4.3.1 Stormwater Basins

General Application Water Quality BMP

Description: A constructed stormwater basin that has a permanent pool (or micropool). Runoff from each rain event is detained and treated in the pool primarily through settling and biological uptake mechanisms.

KEY CONSIDERATIONS

FEASIBILITY GUIDELINES:

- Minimum contributing drainage area of 25 acres; 10 acres for micropool ED basin.
- Requires approximately 2 to 3% of the contributing drainage area.
- Underlying soils of hydrologic groups C or D are typically adequate to maintain a permanent pool. Hydrologic soil groups A and B may require a basin liner.
- Can be used on sites that have a slope no greater than 15% upstream of the basin.
- Six to eight feet of elevation difference is needed from inflow to outflow.
- There are additional design requirements for areas with underlying aquifers or hotspot areas.

ADVANTAGES / BENEFITS:

- Moderate to high removal rate of urban pollutants.
- High community acceptance if aesthetics are maintained.
- Opportunity for wildlife habitat.

DISADVANTAGES / LIMITATIONS:

- Potential for thermal impacts/downstream warming.
- Dam height restrictions for high relief areas.
- Basin drainage can be problematic for low relief terrain.

MAINTENANCE REQUIREMENTS:

- Remove debris from inlet and outlet structures.
- Maintain side slopes / remove invasive vegetation.
- Monitor sediment accumulation and remove periodically.

STORMWATER MANAGEMENT APPLICABILITY

Stormwater Quality:	**Yes**
Channel Protection:	**Yes**
Detention/Retention:	**Yes**

Accepts hotspot runoff: *Yes, but two feet of separation distance required to water table when used in hotspot areas*

COST CONSIDERATIONS

Land Requirement:	**Med - High**
Capital Cost:	**Low**
Maintenance Burden:	**Low**

LAND USE APPLICABILITY

Residential/Subdivision Use:	**Yes**
High Density/Ultra Urban Use:	**Yes**
Commercial/Industrial Use:	**Yes**

POLLUTANT REMOVAL

Total Suspended Solids:	**80%**

4.3.1.1 General Description

Stormwater basins (also referred to as retention basins, wet basins, or wet extended detention basins) are constructed stormwater retention basins that have a permanent (dead storage) pool of water throughout the year. They can be created by excavating an already existing natural depression or through the construction of embankments.

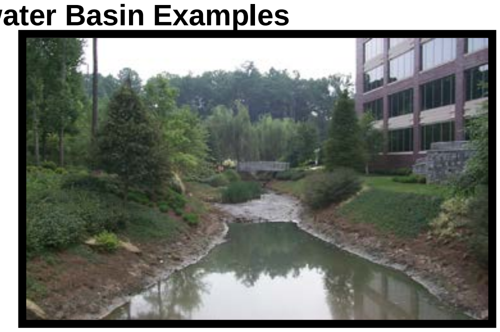
In a stormwater basin, runoff from each rain event is detained and the water quality volume (WQv) is treated in the pool through gravitational settling and biological uptake until it is displaced by runoff from the next storm. The permanent pool also serves to protect deposited sediments from resuspension. Above the permanent pool level, additional temporary storage (live storage) is provided for runoff quantity (i.e., peak discharge and/or volume) control if required by local regulations. The upper stages of a stormwater basin can be designed to provide extended detention for downstream channel protection volume, as well as conventional detention for peak discharge control.

Stormwater basins are among the most cost-effective and widely used stormwater practices. Stormwater basins are generally applicable to most types of new development and redevelopment, and can be used in both residential and nonresidential areas. Basins can also be used for regional applications (i.e., controlling runoff from more than one developed site). A well-designed and landscaped basin can be an aesthetic feature on a development site when planned and located properly. However, limitations on available land may preclude their use for retrofit applications or high-density/ultra urban sites.

There are several variations of stormwater basin design, the most common of which include the wet basin, the wet extended detention basin, and the micropool extended detention basin. In addition, multiple stormwater basins can be placed in series or parallel to increase total suspended solids (TSS) removal efficiency or meet site design constraints. Figure 4-10 shows a number of examples of stormwater basins. Descriptions of each basin type are provided below the figure.

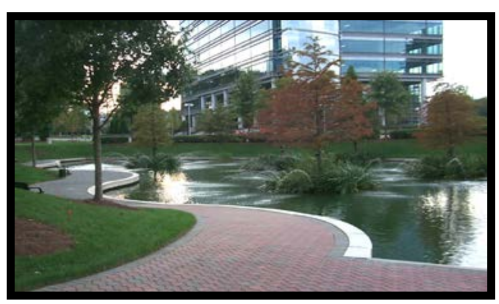
Figure 4-10. Stormwater Basin Examples

Wet Basin



Wet Extended Detention Basin

Micropool Extended Detention Basin



Multiple Basin System

- **Wet Basin** – Wet basins are stormwater basins constructed with a permanent (dead storage) pool of water equal to the WQv. Stormwater runoff displaces the water already present in the pool. Temporary storage (live storage) can be provided above the permanent pool elevation for larger flows.

- **Wet Extended Detention (ED) Basin** – A wet extended detention basin is a wet basin where the WQv is split evenly between the permanent pool and extended detention (ED) storage provided above the permanent pool. During storm events, water is detained above the permanent pool and released over 24 hours. This design has similar pollutant removal to a traditional wet basin, but consumes less space.
- **Micropool Extended Detention (ED) Basin** – The micropool extended detention basin is a variation of the wet ED basin where only a small "micropool" is maintained at the outlet to the basin. The outlet structure is sized to detain the WQv for 24 hours. The micropool prevents resuspension of previously settled sediments and also prevents clogging of the low flow orifice.
- **Multiple Basin System** – A multiple basin system consists of constructed facilities that provide water quality and quantity volume storage in two or more cells. The additional cells can create longer pollutant removal pathways and improved downstream protection.

4.3.1.2 Pollutant Removal Capabilities

Basins treat incoming stormwater runoff through physical, biological, and chemical processes. The primary removal mechanism is gravitational settling of particulates, organic matter, metals, bacteria and organics as stormwater runoff resides in the basin. Another mechanism for pollutant removal is uptake by algae and wetland plants in the permanent pool, particularly of nutrients. Volatilization and chemical activity also work to break down and eliminate a number of other stormwater contaminants such as hydrocarbons.

All of the stormwater basin design variations are presumed capable of removing at least 80% of the total suspended solids load in typical urban post-development runoff when sized, designed, constructed and maintained in accordance with the specifications provided in this manual. The TSS removal performance can be reduced by poor design, construction or maintenance.

Additionally, research has shown that use of stormwater basins will have benefits beyond the removal of TSS, such as the removal of other pollutants (i.e. phosphorous, nitrogen, fecal coliform and heavy metals) as well, which is useful information should the pollutant removal criteria change in the future.

For additional information and data on pollutant removal capabilities for stormwater basins, see the National Pollutant Removal Performance Database (2nd Edition) available at www.stormwatercenter.net and the International Stormwater Best Management Practices Database at www.bmpdatabase.org.

4.3.1.3 Planning and Design Standards

The following standards shall be considered **minimum** design standards for the design of a stormwater basin facility. Stormwater basins that are not designed to these standards will not be approved. Consult with the local municipal engineering department to determine if there are any variations to these criteria or additional standards that must be followed.

A. LOCATION AND SITING

- Stormwater basins must have a minimum contributing drainage area of 25 acres or more for a wet basin or wet ED basin to maintain a permanent pool. For a micropool ED basin, the minimum drainage area is 10 acres. The use of a stormwater basin for a smaller drainage area may be considered when water availability can be confirmed (such as from a groundwater source or areas that typically have a high water table). In such situations, calculation of a water balance for the basin may be required. Water balance calculations are presented in Chapter 3 of this manual. It is important that basins that serve smaller drainage areas have an adequate anti-clogging device provided for the basin outlet.
- It is strongly recommended that stormwater basins be located where the topography allows for maximum runoff storage at minimum excavation or embankment construction costs. When locating a stormwater basin, the site designers should also consider the location and use of other site features, such as buffers and undisturbed natural areas, and should attempt to aesthetically blend the facility into the adjacent landscape.

- Stormwater basins shall not be located on unstable slopes or slopes greater than 15%.
- Stormwater basins shall not be located in a stream or any other navigable waters of the United States, including natural (i.e., not constructed) wetlands. Where an appeal or variance of this policy is desired, the property owner must obtain coverage under a Section 404 permit under the Clean Water Act and/or an Aquatic Resource Alteration Permit (ARAP) and provide proof of such coverage with the site development plans on which the basin design is presented.
- Each stormwater basin shall be placed in a water quality easement that is recorded with the deed. The water quality easement shall be defined at the outer edge of the safety bench, or a minimum of 15 feet from the normal water pool elevation (measured perpendicular from the pool elevation boundary) if a safety bench is not included in the basin design. Minimum setback requirements for the easement shall be as follows unless otherwise specified by local municipal regulations:
  - From a public water system well – TDEC specified distance per designated well category
  - From a private well – 50 feet; if the well is down gradient from a hotspot land use, as defined in this manual, then the minimum setback is 250 feet
  - From a septic system tank/leach field – 50 feet
- The minimum setback for habitable structures from the water quality easement shall be 15 feet. The first floor elevation (FFE) for any structure adjacent to the basin shall have an elevation no lower than 1 foot above the top of the berm.
- All utilities shall be located outside of the water quality easement.

B. GENERAL DESIGN

- A stormwater basin shall consist of the following elements, designed in accordance with the specifications provided in this section.
  (1) Permanent pool of water;
  (2) A sediment forebay at each basin inlet (unless the inlet provides less than 10% of the total inflow to the basin);
  (3) Overlying zone in which runoff control volumes are stored;
  (4) Shallow littoral zone (aquatic bench) along the edge of the permanent pool that acts as a biological filter;
  (5) An emergency spillway;
  (6) Maintenance access;
  (7) Safety bench (if basin side slopes are 4:1 or greater); and,
  (8) Appropriate native landscaping.

C. PHYSICAL SPECIFICATIONS / GEOMETRY

In general, basin designs are unique for each site and application. However, there are a number of geometric ratios and limiting depths for basin design that must be observed for adequate pollutant removal, ease of maintenance, and improved safety.

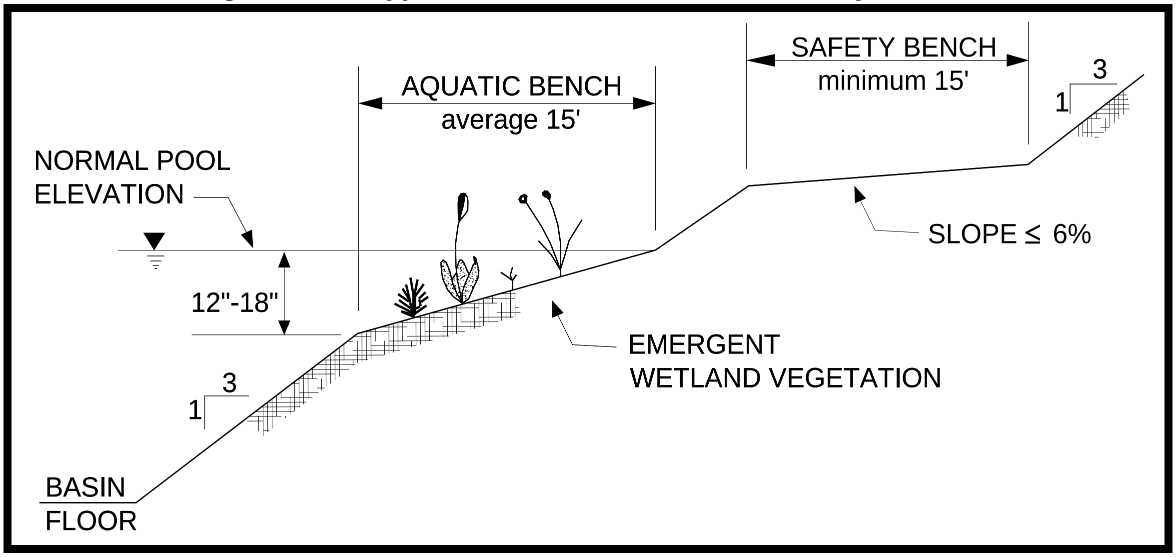
- Permanent pool volume shall be sized as follows:
  - Standard wet basins: 100% of the water quality treatment volume (1.0 X WQv);
  - Wet ED basins: 50% of the water quality treatment volume (0.5 X WQv);
  - Micropool ED basins: Approximately 0.1 foot per impervious acre (4356 ft^3).
- The pretreatment storage volume is part of the total WQv design requirement and may be subtracted from the WQv for permanent pool sizing. See Part D below for more information.

- Proper geometric design is essential to prevent hydraulic short-circuiting (unequal distribution of inflow), which results in the failure of the basin to achieve adequate levels of pollutant removal. The minimum length-to-width ratio permitted for the permanent pool shape is 1.5:1, and should ideally be greater than 3:1 to avoid short-circuiting. In addition, basins should be wedge-shaped when possible so that flow enters the basin and gradually spreads out, improving the sedimentation process. Baffles, basin shaping or islands can be added within the permanent pool to increase the flow path.
- The maximum depth of the permanent pool shall not exceed 8 feet to avoid stratification and anoxic conditions. Greater depths may be approved in the event that measures are taken that will eliminate the possibility of such conditions and safety precautions are adequately considered. The minimum depth for the permanent pool should be 3 to 4 feet. Deeper depths near the outlet will result in cooler bottom water discharges from the basin, which may mitigate downstream thermal effects caused by discharges of warm stormwater runoff.
- Side slopes shall not exceed 3:1 (horizontal to vertical) on one side of the basin to facilitate access for maintenance and repair. The remainder of the basin shall have side slopes no steeper than 2:1 although 3:1 is preferred. Benching of the slope (see safety bench in Figure 4-11) is required for embankments greater than 10 feet in height and having greater than a 3:1 side slope. Riprap-protected embankments shall be no steeper than 2:1.
- The perimeter of all deep pool areas (4 feet or greater in depth) shall be surrounded by two benches: safety and aquatic. For large basins, the safety bench shall extend no less than 15 feet outward from the normal water edge to the toe of the basin side slope. The slope of the safety bench shall not exceed 6%. The requirements for a safety bench may be waived if basin side slopes are 4:1 or gentler. The aquatic bench shall have an average width of 15 feet, and shall extend inward from the normal pool edge and shall have a maximum depth of 18 inches below the normal pool water surface elevation (see Figure 4-11).
- The contours and shape of the permanent pool should be irregular to provide a more natural landscaping effect.

D. PRETREATMENT / INLETS

- Each basin shall have a sediment forebay or equivalent upstream pretreatment. A sediment forebay is designed to remove incoming sediment from the stormwater flow prior to dispersal in a larger permanent pool. The forebay shall consist of a separate cell, formed by an acceptable barrier. A forebay must be provided at each inlet, unless the inlet provides less than 10% of the total design storm inflow to the basin. In some design configurations, the pretreatment volume may be located within the permanent pool.
- The sediment forebay shall be sized to contain 0.1 inch per impervious acre (363 ft^3) of contributing drainage and shall be no more than 4 to 6 feet deep. The pretreatment storage volume is part of the total WQv design requirement and may be subtracted from the WQv for permanent pool sizing.

Figure 4-11. Typical Stormwater Basin Geometry Criteria



- A fixed vertical sediment depth marker shall be installed in the forebay to measure sediment deposition over time. The bottom of the forebay may be hardened (e.g., using concrete, paver blocks, etc.) to make sediment removal easier.
- Inflow channels shall be stabilized with flared riprap aprons, or the equivalent. Inlet pipes to the basin can be partially submerged. Exit velocities of discharges from the forebay to the basin must be non-erosive.

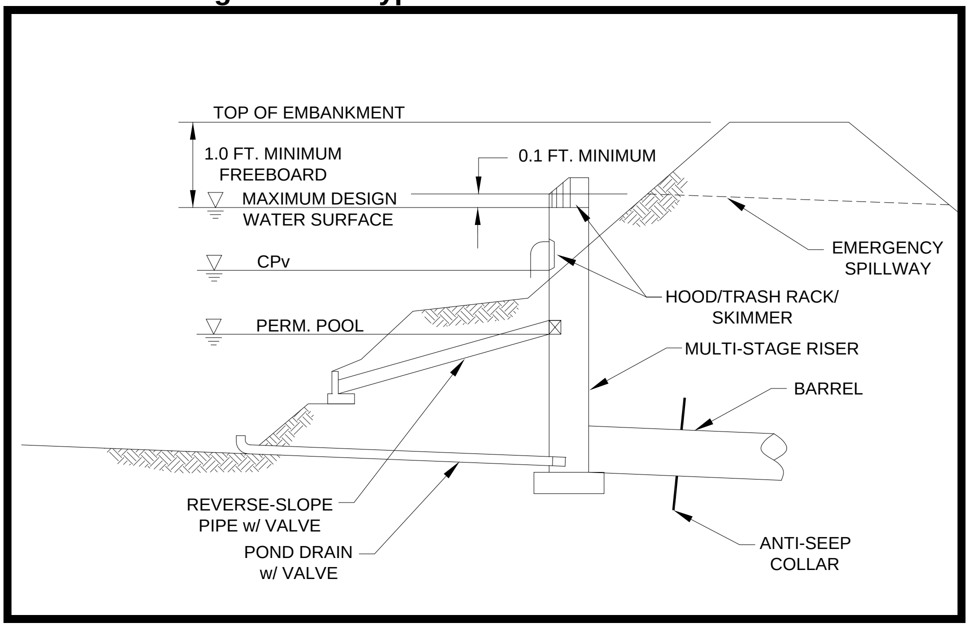
E. OUTLET STRUCTURES

- Flow control from a stormwater basin is typically accomplished with the use of a riser and barrel. The riser is a vertical pipe or inlet structure that is attached to the base of the basin with a watertight connection. The outlet barrel is a horizontal pipe attached to the riser that conveys flow under the embankment (see Figure 4-12). The riser shall be located within the basin embankment for maintenance access, safety and aesthetics.
- A number of outlets at varying depths in the riser provide internal flow control for routing of the WQv and CPv, and for peak discharge control (i.e., detention). The number of orifices can vary and is usually a function of the basin design.

  For example, a wet basin riser configuration is typically comprised of a channel protection (CPv) outlet (usually an orifice) and one or more outlets (often slots or weirs) for peak discharge control to comply with local detention requirements (e.g., control of the post-development 10-year peak discharge to pre-development conditions). The channel protection orifice is sized to release the channel protection storage volume over a 24-hour period. Since the water quality volume is fully contained in the permanent pool, no orifice sizing is necessary for this volume. As runoff from a water quality event enters the wet basin, it simply displaces that same volume through the channel protection orifice. Thus an off-line wet basin providing ***only*** water quality treatment can use a simple overflow weir as the outlet structure.

  In the case of a wet ED basin or micropool ED basin, there is generally a need for an additional outlet (usually an orifice) that is sized to pass the extended detention water quality volume that is surcharged on top of the permanent pool. Flow will first pass through this orifice, which is sized to release the water quality ED volume in 24 hours. The preferred design is a reverse slope pipe attached to the riser, with its inlet submerged 1 foot below the elevation of the permanent pool to prevent floatables from clogging the pipe and to avoid discharging warmer water at the surface of the basin. The next outlet is sized for the release of the channel protection storage volume. The outlet (often an orifice) invert is located at the maximum elevation associated with the extended detention water quality volume and is sized to release the channel protection storage volume over a 24-hour period. The final orifice invert is located at the extreme flood elevation.

Figure 4-12. Typical Basin Outlet Structure



Alternative hydraulic control methods to an orifice can be used and include the use of a broad-crested, rectangular, V-notch, or proportional weir, or an outlet pipe protected by a hood that extends at least 12 inches below the normal pool.

- The water quality outlet (if the design is for a wet ED or micropool ED basin) and channel protection outlet shall be fitted with adjustable gate valves or another mechanism that can be used to adjust detention time.
- Higher flows that must be controlled as part of the local municipality's detention requirements (e.g., Qp_2, through Qp_{100}) pass through openings or slots protected by trash racks further up on the riser.
- After entering the riser, flow is conveyed through the barrel and is discharged downstream. Anti-seep collars shall be installed on the outlet barrel to reduce the potential for pipe or embankment failure.
- Riprap, plunge pads or pools, or other energy dissipators shall be placed at the outlet of the barrel to prevent scouring and erosion. If a basin outlet discharges immediately to a channel that carries dry weather flow (i.e., a stream), care shall be taken to minimize disturbance along the downstream channel, and to reestablish streamside vegetation in the shortest possible distance.
- Each basin shall have a bottom drain pipe with an adjustable valve that can completely or partially drain the basin within 24 hours.
- The basin drain shall be sized one pipe size greater than the calculated design diameter. The drain valve is typically a handwheel activated knife or gate valve. Valve controls shall be located inside of the riser at a point where they: (a) will not normally be inundated; and (b) can be operated in a safe manner.

F. EMERGENCY SPILLWAY

- An emergency spillway shall be included in the stormwater basin design, sized to safely pass the locally regulated peak event. The spillway prevents basin water levels from overtopping the embankment and causing structural damage to the embankment. The emergency spillway shall be located so that downstream structures will not be impacted by spillway discharges.

- A minimum of 1 foot of freeboard shall be provided, measured from the top of the water surface elevation for the extreme flood to the lowest point of the dam embankment, not counting the emergency spillway.

G. MAINTENANCE ACCESS

- A minimum 20' wide maintenance right-of-way or easement shall be provided to the basin from a driveway, public road or private road. The maintenance access easement shall have a maximum slope of no more than 15% and shall have a minimum unobstructed drive path having a width of 12 feet, appropriately stabilized to withstand maintenance equipment and vehicles.
- The maintenance access shall extend to the forebay, safety bench, riser, and outlet, and, to the extent feasible, be designed to allow vehicles to turn around.
- Access to the riser shall be provided by lockable manhole covers, and manhole steps within easy reach of valves and other controls.

H. SAFETY FEATURES

- A safety bench shall be provided for embankments greater than 10 feet in height and having greater than a 3:1 side slope. For large basins, the safety bench shall extend no less than 15 feet outward from the normal water edge to the toe of the basin side slope. The slope of the safety bench shall not exceed 6%.
- All embankments and spillways shall be designed to TDEC rules and regulations as applied to the Safe Dams Act of 1973 (see Appendix H), where applicable.
- The property owner may consider fencing the basin for the purpose of safety management.
- All outlet structures shall be designed so as not to permit access by children. Property owners are encouraged to post warning signs near the basin to prohibit swimming and fishing in the facility.

I. LANDSCAPING

- Aquatic vegetation can play an important role in pollutant removal in a stormwater basin. In addition, vegetation can enhance the appearance of the basin, stabilize side slopes, serve as wildlife habitat, and can temporarily conceal unsightly trash and debris. Therefore, wetland plants should be encouraged in a basin design, along the aquatic bench (fringe wetlands), the safety bench and side slopes (ED basins), and within shallow areas of the pool itself. The best elevations for establishing wetland plants, either through transplantation or volunteer colonization, are within 6 inches (plus or minus) of the normal pool elevation. More information on wetland plants can be found at the following websites:
    - http://wetlands.fws.gov/
    - http://www.npwrc.usgs.gov/resource/plants/floraso/species.htm
- Woody vegetation shall not be planted on the embankment or allowed to grow within 15 feet of the toe of the embankment and 25 feet from the principal spillway structure.
- Fish such as *Gambusia* can be stocked in a basin to aid in mosquito prevention.
- A fountain or aerator may be used for oxygenation of water in the permanent pool and to aid in mosquito breeding prevention.
- Water quality buffers, as defined and described in Chapter 6 of this manual, are not required for stormwater basins that are constructed for the purpose of stormwater quality or quantity control. However, it should be noted that vegetated buffers can be utilized for water quality treatment and can result in a volume credit that reduces the WQv. The criteria for the vegetated buffer credit are presented in Chapter 5 of this manual.

J. ADDITIONAL SITE-SPECIFIC DESIGN CRITERIA AND ISSUES

There are a number of additional site specific design criteria and issues (listed below) that must be considered in the design of a stormwater basin.

Physiographic Factors - Local terrain design constraints:

- Low Relief – Maximum normal pool depth is limited; providing the basin drain can be problematic.
- Karst – Requires poly or clay liner to sustain a permanent pool of water and protect aquifers; limits on ponding depth; geotechnical tests may be required.
- Soils - Hydrologic group "A" soils generally require a basin liner; group "B" soils may require infiltration testing.

Wellhead Protection Areas

- Reduce potential groundwater contamination in wellhead protection areas by preventing infiltration of runoff from hotspot areas, or provide pretreatment of this runoff for the target pollutants that may discharge from the land use.
- Wellhead protection may require liner for type "A" and "B" soils.
- A minimum of two (2) to four (4) feet separation distance of the basin from water table shall be provided.

4.3.1.4 Design Procedures

In general, site designers should perform the following design procedures when designing a stormwater basin.

Step 1. Compute runoff control volumes

Calculate WQv, CPv, and pre- and post-development peak discharges and runoff volumes. The calculation of WQv and CPv is presented in Chapter 3 of this manual. Consult local regulations for peak discharge control (i.e., detention) requirements.

Step 2. Determine if the development site and conditions are appropriate for a stormwater basin

Consider the planning and design standards in sections 4.3.1.3.

Step 3. Confirm additional design criteria and applicability

Consider any special site-specific design conditions/criteria from subsection 4.3.1.3-J. Check with the local municipal engineering department, TDEC, or other agencies to determine if there are any additional restrictions and/or surface water or watershed requirements that may apply to the site.

Step 4. Determine pretreatment volume

A sediment forebay is provided at each inlet, unless the inlet provides less than 10% of the total design storm inflow to the basin. The forebay should be sized to contain 0.1 inch per impervious acre (363 ft^3) of contributing drainage and should be 4 to 6 feet deep. The forebay storage volume counts toward the total WQv requirement and may be subtracted from the WQv for subsequent calculations.

Step 5. Determine permanent pool volume (and water quality ED volume)

Wet Basin: Size permanent pool volume to 1.0 WQv less any forebay storage volume.

Wet ED Basin: Size permanent pool volume to 0.5 WQv less any forebay storage volume. Size extended detention volume to 0.5 WQv less any forebay storage volume.

Micropool ED Basin: Size permanent pool volume at 0.1 foot per impervious acre (4356 ft^3) less any forebay storage volume. Size extended detention volume to remainder of WQv.

Step 6. Determine basin location and preliminary geometry. Conduct basin grading design and determine storage available for permanent pool (and water quality extended detention if needed)

This step involves initially designing the grading of the basin (establishing contours) and determining the elevation-storage relationship for the basin. See subsection 4.3.1.3 for more details.

- Include safety and aquatic benches, if required.
- Set WQv permanent pool elevation (and WQv-ED elevation for wet ED and micropool ED basin) based on volumes calculated earlier.

Step 7. Compute extended detention orifice release rate(s) and size(s), and establish CPv elevation

Wet Basin: The CPv elevation is determined from the stage-storage relationship and the orifice is then sized to release the channel protection storage volume over a 24-hour period. The channel protection orifice should have a minimum diameter of 3 inches and should be adequately protected from clogging by an acceptable external trash rack. A reverse slope pipe attached to the riser, with its inlet submerged 1 foot below the elevation of the permanent pool, is a recommended design. The orifice diameter may be reduced to 1 inch if internal orifice protection is used (i.e., an over-perforated vertical stand pipe with ½-inch orifices or slots that are protected by wirecloth and a stone filtering jacket). Adjustable gate valves can also be used to achieve this equivalent diameter.

Wet ED Basin and Micropool ED Basin: Based on the elevations established in Step 6 for the extended detention portion of the water quality volume, the water quality orifice is sized to release this extended detention volume in 24 hours. The water quality orifice should have a minimum diameter of 3 inches and should be adequately protected from clogging by an acceptable external trash rack. A reverse slope pipe attached to the riser, with its inlet submerged 1 foot below the elevation of the permanent pool, is a recommended design. The orifice diameter may be reduced to 1 inch if internal orifice protection is used (i.e., an over-perforated vertical stand pipe with ½-inch orifices or slots that are protected by wire cloth and a stone filtering jacket). Adjustable gate valves can also be used to achieve this equivalent diameter. The CPv elevation is then determined from the stage-storage relationship. The invert of the channel protection orifice is located at the water quality extended detention elevation, and the orifice is sized to release the channel protection storage volume over a 24-hour period.

Step 8. Calculate peak discharge release rates and water surface elevations for flood control (i.e., detention)

Set up a stage-storage-discharge relationship for the control structure for the extended detention (CPv) requirement and peak discharge control storm orifices.

Step 9. Design embankment(s) and spillway(s)

Using the peak event water surface elevation, set the top of the embankment elevation, and size the emergency spillway, ensuring safe passage of the peak event. Set the invert elevation of the emergency spillway 0.1 foot above the peak event water surface elevation.

Step 10. Investigate potential basin hazard classification

The design and construction of stormwater management basins are required to follow the latest version of the TDEC Rules and Regulations Application to the Safe Dams Act of 1973.

Step 11. Design inlets, sediment forebay(s), outlet structures, maintenance access, and safety features.

See subsection 4.3.1.3-D through H for more details.

Step 12. Design vegetation

A vegetation scheme for a stormwater basin and its buffer should be prepared to indicate how aquatic and terrestrial areas will be stabilized and established with vegetation. See subsection 4.3.1.3-I for more details.

4.3.1.5 Maintenance Requirements and Inspection Checklist

Note: Section 4.3.1.5 must be included in the Operations and Maintenance Plan that is recorded with the deed.

Regular inspection and maintenance is critical to the effective operation of stormwater basins as designed. It is the responsibility of the property owner to maintain all stormwater facilities in accordance with the minimum design standards and other guidance provided in this manual. Consult with the local municipal engineering department to determine if there are additional maintenance requirements.

This page provides guidance on maintenance activities that are typically required for stormwater basins, along with a suggested frequency for each activity. Individual stormwater basins may have more, or less, frequent maintenance needs, depending upon a variety of factors including the occurrence of large storm events, overly wet or dry (i.e.., drought) regional hydrologic conditions, and any changes or redevelopment in the upstream land use. Each property owner shall perform the activities identified below at the frequency needed to maintain the basin in proper operating condition at all times.

Inspection Activities	**Suggested Schedule**
• After several storm events or an extreme storm event, inspect for: bank stability; signs of erosion; and damage to, or clogging of, the inlet/outlet structures and pilot channels.	As needed
• Inspect for: trash and debris; clogging of the inlet/outlet structures and any pilot channels; excessive erosion; sediment accumulation in the basin, forebay and inlet/outlet structures; tree growth on dam or embankment; the presence of burrowing animals; standing water where there should be none; vigor and density of the grass turf on the basin side slopes and floor; differential settlement; cracking; leakage; and slope stability.	Semi-annually
• Inspect that the inlet/outlet structures, pipes, sediment forebays, and upstream, downstream, and pilot channels are free of debris and are operational. • Check for signs of unhealthy or overpopulation of plants and/or fish (if utilized). • Note signs of algal growth or pollution, such as oil sheens, discolored water, or unpleasant odors. • Check sediment marker(s) for sediment accumulation in the facility and forebay. • Check for proper operation of control gates, valves or other mechanical devices. • Note changes to the wet basin or contributing drainage area as such changes may affect basin performance.	Annually
Maintenance Activities	**Suggested Schedule**
• Clean and remove debris from inlet and outlet structures. • Mow side slopes (embankment) and maintenance access. Periodic mowing is only required along maintenance rights-of-way and the embankment. The remaining basin buffer can be managed as a meadow (mowing every other year) or forest.	Monthly
• If wetland vegetation is included, remove invasive vegetation.	Semi-annually
• Repair damage to basin, outlet structures, embankments, control gates, valves, or other mechanical devices; repair undercut or eroded areas. • Remove pollutants or algal overgrowth as appropriate.	As Needed
• Perform wetland plant management and harvesting.	Annually (if needed)
• Remove sediment from the forebay. Sediments excavated from stormwater basins that do not receive runoff from land uses that require a Special Pollution Abatement Permit (SPAP) are not considered toxic or hazardous material and can be safely disposed of by either land application or landfilling. Sediment testing may be required prior to sediment disposal when the basin receives discharge from a land use that requires a SPAP.	5 to 7 years or after 50% of the total forebay capacity has been lost
• Monitor sediment accumulations, and remove sediment when the basin volume has become reduced significantly or the basin is not providing a healthy habitat for vegetation and fish (if used). Discharges of basin water may be considered an illegal discharge, as per the local jurisdiction's requirements. Care should be exercised during basin drawdowns to prevent downstream discharge of sediments, anoxic water, or high flows with erosive velocities. The local jurisdiction should be notified before draining a stormwater basin.	10 to 20 years or after 25% of the permanent pool volume has been lost

The property owner is encouraged to use the inspection checklist that is presented on the next page as a guide in the inspection and maintenance of stormwater basins. Local authorities can require the use of this checklist or other form(s) of maintenance documentation when and where deemed necessary in order to ensure the long-term proper operation of the stormwater basin. Questions regarding stormwater facility inspection and maintenance should be referred to the local municipal engineering department.

INSPECTION CHECKLIST AND MAINTENANCE GUIDANCE (continued)
STORMWATER BASIN INSPECTION CHECKLIST

Location: ____ Owner Change since last inspection? Y N

Owner Name, Address, Phone: ____

Date: ___________ Time: ______________ Site conditions:______________________________________

Inspection Items	Satisfactory (S) or Unsatisfactory (U)	Comments/Corrective Action
Embankment and Emergency Spillway		
Healthy vegetation?		
Erosion on embankment?		
Animal burrows in embankment?		
Cracking, sliding, bulging of dam?		
Blocked or malfunctioning drains?		
Leaks or seeps on embankment?		
Obstructions of spillway(s)?		
Erosion in/around emergency spillway?		
Other (describe)?		
Inlet/Outlet Structures and Channels		
Clear of debris and functional?		
Trash rack clear of debris and functional?		
Sediment accumulation?		
Condition of concrete/masonry?		
Metal pipes in good condition?		
Control valve operation?		
Basin drain valve operation?		
Outfall channels function, not eroding?		
Other (describe)?		
Sediment Forebays		
Evidence of sediment accumulation?		
Permanent Pool Areas (if applicable)		
Undesirable vegetation growth?		
Visible pollution?		
Shoreline erosion?		
Erosion at outfalls into basin?		
Headwalls and endwalls in good condition?		
Encroachment by other activities?		
Evidence of sediment accumulation?		
Dry Basin Areas (if applicable)		
Vegetation adequate?		
Undesirable vegetation growth?		
Excessive sedimentation?		
Hazards		
Have there been complaints from residents?		
Public hazards noted?		

If any of the above inspection items are **UNSATISFACTORY**, list corrective actions and the corresponding completion dates below:

Corrective Action Needed	Due Date

Inspector Signature:________________________________ Inspector Name (printed)____________________________

4.3.1.6 Example Schematics

The example schematics for stormwater wet basins presented in Figures 4-13 through 4-16 can be used to assist in the design of such BMPs.

Figure 4-13. Schematic of a Standard Wet Basin

(Source: modified from a graphic by the Center for Watershed Protection)

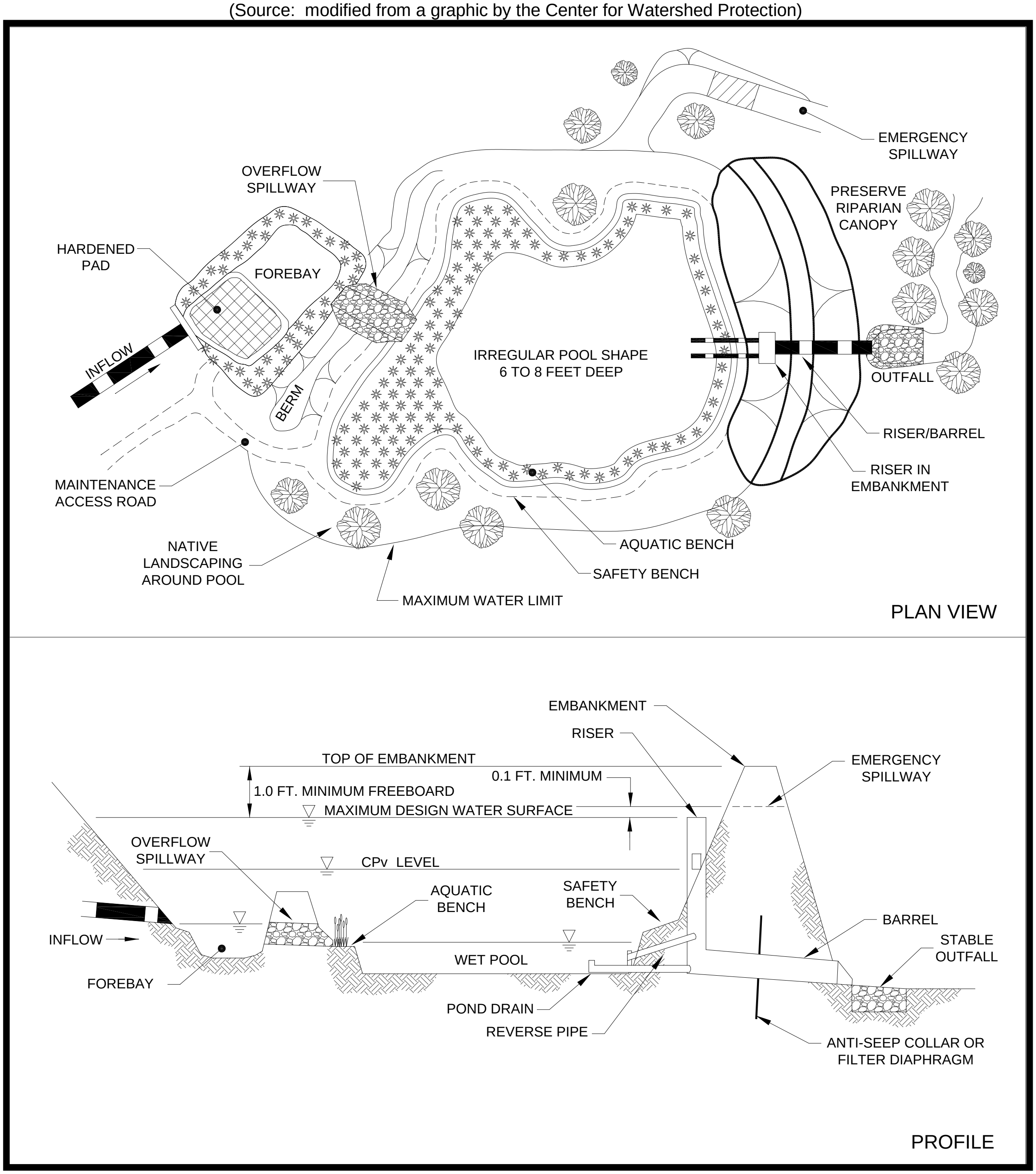


Figure 4-14. Schematic of a Wet Extended Detention Basin
(Source: modified from a graphic by the Center for Watershed Protection)

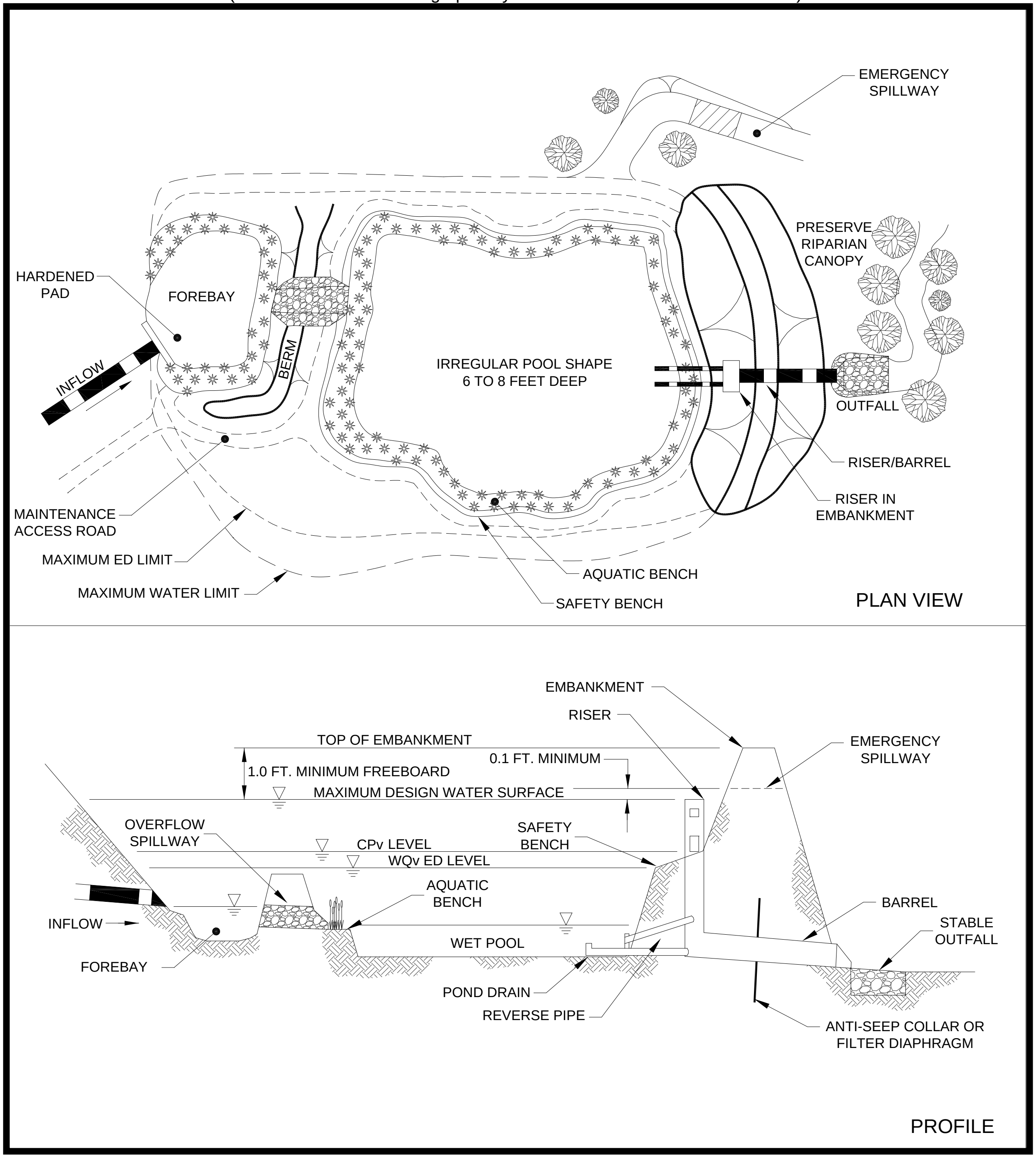


Figure 4-15. Schematic of a Micropool Extended Detention Basin
(Source: modified from a graphic by the Center for Watershed Protection)

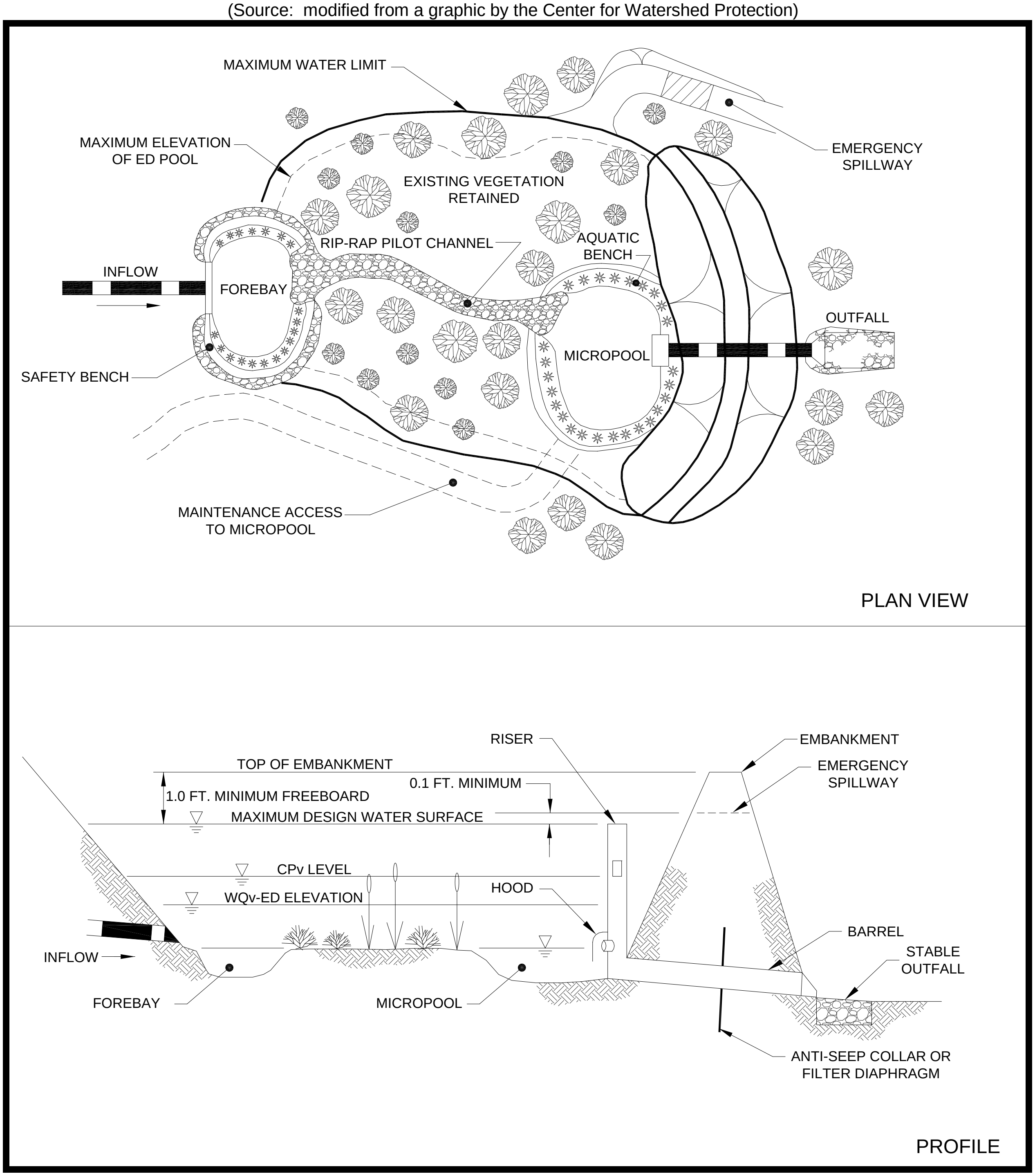
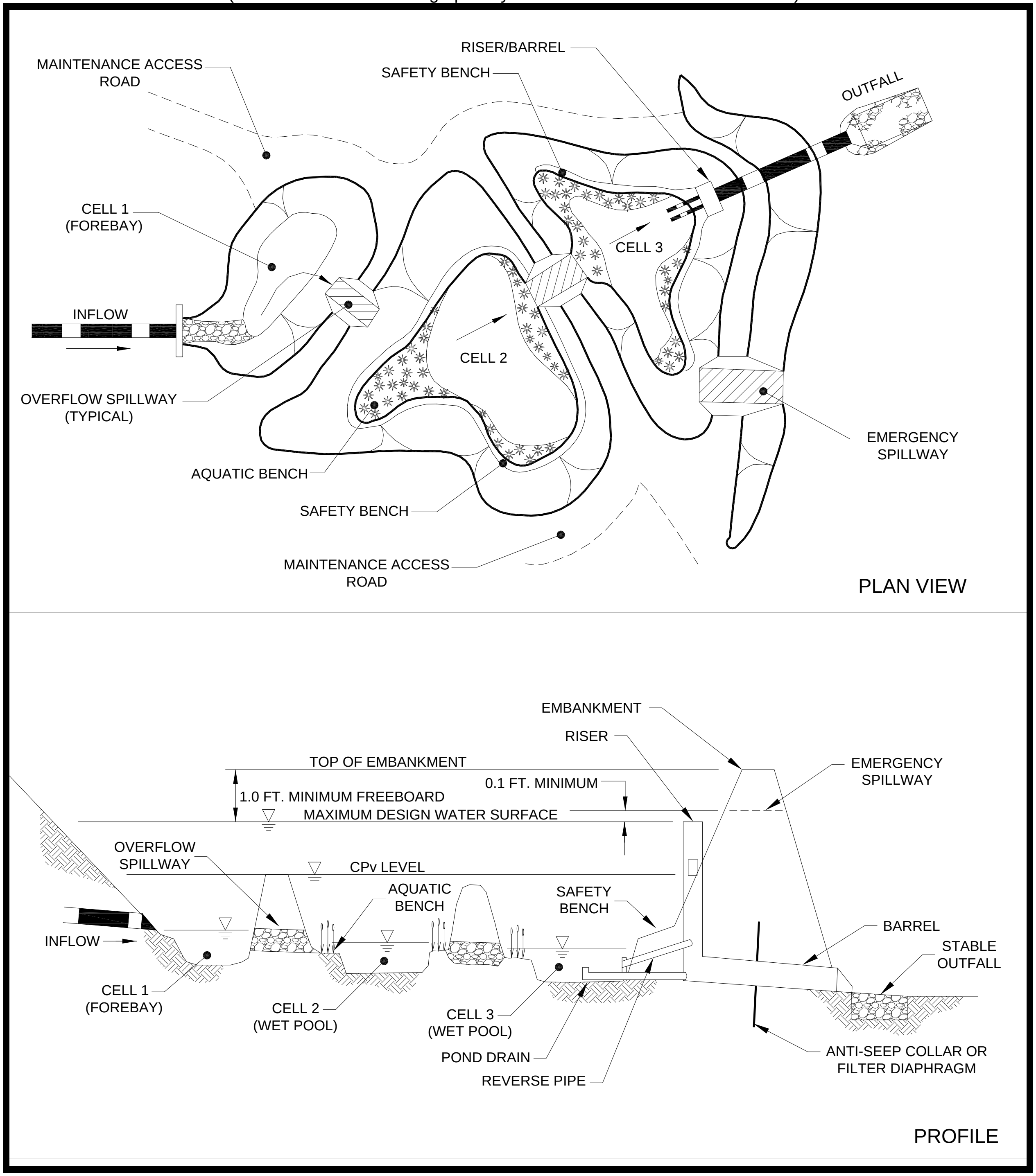


Figure 4-16. Schematic of a Multiple Basin System
(Source: modified from a graphic by the Center for Watershed Protection)



4.3.1.7 Design Form

Use of the following design procedure forms when designing a stormwater wet basin is recommended. Proper use and completion of the form may allow a faster review of the basin design by the local municipal engineering department.

Design Procedure Form: Stormwater Basins

PRELIMINARY HYDROLOGIC CALCULATIONS

1a. Compute WQv volume requirements
Compute Runoff Coefficient, Rv — Rv = ______
Compute WQv — WQv = ______ acre-ft

1b. Compute CPv — CPv = ______ acre-ft
Compute average release rate — release rate = ______ cfs
Compute storage volume required for locally regulated storm events — storage ______ acre-ft; storage ______ acre-ft

STORMWATER BASIN DESIGN

2. Is the use of a stormwater basin appropriate? — ***See subsection 4.3.1.3***

3. Confirm additional design criteria and applicability. — ***See subsection 4.3.1.3 - J***

4. Pretreatment Volume (Forebay)
V_{pre} =(I)(.1")(1'/12") — V_{pre} = ______ acre-ft

5. Allocation of Permanent Pool Volume and ED Volume

Wet Basin — V_{pool}=1.0(WQv)-Vol_{pre} — V_{pool}= ______ acre-ft

Wet ED Basin — V_{pool}=0.5(WQv)-Vol_{pre} — V_{pool}= ______ acre-ft
V_{ED}=0.5(WQv)-Vol_{pre} — V_{ED}= ______ acre-ft

Micropool ED Basin — V_{pool}=(I)(.1")(1'/12") — V_{pool}= ______ acre-ft

6. Conduct grading design and determine storage available for permanent pool (and WQv-ED volume if applicable)

Prepare an elevation-storage table and curve using the average area method for computing volumes.

Elevation MSL	Area ft^2	Ave. Area ft^2	Depth ft	Volume ft^3	Cumulative Volume ft^3	Volume above Permanent Pool acre-ft

Design Procedure Form: Stormwater Basins (continued)

7. WQv Orifice Computations
   Average ED release rate (if applicable) — release rate= ________ cfs
   Average head, h= (ED elev.- Permanent Pool elev.) /2 — head= ________ ft
   Area of orifice from orifice equation — Area= ________ ft^2
   $Q=CA(2gh)^{0.5}$ — diameter ________ inches
   (C varies with orifice condition.)

   Compute Release Rate for CPv-ED control and
   establish CPv elevation — CPv WSEL= ________ ft-NGVD
   Release rate= — release rate= ________ cfs
   Average head, h= (ED elev.- Permanent Pool elev.) /2 — head= ________ ft
   Area of orifice from orifice equation — Area= ________ ft^2
   $Q=CA(2gh)^{0.5}$ C varies with orifice condition. — diameter ________ inches

8. Calculate required local municipality peak discharge release rates and WSELs — Set up a stage-storage-discharge relationship

Elevation	Storage	Low Flow	Riser			Barrel		Emergency	Total
		WQv-ED	CPv-ED	High Storage		Inlet	Pipe	Spillway	Outflow
				Orif.	Weir				
MSL	acre-ft	H(ft) Q(cfs)	H(ft) Q(cfs)	H Q	H Q	H(ft) Q(cfs)	H(ft) Q(cfs)	H(ft) Q(cfs)	Q(cfs)

Qp_{eak}=pre-dev. Peak discharge - (WQv-ED release + CPv-ED release) — Qp_{peak}= ________ cfs

Maximum head = — H= ________ ft
Use weir equation for slot length ($Q=CLH^{3/2}$) — L= ________ ft

Check inlet condition
Check outlet conditions — **Use culvert design guidance from local municipality**

9. Size emergency spillway using the local municipality peak discharge and set top of embankment elevation and emergency spillway elevation based on $WSEL_{peak}$
   $Q_{ES}=Qp_{eak}$ ________ cfs
   $WSEL_{peak}$= ________ ft
   El_{embank} ________ ft
   El_{ES}= ________ ft

10. Investigate potential basin hazard classification — **See TN Safe Dams Act of 1973**

11. Design inlets, sediment forebays, outlet structures, maintenance access, and safety features — **See subsection 4.3.1.3 - D through H**

12. Design basin vegetation according to guidance provided in TVA Riparian Restoration webpage
    www.tva.com/river/landandshore/stabilization/index.htm

4.3.1.8 References

AMEC. *Knox County Stormwater Management Manual Volume 2, Technical Guidance*.

AMEC. *Metropolitan Nashville and Davidson County Stormwater Management Manual Volume 4 Best Management Practices.* 2006.

ARC. *Georgia Stormwater Management Manual Volume 2 Technical Handbook.* 2001.

Center for Watershed Protection. *Manual Builder.* Stormwater Manager's Resource Center, Accessed July 2005. *www.stormwatercenter.net*

4.3.1.9 Suggested Reading

California Storm Water Quality Task Force. *California Storm Water Best Management Practice Handbooks.* 1993.

City of Austin, TX. *Water Quality Management.* Environmental Criteria Manual, Environmental and Conservation Services, 1988.

City of Sacramento, CA. *Guidance Manual for On-Site Stormwater Quality Control Measures.* Department of Utilities, 2000.

Claytor, R.A., and T.R. Schueler. *Design of Stormwater Filtering Systems.* The Center for Watershed Protection, Silver Spring, MD, 1996.

Maryland Department of the Environment. *Maryland Stormwater Design Manual, Volumes I and II.* Prepared by Center for Watershed Protection (CWP), 2000.

Metropolitan Washington Council of Governments (MWCOG). *A Current Assessment of Urban Best Management Practices: Techniques for Reducing Nonpoint Source Pollution in the Coastal Zone.* March, 1992.

United States Environmental Protection Agency. *Methodology for Analysis of Detention Basins for Control of Urban Runoff Quality.* 1986.

Urban Drainage and Flood Control District. *Urban Storm Drainage Criteria Manual – Volume 3 – Best Management Practices – Stormwater Quality.* Denver, Colorado, September 1992.

Walker, W. *Phosphorus Removal by Urban Runoff Detention Basins.* Lake and Reservoir Management, North American Society for Lake Management, 314, 1987.

