slope of one-half percent (0.5%). Provide observation and clean-out pipes for all underdrain piping.

#### **B.5.4 Underground Sand Filter**

Underground sand filters are suitable for intensely developed urban areas where space is at a premium. These systems are also suitable in locations that are easily accessible to the public. *Figure B-7* shows an underground sand filter. In this design, the sand filter is placed in a three chamber underground vault accessible by manholes or grate openings. The first chamber is a three (3)-foot deep sediment chamber used for pretreatment. It is connected to the second chamber (the sand filter bed) by an inverted elbow or submerged slot, which keeps the filter surface free from trash and oil. The filter bed is eighteen (18) to twenty-four (24) inches in depth and has a protective screen of gravel over filter fabric to act as a pre-planned failure plane that can easily be replaced when the filter surface becomes clogged. During a storm, the WQV is temporarily stored in both the first and second chambers. Flows in excess of the filter's capacity are diverted through an overflow weir.

#### ***Design Procedures***

Design procedures are consistent with those described previously for a surface sand filter with the following exceptions. See *Figure B-8* for an illustration of the volume parameters.

After computing the minimum volume which must be stored ( $V_{min.}$ ) and the volume in the filter bed ( $V_f$ ), compute the minimum wet pool volume in the settling basin as  $V_w = 3 \text{ ft} * A_s$ .

Compute the temporary storage volume required within both chambers as  $V_{temp} = V_{min} - (V_f + V_w)$ .

Compute the total surface area of both chambers as  $(A_f + A_s)$ .

Calculate the height of temporary storage needed as  $h_{temp} = V_{temp} / (A_f + A_s)$ .

Check that  $h_{temp}$  is greater than or equal to  $2h_f$ . If not, decrease  $h_f$  and recalculate volume requirements.

### ***Specifications***

Specifications are consistent with those provided for surface sand filters with the following addition.

To help extend the design life of the sand filter bed for the underground sand filter, place a wide mesh geotextile screen on the surface of the filter bed to trap the large quantities of trash, litter, and organic detritus associated with highly urban areas. During maintenance operations the screen is rolled up, removed, cleaned and reinstalled.

## **B.5.5 Perimeter Sand Filters**

The perimeter sand filter consists of two (2) parallel trench-like chambers that are typically installed along the perimeter of a parking lot. *Figure B-9* shows a perimeter sand filter. Parking lot runoff enters the first chamber that has a shallow permanent pool of water. The first trench provides pretreatment before the runoff spills into the second trench, which consists of an eighteen (18)-inch deep sand layer over a gravel/perforated pipe underdrain system. During a storm event, runoff is temporarily ponded above the normal pool and sand layer, respectively. When both chambers fill up to capacity, excess parking lot runoff is routed to a bypass drop inlet.

### ***Design Procedures***

Design procedures are consistent with those described previously for a surface sand filter with the following exceptions. See *Figure B-10* for an illustration of the volume parameters.

After computing the minimum volume which must be stored ( $V_{\min}$ ) and the volume in the filter bed ( $V_f$ ), calculate the minimum wet pool volume in the pretreatment basin as  $V_w = A_s * 2 \text{ ft}$ .

Calculate the temporary storage volume required as  $V_{\text{temp}} = V_{\min} - (V_f + V_w)$ .

Compute the total surface area of both chambers as  $(A_f + A_s)$ .

Check  $h_{\text{temp}}$  is greater than or equal to  $2h_f$ . If not, decrease  $h_f$  and recompute areas and volumes. Note that changing  $h_f$  will change the required  $A_f$ .

### ***Specifications***

Specifications are consistent with those given for a surface sand filter.

## **B.5.6 Organic Filters**

Organic filters are designed consistent with surface or underground filters except that the sand filter bed is replaced or modified with organic media. There are two basic options for organic filters: a peat-sand system and a compost system.

In the peat-sand system, the filter bed is a minimum of twenty-four (24) inches deep over the underdrain system. This twenty-four (24)-inch bed consists of a six (6)-inch sand layer overlain by an eighteen (18)-inch layer of peat-sand mix.

The compost filter system consists of a fabricated leaf compost filtration bed overlying the underdrain system. The compost must be mature and humic so that the organic material is no longer rapidly decaying, and it must be locally available at a reasonable cost.

### ***Design Procedures***

Design procedures are consistent with those given previously for surface sand filters or underground sand filters except that the coefficient of permeability,  $k$ , for the organic filter is modified. For a peat-sand system, use  $k = 2.75 \text{ ft/day}$ . For a compost system, use  $k = 8 \text{ ft/day}$ .

### ***Specifications***

For peat-sand filter beds, select a fibric peat that is shredded, uniform and clean.

For peat-sand filter beds, combine equal volumes of peat and sand and mix to obtain uniform distribution of peat and sand. Sand specifications are given in *Section B.5.3*

For peat-sand filter beds, place a six (6)-inch layer of sand over the gravel underdrain. Separate the sand layer from the gravel layer with geotextile fabric. Select sand and geotextile consistent with specifications in *Section B.5.3*. Above the six (6)-inch sand layer, place eighteen (18) inches of the 50/50 peat-sand mixture. Construct the filter bed so that the surface of each layer is level. Provide nominal compaction of the gravel and sand layers using a mechanical tamper. Do not compact the sand-peat layer.

For a compost filter bed, select a compost that is mature and humic, composed of leaf medium rather than general yard waste compost.

For a compost filter bed, place a minimum of eighteen (18) inches above the geotextile overlying the underdrain system. Do not compact the compost filter bed.

## **B.6 PREFABRICATED TREATMENT DEVICES**

Several manufacturers produce devices that are effective in removing suspended solids and floating oils from storm water runoff. These devices are typically well-suited to sites that are relatively small and have a high percentage of impervious cover. These devices are not as effective in applications where a majority of the ground cover is pervious and a high percentage of the suspended solids are eroded fine soil particulars. Proposed products shall be submitted for review and approval.

### **B.6.1 Design Criteria**

The treatment devices shall be capable of demonstrating eighty percent (80%) capture of particles in a size range of two (2) millimeters (very coarse sand) to 0.125 millimeters (very fine sand). The design storm shall have an intensity of 2.1 inches per hour (three (3)-month frequency storm with a time of concentration of ten (10) minutes).

## **B.7 DETENTION PONDS**

A detention pond is a traditional storm water quantity control device that is designed for peak discharge control. Detention ponds are designed to completely drain after the design storm passes. *Figure B-11* illustrates a detention pond.

### **B.7.1 Applicability**

Detention ponds are not effective as water quality treatment devices and can only be used for water quantity control (i.e. detention).

### **B.7.2 Design Criteria**

Design detention ponds so that discharge rates do not exceed calculated pre-development peak runoff rates for the 10-year six (6)-hour and 100 year six (6)-hour storm.

Design outlet structures so that detention volume is released within twenty-four (24) hours.

Provide an emergency spillway sized to discharge the peak runoff from the 100-year storm assuming the principal spillway is clogged, without overtopping the crest.

Provide a minimum of one (1) foot of freeboard above the calculated high water elevation for the 100-year storm.

Embankment heights shall not exceed twenty (20) feet (measured from the downstream toe) and storage volumes shall not exceed twenty-five (25) acre-feet and shall not be less than 0.3-acre feet. Regional facilities may exceed these limits, but they must comply with the applicable requirements of the Kentucky Division of Water.

Design earthen embankments with side slopes no steeper than 3:1 (horizontal to vertical).

Provide anti-seep collars where the spillway barrel passes through the embankment. Stabilize earthen embankments immediately with temporary or permanent vegetation.

Design ponds to be placed outside the receiving stream except when a pond is designed as a regional detention pond and Warren County Public Works has approved its use as a regional pond.

Reserve adequate access from public or private right-of-way by establishing a maintenance easement. Design the access to be at least ten (10) feet wide and not steeper than 5:1 (h:v). Design the access way to connect to the embankment so that equipment can access the top of the embankment on a slope not steeper than 5:1 (h:v).

Provide a minimum twenty-five (25)-foot wide buffer strip between the pond and the nearest property line. Landscape the buffer strip with low-maintenance native grasses, shrubs and trees. Provide a landscaping plan for the pond and the buffer. Objectives of landscaping include improving the appearance for adjacent residents and providing wildlife habitat.

Outlet works may be a combination of pipes, weirs, orifices and drop inlets, but design any outlet pipes to be at least fifteen (15) inches in diameter to facilitate maintenance.

Design ponds to have a minimum bottom slope of two percent (2%) with a pilot channel for low flow.

### **B.7.3 Design Procedures**

Compute the inflow hydrographs for both pre- and post-developed conditions for the 10-year and 100-year storms.

Size the outlet structure for the maximum allowable peak discharge at the estimated peak stage.

Develop a stage-storage curve for the proposed pond.

Develop a stage-discharge curve for all outlet control structures.

Perform flood routing calculations using the post-development hydrographs determined for the design storms.

If the routed post-development peak discharge(s) from the design storm(s) exceeds the pre-development discharge, or the peak stage varies significantly from the estimated peak stage, revise the pond volume and/or outlet structure design. Develop a revised stage-storage curve and a revised stage-discharge curve and rerun the flood routing.

Design the emergency spillway to handle the 100-year peak discharge from the post-development hydrograph with no conveyance through the primary outlet structure.

Evaluate the downstream effects of detention outflow to ensure that the routed hydrograph does not cause downstream flooding problems.

Evaluate the control structure outlet velocity and provide channel and bank stabilization if the velocities are greater than the natural stream velocities.

### **B.7.4 Material Specifications**

Construct embankments of ML, CL, MH, or CH soils as determined in accordance with the Unified Soil Classification System (USCS).

Determine the maximum standard dry density (ASTM D698) of at least two (2) distinct samples of the soils to be used for embankment construction.

All conduits used for principal spillways shall be reinforced concrete pipe (RCP). The conduits shall be sealed with rubber gaskets to form a flexible watertight seal under all conditions of service. All pipes shall meet the requirements set forth in the Kentucky Transportation Cabinet's Standard Specifications for Road and Bridge Construction, latest edition. The design engineer shall be responsible for determining the size and grade of pipe to be used.

Anti-seep collars shall be provided on all conduits through earthen embankments, foundations, and abutments. The number and size of anti-seep collars shall be determined based on guidance set forth in the Kentucky Department for Environmental Protection, Division of Water's Engineering Memorandum No. 5, Design Criteria for Dams and Associated Structures.

All stone shall meet the requirements set forth in the Kentucky Transportation Cabinet's Standard Specifications for Road and Bridge Construction, latest edition.

Gradation of stone material will be performed in accordance with ASTM C-33. Tests shall be performed on every five (5) tons of stone installed or at least once per installation location in locations where less than five (5) tons are placed.

All geotextiles shall meet the requirements for performance and strength as set forth by the design engineer. Any alternative material used on the project shall be approved by the design engineer.

The following tests shall be performed and included in the manufacturer's certifications for each shipment of geotextile for every five hundred (500) square yards (or once per lot if manufacturer's records show multiple rolls came from same lot), whichever is less:

- Mass per unit area per ASTM D-5261
- Grab tensile strength per ASTM D-4632
- Trapezoidal tear strength per ASTM D-4533
- Burst Strength per ASTM D-3786
- Puncture strength per ASTM D-4833
- Thickness per ASTM D-5199
- Apparent opening size per ASTM D-4751
- Permittivity per ASTM D-4491
- Ultraviolet light resistance per ASTM D-4355

In the case that a more recent testing standard has been released, then that standard shall be used in lieu of the listed testing standards.

#### **B.7.5 Construction Specifications**

Verify areas to be backfilled are free of debris, snow, ice, or water and ground surfaces are not frozen.

When necessary, compact subgrade surfaces to density requirements for the backfill material and prepare subgrade or previous layer of compacted fill prior to placement of additional fill by scarifying or disking.

Cut out soft areas of subgrade not readily capable of in situ compaction. Backfill with subsoil and compact to density equal to requirements for subsequent backfill material.

Backfill areas to contours and elevations. Use materials that are not frozen. The contractors shall keep the foundation and subgrade free from water or unacceptable materials after the fill operations have started.

Backfill systematically, as early as possible, to allow minimum time for natural settlement. Do not backfill over porous, wet or spongy subgrade surfaces.

Place and compact soil fill materials in continuous layers not exceeding eight (8) inches loose depth. Compact soil fill materials to ninety-five percent (95%) of maximum dry density. Field density tests shall be performed on each lift. Areas that fail to meet the requirements will be reworked as necessary to meet the requirements and then tested again. The process shall be repeated until the compaction requirements are met.

Tests shall be performed on each four hundred (400) square feet of surface area and on each lift of the surface area.

Maintain optimum moisture content of backfill material to attain required compaction density as specified. Material deposited on the fill that is too wet shall be removed or spread and permitted to dry, assisted by disking or blading, if necessary, until the moisture content is reduced to the specified limits.

All crushed stone fill and crushed stone backfill under structures and pavements adjacent to structures shall be DGA crushed stone per Kentucky Highway Department Standard Specifications for Road and Bridge Construction, unless indicated otherwise. Stone fill and backfill materials shall be placed in layers not exceeding six (6) inches in thickness and compacted to ninety-five percent (95%) of maximum dry density.

Backfill shall not be placed against or on structures until they have attained sufficient strength to support all loads without distortion, cracking or damage. Deposit soil evenly around the structure.

Slope grade away from structures minimum two (2) inches in ten (10) feet, unless noted otherwise.

Make changes in grade gradual. Blend slopes into level areas.

Remove surplus excavation materials to designated area.

Pipe bedding shall meet the requirements set forth in the Kentucky Highway Department Standard Specifications for Road and Bridge Construction, latest edition, and the Bowling Green and Warren County Standard Drawings, latest edition.

The pipe trench shall be over-excavated six (6) inches and properly backfilled prior to laying pipe. In no case shall pipe be laid on solid or blasted rock.

Pipe bedding material shall be placed in six (6) inch loose lifts and compacted to ninety-five percent (95%) maximum dry density at  $\pm$  two percent (2%) of the optimum moisture content.

When the subgrade is found to be unstable or to include ashes, cinders, refuse, organic material or other unsuitable material, such material shall be removed to the depth ordered by the design engineer and replaced under the directions of the design engineer with clean, stable backfill material. When the bottom of the trench or the subgrade is found to consist of material that is unstable to such a degree that, in the judgement of the design engineer, it cannot be removed, a foundation for the pipe and/or other appurtenance shall be constructed using piling, timber, concrete or other materials as the direction of the design engineer.

All pipe shall be laid with ends abutting and true to the lines and grades indicated on the drawings. The pipe shall be laid straight between changes in alignment and at uniform grade between changes in grade. Pipe shall be fitted and matched so that when laid to grade, it will provide a smooth and uniform invert.

The pipe shall be thoroughly cleaned prior to placement. Any piece of pipe or fitting which is known to be defective shall not be laid. If any defective pipe or fitting shall be discovered after the pipe is laid, it shall be removed and replaced with a satisfactory pipe or fitting.

The interior of the pipe, as the work progresses, shall be cleaned of dirt, jointing materials, and superfluous materials of every description. When laying of pipe is stopped for any reason, the exposed end of such pipe shall be closed with a plug fitted into the pipe bell so as to exclude earth or other material. Other precautions shall be taken to prevent flotation of pipe by runoff into trench.

All pipe shall be laid starting at the lowest point and installed so that the spigot ends point in the direction of flow.

All joint surfaces shall be cleaned immediately before jointing the pipe. The bell or groove shall be lubricated in accordance with the manufacturer's recommendation. Each pipe unit shall then be carefully pushed into place without damage to pipe or gasket. All pipes shall be provided with home marks to insure proper gasket seating. Details of gasket installation and joint assembly shall follow the direction of the manufacturers of the joint material and of the pipe. The resulting joints shall be watertight and flexible. No solvent cement joints shall be allowed.

After the embankment has been built to final grade, scarify or till the top and side slopes to a depth of six (6) inches to prepare a seed bed. Immediately seed and mulch with temporary or permanent seed.

## **B.8 EXTENDED DETENTION PONDS**

In this manual, an extended detention pond is a dry detention pond equipped with an outlet structure that provides extended detention time (typically twenty-four (24) hours) for a specific water quality treatment volume. *Figure B-12* illustrates an extended detention pond.

### **B.8.1 Applicability**

Extended detention ponds can be used for both water quality treatment and water quantity management. For water quality treatment, the extended detention volume is at least equal to WQV derived from *Table B-1* less any credits for infiltration or bioretention.

In locations with continuous dry weather flow, an extended detention pond will tend to be continuously wet. In this instance, quantify the base flow so that the peak flow and water quality control structures can be designed accordingly.

Design ponds to be located outside the receiving stream except when a pond is designed as a regional detention pond.

### **B.8.2 Design Criteria**

The minimum drainage area for extended detention ponds shall be ten (10) acres.

Design the extended detention outlet so that the “design” WQV requires at least twenty-four (24) hours to discharge.

To calculate the design WQV, take the full WQV for the site, minus any credits allowed for bioretention and infiltration practices.

Design extended detention ponds with two (2) stages. The lower stage would be the extended detention pool sized for the design WQV. The upper stage would be larger in area and sized for storm peak control.

Design the bottom slopes with a two percent (2%) minimum slope to promote drainage.

When a base flow into the pond exists, design the lower stage as a wetland marsh. In this case, provide a permanent pool of six (6) to twelve (12) inches below the design WQV. See the Kentucky Division of Water for a list of wetland plants.

Provide an emergency spillway sized to discharge the peak runoff from the 100-year storm, assuming the principal spillway is clogged, without overtopping the crest.

Provide a minimum of one (1) foot of freeboard above the calculated high water elevation for the 100-year storm.

Embankment heights shall not exceed twenty (20) feet (measured from the downstream toe) and storage volumes shall not exceed twenty-five (25) acre-feet. The minimum storage volume shall be 0.3 acre-feet. Regional facilities may exceed these limits, but they must comply with the applicable requirements of the Kentucky Division of Water.

Design earthen embankments with side slopes not steeper than 3:1 (horizontal to vertical).

Provide anti-seep collars where the spillway barrel passes through the embankment. Stabilize earthen embankments immediately with temporary or permanent vegetation in accordance with requirements of Chapter 11.

Reserve adequate access from public or private right-of-way by establishing a maintenance easement. Design the access to be at least ten (10) feet wide and not steeper than 5:1 (h:v) or less. Design the access way to connect to the embankment so that equipment can access the top of the embankment on a slope not greater than 5:1 (h:v).

Provide a minimum twenty-five (25)-foot buffer strip between the pond and the nearest property line. Landscape the buffer strip with low-maintenance native grasses, shrubs, and trees. Provide a landscaping plan for the pond and the buffer. Objectives of landscaping include improving the appearance for adjacent residents and providing a wildlife habitat.

### **B.8.3 Design Procedures**

Design procedures for storm water quantity and peak discharge control are the same for extended detention ponds and traditional dry detention ponds, except that the design WQV will be retained longer in the extended detention pond. To design the storm detention volume and peak control structure for an extended detention pond, follow the procedures given in *Section 10.7.3* and assume for design purposes that the elevation of the dry land bottom corresponds to the elevation of the surface of the design WQV (i.e. the top of the extended detention pool).

#### ***Sand Filter Outlet***

*Figure B-13* illustrates an outlet configuration that may be used to regulate discharge of the extended detention pool. A perforated riser may also be used.

To size this device pick a preliminary configuration and check it using the falling head permeability equation. Set  $t$  equal to twenty-four (24) hours and calculate  $k$ . If the calculated  $k$  varies significantly from 3.54 ft/hr., adjust the filter dimensions and recalculate.