Wanielista. M. *Final Report on Efficiency Optimization of Wet Detention Basins for Urban Stormwater Management.* University of Central Florida, 1989.

4.3.2 Conventional Dry Detention

General Application
Water Quality BMP

Description: A surface storage basin or facility designed to provide water quantity control through detention of stormwater runoff.

KEY CONSIDERATIONS

- Conventional dry detention basins provide control for overbank and extreme flood protection only. These basins are **not** intended to provide water quality treatment.
- Applicable for drainage areas up to 75 acres.
- Typically less costly than stormwater (wet) basins for equivalent flood storage, as less excavation is required.
- Must be used in conjunction with other BMPs that can adequately meet the Northeast Tennessee Regional Stormwater Planning Group's minimum standard of 80% removal of TSS.
- Conventional dry detention basins can be used to provide recreational and other open space opportunities between storm runoff events when the basin bottom is dry.

MAINTENANCE REQUIREMENTS:

- Remove debris from inlet and outlet structures.
- Maintain side slopes and outlet structure.
- Monitor sediment accumulation and remove periodically.

STORMWATER MANAGEMENT APPLICABILITY

Stormwater Quality:	**No**
Channel Protection:	**Yes**
Detention/Retention:	**Yes**

Accepts hotspot runoff: *Yes, but two feet of separation distance required to water table when used in hotspot areas*

COST CONSIDERATIONS

Land Requirement:	**Med - High**
Capital Cost:	**Low**
Maintenance Burden:	**Low**

LAND USE APPLICABILITY

Residential/Subdivision Use:	**Yes**
High Density/Ultra Urban Use:	**No**
Commercial/Industrial Use:	**Yes**

POLLUTANT REMOVAL

Total Suspended Solids:	**10%**

4.3.2.1 General Description

Conventional dry detention basins are surface facilities intended to provide for the temporary storage of stormwater runoff to reduce downstream water quantity impacts. These facilities temporarily detain stormwater runoff, releasing the flow over a period of time. They are designed to completely drain following a storm event and are normally dry between rain events.

Dry detention basins can be utilized to provide flood protection for the locally regulated peak discharge storm event. Such basins provide limited pollutant removal benefits and are **not** intended for water quality treatment. Because conventional dry detention-only facilities can not provide a significant degree of water quality treatment, they must be used in conjunction with other structural controls that provide treatment of the water quality volume (WQv). Chapter 3 provides more information on treatment trains.

4.3.2.2 Planning and Design Standards

The following standards shall be considered **minimum** design standards for the design of a dry detention basin. Dry detention basins that are not designed to these standards will not be approved. Consult with the local municipal engineering department to determine if there are any variations to these criteria or additional standards that must be followed.

<u>A. LOCATION AND SITING</u>

- It is strongly recommended that dry detention basins be located where the topography allows for maximum runoff storage at minimum excavation or embankment construction costs. When locating a dry detention basin, the site designers should also consider the location and use of other land use features, such as planned open spaces and recreational areas, and should attempt to achieve a multi-use objective with the basin where this can be safely achieved.
- Detention basins shall not be located on unstable slopes or slopes greater than 15%.
- Flood protection controls for locally regulated peak discharges should be designed as final controls for on-site stormwater. Therefore, dry detention basins will typically be located downstream of structural stormwater BMPs that are designed to provide treatment of the water quality volume (WQv) and channel protection volume (CPv).
- A single dry detention basin shall not have a contributing drainage area greater than 75 acres unless specifically approved by the local municipality
- Dry detention basins shall not be located in a stream or any other navigable waters of the United States, including natural (i.e., not constructed) wetlands. Where an appeal or variance of this policy is desired, the property owner must obtain coverage under a Section 404 permit under the Clean Water Act and/or an Aquatic Resource Alteration Permit (ARAP) and provide proof of such coverage with the Water Quality Management Plan.
- Each conventional dry detention basin shall be placed in a water quality easement that is recorded with the deed. The water quality easement shall be defined at the outer edge of the safety bench, or a minimum of 15 feet from the normal water pool elevation (measured perpendicular from the pool elevation boundary) if a safety bench is not included in the basin design. The easement limit should be located no closer than as follows unless otherwise specified by the local municipality:
  - From a public water system well – TDEC specified distance per designated category
  - From a private well – 50 feet; if the well is downgradient from a hotspot land use, as defined in this manual, then the minimum setback is 250 feet
  - From a septic system tank/leach field – 50 feet
- The minimum setback for habitable structures from the drainage easement shall be 15 feet. The first floor elevation (FFE) for any structure adjacent to the basin shall have an elevation no lower than 1 foot above the top of the berm.

- All utilities shall be located outside of the basin site.

B. GENERAL DESIGN

- A dry detention basin shall consist of the following elements, designed in accordance with the specifications provided in this section.
  (1) An outlet structure;
  (2) An emergency spillway;
  (3) Maintenance access; and,
  (4) Appropriate landscaping.
- Dry detention basins shall be sized to attenuate peak discharges. Routing calculations must be used to demonstrate that the storage volume is adequate to meet the local municipality regulations.

C. PHYSICAL SPECIFICATIONS / GEOMETRY

- Vegetated embankments shall be less than 20 feet in height. Side slopes shall not exceed 3:1 (horizontal to vertical) on one side of the basin to facilitate access for maintenance and repair. The remainder of the basin shall have side slopes no steeper than 2:1 although 3:1 is preferred. Benching of the slope is required for embankments greater than 10 feet in height and having greater than a 3:1 side slope. Riprap-protected embankments shall be no steeper than 2:1. Geotechnical slope stability analysis is recommended for embankments greater than 10 feet in height and is mandatory for embankment slopes steeper than those given above. All embankments must be designed to State of Tennessee guidelines for dam safety.
- The maximum depth of the basin shall not exceed 10 feet
- Areas above the normal high water elevations of the detention basin shall be sloped toward the basin to allow drainage and to prevent standing water. Careful finish grading is required to avoid creation of upland surface depressions that may retain runoff. The basin bottom shall be graded toward the outlet to prevent standing water. A low flow or pilot channel across the facility bottom from the inlet to the outlet (often constructed with riprap) is recommended to convey low flows and prevent standing water conditions.

D. INLET and OUTLET STRUCTURES

Inflow channels shall be stabilized with flared riprap aprons, or the equivalent. A sediment forebay shall be provided for dry detention basins that are located in a treatment train with off-line water quality treatment structural controls. The sediment forebay shall be sized to contain 0.1 inch per impervious acre (363 ft^3) of contributing drainage and shall be no more than 4 to 6 feet deep.

- The outlet structure shall be sized for peak discharge controls (based upon hydrologic routing calculations) and can consist of a weir, orifice, outlet pipe, combination outlet, or other acceptable control structure. Small outlets that will be subject to clogging or are difficult to maintain shall not be permitted. Seepage control or anti-seep collars shall be provided for all outlet pipes.
- Water shall not be discharged from a detention basin in an erosive manner. Riprap, plunge pads or pools, or other energy dissipators shall be placed at the outlet of the barrel to prevent scouring and erosion. If a basin outlet discharges immediately to a channel that carries dry weather flow, care should be taken to minimize disturbance along the downstream channel and streambanks, and to reestablish a forested riparian zone in the shortest possible distance (if the downstream area is located in a water quality buffer).

E. EMERGENCY SPILLWAY

- An emergency spillway shall be included in the stormwater basin design to safely pass the locally regulated peak storm event. The spillway prevents basin water levels from overtopping the embankment and causing structural damage. The emergency spillway shall be located so that downstream structures will not be impacted by spillway discharges.

- The emergency spillway shall be located a minimum 0.1 foot above the 100-year water surface elevation.
- A minimum of 1 foot of freeboard shall be provided, measured from the top of the water surface elevation for the extreme flood to the lowest point of the dam embankment, not counting the emergency spillway.

F. MAINTENANCE ACCESS

- A maintenance right-of-way or easement having a minimum width of 20 feet shall be provided to the basin from a driveway, public or private road. The maintenance access easement shall have a maximum slope of no more than 15% and shall have a minimum unobstructed drive path having a width of 12 feet, appropriately stabilized to withstand maintenance equipment and vehicles.
- The maintenance access shall extend to the forebay (if included) and outlet works, and, to the extent feasible, be designed to allow vehicles to turn around.

G. SAFETY FEATURES

- A safety bench shall be provided for embankments greater than 10 feet in height and having greater than a 3:1 side slope. For large basins, the safety bench shall extend no less than 15 feet outward from the normal water edge to the toe of the basin side slope. The slope of the safety bench shall not exceed 6%.
- All embankments and spillways shall be designed to TDEC rules and regulations as applied to the Safe Dams Act of 1973, where applicable.
- The property owner may consider fencing the basin for the purpose of safety management.
- All outlet structures shall be designed so as not to permit access by children. The Northeast Tennessee Regional Stormwater Planning Group encourages the posting of warning signs near the basin to prohibit swimming and fishing in the facility.

H. LANDSCAPING

- All areas of the basin shall be stabilized with vegetation to prevent the occurrence of erosion.
- Woody vegetation shall not be planted on the embankment or allowed to grow within 15 feet of the toe of the embankment and 25 feet from the principal spillway structure.
- Water quality buffers, as defined and described in Chapter 6 of this manual, are not required for dry detention basins. However, it should be noted that vegetated buffers can be utilized for water quality treatment and can result in a volume credit that reduces the WQv. The criteria for the vegetated buffer credit are presented in Chapter 5 of this manual.

4.3.2.3 Design Procedures

In general, site designers should perform the following design procedures when designing a dry detention basin.

Step 1. Compute runoff control volumes.

> Calculate pre- and post-development peak discharges and runoff volumes. Consult local regulations for peak discharge control (i.e., detention) requirements.

Step 2. Confirm design criteria and applicability.

> Consider any special site-specific design conditions/criteria from subsection 4.3.2.2. Check with the local municipal authority, TDEC, or other agencies to determine if there are any additional

restrictions and/or surface water or watershed requirements that may apply to the site.

Step 3. Determine basin location and preliminary geometry.

This step involves initially designing the grading of the basin (establishing contours) and determining the elevation-storage relationship for the basin. Include consideration of a safety bench, if used or required by the local municipal authority.

Step 4. Calculate peak discharge release rates and water surface elevations for flood control (i.e., detention)

Set up a stage-storage-discharge relationship for the control structure for the peak discharge control storm orifices.

Step 5. Design embankment(s) and spillway(s)

Size emergency spillway, calculate the peak event water surface elevation, set the top of the embankment elevation a minimum of 1 foot above the water surface elevation of the peak event, and analyze safe passage of the peak event. Set the emergency spillway elevation a minimum 0.1 foot above the peak event water surface elevation. At final design, provide safe passage for the peak event.

Step 6. Investigate potential basin hazard classification

The design and construction of dry detention basins are required to follow the latest version of the TDEC Rules and Regulations Application to the Safe Dams Act of 1973.

Step 7. Design inlets, outlet structures, maintenance access, and safety features.

See subsection 4.3.2.2 for more details.

Step 8. Design vegetation

A vegetation scheme for the detention basin should be prepared to indicate how the basin bottom, side slopes and embankments will be stabilized and established with vegetation.

4.3.2.4 Maintenance Requirements and Inspection Checklist

Note: Section 4.3.2.4 must be included in the Operations and Maintenance Plan that is recorded with the deed.

Regular inspection and maintenance is critical to the effective operation of the detention basin as designed. It is the responsibility of the property owner to maintain all stormwater BMPs in accordance with the minimum design standards and other guidance provided in this manual. The Director has the authority to impose additional maintenance requirements where deemed necessary.

This page provides guidance on maintenance activities that are typically required for detention basins, along with a suggested frequency for each activity. Individual basins may have more, or less, frequent maintenance needs, depending upon a variety of factors including the occurrence of large storm events, overly wet or dry (i.e., drought) regional hydrologic conditions, and any changes or redevelopment in the upstream land use. Each property owner shall perform the activities identified below at the frequency needed to maintain the basin in proper operating condition at all times.

Inspection Activities	Suggested Schedule
• After several storm events or an extreme storm event, inspect for: bank stability; signs of erosion; and damage to, or clogging of, the outlet structures and pilot channels.	As Needed
• Inspect for: trash and debris; clogging of the outlet structures and any pilot channels; excessive erosion; sediment accumulation in the basin and inlet/outlet structures; tree growth on dam or embankment; the presence of burrowing animals; standing water where there should be none; vigor and density of the grass turf on the basin side slopes and floor; differential settlement; cracking; leakage; and slope stability.	Semi-annually
• Inspect that the outlet structures, pipes, and downstream and pilot channels are free of debris and are operational. • Note signs of pollution, such as oil sheens, discolored water, or unpleasant odors. • Check for sediment accumulation in the facility. • Check for proper operation of control gates, valves or other mechanical devices.	Annually
Maintenance Activities	**Suggested Schedule**
• Clean and remove debris from inlet and outlet structures. • Mow side slopes (embankment) and maintenance access. Periodic mowing is only required along maintenance rights-of-way and the embankment.	Monthly or as needed
• Repair and revegetate eroded areas. • Remove vegetation that may hinder the operation of the basin. • Repair damage to the basin, outlet structures, embankments, control gates, valves, or other mechanical devices; repair undercut or eroded areas.	As Needed
• Monitor sediment accumulations, and remove sediment when the basin volume has become reduced significantly.	As Needed (typically every 20 to 50 years)

The property owner is encouraged to use the inspection checklist that is presented on the next page as a guide in the inspection and maintenance of conventional dry detention basins. Local authorities can require the use of this checklist or other form(s) of maintenance documentation when and where deemed necessary in order to ensure the long-term proper operation of the dry ED basin. Questions regarding stormwater facility inspection and maintenance should be referred to the local municipal engineering department.

INSPECTION CHECKLIST AND MAINTENANCE GUIDANCE (continued)
CONVENTIONAL DRY DETENTION BASIN INSPECTION CHECKLIST

Location: ______________________________ Owner Change since last inspection? Y N

Owner Name, Address, Phone: ______________________________

Date: ___________ Time: ______________ Site conditions:______________________________

Inspection Items	Satisfactory (S) or Unsatisfactory (U)	Comments/Corrective Action
Embankment and Emergency Spillway		
Vegetation coverage adequate?		
Erosion on embankment?		
Animal burrows in embankment?		
Cracking, sliding, bulging of dam?		
Blocked or malfunctioning drains?		
Leaks or seeps on embankment?		
Obstructions of spillway(s)?		
Erosion in/around emergency spillway?		
Other (describe)?		
Inlet/Outlet Structures and Channels		
Clear of debris and functional?		
Trash rack clear of debris and functional?		
Sediment accumulation?		
Condition of concrete/masonry?		
Metal pipes in good condition?		
Control valve operational?		
Basin drain valve operational?		
Outfall channels function, not eroding?		
Other (describe)?		
Basin Bottom		
Vegetation adequate?		
Undesirable vegetation growth?		
Excessive sedimentation?		
Hazards		
Have there been complaints from residents?		
Public hazards noted?		

If any of the above inspection items are **UNSATISFACTORY**, list corrective actions and the corresponding completion dates below:

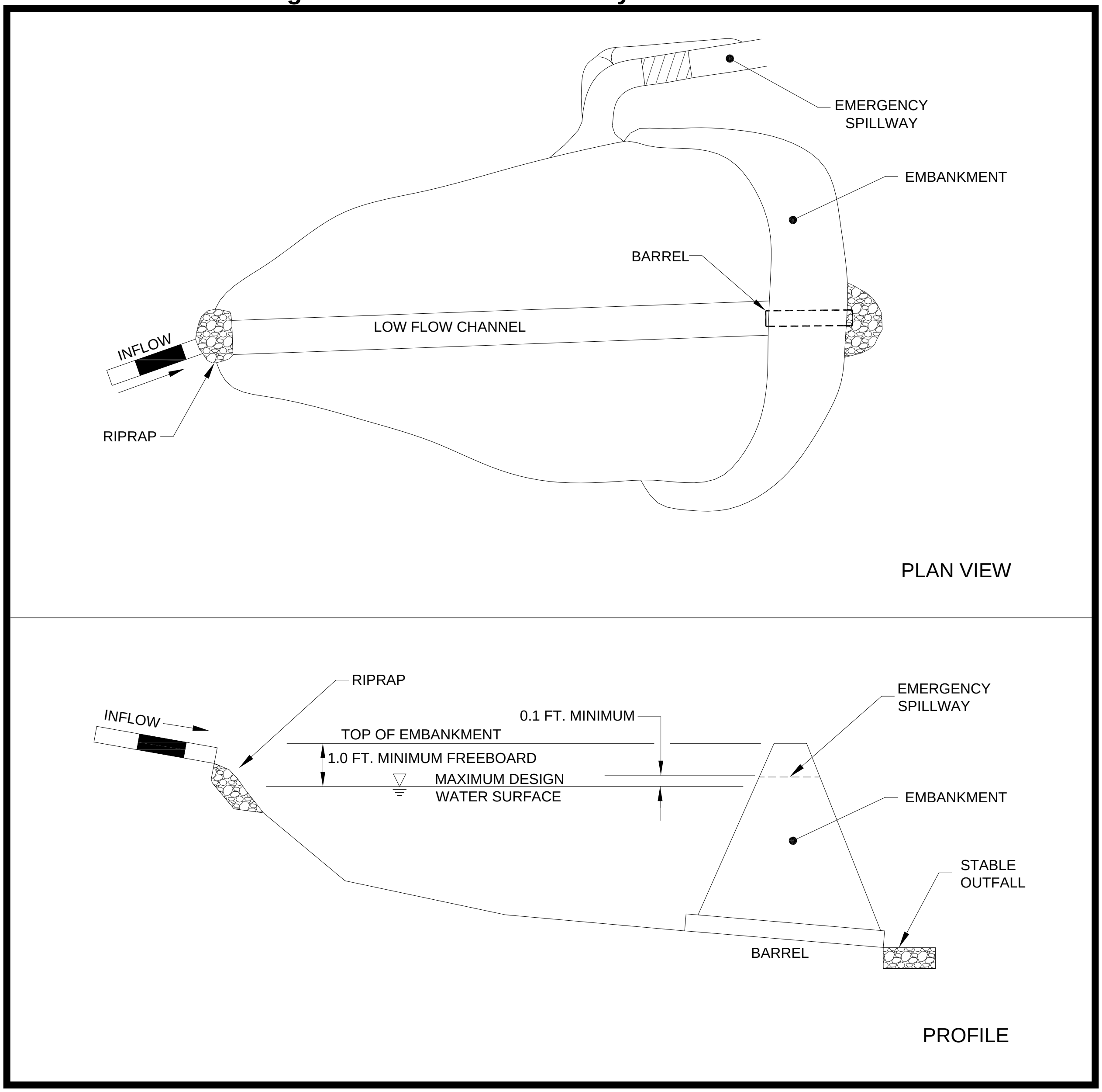
Corrective Action Needed	Due Date

Inspector Signature:______________________________ Inspector Name (printed)______________________________

4.3.2.5 Example Schematic

The example schematics for dry detention basins presented in Figure 4-17 can be used to assist in the design of such a BMP.

Figure 4-17. Schematic of Dry Detention Basin



4.3.2.6 Design Form

Use of the following design procedure forms when designing a conventional dry detention basin is recommended. Proper use and completion of the form may allow a faster review of the basin design by the local municipal engineering department.

Design Procedure Form: Dry Detention Basins

PRELIMINARY HYDROLOGIC CALCULATIONS

1 Compute storage volume required for locally regulated storm events

storage = ____________ acre-ft
storage = ____________ acre-ft

DRY DETENTION BASIN DESIGN

2. Confirm design criteria and applicability.

See Section 4.3.2.2

3. Conduct grading design and determine storage available

Prepare an elevation-storage table and curve using the average area method for computing volumes.

Elevation MSL	Area ft^2	Ave. Area ft^2	Depth ft	Volume ft^3	Cumulative Volume ft^3

4. Calculate required local municipality peak discharge release rates and WSELs

Set up a stage-storage-discharge relationship

Elevation	Storage	Low Flow	Riser			Barrel		Emergency	Total
		WQv-ED	CPv.ED	High Storage		Inlet	Pipe	Spillway	Storage
				Orif.	Weir				
MSL	acre-ft	H(ft) Q(cfs)	H(ft) Q(cfs)	H Q	H Q	H(ft) Q(cfs)	H(ft) Q(cfs)	H(ft) Q(cfs)	acre-ft

Calculate Qp_{peak}

Qp_{peak}= ____________ cfs

Maximum head =
Use weir equation for slot length ($Q=CLH^{3/2}$)

H= ____________ ft
L= ____________ ft

Check inlet condition
Check outlet conditions

Use culvert design guidance from local municipality

5. Size emergency spillway using the local municipality peak discharge and set top of embankment elevation and emergency spillway elevation based on $WSEL_{peak}$

$Q_{ES}=Qp_{peak}$ ____________ cfs
$WSEL_{peak}$= ____________ ft
El_{embank}= ____________ ft
El_{ES}= ____________ ft

6. Investigate potential basin hazard classification

See TN Safe Dams Act of 1973

7. Design inlets, sediment forebays, outlet structures, maintenance access, and safety features

See Section 4.3.2.2

8. Design basin vegetation

4.3.2.7 References

AMEC. *Knox County Stormwater Management Manual Volume 2, Technical Guidance*.

AMEC. *Metropolitan Nashville and Davidson County Stormwater Management Manual Volume 4 Best Management Practices.* 2006.

Atlanta Regional Council (ARC). *Georgia Stormwater Management Manual Volume 2 Technical Handbook.* 2001.

4.3.2.8 Suggested Reading

California Storm Water Quality Task Force. *California Storm Water Best Management Practice Handbooks.* 1993.

City of Austin, TX. *Water Quality Management.* Environmental Criteria Manual, Environmental and Conservation Services, 1988.

City of Sacramento, CA. *Guidance Manual for On-Site Stormwater Quality Control Measures.* Department of Utilities, 2000.

Merritt, F.S., Loftin, M.K., Ricketts, J.T. *Standard Handbook for Civil Engineers*. Fourth Edition McGraw-Hill, 1996.

Metropolitan Washington Council of Governments (MWCOG). *A Current Assessment of Urban Best Management Practices: Techniques for Reducing Nonpoint Source Pollution in the Coastal Zone.* March, 1992.

4.3.3 Dry Extended Detention Basins

General Application Water Quality BMP

Description: A surface storage basin or facility designed to provide water quantity and quality control through detention of stormwater runoff.

KEY CONSIDERATIONS

DESIGN GUIDELINES:

- Maximum contributing drainage area of 75 acres.
- A sediment forebay or equivalent upstream pretreatment must be provided.
- Minimum flow length to width ratio for the basin is 1.5:1. The basin shall be sized to detain the volume of runoff to be treated for a minimum of 24 hours.
- Side slopes to the basin shall not exceed 3:1 (h:v) on one side of the basin to facilitate access. Slopes as steep as 2:1 will be allowed for other areas, with proper stabilization.

ADVANTAGES / BENEFITS:

- Moderate removal rate of urban pollutants.
- High community acceptance.
- Useful for water quality treatment and flood control.

DISADVANTAGES / LIMITATIONS:

- Potential for thermal impacts/downstream warming.
- Dam height restrictions for high relief areas.
- Basin drainage can be problematic for low relief terrain.

MAINTENANCE REQUIREMENTS:

- Remove debris from inlet and outlet structures.
- Maintain side slopes and outlet structure.
- Remove invasive vegetation.
- Monitor sediment accumulation and remove periodically.

OTHER CONSIDERATIONS:

- Outlet clogging
- Safety bench
- Landscaping

STORMWATER MANAGEMENT SUITABILITY

Stormwater Quality:	**Yes**
Channel Protection:	**Yes**
Detention/Retention:	**Yes**

Accepts hotspot runoff: *Yes, but two feet of separation distance required to water table when used in hotspot areas*

COST CONSIDERATIONS

Land Requirement:	**Med - High**
Capital Cost:	**Low**
Maintenance Burden:	**Low**

LAND USE APPLICABILITY

Residential/Subdivision Use:	**Yes**
High Density/Ultra Urban Use:	**No**
Commercial/Industrial Use:	**Yes**

POLLUTANT REMOVAL

Total Suspended Solids:	**60%**

4.3.3.1 General Description

Dry extended detention (ED) basins are surface facilities that provide for the temporary storage of stormwater runoff for some minimum time (e.g., 24 to 72 hours) to allow suspended sediments and other associated pollutants to settle to the basin bottom, and therefore, not discharge to downstream channels. Dry ED basins provide moderate treatment of the water quality volume (WQv), are useful for control of the channel protection volume (CPv), and can provide overbank flood protection and extreme flood protection as well.

4.3.3.2 Pollutant Removal Capabilities

Dry ED basins are presumed capable of removing at least 60% of the total suspended solids load in typical urban post-development runoff when sized, designed, constructed and maintained in accordance with the specifications provided in this manual. The TSS removal performance can be reduced by poor design, construction or maintenance.

Additionally, research has shown that use of dry ED basins will have moderate benefits beyond the removal of TSS, such as the removal of other pollutants (i.e. phosphorous, nitrogen, fecal coliform and heavy metals), as well, which is useful information should the pollutant removal criteria change in the future.

For additional information and data on dry ED basins, see the National Pollutant Removal Performance Database (2nd Edition) available at www.stormwatercenter.net and the International Stormwater Best Management Practices Database at www.bmpdatabase.org.

Because dry ED basins cannot alone provide adequate treatment of the water quality volume, they must be utilized in a treatment train approach with other structural controls to achieve the goal of 80% removal of total suspended solids (TSS). Chapter 3 provides more information on treatment trains.

4.3.3.3 Planning and Design Standards

The following criteria shall be considered **minimum** design standards for the design of a dry ED basin. Dry ED basins that are not designed to these standards will not be approved. Consult with the local municipal engineering department to determine if there are any variations to these criteria or additional standards that must be followed.

A. LOCATION AND SITING

- It is strongly recommended that dry ED basins be located where the topography allows for maximum runoff storage at minimum excavation or embankment construction costs. When locating a dry ED basin, the site designers should also consider the location and use of other land use features, such as planned open spaces and recreational areas, and should attempt to achieve a multi-use objective with the basin where this can be safely achieved.
- Dry ED basins shall not be located on unstable slopes or slopes greater than 15%.
- Flood protection controls for control of the peak discharges should be designed as final controls for on-site stormwater. Because most dry ED basins will be used for flood protection and are not capable of achieving the Northeast Tennessee Regional Stormwater Planning Group's required 80% TSS removal standard, they will typically be located downstream of structural stormwater BMPs that are used in conjunction with the dry ED basin to provide 80% treatment of the WQv.
- A single dry ED basin shall not have a contributing drainage area greater than 75 acres unless specifically approved by the Director.
- Dry ED basins shall not be located in a stream or any other navigable waters of the United States, including natural (i.e., not constructed) wetlands. Where an appeal or variance of this policy is desired, the property owner must obtain coverage under a Section 404 permit under the Clean Water Act and/or an Aquatic Resource Alteration Permit (ARAP) and provide proof of such coverage with the Water Quality Management Plan.

- Each dry ED basin shall be placed in a water quality easement. The water quality easement shall be defined at the outer edge of the safety bench, or a minimum of 15 feet from the normal water pool elevation (measured perpendicular from the pool elevation boundary) if a safety bench is not included in the basin design. The easement limit should be located no closer than as follows unless otherwise specified by the local municipal regulations:
  - From a public water system well – TDEC specified distance per designated well category
  - From a private well – 50 feet; if the well is downgradient from a hotspot land use, as defined in this manual, then the minimum setback is 250 feet
  - From a septic system tank/leach field – 50 feet
- The minimum setback for habitable structures from the water quality easement shall be 15 feet. The first floor elevation (FFE) for any structure adjacent to the basin shall have an elevation no lower than 1 foot above the top of the berm.
- All utilities shall be located outside of the dry ED basin.

B. GENERAL DESIGN

- A dry ED basin shall consist of the following elements, designed in accordance with the specifications provided in this section:
  (1) An outlet structure;
  (2) An emergency spillway;
  (3) A sediment forebay;
  (4) Maintenance access;
  (5) Appropriate landscaping.

C. PHYSICAL SPECIFICATIONS / GEOMETRY

- Vegetated embankments shall be less than 20 feet in height. Side slopes shall not exceed 3:1 (horizontal to vertical) on one side of the basin to facilitate access for maintenance and repair. The remainder of the basin shall have side slopes no steeper than 2:1 although 3:1 is preferred. Benching of the slope is required for embankments greater than 10 feet in height and having greater than a 3:1 side slope. Riprap-protected embankments shall be no steeper than 2:1. Geotechnical slope stability analysis is recommended for embankments greater than 10 feet in height and is mandatory for embankment slopes steeper than those given above. All embankments must be designed to State of Tennessee guidelines for dam safety.
- The maximum depth of the basin shall not exceed 10 feet.
- Areas above the normal high water elevations of the dry ED basin shall be sloped toward the basin to allow drainage and to prevent standing water. Careful finish grading is required to avoid creation of upland surface depressions that may retain runoff. The basin bottom shall be graded toward the outlet to prevent standing water. A low flow or pilot channel across the facility bottom from the inlet to the outlet (often constructed with riprap) is recommended to convey low flows and prevent standing water conditions.

D. PRETREATMENT / INLETS

- A sediment forebay shall be provided for dry ED basins that are located in a treatment train with other water quality treatment structural controls. The sediment forebay is utilized to remove incoming sediment from the stormwater flow prior to dispersal into the larger basin area. The forebay shall consist of a separate cell, formed by an acceptable barrier. A forebay must be provided at each inlet to the dry ED basin, unless the inlet provides less than 10% of the total design storm inflow to the basin.
- The sediment forebay shall be sized to contain 0.1 inch per impervious acre (363 ft^3) of contributing drainage and shall be no more than 4 to 6 feet deep.

- A fixed vertical sediment depth marker shall be installed in the forebay to measure sediment deposition over time. The bottom of the forebay may be hardened (e.g., using concrete, paver blocks, etc.) to make sediment removal easier.
- Inflow channels to the forebay shall be stabilized with flared riprap aprons, or the equivalent. Exit velocities of discharges from the forebay to the basin must be non-erosive.

E. OUTLET STRUCTURES

- Flow control from a dry ED basin that is used for control of the WQv, CPv and the locally regulated peak discharges is typically accomplished with the use of a riser and barrel. The riser is a vertical pipe or inlet structure that is located at the base of the basin. The outlet barrel is a horizontal pipe attached to the riser that conveys flow under the embankment. The riser shall be located within the basin embankment for maintenance access, safety and aesthetics.
- A number of outlets at varying depths in the riser provide internal flow control for routing of the WQv, CPv, and the locally regulated peak discharges. The number of orifices can vary and is usually a function of the basin design. A dry ED basin riser configuration is typically comprised of an outlet that provides water quality (WQv), a channel protection (CPv) outlet (usually an orifice), and outlets for the locally controlled peak events (often a slot or weir). All outlets are protected by trash racks to prevent clogging. The channel protection orifice is sized to release the channel protection storage volume for a minimum 24-hour period.
- The water quality/channel protection outlet can be fitted with adjustable gate valves or another mechanism that can be used to adjust detention time.
- After entering the riser, flow is conveyed through the barrel and is discharged downstream. Anti-seep collars shall be installed on the outlet barrel to reduce the potential for pipe or embankment failure.
- Seepage control or anti-seep collars shall be provided for all outlet pipes.
- Water shall not be discharged from a dry ED basin in an erosive manner. Riprap, plunge pads or pools, or other energy dissipators shall be placed at the outlet of the barrel to prevent scouring and erosion. If a basin outlet discharges immediately to a channel that carries dry weather flow, care should be taken to minimize disturbance along the downstream channel and streambanks, and to reestablish a forested riparian zone in the shortest possible distance (if the downstream area is located in a water quality buffer).

F. EMERGENCY SPILLWAY

- An emergency spillway shall be included in the dry ED basin design to safely pass the locally regulated storm event. The spillway prevents basin water levels from overtopping the embankment and causing structural damage. The emergency spillway shall be located so that downstream structures will not be impacted by spillway discharges.
- The emergency spillway shall be located a minimum 0.1 foot above the 100-year water surface elevation.
- A minimum of 1 foot of freeboard shall be provided, measured from the top of the water surface elevation for the extreme flood to the lowest point of the dam embankment, not counting the emergency spillway.

G. MAINTENANCE ACCESS

- A maintenance right-of-way or easement having a minimum width of 20 feet shall be provided to the basin from a driveway, public or private road. The maintenance access easement shall have a maximum slope of no more than 15% and shall have a minimum unobstructed drive path having a width of 12 feet, appropriately stabilized to withstand maintenance equipment and vehicles.
- The maintenance access shall extend to the forebay (if included) and outlet structure, and, to the extent feasible, be designed to allow vehicles to turn around.

H. SAFETY FEATURES

- A safety bench shall be provided for embankments greater than 10 feet in height and having greater than a 3:1 side slope. For large basins, the safety bench shall extend no less than 15 feet outward from the normal water edge to the toe of the basin side slope. The slope of the safety bench shall not exceed 6%.
- All embankments and spillways shall be designed to TDEC rules and regulations as applied to the Safe Dams Act of 1973, where applicable.
- The property owner may consider fencing the basin for the purpose of safety management.
- All outlet structures shall be designed so as not to permit access by children. The Northeast Tennessee Regional Stormwater Planning Group encourages the posting of warning signs near the basin to prohibit swimming and fishing in the facility.

I. LANDSCAPING

- All areas of the basin shall be stabilized with appropriate vegetation to prevent the occurrence of erosion.
- Woody vegetation shall not be planted on the embankment or allowed to grow within 15 feet of the toe of the embankment and 25 feet from the principal spillway structure.
- Water quality buffers, as defined and described in Chapter 6 of this manual, are not required for dry ED basins. However, it should be noted that vegetated buffers can be utilized for water quality treatment and can result in a volume credit that reduces the WQv. The criteria for the vegetated buffer credit are presented in Chapter 5 of this manual.

4.3.3.4 Design Procedures

In general, site designers should perform the following design procedures when designing a dry ED basin.

Step 1. Compute runoff control volumes

> Calculate WQv, CPv, and pre- and post-development peak discharges and runoff volumes. The calculation of WQv and CPv is presented in Chapter 3 of this manual. Consult local regulations for peak discharge control (i.e., detention) requirements.

Step 2. Confirm design criteria and applicability

> Consider any special site-specific design conditions/criteria from subsection 4.3.3.3. Check with the Northeast Tennessee Regional Stormwater Planning Group, TDEC or other agencies to determine if there are any additional restrictions and/or surface water or watershed requirements that may apply to the site.

Step 3. Determine pretreatment volume

> A sediment forebay is provided at each inlet, unless the inlet provides less than 10% of the total design storm inflow to the basin. The forebay should be sized to contain 0.1 inch per impervious acre (363 ft^3) of contributing drainage and should be 4 to 6 feet deep.

Step 4. Determine basin location and preliminary geometry

> This step involves initially designing the grading of the basin (establishing contours) and determining the elevation-storage relationship for the basin. Include safety bench, if required or used. See subsection 4.3.3.3 for more details.

Step 5. Compute extended detention orifice release rate(s) and size(s), and establish CPv elevation

> The water quality orifice is sized to release the calculated WQv and CPv over a minimum 24 hour period and should be adequately protected from clogging by an acceptable external trash rack. The CPv elevation is then determined from the stage-storage relationship. The invert of the channel

protection orifice is located at the water quality extended detention elevation, and the orifice is sized to release the channel protection storage volume over a 24-hour period.

Step 6. Calculate peak discharge release rates and water surface elevations

Set up a stage-storage-discharge relationship for the control structure for the extended detention and the locally regulated peak discharge orifices.

Step 7. Design embankment(s) and spillway(s)

Size emergency spillway, calculate the peak event water surface elevation, set the top of the embankment elevation, and analyze safe passage of the peak event. Set the invert elevation of the emergency spillway 0.1 foot above the peak event water surface elevation.

Step 8. Investigate potential basin hazard classification

The design and construction of stormwater management basins are required to follow the latest version of the TDEC Rules and Regulations Application to the Safe Dams Act of 1973.

Step 9. Design inlets, sediment forebay(s), outlet structures, maintenance access, and safety features.

See subsection 4.3.3.3 for more details.

Step 10. Design vegetation

A vegetation scheme for the dry ED basin should be prepared to indicate how the basin bottom, side slopes and embankment will be stabilized and established with vegetation.

4.3.3.5 Maintenance Requirements and Inspection Checklist

Note: Section 4.3.3.5 must be included in the Operations and Maintenance Plan that is recorded with the deed.

Regular inspection and maintenance is critical to the effective operation of the dry ED basin as designed. It is the responsibility of the property owner to maintain all stormwater BMPs in accordance with the minimum design standards and other guidance provided in this manual. The Director has the authority to impose additional maintenance requirements where deemed necessary.

This page provides guidance on maintenance activities that are typically required for dry ED basins, along with a suggested frequency for each activity. Individual basins may have more, or less, frequent maintenance needs, depending upon a variety of factors including the occurrence of large storm events, overly wet or dry (i.e.., drought) regional hydrologic conditions, and any changes or redevelopment in the upstream land use. Each property owner shall perform the activities identified below at the frequency needed to maintain the basin in proper operating condition at all times.

Inspection Activities	**Suggested Schedule**
• After several storm events or an extreme storm event, inspect for: bank stability; signs of erosion; and damage to, or clogging of, the outlet structures and pilot channels.	As needed
• Inspect for: trash and debris; clogging of the outlet structures and any pilot channels; excessive erosion; sediment accumulation in the basin, forebay and inlet/outlet structures; tree growth on dam or embankment; the presence of burrowing animals; standing water where there should be none; vigor and density of the grass turf on the basin side slopes and floor; differential settlement; cracking; leakage; and slope stability.	Semi-annually
• Inspect that the outlet structures, pipes, and downstream and pilot channels are free of debris and are operational. • Note signs of pollution, such as oil sheens, discolored water, or unpleasant odors. • Check for sediment accumulation in the facility. • Check for proper operation of control gates, valves or other mechanical devices.	Annually
Maintenance Activities	**Suggested Schedule**
• Clean and remove debris from inlet and outlet structures. • Mow side slopes (embankment) and maintenance access. Periodic mowing is only required along maintenance rights-of-way and the embankment.	Monthly or as needed
• Repair and revegetate eroded areas. • Remove vegetation that may hinder the operation of the basin. • Repair damage to basin, outlet structures, embankments, control gates, valves, or other mechanical devices; repair undercut or eroded areas.	As Needed
• Monitor sediment accumulations, and remove sediment when the basin volume has become reduced significantly.	As Needed (typically every 20 to 50 years)

The property owner is encouraged to use the inspection checklist that is presented on the next page as a guide in the inspection and maintenance of dry ED basins. Local authorities can require the use of this checklist or other form(s) of maintenance documentation when and where deemed necessary in order to ensure the long-term proper operation of the dry ED basin. Questions regarding stormwater facility inspection and maintenance should be referred to the local municipal engineering department.

INSPECTION CHECKLIST AND MAINTENANCE GUIDANCE (continued)
DRY EXTENDED DETENTION BASIN INSPECTION CHECKLIST

Location: ____ Owner Change since last inspection? Y N

Owner Name, Address, Phone: ____

Date: ___________ Time: ______________ Site conditions:____

Inspection Items	Satisfactory (S) or Unsatisfactory (U)	Comments/Corrective Action
Embankment and Emergency Spillway		
Vegetation coverage adequate?		
Erosion on embankment?		
Animal burrows in embankment?		
Cracking, sliding, bulging of dam?		
Blocked or malfunctioning drains?		
Leaks or seeps on embankment?		
Obstructions of spillway(s)?		
Erosion in/around emergency spillway?		
Other (describe)?		
Inlet/Outlet Structures and Channels		
Clear of debris and functional?		
Trash rack clear of debris and functional?		
Sediment accumulation?		
Condition of concrete/masonry?		
Metal pipes in good condition?		
Control valve operational?		
Basin drain valve operational?		
Outfall channels function, not eroding?		
Other (describe)?		
Basin Bottom		
Vegetation adequate?		
Undesirable vegetation growth?		
Excessive sedimentation?		
Hazards		
Have there been complaints from residents?		
Public hazards noted?		

If any of the above inspection items are **UNSATISFACTORY**, list corrective actions and the corresponding completion dates below:

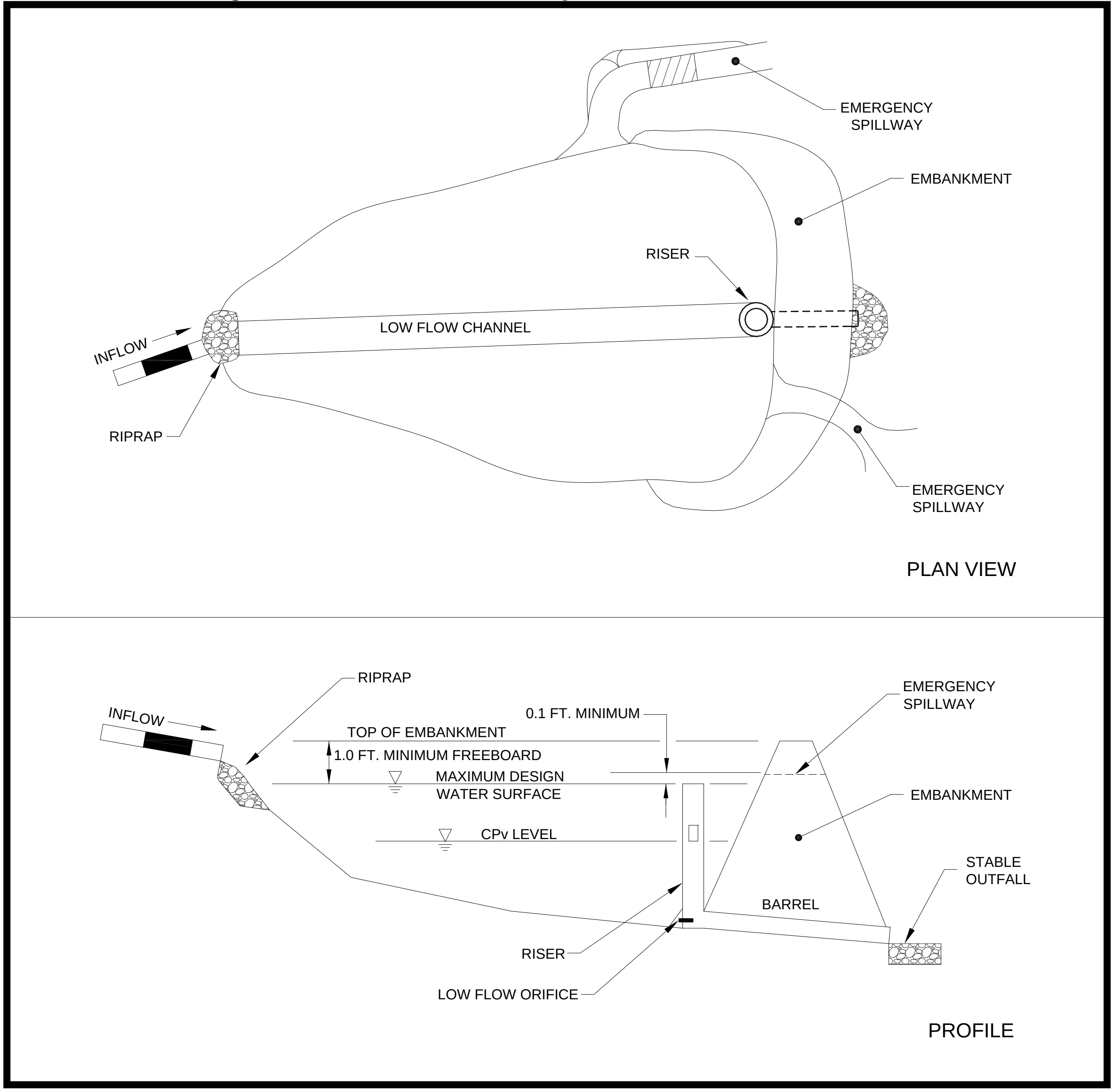
Corrective Action Needed	Due Date

Inspector Signature:___________________________________ Inspector Name (printed)____________________________

4.3.3.6 Example Schematic

The example schematic for a dry extended detention basin presented in Figure 4-18 can be used to assist in the design of such BMPs.

Figure 4-18. Schematic of Dry Extended Detention Basin



4.3.3.7 Design Form

Use of the following design procedure forms when designing a dry extended detention basin is recommended. Proper use and completion of the form may allow a faster review of the basin design by the local municipal engineering department.

Design Procedure Form: Dry Extended Detention Basins

PRELIMINARY HYDROLOGIC CALCULATIONS

1a. Compute WQv volume requirements
Compute Runoff Coefficient, Rv — Rv = ________
Compute WQv — WQv = ________ acre-ft

1b. Compute CPv — CPv = ________ acre-ft
Compute average release rate — release rate = ________ cfs
Compute storage volume required for locally regulated storm events — storage = ________ acre-ft; storage = ________ acre-ft

DRY EXTENDED DETENTION BASINS DESIGN

2. Is the use of a dry extended detention basin appropriate? — ***See subsections 4.3.3.1***
3. Confirm design criteria and applicability. — ***See subsection 4.3.3.3***
4. Pretreatment Volume (Forebay)
V_{pre} =(I)(.1")(1'/12") — V_{pre} = ________ acre-ft
5. Conduct grading design and determine storage available — Prepare an elevation-storage table and curve using the average area method for computing volumes.

Elevation MSL	Area ft^2	Ave. Area ft^2	Depth ft	Volume ft^3	Cumulative Volume ft^3

Design Procedure Form: Dry Extended Detention Basins (continued)

6. WQv Orifice Computations
   Average ED release rate (if applicable) — release rate= ____________ cfs
   Average head, h= (ED elev.- Permanent Pool elev.) /2 — head= ____________ ft
   Area of orifice from orifice equation — Area= ____________ ft2
   $Q=CA(2gh)^{0.5}$ C varies with orifice condition — diameter ____________ inches

   Compute Release Rate for CPv-ED control and establish CPv elevation — CPv WSEL= ____________ ft-NGVD
   Release rate= — release rate= ____________ cfs
   Average head, h= (ED elev.- Permanent Pool elev.) /2 — head= ____________ ft
   Area of orifice from orifice equation — Area= ____________ ft^2
   $Q=CA(2gh)^{0.5}$ C varies with orifice condition — diameter ____________ inches

7. Calculate required local municipality peak discharge release rates and WSELs — Set up a stage-storage-discharge relationship

Elevation	Storage	Low Flow	Riser			Barrel		Emergency	Total
		WQv-ED	CPv-ED	High Storage		Inlet	Pipe	Spillway	Storage
				Orif.	Weir				
MSL	acre-ft	H(ft) Q(cfs)	H(ft) Q(cfs)	H Q	H Q	H(ft) Q(cfs)	H(ft) Q(cfs)	H(ft) Q(cfs)	acre-ft

   Qp_{peak}=pre-dev. Peak discharge - (WQv-ED release + CPv-ED release) — Qp_{peak}= ____________ cfs

   Maximum head = — H= ____________ ft
   Use weir equation for slot length ($Q=CLH^{3/2}$) — L= ____________ ft

   Check inlet condition
   Check outlet conditions — **Use culverty design guidance from local municipality**

8. Size emergency spillway using the local municipality peak discharge and set top of embankment elevation and emergency spillway elevation based on $WSEL_{peak}$ — $Q_{ES}=Qp_{peak}$ ____________ cfs; $WSEL_{peak}$= ____________ ft; El_{embank}= ____________ ft; El_{ES}= ____________ ft

9. Investigate potential basin hazard classification — **See TN Safe Dams Act of 1973**

10. Design inlets, sediment forebays, outlet structures, maintenance access, and safety features — ***See subection 4.3.3.3***

11. Design vegetation according to guidance provided in TVA Riparian Restoration webpage
    www.tva.com/river/landandshore/stabilization/index.htm

4.3.3.8 References

AMEC. *Knox County Stormwater Management Manual Volume 2, Technical Guidance*.

AMEC. *Metropolitan Nashville and Davidson County Stormwater Management Manual Volume 4 Best Management Practices.* 2006.

Atlanta Regional Council (ARC). *Georgia Stormwater Management Manual Volume 2 Technical Handbook.* 2001.

Center for Watershed Protection. *Manual Builder.* Stormwater Manager's Resource Center, Accessed July 2005. *www.stormwatercenter.net*

4.3.3.9 Suggested Reading

California Storm Water Quality Task Force. *California Storm Water Best Management Practice Handbooks.* 1993.

City of Austin, TX. *Water Quality Management.* Environmental Criteria Manual, Environmental and Conservation Services, 1988.

City of Sacramento, CA. *Guidance Manual for On-Site Stormwater Quality Control Measures.* Department of Utilities, 2000.

Maryland Department of the Environment. *Maryland Stormwater Design Manual, Volumes I and II.* Prepared by Center for Watershed Protection (CWP), 2000.

Metropolitan Washington Council of Governments (MWCOG). *A Current Assessment of Urban Best Management Practices: Techniques for Reducing Nonpoint Source Pollution in the Coastal Zone.* March, 1992.

United States Environmental Protection Agency. *Methodology for Analysis of Detention Basins for Control of Urban Runoff Quality.* 1986.

Urban Drainage and Flood Control District. *Urban Storm Drainage Criteria Manual – Volume 3 – Best Management Practices – Stormwater Quality.* Denver, Colorado, September 1992.

Walker, W. *Phosphorus Removal by Urban Runoff Detention Basins.* Lake and Reservoir Management, North American Society for Lake Management, 314, 1987.

4.3.4 Stormwater Wetlands

**General Application
Water Quality BMP**

Description: A constructed wetland system used for stormwater management. Runoff volume is both stored and treated in the wetland facility.

KEY DESIGN CONSIDERATIONS

DESIGN GUIDELINES:

- Minimum contributing drainage area of 25 acres; 5 acres for a pocket wetland.
- Minimum dry weather flow path of 2:1 (length:width) should be provided from inflow to outflow.
- Minimum of 35% of total surface area should have a depth of 6 inches or less; 10 to 20% of surface area should be deep pool (1.5- to 6-foot depth).
- Hydrologic group 'A' and 'B' soils may require a liner.

ADVANTAGES / BENEFITS:

- Good nutrient removal.
- Provides natural wildlife habitat.
- Relatively low maintenance costs.

DISADVANTAGES / LIMITATIONS:

- Requires large land area.
- Needs continuous baseflow for viable wetland.
- Regular sediment removal is critical to sustain wetlands.

MAINTENANCE REQUIREMENTS:

- Replace wetland vegetation to maintain at least 50% surface area coverage.
- Remove invasive vegetation.
- Monitor sediment accumulation and remove periodically.

STORMWATER MANAGEMENT SUITABILITY

Stormwater Quality:	**Yes**
Channel Protection:	**Yes**
Detention/Retention:	**Yes**

Accepts hotspot runoff: *No*

COST CONSIDERATIONS

Land Requirement:	**Med-High**
Capital Cost:	**Med**
Maintenance Burden:	
Shallow Wetland	**Med**
ED Shallow Wetland	**Med**
Pocket Wetland	**High**
Basin/Wetland	**Med**

LAND USE APPLICABILITY

Residential/Subdivision Use:	**Yes**
High Density/Ultra Urban Use:	**Yes**
Commercial/Industrial Use:	**Yes**

POLLUTANT REMOVAL

Total Suspended Solids:	**75%**

~~4.3.4.1 General Description~~

Stormwater wetlands (also referred to as *constructed wetlands*) are constructed shallow marsh systems that are designed to both treat urban stormwater and control runoff volumes. As stormwater runoff flows through the wetland facility, pollutant removal is achieved through settling and uptake by marsh vegetation. Wetlands can be utilized effectively for pollutant removal and also offer aesthetic value and wildlife habitat.

Constructed stormwater wetlands differ from natural wetland systems in that they are engineered facilities designed specifically for the purpose of treating stormwater runoff and typically have less biodiversity than natural wetlands both in terms of plant and animal life. However, as with natural wetlands, stormwater wetlands require a continuous base flow or a high water table to support aquatic vegetation.

There are several design variations of the stormwater wetland, each design differing in the relative amounts of shallow and deep water, and dry storage above the wetland. The variations are shown in Figure 4-19. These include the shallow wetland, the extended detention shallow wetland, basin/wetland system and pocket wetland. Below are descriptions of each design variant:

Figure 4-19. Stormwater Wetland Examples

Shallow Wetland

Extended Detention Shallow Wetland

Pocket wetland

Newly Constructed Shallow Wetland

- **Shallow Wetland** – In the shallow wetland design, most of the water quality treatment volume is in the relatively shallow high marsh or low marsh depths. The only deep portions of the shallow wetland design are the forebay at the inlet to the wetland, and the micropool at the outlet. One disadvantage of this design is that, since the pool is very shallow, a relatively large amount of land is typically needed to store the water quality volume.
- **Extended Detention (ED) Shallow Wetland** – The extended detention (ED) shallow wetland design is the same as the shallow wetland; however, part of the water quality treatment volume is provided as extended detention above the surface of the marsh and released over a period of 24 hours. This design can treat a greater volume of stormwater in a smaller space than the shallow wetland design. In the extended detention shallow wetland option, plants that can tolerate both wet and dry periods need to be specified in the ED zone.
- **Basin/Wetland System** – The basin/wetland system has two separate cells: a wet basin and a shallow marsh. The wet basin traps sediments and reduces runoff velocities prior to entry into the

wetland, where stormwater flows receive additional treatment. Less land is required for a basin/wetland system than for the shallow wetland or the ED shallow wetland systems.

- **Pocket Wetland** – A pocket wetland is intended for smaller drainage areas of 5 to 10 acres and typically requires excavation down to the water table for a reliable water source to support the wetland system.

Certain types of wetlands, such as *submerged gravel wetland systems* are not recommended for general application use to meet stormwater management goals due to limited performance data. They may be applicable in special or retrofit situations where there are severe limitations on what can be implemented. Please see a further discussion of submerged gravel wetlands in Section 4.4.3.

4.3.4.2 Stormwater Management Suitability

Similar to stormwater basins, stormwater wetlands are designed to control both stormwater quantity and quality. Thus, a stormwater wetland can be used to address the minimum design standards for water quality, channel protection and flood protection for a given drainage area.

Water Quality Volume (WQv)
Pollutants are removed from stormwater runoff in a wetland through uptake by wetland vegetation and algae, vegetative filtering, and through gravitational settling in the slow moving marsh flow. Other pollutant removal mechanisms are also at work in a stormwater wetland, including chemical and biological decomposition, and volatilization. Section 4.3.4.3 provides median pollutant removal efficiencies that can be used for planning and design purposes.

Channel Protection Volume (CPv)
The storage volume above the permanent pool/water surface level in a stormwater wetland is used to provide control of the channel protection volume (CPv). This is accomplished by releasing the 1-year, 24-hour storm runoff volume over 24 hours (extended detention). It is best to do this with minimum vertical water level fluctuation, as extreme fluctuation may stress vegetation.

4.3.4.3 Pollutant Removal Capabilities

All of the stormwater wetland design variants are presumed to be able to remove 80% of the total suspended solids load in typical urban post-development runoff when sized, designed, constructed and maintained in accordance with the specifications provided in this manual.

The total suspended solids design pollutant removal rate of 80% is a conservative average pollutant reduction percentage for design purposes derived from sampling data, modeling and professional judgment.

For additional information and data on pollutant removal capabilities for stormwater wetlands, see the National Pollutant Removal Performance Database (2nd Edition) available at www.stormwatercenter.net and the International Stormwater Best Management Practices Database at www.bmpdatabase.org.

4.3.4.4 Application and Site Feasibility Criteria

Stormwater wetlands are generally applicable to most types of new development and redevelopment, and can be utilized in both residential and nonresidential areas. However, due to the large land requirements, wetlands may not be practical in higher density areas. The following criteria should be evaluated to ensure the suitability of a stormwater wetland for meeting stormwater management objectives on a site or development.