The falling head equation is:

$$K = 2.303 * (aL/At) * \log (H/h)$$

Where:

$K$  = coefficient of permeability (ft/hr),

$a$  = average surface area of extended detention pool (ft<sup>2</sup>),

$L$  = depth of sand (ft),

$A$  = surface area of filter = width of sand layer \* length of sand layer (ft<sup>2</sup>),

$t$  = time (hr),

$H$  = height of water over the perforated pipe with full extended detention pool (ft), and

$h$  = height of filter from the top of the perforated pipe to the top of the sand (ft).

Size the sand filter trenches relative to the underdrain pipe such as the sand filter controls the discharge rate rather than the drain pipe. Provide calculations demonstrating that the underdrain pipe will convey the design flow rate under gravity flow conditions.

#### **B.8.4 Specifications**

Specifications are consistent with those provided in *Section B.7*

### **B.9 WET PONDS**

In this manual, wet pond refers to a basin designed for both water quality and water quantity management and which as a permanent pool *Figure B-14* illustrates a wet pond.

#### **B.9.1 Applicability**

Wet ponds can be used for water quantity management and water quality treatment. For water quality treatment, the WQV is at least equal to the WQV derived from *Table B-1*, less any credits earned from bioretention and infiltration.

#### **B.9.2 Design Criteria**

Design ponds to be placed outside the receiving stream except when a pond is designed as a regional detention pond.

Design retention ponds to have a contributing drainage area of at least ten (10) acres and a surface area of at least one-fourth ( $\frac{1}{4}$ ) of an acre.

When using a wet pond with a permanent pool for water quality control, size the permanent pool to at least equal the design WQV.

To calculate the design WQV, take the full WQV for the site, minus any credits allowed for infiltration and bioretention.

Design the permanent pool to have an average depth between three (3) feet and six (6) feet and a maximum depth of no more than eight (8) feet.

Design wet ponds to be wedge-shaped with the narrow end at the inlet and the wide end at the embankment.

Provide a minimum length to width ratio of 3:1 or provide gabion baffles to extend the flow path to a length that meets or exceeds the path that would be achieved using a 3:1 length to width ratio.

Provide irregular shorelines so that the permanent pool has a natural appearance.

Provide a ten (10)-foot wide, twelve (12)-inch deep, underwater bench around the perimeter except at the embankment.

Provide safety benches at least ten (10) feet wide around the perimeter above the permanent pool. Design these benches to have a slope not greater than 10:1 (h:v).

Design a liner for the permanent pool using on-site soils or other materials. Document that the proposed soils are suitable for use as a liner by providing soil classification data (Unified Soil Classification System) and standard moisture-density data (proctor density test). Design soil liners to be at least six (6) inches thick.

Provide an emergency spillway sized to discharge the peak runoff from the 100-year storm, assuming the principal spillway is clogged.

Provide a minimum of one (1) foot of freeboard above the calculated high water elevation for the 100-year storm.

Embankment heights shall not exceed twenty (20) feet (measured from the downstream toe) and storage volumes shall not exceed twenty-five (25) acre-feet. Regional facilities may exceed these limits, but they must comply with the applicable requirements of the Kentucky Division of Water.

Design earthen embankments with side slopes not steeper than 3:1 (horizontal to vertical).

Provide anti-seep collars where the spillway barrel passes through the embankment. Stabilize earthen embankments immediately with temporary or permanent vegetation.

Reserve adequate access from public or private right-of-way by establishing a maintenance easement. Design the access to be at least ten (10) feet wide and no steeper than 5:1 (h:v). Design the access way to connect to the embankment so that equipment can access the top of the embankment on a slope no steeper than 5:1 (h:v).

Provide a minimum twenty-five (25)-foot wide buffer strip between the pond and the nearest lot. Landscape the buffer strip with low-maintenance native grasses, shrubs and trees. Provide a landscaping plan for the pond and the buffer. Objectives of landscaping include improving the appearance for adjacent residents and providing wildlife habitat.

### **B.9.3 Design Procedures**

Design of the storm water detention volume and peak control structure for a wet pond is similar to procedures given for a traditional dry detention pond. The permanent pool is

sized to match the design WQV, which allows for effective water quality treatment. For quantity control, the pond must have capacity to hold the storm water detention volume above the permanent pool. That portion of the storm water detention volume equal to the design WQV is called the extended detention volume. The volume must be discharged slowly to protect the receiving stream from increased flood frequency. See *Figure B-15*.

### ***Reverse Slope Pipe***

This section describes the design procedure for sizing a reverse slope pipe to discharge that portion of the storm water detention volume equal to the design WQV. *Figure B-15* illustrates a reverse slope pipe.

Select a pipe diameter, length and material and use the energy equation to calculate the discharge. The energy equation can be written as:

$$Q = A (2gH)^{0.5} / (1 + K_e + K_b + K_c L)^{0.5}$$

Where:

Q = Discharge (ft<sup>3</sup>/s)

A = cross-sectional area of pipe (ft<sup>2</sup>)

g = 32.2 ft/s<sup>2</sup>

H = head above discharge end of pipe (ft<sup>2</sup>)

K<sub>e</sub> = entrance loss coefficient

K<sub>b</sub> = bend loss coefficient (0 for no bends)

K<sub>c</sub> = head loss coefficient for pipe

L = pipe length (ft)

Assume that the design WQV is placed above the permanent pool and calculate the corresponding height above the permanent pool. This is the head valve, H, corresponding to the WQV.

Calculate the discharge (Q) at 0.25-foot intervals from the top of the design WQV (extended detention pool) to the bottom of the extended detention pool (i.e. top of permanent pool).

Calculate the average discharge for each 0.25-foot increment by averaging the Q calculated at the top and bottom of each increment.

Use the stage-storage curve for the ponds to determine the storage volume in cubic feet corresponding to each 0.25-foot increment of depth.

Divide each incremental storage volume by its corresponding average discharge to calculate the time required for each incremental volume to be discharged through the selected pipe.

Sum the incremental discharge durations to determine if the total design WQV required twenty-four (24) hours to discharge. If not, adjust the pipe size and recalculate.

#### **B.9.4 Specifications**

Specifications are consistent with those provided in *Section B.7*.

### **B.10 CONSTRUCTED WETLANDS**

Constructed wetlands can provide a very effective management measure for mitigation of pollution from runoff, because they have the ability to assimilate large quantities of suspended and dissolved materials from inflow. The term “constructed wetland” can apply to a wetland which is constructed to mitigate impacts to a natural wetland (per a Corps of Engineers permit), or a wetland which is constructed as part of a wastewater treatment system. In this manual, a constructed wetland is advised to be constructed in accordance with the following criteria and procedures to treat and control storm water.

#### **B.10.1 Applicability**

Constructed wetlands can be used for both water quality and water quantity management or for water quality only. For management of water quantity, a wetland would be constructed much like a wet pond with a six (6) to twelve (12) inch deep permanent pool. The most important criterion in determining whether a constructed wetland is applicable is the existence of a base flow that can be used to supply the permanent pool.

#### **B.10.2 Design Criteria**

For water control, size the extended detention pool above the permanent pool equal to the design WQV.

Design the extended detention outlet so that at least twenty-four (24) hours would be required to release the design WQV.

To calculate the design WQV, take the full WQV for the site, minus any credits allowed for infiltration and bioretention.

For storm water quantity control, determine the necessary detention volume and design the peak control outlet consistent with the design criteria and design procedures for detention ponds in *Section B.7*. The extended detention volume is a portion of the total detention volume rather than being an addition to it.

Size the surface area of the wetland according to procedures described in the following section.

Provide a sediment forebay. Design the forebay to be four (4) to six (6) feet deep and have a volume of at least ten percent (10%) of the design WQV at the inlet to the constructed wetland.

Use a reverse slope pipe as the extended detention outlet and protect it from blockage using aggregate as shown in *Figure B-15*.

Provide a micropool at the extended detention outlet so that the reverse slope outlet pipe can be placed one (1) foot below the permanent pool surface. Design the micropool to be four (4) to six (6) feet deep with a volume of at least ten percent (10%) of the WQV.

Provide a drain with a valve at the base of the micropool.

Design the permanent pool, with the exception of the sediment forebay and the outlet micropool, to be three (3) to twelve (12) inches deep with an average depth of six (6) to nine (9) inches.

Design the grades in the constructed wetland so that the wetland will drain to the micropool at the outlet if the micropool is drained. Providing the ability to drain the wetland will facilitate maintenance and revegetation if necessary.

Design the wetland to have low marsh and high marsh in the permanent pool. Low marsh refers to a zone with six (6) to twelve (12) inches of permanent pool, while high marsh refers to a zone with zero to six (6) inches of permanent pool. Design the wetland so that low marsh and high marsh each represent thirty-five to forty-five percent (35-45%) of the total surface area. Design so that the total deep pool (i.e. the micropool plus the sediment forebay) represent ten to twenty percent (10-20%) of the surface area.

Design the wetland to have a length to width ratio of at least 2:1.

Reverse adequate access from public or private right-of-way by establishing a maintenance easement. Design the access to be at least ten (10) feet wide and no steeper than 5:1 (h:v). Design the easement to provide access to the sediment forebay and the outlet micropool.

Check the velocity of design storm flows at the inlet to the wetland and provide a stable entrance to prevent erosion.

Design a planting plan that shows forty to fifty percent (40-50%) of the shallow (twelve (12) inches or less) wetland planted with wetland vegetation. A list of suitable species is available from the Kentucky Division of Water. Plan to include a minimum of three emergent wetland species as the majority planting with at least three (3) additional emergent species comprising the remaining planting.

### B.10.3 Design Procedures

Use *Table B-2* to determine the minimum surface area required based upon the size of the watershed draining to the wetland. Values in *Table B-2* are based upon expected nitrogen and phosphorus loading rates in urban areas and the maximum loading per acre that a constructed wetland can effectively treat.

Procedures for sizing the reverse slope pipe outlet at the micropool are consistent with procedures for wet retention ponds given in *Section B.9*.