General Feasibility

- Suitable for Residential Subdivision Usage
- Suitable for High Density/Ultra Urban Areas, however, land requirements may preclude use
- Suitable for Commercial/Industrial use
- Suitable for Regional Stormwater Control

Physical Feasibility - Physical Constraints at Project Site

- Drainage Area – A minimum of 25 acres and a positive water balance is needed to maintain wetland conditions; a minimum of 5 acres for pocket wetland. The local municipality may approve a smaller drainage area with an adequate water balance and anti-clogging device.
- Space Required – Approximately 3 to 5% of the tributary drainage area
- Site Slope – Wetlands are feasible on sites where the upstream slope (above the wetland) is no more than 15%.
- Minimum Head – Enough elevation drop is required, from inlet to outlet, to allow hydraulic conveyance by gravity. Generally, the minimum head for a pocket wetland is 2 to 3 feet. For all other wetlands the minimum head is 3 to 5 feet.
- Minimum Depth to Water Table – In general, no minimum separation distance to the water table is required for stormwater wetlands. In fact, water table interception may be helpful to sustain a permanent pool. However, some source water protection requirements may dictate a separation distance if there is a sensitive underlying aquifer. In such situations, an impermeable liner, or a minimum separation between 2 to 4 feet is required for portions of the wetland that will have standing water.
- Soils – Permeable soils are not well suited for a constructed stormwater wetland without a high water table. Underlying soils of hydrologic group “C” or “D” should be adequate to maintain wetland conditions. Most group “A” soils and some group “B” soils will require a liner. Evaluation of soils should be based upon an actual subsurface analysis and permeability tests.

4.3.4.5 Planning and Design Standards

The following standards shall be considered **minimum** design standards for the design of a stormwater wetland facility. Stormwater wetlands that are not designed to these standards will not be approved. The local municipality shall have the authority to require additional design conditions if deemed necessary.

A. LOCATION AND SITING

- Stormwater wetlands should normally have a minimum contributing drainage area of 25 acres or more. For a pocket wetland, the minimum drainage area is 5 acres. The local municipality may consider allowing the use of a stormwater wetland for a smaller drainage area when water availability can be confirmed (such as from a groundwater source or areas that typically have a high water table). It is important that wetlands that serve smaller drainage areas have an adequate anti-clogging device provided for the wetland outlet.
- A continuous base flow or high water table is required to support wetland vegetation. A water balance shall be performed to demonstrate that a stormwater wetland can withstand a 30-day drought at summer evaporation rates without completely drawing down (see Chapter 3 for details).
- When determining an appropriate location for a stormwater wetland, the site designer should also take into account the location and use of other site features such as natural depressions, buffers, and undisturbed natural areas. The site designer should attempt to aesthetically “fit” the wetland into the landscape.
- Stormwater wetlands shall not be located in a stream or any other navigable waters of the United States, including natural (i.e., not constructed) wetlands. Where an appeal or variance of this policy is desired, the property owner must obtain coverage under a Section 404 permit under the Clean Water Act and/or an Aquatic Resource Alteration Permit (ARAP) and provide proof of such coverage with the Stormwater Management Plan. The local municipality may approve the conversion of an existing degraded wetland into a stormwater wetland where appropriate for local watershed restoration efforts, and when prior approval for such a conversion is obtained from all applicable State and Federal agencies.
- If a wetland facility is not used for overbank and extreme flood protection, it shall be designed as an off-line system to bypass the higher flows rather than passing them through the wetland system.

- Each wetland or wetland system shall be placed in a water quality easement that is recorded with the deed. The water quality easement shall be defined at the outer edge of the safety bench, or a minimum of 15 feet from the normal water pool elevation (measured perpendicular from the pool elevation boundary) if a safety bench is not included in the wetland design. Minimum setback requirements for the easement shall be as follows unless otherwise specified by the local municipality:
  - From a property line – 10 feet;
  - From a public water system well – TDEC specified distance per designated category;
  - From a private well – 100 feet; if well is downgradient from a land use that requires a Special Pollution Abatement Permit, then the minimum setback is 250 feet;
  - From a septic system tank/leach field – 50 feet.
- All utilities should be located outside of the wetland site.

B. GENERAL DESIGN

- A stormwater wetland shall consist of the following elements, design in accordance with the specifications provided in this section.
  - Shallow marsh areas of varying depths with wetland vegetation;
  - Permanent micropool;
  - Overlying zone in which runoff control volumes are stored if the wetland will be used for storage of the CPv and the locally regulated peak discharge.
  - Emergency spillway;
  - Maintenance access;
  - Safety bench;
  - Sediment forebay at each wetland inlet (unless the inlet provides less than 10% of the total inflow to the wetland);
  - Wetland buffer (this is not the same as a regulatory water quality buffer – see section I-Landscaping for more information); and
  - Appropriate wetland vegetation and native landscaping.
  - Basin/wetland systems also include stormwater basin facilities that must meet all of the design parameters in Section 4.3.1 for basin design.

C. PHYSICAL SPECIFICATIONS / GEOMETRY

In general, wetland designs are unique for each site and application. However, there are number of geometric ratios and limiting depths for the design of a stormwater wetland that shall be observed for adequate pollutant removal, ease of maintenance, and improved safety. Table 4-8 provides the recommended physical specifications and geometry for the various stormwater wetland design variants.

Table 4-8. Recommended Design Criteria for Stormwater Wetlands
(Source: Modified from Massachusetts DEP, 1997; Schueler, 1992)

Design Criteria	Shallow Wetland	ED Shallow Wetland	Basin/ Wetland	Pocket Wetland
Length to Width Ratio (minimum)	2:1	2:1	2:1	2:1
Extended Detention (ED)	No	Yes	Optional	Optional

Allocation of WQv Volume (pool/marsh/ED) in %	25/75/0	25/25/50	70/30/0 (includes basin volume)	25/75/0
Allocation of Surface Area (deepwater/low marsh/high marsh/semi-wet)[1] in %	20/35/40/5	10/35/45/10	45/25/25/5 (includes basin surface area)	10/45/40/5
Forebay	Required	Required	Required	See section D below
Micropool	Required	Required	Required	Required
Outlet Configuration	Reverse-slope pipe or hooded broad-crested weir	Reverse-slope pipe or hooded broad-crested weir	Reverse-slope pipe or hooded broad-crested weir	Hooded broad-crested weir

1 – Depth Considerations:
Deepwater: 1.5 to 6 feet below normal pool elevation
Low marsh: 6 to 18 inches below normal pool elevation
High marsh: 6 inches or less below normal pool elevation
Semi-wet zone: Above normal pool elevation

- The stormwater wetland shall be designed with the recommended proportion of “depth zones.” Each of the four wetland design variants has depth zone allocations which are given as a percentage of the stormwater wetland surface area. Target allocations are found in Table 4-8. The four basic depth zones are:

  Deepwater zone
  From 1.5 to 6 feet deep. Includes the outlet micropool and deepwater channels through the wetland facility. This zone supports little emergent wetland vegetation, but may support submerged or floating vegetation.

  Low marsh zone
  From 6 to 18 inches below the normal permanent pool or water surface elevation. This zone is suitable for the growth of several emergent wetland plant species.

  High marsh zone
  From 6 inches below the pool to the normal pool elevation. This zone will support a greater density and diversity of wetland species than the low marsh zone. The high marsh zone should have a higher surface area to volume ratio than the low marsh zone.

  Semi-wet zone
  Those areas above the permanent pool that are inundated during larger storm events. This zone supports a number of species that can survive flooding.

- A dry weather flow path shall be provided from inflow to outlet across the stormwater wetland. The path shall have a minimum length to width ratio of 2:1. Ideally, the path length to width ration should be greater than 3:1. This path may be achieved by constructing internal dikes or berms, using marsh plantings, and/or by using multiple cells. Finger dikes are commonly used in surface flow systems to create serpentine configurations and prevent short-circuiting. Microtopography (contours along the bottom of a wetland or marsh that provide a variety of conditions for different species needs and increases the surface area to volume ratio) is encouraged to enhance wetland diversity.
- A micropool having a depth no greater than 4 to 6 feet shall be included in the design at the outlet to prevent the outlet from clogging and resuspension of sediments, and to mitigate thermal effects.
- Maximum depth of any permanent pool areas shall not exceed 6 feet.
- The volume that is handled through extended detention shall not comprise more than 50% of the total WQv, and its maximum water surface elevation shall not extend more than 3 feet above the normal

pool. Storage of CPv and the locally regulated peak discharge can be provided above the maximum WQv elevation within the wetland.

- The perimeter of all deep pool areas (4 feet or greater in depth) shall be surrounded by safety and aquatic benches similar to those for stormwater basins (see subsection 4.3.1).
- The contours of the wetland shall be irregular to provide a more natural landscaping effect.

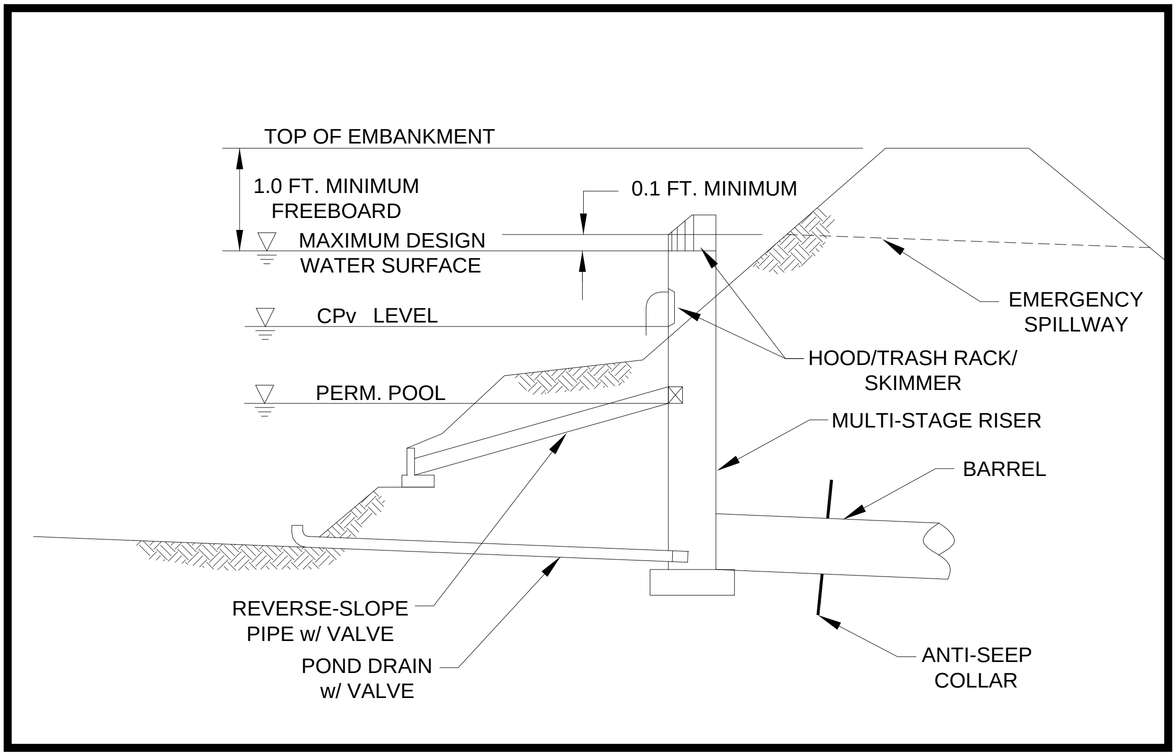
D. PRETREATMENT / INLETS

- Sediment regulation and removal is critical to sustain stormwater wetlands. A wetland facility shall have a sediment forebay or equivalent upstream pretreatment. In some cases, a pocket wetland design may not allow construction of a sediment forebay because of space limitations on small sites. In this case, a smaller "cattail" forebay is recommended to capture trash, debris and oil.
- A sediment forebay is designed to remove incoming sediment from the stormwater flow prior to dispersal into the wetland. The forebay shall consist of a separate cell, formed by an acceptable barrier. A forebay shall be provided at each inlet, unless the inlet provides less than 10% of the total design storm inflow to the wetland facility.
- The forebay shall be sized to contain 0.1 inches per impervious acre (363 ft^3) of contributing drainage and shall be no more than 4 to 6 feet deep. The pretreatment storage volume is part of the total WQv design requirement and may be subtracted from the WQv for wetland storage sizing.
- A fixed vertical sediment depth marker shall be installed in the forebay to measure sediment deposition over time. The bottom of the forebay may be hardened (e.g., using concrete, paver blocks, etc.) to make sediment removal easier.
- Inflow channels shall be stabilized with flared riprap aprons, or the equivalent. Inlet pipes to the basin can be partially submerged. Exit velocities from the forebay to the wetland shall be nonerosive.

E. OUTLET STRUCTURES

- Flow control from a stormwater wetland is typically accomplished with the use of a concrete or corrugated metal riser and barrel. The riser is a vertical pipe or inlet structure that is attached to the base of the micropool with a watertight connection. The outlet barrel is a horizontal pipe attached to the riser that conveys flow under the embankment (see Figure 4-20). The riser shall be located within the embankment for maintenance access, safety and aesthetics.

Figure 4-20. Typical Wetland Facility Outlet Structure



- A number of outlets at varying depths in the riser provide internal flow control for routing of WQv, CPv, and the locally regulated peak discharge. The number of orifices can vary and is usually a function of the wetland design.

  For shallow and pocket wetlands, the riser configuration is typically comprised of a channel protection outlet (usually an orifice) and overbank flood protection outlet (often a slot or weir). The channel protection orifice is sized to release the channel protection storage volume over a 24-hour period. Since the water quality volume is fully contained in the permanent pool, no orifice sizing is necessary for this volume. As runoff from a water quality event enters the wet basin, it simply displaces that same volume through the channel protection orifice. Thus an off-line shallow or pocket wetland providing <u>only</u> water quality treatment can use a simple overflow weir as the outlet structure.

  In the case of an extended detention (ED) shallow wetland; there is generally a need for an additional outlet (usually an orifice) that is sized to pass the extended detention water quality volume that is surcharged on top of the permanent pool. Flow will first pass through this orifice, which is sized to release the water quality ED volume in 24 hours. The preferred design is a reverse slope pipe attached to the riser, with its inlet submerged 1 foot below the elevation of the permanent pool to prevent floatables from clogging the pipe and to avoid discharging warmer water at the surface of the basin. The next outlet is sized for the release of the channel protection storage volume. The outlet (often an orifice) invert is located at the maximum elevation associated with the extended detention water quality volume and is sized to release the channel protection storage volume over a 24-hour period.

  Alternative hydraulic control methods to an orifice can be used and include the use of a broad-crested rectangular, V-notch, proportional weir, or an outlet pipe protected by a hood that extends at least 12 inches below the normal pool.

- The water quality outlet (if design is for an ED shallow wetland) and channel protection outlet shall be fitted with adjustable gate valves or other mechanism that can be used to adjust detention time.

- Higher flows (locally regulated peak discharge) pass through openings or slots protected by trash racks that are located further up on the riser.

- After entering the riser, flow is conveyed through the barrel and is discharged downstream. Anti-seep collars shall be installed on the outlet barrel to reduce the potential for pipe failure.
- Riprap, plunge pools or pads, or other energy dissipators shall be placed at the outlet of the barrel to prevent scouring and erosion. If a wetland facility discharges to a stream that has dry weather flow at any time during the year, care should be taken to minimize land disturbance along the downstream channel, and to reestablish a forested riparian zone in the shortest possible distance. See Chapter 7 (Construction Site Stormwater Management) and Chapter 6 (Water Quality Buffers) for more guidance on outlet designs and rules and regulations for disturbances in a water quality buffer.
- The wetland facility shall have a bottom drain pipe located in the micropool with an adjustable valve that can completely or partially drain the wetland within 24 hours.
- The wetland drain shall be sized one pipe size greater than the calculated design diameter. The drain valve is typically a handwheel activated knife or gate valve. Valve controls shall be located inside of the riser at a point where they (a) will not normally be inundated and (b) can be operated in a safe manner.

See the design procedures in subsection 4.3.4.6 as well as Chapter 3 for additional information and specifications on basin routing and outlet operations.

F. EMERGENCY SPILLWAY

- An emergency spillway shall be included in the stormwater wetland design to safely pass the locally regulated peak discharge. The spillway prevents the wetland's water levels from overtopping the embankment and causing structural damage. The emergency spillway shall be located so that downstream structures will not be impacted by spillway discharges.
- A minimum of 1 foot of freeboard must be provided, measured from the top of the water surface elevation for the locally regulated peak discharge to the lowest point of the dam embankment, not counting the emergency spillway.

G. MAINTENANCE ACCESS

- A minimum 20' wide maintenance right of way or easement shall be provided from a driveway, public or private road. The maintenance access easement shall have a maximum slope of no more than 15% and shall have a minimum unobstructed drive path having a width of 12 feet, appropriately stabilized to withstand maintenance equipment and vehicles.
- The maintenance access shall extend to the forebay, safety bench, riser, and outlet, and, to the extent feasible, be designed to allow vehicles to turn around.
- Access to the riser shall be provided by lockable manhole covers, and manhole steps within easy reach of valves and other controls.

H. SAFETY FEATURES

- All embankments and spillways shall be designed to the requirements set by TDEC's Safe Dams Act of 1973.
- Fencing of wetlands is not generally desirable, but may be required by the local municipality. A preferred method is to manage the contours of deep pool areas through the inclusion of a safety bench (see above) to eliminate dropoffs and reduce the potential for accidental drowning. In addition, the safety bench may be landscaped to deter access to the pool.
- All outlet structures shall be designed so as not to permit access by children.

I. LANDSCAPING

- A landscaping plan shall be developed that indicates the methods used to establish and maintain wetland coverage. Minimum considerations of the plan include: delineation of landscaping zones, selection of corresponding plant species, planting plan, sequence for preparing wetland bed (including soil amendments, if needed) and sources of plant material. More information on wetland plants can be found at the following websites:

- http://wetlands.fws.gov/
- http://www.npwrc.usgs.gov/resource/plants/floraso/species.htm
- http://www.tva.gov/river/landandshore/stabilization/plantsearch.htm

- Landscaping zones include low marsh, high marsh, and semi-wet zones. The low marsh zone ranges from 6 to 18 inches below the normal pool. This zone is suitable for the growth of several emergent plant species. The high marsh zone ranges from 6 inches below the pool up to the normal pool. This zone will support greater density and diversity of emergent wetland plant species. The high marsh zone should have a higher surface area to volume ratio than the low marsh zone. The semi-wet zone refers to those areas above the permanent pool that are inundated on an infrequent basis and can be expected to support wetland plants.
- The landscaping plan should provide elements that promote greater wildlife and waterfowl use within the wetland and buffers.
- Woody vegetation shall not be planted on the embankment or allowed to grow within 15 feet of the toe of the embankment and 25 feet from the principal spillway structure.
- Water quality buffers, as defined and described in Chapter 6 of this manual, are not required for wetlands that are constructed for the purpose of stormwater quality or quantity control. However, it should be noted that vegetated buffers can be utilized for water quality treatment and can result in a volume credit that reduces the WQv. The criteria for the vegetated buffer credit are presented in Chapter 5 of this manual.
- Existing trees should be preserved in the wetland area during construction, or should be replanted. It is desirable to locate forest conservation areas adjacent to wetlands. To discourage resident waterfowl populations, the wetland buffer can be planted with trees, shrubs and native ground covers.
- The soils in planting areas within and surrounding a wetland are often severely compacted during the construction process to ensure stability. The density of these compacted soils is so great that it effectively prevents root penetration and therefore may lead to premature mortality or loss of vigor. Consequently, it is advisable to excavate large and deep holes around the proposed planting sites and backfill these with <u>uncompacted</u> topsoil.
- Native species of fish can be stocked in the permanent pool to aid in mosquito prevention The Northeast Tennessee Stormwater Planning Group strongly discourages the use non-native fish species in a stormwater facility due to the possibility that the fish will enter downstream receiving waters.
- A fountain or aerator may be used for oxygenation of water in the permanent pool and to aid in mosquito breeding prevention.

J. ADDITIONAL SITE-SPECIFIC DESIGN CRITERIA AND ISSUES

There are a number of additional site specific design criteria and issues (listed below) that must be considered in the design of wetlands.

<u>Physiographic Factors - Local terrain design constraints</u>

- <u>Low Relief</u> – Providing wetland drain can be problematic
- <u>Karst</u> – Requires poly or clay liner to sustain a permanent pool of water and protect aquifers; limits on ponding depth; geotechnical tests may be required. Stormwater wetlands are the preferred BMP over basins in the karst areas.

<u>Soils</u>

- Hydrologic group “A” soils and some group “B” soils may require liner (not relevant for pocket wetland)

Special Watershed Considerations

- Wellhead Protection – The potential for groundwater contamination (in required wellhead protection areas) shall be reduced through pretreatment of runoff, and installation of a liner for type “A” and “B” soils; Pretreat hotspots; 2 to 4 foot separation distance from water table.

4.3.4.6 Design Procedures

Step 1. Compute runoff control volumes

Calculate the WQv, CPv, and the locally regulated peak discharge, in accordance with the guidance presented in Chapter 3.

Step 2. Determine if the development site and conditions are appropriate for the use of a stormwater wetland

Consider the Application and Site Feasibility Criteria in subsections 4.3.4.4 and 4.3.4.5-A (Location and Siting).

Step 3. Confirm design criteria and applicability

Consider any special site-specific design conditions/criteria from subsection 4.3.4.5-J (Additional Site-Specific Design Criteria and Issues).

Check with the local municipality, TDEC, or other agencies to determine if there are any additional restrictions and/or surface water or watershed requirements that may apply.

Step 4. Determine pretreatment volume

A sediment forebay is provided at each inlet, unless the inlet provides less than 10% of the total design storm inflow to the basin. The forebay shall be sized to contain 0.1 inches per impervious acre (363 ft^3) of contributing drainage and shall be 4 to 6 feet deep. The forebay storage volume counts toward the total WQv requirement and may be subtracted from the WQv for subsequent calculations.

Step 5. Allocate the WQv volume among marsh, micropool, and ED volumes

Use recommended criteria from Table 4-8 in Section 4.3.4.5.

Step 6. Determine wetland location and preliminary geometry, including distribution of wetland depth zones

This step involves initially laying out the wetland design and determining the distribution of wetland surface area among the various depth zones (high marsh, low marsh, and deepwater). Set WQv permanent pool elevation (and WQv-ED elevation for ED shallow wetland) based on volumes calculated earlier.

Step 7. Compute extended detention orifice release rate(s) and size(s), and establish CPv elevation

Shallow Wetland and Pocket Wetland: The CPv elevation is determined from the stage-storage relationship and the orifice is then sized to release the channel protection storage volume over a 24-hour period. The channel protection orifice should have a minimum diameter of 3 inches and should be adequately protected from clogging by an acceptable external trash rack. A reverse slope pipe attached to the riser, with its inlet submerged 1 foot below the elevation of the permanent pool is a recommended design. The orifice diameter may be reduced to 1 inch if internal orifice protection is used (i.e., an over-perforated vertical stand pipe with ½-inch orifices or slots that are protected by wirecloth and a stone filtering jacket). Adjustable gate valves can also be used to achieve this equivalent diameter.

ED Shallow Wetland: Based on the elevations established in Step 6 for the extended detention portion of the water quality volume, the water quality orifice is sized to release this extended detention volume in 24 hours. The water quality orifice should have a minimum diameter of 3 inches, and should be adequately protected from clogging by an acceptable external trash rack. A reverse slope pipe attached to the riser, with its inlet submerged one foot below the elevation of the permanent pool, is a recommended design. The orifice diameter may be reduced to 1 inch if internal orifice protection is used (i.e., an over-perforated vertical stand pipe with ½-inch orifices or slots that are protected by wire cloth and a stone filtering jacket). Adjustable gate valves can also be used to achieve this equivalent diameter. The CPv elevation is then determined from the stage-storage relationship. The invert of the channel protection orifice is located at the water quality extended detention elevation, and the orifice is sized to release the channel protection storage volume over a 24-hour period.

Step 8. Calculate the locally regulated peak discharge release rates and water surface elevations

Set up a stage-storage-discharge relationship for the control structure for the extended detention orifice(s) and the 25-year storm.

Step 9. Design embankment(s) and spillway(s)

Calculate the locally regulated peak discharge water surface elevation, set the top of the embankment elevation, and size the emergency spillway, ensuring safe passage of the locally regulated peak discharge. Set the invert elevation of the emergency spillway 0.1 foot above the locally regulated peak discharge water surface elevation.

Step 10. Investigate potential basin/wetland hazard classification

The design and construction of stormwater management facilities are required to follow the latest version of the TDEC Rules and Regulations Application to the Safe Dams Act of 1973.

Step 11. Design inlets, sediment forebay(s), outlet structures, maintenance access, and safety features.

See subsection 4.3.4.5-D through H for more details.

Step 12. Design landscape plan

A landscape plan for a stormwater wetland and its buffer shall be prepared to indicate how aquatic and terrestrial areas will be stabilized and established with vegetation. See subsection 4.3.4.5-I (Landscaping) for more details.

4.3.4.7 Maintenance Requirements and Inspection Checklist

Note: Section 4.3.4.7 must be included in the Operations and Maintenance Plan that is recorded with the deed.

Regular inspection and maintenance is critical to the effective operation of stormwater wetlands as designed. It is the responsibility of the property owner to maintain all stormwater BMPs in accordance with the minimum design standards and other guidance provided in this manual. The local municipality has the authority to impose additional maintenance requirements where deemed necessary. This page provides guidance on maintenance activities that are typically required for stormwater wetlands, along with a suggested frequency for each activity. Individual wetlands may have more, or less, frequent maintenance needs, depending upon a variety of factors including the occurrence of large storm events, overly wet or dry (i.e.., drought) regional hydrologic conditions, and any changes or redevelopment in the upstream land use. Each property owner shall perform the activities identified below at the frequency needed to maintain the basin in proper operating condition at all times.

Inspection Activities	Suggested Schedule
• After several storm events or an extreme storm event, inspect for: bank stability; signs of erosion; vegetation growth; drainage system function; and structural damage.	As needed
• Inspect for: invasive vegetation; trash and debris; clogging of the inlet/outlet structures and any pilot or low flow channels; excessive erosion; sediment accumulation in the basin, forebay and inlet/outlet structures; tree growth on dam or embankment; the presence of burrowing animals; standing water where there should be none; vigor and density of the grass turf on the basin side slopes and floor; differential settlement; cracking; leakage; and slope stability.	Semi-annually
• Inspect the inlet/outlet structures, pipes, sediment forebays, and upstream, downstream, and pilot channels are free of debris and are operational. • Check for signs of unhealthy or overpopulation of plants and/or fish (if utilized). • Note signs of pollution, such as oil sheens, discolored water, or unpleasant odors. • Check sediment marker(s) for sediment accumulation in the facility and forebay. • Check for proper operation of control gates, valves or other mechanical devices. • Note changes to the wetland or contributing drainage area as such changes may affect wetland performance.	Annually
Maintenance Activities	**Suggested Schedule**
• Replace wetland vegetation to maintain at least 50% surface area coverage in wetland plants after the second growing season.	One-time
• Clean and remove debris from inlet and outlet structures. Mow side slopes (embankment) and maintenance access. Periodic mowing is only required along maintenance rights-of-way and the embankment. The wetland buffer surrounding the wetland can be managed as a meadow (mowing every other year) or forest.	Frequently (3 to 4 times per year)
• Supplement wetland plants if a significant portion have not established (at least 50% of the surface area). Remove unhealthy, invasive or nuisance plant species and replant with appropriate species if necessary. Harvest plant species if vegetation becomes too thick causing flow backup and flooding, or an overabundance of undesirable wildlife.	Annually (if needed)
• Repair damage to basin, outlet structures, embankments, control gates, valves, or other mechanical devices; repair undercut or eroded areas. Remove litter, debris, pollutants as appropriate.	As Needed
• Remove sediment from the forebay. Sediments excavated from stormwater wetlands that receive treated runoff from hotspot land uses are not considered toxic or hazardous material and can be safely disposed of by either land application or landfilling.	As needed (typically every 5 to 7 years)
• Monitor sediment accumulations, and remove sediment when the volume in the wetland, forebay, or micropool has become reduced significantly or the wetland area is not providing a healthy habitat for vegetation and fish (if used). Discharges of turbid or untreated stormwater from the wetland may be considered an illegal discharge, as per the local stormwater management regulations. Care should be exercised during wetland drawdowns to prevent downstream discharge of sediments, anoxic water, or high flows with erosive velocities. The local municipality should be notified before draining a stormwater wetland.	As needed (typically every 20 to 50 years)

The local municipality encourages the use of the inspection checklist that is presented on the next page to guide the property owner in the inspection and maintenance of stormwater wetlands. The local municipality can require the use of this checklist or other form(s) of maintenance documentation when and where deemed necessary in order to ensure the long-term proper operation of the wetland. Questions regarding stormwater facility inspection and maintenance should be referred to the local municipality.

INSPECTION CHECKLIST AND MAINTENANCE GUIDANCE (continued)
STORMWATER WETLAND INSPECTION CHECKLIST

Location: ____ Owner Change since last inspection? Y N

Owner Name, Address, Phone: ____

Date: ___________ Time: ______________ Site conditions:______________________________

Inspection Items	Satisfactory (S) or Unsatisfactory (U)	Comments/Corrective Action
Embankment and Emergency Spillway		
Healthy vegetation?		
Erosion on embankment?		
Animal burrows in embankment?		
Cracking, sliding, bulging of dam?		
Blocked or malfunctioning drains?		
Leaks or seeps on embankment?		
Obstructions of spillway(s)?		
Erosion in/around emergency spillway?		
Other (describe)?		
Inlet/Outlet Structures and Channels		
Clear of debris and functional?		
Trash rack clear of debris and functional?		
Sediment accumulation?		
Condition of concrete/masonry?		
Metal pipes in good condition?		
Control valve operation?		
Drain valve operation?		
Outfall channels function, not eroding?		
Other (describe)?		
Sediment Forebays		
Evidence of sediment accumulation?		
Permanent Pool Areas (if applicable)		
Undesirable vegetation growth?		
Visible pollution?		
Shoreline erosion?		
Erosion at outfalls into wetland?		
Headwalls and endwalls in good condition?		
Encroachment by other activities?		
Evidence of sediment accumulation?		
Wetland Vegetation Areas		
Vegetation adequate?		
Undesirable vegetation growth?		
Excessive sedimentation?		
Hazards		
Have there been complaints from residents?		
Public hazards noted?		

If any of the above inspection items are **UNSATISFACTORY**, list corrective actions and the corresponding completion dates below:

Corrective Action Needed	Due Date

Inspector Signature:___________________________ Inspector Name (printed)___________________________

4.3.4.8 Example Schematics

Figure 4-21. Schematic of a Shallow Wetland

(Source: Adapted from Atlanta Regional Council, 2000)

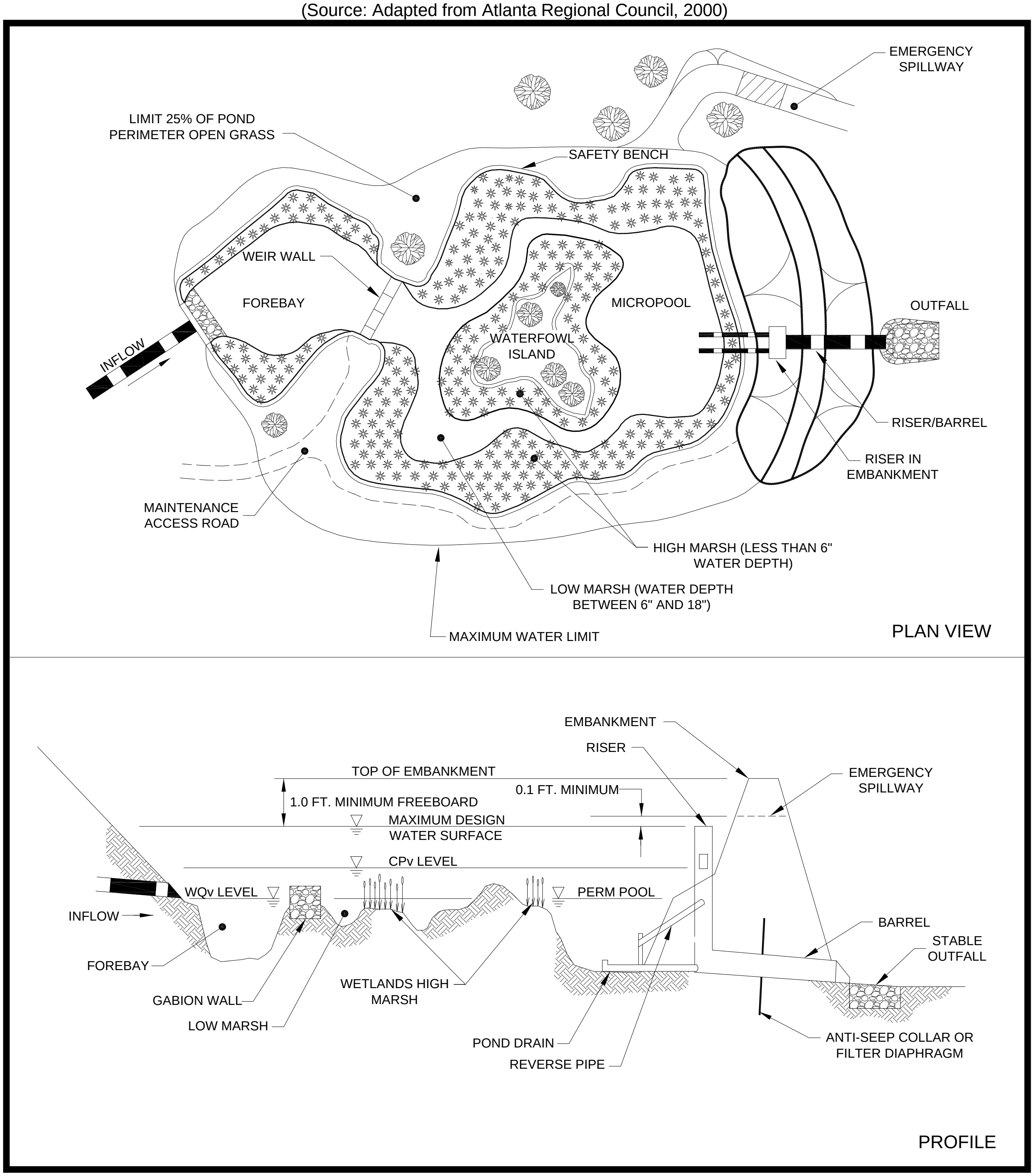


Figure 4-22. Schematic of an Extended Detention Shallow Wetland
(Source: Adapted from Atlanta Regional Council, 2000)

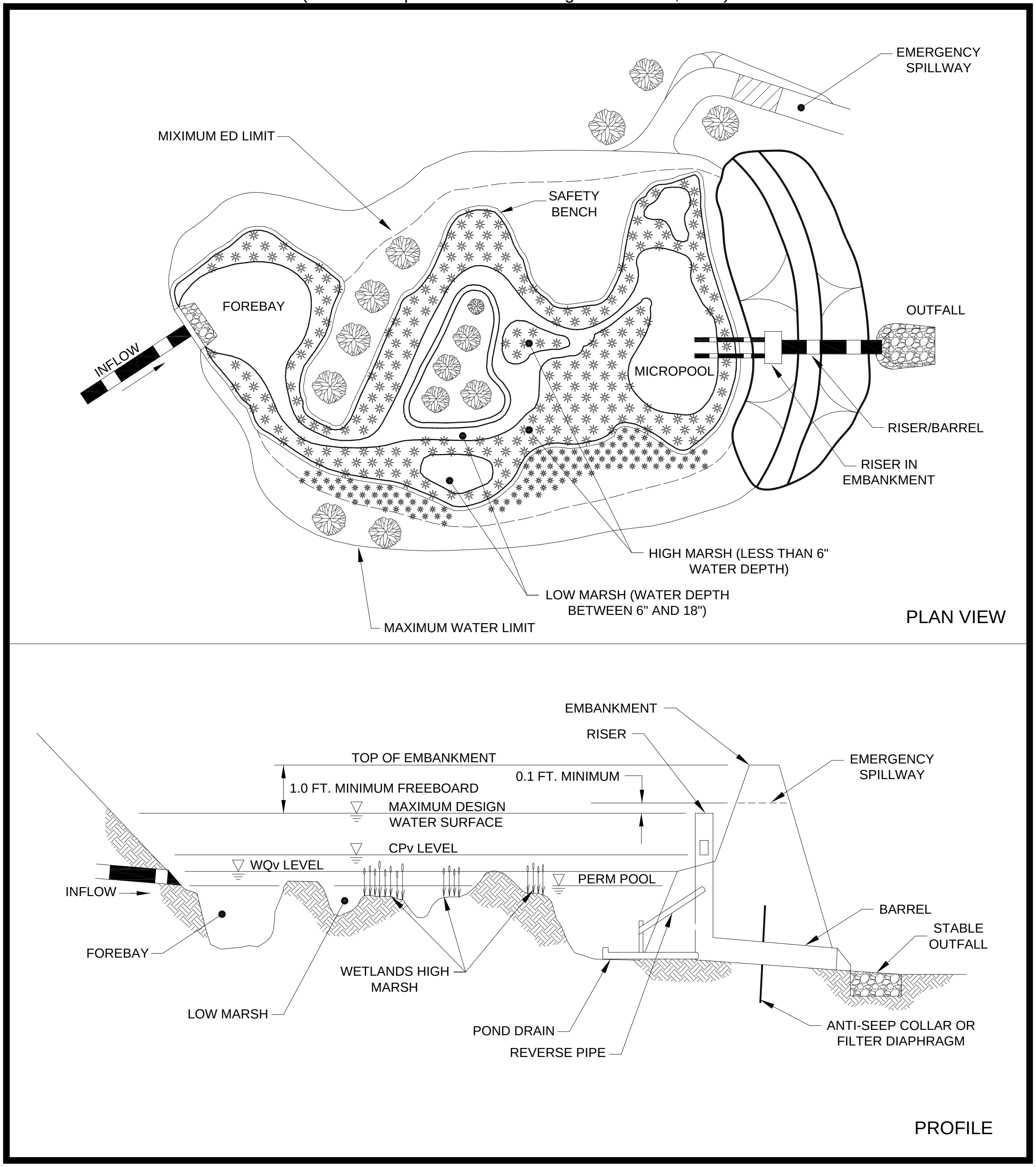


Figure 4-23. Schematic of a Basin/Wetland System

(Source: Adapted from Atlanta Regional Council, 2000)

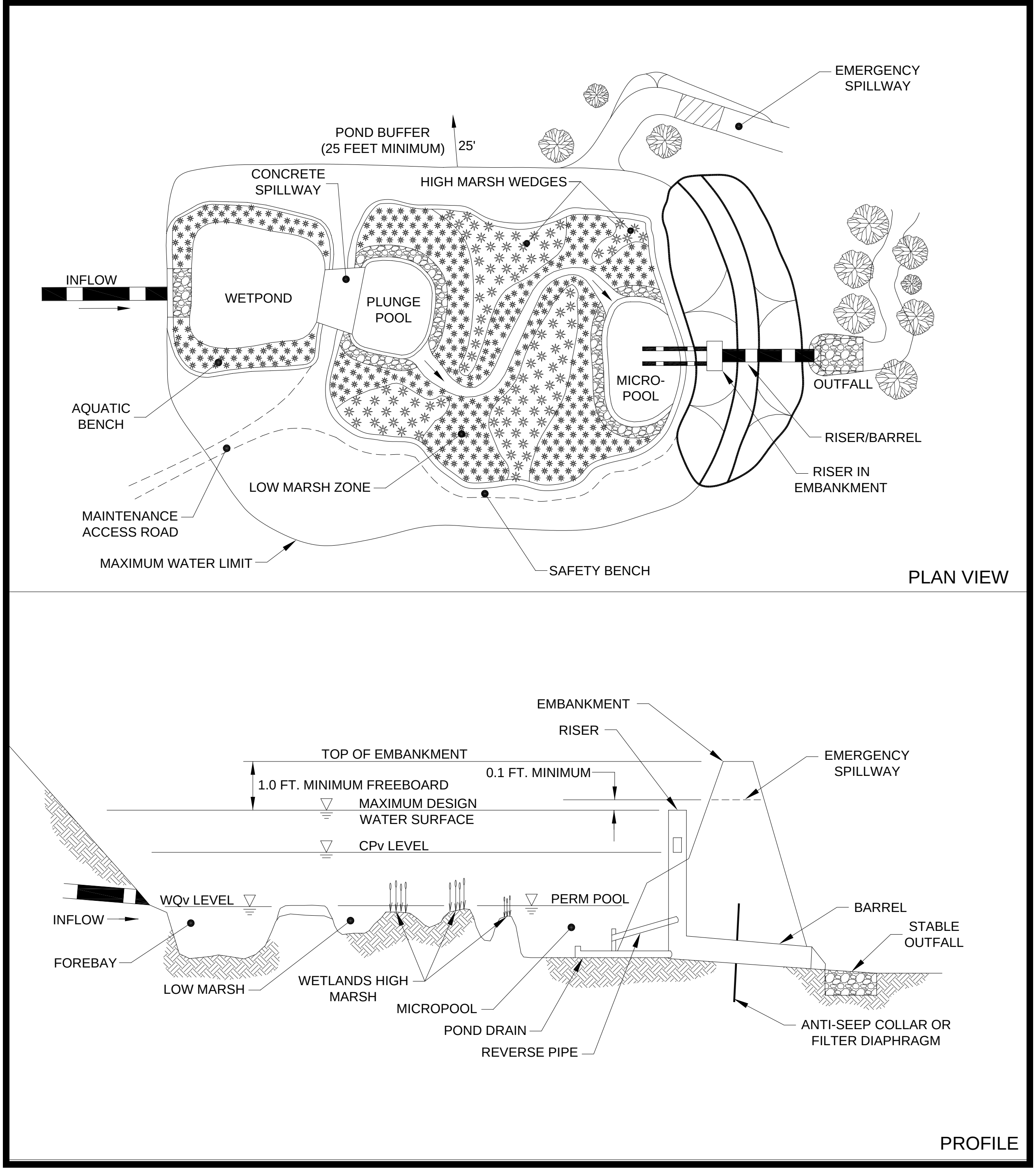
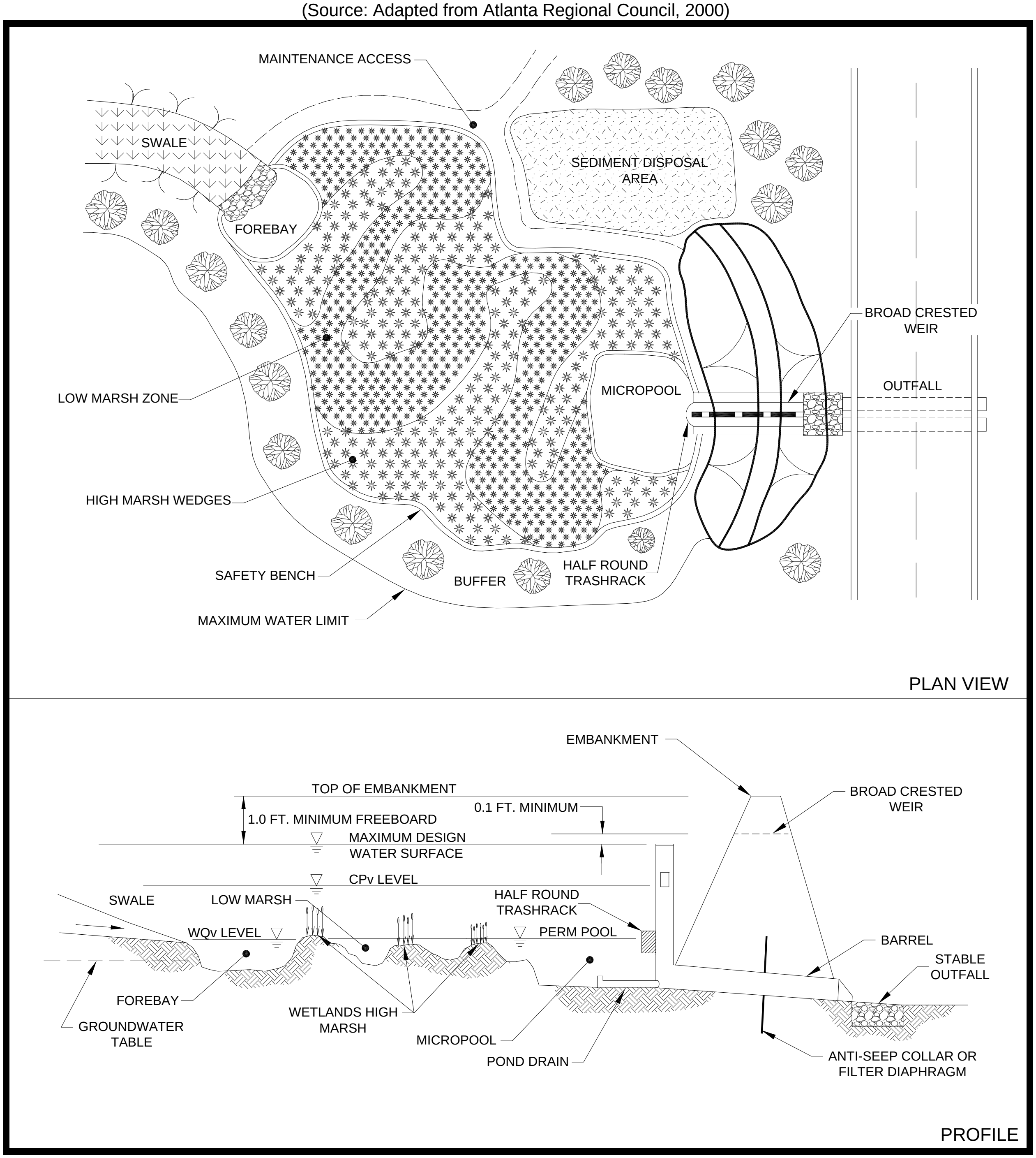


Figure 4-24. Schematic of a Pocket Wetland
(Source: Adapted from Atlanta Regional Council, 2000)



4.3.4.9 Design Form

The local municipality recommends the use of the following design procedure forms when designing a stormwater wetland. Proper use and completion of the form may allow a faster review of the Water Quality Management Plan by the local municipality.

Design Procedure Form: Stormwater Wetlands

PRELIMINARY HYDROLOGIC CALCULATIONS

1a. Compute WQv volume requirements
Compute Runoff Coefficient, Rv — Rv = ________
Compute WQv — WQv = ________ acre-ft

1b. Compute CPv — CPv = ________ acre-ft
Compute average release rate — release rate = ________ cfs
Compute storage volume required for locally regulated storm events — storage = ________ acre-ft; storage = ________ acre-ft

STORMWATER WETLAND DESIGN

2. Is the use of a stormwater wetland appropriate? — ***See subsections 4.3.4.4 and 4.3.4.5 - A***

3. Confirm design criteria and applicability. — ***See subsection 4.3.4.5 - J***

4. Pretreatment Volume (Forebay)
V_{pre} =(I)(.1")(1'/12") — V_{pre} = ________ acre-ft

5. Allocation of pool, Marsh, and ED Volumes

Shallow Wetland	Vol_{pool}=	$0.2(WQv)-Vol_{pre}$	Vol_{pool}= ________ acre-ft
	Vol_{marsh}=	$0.7(WQv)-Vol_{pre}$	Vol_{marsh}= ________ acre-ft
Shallow ED Wetland	Vol_{pool}=	$0.1(WQv)-Vol_{pre}$	Vol_{pool}= ________ acre-ft
	Vol_{marsh}=	$0.3(WQv)-Vol_{pre}$	Vol_{marsh}= ________ acre-ft
	Vol_{ED}=	0.5(WQv)-Volpre	Vol_{ED}= ________ acre-ft
Pocket Wetland	Vol_{pool}=	$0.1(WQv)-Vol_{pre}$	Vol_{pool}= ________ acre-ft
	Vol_{marsh}=	$0.8(WQv)-Vol_{pre}$	Vol_{marsh}= ________ acre-ft

6. Allocation of Surface Area

Pool/Deepwater Wetland Zone (1.5-6 feet deep)	$Area_{water}$= ________ acres,	%= ________
Low Marsh Wetland Zone (6-18 inches deep)	$Area_{low}$= ________ acres,	%= ________
High Marsh Wetland Zone (0-6 inches deep)	$Area_{high}$= ________ acres,	%= ________
Semi-Wet Wetland Zone (above pool depth)	$Area_{semi}$= ________ acres,	%= ________
		100.00%

Conduct grading and determine storage available for marsh zones (and ED if applicable), and compute orifice size

Prepare an elevation-storage table and curve using the average area method for computing volumes.

Elevation MSL	Area ft^2	Ave. Area ft^2	Depth ft	Volume ft^3	Cumulative Volume ft^3	Cumulative Volume acre-ft	Volume above Permanent Pool acre-ft

Design Procedure Form: Stormwater Wetlands (continued)

7. WQv Orifice Computations
   Average ED release rate (if applicable) — release rate= ______ cfs
   Average head, h = (ED elev. - Permanent pool elev.) / 2 — head= ______ ft
   Area of orifice from orifice equation — Area= ______ ft^2
   $Q=CA(2gh)^{0.5}$ C varies with orifice condition — diameter ______ inches

   Compute release rate for CPv-ED control and establish CPv elevation — WSEL= ______ ft-NGVD
   Release rate = — release rate= ______ cfs
   Average head, h = (ED elev. - Permanent pool elev.) / 2 — head= ______ ft
   Area of orifice from orifice equation — Area= ______ ft2
   $Q=CA(2gh)^{0.5}$ C varies with orifice condition — diameter ______ inches

8. Calculate required local municipality peak discharge release rates and WSELs

   Set up a stage-storage-discharge relationship

Elevation	Storage	Low Flow	Riser			Barrel		Emergency	Total
		WQv-ED	CPv-ED	High Storage		Inlet	Pipe	Spillway	Outflow
				Orif.	Weir				
MSL	acre-ft	H(ft) Q(cfs)	H(ft) Q(cfs)	H Q	H Q	H(ft) Q(cfs)	H(ft) Q(cfs)	H(ft) Q(cfs)	Q (cfs)

   Qp_{eak}=pre-dev. Peak discharge - (WQv-ED release + CPv-ED release) — Qp_{peak}= ______ cfs

   Maximum head = — H= ______ ft
   Use weir equation for slot length ($Q=CLH^{3/2}$) — L= ______ ft

   Check inlet condition
   Check outlet condition

   Use culvert design guidance from local municipality

9. Size emergency spillway using the local municipality peak discharge and set top of embankment elevation and emergency spillway elevation based on $WSEL_{peak}$
   $Q_{ES}=Qp_{eak}$ ______ cfs
   $WSEL_{peak}$= ______ ft
   El_{embank} ______ ft
   El_{ES}= ______ ft

10. Investigate potential pond hazard classification — **See TN Safe Dams Act of 1973**

11. Design inlets, sediment forebays, outlet structures, maintenance access, and safety features — **See subsection 4.3.4.5 - D through H**

12. Design vegetation according to guidance provided in TVA Riparian Restoration webpage
    www.tva.com/river/landandshore/stabilization/index.htm

4.3.4.10 References

AMEC. *Knox County Stormwater Management Manual Volume 2, Technical Guidance*.

AMEC. *Metropolitan Nashville and Davidson County Stormwater Management Manual Volume 4 Best Management Practices.* 2006.

Atlanta Regional Council (ARC). *Georgia Stormwater Management Manual Volume 2 Technical Handbook.* 2000.

Center for Watershed Protection. *Manual Builder.* Stormwater Manager's Resource Center, Accessed July 2005. *www.stormwatercenter.net*

Massachusetts Department of Environmental Protection and the Massachusetts Office of Coastal Zone Management. *Stormwater Management -- Volume One: Stormwater Policy Handbook, and Volume Two: Stormwater Technical Handbook*, 1997.

Schueler, T.J. *Design of Stormwater Wetland Systems*, Metrolpolitan Washington Council of Governments, Washington, D.C., April, 1992.

4.3.4.11 Suggested Reading

Adams, L., Dove L.E., D.L. Leedy, and T. Franklin. *Urban Wetlands for Stormwater Control and Wildlife Enhancement – Analysis and Evaluation.* Urban Wildlife Research Center, Columbia, Maryland, 1983.

California Storm Water Quality Task Force. *California Storm Water Best Management Practice Handbooks.* 1993.

City of Austin, TX. *Water Quality Management.* Environmental Criteria Manual, Environmental and Conservation Services, 1988.

City of Sacramento, CA. *Guidance Manual for On-Site Stormwater Quality Control Measures.* Department of Utilities, 2000.

Claytor, R.A., and T.R. Schueler. *Design of Stormwater Filtering Systems.* The Center for Watershed Protection, Silver Spring, MD, 1996.

US EPA. *Storm Water Technology Fact Sheet: Storm Water Wetlands.* EPA 832-F-99-025, Office of Water, 1999.

Faulkner, S. and C. Richardson. *Physical and Chemical Characteristics of Freshwater Wetland Soils.* Constructed Wetlands for Wastewater Treatment, ed. D. Hammer, Lewis Publishers, 831 pp, 1991.

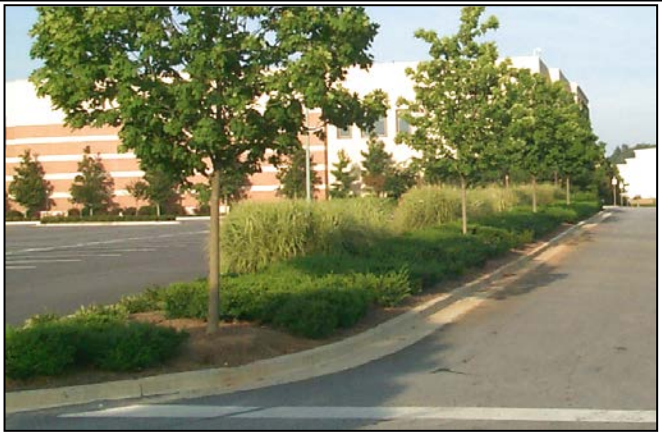
Guntenspergen, G.R., F. Stearns, and J. A. Kadlec. *Wetland Vegetation.* Constructed Wetlands for Wastewater Treatment, ed. D. A. Hammer, Lewis Publishers, 1991.

Maryland Department of the Environment. *Maryland Stormwater Design Manual, Volumes I and II.* Prepared by Center for Watershed Protection (CWP), 2000.

Metropolitan Washington Council of Governments (MWCOG). *A Current Assessment of Urban Best Management Practices: Techniques for Reducing Nonpoint Source Pollution in the Coastal Zone.* March, 1992.

4.3.5 Bioretention Areas

**General Application
Water Quality BMP**



Description: Shallow stormwater basin or landscaped area that utilizes engineered soils and vegetation to capture and treat runoff.

KEY CONSIDERATIONS

DESIGN GUIDELINES:

- Maximum contributing drainage area of 5 acres.
- Often located in "landscaping islands."
- Treatment area consists of grass filter, sand bed, ponding area, organic/mulch layer, planting soil, and vegetation.
- Typically requires 5 feet of elevation difference from inflow to outflow.
- Planting soils must meet specified criteria; no restrictions on surrounding soils.
- Use of native plants is recommended.

ADVANTAGES / BENEFITS:

- Applicable to small drainage areas.
- Good for highly impervious areas, particularly parking lots.
- Good retrofit capability.
- Relatively low maintenance requirements.
- Can be planned as an aesthetic feature.

DISADVANTAGES / LIMITATIONS:

- Requires extensive landscaping.
- Not recommended for areas with steep slopes.

MAINTENANCE REQUIREMENTS:

- Inspect and repair/replace treatment area components.

STORMWATER MANAGEMENT SUITABILITY

Stormwater Quality:	**Yes**
Channel Protection:	✷
Detention/Retention:	**Yes**

✷ in certain situations

Accepts hotspot runoff: *Yes*

COST CONSIDERATIONS

Land Requirement:	**Med**
Capital Cost:	**Med**
Maintenance Burden:	**Low**

LAND USE APPLICABILITY

Residential/Subdivision Use:	**Yes**
High Density/Ultra Urban Use:	**Yes**
Commercial/Industrial Use:	**Yes**

POLLUTANT REMOVAL

Total Suspended Solids:	**85%**

4.3.5.1 General Description

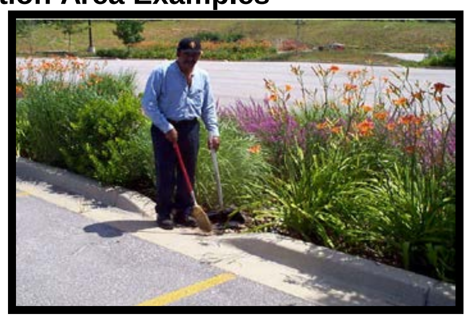
Bioretention areas (also referred to as *bioretention filters* or *rain gardens*) are structural stormwater controls that capture and temporarily store the water quality volume (WQv) using soils and vegetation in shallow basins or landscaped areas to remove pollutants from stormwater runoff.

Bioretention areas are engineered facilities in which runoff is conveyed as sheet flow to the "treatment area," which consists of a grass buffer strip, ponding area, organic or mulch layer, planting soil, and vegetation. An optional sand bed can also be included in the design to provide aeration and drainage of the planting soil. The filtered runoff is typically collected and returned to the conveyance system, though it can also permeate into the surrounding soil in areas with porous soils.

There are numerous design applications, both on- and off-line, for bioretention areas. These include use on single-family residential lots (*rain gardens*), as off-line facilities adjacent to parking lots, along road drainage swales, within larger landscaped pervious areas, and as landscaped islands in impervious or high-density environments. Figures 4-25 and 4-26 illustrate a number of examples of bioretention facilities in both photographs and drawings.

Figure 4-25. Bioretention Area Examples

Single-Family Residential "Rain Garden"

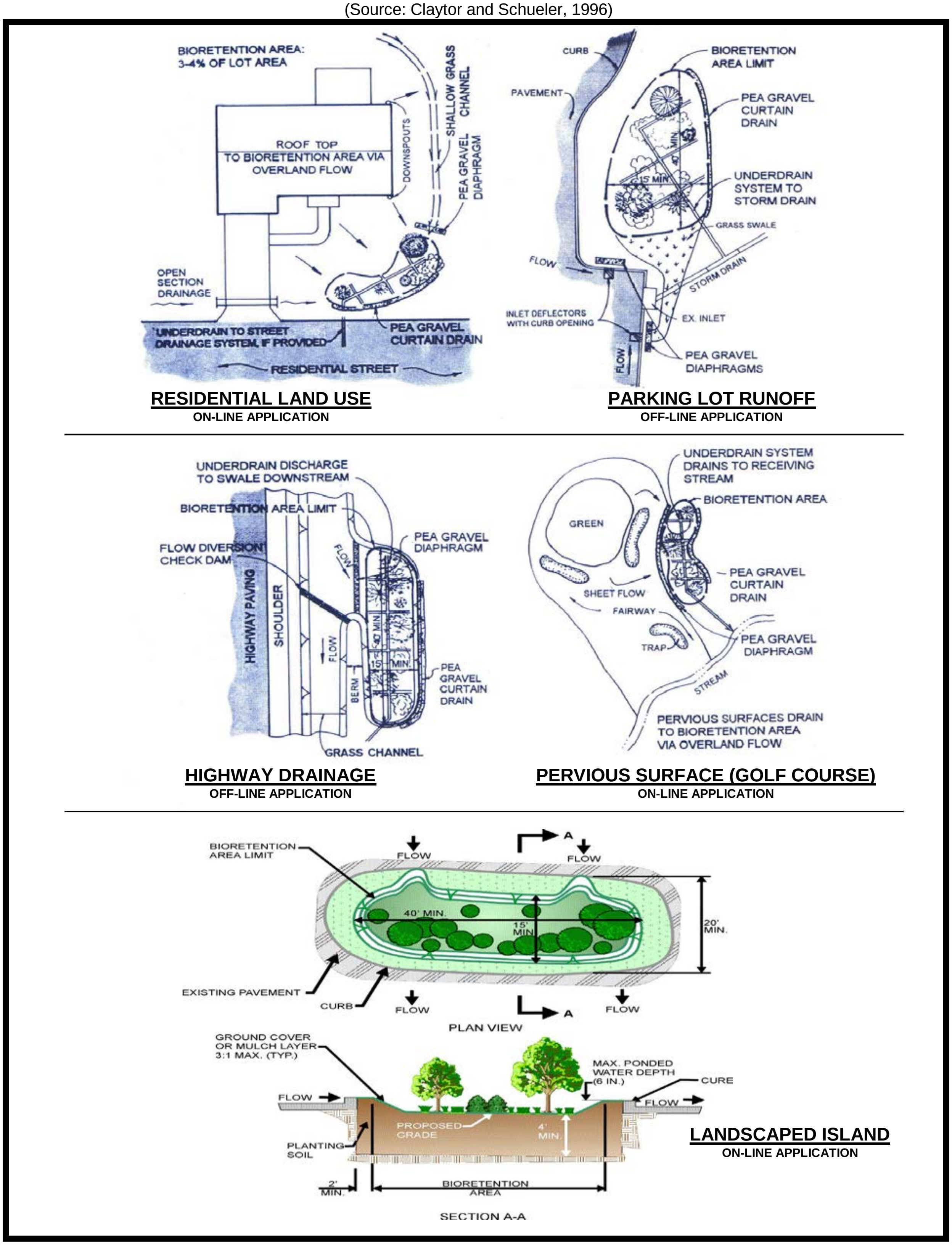


Landscaped Island

Newly Constructed Bioretention Area

Newly Planted Bioretention Area after Storm Event

Figure 4-26. Bioretention Area Applications
(Source: Claytor and Schueler, 1996)



4.3.5.2 Stormwater Management Suitability

Bioretention areas are designed primarily for stormwater quality and can provide limited runoff quantity control, primarily for smaller storm events. These facilities may sometimes be used to partially or completely meet channel protection volume (CPv) requirements on smaller sites. However, bioretention areas will typically need to be used in conjunction with other structural BMPs to provide channel protection as well as protection of the locally regulated peak discharge. It is important to ensure that a bioretention area safely bypasses higher flows.

Water Quality (WQv)
Bioretention is an excellent stormwater treatment practice due to the variety of pollutant removal mechanisms. Each of the components of the bioretention area is designed to perform a specific function (see Figure 4-27). The *grass filter strip (or grass channel)* reduces incoming runoff velocity and filters particulates from the runoff. The *ponding area* provides for temporary storage of stormwater runoff prior to its evaporation, infiltration, or uptake and provides additional settling capacity. The *organic or mulch layer* provides filtration as well as an environment conducive to the growth of microorganisms that degrade hydrocarbons and organic material. The *planting soil* in the bioretention facility acts as a filtration system, and clay in the soil provides adsorption sites for heavy metals, nutrients and other pollutants. Both *woody and herbaceous plants* in the ponding area provide vegetative uptake of runoff and pollutants and also serve to stabilize the surrounding soils. Finally, an *underdrain system* provides for positive drainage and aerobic conditions in the planting soil.

Section 4.3.5.3 provides median pollutant removal efficiencies that can be used for planning and design purposes.

Channel Protection (CPv)
For smaller sites, a bioretention area may be designed to capture the entire channel protection volume (CPv) in either an off or on-line configuration. Given that a bioretention facility must be designed to completely drain over 48 hours, the requirement of extended detention of the 1-year, 24-hour storm runoff volume will be met. For larger sites or where only the WQv is diverted to the bioretention facility, another structural BMP must be used to provide CPv extended detention.

4.3.5.3 Pollutant Removal Capabilities

Bioretention areas are presumed to be able to remove 85% of the total suspended solids load in typical urban post-development runoff when sized, designed, constructed and maintained in accordance with the recommended specifications. Undersized or poorly designed bioretention areas can reduce TSS removal performance.

The total suspended solids design pollutant removal rate of 85% is a conservative average pollutant reduction percentage for design purposes derived from sampling data, modeling and professional judgment.

For additional information and data on pollutant removal capabilities for bioretention areas, see the National Pollutant Removal Performance Database (2nd Edition) available at www.stormwatercenter.net and the International Stormwater Best Management Practices (BMP) Database at www.bmpdatabase.org.

4.3.5.4 Application and Site Feasibility Criteria

Bioretention areas are suitable for many types of development, from single-family residential to high-density commercial projects. Bioretention is also well suited for small lots, including those of 1 acre or less. Because of its ability to be incorporated in landscaped areas, the use of bioretention is extremely flexible. Bioretention areas are an ideal structural stormwater BMP for use as roadway median strips and parking lot islands and are also good candidates for the treatment of runoff from pervious areas, such as a lawn area. Bioretention can also be used to retrofit existing development with stormwater quality treatment capacity.

The following criteria should be evaluated to ensure the suitability of a bioretention area for meeting stormwater management objectives on a site or development.

General Feasibility

- Suitable for Residential Subdivision Usage – YES
- Suitable for Regional Stormwater Control – NO

Physical Feasibility - Physical Constraints at Project Site

- Drainage Area – 5 acres maximum; 0.5 to 2 acres are preferred.
- Space Required – Approximately 5% of the tributary impervious area is required; minimum 200 ft^2 area for small sites (10 feet x 20 feet).
- Site Slope – No more than 6% slope in the contributing drainage area.
- Minimum Head – Elevation difference needed at a site from the inflow to the outflow underdrain or peak gravel under-layer: 5 feet.
- Minimum Depth to Water Table – A separation distance of 2 feet is recommended between the bottom of the bioretention facility and the elevation of the seasonally high water table.
- Soils – No restrictions; engineered media required. Karst areas may require a liner.

Other Constraints / Considerations

- Wellhead Protection – Reduce potential groundwater contamination (in required wellhead protection areas) by preventing infiltration of hotspot runoff. May require liner for type “A” and “B” soils; pretreat hotspots; 2 to 4 foot separation distance from water table. Wellhead protection areas may require guidance from other agencies, such as TDEC.

4.3.5.5 Planning and Design Standards

The following standards are to be considered **minimum** standards for the design of a bioretention facility. Consult with the local municipality to determine if there are any variations to these criteria or additional standards that must be followed.

A. LOCATION AND SITING

- Bioretention areas should have a maximum contributing drainage area of 5 acres or less; 0.5 to 2 acres are preferred. Multiple bioretention areas can be used for larger areas.
- Bioretention areas can either be used to capture sheet flow from a drainage area or function as an off-line device. On-line designs should be limited to a maximum drainage area of 0.5 acres.
- When used in an off-line configuration, the WQv is diverted to the bioretention area through the use of a flow splitter or other means. Stormwater flows greater than the WQv are diverted to other controls or downstream (see Chapter 4, Section 4.2 for more discussion of off-line systems and design guidance for diversion structures and flow splitters).
- Bioretention systems are designed for intermittent flow and must be allowed to drain and reaerate between rainfall events. Bioretention systems will not be allowed for sites that have a continuous flow from groundwater, sump pumps, or other sources.
- Aesthetic considerations should be taken into account in the siting and design of bioretention areas. Elevations must be carefully determined to ensure that the desired runoff flow enters the facility with no more than the maximum design depth.

B. GENERAL DESIGN

- A bioretention area shall consist of:
  (1) A grass filter strip (or grass channel) between the contributing drainage area and the ponding area,
  (2) A ponding area containing vegetation with a planting soil bed,
  (3) An organic/mulch layer,
  (4) A gravel and perforated pipe underdrain system to collect runoff that has filtered through the soil layers (bioretention areas can optionally be designed to infiltrate into the soil – see description of infiltration trenches for infiltration criteria).
- A bioretention area design may also include some of the following:
  (1) An optional sand filter layer with geotextile fabric to spread flow, filter runoff, and aid in aeration and drainage of the planting soil, located between the underdrain and planting soil.
  (2) A pea gravel diaphragm at the beginning of the grass filter strip to reduce runoff velocities and spread flow into the grass filter.
  (3) Energy dissipation techniques will be required for contributing drainage areas that have a 6% slope or greater.
  (4) Inflow diversion or an overflow structure(s) that are designed based on one of five main methods:
    - Use of a flow diversion structure;
    - Use of curbed pavements as an inlet deflector (see Figure 4-30);
    - Use of a slotted curb along with the design of parking lot grades to divert the WQv into the bioretention facility. Additional runoff will be bypassed to a downstream catch basin inlet. The alternative requires temporary ponding in the parking lot (see Figure 4-29);
    - Figure 4-29 illustrates the use of a short deflector weir (maximum height 6 inches) designed to divert the maximum water quality peak flow into the bioretention area;
    - Use of an in-system overflow consisting of an overflow catch basin inlet and/or a pea gravel curtain drain overflow.

See Figure 4-27 for an overview of the various components of a bioretention area. Figure 4-28 provides a plan view and profile schematic of an on-line bioretention area. An example of an off-line facility is shown in Figure 4-29.

C. PHYSICAL SPECIFICATIONS / GEOMETRY

- The minimum dimensions of a bioretention area shall be 10 feet wide by 20 feet long, or 200 square feet in area for roughly circular designs. All designs, except small residential applications such as bio-retention areas placed in cul-de-sac islands to treat runoff from the surrounding street, shall maintain a length to width ratio of at least 2:1.
- The planting soil filter bed shall be sized using a Darcy's Law equation with a filter bed drain time of 48 hours and a coefficient of permeability (k) of 0.5 ft/day.
- The maximum ponding depth of a bioretention area is 6 inches.
- The planting soil bed shall be at least 4 feet in depth when trees are planted in the bioretention area but can be a minimum of 2 feet deep in facilities that will utilize plants other than trees. Planting soils shall consist of a sandy loam, loamy sand, or loam texture with a clay content ranging from 10 to 25%. The soil must have an infiltration rate of at least 0.5 inches per hour and a pH between 5.5 and 6.5. In addition, the planting soil must have a 1.5 to 3% organic content and a maximum 500 ppm concentration of soluble salts.

- The mulch layer must consist of 2 to 4 inches of commercially available fine shredded hardwood mulch or shredded hardwood chips.
- The sand bed must be 12 to 18 inches thick. Sand shall be clean and have less than 15% silt or clay content.
- Pea gravel for the diaphragm and curtain, when used, should be ASTM D 448 size No. 6 (1/8” to ¼”).
- The underdrain collection system shall include a 4 to 6 inch pipe wrapped in a 6 to 8 inch gravel layer. The pipe shall have 3/8-inch perforations, spaced at 6-inch centers, with a minimum of 4 holes per row around the circumference of the pipe. The pipe spacing shall be at a maximum of 10 feet on center and a minimum grade of 0.5% must be maintained. A permeable filter fabric shall be required between the gravel layer and the planting soil bed. High density polyethylene (HDPE) pipe is the preferred pipe material, however other suitable pipe materials may be approved.

D. PRETREATMENT / INLETS

- Adequate pretreatment and inlet protection for bioretention systems shall be provided, such as: a grass filter strip below a flow spreader, or a grass channel, or a pea gravel diaphragm.
- For on-line configurations, a grass filter strip with a pea gravel diaphragm or other flow spreader shall be utilized (see Figure 4-28) as the pretreatment measure. The required length of the filter strip depends on the drainage area, imperviousness, and the filter strip slope. Design guidance on filter strips for pretreatment can be found in Chapter 4, Section 4.3.9 of this manual.
- For off-line applications, a grass channel with a pea gravel diaphragm or other flow spreader shall be used for pretreatment. The length of the grass channel depends on the drainage area, land use, and channel slope. The minimum grassed channel length shall be 20 feet. Design guidance on grass channels for pretreatment can be found in Chapter 4, Section 4.3.10 of this manual.

E. OUTLET STRUCTURES

- For bioretention areas placed in soils having a hydrologic soil group designation of C or D, an outlet pipe shall be provided from the underdrain system to the facility discharge. Outlet pipes are optional for group B soils. Discharges shall not exit the outlet pipe in an erosive manner. Due to the slow rate of discharge, outlet erosion protection is generally unnecessary.

F. EMERGENCY SPILLWAY

- An overflow structure and nonerosive overflow channel must be provided to safely pass flows that exceed the storage capacity of the bioretention area to a stabilized downstream area or watercourse. If the system is located off-line, the overflow shall be set above the shallow ponding limit.
- A high flow overflow system within a bioretention structure may consist of a yard drain catchbasin (Figure 4-27), though any number of conventional systems could be used. The throat of the catch basin inlet located in a bioretention facility must be no more than 6 inches above the mulch layer at the elevation of the shallow ponding area.

G. MAINTENANCE ACCESS

- A minimum 20’ wide maintenance right-of-way or easement shall be provided from a driveway, public or private road. The maintenance access easement shall have a maximum slope of no more than 15% and shall have a minimum unobstructed drive path having a width of 12 feet, appropriately stabilized to withstand maintenance equipment and vehicles.
- The maintenance access shall be designed such that all areas of the bioretention area can be easily accessed, and shall be designed to allow vehicles to turn around.

H. SAFETY FEATURES

- Bioretention areas generally do not require any special safety features. Fencing of bioretention facilities is not generally desirable.

I. LANDSCAPING

- Landscaping is critical to the performance and function of bioretention areas.
- A dense and vigorous vegetative cover that is appropriate for use in a bioretention area shall be established over the contributing pervious drainage areas before runoff can be accepted into the facility. When the contributing drainage area is completely or partially disturbed or unstabilized, sediment laden runoff reaching the bioretention can clog the soils and cause the bioretention are to fail.
- In general, vegetation utilized in the bioretention area should be native to East Tennessee, resistant to drought and inundation, tolerant of pollutants, have low fertilization requirements, and be easily maintained. Grasses, shrubs, and trees are all permissible vegetation types for bioretention areas, as long as the species used meet the general guidance provided herein.
- Bioretention areas that will contain trees shall be vegetated as follows:
  - The bioretention area shall be vegetated to resemble a terrestrial forest ecosystem, with a mature tree canopy, subcanopy of understory trees, shrub layer, and herbaceous ground cover. Three species each of both trees and shrubs are recommended to be planted.
  - The tree-to-shrub ratio should be 2:1 to 3:1. On average, the trees should be spaced 8 feet apart. Plants should be placed at regular intervals to replicate a natural forest. Woody vegetation should not be specified at inflow locations.
  - After the trees and shrubs are established, the ground cover and mulch should be established.

Additional information and guidance on bioretention area design and vegetation can be found on the EPA website at http://cfpub.epa.gov/npdes/stormwater and on the North Carolina State University Biological and Agricultural Engineering website at http://bae.ncsu.edu/stormwater/ .

J. ADDITIONAL SITE-SPECIFIC DESIGN CRITERIA AND ISSUES

Physiographic Factors - Local terrain design constraints

- Low Relief – Use of bioretention areas may be limited by low head.
- High Relief – Ponding area surface must be relatively level.
- Karst – Use poly-liner or impermeable membrane to seal bottom.

Soils

- No restrictions, however, planting soil must meet the required design infiltration rate.

Special Downstream Watershed Considerations

- Wellhead Protection – Reduce potential groundwater contamination (in required wellhead protection areas) by preventing infiltration of hotspot runoff. May require liner for type “A” and “B” soils; pretreat hotspots; 2 to 4 foot separation distance from water table. Wellhead protection areas may require guidance from other agencies, such as TDEC.

4.3.5.6 Design Procedures

Step 1. Compute runoff control volumes

> Calculate the locally regulated peak discharge, in accordance with the guidance presented in Chapter 3.

Step 2. Determine if the development site and conditions are appropriate for the use of a bioretention area

Consider the subsections 4.3.5.4 and 4.3.5.5-A (Location and Siting).

Step 3. Confirm design criteria and applicability

Consider any special site-specific design conditions/criteria from subsection 4.3.5.5-J (Additional Site-Specific Design Criteria and Issues).

Check with the local municipality and other agencies to determine if there are any additional restrictions and/or surface water or watershed requirements that may apply.

Step 4. Compute WQv peak discharge (Q_{wq})

The peak rate of discharge for water quality design storm is needed for sizing of off-line diversion structures (see Chapter 3 for more detail).

(a) Using WQv (or total volume to be captured), compute CN
(b) Compute time of concentration using TR-55 method
(c) Determine appropriate unit peak discharge from time of concentration
(d) Compute Q_{mg} from unit peak discharge, drainage area, and WQv.

Step 5. Size flow diversion structure, if needed

A flow regulator (or flow splitter diversion structure) should be supplied to divert the WQv to the bioretention area.

Size low flow orifice, weir, or other device to pass Q_{wq}.

Step 6. Determine size of bioretention ponding/filter area

The required planting soil filter bed area is computed using the following equation (based on Darcy's Law):

$$A_f = \frac{(WQ_v)(d_f)}{[(k)(h_f + d_f)(t_f)]}$$

where:

A_f = surface area of ponding area (ft^2)
WQv = water quality volume (or total volume to be captured)
d_f = filter bed depth
(4 feet minimum)
k = coefficient of permeability of filter media (ft/day)
(use 0.5 ft/day for silt-loam)
h_f = average height of water above filter bed (ft)
(typically 3 inches, which is half of the 6-inch ponding depth)
t_f = design filter bed drain time (days)
(2.0 days or 48 hours is recommended maximum)

Step 7. Set design elevations and dimensions of facility

See subsection 4.3.5.5-C (Physical Specifications/Geometry).

Step 8. Design conveyances to facility (off-line systems)

See the example figures to determine the type of conveyances needed for the site.

Step 9. Design pretreatment

Pretreat with a grass filter strip (on-line configuration) or grass channel (off-line), and stone diaphragm.

Step 10. Size underdrain system

See subsection 4.3.5.5-C (Physical Specifications/Geometry)

Step 11. Design emergency overflow

An overflow must be provided to bypass and/or convey larger flows to the downstream drainage system or stabilized watercourse. Nonerosive velocities need to be ensured at the outlet point.

Step 12. Design vegetation

A landscaping plan for the bioretention area should be prepared to indicate how it will be established with vegetation.

See subsection 4.3.5.5-I (Landscaping) for more details.

4.3.5.7 Maintenance Requirements and Inspection Checklist

Note: Section 4.3.5.7 must be included in the Operations and Maintenance Plan that is recorded with the deed.

Regular inspection and maintenance is critical to the effective operation of bioretention areas as designed. It is the responsibility of the property owner to maintain all stormwater BMPs in accordance with the minimum design standards and other guidance provided in this manual. The local municipality has the authority to impose additional maintenance requirements where deemed necessary.

This section provides guidance on maintenance activities that are typically required for bioretention areas, along with a suggested frequency for each activity. Individual bioretention areas may have more, or less, frequent maintenance needs, depending upon a variety of factors including the occurrence of large storm events, overly wet or dry (i.e.., drought) regional hydrologic conditions, and any changes or redevelopment in the upstream land use. Each property owner shall perform the activities identified below at the frequency needed to maintain the basin in proper operating condition at all times.

Inspection Activities	Suggested Schedule
• After several storm events or an extreme storm event, inspect for signs of erosion, signs of mulch movement out of the treatment area, signs of damage to plants or dead or diseased vegetation.	As needed
• Inspect: inflow points for clogging (off-line systems), strip/grass channel for erosion or gullying, • Inspect trees, shrubs and other vegetation to evaluate their health and replace any dead or diseased vegetation. • Inspect surrounding drainage area for erosion or signs of sediment delivery to the bioretention area.	Semi-annually
• Check for signs of vegetation overgrowth. • Inspect treatment area during a rain event and visually verify that stormwater recedes within 24-48 hours from the treatment area.	Annually
Maintenance Activities	**Suggested Schedule**
• Replace mulch and repair areas of erosion, when identified. • Replace dead or diseased plants.	As needed
• Remove clogs from the stormwater system inflow and overflow components. • Remove sediments from pretreatment areas and restabilize with stone or vegetation as appropriate.	Semi-annually
• Harvest overgrown vegetation and remove from the bioretention area.	As Needed
• The planting soils should be tested for pH to establish acidic levels. If the pH is below 5.2, limestone should be applied. If the pH is above 7.0 to 8.0, then iron sulfate plus sulfur can be added to reduce the pH. • Check that planting soils still have infiltration rate.	Annually
• Replace mulch over the entire area. • Replace pea gravel diaphragm if warranted. • Note that the surface of the ponding area may become clogged with fine sediment over time. Core aeration or cultivating of un-vegetated areas may be required to ensure adequate filtration.	2 to 3 years

The local municipality encourages the use of the inspection checklist that is presented on the next page to guide the property owner in the inspection and maintenance of bioretention areas. The local municipality can require the use of this checklist or other form(s) of maintenance documentation when and where deemed necessary in order to ensure the long-term proper operation of the bioretention area. Questions regarding stormwater facility inspection and maintenance should be referred to the local municipality.

INSPECTION CHECKLIST AND MAINTENANCE GUIDANCE (continued)
BIORETENTION AREA INSPECTION CHECKLIST

Location: ______________________________ Owner Change since last inspection? Y N

Owner Name, Address, Phone:______________________________

Date: ___________ Time: ______________ Site conditions:______________________________

Inspection Items	Satisfactory (S) or Unsatisfactory (U)	Comments/Corrective Action
Inflow and Overflow Points		
Clear of debris and functional?		
Sediment accumulation?		
Vegetation in good condition?		
Signs of erosion?		
Other (describe)?		
Sediment Pretreament		
Evidence of sediment accumulation?		
Treatment Area and Vegetation		
Signs of erosion or movement of mulch?		
Vegetation healthy or damaged?		
Signs of sediment?		
Signs of thinning mulch layer?		
Vegetation overgrown and in need of harvesting?		
Standing water for more than 24-48 hours after rain events?		
Other (describe)?		
Hazards		
Have there been complaints from residents?		
Public hazards noted?		

If any of the above inspection items are **UNSATISFACTORY**, list corrective actions and the corresponding completion dates below:

Corrective Action Needed	Due Date

Inspector Signature:________________________________ Inspector Name (printed)___________________________

4.3.5.8 Example Schematics

Figure 4-27. Schematic of a Typical Bioretention Area

(Source: Claytor and Schueler, 1996)

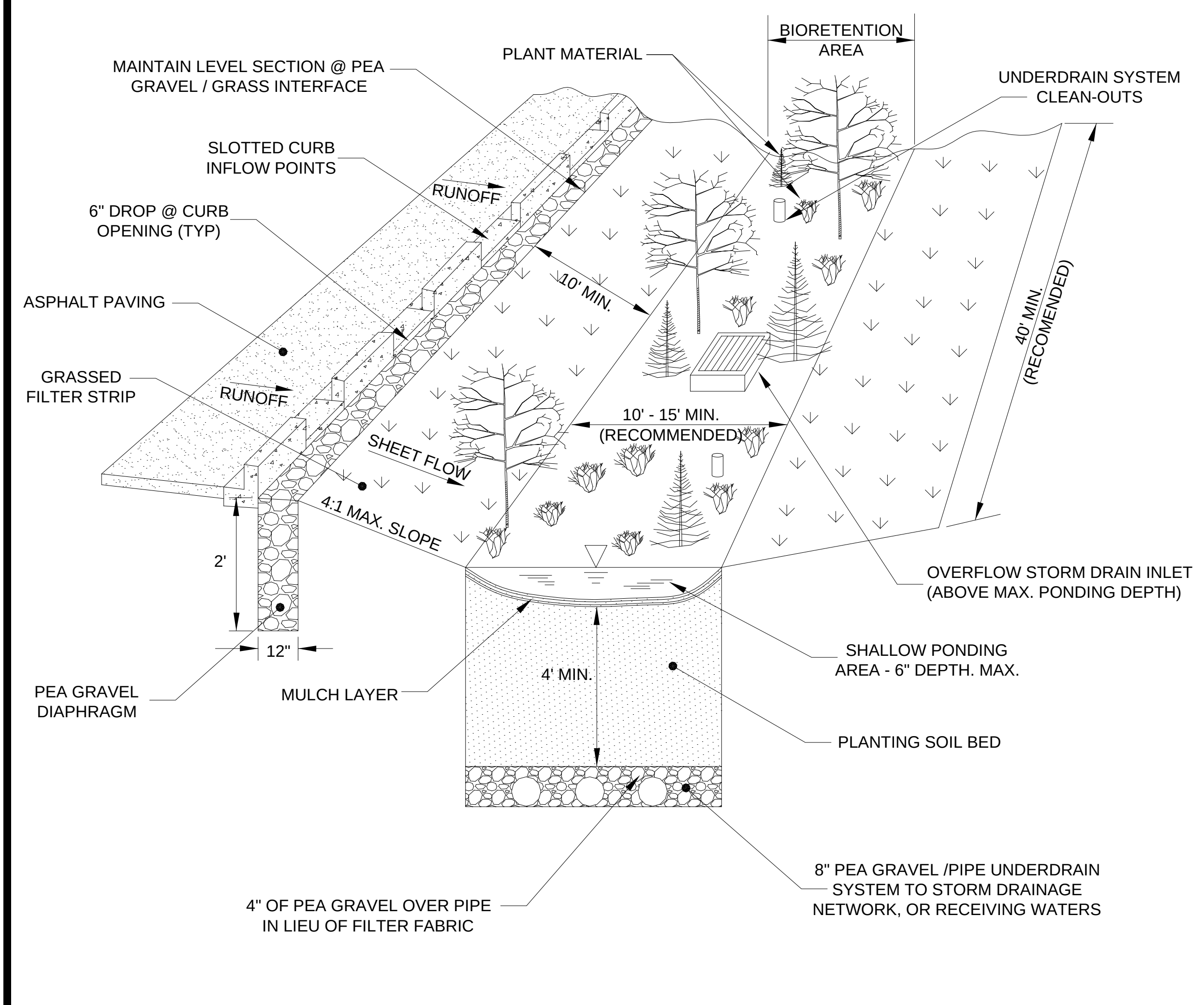


Figure 4-28. Schematic of a Typical On-line Bioretention Area
(Source: Claytor and Schueler, 1996)

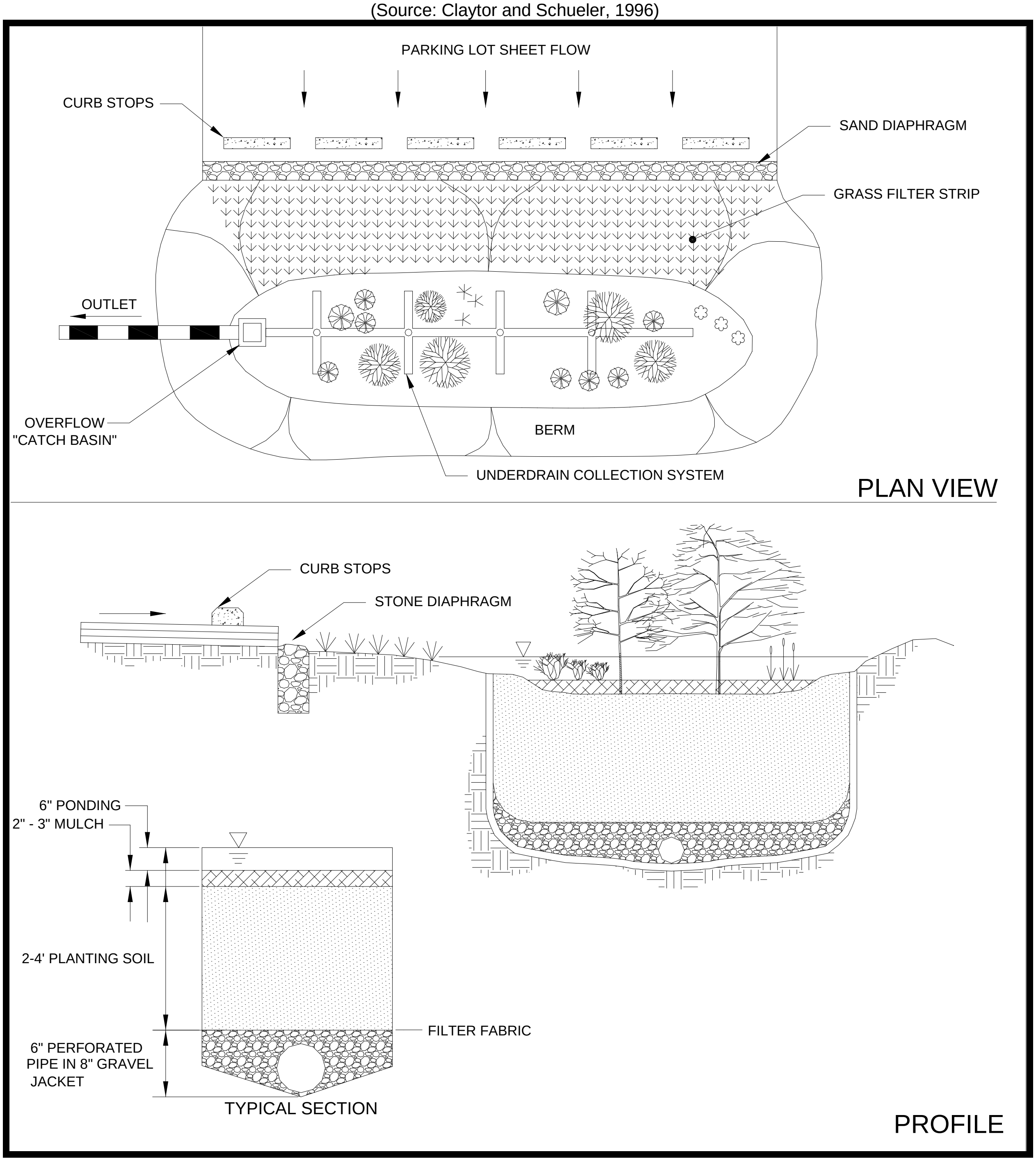


Figure 4-29. Schematic of a Typical Off-line Bioretention Area

(Source: Claytor and Schueler, 1996)

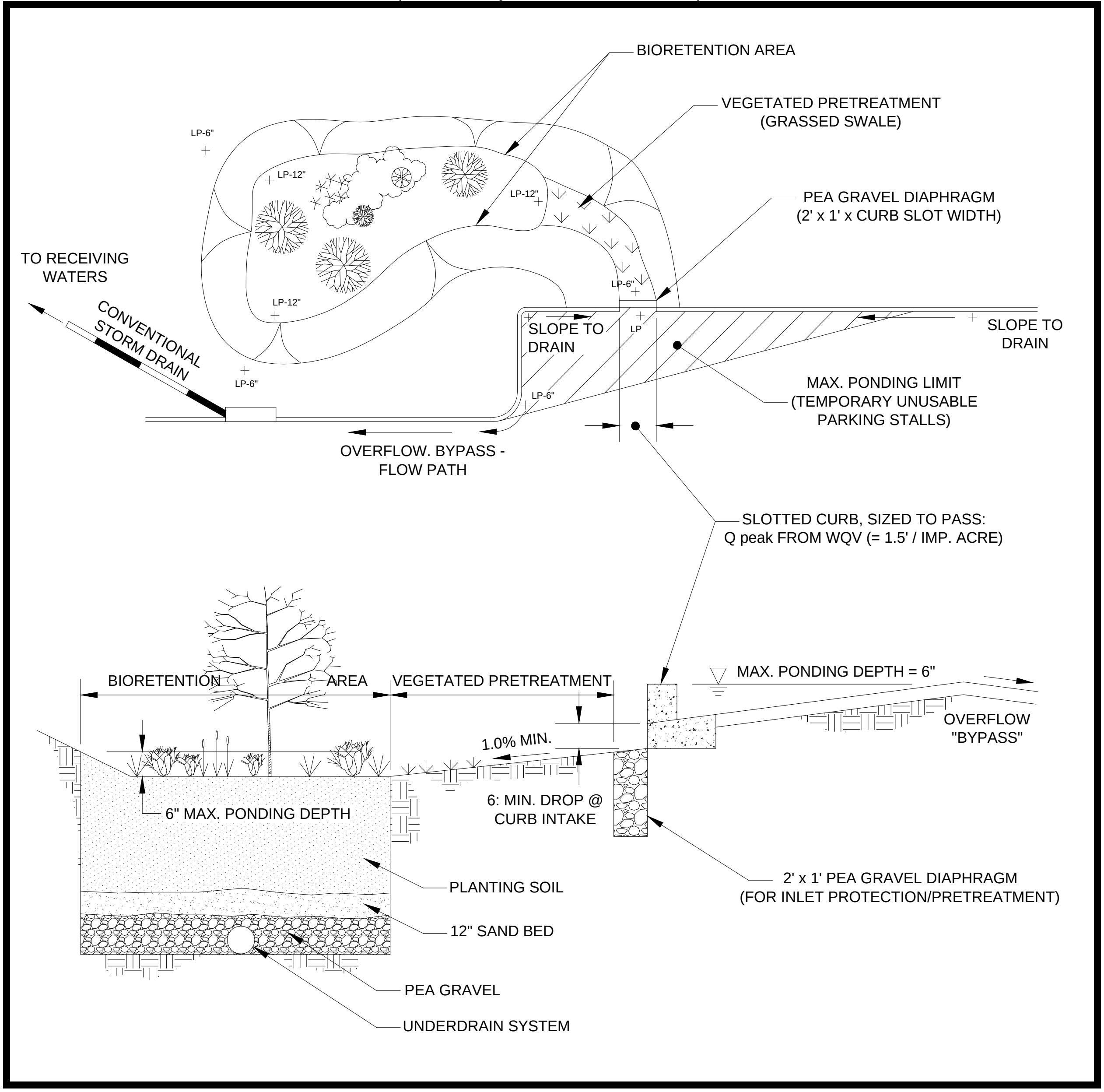
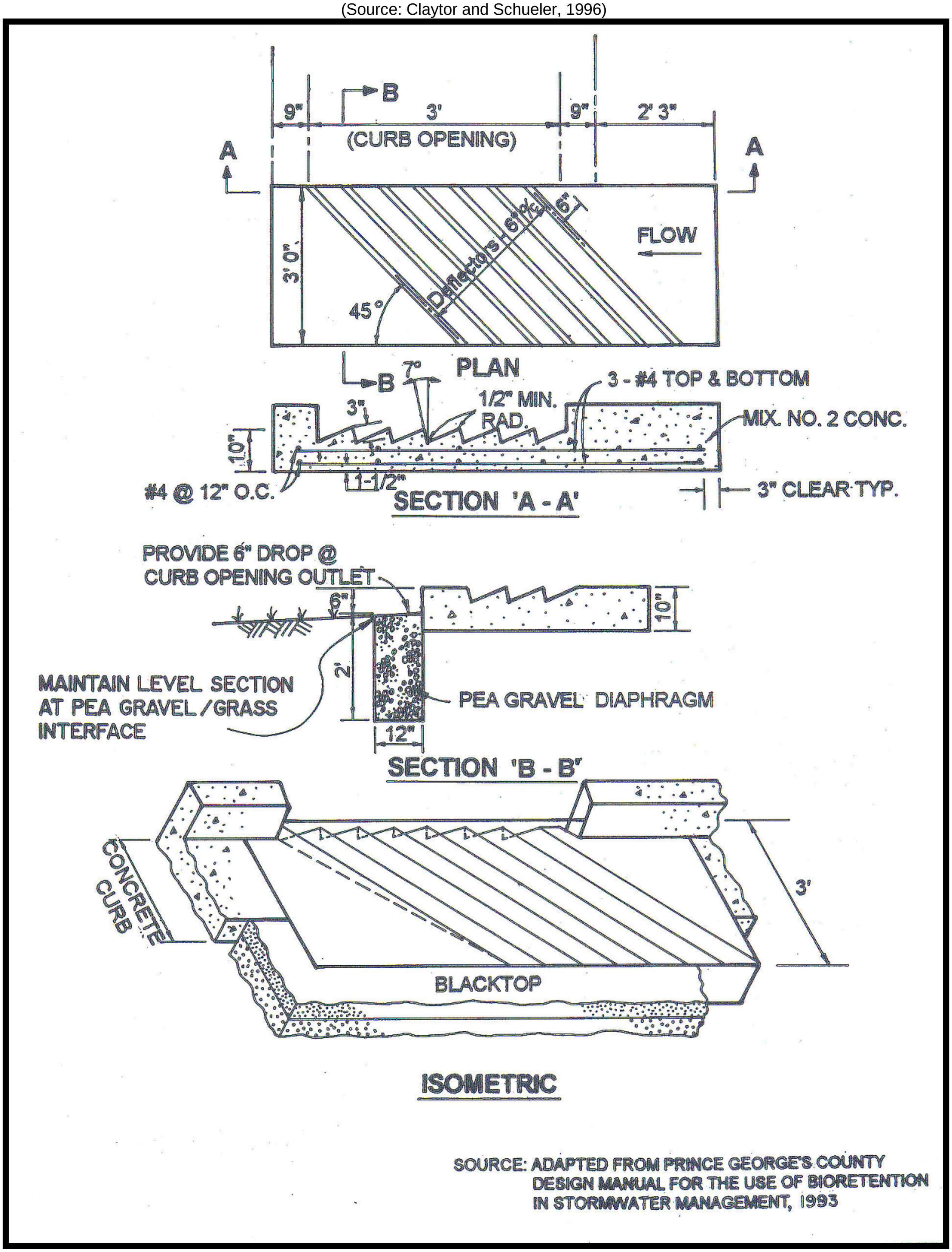


Figure 4-30. Schematic of a Typical Inlet Deflector
(Source: Claytor and Schueler, 1996)



4.3.5.9. Design Form

The local municipality recommends the use of the following design procedure forms when designing a bioretention area. Proper use and completion of the form may allow a faster review of the Stormwater Management Plan by the local municipality.

Design Procedure Form: Bioretention Areas

PRELIMINARY HYDROLOGIC CALCULATIONS	
1a. Compute WQv volume requirements	
Compute Runoff Coefficient, Rv	Rv = ________
Compute WQv	WQv = ________ acre-ft
1b. Compute CPv	CPv = ________ acre-ft
Compute average release rate	release rate = ________ cfs
Compute storage volume required for locally regulated storm events	storage = ________ acre-ft storage = ________ acre-ft
BIORETENTION AREA DESIGN	
2. Is the use of a bioretention area appropriate?	***See subsections 4.3.5.4 and 4.3.5.5 - A***
3. Confirm design criteria and applicability.	***See subsection 4.3.5.5 - J***
4. Determine size of bioretention filter area	A_f= ________ ft^2
5. Set design elevations and dimensions	Length = ________ ft Width = ________ ft ________ elevation top of facility ________ other elev: ________ ________ other elev: ________ ________ other elev: ________
6. Conveyance to bioretention facility	________ Online or ________ Offline ?
7. Pretreatment	Type: ________________
8. Size underdrain area Based on guidance: Approx. 10% A_f	Length= ________ ft
9. Overdrain design	Type: ________________ Size: ________
10. Emergency storm weir design Overflow weir - Weir equation	Length= ________ ft
11. Choose plants for planting area	Select native plants based on resistance to drought and inundation, cost, aeshetics, maintenance, etc.

4.3.5.10 References

AMEC. *Knox County Stormwater Management Manual Volume 2, Technical Guidance*.

AMEC. *Metropolitan Nashville and Davidson County Stormwater Management Manual Volume 4 Best Management Practices.* 2006.

Atlanta Regional Council (ARC). *Georgia Stormwater Management Manual, Volume 2: Technical Handbook.* 2001.

Center for Watershed Protection. *Manual Builder.* Stormwater Manager's Resource Center, Accessed July 2005. *www.stormwatercenter.net*

City of Portland, OR. *Stormwater Management Manual.* 2004.

Claytor, R.A., and T.R. Schueler. *Design of Stormwater Filtering Systems.* The Center for Watershed Protection, Silver Spring, MD, 1996.

Prince George's County. *Design Manual for Use of Bioretention in Stormwater Management.* Department of Environmental Resources, Prince George's County, Landover, MD, 1993.

4.3.5.11 Suggested Reading

Bell, W. *BMP Technologies for Ultra-Urban Settings. In Proceedings of Effective Land Management for Reduced Environmental Impact.* Tidewater's Land Management Conference on Water Quality, August 22, 1996.

City of Austin, TX. *Water Quality Management.* Environmental Criteria Manual, Environmental and Conservation Services, 1988.

City of Sacramento, CA. *Guidance Manual for On-Site Stormwater Quality Control Measures.* Department of Utilities, 2000.

US EPA. *Storm Water Technology Fact Sheet: Bioretention.* EPA 832-F-99-012, Office of Water, 1999.

Maryland Department of the Environment. *Maryland Stormwater Design Manual, Volumes I and II.* Prepared by Center for Watershed Protection (CWP), 2000.

Washington State Department of Transportation (WSDOT). *Highway Runoff Manual.* Washington State Department of Transportation, 1995.

4.3.6 Surface Sand Filters

General Application Water Quality BMP

Description: Surface sand filters are multi-chamber structures located above ground that are designed to treat stormwater runoff through filtration, using a sediment forebay, a sand bed as its primary filter media and, typically, an underdrain collection system.

KEY DESIGN CONSIDERATIONS

DESIGN GUIDELINES:

- Typically requires 2 to 6 feet of head.
- Maximum contributing drainage area of 10 acres for surface sand filter; 2 acres for perimeter sand filter.
- Sand filter media with underdrain system.
- Typically needs to be combined with other controls to provide water quality control.

ADVANTAGES / BENEFITS:

- Applicable to small drainage areas.
- Good for highly impervious areas.
- Good retrofit capability.

DISADVANTAGES / LIMITATIONS:

- High maintenance burden.
- Not recommended for areas with high sediment content in stormwater or clay/silt runoff areas.
- Relatively costly.
- Possible odor problems.
- Cannot be installed until site construction is complete.

MAINTENANCE REQUIREMENTS:

- Inspect for clogging – rake first inch of sand.
- Remove sediment from forebay/chamber.
- Replace sand filter media as needed.

STORMWATER MANAGEMENT SUITABILITY

Stormwater Quality:	**Yes**
Channel Protection:	✷
Detention/Retention:	**No**

✷ in certain situations

Accepts hotspot runoff: *Yes (requires impermeable liner)*

COST CONSIDERATIONS

Land Requirement:	**Low**
Capital Cost:	**High**
Maintenance Burden:	**High**

LAND USE APPLICABILITY

Residential/Subdivision Use:	**No**
High Density/Ultra Urban Use:	**Yes**
Commercial/Industrial Use:	**Yes**

POLLUTANT REMOVAL

Total Suspended Solids:	**80%**

4.3.6.1 General Description

Surface sand filters (also referred to as *sand filters* or *filtration basins*) are ground-level, open air structures that capture and temporarily store stormwater runoff and pass it through a filter bed of sand. An example of a surface sand filter is presented in Figure 4-31. Underground sand filters, discussed in Section 4.4.2, treat stormwater in the same manner, but are located below the ground surface. Because of the increased maintenance requirements, underground sand filters are considered Limited Application BMPs.

Figure 4-31. Example of a Surface Sand Filter

Most sand filter systems, surface and underground, consist of two-chamber structures. The first chamber is a sediment forebay or sedimentation chamber, which removes floatables and heavy sediments. The second is the filtration chamber, which removes finer sediments and other pollutants by filtering the runoff through a sand bed. The filtered runoff is typically collected and returned to the conveyance system, though it can also partially or fully permeate into the surrounding soil in areas with porous soils.

This system can treat drainage areas up to 10 acres in size and is typically located off-line. Surface sand filters can be designed as an excavation with earthen embankments or as a concrete or block structure. Because they have few site constraints beside head requirements, sand filters can be used on development sites where the use of other structural BMPs may be precluded. However, sand filter systems can be relatively expensive to construct and install, and require a relatively high level of maintenance and inspection. Because of this, surface sand filters are not recommended for use in residential areas.

4.3.6.2 Stormwater Management Suitability

Surface sand filter systems are designed primarily as off-line systems for treatment of the water quality volume and will typically need to be used in conjunction with another structural BMP that can provide downstream channel protection and protection of the locally regulated peak discharge. However, under certain circumstances, filters can provide limited runoff quantity control, particularly for smaller storm events.

Water Quality (WQv)
In sand filter systems, stormwater pollutants are removed through a combination of gravitational settling, filtration and adsorption. The filtration process effectively removes suspended solids and particulates, biochemical oxygen demand (BOD), fecal coliform bacteria, and other pollutants. Surface sand filters with a grass cover have additional opportunities for bacterial decomposition as well as vegetation uptake of pollutants, particularly nutrients.

Channel Protection (CPv)
For smaller sites, a sand filter may be designed to capture the entire channel protection volume (CPv) in either an off- or on-line configuration. Given that a sand filter system is typically designed to completely drain over 40 hours, the channel protection design requirement for extended detention of the 1-year, 24-hour storm runoff volume can be met. For larger sites or where only the WQv is diverted to the sand filter facility, another structural control must be used to provide extended detention of the CPv.

4.3.6.3 Pollutant Removal Capabilities

Surface sand filters are presumed to be able to remove 80% of the total suspended solids (TSS) load in typical urban post-development runoff when sized, designed, constructed and maintained in accordance with the recommended specifications. Undersized or poorly designed sand filters can reduce TSS removal performance.

The total suspended solids design pollutant removal rate of 80% is a conservative average pollutant reduction percentage for design purposes derived from sampling data, modeling and professional judgment.

For additional information and data on pollutant removal capabilities for sand filters, see the National Pollutant Removal Performance Database (2nd Edition) available at www.cwp.org and the International Stormwater Best Management Practices (BMP) Database at www.bmpdatabase.org.

4.3.6.4 Application and Site Feasibility Criteria

Surface sand filter systems are well-suited for highly impervious areas where land available for structural BMPs is limited. Sand filters should primarily be considered for new construction or retrofit opportunities for commercial, industrial, and institutional areas where the sediment load is relatively low, such as: parking lots, driveways, loading docks, gas stations, garages, airport runways/taxiways, and storage yards. Sand filters may also be feasible and appropriate in some multi-family residential developments where maintenance is performed by a landscaping (or other suitably capable) company.

To avoid rapid clogging and failure of the filter media, the use of sand filters should be avoided in areas with less than 50% impervious cover, or high sediment yield sites with clay/silt soils.

The following basic criteria should be evaluated to ensure the suitability of a sand filter facility for meeting stormwater management objectives on a site or development.

General Feasibility

- Not suitable for use in a residential subdivision
- Suitable for use in high density/ultra-urban areas
- Not suitable for use as a regional stormwater control. On-site applications are typically most feasible.

Physical Feasibility - Physical Constraints at Project Site

- Drainage Area – 10 acres maximum for surface sand filter; 2 acres maximum for perimeter sand filter
- Space Required – Function of available head at site
- Minimum Head – The surface slope across the filter location should be no greater than 6%. The elevation difference needed at a site from the inflow to the outflow: 5 feet for surface sand filters; 2 to 3 feet for perimeter sand filters.

- Minimum Depth to Water Table – If used on a site with an underlying water supply aquifer, a separation distance of 2 feet is required between the bottom of the sand filter and the elevation of the seasonally high water table to prevent groundwater contamination.
- Soils – Not recommended for clay/silt drainage areas that are not stabilized. Karst areas may require a liner.

Other Constraints / Considerations

- Aquifer Protection – Do not allow infiltration of filtered hotspot runoff into groundwater

4.3.6.5 Planning and Design Standards

The following standards shall be considered **minimum** design standards for the design of sand filters. Sand filters that are not designed to these standards will not be approved. The local municipality shall have the authority to require additional design conditions if deemed necessary.

A. CONSTRUCTION SEQUENCING

- Ideally, the construction of a sand filter shall take place **after** the construction site has been stabilized.
- In the event that the sand filter is not constructed after site stabilization, care shall be taken during construction to minimize the risk of premature failure of the sand filter due to deposition of sediments from disturbed, unstabilized areas.
- Diversion berms and erosion prevention and sediment controls shall be maintained around the sand filter during all phases of construction. No runoff or sediment shall enter the sand filter area prior to completion of construction and the complete stabilization of construction areas.
- Sand filters shall not be used as a temporary sediment trap for construction activities.
- During and after excavation of the sand filter, all excavated materials shall be placed downstream, away from the sand filters, to prevent redeposit of the material during runoff events.

B. LOCATION AND SITING

- Surface sand filters shall have a contributing drainage area of 10 acres or less.
- Surface sand filter systems are generally applied to land uses with a high percentage of impervious surfaces. Sand filters shall not be utilized for sites that have less than 50% impervious cover. Pretreatment must be provided as described in part D below, due to the potential for high clay/silt sediment loads that could result in clogging and failure of the filter bed. Any disturbed or denuded areas located within the area draining to and treated by the sand filter shall be stabilized prior to construction and use of the sand filter. The sand filter shall only be constructed after the construction site is stabilized.
- It is preferred that surface sand filters are to be used in an off-line configuration where the water quality volume (WQv) is diverted to the filter facility through the use of a flow diversion structure and flow splitter. Stormwater flows greater than the WQv shall be diverted to other controls or downstream using a diversion structure or flow splitter. In certain situations, as determined by the local municipality, a surface sand filter may be used in an on-line configuration.
- Sand filter systems shall be designed for intermittent flow and must be allowed to drain and re-aerate between rainfall events. They shall not be used on sites with a continuous flow from groundwater, sump pumps, or other sources.

C. GENERAL DESIGN

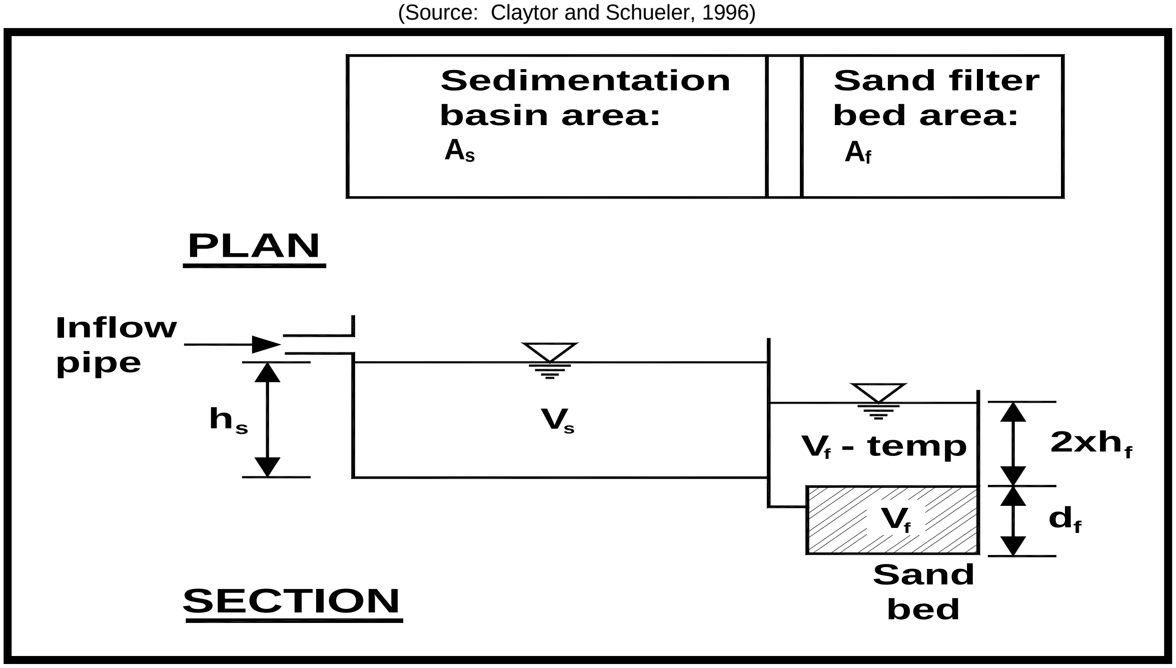
- A surface sand filter facility shall consist of a two-chamber open-air structure, which is located at ground-level. The first chamber is the sediment forebay (commonly referred to as the sedimentation chamber) while the second chamber houses the sand filter bed. Flow enters the sedimentation chamber where settling of larger sediment particles occurs. Runoff is then discharged from the sedimentation chamber through a perforated standpipe into the filtration chamber. After passing though the filter bed, runoff is collected by a perforated pipe and gravel underdrain system.