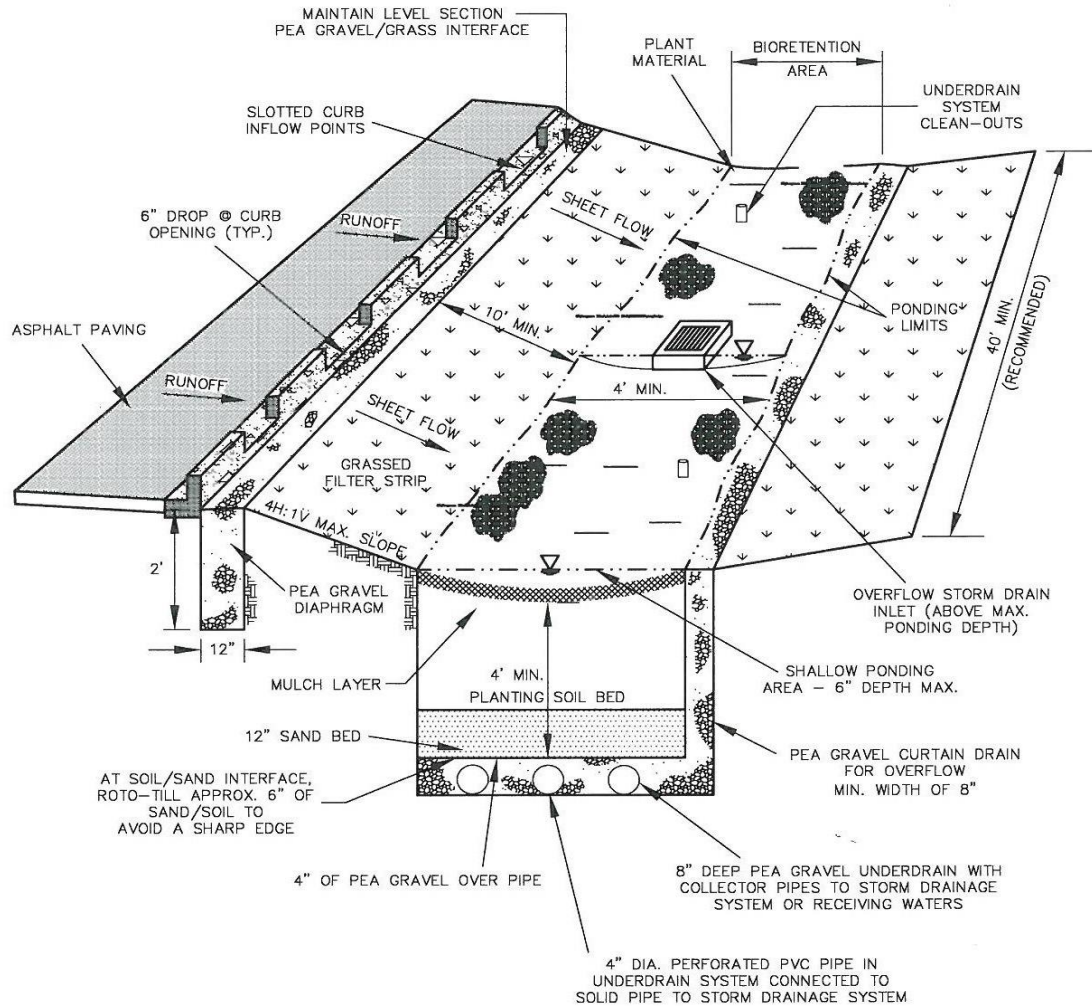
**TABLE B-2**  
**WETLAND SURFACE AREA**

% IMPERVIOUS SURFACE	SURFACE AREA IN ACRES PER ACRE OF WATERSHED
10	0.025
20	0.031
30	0.037
40	0.042
50	0.049
60	0.055
70	0.060
80	0.066
90	0.072
100	0.078

**Note:** Use linear interpolation for percent impervious values between those given in this table.

# STORMWATER GUIDE

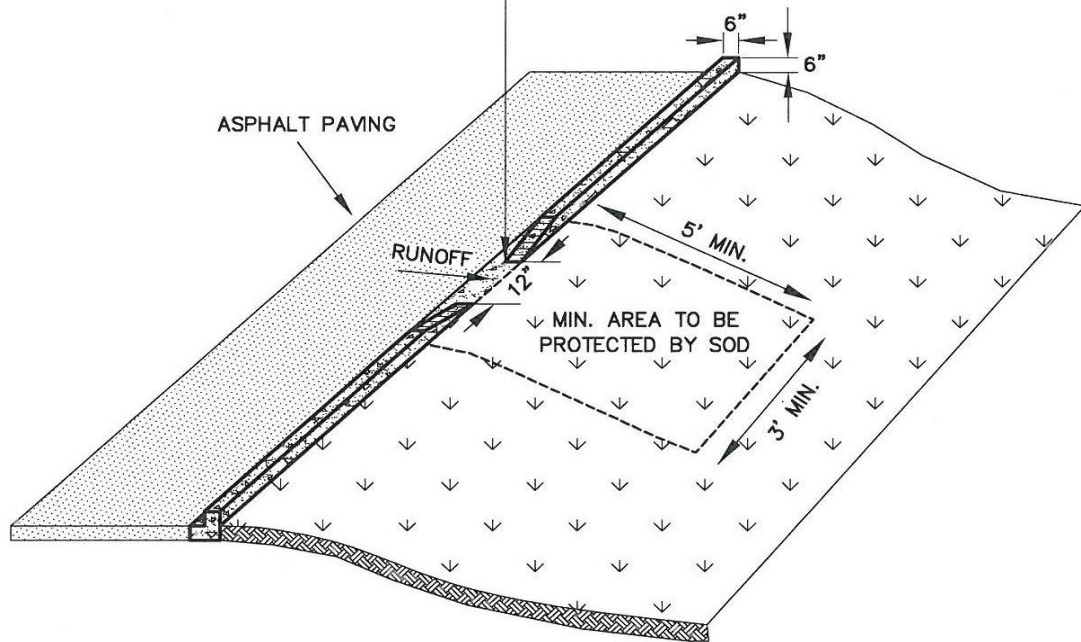
**Figure B-1**  
**Bioretention System**



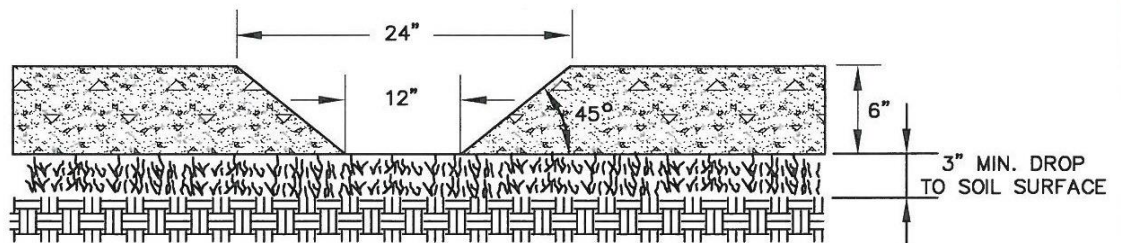
# STORMWATER GUIDE

**Figure B-2**  
**Curb Cut to Swale**

PROVIDE 3" MIN. DROP TO SOIL SURFACE  
SO THAT GRASS BUILDUP DOES NOT BLOCK  
CURB CUT



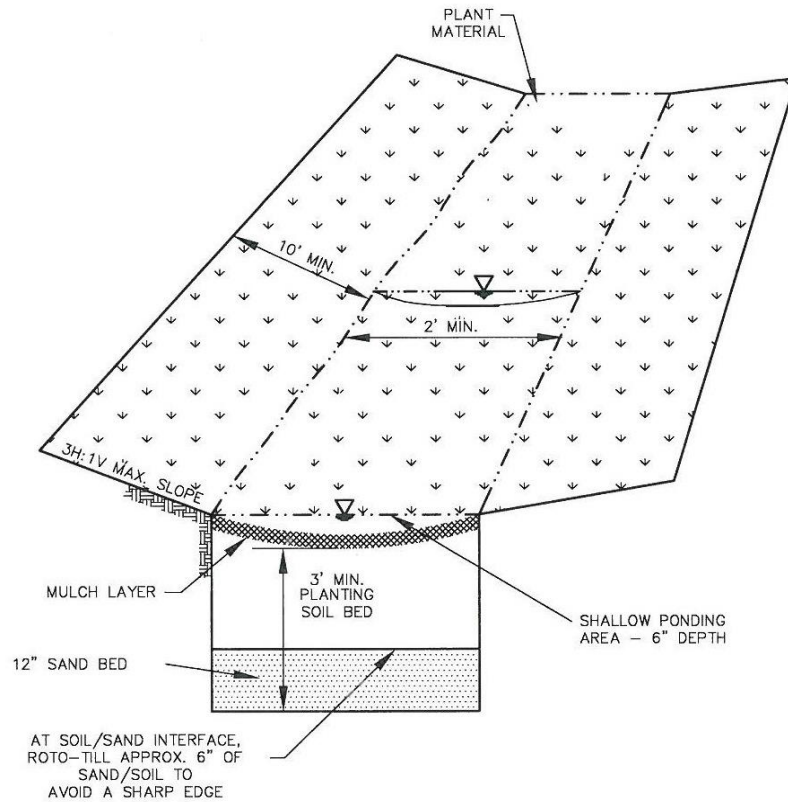
**ISOMETRIC VIEW**  
N.T.S.