D. PHYSICAL SPECIFICATIONS / GEOMETRY

- The entire treatment system (including the sedimentation chamber) shall be designed to temporarily hold at least 75% of the WQv prior to filtration. Figure 4-32 illustrates the distribution of the treatment volume (0.75 WQv) among the various components of the surface sand filter, including:
  - V_s – volume within the sedimentation basin
  - V_f – volume within the voids in the filter bed
  - $V_{f\text{-temp}}$ – temporary volume stored above the filter bed
  - A_s – the surface area of the sedimentation basin
  - A_f – surface area of the filter media
  - h_s – height of water in the sedimentation basin
  - h_f – average height of water above the filter media
  - d_f – depth of filter media

Figure 4-32. Surface Sand Filter Volumes

(Source: Claytor and Schueler, 1996)



- The sedimentation chamber shall be sized to hold at least 25% of the computed WQv and have a length-to-width ratio of at least 2:1. Inlet and outlet structures should be located at opposite ends of the chamber.
- The filter area shall be sized based on the principles of Darcy's Law. A coefficient of permeability (k) of 3.5 ft/day for sand shall be used. The filter bed shall be designed to completely drain in 40 hours or less.
- The filter media shall consist of an 18-inch layer of clean washed medium aggregate concrete sand (ASTM C-33) on top of the underdrain system. Three inches of topsoil shall be placed over the sand bed. Permeable filter fabric shall be placed both above and below the sand bed to prevent clogging of the sand filter and the underdrain system. Figure 4-33 illustrates a typical media cross section.
- The filter bed shall be equipped with a 6-inch perforated pipe underdrain (PVC AASHTO M 252, HDPE, or other suitable pipe material) in a gravel layer. The underdrain shall have a minimum grade of 1/8-inch per foot (1% slope). Holes shall be 3/8-inch diameter and spaced approximately 6 inches

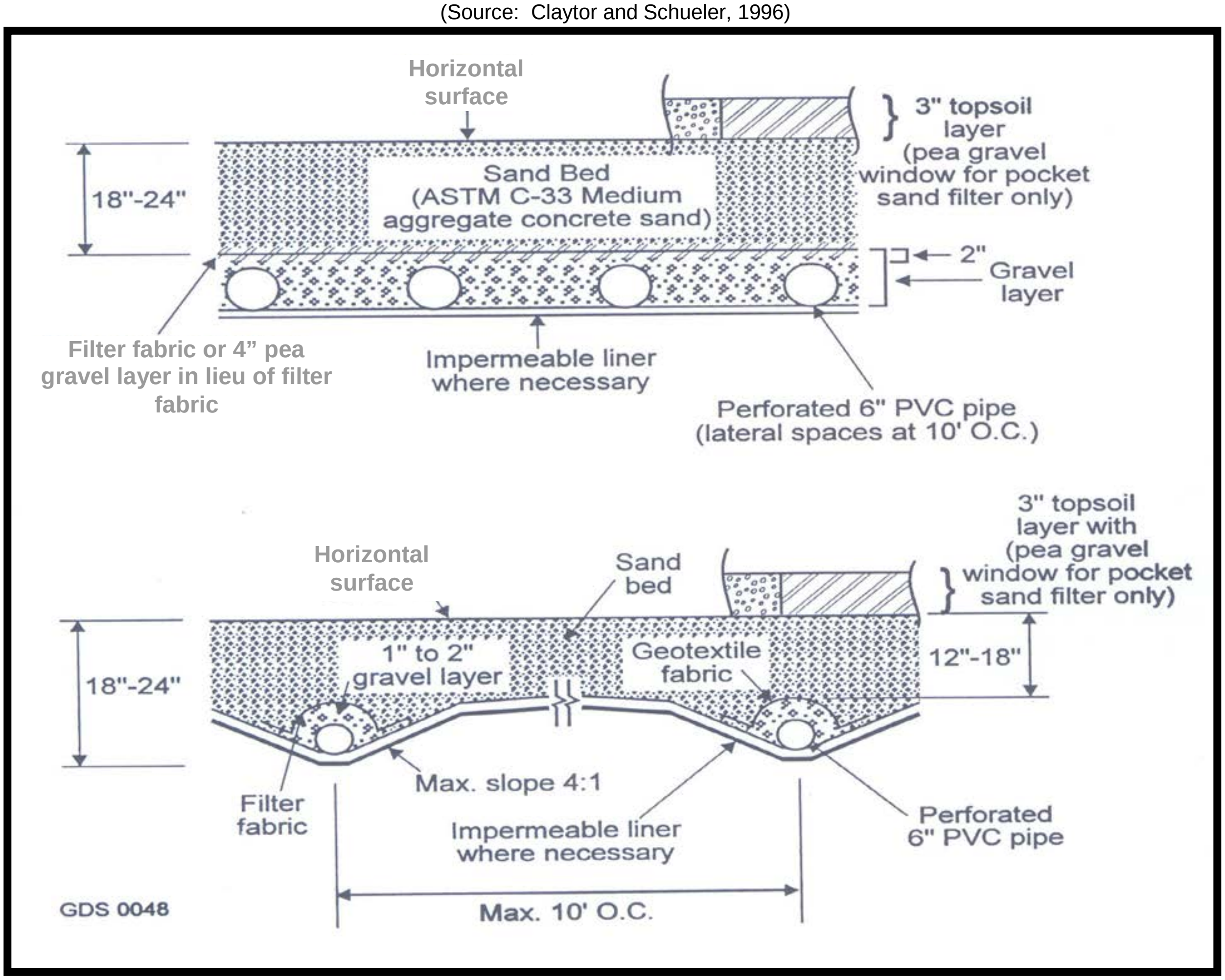
on center. Gravel shall be clean-washed aggregate with a maximum diameter of 3.5 inches and a minimum diameter of 1.5 inches with a void space of about 40%. Aggregate contaminated with soil shall not be used.

- The structure of the surface sand filter may be constructed of impermeable media such as concrete, or through the use of excavations and earthen embankments. When constructed with earthen walls/embankments, filter fabric shall be used to line the bottom and side slopes of the structures before installation of the underdrain system and filter media.

E. PRETREATMENT / INLETS

- Pretreatment of runoff in a sand filter system shall be by a sedimentation chamber, designed in accordance with the criteria stated above.
- Energy dissipators shall be used at the inlets to surface sand filters. Figure 4-34 shows a typical inlet pipe from the sedimentation basin to the filter media basin for the surface sand filter.
- The sand filter shall be designed such that runoff exits the sedimentation chamber at a non-erosive velocity.

Figure 4-33. Typical Sand Filter Media Cross Sections
(Source: Claytor and Schueler, 1996)



F. OUTLET STRUCTURES

- An outlet pipe shall be provided from the underdrain system to the facility discharge. Due to the slow rate of filtration, outlet protection is generally unnecessary (except for emergency overflows and spillways). However, the design shall ensure that the discharges from the underdrain system occur in a non-erosive manner.

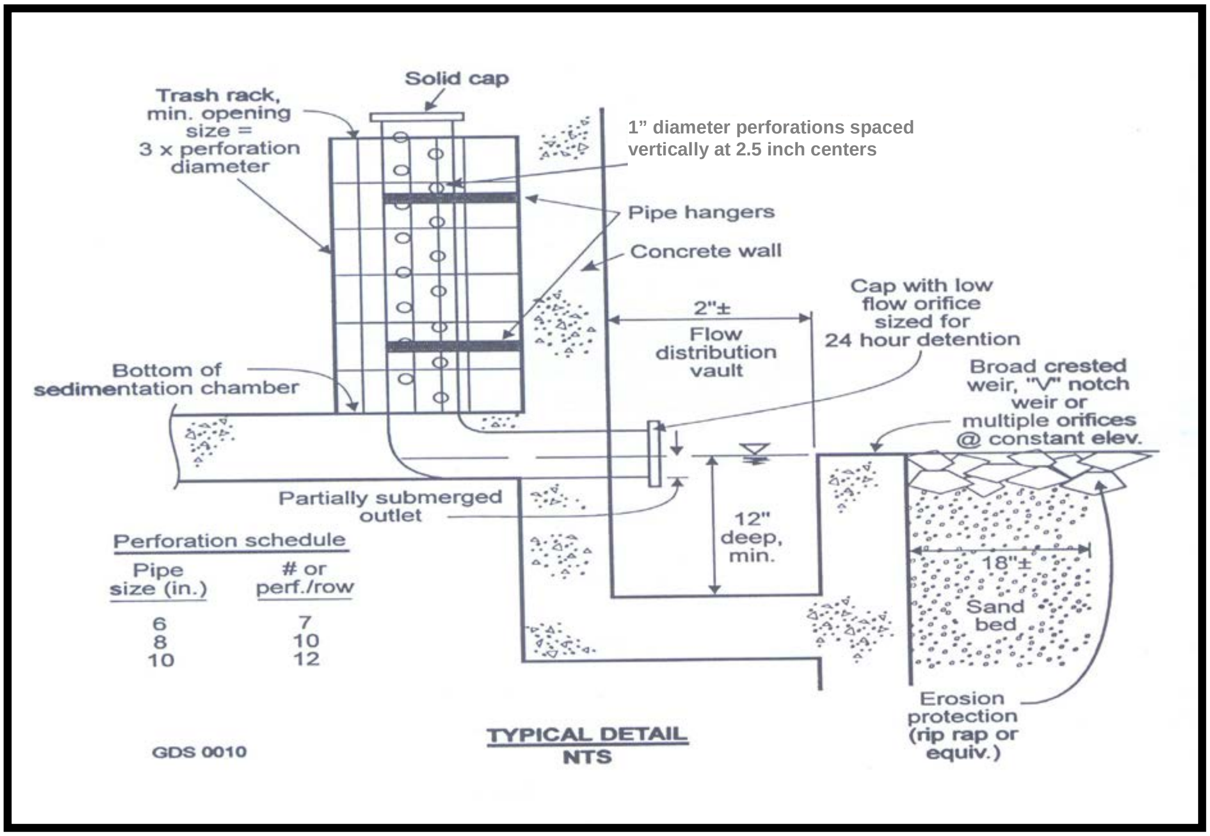
G. EMERGENCY SPILLWAY

- An emergency or bypass spillway must be included in the surface sand filter design to safely pass flows that exceed the WQv (and CPv if the filter is utilized for channel protection purposes). The spillway prevents filter water levels from overtopping the embankment and causing structural damage. The emergency spillway shall be located so that embankments, downstream buildings and structures will not be impacted by spillway discharges.

H. MAINTENANCE ACCESS

- A minimum 20' wide maintenance right of way or drainage easement shall be provided for a sand filter from a driveway, public or private road. The maintenance access easement shall have a maximum slope of no more than 15% and shall have a minimum unobstructed drive path having a width of 12 feet, appropriately stabilized to withstand maintenance equipment and vehicles. Facility designs must enable maintenance personnel to easily remove and replace upper layers of the filter media.

Figure 4-34. Surface Sand Filter Perforated Stand-Pipe
(Source: Claytor and Schueler, 1996)



I. SAFETY FEATURES

- Where necessary, surface sand filter facilities can be fenced to prevent access.

J. LANDSCAPING

- Surface sand filters can be designed with a grass cover to aid in pollutant removal and prevent clogging. The grass should be capable of withstanding frequent periods of inundation and drought.

K. ADDITIONAL SITE-SPECIFIC DESIGN CRITERIA AND ISSUES

Physiographic Factors - Local terrain design constraints

- Low Relief – Use of surface sand filter may be limited by low head
- High Relief – Filter bed surface must be level
- Karst – Use liner or impermeable membrane to seal bottom earthen surface of the sand filter or use watertight structure

Special Downstream Watershed Considerations

- Wellhead Protection – Reduce potential groundwater contamination (in required wellhead protection areas) by preventing infiltration of hotspot runoff. May require liner for type "A" and "B" soils; Pretreat hotspots; provide 2 to 4 foot separation distance from water table

4.3.6.6 Design Procedures

Step 1. Compute runoff control volumes

Calculate WQv, CPv, and the locally regulated peak discharge, in accordance with the guidance presented in Chapter 3.

Step 2. Determine if the development site and conditions are appropriate for the use of a surface sand filter.

Consider the Application and Site Feasibility Criteria, and the Additional Site Specific Design Criteria and Issues noted above. Check with the local municipality and other agencies as appropriate to determine if there are any additional restrictions and/or surface water or watershed requirements that may apply.

Step 3. Compute WQv peak discharge (Q_{wq})

The peak rate of discharge for water quality design storm is needed for sizing of off-line diversion structures (see Chapter 3 for more information on this calculation).

(1) Using WQv, compute CN

(2) Compute time of concentration using TR-55 method

(3) Determine appropriate unit peak discharge from time of concentration

(4) Compute Q_{wq} in inches from unit peak discharge, drainage area, and WQv.

Step 4. Size flow diversion structure, if needed

A flow regulator (or flow splitter diversion structure) should be supplied to divert the WQv to the sand filter facility. Size low flow orifice, weir, or other device to pass Q_{wq}.

Step 5. Size filtration basin chamber

The filter area is sized using the following equation (based on Darcy's Law):

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

where:

A_f = surface area of filter bed (ft^2)
d_f = filter bed depth (1.5 ft) (at least 18 inches, no more than 24 inches)
k = coefficient of permeability of filter media (ft/day) (use 3.5 ft/day for sand)
h_f = average height of water above filter bed (ft)
(1/2 h_{max}, which varies based on site but h_{max} is typically $\leq$ 6 feet)
t_f = design filter bed drain time (days) (1.67 days or 40 hours is maximum time)

Set preliminary dimensions of filtration basin chamber.

Step 6. Size sedimentation chamber

The sedimentation chamber shall be sized to at least 25% of the computed WQv and have a length-to-width ratio of 2:1. The Camp-Hazen equation is used to compute the required surface area:

$$A_s = -(Q_o/w) * \text{Ln}\ (1-E)$$

where:

A_s = sedimentation basin surface area (ft^2)
Q_o = rate of outflow = the WQv (ft^3) / 86400 seconds
w = particle settling velocity (ft/sec)
E = trap efficiency

Assuming:

- 90% sediment trap efficiency (0.9)

- particle settling velocity (ft/sec) = 0.0033 ft/sec for imperviousness ≥ 75%
- particle settling velocity (ft/sec) = 0.0004 ft/sec for imperviousness < 75%
- average of 24 hour holding period

Then:

A_s = (0.0081) (WQv) ft^2 for I ≥ 75%
A_s = (0.066) (WQv) ft^2 for I < 75%

Set preliminary dimensions of sedimentation chamber.

Step 7. Compute V_{min}

$$V_{min} = 0.75 * WQv$$

Step 8. Compute storage volumes within entire facility and sedimentation chamber orifice size

$$V_{min} = 0.75\ WQv = V_s + V_f + V_{f\text{-}temp}$$

(1) Compute V_f = water volume within filter bed/gravel/pipe = $A_f * d_f * n$
Where: n = porosity = 0.4 for most applications

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

(3) Compute V_s = volume within sediment chamber = $V_{min} - V_f - V_{f\text{-}temp}$

(4) Compute h_s = height in sedimentation chamber = V_s/A_s

(5) Ensure h_s and h_f fit available head and other dimensions still fit – change as necessary in design iterations until all site dimensions fit.

(6) Size orifice from sediment chamber to filter chamber to release V_s within 24-hours at average release rate with 0.5 h_s as average head.

(7) Design outlet structure with perforations allowing for a safety factor of 10 times the orifice capacity.

(8) Size distribution chamber to spread flow over filtration media – level spreader weir or orifices.

Step 9. Design inlets, pretreatment facilities, underdrain system, and outlet structures

See design criteria above for more details.

Step 10. Compute overflow weir sizes

(1) Size overflow weir at elevation hs in sedimentation chamber (above perforated stand pipe) to handle surcharge of flow through filter system from 25-year storm.

(2) Plan inlet protection for overflow from sedimentation chamber and size overflow weir at elevation hf in filtration chamber (above perforated stand pipe) to handle surcharge of flow through filter system from 25-year storm.

4.3.6.7 Maintenance Requirements and Inspection Checklist

Note: Section 4.3.6.7 must be included in the Operations and Maintenance Plan that is recorded with the deed.

Regular inspection and maintenance is critical to the effective operation of a sand filter as designed. It is the responsibility of the property owner to maintain all stormwater BMPs in accordance with the minimum design standards and other guidance provided in this manual. The local municipality has the authority to impose additional maintenance requirements where deemed necessary.

This page provides guidance on maintenance activities that are typically required for sand filters, along with a suggested frequency for each activity. Individual sand filters may have more, or less, frequent maintenance needs, depending upon a variety of factors including the occurrence of large storm events, overly wet or dry (i.e.., drought) regional hydrologic conditions, and any changes or redevelopment in the upstream land use. Each property owner shall perform the activities identified below at the frequency needed to maintain the sand filter in proper operating condition at all times.

Inspection Activities	**Suggested Schedule**
• A record should be kept of the dewatering time (i.e., the time required to drain the filter bed completely after a storm event) for a sand filter to determine if maintenance is necessary. The filter bed should drain completely in about 40 hours after the end of the rainfall. • Check to ensure that the filter surface does not clog after storm events.	After Rain Events
• Check the contributing drainage area, facility, inlets and outlets for debris. • Check to ensure that the filter surface is not clogging.	Monthly
• Check to see that the filter bed is clean of sediment, and the sediment chamber is not more than 50% full or 6 inches, whichever is less, of sediment. Remove sediment as necessary. • Make sure that there is no evidence of deterioration, spalling, bulging, or cracking of concrete. • Inspect grates (perimeter sand filter). • Inspect inlets, outlets and overflow spillway to ensure good condition and no evidence of erosion. • Check to see if stormwater flow is bypassing the facility. • Ensure that no noticeable odors are detected outside the facility.	Annually
Maintenance Activities	**Suggested Schedule**
• Mow and stabilize (prevent erosion, vegetate denuded areas) the area draining to the sand filter. Collect and remove grass clippings. Remove trash and debris. • Ensure that activities in the drainage area minimize oil/grease and sediment entry to the system. • If permanent water level is present (perimeter sand filter), ensure that the chamber does not leak, and normal pool level is retained.	Monthly
• Check to see that the filter bed is clean of sediment, and the sediment chamber is not more than 50% full or 6 inches, whichever is less, of sediment. Remove sediment as necessary. • Repair or replace any damaged structural parts. • Stabilize any eroded areas.	Annually
• If filter bed is clogged or partially clogged, manual manipulation of the surface layer of sand may be required. Remove the top few inches of sand, roto-till or otherwise cultivate the surface, and replace media with sand meeting the design specifications. • Replace any filter fabric that has become clogged.	As needed

The local municipality encourages the use of the inspection checklist that is presented on the next page to guide the property owner in the inspection and maintenance of sand filters. The local municipality can require the use of this checklist or other form(s) of maintenance documentation when and where deemed necessary in order to ensure the long-term proper operation of the sand filter. Questions regarding stormwater facility inspection and maintenance should be referred to the local municipality.

INSPECTION CHECKLIST AND MAINTENANCE GUIDANCE (continued)
SURFACE SAND FILTER INSPECTION CHECKLIST

Location: ____ Owner Change since last inspection? Y N

Owner Name, Address, Phone: ____

Date: ___________ Time: ______________ Site conditions:____

Inspection Items	Satisfactory (S) or Unsatisfactory (U)	Comments/Corrective Action
Sand Filter Inspection List		
Complete drainage of the filter in about 40 hours after a rain event?		
Clogging of filter surface?		
Clogging of inlet/outlet structures?		
Clogging of filter fabric?		
Filter clear of debris and functional?		
Leaks or seeps in filter?		
Obstructions of spillway(s)?		
Animal burrows in filter?		
Sediment accumulation in filter bed (less than 50% is acceptable)?		
Cracking, spalling, bulging or deterioration of concrete?		
Erosion in area draining to sand filter?		
Erosion around inlets, filter bed, or outlets?		
Pipes and other structures in good condition?		
Undesirable vegetation growth?		
Other (describe)?		
Hazards		
Have there been complaints from residents?		
Public hazards noted?		

If any of the above inspection items are **UNSATISFACTORY**, list corrective actions and the corresponding completion dates below:

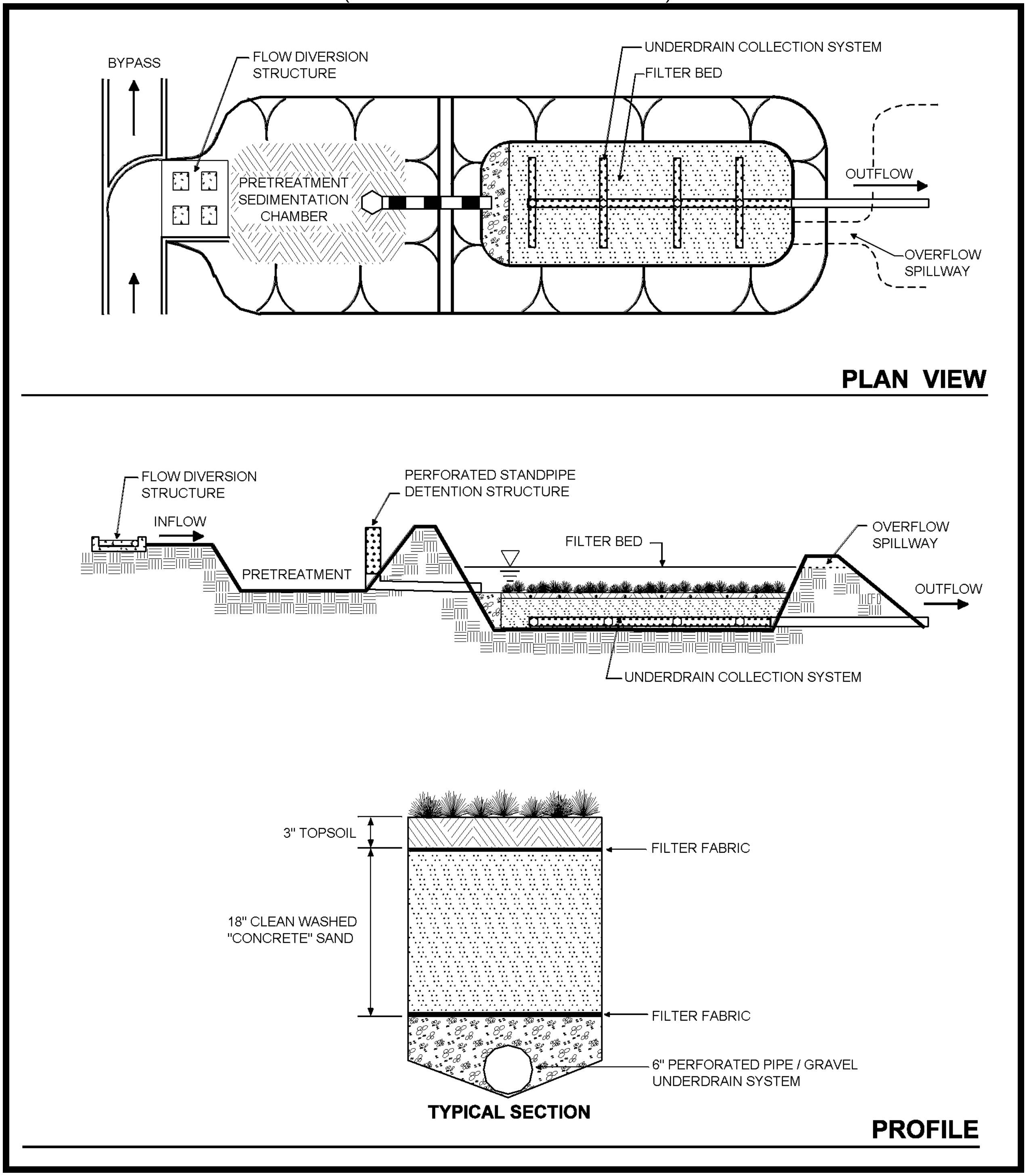
Corrective Action Needed	Due Date

Inspector Signature:_________________________________ Inspector Name (printed)____________________________

4.3.6.8 Example Schematic

Figure 4-35. Schematic of a Surface Sand Filter

(Source: Center for Watershed Protection)



4.3.6.9 Design Form

The local municipality recommends the use of the following design procedure forms when designing sand filters. Proper use and completion of the form may allow a faster review of the Water Quality Management Plan by the local municipality.

Design Procedure Forms: Sand Filters

PRELIMINARY HYDROLOGIC CALCULATIONS	
1a. Compute WQv volume requirements	
Compute Runoff Coefficient, Rv	Rv = ________
Compute WQv	WQv = ________ acre-ft
1b. Compute CPv	CPv = ________ acre-ft
Compute average release rate	release rate = ________ cfs
Compute storage volume required for locally regulated	storage = ________ acre-ft
storm events.	storage = ________ acre-ft
SAND FILTER DESIGN	
2. Is the use of a sand filter appropriate?	Low point in development area = ________
	Low point at stream invert = ________
	Total available head = ________
	Average depth, h_f = ________
	See subsections 4.3.6.4 and 4.3.6.5 - A
3. Confirm design criteria and applicability.	***See subsection 4.3.6.5 - J***
4. Compute WQv peak discharge (Q_{wq})	
Compute Curve Number	CN = ________
Compute Time of Concentration, t_c	t_c = ________ hour
Compute Q_{wq}	Q_{wq} = ________ cfs
5. Size flow diversion structure	
Low flow orifice - orifice equation	A = ________ ft^2
	diameter = ________ in
	length = ________ ft
Overflow weir - Weir equation	
6. Size filtration bed chamber	
Compute area from Darcy's Law	A_f = ________ ft^2
Using length to width (2:1) ratio	L = ________ ft
	W = ________ ft
7. Size sedimentation chamber	
Compute area from Camp-Hazen equation	A_s = ________ ft^2
Given W from step 5, compute Length	L = ________
8. Compute V_{min}	V_{min} = ________ ft^3

Design Procedure Form: Sand Filters (continued)

9. Compute volume within practice	
Surface Sand Filter	
Volume within filter bed	V_f = ________ ft^3
Temporary storage above filter bed	$V_{f\text{-}temp}$ = ________ ft3
Sedimentation chamber (remaining volume)	V_s = ________ ft3
Height in sedimentation chamber	h_s = ________ ft
Perforated stand pipe - orfice equation	A = ________ ft^2
	diameter = ________ in
Perimeter Sand Filter	
Compute volume in filter bed	V_f = ________ ft^3
Compute wet pool storage	V_w = ________ ft^3
Compute temporary storage	$V_{f\text{-}temp}$ = ________ ft^3
	h_{temp} = ________ ft
10. Compute overflow weir sizes	
Compute overflow - Orifice equation	Q = ________ cfs
Weir from sedimentation chamber - Weir equation	Length = ________ ft
Weir from filtration chamber - Weir equation	Length = ________ ft

4.3.6.10 References

AMEC. *Knox County Stormwater Management Manual Volume 2, Technical Guidance*.

AMEC. *Metropolitan Nashville and Davidson County Stormwater Management Manual Volume 4 Best Management Practices.* 2006.

Atlanta Regional Council (ARC). *Georgia Stormwater Management Manual Volume 2 Technical Handbook.* 2001.

Center for Watershed Protection. *Manual Builder.* Stormwater Manager's Resource Center, Accessed July 2005. *www.stormwatercenter.net*.

City of Knoxville. *Knoxville Best Management Practices Manual.* City of Knoxville Stormwater Engineering Division, March 2003.

Claytor, R.A., and T.R. Schueler. *Design of Stormwater Filtering Systems.* The Center for Watershed Protection, Silver Spring, MD, 1996.

Connecticut Department of Environmental Protection. *Stormwater Quality Manual.* 2004.

Minnesota Pollution Control Agency. *Minnesota Stormwater Manual.* Accessed January 2006. http://www.pca.state.mn.us/water/stormwater/stormwater-manual.html

New Jersey Department of Environmental Protection. *Stormwater Best Management Practices Manual.* 2004.

StormwaterAuthority.com. *Sand and Organic Filters.* Accessed January 2006. www.stormwaterauthority.com

4.3.6.11 Suggested Reading

Bell, W., L. Stokes, L.J. Gavan, and T. Nguyen. *Assessment of the Pollutant Removal Efficiencies of Delaware Sand Filter BMPs.* City of Alexandria, Department of Transportation and Environmental Services, Alexandria, VA, 1995.

California Storm Water Quality Task Force. *California Storm Water Best Management Practice Handbooks,* 1993.

City of Sacramento, CA. *Guidance Manual for On-Site Stormwater Quality Control Measures.* Department of Utilities, 2000.

Horner, R.R., and C.R. Horner. *Design, Construction, and Evaluation of a Sand Filter Stormwater Treatment System. Part II: Performance Monitoring.* Report to Alaska Marine Lines, Seattle, WA, 1995.

Metropolitan Washington Council of Governments (MWCOG). *A Current Assessment of Urban Best Management Practices: Techniques for Reducing Nonpoint Source Pollution in the Coastal Zone.* March, 1992.

Northern Virginia Regional Commission (NVRC). *The Northern Virginia BMP Handbook.* Annandale, VA, 1992.

Schueler, T.R. *Developments in Sand Filter Technology to Improve Stormwater Runoff Quality.* Watershed Protection Techniques 1(2):47-54, 1994.

US EPA. *Storm Water Technology Fact Sheet: Sand Filters. EPA 832-F-99-007.* Office of Water. 1999.

Young, G.K., S. Stein, P. Cole, T. Kammer, F. Graziano, and F. Bank. *Evaluation and Management of Highway Runoff Water Quality.* FHWA-PD-96-032. Federal Highway Administration, Office of Environment and Planning, 1996.

4.3.7 Infiltration Trench

General Application Water Quality BMP

Description: An infiltration trench is an excavated trench filled with stone aggregate used to capture and allow infiltration of stormwater runoff into the surrounding soils from the bottom and sides of the trench.

KEY CONSIDERATIONS

DESIGN GUIDELINES:

- Soil infiltration rate of 0.5 in/hr or greater required.
- Excavated trench (3 to 8 foot depth) filled with stone media (1.5- to 2.5-inch diameter); pea gravel and sand filter layers.
- A sediment forebay and grass channel, or equivalent upstream pretreatment, must be provided.
- Observation well to monitor percolation.
- Size of drainage area.
- Maximum contributing drainage area of 5 acres.
- Must not be placed under pavement or concrete.

ADVANTAGES / BENEFITS:

- Provides for groundwater recharge.
- Good for small sites with porous soils.

DISADVANTAGES / LIMITATIONS:

- Potential for groundwater contamination.
- High clogging potential; should not be used on sites with fine-particle soils (clays or silts) in drainage area.
- Significant setback requirements.
- Restrictions in karst areas.
- Geotechnical testing required; two borings per facility.

MAINTENANCE REQUIREMENTS:

- Inspect for clogging.
- Remove sediment from forebay.
- Replace pea gravel layer as needed.

STORMWATER MANAGEMENT SUITABILITY

Stormwater Quality:	**Yes**
Channel Protection:	✷
Detention/Retention:	**No**

✷ in certain situations

Accepts hotspot runoff: *No*

COST CONSIDERATIONS

Land Requirement:	**Med**
Capital Cost:	**High**
Maintenance Burden:	**High**

LAND USE APPLICABILITY

Residential/Subdivision Use:	**Yes**
High Density/Ultra Urban Use:	**Yes**
Commercial/Industrial Use:	**Yes**

POLLUTANT REMOVAL

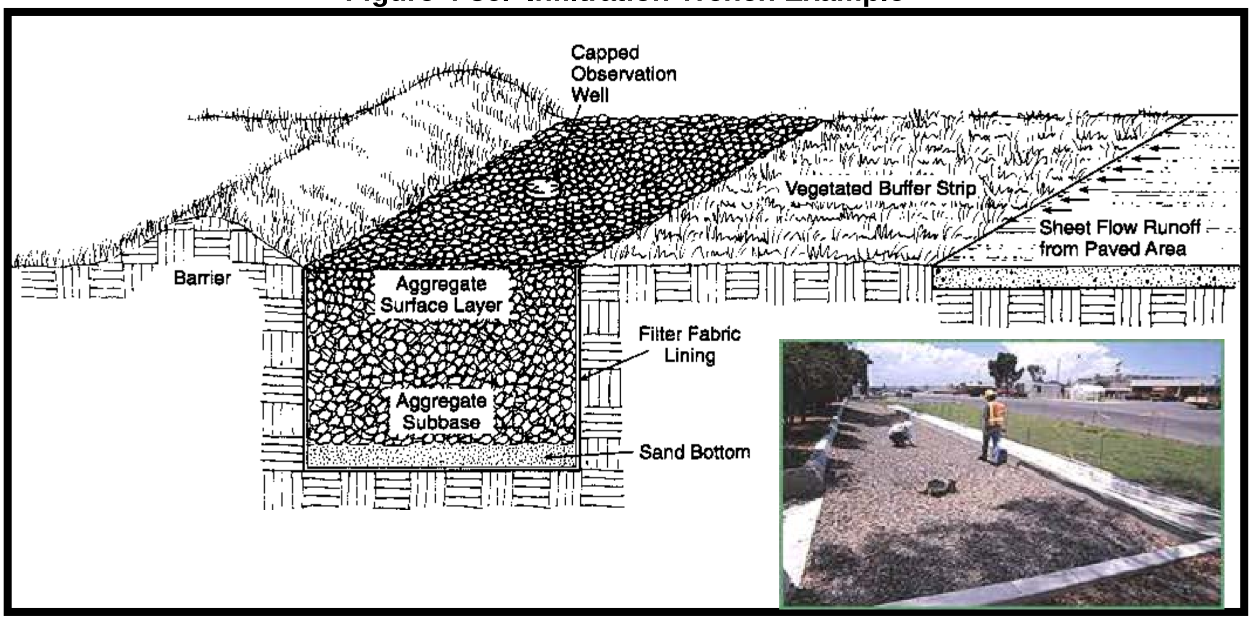
Total Suspended Solids:	**90%**

4.3.7.1 General Description

Infiltration trenches are excavations typically filled with stone to create an underground reservoir for stormwater runoff (see Figure 4-36). This runoff volume gradually infiltrates through the bottom and sides of the trench into the subsoil over a 2-day period and eventually reaches the water table. By diverting runoff into the soil, an infiltration trench not only treats the water quality volume, but also helps to preserve the natural water balance on a site and can recharge groundwater and preserve baseflow. Due to this fact, infiltration systems are limited to areas with highly porous soils where the water table and/or bedrock are located well below the bottom of the trench. In addition, infiltration trenches must be carefully sited to avoid the potential of groundwater contamination.

Infiltration trenches are not intended to trap sediment and must always be designed with a sediment forebay and grass channel or filter strip, or other appropriate pretreatment measures to prevent clogging and failure. Due to their high potential for failure, these facilities must only be considered for sites where upstream sediment control can be ensured.

Figure 4-36. Infiltration Trench Example



4.3.7.2 Stormwater Management Suitability

Infiltration trenches are designed primarily for stormwater quality. However, they can provide limited runoff quantity control, particularly for smaller storm events. For some smaller sites, trenches can be designed to capture and infiltrate the channel protection volume (CPv) in addition to the water quality volume (WQv). An infiltration trench will need to be used in conjunction with another structural BMP to provide flood protection from locally regulated peak discharges, if required.

<u>Water Quality (WQv)</u>
Using the natural filtering properties of soil, infiltration trenches can remove a wide variety of pollutants from stormwater through sorption, percolation, filtering, and bacterial and chemical degradation. Sediment load and other suspended solids are removed from runoff by pretreatment measures in the facility that treats flows before they reach the trench surface.

<u>Channel Protection (CPv)</u>
For smaller sites, an infiltration trench may be designed to capture and infiltrate the entire CPv in either an off or on-line configuration. For larger sites, or where only the WQv is diverted to the trench, another structural BMP must be used to provide CPv extended detention.

4.3.7.3 Pollutant Removal Capabilities

An infiltration trench is presumed to be able to remove 90% of the total suspended solids load in typical urban post-development runoff when sized, designed, constructed and maintained in accordance with the recommended specifications. The TSS removal performance is reduced for undersized, poorly designed, or unmaintained infiltration trenches.

The total suspended solids design pollutant removal rate of 90% is a conservative average pollutant reduction percentage for design purposes derived from sampling data, modeling and professional judgment.

For additional information and data on pollutant removal capabilities for infiltration trenches, see the National Pollutant Removal Performance Database (2nd Edition) available at www.cwp.org and the International Stormwater Best Management Practices (BMP) Database at www.bmpdatabase.org.

4.3.7.4 Application and Site Feasibility Criteria

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

Infiltration trenches can either be used to capture sheet flow from a drainage area or function as an off-line device. Due to the relatively narrow shape, infiltration trenches can be adapted to many different types of sites and can be utilized in retrofit situations. Unlike some other structural stormwater BMPs, they can easily fit into the margin, perimeter, or other unused areas of developed sites.

To protect groundwater from potential contamination, infiltration trenches cannot be utilized to treat runoff from hotspot land uses or activities, as identified by the local municipality. For example, infiltration trenches should not be used for manufacturing and industrial sites, where there is a potential for high concentrations of soluble pollutants and heavy metals, or for areas that may have a high pesticide concentration. Infiltration trenches are also not suitable in areas with karst geology without adequate geotechnical testing by qualified individuals.

The following criteria should be evaluated to ensure the suitability of an infiltration trench for meeting stormwater management objectives on a site or development.

General Feasibility

- Suitable for use in a residential subdivision
- Suitable for use in high density/ultra-urban areas
- Not suitable for use as a regional (i.e., off-site or treating more than one site) stormwater control

Physical Feasibility - Physical Constraints at Project Site

- Drainage Area – 5 acres maximum
- Space Required – Will vary depending on the depth of the facility
- Site Slope – No more than 6% slope (for pre-construction facility footprint) across the location of the infiltration trench
- Minimum Head – Elevation difference needed from the inflow of the infiltration trench to the outflow: 1 foot
- Minimum Depth to Water Table – 4 feet recommended between the bottom of the infiltration trench and the elevation of the seasonally high water table
- Soils – Infiltration rate greater than 0.5 inches per hour required (typically hydrologic group “A”, some

group “B” soils)

Other Constraints/Considerations

- Wellhead Protection – Reduce potential groundwater contamination (in required wellhead protection areas) by preventing infiltration of hotspot runoff. May require liner for type “A” and “B” soils; pretreat hotspots; provide 2 to 4 foot separation distance from water table.

4.3.7.5 Planning and Design Standards

The following standards are to be considered **minimum** standards for the design of an infiltration trench facility. Consult with the local municipality to determine if there are any variations to these criteria or additional standards that must be followed.

A. CONSTRUCTION SEQUENCING

- Ideally, the construction of an infiltration trench shall take place **after** the construction site has been stabilized.
- In the event that the infiltration trench is not constructed after stabilization, care shall be taken during construction to minimize the risk of premature failing of the infiltrations trench due to deposition of sediments from disturbed, unstabilized areas.
- Diversion berms and erosion prevention and sediment controls shall be maintained around an infiltration trench during all phases of construction. No runoff or sediment shall enter the infiltration trench area prior to completion of construction and the complete stabilization of construction areas.
- Infiltration trenches shall not be used as a temporary sediment trap for construction activities.
- During and after excavation of the infiltration trench, all excavated materials shall be placed downstream, away from the trench, to prevent redeposit of the material during runoff events.

B. LOCATION AND SITING

- To be suitable for infiltration, underlying soils should have an infiltration rate (f_c) of 0.5 inches per hour or greater, as initially determined from NRCS soil textural classification, and subsequently confirmed by field geotechnical tests. The minimum geotechnical testing is one test hole per 5,000 square feet, with a minimum of two borings per facility (taken within the proposed limits of the facility). Infiltration trenches cannot be used in fill soils.
- Heavy equipment shall not be utilized in the area where the infiltration trench will be located. Soil compaction will adversely affect the performance of the trench. Infiltration trench sites should be roped-off and flagged during construction.
- During excavation and trench construction, only light equipment such as backhoes or wheel and ladder type trenchers should be used to minimize compaction of surrounding soils.
- Infiltration trenches should have a contributing drainage area of 5 acres or less.
- Soils on the drainage area tributary to an infiltration trench should have a clay content of less than 20% and a silt/clay content of less than 40% to prevent clogging and failure.
- There should be at least 4 feet between the bottom of the infiltration trench and the elevation of the seasonally high water table.
- Clay lenses, bedrock or other restrictive layers below the bottom of the trench will reduce infiltration rates unless excavated.

Minimum setback requirements for infiltration trench facilities (when not specified by the local municipality):

- From a building foundation – 25 feet
- From a private well – 100 feet

- From a public water supply well – 1,200 feet
- From a septic system tank/leach field – 100 feet
- From surface waters – 100 feet
- From surface drinking water sources – 400 feet (100 feet for a tributary)

- When used in an off-line configuration, the water quality volume (WQv) is diverted to the infiltration trench through the use of a flow splitter. Stormwater flows greater than the WQv are diverted to other controls or downstream using a diversion structure or flow splitter.
- To reduce the potential for costly maintenance and/or system reconstruction, it is strongly recommended that the trench be located in an open or lawn area, with the top of the structure as close to the ground surface as possible. Infiltration trenches shall not be located beneath paved surfaces, such as parking lots.
- Infiltration trenches are designed for intermittent flow and must be allowed to drain and allow reaeration of the surrounding soil between rainfall events. They must not be used on sites with a continuous flow from groundwater, sump pumps, or other sources.

C. GENERAL DESIGN

- A well-designed infiltration trench consists of:
  (1) Excavated shallow trench backfilled with sand, coarse stone, and pea gravel, and lined with a filter fabric;
  (2) Appropriate pretreatment measures; and
  (3) One or more observation wells to show how quickly the trench dewaters or to determine if the device is clogged.

Figure 4-37 provides a plan view and profile schematic for the design of an off-line infiltration trench facility. An example of an observation well is shown in Figure 4-38.

D. PHYSICAL SPECIFICATIONS / GEOMETRY

- The required trench storage volume is equal to the water quality volume (WQv). For smaller sites, an infiltration trench can be designed with a larger storage volume to include the channel protection volume (CPv).
- A trench must be designed to fully dewater the entire WQv within 24 to 48 hours after a rainfall event. The slowest infiltration rate obtained from tests performed at the site should be used in the design calculations.
- Trench depths should be between 3 and 8 feet, to provide for easier maintenance. The width of a trench must be less than 25 feet.
- Broad, shallow trenches reduce the risk of clogging by spreading the flow over a larger area for infiltration.
- The surface area required is calculated based on the trench depth, soil infiltration rate, aggregate void space, and fill time (assume a fill time of 2 hours for most designs).
- The bottom slope of a trench should be flat across its length and width to evenly distribute flows, encourage uniform infiltration through the bottom, and reduce the risk of clogging.
- The stone aggregate used in the trench should be washed, bank-run gravel, 1.5 to 2.5 inches in diameter with a void space of about 40%. Aggregate contaminated with soil shall not be used. A porosity value (void space/total volume) of 0.32 should be used in calculations, unless aggregate specific data exist.
- A 6-inch layer of clean, washed sand is placed on the bottom of the trench to encourage drainage and prevent compaction of the native soil while the stone aggregate is added.

- The infiltration trench is lined on the sides and top by an appropriate geotextile filter fabric that prevents soil piping but has greater permeability than the parent soil. The top layer of filter fabric is located 2 to 6 inches from the top of the trench and serves to prevent sediment from passing into the stone aggregate. Since this top layer serves as a sediment barrier, it will need to be replaced more frequently and must be readily separated from the side sections.
- The top surface of the infiltration trench above the filter fabric is typically covered with pea gravel. The pea gravel layer improves sediment filtering and maximizes the pollutant removal in the top of the trench. In addition, it can easily be removed and replaced should the device begin to clog. Alternatively, the trench can be covered with permeable topsoil and planted with grass in a landscaped area.
- An observation well must be installed in every infiltration trench and should consist of a perforated PVC pipe, 4 to 6 inches in diameter, extending to the bottom of the trench. The observation well will show the rate of dewatering after a storm, as well as provide a means of determining sediment levels at the bottom and when the filter fabric at the top is clogged and maintenance is needed. It should be installed along the centerline of the structure, flush with the ground elevation of the trench. A visible floating marker should be provided to indicate the water level. The top of the well should be capped and locked to discourage vandalism and tampering.
- The trench excavation should be limited to the width and depth specified in the design. Excavated material should be placed away from the open trench so as not to jeopardize the stability of the trench sidewalls. The bottom of the excavated trench shall not be loaded in a way that causes soil compaction, and should be scarified prior to placement of sand. The sides of the trench shall be trimmed of all large roots. The sidewalls shall be uniform with no voids and scarified prior to backfilling. All infiltration trench facilities should be protected during site construction and should be constructed after upstream areas have been stabilized.
- Smearing of the soil at its interface with the trench bottom or sides must be avoided or corrected. Smearing can be corrected by raking or roto-tilling.

E. PRETREATMENT / INLETS

- Pretreatment facilities **must always** be used in conjunction with an infiltration trench to prevent clogging and failure.
- For a trench receiving sheet flow from an adjacent drainage area, the pretreatment system should consist of a vegetated filter strip with a minimum 25-foot length. A vegetated buffer strip around the entire trench is required if the facility is receiving runoff from both directions. If the infiltration rate for the underlying soils is greater than 2 inches per hour, 50% of the WQv should be pretreated by another method prior to reaching the infiltration trench.
- For an off-line configuration, pretreatment should consist of a sediment forebay, vault, plunge pool, or similar sedimentation chamber (with energy dissipaters) sized to 25% of the water quality volume (WQv). Exit velocities from the pretreatment chamber must be non-erosive for the 2-year design storm.

F. OUTLET STRUCTURES

- Outlet structures are not required for infiltration trenches.

G. EMERGENCY SPILLWAY

- Typically for off-line designs, there is no need for an emergency spillway. However, a non-erosive overflow channel should be provided to safely pass flows that exceed the storage capacity of the trench to a stabilized downstream area or watercourse.

H. MAINTENANCE ACCESS

- A minimum 20' wide maintenance right-of-way or drainage easement shall be provide for an infiltration trench, from a driveway, public or private road. The maintenance access easement shall have a maximum slope of no more than 15% and shall have a minimum unobstructed drive path having a width of 12 feet, appropriately stabilized to withstand maintenance equipment and vehicles. Adequate access must be provided to the grates to the filter bed for perimeter sand filter design. Facility designs must enable maintenance personnel to easily remove and replace upper layers of the infiltration media.

I. SAFETY FEATURES

- In general, infiltration trenches are not likely to pose a physical threat to the public and do not need to be fenced.

J. LANDSCAPING

- Vegetated filter strips and buffers should fit into and blend with surrounding area. Native grasses are preferable, if compatible. The trench may be covered with permeable topsoil and planted with grass in a landscaped area

K. ADDITIONAL SITE-SPECIFIC DESIGN CRITERIA AND ISSUES

There are a number of additional site specific design criteria and issues (listed below) that must be considered in the design of an infiltration trench.

Physiographic Factors - Local terrain design constraints

- High Relief – Maximum site slope of 6%
- Karst – Not suitable without adequate geotechnical testing

Special Downstream Watershed Considerations

- Wellhead Protection – Reduce potential groundwater contamination (in required wellhead protection areas) by preventing infiltration of hotspot runoff. May require liner for type “A” and “B” soils; Pretreat hotspots; provide 2 to 4 foot separation distance from water table.

4.3.7.6 Design Procedures

Step 1. Compute runoff control volumes

Calculate WQv, CPv, and the locally regulated peak discharge, in accordance with the guidance presented in Chapter 3.

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

Consider the subsections 4.3.7.4 and 4.3.7.5-B (Location and Siting).

Step 3. Confirm design criteria and applicability

Consider any special site-specific design conditions/criteria from subsection 4.3.7.5-K (Additional Site-Specific Design Criteria and Issues).

Check with the local municipality and other agencies to determine if there are any additional restrictions and/or surface water or watershed requirements that may apply.

Step 4. Compute WQv peak discharge (Q_{wq})

The peak rate of discharge for water quality design storm is needed for sizing of off-line diversion (see Chapter 3 for more information).

Step 5. Size flow diversion structure, if needed

A flow regulator (or flow splitter diversion structure) should be supplied to divert the WQv to the infiltration trench.

Size low flow orifice, weir, or other device to pass Q_{wq}.

Step 6. Size infiltration trench

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

$$A = \frac{WQv}{(nd + kT/12)}$$

where:

A	=	Surface Area
WQv	=	Water Quality Volume (or total volume to be infiltrated)
n	=	porosity
d	=	trench depth (feet)
k	=	percolation (inches/hour)
T	=	Fill Time (time for the practice to fill with water), in hours

A porosity value *n* = 0.32 should be used.

All infiltration systems should be designed to fully dewater the entire WQv within 24 to 48 hours after the rainfall event.

A fill time T=2 hours can be used for most designs.
See subsection 4.3.7.5-D (Physical Specifications/Geometry) for more specifications.

Step 7. Determine pretreatment volume and design pretreatment measures

Size pretreatment facility to treat 25% of the water quality volume (WQv) for off-line configurations. See subsection 4.3.7.5-E (Pretreatment / Inlets) for more details.

Step 8. Design spillway(s)

Adequate stormwater outfalls should be provided for the overflow exceeding the capacity of the trench, ensuring non-erosive velocities on the down-slope.

4.3.7.7 Maintenance Requirements and Inspection Checklist

Note: Section 4.3.7.7 must be included in the Operations and Maintenance Plan that is recorded with the deed.

Regular inspection and maintenance is critical to the effective operation of an infiltration trench as designed. It is the responsibility of the property owner to maintain all stormwater BMPs in accordance with the minimum design standards and other guidance provided in this manual. The local municipality has the authority to impose additional maintenance requirements where deemed necessary.

This page provides guidance on maintenance activities that are typically required for infiltration trenches, along with a suggested frequency for each activity. Individual trenches may have more, or less, frequent maintenance needs, depending upon a variety of factors including the occurrence of large storm events, overly wet or dry (i.e.., drought) regional hydrologic conditions, and any changes or redevelopment in the upstream land use. Each property owner shall perform the activities identified below at the frequency needed to maintain the infiltration trench in proper operating condition at all times.

Inspection Activities	**Suggested Schedule**
• A record should be kept of the dewatering time (i.e., the time required to drain the infiltration trench completely after a storm event) of the trench to determine if maintenance is necessary. The trench should drain completely in about 24 hours after the end of the rainfall. Ponded water inside the trench (as visible from the observation well or on the surface) longer than 24 hours or several days after a storm event is an indication that the trench is clogged.	After Rain Events
• Check that the area draining to the trench, the trench and its inlets are clear of debris. • Check the area draining to the trench for evidence of erosion.	Monthly
• Check observation wells following 3 days of dry weather. Failure to percolate within this time period indicates clogging. • Inspect pretreatment devices and diversion structures for sediment build-up and structural damage.	Semi-annual Inspection
Maintenance Activities	**Suggested Schedule**
• Remove sediment and oil/grease from pretreatment devices, as well as overflow structures. • Mow grass filter strips as necessary. Remove grass clippings.	Monthly
• Remove trees that start to grow in the vicinity of the trench.	Semi-annual Inspection
• Replace pea gravel/topsoil and top surface filter fabric (when clogged). Removed sediment and media may usually be disposed of in a landfill. • Stabilize (i.e., vegetate or cover) areas of erosion in the area draining to the trench.	As needed
• Perform total rehabilitation of the trench to maintain design storage capacity. • Excavate trench walls to expose clean soil.	Upon Failure

The local municipality encourages the use of the inspection checklist that is presented on the next page to guide the property owner in the inspection and maintenance of an infiltration trench. The local municipality can require the use of this checklist or other form(s) of maintenance documentation when and where deemed necessary in order to ensure the long-term proper operation of the trench. Questions regarding stormwater facility inspection and maintenance should be referred to the local municipality.

INSPECTION CHECKLIST AND MAINTENANCE GUIDANCE (continued)
INFILTRATION TRENCH INSPECTION CHECKLIST

Location: ______________________________________ Owner Change since last inspection? Y N

Owner Name, Address, Phone: ______________________________________

Date: ___________ Time: ______________ Site conditions:______________________________

Inspection Items	Satisfactory (S) or Unsatisfactory (U)	Comments/Corrective Action
Inspection List		
Complete drainage of the filter in about 24 to 48 hours after a rain event?		
Clogging of trench surface?		
Clogging of inlet/outlet structures?		
Standing water in observation well when no water should be present?		
Trench clear of debris and functional?		
Evidence of leaks or seeps?		
Animal burrows in trench?		
Cracking, spalling, bulging or deterioration of concrete?		
Erosion in area draining to trench?		
Erosion around inlets, trench, or outlets?		
Pipes and other structures in good condition?		
Undesirable vegetation growth?		
Other (describe)?		
Hazards		
Have there been complaints from residents?		
Public hazards noted?		

If any of the above inspection items are **UNSATISFACTORY**, list corrective actions and the corresponding completion dates below:

Corrective Action Needed	Due Date

Inspector Signature:________________________________ Inspector Name (printed)____________________________

4.3.7.8 Example Schematics

Figure 4-37. Schematic of an Infiltration Trench

(Source: Center for Watershed Protection)

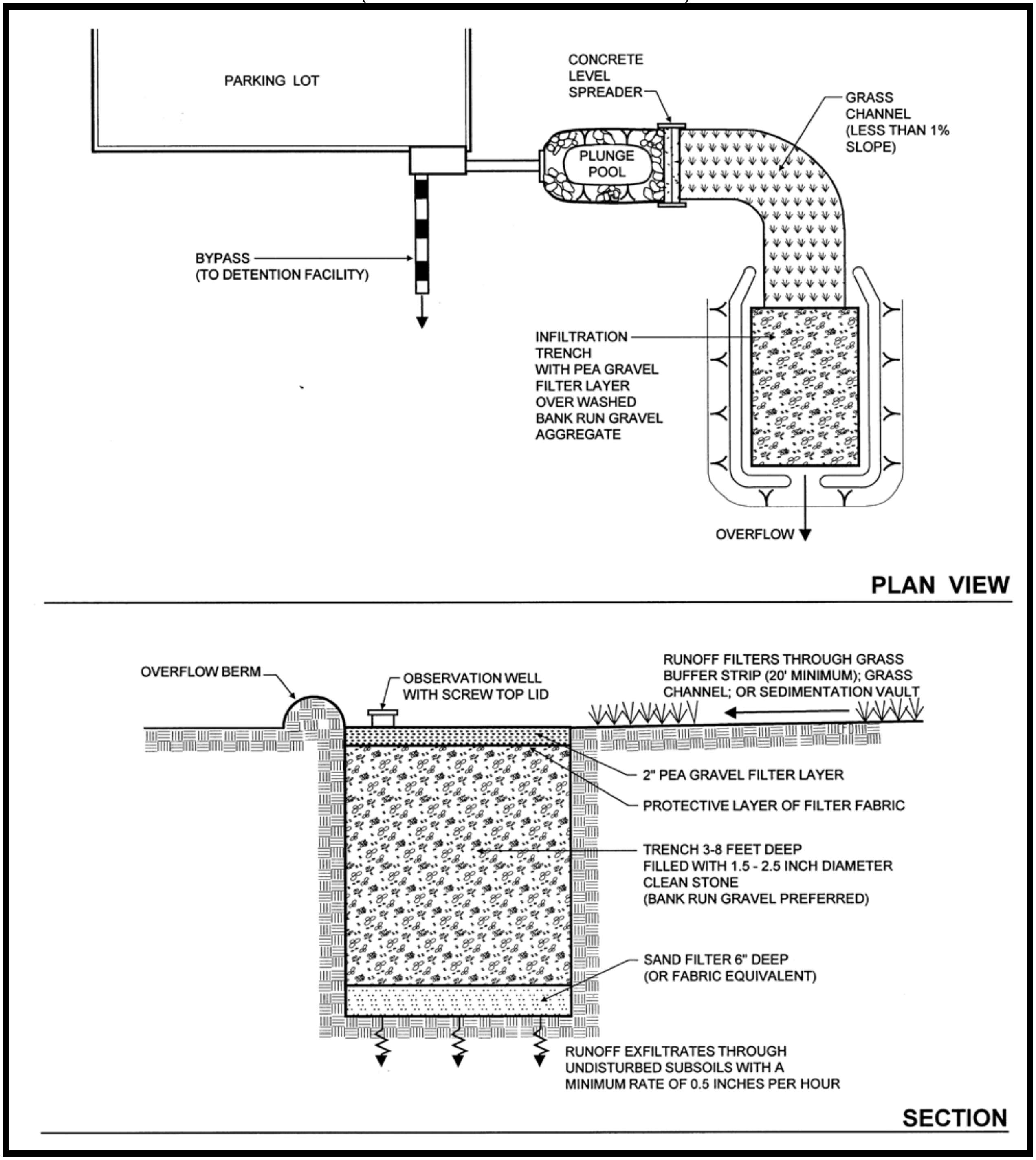
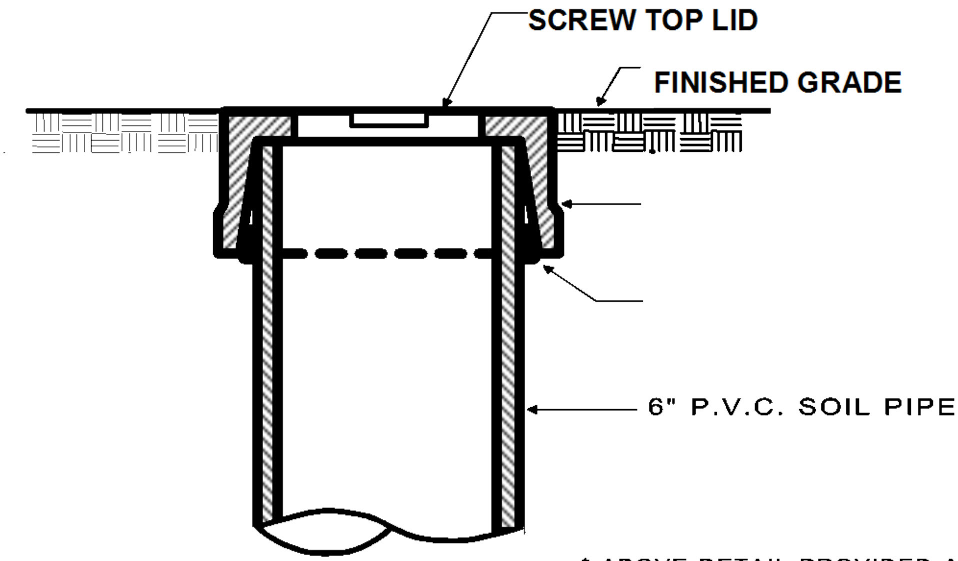


Figure 4-38. Observation Well Detail



* ABOVE DETAIL PROVIDED AS SCHEMATIC
SCREW TOP P.V.C. WELL CAP ONLY

EACH OBSERVATION WELL / CLEANOUT SHALL INCLUDE THE FOLLOWING:

1. FOR AN UNDERGROUND FLUSH MOUNTED OBSERVATION WELL / CLEANOUT, PROVIDE A TUBE MADE OF NON-CORROSIVE MATERIAL, SCHEDULE 40 OR EQUAL, AT LEAST THREE FEET LONG WITH AN INSIDE DIAMETER OF AT LEAST 6 INCHES.

2. THE TUBE SHALL HAVE A FACTORY ATTACHED CAST IRON OR HIGH IMPACT PLASTIC COLLAR WITH RIBS TO PREVENT ROTATION WHEN REMOVING SCREW TOP LID. THE SCREW TOP LID SHALL BE CAST IRON OR HIGH IMPACT PLASTIC THAT WILL WITHSTAND ULTRA-VIOLET RAYS.

4.3.7.9 Design Form

The local municipality recommends the use of the following design procedure forms when designing infiltration trenches. Proper use and completion of the form may allow a faster review of the Water Quality Management Plan by the local municipality.

Design Procedure Form: Infiltration Trench

PRELIMINARY HYDROLOGIC CALCULATIONS	
1a. Compute WQv volume requirements	
Compute Runoff Coefficient, R_v	Rv = ________
Compute WQv	WQv = ________ acre-ft
1b. Compute CPv	CPv = ________ acre-ft
Compute average release rate	release rate = ________ cfs
Compute storage volume required for locally regulated storm events	storage = ________ acre-ft storage = ________ acre-ft
INFILTRATION TRENCH DESIGN	
2. Is the use of an infiltration trench appropriate?	***See subsections 4.3.7.4 and 4.3.7.5 - B***
3. Confirm local design criteria and applicability.	***See subsection 4.3.7.5 - K***
4. Compute WQv peak discharge (Q_{wq})	
Compute Curve Number	CN = ________
Compute Time of Concentration t_c	t_c = ________ hour
Compute Q_{wq}	Q_{wq} = ________ cfs
5. Size infiltration trench	Area = ________ ft^2
Width must be less than 25 ft	Width = ________ ft Length = ________ ft
6. Size the flow diversion structures	
Low flow orifice from orifice equation	
$Q = CA(2gh)^{0.5}$	A = ________ ft^2
C varies with orifice condition	diam. = ________ inch
Overflow weir from weir equation	
$Q = CLH^{3/2}$	Length = ________ ft
7. Pretreatment volume (for offine designs)	
$Vol_{pre} = 0.25(WQv)$	Vol_{pre} = ________ ft^3
8. Design spillway(s)	

4.3.7.10 References

AMEC. *Knox County Stormwater Management Manual Volume 2, Technical Guidance*.

AMEC. *Metropolitan Nashville and Davidson County Stormwater Management Manual Volume 4 Best Management Practices.* 2006.

Atlanta Regional Council (ARC). *Georgia Stormwater Management Manual Volume 2 Technical Handbook.* 2001.

Center for Watershed Protection. *Manual Builder.* Stormwater Manager's Resource Center, Accessed July 2005. *www.stormwatercenter.net*.

Federal Highway Administration (FHWA). *Stormwater Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring.* United States Department of Transportation, Accessed January 2006. http://www.fhwa.dot.gov/environment/ultraurb/index.htm

4.3.7.11 Suggested Reading

California Storm Water Quality Task Force. *California Storm Water Best Management Practice Handbooks.* 1993.

City of Austin, TX. *Water Quality Management.* Environmental Criteria Manual, Environmental and Conservation Services, 1988.

City of Sacramento, CA. *Guidance Manual for On-Site Stormwater Quality Control Measures.* Department of Utilities, 2000.

Claytor, R.A., and T.R. Schueler. *Design of Stormwater Filtering Systems.* The Center for Watershed Protection, Silver Spring, MD, 1996.

US EPA. *Storm Water Technology Fact Sheet: Storm Water Wetlands.* EPA 832-F-99-025. Office of Water, 1999.

Faulkner, S. and C. Richardson. *Physical and Chemical Characteristics of Freshwater Wetland Soils.* Constructed Wetlands for Wastewater Treatment, ed. D. Hammer, Lewis Publishers, 831 pp, 1991.

Guntenspergen, G.R., F. Stearns, and J. A. Kadlec. *Wetland Vegetation.* Constructed Wetlands for Wastewater Treatment, ed. D. A. Hammer, Lewis Publishers, 1991.

Maryland Department of the Environment. *Maryland Stormwater Design Manual, Volumes I and II.* Prepared by Center for Watershed Protection (CWP), 2000.

Metropolitan Washington Council of Governments (MWCOG). *A Current Assessment of Urban Best Management Practices: Techniques for Reducing Nonpoint Source Pollution in the Coastal Zone.* March, 1992.

4.3.8 Enhanced Swales

General Application
Water Quality BMP

Description: Enhanced swales are vegetated open channels that are explicitly designed and constructed to capture and treat stormwater runoff within dry or wet cells formed by check dams or other means.

KEY CONSIDERATIONS

DESIGN GUIDELINES:

- Maximum contributing drainage area of 5 acres.
- Longitudinal slopes must be less than 4%.
- Bottom width of 2 to 8 feet.
- Side slopes 2:1 or flatter; 4:1 recommended.
- Convey the 25-year storm event with a minimum of 6 inches of freeboard.
- No soil restrictions.
- Dry swales require a permeable soil layer.
- Wet swales require wetland plants.

ADVANTAGES / BENEFITS:

- Combines stormwater treatment with runoff conveyance system.
- Less expensive than curb and gutter.
- Reduces runoff velocity and the potential for channel/ditch erosion.

DISADVANTAGES / LIMITATIONS:

- Higher maintenance than curb and gutter.
- Cannot be used on steep slopes.
- Possible resuspension of sediment.
- Potential for odor / mosquitoes (wet swale).

MAINTENANCE REQUIREMENTS:

- Maintain grass heights of approximately 4 to 6 inches (dry swale).
- Occasional sediment removal from forebay and channel.

STORMWATER MANAGEMENT SUITABILITY

Stormwater Quality:	**Yes**
Channel Protection:	✷
Detention/Retention:	**No**

✷ in certain situations

Accepts hotspot runoff: *Yes (requires impermeable liner)*

COST CONSIDERATIONS

Land Requirement:	**High**
Capital Cost:	**Med**
Maintenance Burden:	**Low**

LAND USE APPLICABILITY

Residential/Subdivision Use:	**Yes**
High Density/Ultra Urban Use:	**No**
Commercial/Industrial Use:	**Yes**

POLLUTANT REMOVAL

Total Suspended Solids:	**75-90%**

4.3.8.1 General Description

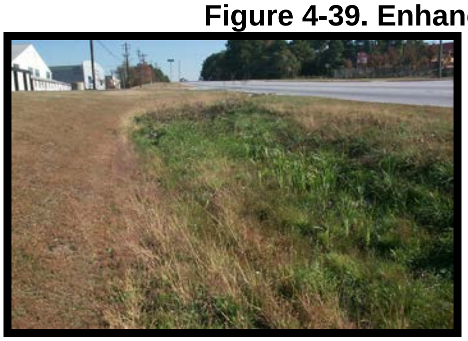
Enhanced swales (also referred to as *vegetated open channels* or *water quality swales*) are conveyance channels engineered to capture and treat the water quality volume (WQv) for a drainage area. They differ from a normal drainage channel or conventional swale because they incorporate specific features that enhance stormwater pollutant removal effectiveness.

Enhanced swales are designed with limited longitudinal slopes to force the stormwater flow to be slow and shallow, thus allowing for particulates to settle and limiting the effects of erosion. Berms and/or check dams installed perpendicular to the flow path promote settling and infiltration.

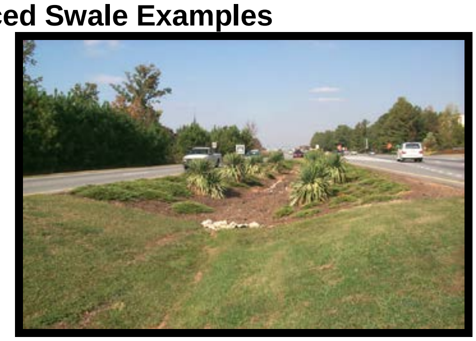
There are two primary enhanced swale designs, the *dry swale* and the *wet swale* (or *wetland channel*). Below are descriptions of these two designs:

- **Dry Swale** – The dry swale is a vegetated conveyance channel designed to include a filter bed of prepared soil that overlays an underdrain system. Dry swales are sized to allow the entire WQv to be filtered or infiltrated through the bottom of the swale. Because they are dry most of the time, they are often the preferred option in residential settings.
- **Wet Swale (Wetland Channel)** – The wet swale is a vegetated channel designed to retain water or marshy conditions that support wetland vegetation. A high water table or poorly drained soils are necessary to retain water. The wet swale essentially acts as a linear shallow wetland treatment system, where the WQv is retained.

Figure 4-39. Enhanced Swale Examples



Enhanced Dry Swale



Enhanced Wet Swale

Enhanced swales must not to be confused with a *filter strip* or *grass channel*, because they afford a much higher level of water quality treatment than the latter BMPs. Ordinary *grass channels* are not engineered to provide the same treatment capability as a well-designed dry swale with filter media. *Filter strips* are designed to accommodate overland flow rather than channelized flow and can be used as stormwater credits to help reduce the total water quality treatment volume for a site. Both of these practices may be used for pretreatment or included in a "treatment train" approach where redundant treatment is provided. Please see a further discussion of these structural controls in subsections 4.3.9 and 4.3.10, respectively.

4.3.8.2 Stormwater Management Suitability

Enhanced swale systems are designed primarily for stormwater quality and have only a limited ability to provide channel protection or flood protection.

<u>Water Quality (WQv) and Channel Protection (CPv)</u>
Dry swale systems rely primarily on filtration through an engineered media to provide removal of stormwater contaminants. Wet swales achieve pollutant removal both from sediment accumulation and biological removal. Generally only the WQv is treated by a dry or wet swale, and another structural BMP

must be used to provide extended detention of the CPv. However, for some smaller sites, a swale may be designed to capture and detain the full CPv.

4.3.8.3 Pollutant Removal Capabilities

The dry enhanced swale is presumed to be able to remove 90% of the TSS load in typical urban post-development runoff when sized, designed, constructed and maintained in accordance with the recommended specifications. The TSS removal value for wet swales is 75%. Undersized or poorly designed swales can reduce TSS removal performance.

The following design pollutant removal rates are conservative average pollutant reduction percentages for design purposes derived from sampling data, modeling and professional judgment. In a situation where a removal rate is not deemed sufficient, additional controls may be put in place at the given site in a series or "treatment train" approach.

- Total Suspended Solids – Dry Swale 90% / Wet Swale 75%

For additional information and data on pollutant removal capabilities for enhanced dry and wet swales, see the National Pollutant Removal Performance Database (2nd Edition) available at www.cwp.org and the International Stormwater Best Management Practices (BMP) Database at www.bmpdatabase.org.

4.3.8.4 Application and Feasibility Criteria

Enhanced swales can be used in a variety of development types; however, they are primarily applicable to residential and commercial areas of low to moderate density where the impervious cover in the contributing drainage area is relatively small, and along roads and highways. Dry swales are mainly used in moderate to large lot residential developments, small impervious areas (parking lots and rooftops), and along rural highways. Wet swales tend to be used for highway runoff applications, small parking areas, and in commercial developments as part of a landscaped area.

Because of their relatively large land requirement, enhanced swales are generally not used in higher density areas. In addition, wet swales may not be desirable for some residential applications, due to the presence of standing and stagnant water, which may create nuisance odor or mosquito problems.

The topography and soils of a site will determine the applicability of one of the two enhanced swale designs. Overall, the topography should allow for the design of a swale with sufficient slope and cross-sectional area to maintain non-erosive velocities. The following criteria should be evaluated to ensure the suitability of a stormwater basin for meeting stormwater management objectives on a site or development.

<u>General Feasibility</u>

- Suitable for use in residential subdivisions and in non-residential areas.
- Not generally suitable for high density/ultra-urban areas, as land requirements may preclude their use.
- Not suitable for use as a regional stormwater control.

<u>Physical Feasibility - Physical Constraints at Project Site</u>

- <u>Drainage Area</u> – 5 acres maximum
- <u>Space Required</u> – Approximately 10 to 20% of the tributary impervious area
- <u>Channel Slope</u> – Channel slope shall not exceed 4%
- <u>Minimum Head</u> – Elevation difference needed at a site from the inflow to the outflow: 3 to 5 feet for dry swale; 1 foot for wet swale

- Minimum Depth to Water Table – 2 feet required between the bottom of a dry swale and the elevation of the seasonally high water table, if an aquifer or treating a stormwater discharging from a hotspot land use; wet swale is below water table or placed in poorly drained soils
- Soils – Engineered media for dry swale

Other Constraints / Considerations

- Aquifer Protection – Exfiltration from the enhanced swale should be prevented in enhanced swales that serve hotspot land uses.

4.3.8.5 Planning and Design Standards

The following standards shall be considered **minimum** design standards for the design of an enhanced swale. Enhanced swales that are not designed to these standards will not be approved. The local municipality shall have the authority to require additional design conditions if deemed necessary.

A. LOCATION AND SITING

- A dry or wet swale shall be located on a property such that the topography allows for the design of a channel with sufficiently mild slope, as discussed in part C below (unless small drop structures are used), and sufficient cross-sectional area to maintain non-erosive velocities. Site designers shall also take into account the location and use of other site features, such as buffers and undisturbed natural areas when determining the location of an enhanced swale, and should attempt to aesthetically "fit" the facility into the landscape.
- Enhanced swale systems shall have a contributing drainage area of 5 acres or less.
- A wet swale shall only be used where the water table is at or near the soil surface, or where there is a sufficient water balance in poorly drained soils to support a wetland plant community.

B. GENERAL DESIGN

- Enhanced swales that are located "on-line" shall also be designed to safely pass larger flows in accordance with the local municipality's design criteria for open channels (Chapter 2). Flow enters the channel through a pretreatment forebay. Runoff can also enter along the sides of the channel as sheet flow through the use of a pea gravel flow spreader trench located along the top of the bank of the swale.

Dry Swale

- A dry swale system shall consist of an open conveyance channel with a filter bed of permeable soils that overlay an underdrain system. Flow passes into and is detained in the main portion of the channel where it is filtered through the soil bed. Runoff is collected and conveyed by a perforated pipe and gravel underdrain system to the outlet. Figure 4-40 presented at the end of this section provides a plan view and profile schematic for the design of a dry swale system.

Wet Swale

- A wet swale or wetland channel shall consist of an open conveyance channel which has been excavated to the water table or to poorly drained soils. Check dams are used to create multiple wetland "cells," which act as miniature shallow marshes. Figure 4-41 presented at the end of this section provides a plan view and profile schematic for the design of a wet swale system.

C. PHYSICAL SPECIFICATIONS / GEOMETRY

General

- The enhanced swale shall have a minimum slope of 1%, and the slope shall not exceed 4%. A 1% to 2% slope is considered ideal. Where topography necessitates a slope steeper than 2%, 6 to 12-inch drop structures must be designed and constructed to limit the energy slope to within the recommended 1 to 2% range. Energy dissipation is required below the drops. The drops shall be spaced a minimum of 50 feet apart.

- The maximum WQv ponding depth in the enhanced swale shall not exceed 18 inches at the end point of the swale. An average depth of 12-inches shall be maintained.
- Enhanced swales shall have a bottom width ranging from 2 to 8 feet to ensure adequate filtration. Wider channels will be permitted, but must contain berms, walls, or a compound cross-section to prevent channel braiding or uncontrolled sub-channel formation.
- Enhanced swales shall have a trapezoidal or compound cross-section. Side slopes shall not exceed 2:1. The local municipality may approve side slopes up to 4:1 where side inflows by sheet flow will not be substantial, and where such swales can be easily maintained. Side slopes greater than 2:1 in residential areas are strongly discouraged.
- Enhanced swales shall be designed such that the peak velocity for the 2-year storm must be conveyed in a non-erosive manner, given the soil and vegetative cover provided.
- If the enhanced swale is on-line, the swale shall be sized to convey runoff for the locally regulated peak discharge.

Dry Swale

- Dry swale channels shall be sized to store and infiltrate the entire water quality volume (WQv) with less than 18 inches of ponding and allow for full filtering through the permeable soil layer. Ponding shall occur for no longer than 48 hours, though a 24-hour ponding time is more desirable.
- The bed of a dry swale shall consist of a permeable soil layer of at least 30 inches in depth, above a 4-inch diameter perforated longitudinal underdrain (PVC AASHTO M 252, HDPE or other suitable underdrain pipe material) in a 6-inch gravel layer. The soil media shall have an infiltration rate of at least 1 foot per day (1.5 feet per day maximum) and contain a high level of organic material to facilitate pollutant removal. A permeable filter fabric shall be placed between the gravel layer and the overlying soil.
- Excavation of the dry swale and its associated underdrain shall be limited to the width and depth specified in the design. The bottom of the excavated trench shall not be loaded in a way that causes soil compaction, and shall be scarified prior to placement of gravel and permeable soil. The sides of the channel shall be trimmed of all large roots. The sidewalls shall be uniform with no voids and scarified prior to backfilling.

Wet Swale

- Wet swale channels are sized to retain the entire water quality volume (WQv) with less than 18 inches of ponding at the maximum depth point.
- Check dams can be used to achieve multiple wetland cells. V-notch weirs in the check dams can be utilized to direct low flow volumes.

<u>D. PRETREATMENT / INLETS</u>

- Inlets to enhanced swales shall include energy dissipators, such as riprap.
- Pretreatment of runoff in both a dry and wet swale system shall be provided by a sediment forebay located at the inlet. The pretreatment volume shall be equal to 0.1 inches per impervious acre (363 ft^3). This storage can be obtained by providing check dams at pipe inlets and/or driveway crossings.
- Enhanced swale systems that receive direct concentrated runoff (as opposed to shallow concentrated or overland flow) shall have a 6-inch drop to a pea gravel diaphragm flow spreader at the upstream end of the control.
- A pea gravel diaphragm and gentle side slopes shall be provided along the top of channels to provide pretreatment for lateral sheet inflows.

E. OUTLET STRUCTURES

Dry Swale

- The underdrain system shall discharge to the storm drainage infrastructure or a stable outfall in a non-erosive manner.

Wet Swale

- Outlet protection shall be used at any discharge point from a wet swale to prevent scour and downstream erosion.

F. MAINTENANCE ACCESS

- A minimum 20' wide maintenance right-of-way or drainage easement shall be provided for the length of the enhanced swale from a driveway, public or private road. The maintenance access easement shall have a maximum slope of no more than 15% and shall have a minimum unobstructed drive path having a width of 12 feet, appropriately stabilized to withstand maintenance equipment and vehicles. The right-of-way shall be located such that maintenance vehicles and equipment can access the entire enhanced swale.

G. LANDSCAPING

- The water quality management plan shall specify the landscape design of the enhanced swale, and shall include appropriate grass species and/or wetland plants based on specific site, soils and hydric conditions present along the swale. Vegetation shall be limited to grasses and non-woody wetland plants. Trees and other large woody plant species are not appropriate for use in an enhanced swale and are prohibited.

Dry Swale

- Turf grasses that require minimal maintenance shall be used in dry swales. Native grasses are preferred, but not required. Maintenance of the turf grasses shall be performed as appropriate to maintain a stable and viable coverage of the swale bottom and side slopes.

Wet Swale

- At the time of construction, emergent vegetation shall be planted in the swale, or wetland soils may be spread on the swale bottom for seed stock. More information on wetland plants can be found at the following websites:
    - http://wetlands.fws.gov/
    - http://www.npwrc.usgs.gov/resource/plants/floraso/species.htm
- Where wet swales do not intercept the groundwater table, a water balance calculation shall be performed to ensure an adequate water budget to support the specified wetland species. See Chapter 3 of the Northeast Tennessee Stormwater Planning Group Regional Water Quality BMP Manual for guidance on water balance calculations.

H. ADDITIONAL SITE-SPECIFIC DESIGN CRITERIA AND ISSUES

There are a number of additional site specific design criteria and issues (listed below) that must be considered in the design of an enhanced swale.

Physiographic Factors - Local terrain design constraints

- Low Relief – Reduced need for use of check dams
- High Relief – Not feasible if slopes are greater than 4%
- Karst – No exfiltration of runoff from dry swales located in hotspot land uses; an impermeable liner shall be utilized for swales that control stormwater discharges from hotspot land uses.

Special Downstream Watershed Considerations

- Wellhead Protection – Reduce potential groundwater contamination (in required wellhead protection areas) by preventing infiltration of runoff from land uses that have a high pollution potential. May require liner for type “A” and “B” soils; Pretreat runoff from polluted areas and hotspot land uses; 2 to 4 foot separation distance from water table

4.3.8.6 Design Procedures

Step 1. Compute appropriate runoff control volumes and peak discharges

Calculate WQv, CPv, and the locally regulated peak discharge, in accordance with the guidance presented in Chapter 3.

Step 2. Determine if the development site and conditions are appropriate for the use of an enhanced swale system (dry or wet swale).

Consider the subsections 4.3.8.4 and 4.3.8.5-A (Location and Siting). Check with the local municipality and other agencies to determine if there are any additional restrictions and/or surface water or watershed requirements that may apply.

Step 3. Determine pretreatment volume

The sediment forebay should be sized to contain 0.1 inches per impervious acre (363 ft^3) of contributing drainage. The forebay storage volume counts toward the total WQv requirement, and should be subtracted from the WQv for subsequent calculations.

Step 4. Determine swale dimensions and compute number of check dams (or similar structures) required to detain WQv as per the above stated design criteria.

Size bottom width, depth, length, and slope necessary to store WQv with less than 18 inches of ponding at the downstream end.

- Slope cannot exceed 4% (1 to 2% recommended)
- Bottom width should range from 2 to 8 feet
- Ensure that side slopes are no greater than 2:1

Step 5. Calculate draw-down time

Dry swale: Planting soil should pass a maximum rate of 1.5 feet in 24 hours and must completely filter WQv within 48 hours.

Wet swale: Must hold the WQv.

Step 6. Check 2-year and 25-year velocity erosion potential and freeboard

Check for erosive velocities and modify design as appropriate. Provide 6 inches of freeboard for the 25-year event.

Step 7. Design low flow orifice at downstream headwalls and check dams

Design orifice to pass WQv in six hours.

Step 8. Design inlets, sediment forebay(s), and underdrain system (dry swale)

See design criteria above for further details.

Step 9. Prepare Vegetation and Landscaping Plan

A landscaping plan for a dry or wet swale shall be submitted with the stormwater management plan that indicates the vegetation proposed for the swale, and how the enhanced swale system will be stabilized and established with vegetation.

4.3.8.7 Maintenance Requirements and Inspection Checklist

Note: Section 4.3.8.7 must be included in the Operations and Maintenance Plan that is recorded with the deed.

Regular inspection and maintenance is critical to the effective operation of enhanced swales as designed. It is the responsibility of the property owner to maintain all stormwater BMPs in accordance with the minimum design standards and other guidance provided in this manual. The local municipality has the authority to impose additional maintenance requirements where deemed necessary.

This page provides guidance on maintenance activities that are typically required for enhanced swales, along with a suggested frequency for each activity. Individual enhanced swales may have more, or less, frequent maintenance needs, depending upon a variety of factors including the occurrence of large storm events, overly wet or dry (i.e.., drought) regional hydrologic conditions, and any changes or redevelopment in the upstream land use. Each property owner shall perform the activities identified below at the frequency needed to maintain the swale in proper operating condition at all times.

Inspection Activities	Suggested Schedule
• Inspect after seeding and after first major storm for any damage to vegetation, side slopes and bottom.	Post construction
• Inspect for signs of erosion, unhealthy or damaged vegetation, denuded areas, channelization of flow, debris and litter, and areas of sediment accumulation. Perform inspections at the beginning and end of the wet season. Additional inspections after periods of heavy rainfall are desirable.	Semi-annually
• Inspect level spreader for clogging (if applicable), grass along side slopes for erosion and formation of rills or gullies, and sand/soil bed for erosion problems. Inspect pea gravel diaphragm for clogging. • Inspect sediment forebays and/or pretreatment areas for debris and sediment accumulation.	Annually
Maintenance Activities	**Suggested Schedule**
• Mow grass to maintain a height of 3–4 inches, for safety, aesthetic, or other purposes, if needed. Litter should always be removed prior to mowing. Grass clippings, if captured, should not be dumped in the swale. • Irrigate swale during dry season (April through October) or when necessary to maintain the vegetation. • Repair damaged areas (e.g., erosion rills or gullies) and re-establish vegetation where needed. Remove invasive species manually. The use of fertilizers, herbicides and pesticides should occur only when absolutely necessary, and then in minimal amounts.	As needed (frequent, seasonally)
• Remove litter, branches, rocks blockages, and other debris and dispose of properly. • Clear accumulated debris and sediment from the inlet flow spreader (if applicable) and pea gravel diaphragm.	Semi-annually
• Inspect pea gravel diaphragm for clogging and correct the problem. • Plant an alternative grass species if the original grass cover has not been successfully established. Reseed and apply mulch to damaged areas.	Annually (if needed)
• Remove all accumulated sediment that may obstruct flow through the swale. Sediment accumulating near culverts and in channels should be removed when it builds up to 3 in. at any spot, or covers vegetation, or once it has accumulated to 10% of the original design volume. Replace the grass areas damaged in the process. • Remove all accumulated sediment in the sediment forebay and pretreatment areas. • Repair areas of erosion around swale and underdrain outlets. Reestablish soil stabilization measures (e.g., rip-rap stone, turf grasses) as needed. • Roto-till or cultivate the surface of the sand/soil bed of dry swales if the swale does not draw down within 48 hours. Re-establish swale vegetation after roto-till activities.	As needed (infrequent)

The local municipality encourages the use of the inspection checklist that is presented on the next page to guide the property owner in the inspection and maintenance of enhanced swales. The local municipality can require the use of this checklist or other form(s) of maintenance documentation when and where deemed necessary in order to ensure the long-term proper operation of the enhanced swale.

INSPECTION CHECKLIST AND MAINTENANCE GUIDANCE (continued)
ENHANCED SWALE INSPECTION CHECKLIST

Location: ____ Owner Change since last inspection? Y N

Owner Name, Address, Phone: ____

Date: ___________ Time: ______________ Site conditions:____

Inspection Items	Satisfactory (S) or Unsatisfactory (U)	Comments/Corrective Action
Enhanced Swale		
Healthy vegetation?		
Erosion on bottom or side slopes?		
Animal burrows in swale?		
Clear of debris and functional?		
Check dams in place (if applicable)?		
Evidence of sediment accumulation?		
Unintentional obstructions or blockages?		
Clogged pea gravel diaphragm?		
Undesirable vegetation growth?		
Visible pollution?		
Other (describe)?		
Inlet/Outlet Channels		
Clear of debris and functional?		
Sediment accumulation?		
Signs of erosion?		
Other (describe)?		
Sediment Forebays or Pretreatment Areas		
Evidence of sediment accumulation?		
Hazards		
Have there been complaints from residents?		
Public hazards noted?		

If any of the above inspection items are **UNSATISFACTORY**, list corrective actions and the corresponding completion dates below:

Corrective Action Needed	Due Date

Inspector Signature: ______________________________ **Inspector Name (printed)**______________________

4.3.8.8 Example Schematics

Figure 4-40. Schematic of a Dry Swale
(Source: Center for Watershed Protection)

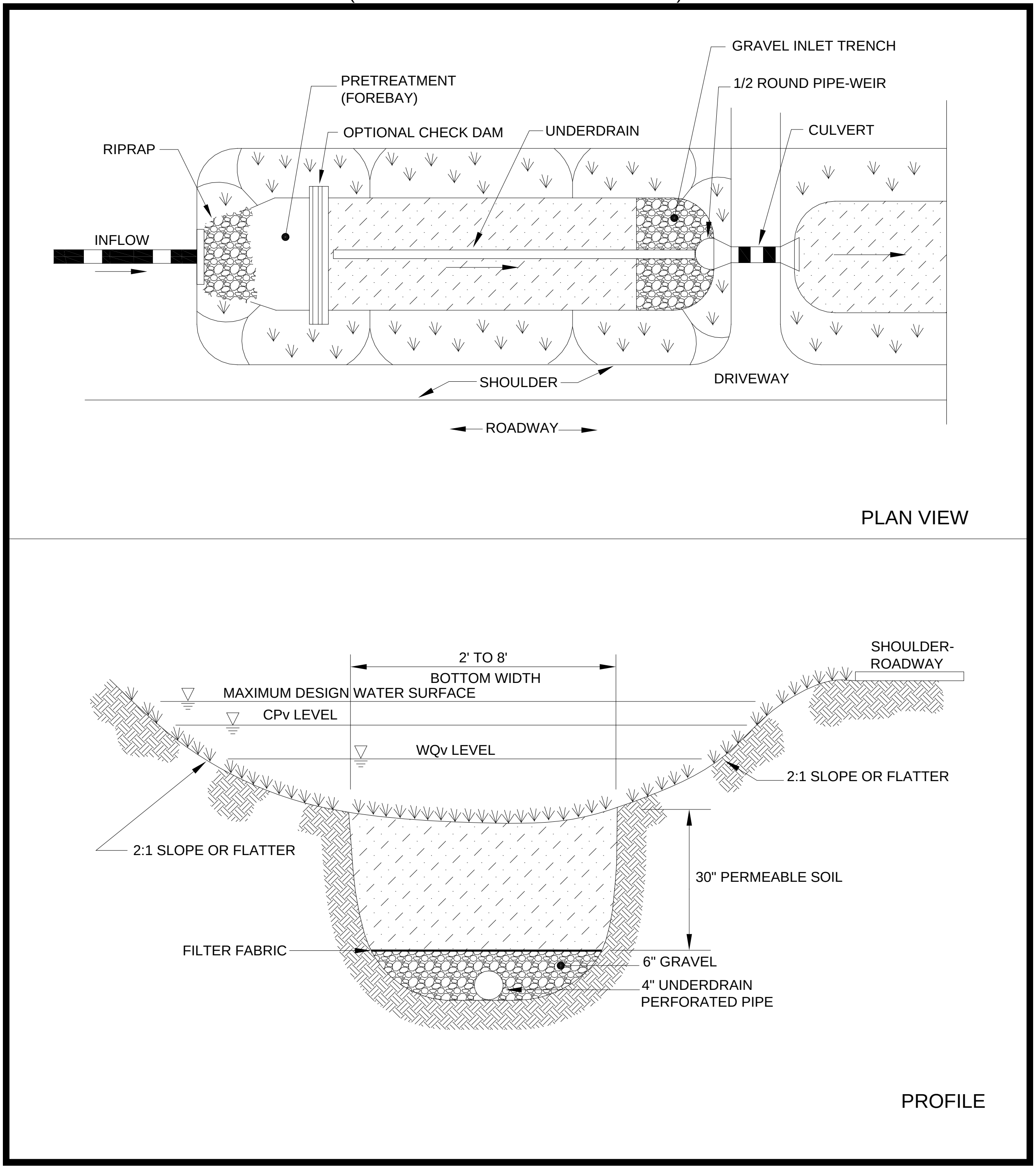
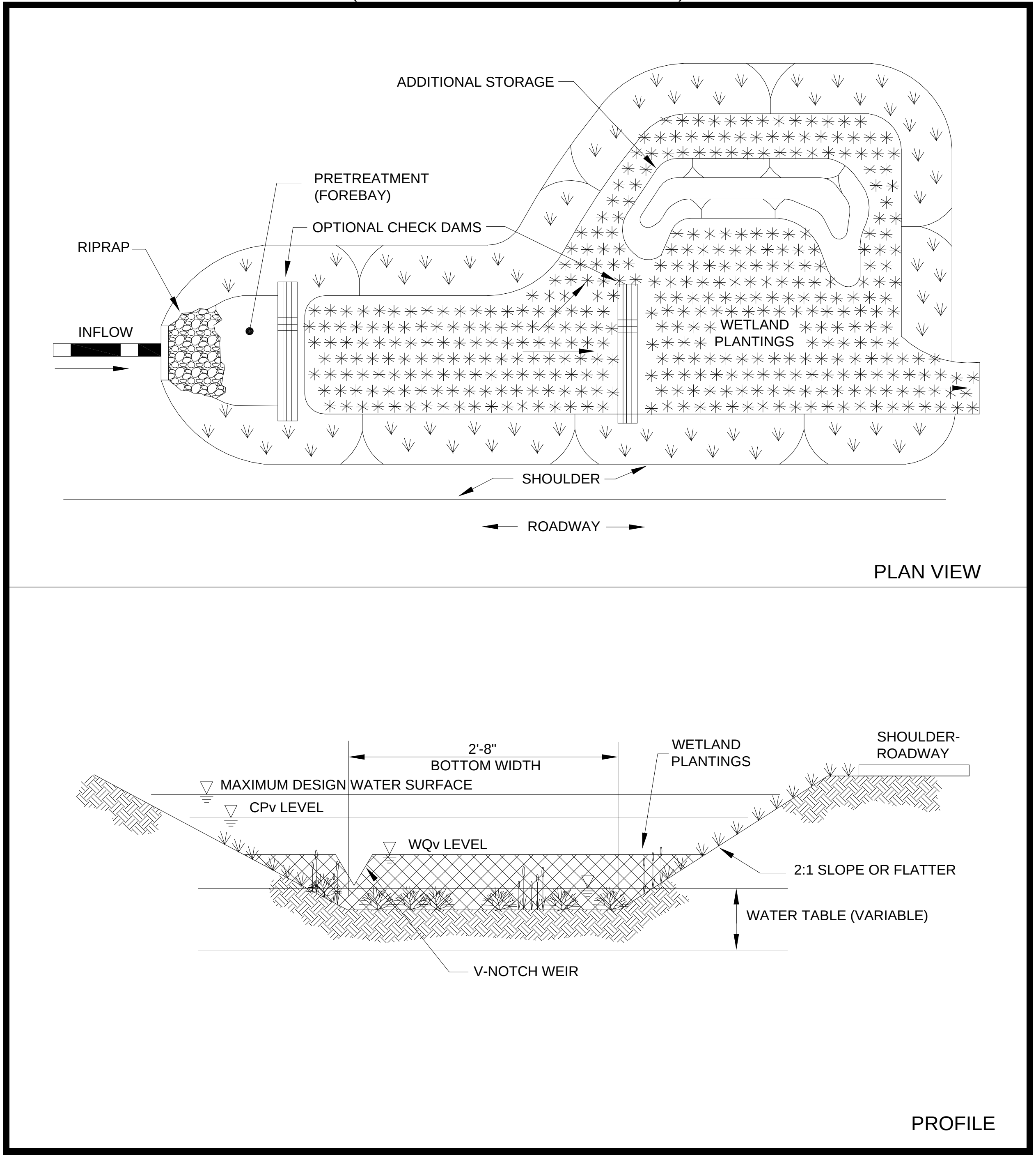


Figure 4-41. Schematic of a Wet Swale

(Source: Center for Watershed Protection)



4.3.8.9 Design Form

The local municipality recommends the use of the following design procedure forms when designing enhanced swales. Proper use and completion of the form may allow a faster review of the Water quality Management Plan by the local municipality.

Design Procedure Form: Enhanced Swales

PRELIMINARY HYDROLOGIC CALCULATIONS	
1a. Compute WQv volume requirements	
Compute Runoff Coefficient, Rv	Rv = ________
Compute WQv	WQv = ________ acre-ft
1b. Compute CPv	CPv = ________ acre-ft
Compute average release rate	release rate = ________ cfs
Compute storage volume required for locally regulated storm events	storm = ________ acre-ft storm = ________ acre-ft
ENHANCED SWALE DESIGN	
2. Is the use of an enhanced swale appropriate?	***See subsections 4.3.8.4 and 4.3.8.5 - A***
Confirm design criteria and applicability.	***See subsection 4.3.8.5 - J***
3. Pretreatment Volume (Forebay)	
V_{pre} =(I)(.1")(1'/12")	V_{pre} = ________ acre-ft
4. Determine swale dimensions	
Assume trapezoidal channel with max depth of 18 inches	Length = ________ ft Width = ________ ft Side Slopes = ________ Area = ________ ft^2
Compute number of check dams (or similar structures) required to detain WQv	Slope = ________ ft/ft Depth = ________ ft Distance = ________ ft Number = ________ each
5. Calculate draw-down time	
Require k = 1.5 ft per day for dry swales	t = ________ hr
6. Check 25-year velocity erosion potential and freeboard	V_{min} = ________ fps
Requires separate computer analysis for velocity	
Overflow wier (use weir equation) Use weir equation for slot length ($Q = CLH^{3/2}$)	Weir Length = ________ ft
7 Design low flow orifice at headwall	
Area of orifice from orifice equation	Area = ________ ft^2
$Q = CA(2gh)^{0.5}$ C varies with orifice condition	diameter ________ inches
8 Design inlets, sediment forebays, outlet structures, maintenance access, and safety features.	***See subsection 4.3.8.5 - D through H***
9. Design landscaping plan (including wetland vegetation)	

Notes: ____

4.3.8.10 References

AMEC. *Knox County Stormwater Management Manual Volume 2, Technical Guidance*.

AMEC. *Metropolitan Nashville and Davidson County Stormwater Management Manual Volume 4 Best Management Practices.* 2006.

Atlanta Regional Council (ARC). Georgia *Stormwater Management Manual Volume 2 Technical Handbook.* 2001.

Center for Watershed Protection. *Manual Builder.* Stormwater Manager's Resource Center, Accessed July 2005. *www.stormwatercenter.net*

Connecticut Department of Environmental Protection. *Stormwater Quality Manual.* 2004.

Federal Highway Administration (FHWA), United States Department of Transportation. *Stormwater Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring.* Accessed January 2006. http://www.fhwa.dot.gov/environment/ultraurb/index.htm

Natural Resources Conservation Service (NRCS), United States Department of Agriculture, www.soils.gov

4.3.8.11 Suggested Reading

California Storm Water Quality Task Force. *California Storm Water Best Management Practice Handbooks.* 1993.

City of Austin, TX. *Water Quality Management.* Environmental Criteria Manual. Environmental and Conservation Services, 1998.

City of Sacramento, CA. *Guidance Manual for On-Site Stormwater Quality Control Measures.* Department of Utilities, 2000.

Claytor, R.A., and T.R. Schueler. *Design of Stormwater Filtering Systems.* The Center for Watershed Protection, Silver Spring, MD, 1996.

Maryland Department of the Environment. *Maryland Stormwater Design Manual, Volumes I and II.* Prepared by Center for Watershed Protection (CWP), 2000.

Metropolitan Washington Council of Governments (MWCOG). *A Current Assessment of Urban Best Management Practices: Techniques for Reducing Nonpoint Source Pollution in the Coastal Zone.* March, 1992.

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4.3.9 Filter Strip

General Application Water Quality BMP

Description: Filter strips are uniformly graded and densely vegetated sections of land engineered and designed to treat runoff and remove pollutants through vegetative filtering and infiltration.

KEY CONSIDERATIONS

DESIGN GUIDELINES:

- Drainage area size based on flow length and slope.
- Must have slopes between 2% and 6%.
- Must maintain sheet flow across the entire filter strip.
- Minimum 15 ft flow length; the longer the flow length, the higher the pollutant removal, if sheet flow is maintained.

ADVANTAGES / BENEFITS:

- High community acceptance in any type of setting.
- Easy to maintain once ground cover and/or trees are established.
- Can be used as pre-treatment for other BMPs, with an effect similar to a sediment forebay.
- Filter strips are easily incorporated into new construction/development designs.

DISADVANTAGES / LIMITATIONS:

- Cannot meet the 80% TSS goal without another BMP in a treatment train. A 50' filter strip is assumed to achieve a 50% TSS removal. A 25 ft strip is assumed to achieve a 10% TSS removal.
- Filter strips and level spreaders have limited drainage areas.
- It can be difficult to construct a level lip on level spreaders.

MAINTENANCE REQUIREMENTS:

- Maintain a dense, healthy stand of grass and other vegetation.
- Repair areas of erosion and re-vegetate as needed.
- Remove sediment build-up.

STORMWATER MANAGEMENT SUITABILITY

Stormwater Quality:	**Yes**
Channel Protection:	**No**
Detention/Retention:	**No**

Accepts hotspot runoff: *Yes, with pre-treatment*

COST CONSIDERATIONS

Land Requirement:	**Med - High**
Capital Cost:	**Low**
Maintenance Burden:	**Low**

LAND USE APPLICABILITY

Residential/Subdivision Use:	**Yes**
High Density/Ultra Urban Use:	**Yes**
Commercial/Industrial Use:	**Yes**

POLLUTANT REMOVAL

Total Suspended Solids:	**10 to 50%**

4.3.9.1 General Description

Filter strips are uniformly graded and densely vegetated sections of land, engineered and designed to treat runoff and remove pollutants through vegetative filtering and infiltration. Because they cannot accept channelized runoff, filter strips are best suited to treating runoff from roads and highways, roof downspouts, very small parking lots, and pervious surfaces. They are also ideal for use as pre-treatment measures for a stream buffer or structural stormwater controls such as enhanced swales or basins. Filter strips can serve as a buffer between incompatible land uses, can be landscaped to be aesthetically pleasing, and can provide groundwater recharge in areas with pervious soils.

Pollutant removal from filter strips is highly variable and depends primarily on density of vegetation and contact time for filtration and infiltration. These, in turn, depend on soil and vegetation type, slope, and presence of sheet flow. Pollutant removal efficiencies are based upon a 50-foot long strip. Filter strips with shorter flow lengths are considered to have lower removal efficiencies and should be used as coarse sediment settling areas for other structural controls. Filter strips are often considered to be an integral component of those controls, similar to sediment forebays for stormwater basins or other structural BMPs. Uniform sheet flow must be maintained through the filter strip to provide pollutant reduction and avoid erosion. To obtain sheet flow when discharging runoff from a developed area, a level spreader may be required.

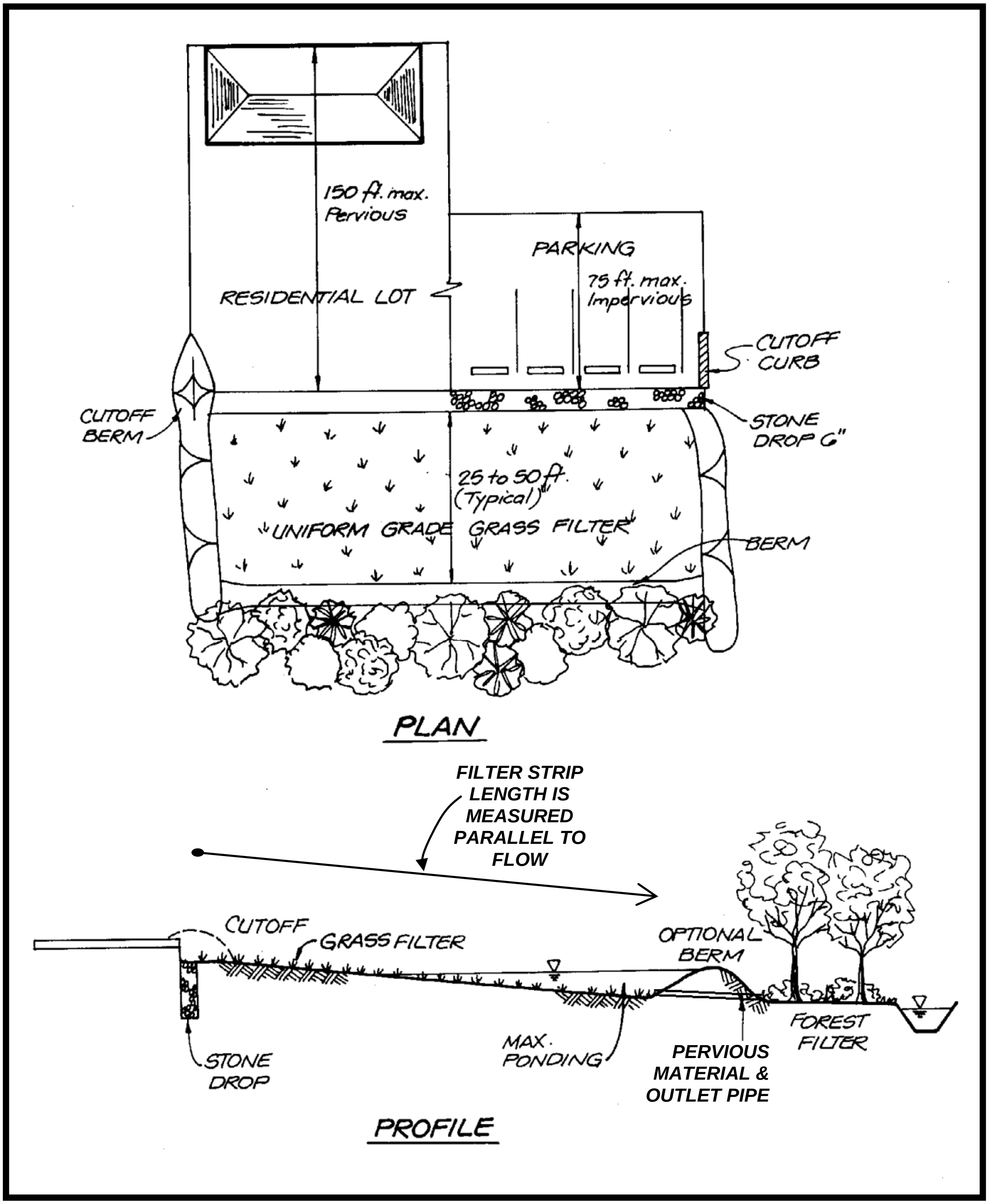
There are two different filter strip designs: a simple filter strip and a design that includes a permeable berm at the bottom. The presence of the berm increases the contact time between the filter strip and the runoff, thus reducing the overall width of the filter strip required to treat stormwater runoff. An example schematic of a filter strip is presented in Figure 4-42.

4.3.9.2 Stormwater Management Suitability

Filter strips are designed primarily for stormwater quality and do not have the ability to provide channel protection or flood protection.

<u>Water Quality (WQv)</u>
To treat stormwater runoff, filter strips rely on the use of vegetation to slow runoff velocities and filter out sediment and other pollutants from urban stormwater. There can also be a significant reduction in runoff volume for smaller flows that infiltrate through pervious soils within the filter strip. To be effective, however, sheet flow must be maintained across the entire filter strip. Once runoff flow concentrates, it effectively short-circuits the filter strip and reduces any water quality benefits. Therefore, a flow spreader must normally be included in the filter strip design.

Figure 4-42. Schematic of a Filter Strip (with Berm)



4.3.9.3 Pollutant Removal Capabilities

The following design pollutant removal rates are conservative average pollutant reduction percentages for design purposes derived from sampling data, modeling and professional judgment. Research indicates that the pollutant removal ability of a filter strip is highly dependant upon the minimum flow path length, as follows.

Filter Strips that have a minimum flow path length of 50 feet or greater:

- Total Suspended Solids – 50%

Filter Strips that have a minimum flow path length between 25 feet and 50 feet (pretreatment control for coarse sediments):

- Total Suspended Solids – 10%

Filter strips that have a flow path length less than 25 feet are assigned a 0% TSS removal value.

4.3.9.4 Application and Feasibility Criteria

Filter strips can be used in a variety of development types. However, because of their relatively large land requirement, filter strips are generally not determined to be useful in higher density areas. The topography and proposed site layout will determine the applicability of filter strips.

General Feasibility

- Suitable for use in residential subdivisions and in non-residential areas.
- Can be used in high density/ultra-urban areas, but land requirements may preclude their use.
- Not suitable for use as a regional stormwater control.

4.3.9.5 Planning and Design Standards

The following standards shall be considered **minimum** design standards for the design of a filter strip. Filter strips that are not designed to these standards will not be approved. The local municipality shall have the authority to require additional design conditions if deemed necessary.

A. LOCATION AND SITING

- Filter strips are most appropriate for treating the stormwater runoff from small drainage areas. Flow must enter the filter strip as sheet flow spread out over the length (long dimension normal to flow) of the strip. The design depth of flow shall be no greater than 2 inches. As a rule, flow starts to channelize within a maximum of 75 feet for impervious surfaces, and 150 feet for pervious surfaces (CWP, 1996). For longer flow paths, special provision must be made to ensure design flows spread evenly across the filter strip.
- A level spreader may be needed to achieve sheet flow, the design of which should be factored into the location and siting of the filter strip and into the overall site layout. Level spreader design is presented in Chapter 3 of this manual.
- Filter strips should be integrated into site designs.
- Filter strips should be constructed outside the natural stream buffer area whenever possible to maintain a more natural buffer along the streambank.
- Filter strips shall not be in areas or on soils that cannot sustain a dense vegetative cover with high retardance.
- Pedestrian traffic across the filter strip should be limited through channeling onto sidewalks.

B. PHYSICAL SPECIFICATIONS / GEOMETRY

- Filter strips shall be designed having a slope between 2% and 6%. Greater slopes than this will encourage the formation of concentrated flow. Flatter slopes will encourage standing water. Both the top and toe of the slope shall be as flat as possible to encourage sheet flow and prevent erosion.
- The filter strip shall have a minimum length (flow path) of 25 feet long to provide filtration and contact time for water quality treatment. At least fifty (50) feet is necessary to achieve the 50% TSS removal value.
- Flow must enter the filter strip as sheet flow, designed to spread out over the width of the strip with a depth of 1 to 2 inches.
- The design of the filter strip and the area draining to the filter strip shall be such that stormwater flows in excess of the design flow can discharge across or around the strip without causing erosion or other damage. Often a bypass channel or overflow spillway with a protected channel section is designed to handle higher flows.
- An effective flow spreader is to use a pea gravel diaphragm at the top of the slope (ASTM D 448 size no. 6, 1/8" to 3/8"). The pea gravel diaphragm (a small trench running along the top of the filter strip) serves two purposes. First, it acts as a pre-treatment device, settling out sediment particles before they reach the practice. Second, it acts as a level spreader, maintaining sheet flow as runoff flows over the filter strip. Other types of flow spreaders include a concrete sill, curb stops, or curb and gutter with "sawteeth" cut into it. Level spreader design can be found in Chapter 3 of this manual.
- Maximum discharge loading per foot of filter strip width (perpendicular to flow path) shall be determined using the Manning equation:

Equation 4.3.9.1

$$q = \frac{0.00236}{n} Y^{\frac{5}{3}} S^{\frac{1}{2}}$$

where: q = discharge per foot of width of filter strip (cfs/ft)
Y = allowable depth of flow (inches) = 2 inches maximum
S = slope of filter strip (percent)
n = Manning's "n" roughness coefficient (use 0.15 for medium grass, 0.25 for dense grass, and 0.35 for very dense Bermuda-type grass)

- Using *q* computed above, the minimum width of a filter strip shall be calculated using the following equation:

Equation 4.3.9.2

$$W_{fMIN} = \frac{Q_{wq}}{q}$$

where: W_{fMIN} = minimum filter strip width perpendicular to flow (feet)
Q = peak discharge of stormwater runoff (cfs)
q = discharge per foot of width of filter strip (cfs/ft)

Filter Strips without a permeable berm:

- The length of the filter strip (parallel to flow path across the filter strip) shall be sized to achieve a contact time between the stormwater runoff and filter strip vegetation of no less than five (5) minutes. The equation for filter strip length (the flow path) is based on the SCS TR-55 travel time equation (SCS, 1986):

Equation 4.3.9.3

$$L_f = \frac{(T_t)^{1.25}(P_{2-24})^{0.625}(S)^{0.5}}{3.34n}$$

where: L_f = length of filter strip parallel to flow path (ft)
T_t = travel time through filter strip (minutes), minimum 5 minutes
P_{2-24} = 2-year, 24-hour rainfall depth (inches)
S = slope of filter strip (percent)
n = Manning's "n" roughness coefficient (use 0.15 for medium grass, 0.25 for dense grass, and 0.35 for very dense Bermuda-type grass)

Filter Strips with a permeable berm:

- The filter strip shall be sized to contain the entire WQv within the wedge of water that backs up behind the berm.
- The maximum height of the berm is 12 inches.
- Outlet pipes from the berm shall be sized to ensure that the runoff stored behind the berm drains within 24 hours.
- The outlet pipes shall be designed such that runoff discharges from the berm in a non-erosive manner.
- The berm shall be constructed of a mixture of sand, gravel and sandy loam to encourage grass cover. Specifications for sand and gravel are: sand - ASTM C-33 fine aggregate concrete sand 0.02"-0.04"; gravel - AASHTO M-43 ½" to 1".

Filter Strips used for pre-treatment:

- A number of other structural controls, including bioretention areas and infiltration trenches, may utilize a filter strip as a pre-treatment measure. The required length of the filter strip depends on the drainage area, imperviousness, and the filter strip slope. Table 4-9 provides sizing guidance for using filter strips for pre-treatment.

Table 4-9. Sizing of Filter Strips for Pre-treatment
(Source: Adapted from Georgia Stormwater Management Manual)

Parameter	Impervious Areas[1]				Pervious Areas (Lawns, etc)[2]			
Maximum inflow approach length (feet)	35		75		75		100	
Filter strip slope (max = 6%)	≤ 2%	> 2%	≤ 2%	> 2%	≤ 2%	> 2%	≤ 2%	> 2%
Filter strip minimum length (feet)[3]	10	15	20	25	10	12	15	18

1 – 75 feet maximum impervious area flow length to filter strip.
2 – 150 feet maximum pervious area flow length to filter strip.
3 – At least 25 feet is required for minimum pre-treatment credit of 10% TSS removal. Fifty feet is required for 50% removal.

C. SPECIAL CONSIDERATIONS FOR THE AS-BUILT CERTIFICATION

- Like any other water quality BMP, the filter strip must be shown on the as-built certification specifically as a water quality BMP. The following components must be addressed in the as-built certification:
  1. Ensure the design flows are spread evenly across the filter strip.
  2. Ensure the design slope is between 2% and 6%.
  3. The dimensions of the filter strip must be verified.
  4. The type of vegetation used in the filter strip.

D. MAINTENANCE ACCESS

- A minimum 20 foot wide maintenance right-of-way or drainage easement shall be provided for the length and width of the filter strip from a driveway, public or private road. The maintenance access easement shall have a maximum slope of no more than 15% and shall have a minimum unobstructed drive path having a width of 12 feet, appropriately stabilized to withstand maintenance equipment and vehicles. The right-of-way shall be located such that maintenance vehicles and equipment can access the entire filter strip.

E. LANDSCAPING

- The vegetation in a filter strip can be grassed, or a combination of grass and woody plants. Filter strips that are vegetated with forest vegetation may be able to qualify as a water quality volume (WQv) credit. See Chapter 5 for more information on the stream and vegetated buffer credit.
- Designers should choose a grass that can withstand relatively high velocity flows at the entrances, and both wet and dry periods.
- For filter strips with a permeable berm, vegetation that can withstand frequent inundation must be utilized in the area where shallow ponding will occur.