**ELEVATION VIEW**  
N.T.S.

# STORMWATER GUIDE

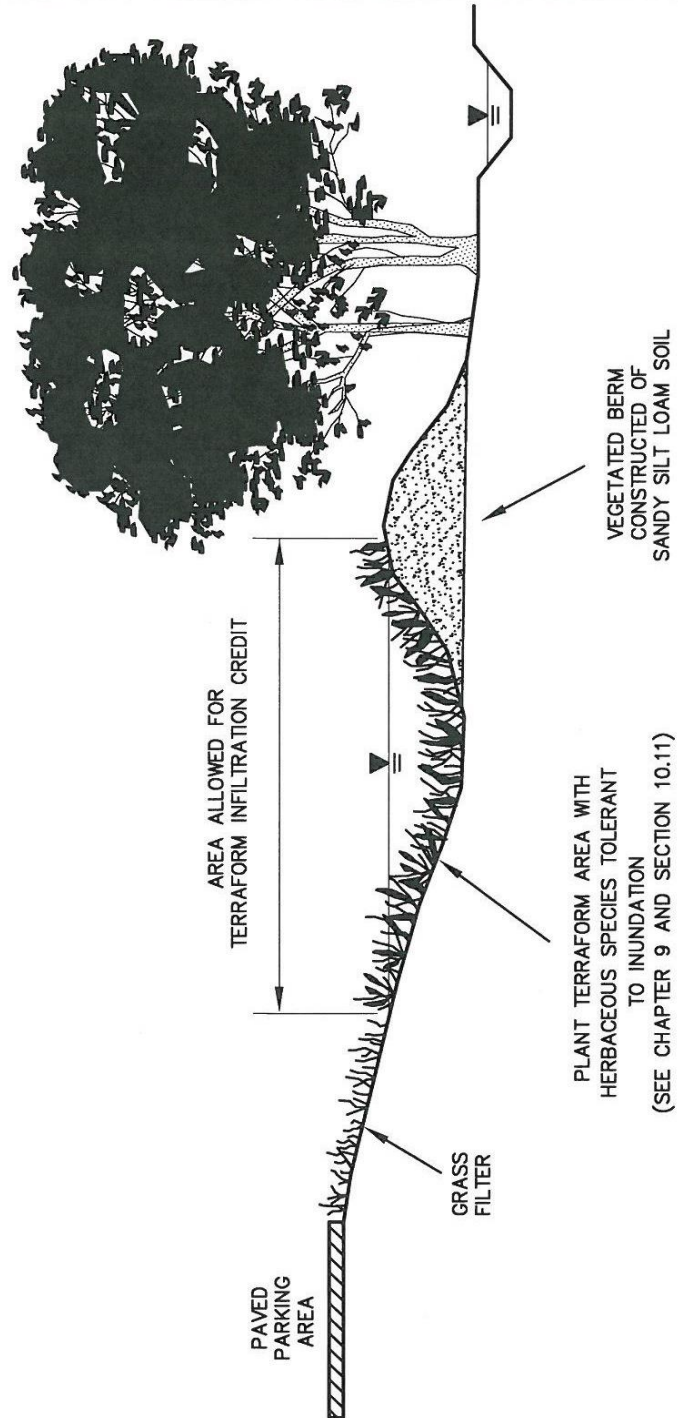
**Figure B-3**  
**Biofiltration Swale**



NOTE:  
IF LONGITUDINAL SLOPE EXCEEDS 2 PERCENT, CONSTRUCT A BERM AT THE DOWNSTREAM END OF BIOFILTRATION SWALE. CONSTRUCT BERM SO THAT IT IS 12 TO 18 INCHES HIGH IN CENTER WITH A LEVEL TOP ACROSS THE PLANTING BED. CONSTRUCT THE BERM TO HAVE SIDE SLOPES NO GREATER THAN 2 HORIZONTAL TO 1 VERTICAL.

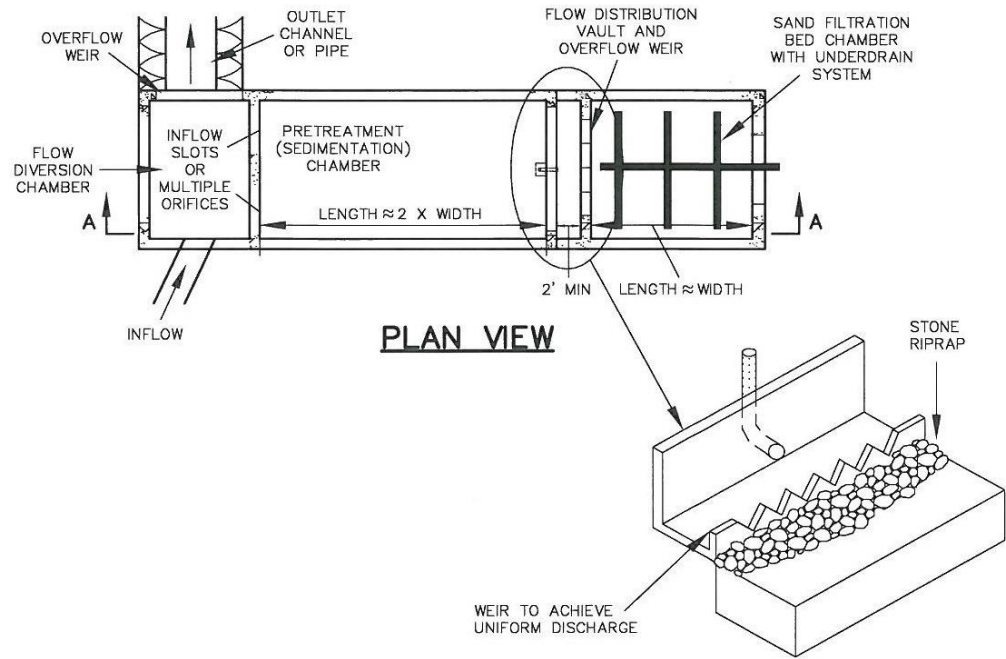
# STORMWATER GUIDE

**Figure B-4**  
Terraform Berm

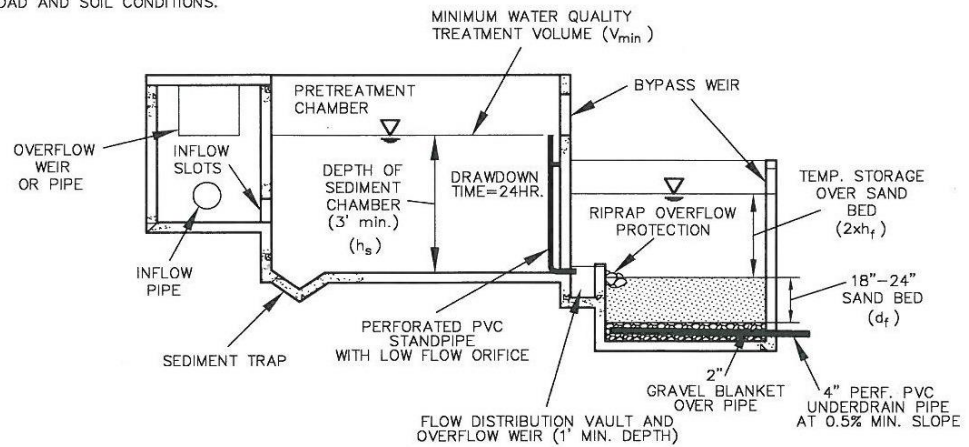


# STORMWATER GUIDE

**FIGURE B-5**  
**Surface Sand Filter**



NOTE: STRUCTURAL CONCRETE DESIGNED FOR LOAD AND SOIL CONDITIONS.



**SECTION A-A**

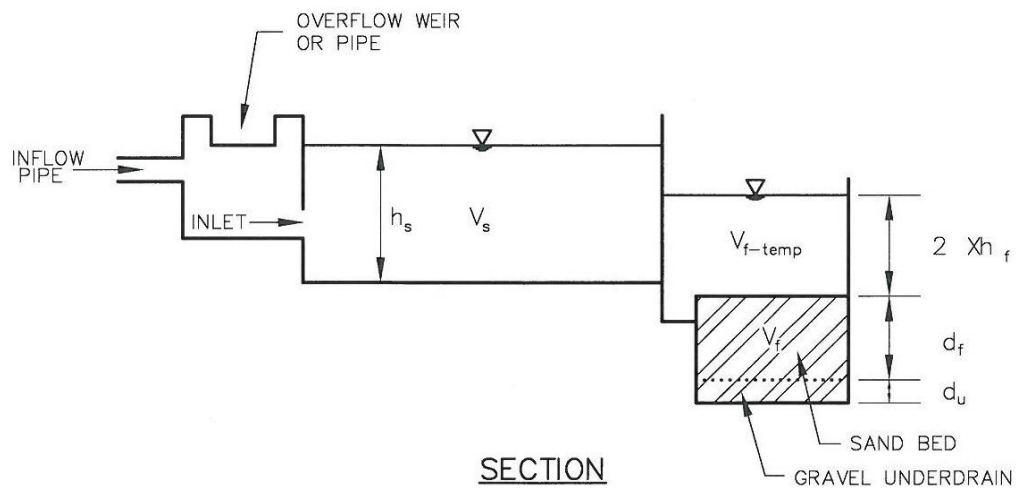
SOURCE: CLAYTOR AND SCHUELER, 1996

# STORMWATER GUIDE

**Figure B-6**  
**Surface Sand Filter Schematic**

FLOW DIVERSION CHAMBER	PRETREATMENT (SEDIMENTATION) BASIN AREA: $A_s$	SAND FILTER BED AREA $A_f$
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## PLAN