4.3.9.6 Design Example

Basic Data

Small commercial lot 150 feet deep x 100 feet wide

- Drainage area (A) = 0.34 acres
- Impervious percentage (I) = 70%
- Slope equals 4%
- Manning's n = 0.25

Step 1: Calculate Maximum Discharge Loading Per Foot of Filter Strip Width (q):

Using Equation 4.3.9.1 above:

$$q = (0.00236/0.25) * (1.0)^{5/3} * (4)^{1/2} = 0.019 \text{ cfs/ft}$$

Step 2: Calculate the Water Quality Flow Rate (Q_{wq}):

(See Chapter 3 for equation information)
Compute the Runoff Peak Volume (Q_{wv}) in inches for 1.1-inch rainfall (P = 1.1):

$$Q_{wv} = PRv = 1.1Rv = 1.1(0.015 + (0.0092)(70)) = 0.72 \text{ inches}$$

Compute modified CN:

$$\begin{aligned} CN &= 1000/[10+5P+10\,Q_{wv} - 10(Q_{wv}^{\,2}+1.25Q_{wv}P)^{½}] \\ &= 1000/[10+5(1.1)+10(0.72)-10(0.72^2+1.25(0.72)1.1)^{½}] \\ &= 95.98 \text{ (Use CN = 96)} \end{aligned}$$

For CN = 96 and an estimated time of concentration (T_c) of 8 minutes (0.13 hours), compute the Q_{wq} for a 1.1 inch storm.

I_a = 0.083 (from Table 3-14 in Chapter 3), therefore I_a/P = 0.083/1.1 = 0.075.

Using Figure 3-6 in Chapter 3, q_u can be estimated for a Type II storm at approximately 950 csm/in. q_u = 950 csm/in, and therefore:

$$Q_{wq} = q_u A\, Q_{wv} = (950 \text{ csm/in}) (0.34\text{ac}/640\text{ac/mi}^2) (0.72\text{in}) = 0.36 \text{ cfs}$$

Step 3: Calculate the Minimum Filter Width

Using Equation 4.3.9.2 above:

$W_{fMIN} = Q_{wq}/q = 0.36/0.019 = 19$ feet

Since the width of the lot is 100 feet, the actual width of the filter strip will depend on site grading and the ability to deliver the drainage to the filter strip in sheet flow through a pea gravel filled trench.

The next step is to calculate the filter length. This calculation is different for a filter designed without a permeable berm (presented in Step 4a), than for a filter designed with a berm (presented in Step 4b).

Step 4a: Calculate the Filter Length (L_f) for a filter without a berm:

Basic Data:

- Depth of 2-year, 24-hour storm = 3.3 inches (see Chapter 3, Table 3-5)
- Use 5 minute travel (contact) time

Using Equation 4.3.9.3 above:

$L_f = (5)^{1.25}(3.3)^{0.625}(4)^{0.5} / (3.34)(0.25) = 37.8$ feet (use 38 feet)

Note: Reducing the filter strip slope to 2% and planting a more dense grass (raising the Manning "n" to 0.35) would reduce the filter strip length to 19 feet.

Step 4b: Calculate the Filter Length (assume filter is designed with a berm):

(See Chapter 3 for equation information)

Basic Data:

- The height of the permeable berm (h) will be 6 inches (0.5 feet).
- Assume the filter width = the maximum lot width (W_f) = 100 feet.

Compute the Water Quality Volume (WQv) in cubic feet:

$WQv = 1.1R_vA/12 = 1.1(0.015 + 0.0092(70))0.34/12 = 0.021$ ac-ft or 895 ft^3

This is the volume of the "wedge" of water that ponds behind the berm.

For a berm height of 6 inches (0.5 feet), the "wedge" of volume captured by the filter strip is:

The area of the "wedge" = $\frac{1}{2}L_fh$, therefore,

The volume of the "wedge" = $W_f\frac{1}{2}L_fh = (100)\ \frac{1}{2}(L_f)(0.5) = 895\ ft^3$

Solving for L_f, the length of the filter = 35.8 feet (use 36 feet).

Note: Increasing the berm height to 1 foot will result in a filter length of 18 feet.

4.3.9.7 Maintenance Requirements and Inspection Checklist

Note: Section 4.3.9.7 must be included in the Operations and Maintenance Plan that is recorded with the deed.

Regular inspection and maintenance is critical to the effective use of filter strips as stormwater best management practices. It is the responsibility of the property owner to maintain all stormwater facilities in accordance with the minimum design standards and other guidance provided in this manual. The local municipality has the authority to impose additional maintenance requirements where deemed necessary.

This page provides guidance on maintenance activities that are typically required for filter strips, along with a suggested frequency for each activity. Individual filter strips may have more, or less, frequent maintenance needs, depending upon a variety of factors including the occurrence of large storm events, overly wet or dry (i.e., drought) regional hydrologic conditions, and any changes or redevelopment in the upstream land use. Each property owner shall perform the activities identified below at the frequency needed to maintain filter strips properly at all times.

Inspection Activities	Suggested Schedule
• Inspect pea gravel diaphragm for clogging (i.e., standing water or sediment build-up). • Inspect vegetation for signs of erosion or un-vegetated areas. • Inspect to ensure that grass has established. • Inspect general flow paths to determine if runoff discharges into and across the filter strip in an unchannelized fashion.	Annually (Semi-annually first year)
Maintenance Activities	**Suggested Schedule**
• Maintain a dense, healthy stand of grass and other vegetation by frequent mowing. Grass heights of 3 to 5 inches should be maintained, with a maximum grass height of 8 inches.	Regularly (frequently)
• Repair areas of erosion and re-vegetate. • Re-vegetate as needed to maintain healthy vegetation. • Remove sediment buildup.	As needed

The local municipality encourages the use of the inspection checklist presented below for guidance in the inspection and maintenance of the filter strip. The local municipality can require the use of this checklist or other form(s) of maintenance documentation when and where deemed necessary in order to ensure the long-term proper operation of the filter strip. Questions regarding inspection and maintenance should be referred to the local municipality.

INSPECTION CHECKLIST FOR FILTER STRIPS

Location: ____ Owner Change since last inspection? Y N

Owner Name, Address, Phone: ____

Date: __________ Time: ____________ Site conditions:____

Inspection Items	Satisfactory (S) or Unsatisfactory (U)	Comments/Corrective Action
Healthy vegetation?		
Signs of erosion?		
Clogged pea gravel diaphragm?		
Sediment buildup behind level spreader at top?		
Sediment buildup in filter strip?		
Other (describe)?		
Hazards		
Have there been complaints from residents?		
Public hazards noted?		

If any of the above inspection items are **UNSATISFACTORY**, list corrective actions and the corresponding completion dates below:

Corrective Action Needed	Due Date

Inspector Signature:______________________________ Inspector Name (printed)__________________________

4.3.9.8 References

AMEC. *Knox County Stormwater Management Manual Volume 2, Technical Guidance*.

AMEC. *Metropolitan Nashville and Davidson County Stormwater Management Manual Volume 4 Best Management Practices.* 2006.

Atlanta Regional Council (ARC). *Georgia Stormwater Management Manual Volume 2 Technical Handbook.* 2001.

4.3.9.9 Suggested Reading

California Storm Water Quality Task Force. *California Storm Water Best Management Practice Handbooks.* 1993.

City of Austin, TX. *Water Quality Management*. Environmental Criteria Manual. Environmental and Conservation Services, 1988.

City of Sacramento, CA. *Guidance Manual for On-Site Stormwater Quality Control Measures.* Department of Utilities, 2000.

Claytor, R.A., and T.R. Schueler. *Design of Stormwater Filtering Systems.* The Center for Watershed Protection, Silver Spring, MD, 1996.

Driscoll, E., and P. Mangarella. *Urban Targeting and BMP Selection.* Prepared by Woodward-Clyde Consultants, Oakland, CA, for U.S. Environmental Protection Agency, Washington, DC, 1990.

Maryland Department of the Environment. *Maryland Stormwater Design Manual, Volumes I and II.* Prepared by Center for Watershed Protection (CWP), 2000.

Metropolitan Washington Council of Governments (MWCOG), *A Current Assessment of Urban Best Management Practices: Techniques for Reducing Nonpoint Source Pollution in the Coastal Zone.* March 1992.

Urbonas, B.R., J.T. Doerfer, J. Sorenson, J.T. Wulliman, and T. Fairley. *Urban Storm Drainage Criteria Manual. Vol. 3. Best Management Practices, Stormwater Quality.* Urban Drainage and Flood Control District, Denver, CO, 1992.

Wong, S.L., and R.H. McCuen. *The Design of Vegetative Buffer Strips for Runoff and Sediment Control. Appendix J in Stormwater Management for Coastal Areas.* American Society of Civil Engineers, New York, New York, 1982.

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4.3.10 Grass Channel

General Application Water Quality BMP

Description: Grass channels are vegetated open channels that are designed to filter stormwater runoff, as well as slow water for treatment by another structural BMP.

KEY CONSIDERATIONS

DESIGN GUIDELINES:

- Broad bottom channel on slopes of 4% or less.
- Gentle side slopes (3:1 (H:V) or less).
- Check dams can be installed to maximize treatment.
- Requires vegetation that can withstand both relatively high velocity flows and wet and dry periods.
- Maximum contributing drainage area of 5 acres.

ADVANTAGES / BENEFITS:

- Provides pretreatment if used as part of runoff conveyance system.
- Provides partial infiltration of runoff in suitable soil conditions.
- Generally less expensive than extruded curb.
- Good for small drainage areas.
- Relatively low maintenance requirements.
- Well suited to a large number of applications.

DISADVANTAGES / LIMITATIONS:

- Cannot alone achieve 80% removal of TSS.
- Must be carefully designed to achieve low flow rates in the channel for WQv purposes (<1.0 ft/s).
- May re-suspend sediment.
- May not be acceptable for some areas because of standing water in channel.

MAINTENANCE REQUIREMENTS:

- Maintain a dense, healthy stand of grass.
- Repair areas of erosion and re-vegetate as needed.
- Remove sediment buildup.

STORMWATER MANAGEMENT SUITABILITY

Stormwater Quality:	**Yes**
Channel Protection:	**No**
Detention/Retention:	**No**

Accepts hotspot runoff: *Yes, with pre-treatment*

COST CONSIDERATIONS

Land Requirement:	**Low**
Capital Cost:	**Low**
Maintenance Burden:	**Low**

LAND USE APPLICABILITY

Residential/Subdivision Use:	**Yes**
High Density/Ultra Urban Use:	✷
Commercial/Industrial Use:	✷

✷ in certain situations

POLLUTANT REMOVAL

Total Suspended Solids:	**30%**

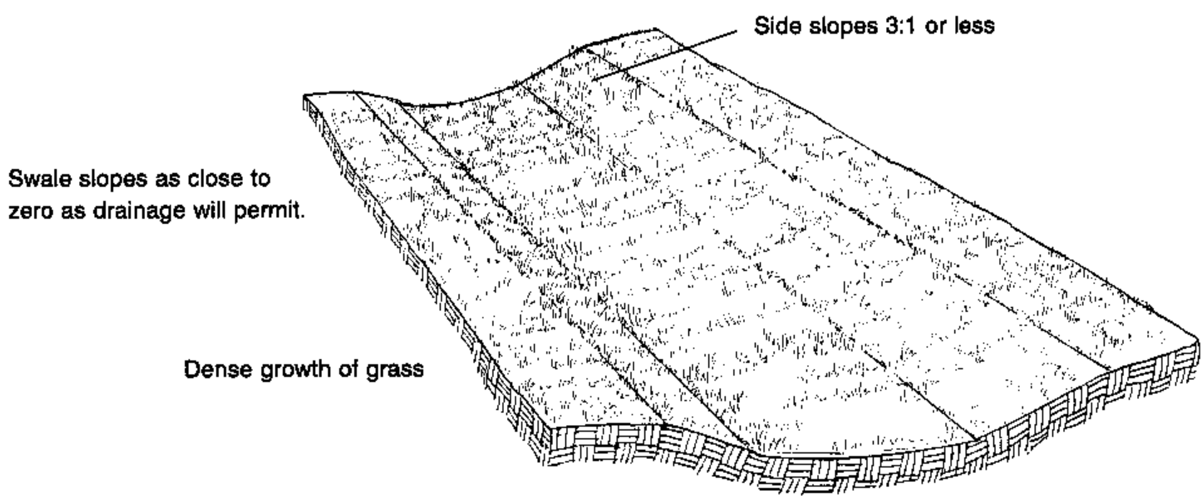
4.3.10.1 General Description

Grass channels, sometimes called biofilters, are conveyance channels that are designed to provide some treatment of runoff, as well as to slow down runoff velocities for treatment in other structural controls. Grass channels are appropriate for a number of applications including treating runoff from paved roads and from pervious areas.

In addition to their ability to provide a minimal level of filtration of pollutants, grass channels can partially infiltrate runoff from small storm events when they are located in areas that have suitable soils (types A, B, and sometimes C). When properly incorporated into a site's layout, grass channels can provide other ancillary benefits, such as reduction of impervious cover, accent of natural features and reduced construction and maintenance costs when compared with traditional extruded curb.

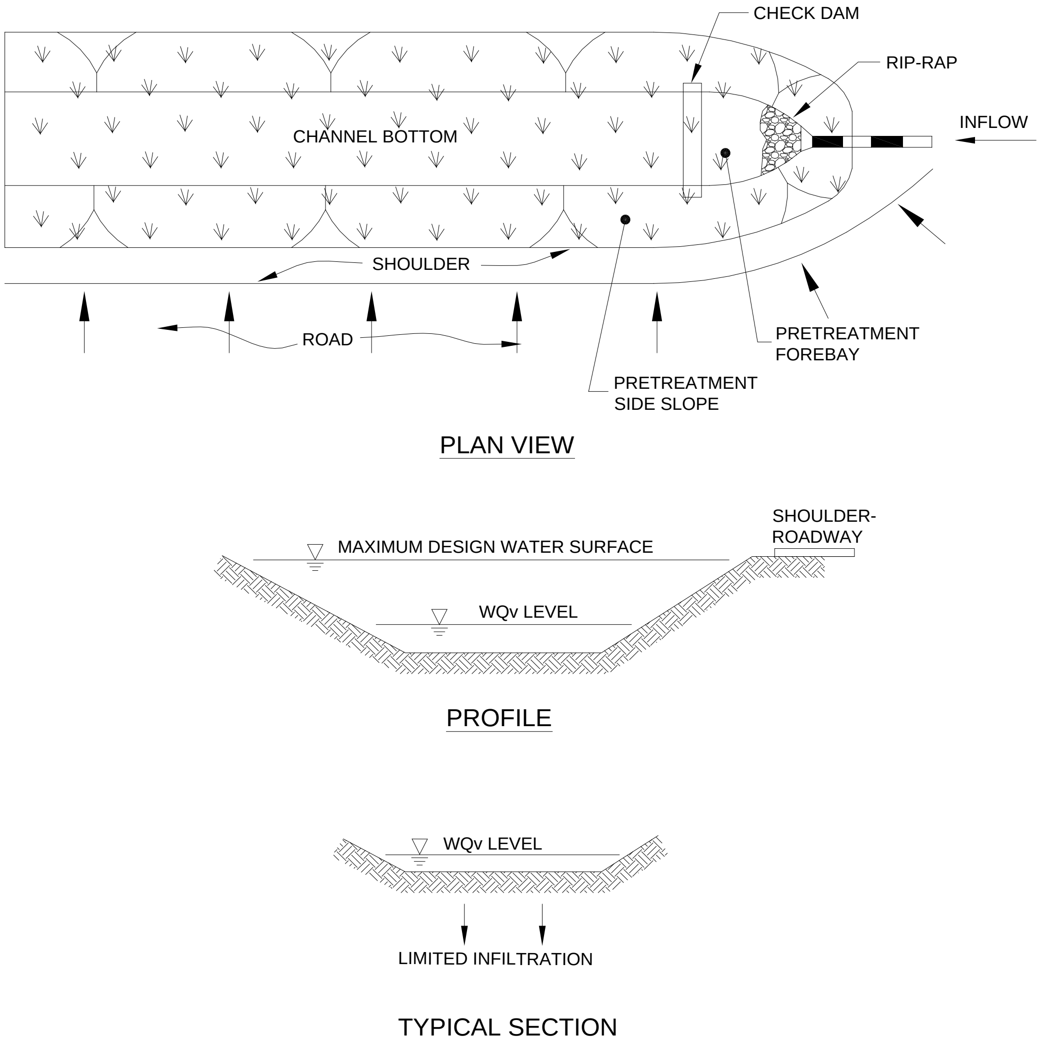
When designing a grass channel, the two primary considerations are channel capacity and minimization of erosion. The channel must be designed with a runoff velocity less than 1.0 foot per second during the peak discharge associated with the water quality design rainfall event, and the total length of a grass channel should provide at least 5 minutes of residence time. To enhance water quality treatment, grass channels must have broader bottoms, lower slopes and denser vegetation than most drainage channels. Additional treatment can be provided by placing check-dams across the channel below pipe inflows, and at various other points along the channel. Example schematics of grass channels are presented in Figures 4-43 and 4-44.

Figure 4-43. Typical Grass Channel



Source: Modified from Galli, 1992

Figure 4-44. Typical Grass Channel (Plan and Profile Views)



4.3.10.2 Stormwater Management Suitability

Grass channels are designed primarily for stormwater quality treatment and runoff conveyance and do not have the ability to provide channel protection or flood protection.

Water Quality (WQv)

To treat stormwater runoff, grass channels rely on the use of vegetation to slow runoff velocities and filter out sediment and other pollutants from urban stormwater. There can also be a reduction in runoff volume for smaller flows that infiltrate through pervious soils within the filter strip.

4.3.10.3 Pollutant Removal Capabilities

Grass channels differ from enhanced swales (discussed in Section 4.3.8 of this manual) in that they do not have an engineered filter media to enhance pollutant removal capabilities. Because of this, grass channels have a lower pollutant removal rate than for a dry or wet (enhanced) swale.

The following design pollutant removal rates are based upon a grass channel that has sufficient length for a runoff residence time (in the channel) of at least 5 minutes. The total suspended solids design pollutant removal rate of 30% is a conservative average pollutant reduction percentage for design purposes derived from sampling data, modeling and professional judgment.

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4.3.10.4 Application and Feasibility Criteria

Grass channels can be used in a variety of development types. However, because of strict requirements for low slopes, grass channels will generally not be useful in developments that have steep topography.

General Feasibility

- Suitable for use in residential subdivisions and in non-residential areas.
- Can be used in high density/ultra-urban areas, but runoff velocity restrictions may preclude their use.
- Not suitable for use as a regional stormwater control due to small drainage area requirements.

4.3.10.5 Planning and Design Standards

The following standards shall be considered **minimum** design standards for the design of a grass channel. Grass channels that are not designed to these standards will not be approved. The local municipality shall have the authority to require additional design conditions if deemed necessary.

A. LOCATION AND SITING

- The drainage area (contributing or effective) for a grass channel shall be 5 acres or less. Runoff flows and volumes from larger drainage areas prevent proper filtration and infiltration of stormwater.
- Grass channels can be used on most soils. However, grass channels shall not be used for water quality treatment purposes on soils with infiltration rates less than 0.27 inches per hour.

B. PHYSICAL SPECIFICATIONS / GEOMETRY

The following specifications apply to grass channels that are designed to achieve a % TSS removal rate of 30%. The reader should refer to, Chapter 3 for additional specifications and design information on runoff conveyance in open grass channels.

- Grass channels shall be designed on relatively flat slopes of less than 4%; channel slopes between 1% and 2% are recommended.
- A grass channel shall be designed to accommodate the peak flow for the water quality design storm, Q_{wq}, and the 2-year, 24-hour design storm without eroding (see Chapter 3 for more information on Q_{wq}). Larger flows should be accommodated by the channel if dictated by the surrounding conditions. Consult the local municipality to verify if accommodation of larger flows is required.
- Grass channels shall have a trapezoidal or parabolic cross-section and shall have side slopes of 3:1 (horizontal:vertical) or flatter.
- For trapezoidal sections, the minimum width of the channel bottom shall be no less than 2 feet. The maximum width of the channel bottom shall be no greater than 6 feet. The minimum width ensures a minimum filtering surface for water quality treatment, and the maximum width prevents braiding, which is the formation of small channels within the swale bottom. The bottom width is a dependent variable in the calculation of velocity based on Manning's equation. If a larger channel is needed, the use of a compound cross section is recommended.
- The channel shall be designed to have a depth of flow no greater than 4-inches, for the WQv design flow.

- Runoff velocities carried in the channel must be non-erosive. The full-channel design velocity will typically govern.
- The channel shall be designed such that the water quality peak flow (Q_{wq}) is contained in the channel for no less than 5-minutes. This residence time may be increased by reducing the slope of the channel, increasing the wetted perimeter, or planting a denser grass (raising the Manning's "n"). Check dams can be utilized in the channel to maximize Q_{wq} retention time. However, the channel must not be designed to hold a permanent pool of standing water. Channel slope shall be sufficient to drain the channel if infiltration does not occur.
- The depth from the bottom of the channel to groundwater shall be at least 2 feet to prevent a moist swale bottom, or contamination of the groundwater.
- Designers should choose a grass that can withstand relatively high velocity flows at the entrances, and both wet and dry periods.

Grass Channels Used for Pretreatment:

- A number of other structural controls, including bioretention areas and infiltration trenches, may utilize a grass channel as a pretreatment measure. The length of the grass channel depends on the drainage area, land use, and channel slope. To be used as a pretreatment measure, the grass channel must have a minimum length of 20 feet. Table 4-10 provides minimum lengths for grass channels based on channel slope and percent imperviousness (of the contributing drainage area).

Table 4-10. Grass Channel Sizing Guidance

(Source: Georgia Stormwater Management Manual)

Parameter	**≤ 33% Impervious**		**Between 34% and 66% Impervious**		**≥ 67% Impervious**	
Slope (max = 4%)	≤ 2%	> 2%	≤ 2%	> 2%	≤ 2%	> 2%
Grass channel min. length (feet) assumes 2-ft bottom width	25	40	30	45	35	50

C. SPECIAL CONSIDERATIONS FOR THE AS-BUILT CERTIFICATION

- Like any other water quality BMP, the grass channel must be shown on the as-built certification specifically as a water quality BMP. The following components must be addressed in the as-built certification:
  1. The channel must be adequately vegetated.
  2. The channel flow velocities must not exceed 1.0 foot per second for the WQv design flow.
  3. A mechanism for overflow of large storm events must be provided.

D. MAINTENANCE ACCESS

- A minimum 20 foot wide maintenance right-of-way or drainage easement shall be provided for the length and width of the grass channel from a driveway, public or private road. The maintenance access easement shall have a maximum slope of no more than 15% and shall have a minimum unobstructed drive path having a width of 12 feet, appropriately stabilized to withstand maintenance equipment and vehicles. The right-of-way shall be located such that maintenance vehicles and equipment can access the entire channel.

E. LANDSCAPING

- The vegetation in a grass channel shall be composed entirely of grasses that can withstand relatively high velocity flows at the entrances and periods of inundation and drought.

4.3.10.6 Design Example

Basic Data

Small commercial lot 300 feet deep x 145 feet wide

- Drainage area (A) = 1.0 acres
- Impervious percentage (I) = 70%
- Site slope (S) = 2%

Step 1: Calculate the Water Quality Peak Flow Rate (Q_{wq}):

(See Chapter 3 for equation information)
Compute the Runoff Peak Volume (Q_{wv}) in inches for 1.1-inch rainfall (P = 1.1):

$Q_{wv} = PRv = 1.1Rv = 1.1(0.015 + (0.0092)(70)) = 0.72$ inches

Compute modified CN:

$$\begin{aligned} CN &= 1000/[10+5P+10\,Q_{wv} - 10(Q_{wv}^{\,2}+1.25Q_{wv}P)^{½}] \\ &= 1000/[10+5(1.1)+10(0.72)-10(0.72^2+1.25(0.72)1.1)^{½}] \\ &= 95.98 \quad \text{(Use CN = 96)} \end{aligned}$$

For CN = 96 and an estimated time of concentration (T_c) of 8 minutes (0.13 hours), compute the Q_{wq} for a 1.1 inch storm.

$I_a = 0.083$ (from Table 3-14 in Chapter 3), therefore $I_a/P = 0.083/1.1 = 0.075$.

Using Figure 3-6 in Chapter 3, q_u can be estimated for a Type II storm at approximately 950 csm/in.

$q_u = 950$ csm/in, and therefore:

$Q_{wq} = q_u A\, Q_{wv} = (950 \text{ csm/in})\ (1.0\text{ac}/640\text{ac/mi}^2)\ (0.72\text{in}) = 1.07$ cfs

Step 2: Utilize Q_{wq} to Calculate the Minimum Channel Bottom Width

The maximum flow depth for water quality treatment should be approximately the same height of the grass. A maximum flow depth of 4 inches is allowed for water quality design. A maximum flow velocity of 1.0 foot per second for water quality treatment is required. For Manning's "n" use 0.15 for medium grass, 0.25 for dense grass, and 0.35 for very dense Bermuda-type grass.

Input variables: n = 0.15
S = 0.02 ft/ft
D = 4/12 = 0.33 ft

Then: $Q_{wq} = Q = VA = 1.49/n\ D^{2/3}\ S^{1/2}\ DW$

where: Q = peak flow (cfs)
V = velocity (ft/sec)
A = flow area (ft^2) = WD
W = channel bottom width (ft)
D = flow depth (ft) *(approximates the hydraulic radius for shallow flows)*
S = slope (ft/ft)

The above equation can be solved for the minimum channel bottom width (W), as follows:

$(nQ)/(1.49\ D^{5/3}\ S^{1/2}) = W = (0.15*1.07)/(1.49*0.33^{5/3}*0.02^{1/2}) = 4.8$ feet *(minimum width)*

The velocity of the water quality peak flow rate must be less than 1.0 feet per second (fps). Check this, as follows:

V = Q/(WD) *(where WD approximates the flow area, A, for shallow flows)*
V = 1.07/(4.0 * 4/12) = 0.80 fps *(Design confirmed: the velocity is < 1.0 fps.)*

Step 3: Calculate the Channel Length

The minimum length for a 5-minute (300 seconds) residence time is calculated as follows:

V = L/T

where:
V = velocity (ft/sec)
L = channel length (ft)
T = residence time (seconds)

The above equation can be solved for the minimum channel length (L), as follows:

L = (0.8)(5*60) = 240 feet

Depending on the site geometry, the width or the slope or density of grass (Manning's "n" value) can be adjusted to slow the velocity and shorten the channel within the design specifications discussed above.

Step 4: Complete the Grass Channel design for other design storms

Refer to, Chapter 3 to complete the grass channel design for a specified design storm event.

4.3.10.7 Maintenance Requirements and Inspection Checklist

Note: Section 4.3.10.7 must be included in the Operations and Maintenance Plan that is recorded with the deed.

Regular inspection and maintenance is critical to the effective use of grass channels as stormwater best management practices. It is the responsibility of the property owner to maintain all stormwater facilities in accordance with the minimum design standards and other guidance provided in this manual. The local municipality has the authority to impose additional maintenance requirements where deemed necessary.

This page provides guidance on maintenance activities that are typically required for grass channels, along with a suggested frequency for each activity. Individual grass channels may have more, or less, frequent maintenance needs, depending upon a variety of factors including the occurrence of large storm events, overly wet or dry (i.e., drought) regional hydrologic conditions, and any changes or redevelopment in the upstream land use. Each property owner shall perform the activities identified below at the frequency needed to maintain grass channels properly at all times.

Inspection Activities	Suggested Schedule
• Inspect check dams (if used) for clogging (i.e., standing water or sediment build-up). • Inspect vegetation for signs of erosion or un-vegetated areas. • Inspect to ensure that grass is healthy and well-established.	Annually (Semi-annually first year)
Maintenance Activities	**Suggested Schedule**
• Maintain a dense, healthy stand of grass and other vegetation by frequent mowing. Grass heights of 3 to 5 inches should be maintained, with a maximum grass height of 8 inches.	Regularly (frequently)
• Remove trash, debris and sediment accumulated in the channel or behind check dams (if present). • Repair areas of erosion and re-vegetate. • Re-vegetate as need to maintain healthy vegetation.	As-needed

The local municipality encourages the use of the inspection checklist presented below for guidance in the inspection and maintenance of the grass channel. The local municipality can require the use of this checklist or other form(s) of maintenance documentation when and where deemed necessary in order to ensure the long-term proper operation of the channel. Questions regarding inspection and maintenance should be referred to the local municipality.

INSPECTION CHECKLIST FOR GRASS CHANNELS

Location: ______________________________ Owner Change since last inspection? Y N
Owner Name, Address, Phone: ______________________________
Date: __________ Time: __________ Site conditions:______________________________

Inspection Items	Satisfactory (S) or Unsatisfactory (U)	Comments/Corrective Action
Healthy vegetation?		
Signs of erosion?		
Clogged check dams?		
Sediment build-up on channel bottom?		
Standing water for extended periods?		
Soggy channel bottom for extended periods?		
Other (describe)?		
Hazards		
Have there been complaints from residents?		
Public hazards noted?		

If any of the above inspection items are **UNSATISFACTORY**, list corrective actions and the corresponding completion dates below:

Corrective Action Needed	Due Date

Inspector Signature:______________________________ Inspector Name (printed)______________________________

4.3.10.8 References

AMEC. *Knox County Stormwater Management Manual Volume 2, Technical Guidance*.

AMEC. *Metropolitan Nashville and Davidson County Stormwater Management Manual Volume 4 Best Management Practices.* 2006.

Atlanta Regional Council (ARC). *Georgia Stormwater Management Manual Volume 2 Technical Handbook.* 2001.

Claytor, R.A., and T.R. Schueler. *Design of Stormwater Filtering Systems.* The Center for Watershed Protection, Silver Spring, MD, 1996.

4.3.10.9 Suggested Reading

California Storm Water Quality Task Force. *California Storm Water Best Management Practice Handbooks.* 1993.

City of Austin, TX. *Water Quality Management*. Environmental Criteria Manual, Environmental and Conservation Services, 1988.

City of Sacramento, CA. *Guidance Manual for On-Site Stormwater Quality Control Measures.* Department of Utilities, 2000.

Horner, R.R. *Biofiltration Systems for Storm Runoff Water Quality Control.* Washington State Department of Ecology, 1988.

IEP. *Vegetated Buffer Strip Designation Method Guidance Manual.* Narragansett Bay Project, 1991.

Maryland Department of the Environment. *Maryland Stormwater Design Manual, Volumes I and II.* Prepared by Center for Watershed Protection (CWP), 2000.

Metropolitan Washington Council of Governments (MWCOG). *A Current Assessment of Urban Best Management Practices: Techniques for Reducing Nonpoint Source Pollution in the Coastal Zone.* March, 1992.

4.3.11 Modular Porous Paver Systems

General Application Water Quality BMP

Description: A pavement surface composed of structural units with void areas that are filled with pervious materials such as sand or grass turf. Porous pavers are installed over a gravel base course that provides storage as runoff infiltrates through the porous paver system into underlying permeable soils.

KEY CONSIDERATIONS

DESIGN GUIDELINES:

- Design considerations are similar to any paved area (soil properties, load-bearing design, hydrologic design of pavement and subgrade).
- Soil infiltration rate of 0.5 in/hr or greater is required, if no underdrain is present.
- The infiltration rate of native soil determines appropriateness and need for an underdrain. Soil groups "D" and "C" typically require and underdrain.
- Not appropriate for heavy or high traffic areas.

ADVANTAGES / BENEFITS:

- Reduces runoff volume, attenuates peak runoff rate and outflow.
- Can be used as pretreatment for other BMPs for pollutants other than TSS.
- High level of pollutant removal for pollutants other than TSS.

DISADVANTAGES / LIMITATIONS:

- Sediment-laden runoff can clog modular porous paver systems causing failure.
- Subgrade cannot be overly compacted.
- Construction must be sequenced to avoid compaction and clogging pavement.

MAINTENANCE REQUIREMENTS:

- Vacuum to increase porous paver system life and avoid clogging.
- Ensure that contributing area is clear of debris and areas of erosion.

STORMWATER MANAGEMENT SUITABILITY

Stormwater Quality:	**Yes**
Channel Protection:	**No**
Detention/Retention:	**No**

Accepts hotspot runoff: *Yes, but does not provide stormwater treatment.*

COST CONSIDERATIONS

Land Requirement:	**Low**
Capital Cost:	**Med-High**
Maintenance Burden:	**Med**

LAND USE APPLICABILITY

Residential/Subdivision Use:	**Yes**
High Density/Ultra Urban Use:	**No**
Commercial/Industrial Use:	**No**

POLLUTANT REMOVAL

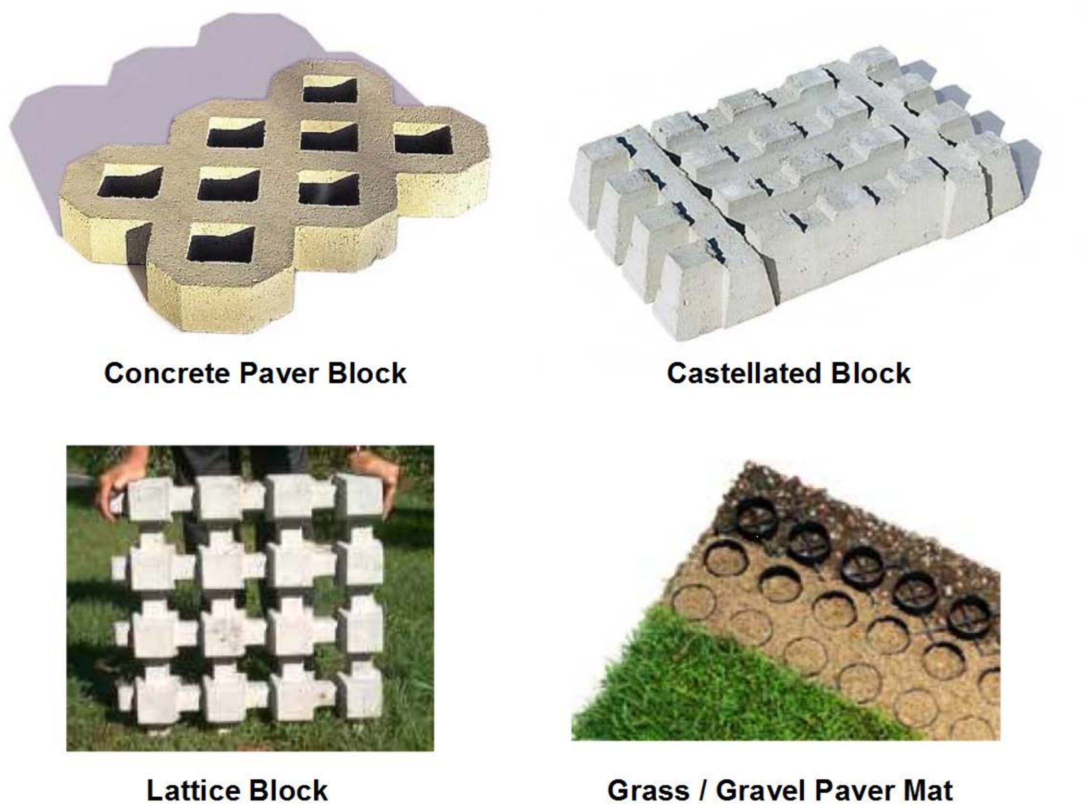
Total Suspended Solids:	**N/A**

4.3.11.1 General Description

While porous paver systems are not a recommended practice to reduce TSS, they are an excellent application to reduce the effective impervious area on a site, therefore, reducing the Water Quality Volume (WQv) that must be treated. Modular porous pavers are structural units, such as concrete blocks, bricks, or reinforced plastic mats, with regularly dispersed void areas used to create a load-bearing pavement surface. The void areas are filled with pervious materials (gravel, sand, or grass turf) to create a system that allows for the infiltration of stormwater runoff. Porous paver systems provide water quality benefits in addition to groundwater recharge and a reduction in stormwater volume.

There are many different types of modular porous pavers that are available from different manufacturers, including both pre-cast and mold in-place concrete blocks, concrete grids, interlocking bricks, and plastic mats with hollow rings or hexagonal cells (see Figure 4-45). The two main types of modular porous pavement systems are plastic grid and open cell paving grid.

Figure 4-45. Examples of Modular Porous Pavers



Plastic grid systems are often referred to as *geocells* and are defined by manufactured plastic lattices or mattresses that form networks of box-like cells that are filled with earth material. The lattice is typically 3 to 8 inches thick, and the cells range from 8.8 to 20 inches wide. Porosity and permeability of these systems is entirely dependent on the type of fill and vegetation that exists within each cell. Like any other pavement surface, geocells require a firm gravel base that provides strength and storage capacity as runoff infiltrates. Geocells are lightweight and easy to transport and install. However, they may be jarred easily by moving traffic, resulting in cell failure, cell movement, and possibly the need for replacement.

Open cell paving grids, commonly called *block pavers or grid pavers*, are structural units, such as concrete blocks or bricks with regularly spaced voids that penetrate their entire thickness. Grids are made of concrete or brick and the open cells are filled with porous aggregate or vegetated soil. Block pavers are more rigid and, therefore, can bear larger traffic loads than plastic grid systems.

Modular porous pavement systems are typically placed on a gravel (stone aggregate) base course. Runoff infiltrates through the porous paver surface into the gravel base course, which acts as a storage reservoir as it infiltrates to the underlying soil. The infiltration rate of the soils in the subgrade must be adequate to support drawdown of the entire runoff capture volume within 24 to 48 hours. If the surrounding soil infiltration is insufficient or if the potential for contamination of groundwater exists from pollutants such as chemicals, fertilizers, petroleum products, fats or greases, an underdrain is required to allow discharge of the runoff to additional BMPs for treatment. Additionally, special care must be taken during construction to avoid undue compaction of the underlying soils, which could affect the soils' infiltration capability.

Construction and maintenance costs and requirements should be considered when utilizing porous paver systems. Modular porous paver systems require a high level of construction workmanship to ensure that they function as designed. In addition, the repair or replacement of the surfaces can be costly should they become clogged.

4.3.11.2 Stormwater Management Suitability

Porous paver systems can not be used for stormwater treatment (i.e., 80% TSS removal) or flood control. The major benefit in using these systems lies in the overall reduction of stormwater runoff that can be provided. Areas covered by porous paver systems can be considered as pervious surfaces, thereby reducing water quality treatment and channel protection volumes, and flood protection peak discharges.

<u>Water Quality (WQv)</u>
Porous paver systems do not have the ability to provide stormwater quality treatment for total suspended solids (TSS). However, these systems provide for infiltration of stormwater and can provide for the removal of other pollutants, such as hydrocarbons (e.g., motor oil and gasoline).

4.3.11.3 Pollutant Removal Capabilities

Porous paver systems provide for the infiltration of stormwater runoff and they have a high removal rate of soluble pollutants. Pollutants become trapped and are then absorbed or broken down in the underlying soil layers. However, due to the potential for clogging, porous paver surfaces shall **not** be used for the removal of sediment or other particulate pollutants.

4.3.11.4 Application and Feasibility Criteria

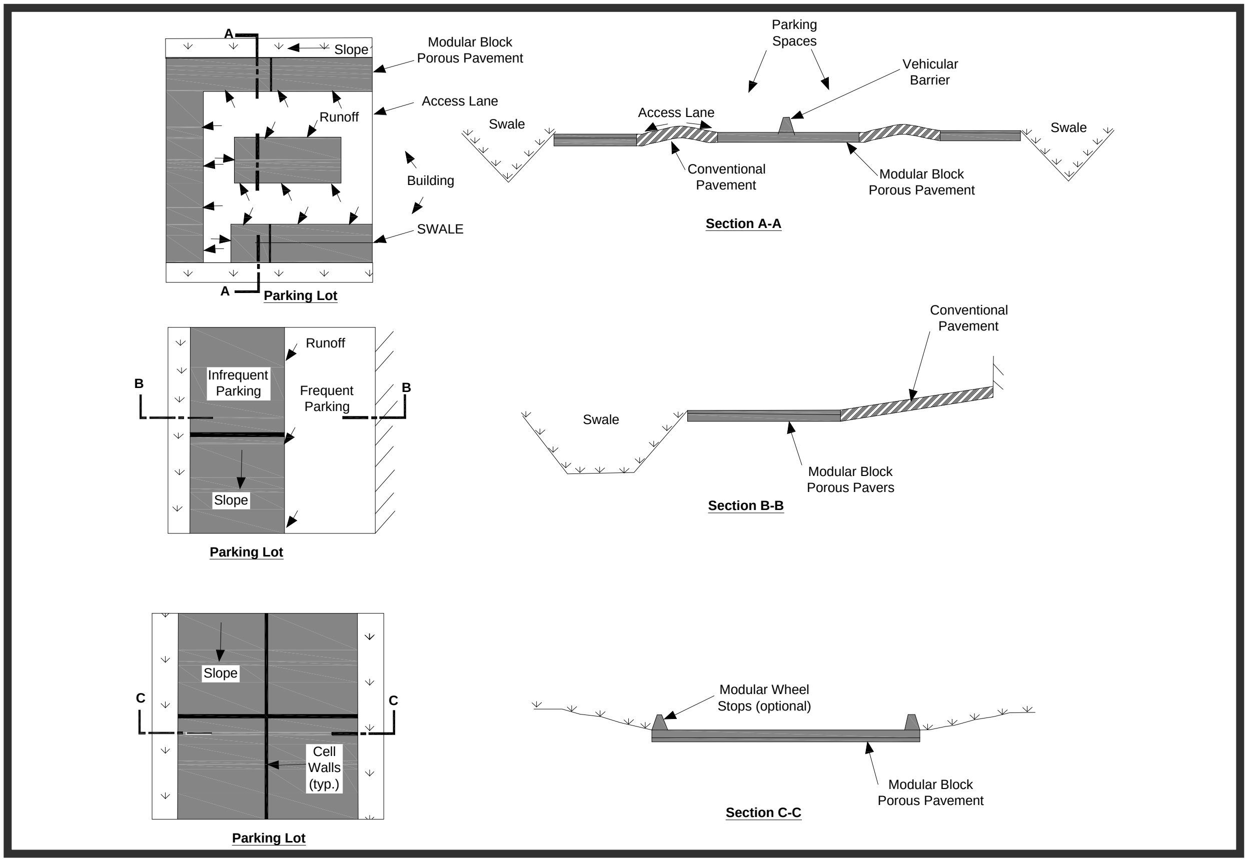
Modular porous paver systems are typically used in low-traffic areas, such as:

- parking pads in parking lots;
- overflow parking areas;
- residential driveways;
- residential street parking lanes;
- recreational trails;
- golf cart and pedestrian paths; and
- emergency vehicle and fire access lanes.

Porous paver systems shall not be used in high traffic areas due to the potential for cell compaction and failure. Examples of paver systems that have been used for some of the above listed applications are presented in Figures 4-46 and 4-47.

Figure 4-46. Examples of Porous Paver Surfaces
(Sources: Invisible Structures, Inc.; EP Henry Corp.)

Figure 4-47. Typical Modular Porous Paver System Applications
(Source: Urban Drainage and Flood Control District, 2004)



4.3.11.5 Planning and Design Standards

The Northeast Tennessee Stormwater Planning Group's design standards for modular porous paver systems are presented below. Design specifications developed by a commercial vendor for prefabricated proprietary systems can also be utilized, but must be approved where such specifications differ and/or are less stringent from the standards presented below. The local municipality shall have the authority to require additional design conditions if deemed necessary.

A. CONSTRUCTION SEQUENCING

- Ideally, the construction of the porous paver system should take place **after** the construction site has been stabilized.
- In the event that the system is not constructed after site stabilization, care should be taken during construction to minimize the compaction of the soil in the area of the porous paver system and the deposition of sediments from disturbed, unstabilized areas to the system after its installation.
- Diversion berms and erosion prevention and sediment controls shall be maintained around the paver system area during all phases of construction. No runoff or sediment shall enter the area prior to completion of construction and the complete stabilization of construction areas.
- Porous paver systems shall not be used as a temporary sediment trap for construction activities.
- During and after excavation of the area where the porous paver system will be located, all excavated materials shall be placed downstream, away from the porous paver location, to prevent redeposition of the material during runoff events.

B. LOCATION AND SITING

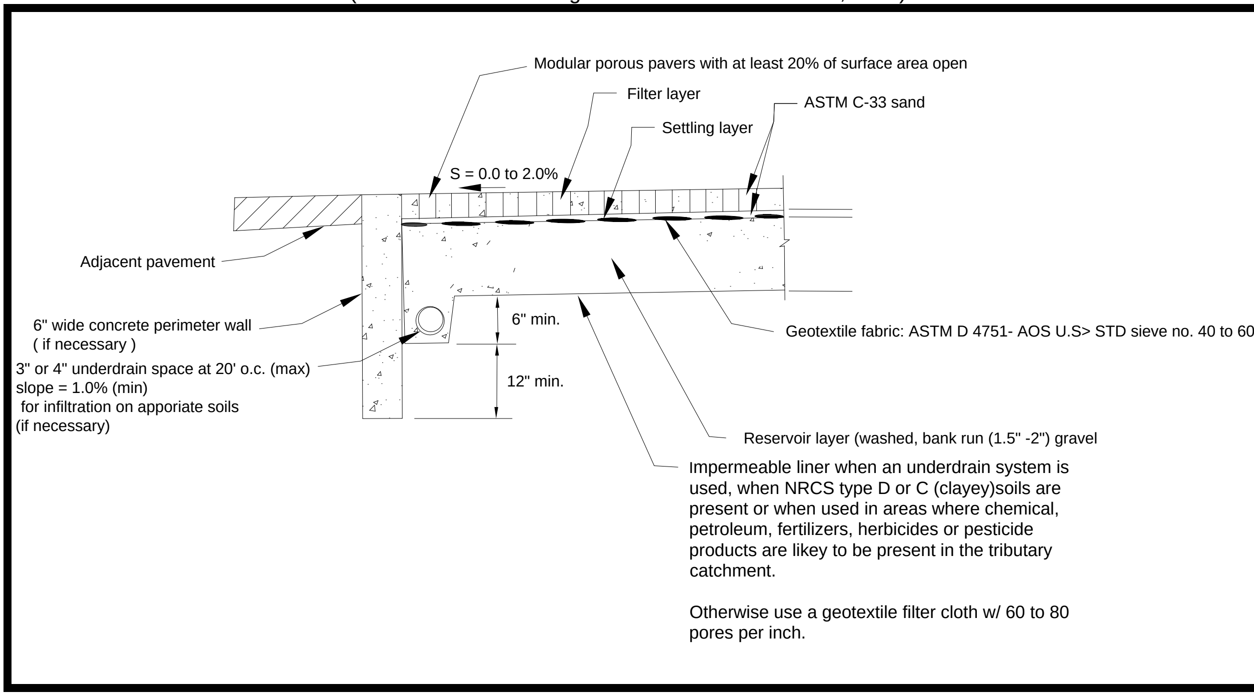
- The use of porous paver systems is limited to low traffic volume areas, such as those identified above, that have a minimum soil infiltration rate of 0.5 in/hr, if an underdrain system is not present.
- Geotechnical testing of potential installation sites is required to verify an acceptable infiltration rate.
- Modular porous paver systems should not be located:
  - Within 4 feet above bedrock or the seasonally high water level,
  - Within 100 feet of a well,
  - Within 10 feet of a building foundation that is above the proposed porous paver area or 100 feet from a building foundation that is below the proposed porous paver location,
  - Within close proximity of sources of contaminants such as gas stations,
  - On slopes greater than 5%.
- Because porous paver systems are not stormwater control devices, ideally, the area where the porous paver system is located should not receive stormwater runoff discharges from other areas. However, if that situation cannot be avoided, pretreatment of the discharges must be performed to remove sediment and other solids that can clog the porous paver system. Further, stormwater runoff discharging to the paver system area must flow into the area in a manner that will not cause damage to, or undermine, the porous paver system. Low velocity, unchannelized discharges are most favorable.

C. PHYSICAL SPECIFICATIONS / GEOMETRY

Several options exist for the top layer or surface of modular porous paver systems. The top layer should be chosen depending on strength required due to traffic loads, infiltration needs, and the manufacturer's recommendations. However, the sub-layers are generally similar, consisting of four to five layers as shown in Figure 4-48. Descriptions of each layer shown in Figure 4-48 are presented below:

- The ***Modular Porous Paver Layer*** shall consist of a modular pavement grid of plastic, concrete, or brick and an aggregate or a vegetation medium. The depth of this layer shall be 2 to 8 inches deep depending on required bearing strength, pavement design requirements, and manufacturer's specifications.
- The ***Settling Layer*** shall consist of a 0.5-inch diameter crushed stone to a depth of 1 to 2 inches. This layer serves to stabilize the porous asphalt or concrete layer and can be combined with the reservoir layer using suitable stone.
- The ***Reservoir Layer*** (or Open Graded Base Material) shall consist of washed, bank-run gravel, 1.5 to 2.5 inches in diameter with a void space of about 40%. The depth of this layer depends on the desired storage volume, which is a function of the soil infiltration rate and void spaces, but typically ranges from two to four feet. The layer must have a minimum depth of 9 inches. The layer shall be designed to drain completely in 48 hours and to store, at a minimum, the WQv. Aggregate contaminated with soil is prohibited for use in this layer. The aggregate reservoir layer can be avoided or minimized if the subgrade is sandy and there is adequate time to infiltrate the necessary runoff volume into the sandy soil without by-passing the water quality volume. Consult the manufacturer's specifications to determine the appropriate layer design.

Figure 4-48. Modular Porous Pavement Layers
(Source: Urban Drainage and Flood Control District, 2004)



- The *__Bottom Filter Layer__* (not shown in diagram) is not always required. In cases where infiltration needs to be increased, a 6 inch layer of sand or a 2 inch thick layer of 0.5 inch crushed stone can be installed. The layer shall be graded to be completely flat to promote infiltration across the entire surface. This layer serves to stabilize the reservoir layer, to protect the underlying soil from compaction, and act as the interface between the reservoir layer and the filter fabric covering the underlying soil.
- A *__Lateral Flow Barrier__* as shown in Figure 4-49 is recommended around the modular porous paver area to prevent flow of water downstream and then surfacing at the toe of the porous paver installation. If the porous paver system is large enough, it may be divided into cells with cut-off barriers (also called cell walls) having a maximum distance (L_{max}) between them that shall not exceed:

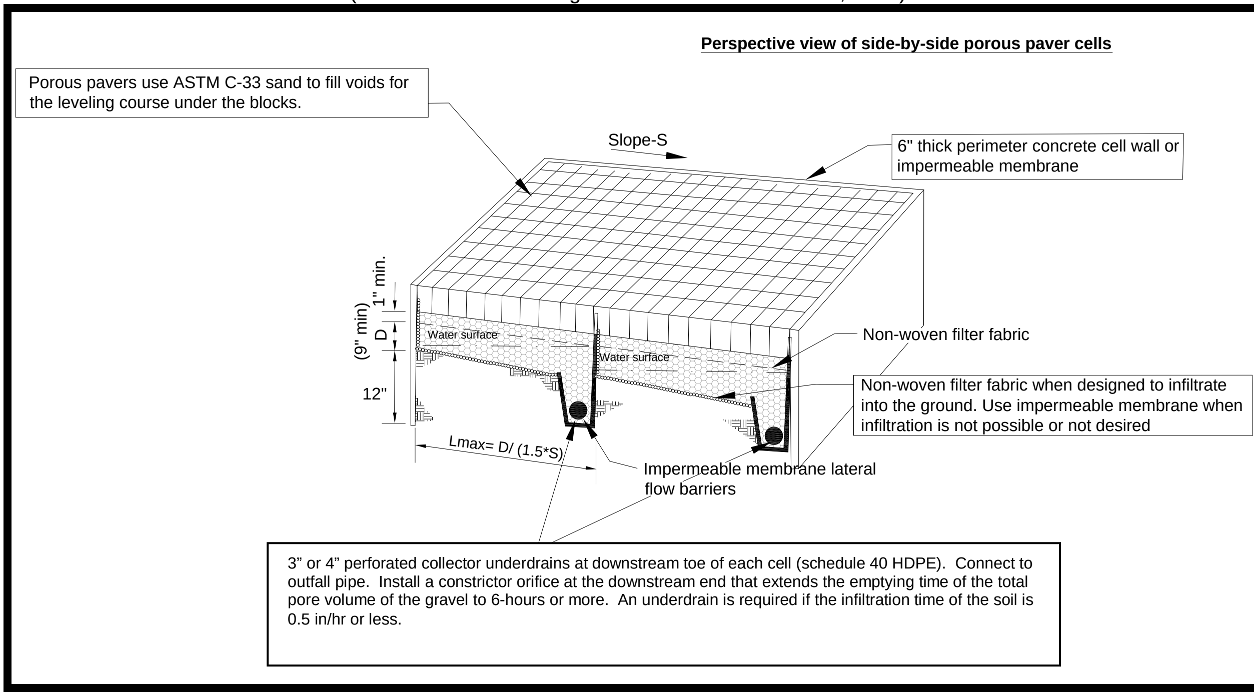
Equation 4.3.11.1

$$L_{max} = \frac{D}{1.5S}$$

where: L_{max} = Maximum distance between cut-off membrane normal to the flow (ft)
S = Slope of the reservoir layer (ft/ft)
D = Depth of reservoir layer (ft)

- *__Filter Fabric__* serves to inhibit soil from migrating into the reservoir and reducing storage capacity. The entire trench area, including the sides, shall be lined with filter fabric prior to placement of the aggregate.
- The *__Underlying Soil__* shall have an infiltration capacity of at least 0.5-inches/hour, but preferably greater than 0.5-inches/hour when an underdrain system is not present. Soils at the lower end of this range may not be suited for a full infiltration system or may require additional infiltration measures such as a perforated pipe or additional sand layer. Test borings are recommended to determine the soil classification, seasonal high ground water table elevation, and impervious substrata, and an initial estimate of permeability.

Figure 4-49. Schematic of Lateral Flow Barriers
(Source: Urban Drainage and Flood Control District, 2004)



- The *Underdrain System* (if required) shall be designed per the modular porous paver system manufacturers' recommendation or a typical underdrain schematic (taken from the Urban Storm Drainage Criteria Manual-Volume 3 - Best Management Practices of the Urban Drainage and Flood Control District in Denver, Colorado). An underdrain system is shown in Figure 4-50.

D. PRETREATMENT

- Stormwater runoff that discharges to the modular porous paver system from surrounding areas require pretreatment to remove sediment and debris. Pretreatment can be provided by a sediment forebay or equivalent upstream pretreatment. A sediment forebay is designed to remove incoming sediment from the stormwater flow prior to run-on to the area covered by porous pavers.

  If a sediment forebay is used, it shall be sized to contain 0.1 inch per impervious acre (363 ft^3) of contributing drainage and shall be no more than 4 to 6 feet deep. The pretreatment storage volume is part of the total WQv design requirement and may be subtracted from the WQv calculated for the site.