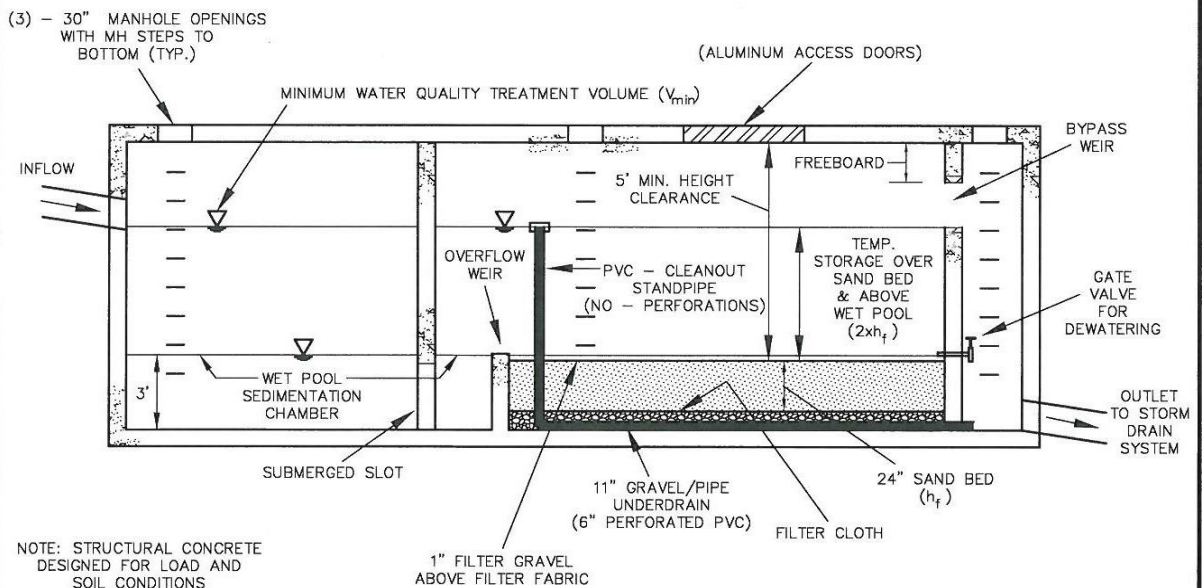
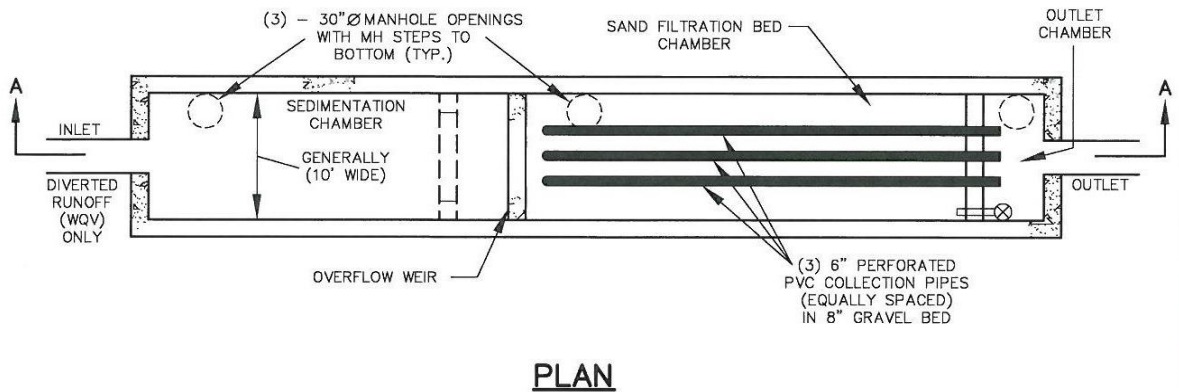
$$V_{TOTAL} = V_s + V_{f-temp} + V_f$$

$$CHECK\ THAT\ V_{TOTAL} \geq V_{MIN} = 0.75 \times WQV$$

SOURCE: CLAYTOR AND SCHUELER, 1996

# STORMWATER GUIDE

**Figure B-7**  
**Underground Sand Filter**



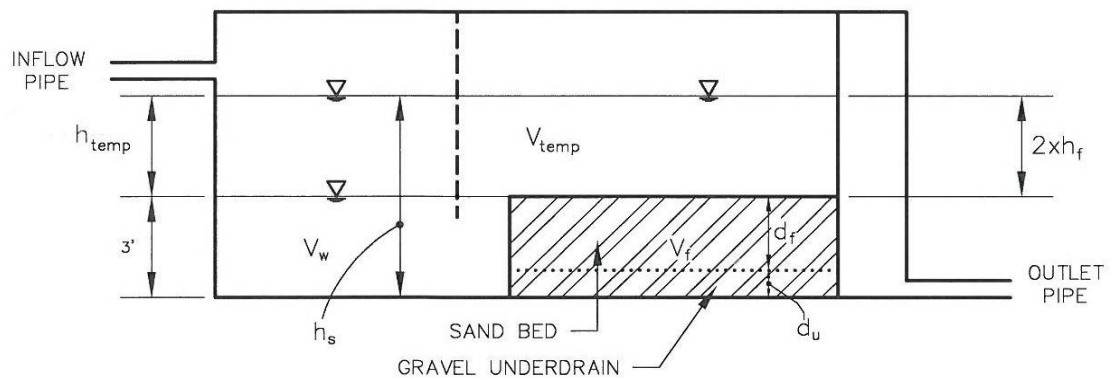
SOURCE: CLAYTOR AND SCHUELER, 1996

# STORMWATER GUIDE

**Figure B-8**  
**Underground Sand Filter Schematic**



PLAN



SECTION

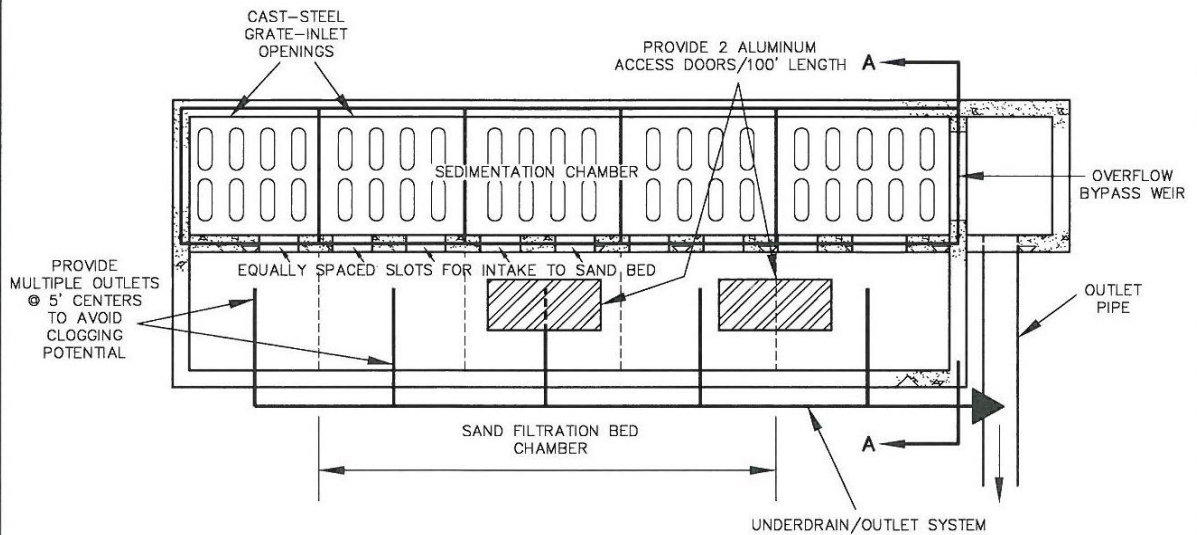
$$V_{TOTAL} = V_w + V_{temp} + V_f$$

$$CHECK\ THAT\ V_{TOTAL} \geq V_{MIN} = 0.75 \times WQV$$

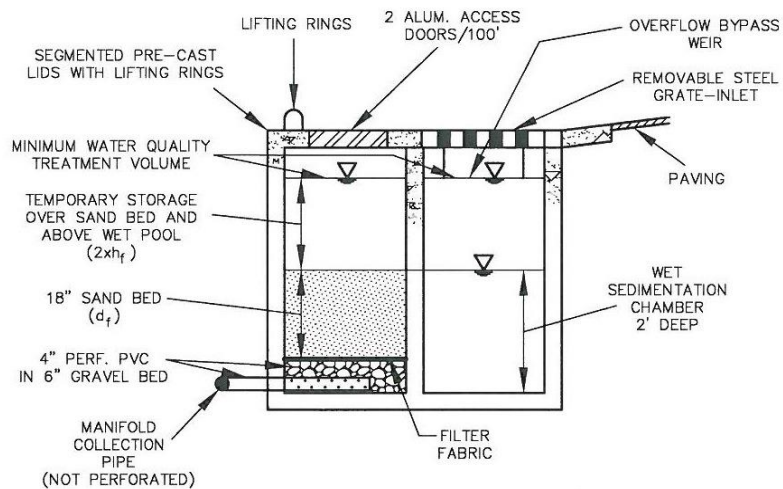
SOURCE: CLAYTOR AND SCHUELER, 1996

# STORMWATER GUIDE

**Figure B-9**  
**Perimeter Sand Filter**



**PLAN**

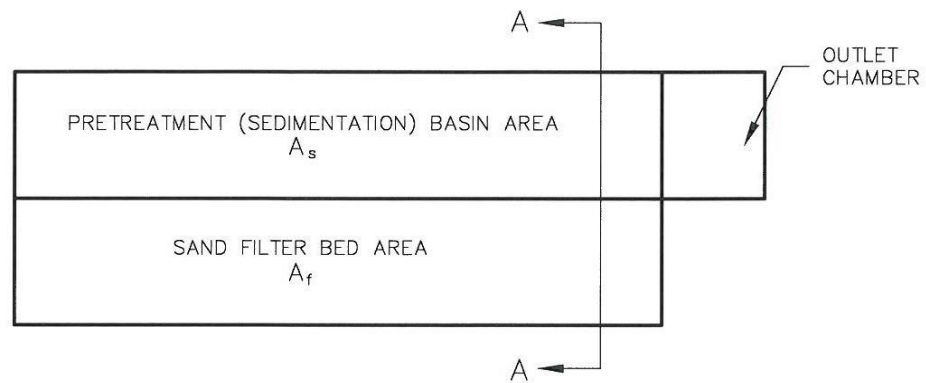


**SECTION A-A**

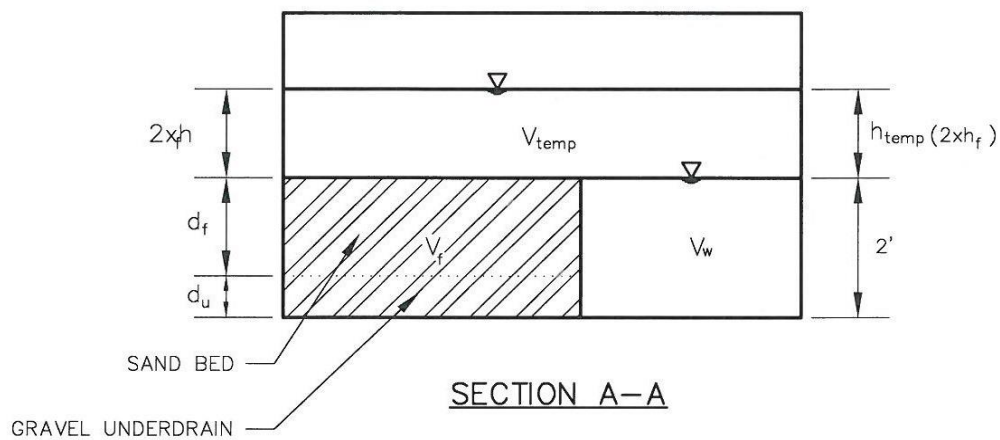
SOURCE: CLAYTOR AND SCHUELER, 1996

# STORMWATER GUIDE

**Figure B-10**  
**Perimeter Sand Filter Schematic**



PLAN



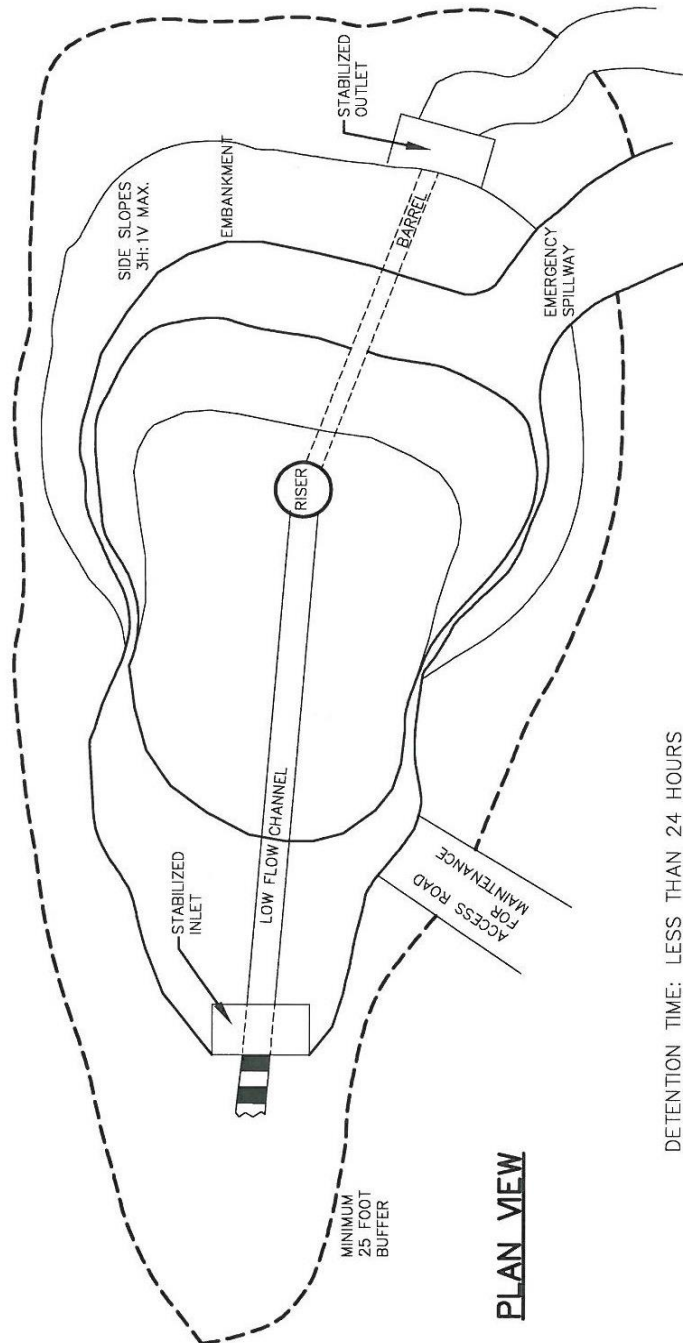
$$V_{TOTAL} = V_w + V_{temp} + V_f$$

$$\text{CHECK THAT } V_{TOTAL} \geq V_{MIN} = 0.75 \times WQV$$

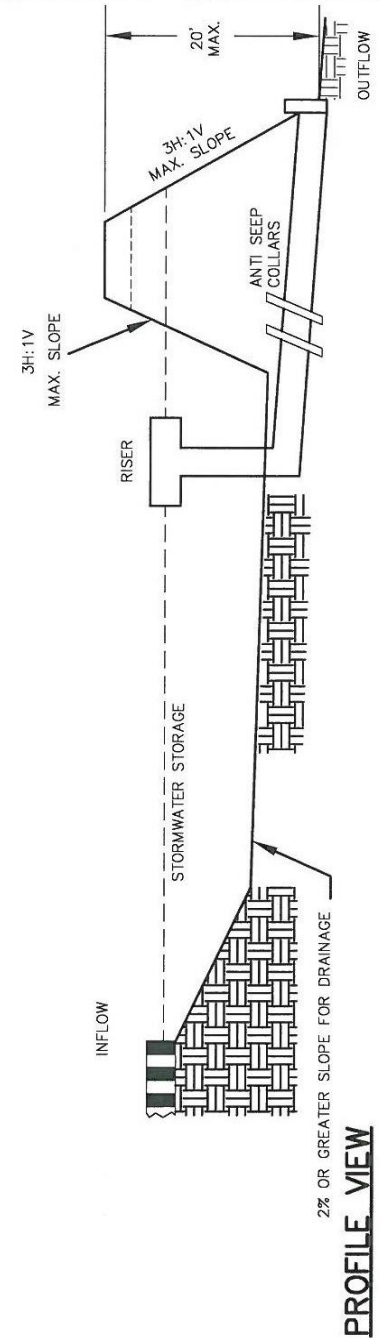
SOURCE: CLAYTOR AND SCHUELER, 1996

# STORMWATER GUIDE

**Figure B-11**  
**Detention Pond**

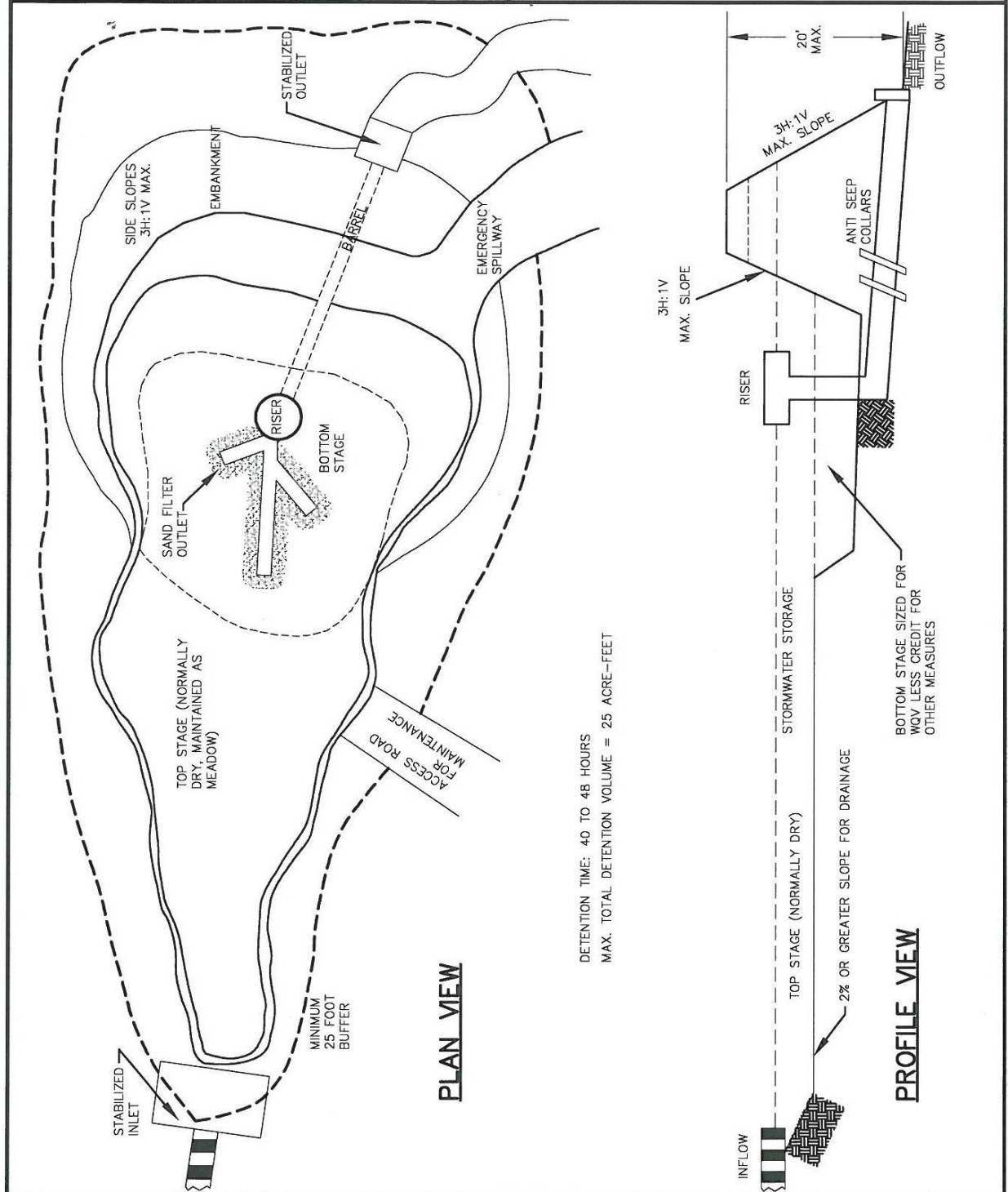


DETENTION TIME: LESS THAN 24 HOURS  
MAX. TOTAL DETENTION VOLUME = 25 ACRE-Feet



# STORMWATER GUIDE

**Figure B-12**  
**Extended Detention Pond**



# STORMWATER GUIDE

**Figure B-13**  
**Extended Detention Outlet**  
**Using Sand Filter**

Diagram illustrating the Plan View of an Extended Detention Outlet Using a Sand Filter. The structure consists of an inlet channel leading into a basin stabilized down to the dewatering elevation or lower. The basin is divided into multiple sand filter branches by a solid-walled pipe through the embankment. A riser is located within the basin. The outlet is stabilized and includes a valve. The principal spillway has a 3:1 (H:V) slope. An emergency spillway is also shown.

Labels include: OPEN CHANNEL, INLET TO BASIN STABILIZED DOWN TO THE DEWATERING ELEVATION OR LOWER, SAND FILTERS (LENGTH AND NUMBER OF BRANCHES MAY VARY), SOLID-WALLED PIPE THROUGH EMBANKMENT, RISER, PRINCIPAL SPILLWAY, 3:1 (H:V), VALVE, STABILIZED OUTLET, EMERGENCY SPILLWAY.

## PLAN VIEW N.T.S.

Diagram illustrating the Typical Section of the sand filter structure. The structure is built with a geotextile liner. The filter material consists of a 9" minimum depth of clean sand over a 3" minimum depth of KTC NO. 57 stone. The total depth of the filter material is 10" minimum. The structure is supported by a 6" minimum depth of KTC NO. 57 stone. A 4" diameter perforated PVC pipe is used for the outlet. The water level is indicated as h' in calculations.

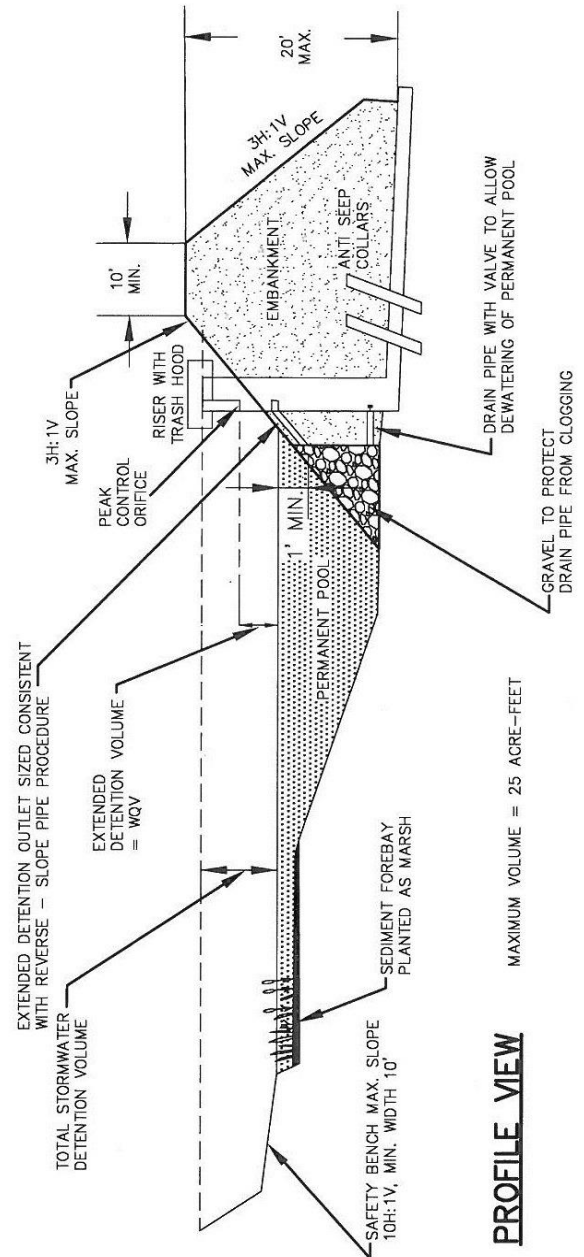
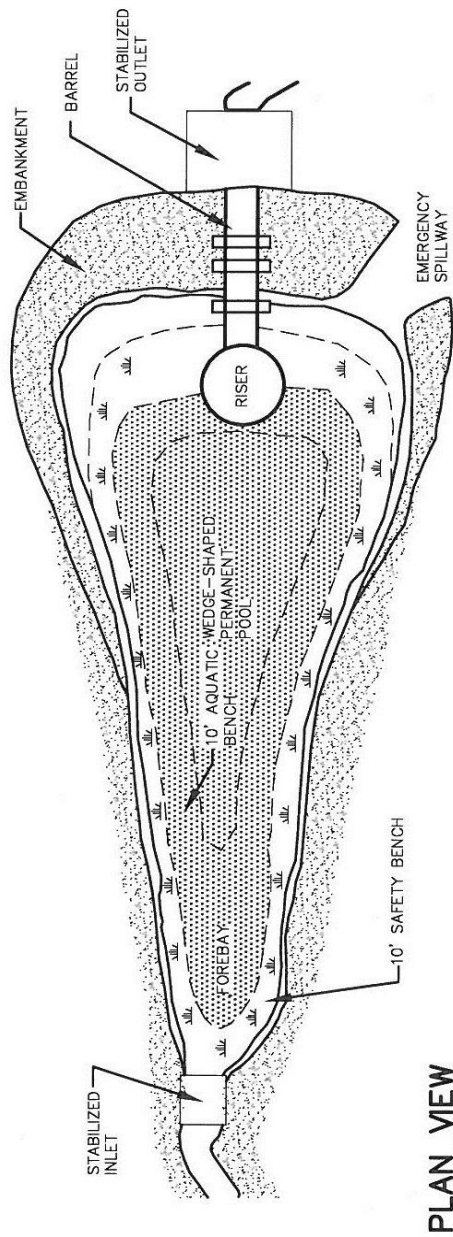
Labels include: 9" MINIMUM DEPTH OF CLEAN SAND, 3" MINIMUM DEPTH OF KTC NO. 57 STONE, 10" MINIMUM, GEOTEXTILE, 6" MINIMUM DEPTH OF KTC NO. 57 STONE, 4" DIA. PERFORATED PVC PIPE, h' IN CALCULATIONS.

## TYPICAL SECTION N.T.S.

# STORMWATER GUIDE

**Figure B-14**

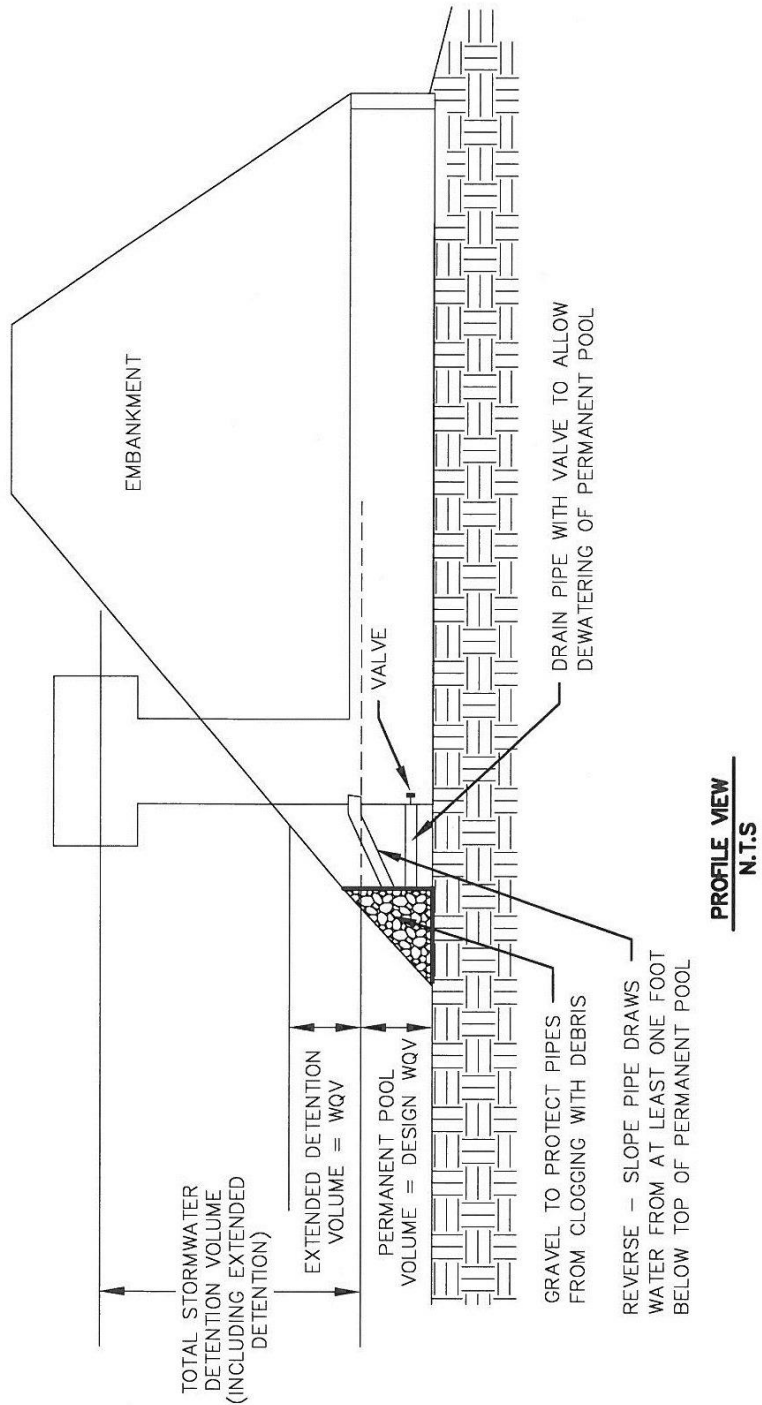
## Wet Pond



# STORMWATER GUIDE

**Figure B-15**

**Extended Detention Outlet  
for Wet Pond**



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