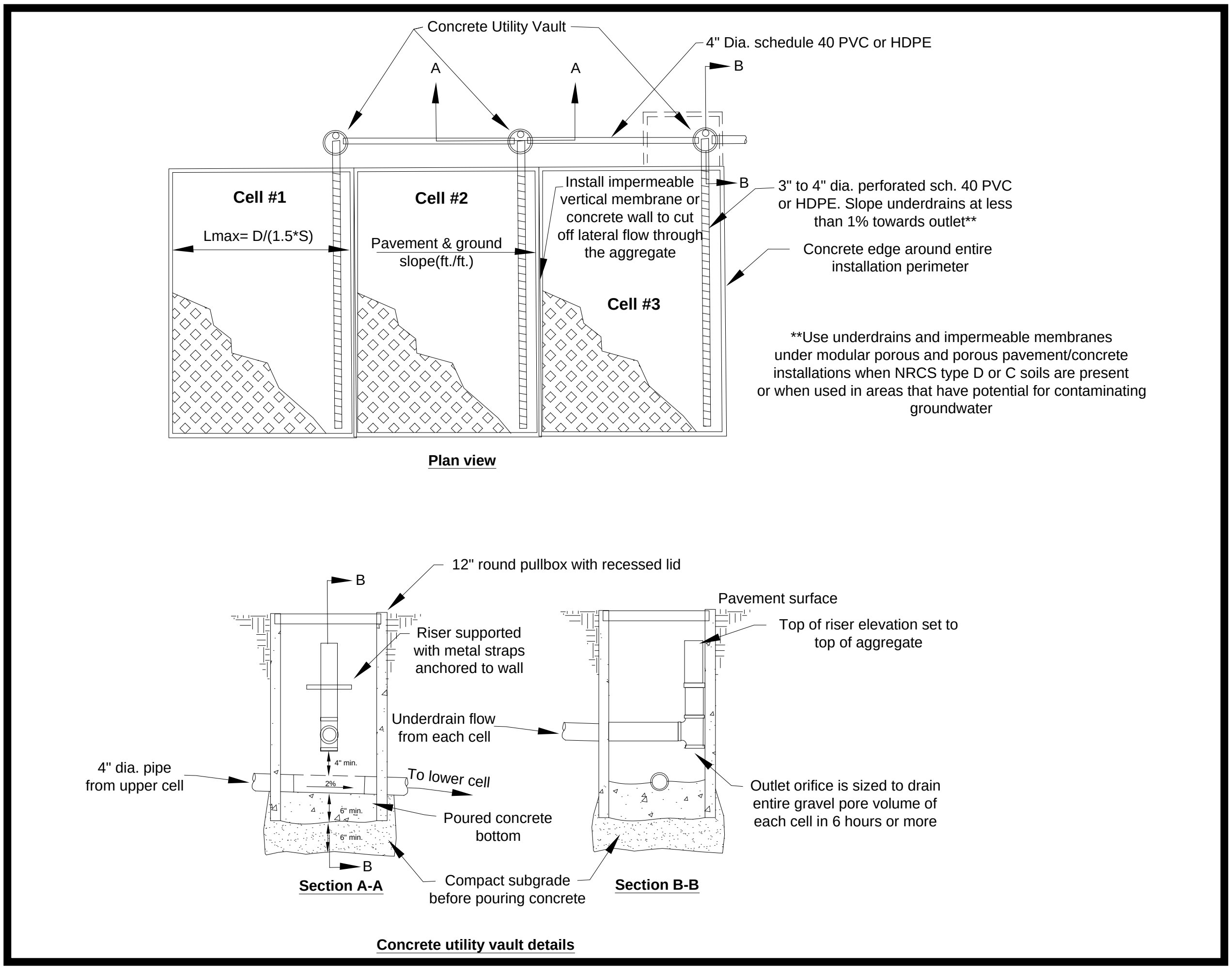
E. OUTLET STRUCTURES

- If an underdrain is incorporated into the design, an outlet pipe shall be provided from the underdrain system to the local stormwater conveyance system. Discharges shall not exit the outlet pipe in an erosive manner. Due to the slow rate of discharge, outlet erosion protection is generally unnecessary for modular porous pavement systems.

F. MAINTENANCE ACCESS

- A minimum 20' wide maintenance right of way or easement shall be provided from a driveway, public or private road. The maintenance access easement shall have a minimum unobstructed drive path width of 12 feet, appropriately stabilized to withstand maintenance equipment and vehicles.

Figure 4-50. Schematic of an Underdrain System
(Source: Urban Drainage and Flood Control District, 2004)



G. LANDSCAPING

- Porous paver systems can be designed with a grass cover to aid in pollutant removal and prevent clogging. The grass should be capable of withstanding traffic and parking requirements, and frequent periods of inundation and drought.
- Ideally, landscaped areas that may discharge, or are adjacent to, the porous paver system should consist largely of grassy vegetation and have no exposed soil. Mulch, sticks, and leaves are debris that can clog the surface of the paver system, reducing its ability to infiltrate stormwater runoff and potentially affecting the structural integrity of the system. If such landscaped areas are utilized near the paver system, care should be taken to design and maintain the landscaped area in a manner and frequency that prevents such debris from entering the paver area, or ensures frequent removal of such debris from the area. For example, maintenance practices should increase during the fall to remove leaves from the paver system if deciduous trees are located near the system.

H. SPECIAL CONSIDERATIONS FOR THE AS-BUILT CERTIFICATION AND PLANS/PLATS

- Because the use of the modular porous paver area reduces the WQv for the site and provides for stormwater treatment of some pollutants, the area must be shown on the as-built certification and the final plat specifically as a water quality BMP. The following components must be addressed in the as-built certification and final plat:

1. The boundaries of the porous pavement area; clearly identified with a note that states "Do not pave over this area. Only porous pavement is allowed in this area".
2. Clear identification of the manufacturer and type of paver system used.
3. A copy of the manufacturer's specifications for the design and installation of the system.
4. The underdrain design and specifications (if an underdrain is utilized).

4.3.11.6 Maintenance Requirements and Inspection Checklist

Note: Section 4.3.11.6 must be included in the Operations and Maintenance Plan that is recorded with the deed.

Regular inspection and maintenance is critical to the effective use of porous paver systems as stormwater best management practices. It is the responsibility of the property owner to maintain all stormwater facilities in accordance with the minimum design standards and other guidance provided in this manual. The local municipality has the authority to impose additional maintenance requirements where deemed necessary.

This page provides guidance on maintenance activities that are typically required for porous paver systems, along with a suggested frequency for each activity. Individual porous paver systems may have more, or less, frequent maintenance needs, depending upon a variety of factors including traffic volume, overly wet or dry (i.e., drought) regional hydrologic conditions, and any changes or redevelopment in the upstream land use. Each property owner shall perform the activities identified below at the frequency needed to maintain porous paver systems properly at all times.

Inspection Activities	Suggested Schedule
• Determine if the porous paver surface is free of sediment and debris (e.g., mulch, leaves, trash, etc.). • Determine if standing water exists for long periods of time after a storm event.	As needed
• Check that stormwater is not stored in the paver system longer than 48 hours after a storm. • Inspect vegetated areas that drain to the paver system and the paver system itself for evidence of erosion.	Monthly
• Inspect the surface of the paver system for structural integrity, deterioration, compaction, or spalling.	Annually
Maintenance Activities	**Suggested Schedule**
• Ensure that contributing area and porous paver surface are clear of debris (e.g., mulch, leaves, trash, etc.). • Stabilize (i.e., cover exposed soil) vegetated areas that discharge, or are adjacent to, the porous paver system. Grassy areas should be fully vegetated and mowed, with grass clippings removed. Landscaped areas should be designed and/or maintained such that they will not discharge debris (e.g., mulch, leaves) to the paver system, or that such debris is removed often.	As needed
• Vacuum sweep porous paver surface to keep free of sediment.	Quarterly
• Repair or reinstall the porous paver system, including the top and base course.	As needed

Additional Maintenance Considerations and Requirements

- Additional maintenance requirements for a porous paver system should be obtained from the manufacturer of the system and included in the Operations and Maintenance Plan for the site.
- The local municipality encourages the use of the inspection checklist presented below for guidance in the inspection and maintenance of the porous paver system. Additional items should be added to the list, based on the inspection and maintenance information provided by the manufacturer of the pavers. The local municipality can require the use of this checklist or other form(s) of maintenance documentation when and where deemed necessary in order to ensure the long-term proper operation of the unit. Questions regarding inspection and maintenance should be referred to the local municipality.

INSPECTION CHECKLIST – POROUS PAVEMENT SYSTEMS

Location: ____ Owner Change since last inspection? Y N

Owner Name, Address, Phone: ____

Date: ___________ Time: ______________ Site conditions:____

Inspection Items	Satisfactory (S) or Unsatisfactory (U)	Comments/Corrective Action
Signs of clogging (e.g., standing water)?		
Debris (e.g., mulch, trash) accumulation?		
Sediment accumulation?		
Standing water?		
Erosion from paver system underdrain?		
Exposed soil in areas discharging or adjacent to the paver system?		
Other (describe)?		
Other (describe)?		
Other (describe)?		
Hazards		
Have there been complaints from residents?		
Public hazards noted?		

If any of the above inspection items are **UNSATISFACTORY**, list corrective actions and the corresponding completion dates below:

Corrective Action Needed	Due Date

Inspector Signature:________________________________ Inspector Name (printed)___________________________________

4.3.11.7 References

AMEC. *Knox County Stormwater Management Manual Volume 2, Technical Guidance*.

AMEC. *Metropolitan Nashville and Davidson County Stormwater Management Manual, Volume 4 Best Management Practices.* 2006.

Atlanta Regional Council (ARC). *Georgia Stormwater Management Manual Volume 2 Technical Handbook.* 2001.

City of Knoxville. *Knoxville Best Management Practices Manual.* City of Knoxville Stormwater Engineering Division, March 2003.

Metropolitan Council. *Minnesota Urban Small Sites BMP Manual.* Metropolitan Council Services, St. Paul Minnesota, 2001.

Urban Drainage and Flood Control District, Denver, Colorado. *Urban Storm Drainage Criteria Manual – Volume 3 – Best Management Practices – Stormwater Quality.* 2004

4.3.11.8 Suggested Reading

California Storm Water Quality Task Force. *California Storm Water Best Management Practice Handbooks.* 1993.

US EPA. *Storm Water Technology Fact Sheet: Modular Treatment Systems.* EPA 832-F-99-044, Office of Water, 1999.

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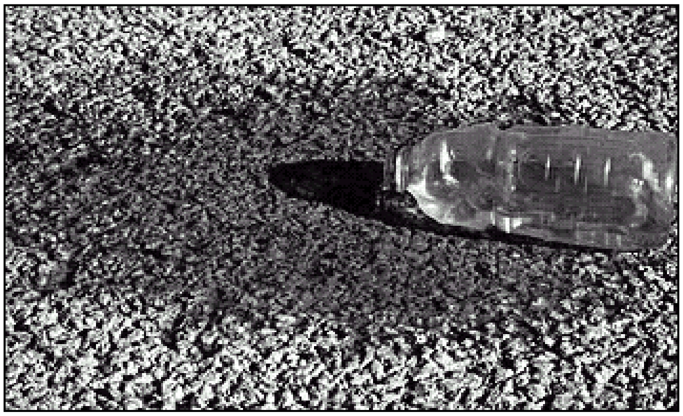
4.3.12 Porous Pavement

General Application Water Quality BMP



Description: Infiltration practices that are alternatives to traditional asphalt and concrete surfaces. Stormwater runoff is infiltrated into the ground through a permeable layer of pavement and is naturally filtered.

KEY CONSIDERATIONS

DESIGN GUIDELINES:

- Design considerations are similar to any paved area (soil properties, load-bearing design, hydrologic design of pavement and subgrade).
- Soil infiltration rate of 0.5 in/hr or greater is required if no underdrain is present.
- Soil groups "D" and "C" typically require and underdrain.
- Not appropriate for heavy or high traffic areas.
- Not appropriate as a water quality treatment BMP for drainage discharged from other areas.

ADVANTAGES / BENEFITS:

- Reduces runoff volume, attenuates peak runoff rate and outflow.
- Can be used as pretreatment for other BMPs for pollutants other than TSS.
- High level of pollutant removal for pollutants other than TSS.

DISADVANTAGES / LIMITATIONS:

- Sediment-laden runoff can clog porous pavement causing failure.
- Subgrade cannot be overly compacted.
- Construction must be sequenced to avoid compaction and clogging of pavement.

MAINTENANCE REQUIREMENTS:

- Vacuum to increase porous pavement life and avoid clogging.
- Ensure that contributing area is clear of debris and areas of erosion.

STORMWATER MANAGEMENT SUITABILITY

Stormwater Quality:	**Yes**
Channel Protection:	**No**
Detention/Retention:	**No**

Accepts hotspot runoff: *Yes, but does not provide stormwater treatment.*

COST CONSIDERATIONS

Land Requirement:	**Low**
Capital Cost:	**Med - High**
Maintenance Burden:	**Med**

LAND USE APPLICABILITY

Residential/Subdivision Use:	**Yes**
High Density/Ultra Urban Use:	**No**
Commercial/Industrial Use:	**No**

POLLUTANT REMOVAL

Total Suspended Solids:	**N/A**

4.3.12.1 General Description

Porous pavement is a paved concrete or asphalt driving surface that permits the infiltration of water through the pavement and into the underlying soil. When considering the post-development stormwater runoff from a site, porous pavement is a best management practice (BMP) that allows a developed land surface to "appear" more like undeveloped land – runoff volumes and peak discharges of stormwater runoff from a developed site with porous pavement will be less than on a site without porous pavement. Porous pavement is an excellent application to reduce the effective impervious area on a site, therefore, reducing the design volumes and peak discharges that must be controlled. This will allow a reduction in the cost of other stormwater infrastructure, a fact that may offset the greater placement cost somewhat. Porous pavement can also eliminate problems with standing water, provide for groundwater recharge, control erosion of streambeds and riverbanks, facilitate pollutant removal, reduce thermal pollution of receiving waters, and provide for a more aesthetically pleasing site. **Porous pavement is not a BMP that can be used to remove total suspended solids (TSS).**

There are two types of porous pavement: porous asphalt and pervious concrete. Porous asphalt pavement consists of open-graded coarse aggregate, bonded together by asphalt cement, with sufficient interconnected voids to make it highly permeable to water. Pervious concrete consists of a specially formulated mixture of Portland cement, uniform, open-graded coarse aggregate, and water. Pervious concrete has enough void space to allow rapid percolation of water through the pavement. The void space in pervious concrete is in the 15%-22% range compared to 3%-5% for conventional pavements. The permeable surface is placed over a layer of open-graded gravel and crushed stone. The void spaces in the stone act as a storage reservoir for runoff. Pervious concrete is considered to be more durable than porous asphalt and is thought to have a greater ability than pervious asphalt to maintain its porosity in hot weather.

Porous pavements are best applied in areas that experience low vehicular traffic including parking lots and overflow parking areas; portions of streets such as residential parking lanes; driveways; plazas; and pedestrian or golf cart paths. Porous pavements are not recommended, and will not be approved, for use on driving surfaces that experience high traffic volume, heavy loads, and sediment-laden traffic (e.g., construction areas, dump sites).

A drawback to porous pavement is the cost and complexity of it compared to conventional pavements. Porous pavement requires a very high level of construction workmanship to ensure that it functions as designed. Like any BMP, porous pavement can fail, either for use as a driving/parking surface or an impervious area reduction measure, when improperly designed, constructed, or used. Past failures of porous pavement have been attributed to poor design, inadequate construction techniques, soils with low permeability, heavy vehicular traffic, and poor maintenance (USEPA, 1999). This measure, if used, should be monitored and maintained over the life of the development.

Porous pavement is designed primarily for impervious area reduction and the subsequent reduction in stormwater treatment volumes and peak discharges, particularly for smaller storm events. For some smaller sites, trenches can be designed to capture and infiltrate the water quality volume (WQv), and in some cases, the channel protection volume (CPv). Modifications or additions to the standard design presented in this section have been used to pass flows and volumes in excess of the WQv, or to increase storage capacity or treatment. These include:

- placing a perforated pipe near the top of the crushed stone reservoir to pass excess flows after the reservoir is filled;
- providing surface detention storage in a parking lot, adjacent swale, or detention basin with suitable overflow conveyance;
- connecting the stone reservoir layer to a stone filled trench;
- adding a sand layer and perforated pipe beneath the stone layer for filtration of the water quality volume; or,
- placing an underground detention tank or vault system beneath the layers.

Porous pavement has the positive characteristics of volume reduction due to infiltration, groundwater recharge, and an ability to blend into the normal urban landscape relatively unnoticed.

4.3.12.2 Stormwater Management Suitability

Water Quality (WQv)

Porous pavement is designed solely for impervious area reduction and stormwater quality treatment of pollutants other than TSS. Porous pavements shall not be used for TSS removal. These pavements require some pretreatment BMP such as a filter strip for runoff entering the pavement to prevent clogging from sediment.

4.3.12.3 Pollutant Removal Capabilities

Porous pavement has a high removal of soluble pollutants, where they become trapped, absorbed or broken down in the underlying soil layers. However, due to the potential for clogging, porous pavement surfaces shall **not** be used for the removal of sediment or other particulate pollutants.

4.3.12.4 Application and Feasibility Criteria

Porous pavement is applicable only for use in low-traffic areas that do not encounter heavy loads and/or sediment-laden traffic or runoff, such as:

- parking pads in parking lots;
- overflow parking areas;
- residential driveways;
- residential street parking lanes;
- recreational trails;
- golf cart and pedestrian paths; and,
- emergency vehicle and fire access lanes.

4.3.12.5 Planning and Design Standards

The Northeast Tennessee Regional Stormwater Planning Group's design standards for porous pavement are presented below. Design specifications developed by a commercial vendor for prefabricated proprietary systems can also be utilized, but must be approved where such specifications differ and/or are less stringent from the standards presented below. The local municipality shall have the authority to require additional design conditions if deemed necessary.

A. CONSTRUCTION SEQUENCING

- Ideally, the construction of the porous pavement should take place after the construction site has been stabilized.
- In the event that the pavement is not constructed after site stabilization, care should be taken during construction to minimize the compaction of the soil in the area of the porous pavement and the deposition of sediments from disturbed, unstabilized areas.
- Diversion berms and erosion prevention and sediment controls shall be maintained around the porous pavement area during all phases of construction. No runoff or sediment shall enter the area prior to completion of construction and the complete stabilization of construction areas.
- Porous pavement shall not be used as a temporary sediment trap for construction activities.
- During and after excavation of the porous pavement area, all excavated materials shall be placed downstream, to prevent redeposition of the material during runoff events.

B. LOCATION AND SITING

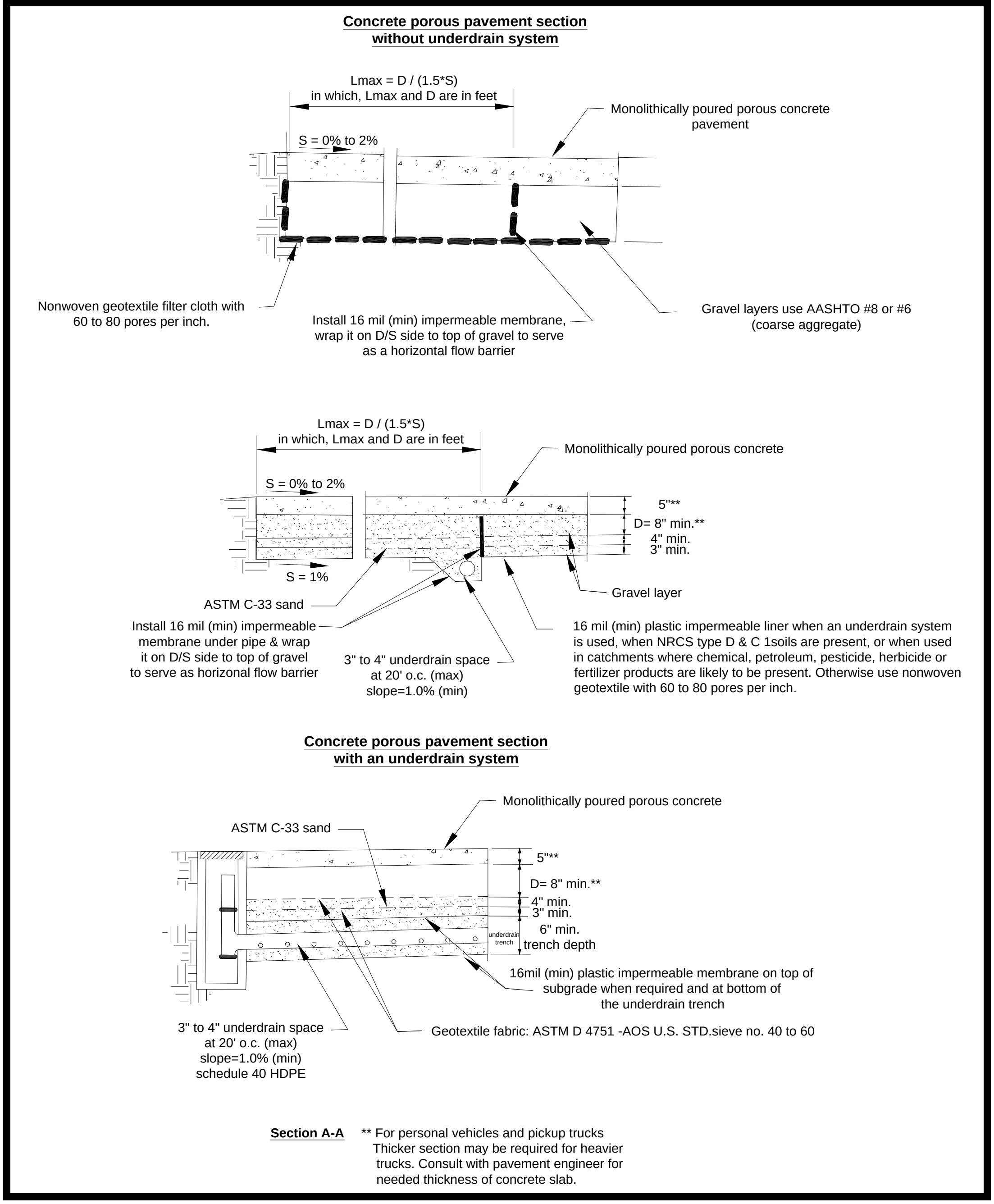
- Suitable sites for porous pavement are limited to low traffic volume areas with a minimum soil infiltration rate of 0.5 in/hr without an underdrain system. Ideally, the soil should allow the entire runoff capture volume to be discharged from the porous pavement within 24 to 48 hours.

- Geotechnical testing of the proposed installation site is required to verify an acceptable infiltration rate.
- Porous pavement shall **not** be located:
    - within two (2) feet above bedrock or the seasonally high water level,
    - within 100 feet of a well,
    - within ten (10) feet of a building foundation that is above the proposed porous pavement area or 100 feet from a building foundation that is below the proposed porous pavement location,
    - within close proximity of sources of contaminants such as gas stations,
    - on slopes greater than 5%.
- Ideally, slopes should be flat or nearly flat to facilitate infiltration as opposed to runoff.
- The seasonally high water table or bedrock should be at least two feet below the bottom of the gravel layer if infiltration is to be relied on to remove the stored volume.
- Because porous pavement is not a stormwater control device, the area where the porous pavement is located should not receive stormwater runoff discharges from other areas. However, if that situation cannot be avoided, pretreatment of the discharges must be performed to remove sediment and other solids that can clog the porous pavement. Further, stormwater runoff discharging to the porous pavement area must flow into the area in a manner that will not cause damage to, or undermine, the porous pavement. Low velocity, unchannelized discharges are most favorable.

C. PHYSICAL SPECIFICATIONS / GEOMETRY

Porous asphalt or pervious concrete for the top layer or surface of the porous pavement should be chosen depending on strength required due to traffic loads, infiltration needs, and other site constraints. However, the sub-layers are generally similar, consisting of four to five layers as shown in Figure 4-51. The aggregate reservoir layer can sometimes be avoided or minimized if the subgrade is sandy and if there is adequate time to infiltrate the water quality volume into the sandy soil without bypassing any of the water quality volume. Descriptions of each of the layers is presented below.

Figure 4-51. Porous Pavement Layers
(Source: Urban Drainage and Flood Control District, 2004)



- *Porous Pavement Layer* – This layer consists of a porous mixture of concrete or asphalt or a modular pavement grid of plastic, concrete, or brick and an aggregate or a vegetation medium. This layer is usually 2 to 4 inches deep depending on required bearing strength, pavement design requirements, and manufacturer's specifications.

- *Reservoir Layer or Open Graded Base Material* – The reservoir gravel base layer consists of washed, bank-run gravel, 1.5 to 2.5-inches in diameter with a void space of about 40%. The depth of this layer depends on the desired storage volume, which is a function of the soil infiltration rate and void spaces, but typically ranges from two to four feet. The layer must have a minimum depth of nine inches. The layer shall be designed to drain completely in 48 hours. If the porous pavement area is being utilized for stormwater quality treatment (for pollutants other than sediment/TSS), then the area must be designed to store, at a minimum, the WQv. Aggregate contaminated with soil shall not be used for the reservoir layer.

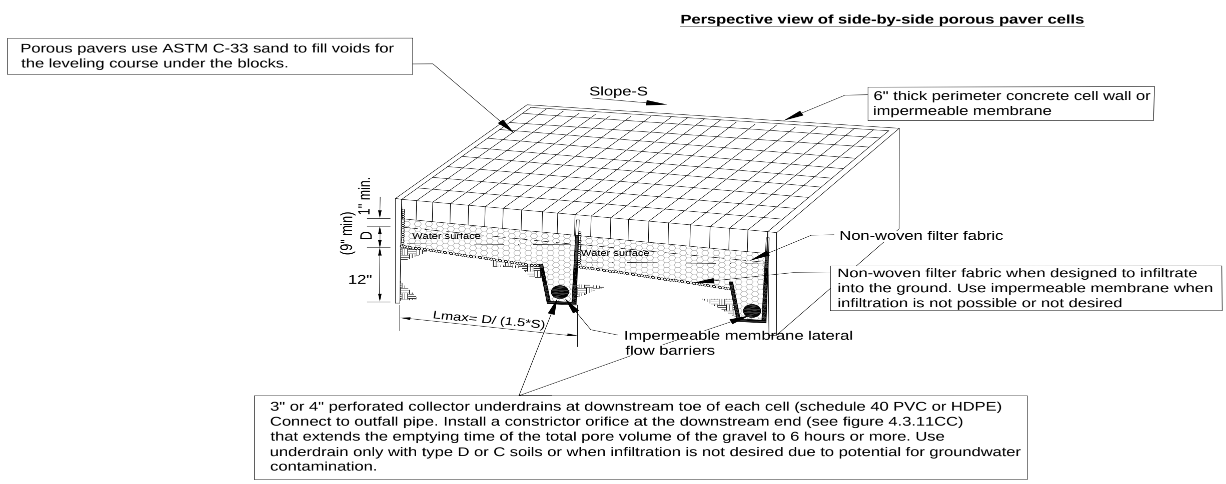
- *Bottom Filter Layer* – In cases where infiltration needs to be increased, a 6-inch layer of sand or a 2-inch thick layer of 0.5-inch crushed stone can be installed. The layer must be completely flat to promote infiltration across the entire surface. This layer serves to stabilize the reservoir layer, to protect the underlying soil from compaction, and act as the interface between the reservoir layer and the filter fabric covering the underlying soil.
- A *Lateral Flow Barrier -* as shown in Figure 4-52 is recommended around the porous pavement area to prevent flow of water downstream and then surfacing at the toe of the porous pavement installation. If the porous pavement area is large enough, it may be divided into cells with cut-off barriers having a maximum distance (L_{max}) between them that shall not exceed:

Equation 4.3.12.1

$$L_{\max} = \frac{D}{1.5S}$$

where: L_{max} = Maximum distance between cut-off membrane normal to the flow (ft)
S = Slope of the reservoir layer (ft/ft)
D = Depth of reservoir layer (ft)

Figure 4-52. Schematic of Lateral Flow Barriers
(Source: Urban Drainage and Flood Control District, 2004)

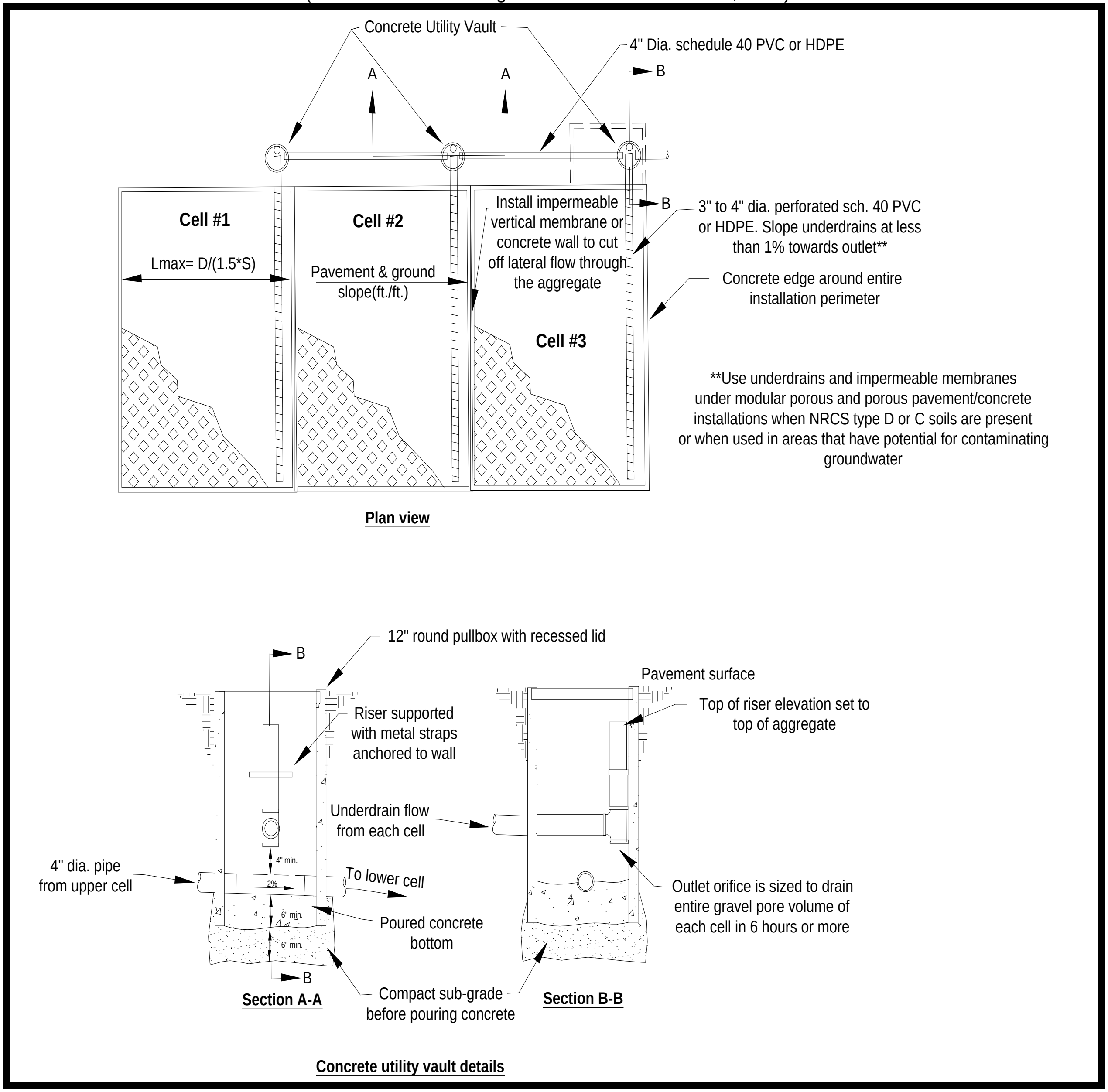


- *Filter Fabric* – It is very important to line the entire trench area, including the sides, with filter fabric prior to placement of the aggregate. The filter fabric serves to inhibit soil from migrating into the reservoir and reducing storage capacity.
- *Underlying Soil* – The underlying soil should have an infiltration capacity of at least 0.5-inches/hour but preferably greater than 0.5-inches/hour. Soils at the lower end of this range may not be suited for a full infiltration system or may require additional infiltration measures such as a perforated pipe or

additional sand layer. Test borings are recommended to determine the soil classification, seasonal high ground water table elevation, and impervious substrata, and an initial estimate of permeability.

- The *Underdrain System* (if required) shall be designed per the porous pavement manufacturers' recommendation or through the use of another reference. A typical underdrain schematic is shown in Figure 4-53.

Figure 4-53. Schematic of an Underdrain System
(Source: Urban Drainage and Flood Control District, 2004)



D. PRETREATMENT

- Although it is not recommended that runoff from other areas be discharged to the porous pavement area, stormwater runoff that discharges to the porous pavement system from surrounding areas requires pretreatment to remove sediment and debris. Pretreatment can be provided by a sediment forebay or equivalent upstream pretreatment. A sediment forebay is designed to remove incoming sediment from the stormwater flow prior to run-on to the area covered by porous pavement.
- If a sediment forebay is used, it shall be sized to contain 0.1 inch per impervious acre (363 ft^3) of contributing drainage and shall be no more than 4 to 6 feet deep. The pretreatment storage volume is part of the total WQv design requirement and may be subtracted from the WQv calculated for the site.

E. OUTLET STRUCTURES

- If an underdrain system is incorporated into the design, an outlet pipe shall be provided from the underdrain system to the local stormwater conveyance system. Discharges shall not exit the outlet pipe in an erosive manner. Due to the slow rate of discharge, outlet erosion protection is generally unnecessary for modular porous pavement systems.

F. MAINTENANCE ACCESS

- A minimum 20' wide maintenance right-of-way or easement shall be provided from a driveway, public or private road. The maintenance access easement shall have a minimum unobstructed drive path width of 12 feet, appropriately stabilized to withstand maintenance equipment and vehicles.

G. LANDSCAPING

- Landscaped areas that may discharge, or are adjacent to, the porous pavement should consist largely of grassy vegetation and have no exposed soil. Mulch, sticks, and leaves are debris that can clog the surface of the porous pavement, reducing its ability to infiltrate stormwater runoff. If such landscaped areas are utilized near the porous pavement, care should be taken to design and maintain the landscaped area in a manner and frequency that prevents such debris from entering the porous pavement, or ensures frequent removal of such debris from the area. For example, maintenance practices should increase during the fall to remove leaves from the porous pavement if deciduous trees are located near the system.

H. SPECIAL CONSIDERATIONS FOR THE AS-BUILT CERTIFICATION AND PLANS/PLATS

- Because the use of porous pavement reduces the WQv for the site and provides for stormwater treatment of some pollutants, the area must be shown on the as-built certification and the final plat specifically as a water quality BMP. The following components must be addressed in the as-built certification and final plat:

    1. The boundaries of the porous pavement area; clearly identified with a note that states “Pervious pavement area. Do not pave with impervious pavement surfaces.”
    2. Clear identification of the type of porous pavement used.
    3. The underdrain design and specification (if an underdrain is utilized).

4.3.12.6 Maintenance Requirements and Inspection Checklist

Note: Section 4.3.12.6 must be included in the Operations and Maintenance Plan that is recorded with the deed.

Regular inspection and maintenance is critical to the effective use of porous pavement as a stormwater best management practice. It is the responsibility of the property owner to maintain all stormwater facilities in accordance with the minimum design standards and other guidance provided in this manual. The local municipality has the authority to impose additional maintenance requirements where deemed necessary.

This page provides guidance on maintenance activities that are typically required for porous pavement, along with a suggested frequency for each activity. Individual porous pavement applications may have more, or less, frequent maintenance needs, depending upon a variety of factors including traffic loads, the occurrence of large storm events, overly wet or dry (i.e., drought) regional hydrologic conditions, and any changes or redevelopment in the upstream land use. Each property owner shall perform the activities identified below at the frequency needed to maintain porous pavement properly at all times.

Inspection Activities	**Suggested Schedule**
• Ensure that the porous pavement surface is free of sediment and debris (e.g., mulch, leaves, trash, etc.). • Ensure that the contributing area upstream of the porous pavement surface is free of sediment and debris.	As needed
• Check to make sure that the porous pavement dewaters between storms.	Monthly
• Inspect the surface for structural integrity. Inspect for evidence of deterioration or spalling.	Annually
Maintenance Activities	**Suggested Schedule**
• Ensure that contributing area and porous pavement surface are clear of debris (e.g., mulch, leaves, trash, etc.). • Ensure that the contributing and adjacent area is stabilized and mowed, with clippings removed.	As needed, based on inspection
• Vacuum sweep porous pavement surface to keep free of sediment.	Typically three to four times a year
• Replace the porous pavement, including the top and base course, as needed.	Upon failure

The local municipality encourages the use of the inspection checklist presented below for guidance in the inspection and maintenance of porous pavement. The local municipality can require the use of this checklist or other form(s) of maintenance documentation when and where deemed necessary in order to ensure the long-term proper operation of the unit. Questions regarding inspection and maintenance should be referred to the local municipality.

INSPECTION CHECKLIST – POROUS PAVEMENT

Location: ____ Owner Change since last inspection? Y N

Owner Name, Address, Phone: ____

Date: ___________ Time: ______________ Site conditions:____

Inspection Items	Satisfactory (S) or Unsatisfactory (U)	Comments/Corrective Action
Signs of clogging (e.g., standing water)?		
Debris (mulch, trash) accumulation?		
Sediment accumulation?		
Standing water?		
Erosion from underdrain (if present)?		
Exposed soil in areas discharging or adjacent to the porous pavement area?		
Runoff discharge from pavement area 24 to 48 hours after the end of a storm event?		
Other (describe)?		
Other (describe)?		
Hazards		
Have there been complaints from residents?		
Public hazards noted?		

If any of the above inspection items are **UNSATISFACTORY**, list corrective actions and the corresponding completion dates below:

Corrective Action Needed	Due Date

Inspector Signature:_________________________________ Inspector Name (printed)_________________________________

4.3.12.7 Example Schematics

Figure 4-54. Porous Pavement Installation

Figure 4-55. Typical Porous Pavement Applications
(Photos by Bruce Ferguson, Don Wade)

4.3.12.8 References

AMEC. *Knox County Stormwater Management Manual Volume 2, Technical Guidance*.

AMEC. *Metropolitan Nashville and Davidson County Stormwater Management Manual, Volume 4 Best Management Practices.* 2006.

Atlanta Regional Council (ARC). *Georgia Stormwater Management Manual Volume 2 Technical Handbook.* 2001.

City of Knoxville. *Knoxville Best Management Practices Manual.* City of Knoxville Stormwater Engineering Division, March 2003.

Metropolitan Council. *Minnesota Urban Small Sites BMP Manual.* Metropolitan Council Services, St. Paul Minnesota, 2001.

Urban Drainage and Flood Control District, Denver, Colorado. *Urban Storm Drainage Criteria Manual – Volume 3 – Best Management Practices – Stormwater Quality.* 2004

4.3.12.9 Suggested Reading

California Storm Water Quality Task Force. *California Storm Water Best Management Practice Handbooks.* 1993.

US EPA. *Storm Water Technology Fact Sheet: Modular Treatment Systems.* EPA 832-F-99-044, Office of Water, 1999.

4.4.1 Organic Filter

Limited Application Water Quality BMP

Description: The organic filter is a design variation of the surface sand filter that uses organic media to filter stormwater, as opposed to sand. An organic filter has two chambers. The first chamber is used for settling of heavy pollutant particles. The second chamber is filled with organic media and used to filter out fine particles.

KEY CONSIDERATIONS

DESIGN GUIDELINES:

- Maximum drainage area of 10 acres.
- Minimum head requirement of 5 to 8 feet.
- Requires the use of a peat/sand mixture as the filter media.
- Runoff discharges to an underdrain system.
- Intended for hotspot or space-limited applications, or for areas requiring enhanced pollutant removal capability.

ADVANTAGES / BENEFITS:

- Useful for treatment of small drainage areas and highly impervious areas.
- Good retrofit capability.

DISADVANTAGES / LIMITATIONS:

- High installation and maintenance burden.
- Not recommended for areas that have high sediment content in stormwater or clay/silt runoff areas.
- Possible odor problems.
- Should be installed after site construction is complete.

MAINTENANCE REQUIREMENTS:

- Inspect for clogging.
- Remove sediment from forebay/chamber.
- Replace filter media as needed.
- Stabilize, clean and maintain upstream drainage areas.

STORMWATER MANAGEMENT SUITABILITY

Stormwater Quality:	**Yes**
Channel Protection:	✷
Detention/Retention:	**No**

Accepts hotspot runoff: *Yes, but two feet of separation distance required to water table when used in hotspot areas*

COST CONSIDERATIONS

Land Requirement:	**Low**
Capital Cost:	**High**
Maintenance Burden:	**High**

LAND USE APPLICABILITY

Residential/Subdivision Use:	✷
High Density/Ultra Urban Use:	**Yes**
Commercial/Industrial Use:	**Yes**

POLLUTANT REMOVAL

Total Suspended Solids:	**80%**

✷ in certain situations

4.4.1.1 General Description

The organic filter is a design variant of the surface sand filter, which uses organic materials such as leaf compost or a peat/sand mixture as the filter media. The organic material enhances pollutant removal by providing adsorption of contaminants such as soluble metals, hydrocarbons, and other organic chemicals.

As with the surface sand filter, an organic filter consists of a pretreatment chamber, and one or more filter cells. Each filter bed contains a layer of leaf compost or the peat/sand mixture, followed by filter fabric and a gravel/perforated pipe underdrain system. The filter bed and subsoils can be separated by an impermeable polyliner or concrete structure to prevent movement into groundwater.

Organic filters are typically used in high-density applications, or for areas requiring enhanced pollutant removal ability. Maintenance is typically higher than the surface sand filter facility due to the need to reduce the potential for debris and sediment clogging the organic filter. In addition, organic filter systems have a higher head requirement than sand filters.

4.4.1.2 Stormwater Management Suitability

Organic filter systems are designed primarily as off-line systems for treatment of the water quality volume. They are not useful for flood protection and will typically need to be used in conjunction with another structural BMP, such as a conventional detention basin that can provide downstream channel protection, overbank flood protection, and extreme flood protection. Further, organic filter facilities must provide flow diversion and/or be designed to safely pass extreme storm flows and protect the filter bed and facility. Under certain circumstances, organic filters can provide limited runoff quantity control, particularly for smaller storm events.

Water Quality (WQv)
In organic filter systems, stormwater pollutants are removed through a combination of gravitational settling, filtration and adsorption. The filtration process effectively removes suspended solids and particulates, biochemical oxygen demand (BOD), fecal coliform bacteria, and other pollutants. Organic filters with a grass cover have additional opportunities for bacterial decomposition as well as vegetation uptake of pollutants, particularly nutrients.

Channel Protection (CPv)
For smaller sites, an organic filter may be designed to capture the entire channel protection volume (CPv) in either an off- or on-line configuration. Given that an organic filter system is typically designed to completely drain over 40 hours, the channel protection design requirement for extended detention of the 1-year, 24-hour storm runoff volume can be met. For larger sites or where only the WQv is diverted to the organic filter facility, another structural control must be used to provide extended detention of the CPv.

4.4.1.3 Pollutant Removal Capabilities

Peat/sand filter systems provide good removal of bacteria and organic waste metals. The total suspended solids design pollutant removal rate of 80% is a conservative average pollutant reduction percentage for design purposes derived from sampling data, modeling and professional judgment.

For additional information and data on pollutant removal capabilities for organic filters, see the National Pollutant Removal Performance Database (2nd Edition) available at www.cwp.org and the International Stormwater Best Management Practices (BMP) Database at www.bmpdatabase.org.

4.4.1.4 Application and Site Feasibility Criteria

Organic filter systems are well-suited for highly impervious areas where land available for structural BMPs is limited. Organic filters should primarily be considered for new construction or retrofit opportunities for commercial, industrial, and institutional areas where the sediment load is relatively low, such as: parking lots, driveways, loading docks, gas stations, garages, airport runways/taxiways, and storage yards. Organic filters may also be feasible and appropriate in some multi-family residential developments where maintenance is performed by a landscaping (or other suitably capable) company.

To avoid rapid clogging and failure of the filter media, the use of organic filters should be avoided in areas with less than 50% impervious cover, or high sediment yield sites with clay/silt soils.

The following basic criteria should be evaluated to ensure the suitability of an organic filter facility for meeting stormwater management objectives on a site or development.

General Feasibility

- Not generally suitable for use in a residential subdivision.
- Suitable for use in high density/ultra urban areas.
- Not suitable for use as a regional stormwater control. On-site applications are typically most feasible.

Physical Feasibility - Physical Constraints at Project Site

- Drainage Area – Ten (10) acres maximum
- Space Required – Function of available head at site
- Minimum Head – The surface slope across the filter location should be no greater than 6%. The elevation difference needed at a site from the inflow to the outflow is 5 to 8 feet.
- Minimum Depth to Water Table – If used on a site with an underlying water supply aquifer, a separation distance of 2 feet required between the bottom of the organic filter and the elevation of the seasonally high water table to prevent groundwater contamination.
- Soils – Not recommended for drainage areas with exposed soil. Karst areas may require a liner.

Other Constraints / Considerations

- Aquifer Protection – Do not allow infiltration of filtered hotspot runoff into groundwater

4.4.1.5 Planning and Design Standards

The following standards shall be considered **minimum** design standards for the design of organic filters. Organic filters that are not designed to these standards will not be approved. The local municipality shall have the authority to require additional design conditions if deemed necessary.

A. CONSTRUCTION SEQUENCING

- Ideally, the construction of an organic filter shall take place **after** the construction site has been stabilized.
- In the event that the organic filter is not constructed after site stabilization, care shall be taken during construction to minimize the risk of premature failure of the organic filter due to deposition of sediments from disturbed, unstabilized areas.
- Diversion berms and erosion prevention and sediment controls shall be maintained around an organic filter during all phases of construction. No runoff or sediment shall enter the organic filter area prior to completion of construction and the complete stabilization of construction areas.
- Organic filters shall not be used as a temporary sediment trap for construction activities.
- During and after excavation of the organic filter, all excavated materials shall be placed downstream, away from the organic filters, to prevent redeposit of the material during runoff events.

B. LOCATION AND SITING

- Organic filter systems are generally applied to land uses with a high percentage of impervious surfaces. Organic filters shall not be utilized for sites that have less than 50% impervious cover. Pretreatment must be provided as described in part E below, due to the potential for high clay/silt sediment loads that could result in clogging and failure of the filter bed. Any disturbed or denuded areas located within the area draining to and treated by the organic filter shall be stabilized prior to construction and use of the organic filter.

- It is preferred that organic filters only be used in an off-line configuration where the WQv (and CPv if used for this purpose) is diverted to the filter facility through the use of a flow diversion structure and flow splitter. Stormwater flows greater than the WQv (and CPv if used for this purpose) are then diverted to other controls or downstream using a diversion structure or flow splitter.
- Organic filter systems shall be designed for intermittent flow and must be allowed to drain and re-aerate between rainfall events. They shall not be used on sites with a continuous flow from groundwater, sump pumps, or other sources.

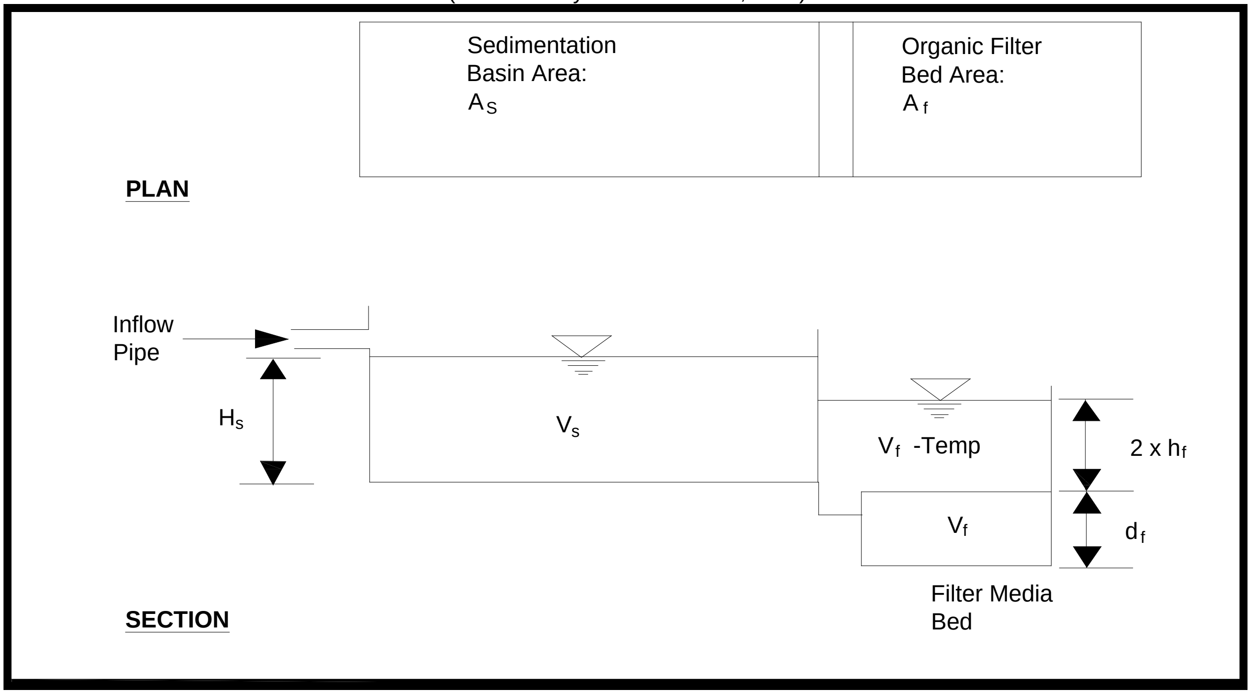
C. GENERAL DESIGN

- An organic filter facility shall consist of a two-chamber open-air structure, which is located at ground-level. The first chamber is the sediment forebay (commonly referred to as the sedimentation chamber) while the second chamber houses the filtration chamber (organic filter bed). Flow enters the sedimentation chamber where settling of larger sediment particles occurs. Runoff is then discharged from the sedimentation chamber through a perforated standpipe into the filtration chamber. After passing though the filter bed, runoff is collected by a perforated pipe and gravel underdrain system. Figure 4-58 provides a plan view and profile schematic of an organic filter.
- Organic filters can utilize a variety of organic materials as the filtering media. Two typical media bed configurations are the peat/sand filter and compost filter (see Figure 4-58). The peat filter includes an 18-inch 50/50 peat/sand mix over a 6-inch sand layer and can be optionally covered by 3 inches of topsoil and vegetation. The compost filter has an 18-inch compost layer.
- The type of peat used in a peat/sand filter is critically important. Fibric peat in which undecomposed fibrous organic material is readily identifiable is the preferred type. Hemic peat containing more decomposed material may also be used. Sapric peat made up of largely decomposed matter should *not* be used in an organic filter.

D. PHYSICAL SPECIFICATIONS / GEOMETRY

- The entire organic filter treatment system (including the sedimentation chamber) shall be designed to temporarily hold at least 75% of the WQv prior to filtration. Figure 4-56 illustrates the distribution of the treatment volume (0.75 WQv) among the various components of the surface sand filter, including:
  - V_s – volume within the sedimentation basin
  - V_f – volume within the voids in the filter bed
  - $V_{f\text{-}temp}$ – temporary volume stored above the filter bed
  - A_s – the surface area of the sedimentation basin
  - A_f – surface area of the filter media
  - h_s – height of water in the sedimentation basin
  - h_f – average height of water above the filter media
  - d_f – depth of filter media

Figure 4-56. Organic Filter Volumes
(Source: Claytor and Schueler, 1996)



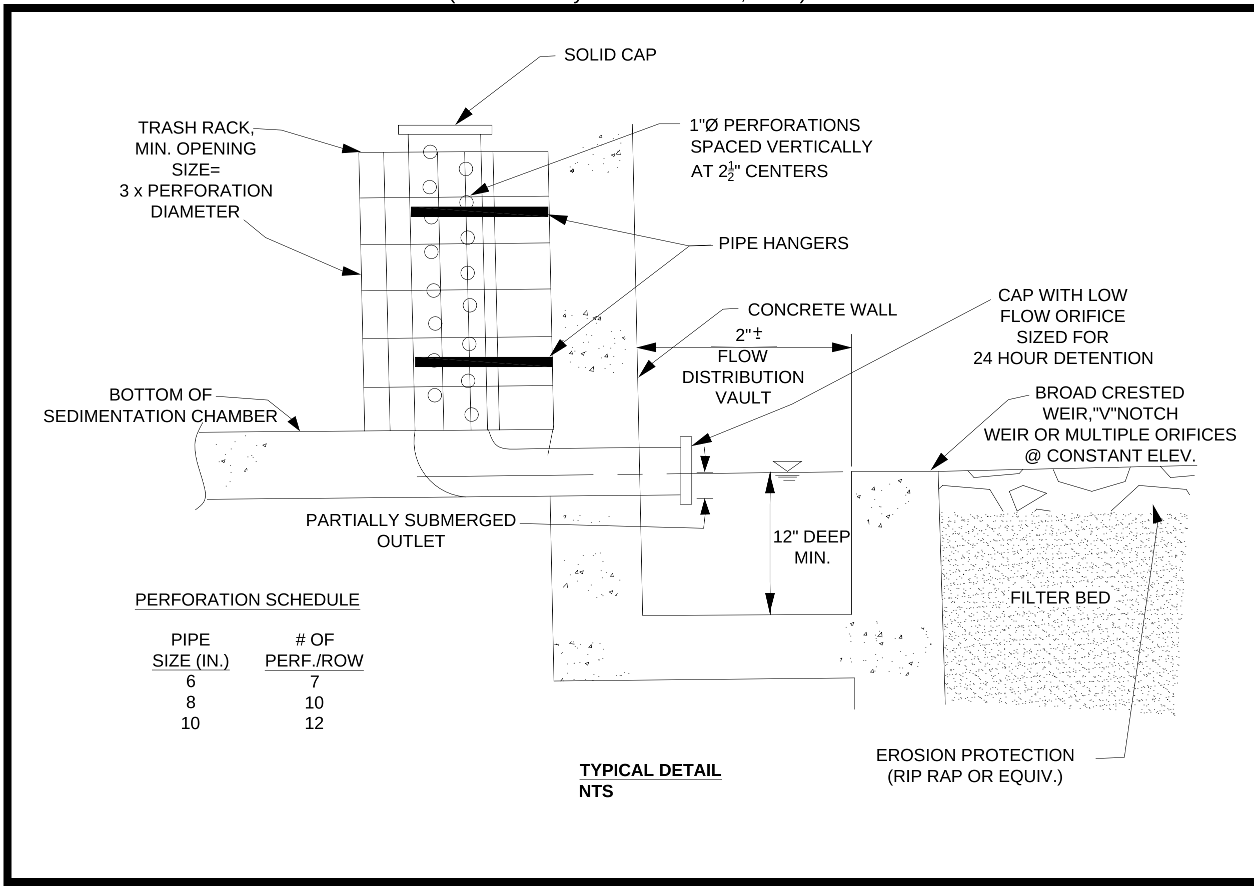
- The sedimentation chamber shall be sized to hold at least 25% of the computed WQv and have a length-to-width ratio of at least 2:1. Inlet and outlet structures should be located at opposite ends of the chamber.
- The filter area shall be sized based on the principles of Darcy's Law. A coefficient of permeability (k) of 3.5 ft/day for sand, 2.0 ft/day for peat and 8.7 ft/day for leaf compost shall be used. The filter bed shall be designed to completely drain in 40 hours or less.
- The filter media for an organic filter shall consist of either an 18" layer of peat/sand mixture on top of a 6" sand layer or an 18" layer of leaf compost. Both types of media are placed on top of the underdrain system. Three inches of topsoil shall be placed over the sand bed. Permeable filter fabric shall be placed both above and below the filter bed to prevent clogging of the filter media and the underdrain system. Figure 4-58 illustrates a typical media cross section.
- The filter bed shall be equipped with a 6-inch perforated pipe underdrain (PVC AASHTO M 252, HDPE, or other suitable pipe material) in a gravel layer. The underdrain shall have a minimum grade of 1/8-inch per foot (1% slope). Holes shall be 3/8-inch diameter and spaced approximately 6 inches on center. Gravel shall be clean-washed aggregate with a maximum diameter of 3.5 inches and a minimum diameter of 1.5 inches with a void space of about 40%. Aggregate contaminated with soil shall not be used.
- The structure of the organic filter may be constructed of impermeable media such as concrete, or through the use of excavations and earthen embankments. When constructed with earthen walls/embankments, filter fabric shall be used to line the bottom and side slopes of the structures before installation of the underdrain system and filter media.

E. PRETREATMENT / INLETS

- Pretreatment of runoff in an organic filter system shall be by a sedimentation chamber, designed in accordance with the criteria stated above.
- Energy dissipators shall be used at the inlets to organic filters. Figure 4-57 shows a typical inlet pipe from the sedimentation basin to the filter media basin for the surface sand filter which can be also be utilized for an organic filter.

- The organic filter shall be designed such that runoff exits the sedimentation chamber at a non-erosive velocity.

Figure 4-57. Surface Sand Filter Perforated Stand-Pipe
(Source: Claytor and Schueler, 1996)



F. OUTLET STRUCTURES

- An outlet pipe shall be provided from the underdrain system to the facility discharge. Due to the slow rate of filtration, outlet protection is generally unnecessary (except for emergency overflows and spillways). However, the design shall ensure that the discharges from the underdrain system occur in a non-erosive manner.

G. EMERGENCY SPILLWAY

- An emergency or bypass spillway must be included in the organic filter design to safely pass flows that exceed the WQv (and CPv if the filter is utilized for channel protection purposes). The spillway prevents filter water levels from overtopping the embankment and causing structural damage. The emergency spillway shall be located so that embankments, downstream buildings and structures will not be impacted by spillway discharges.

H. MAINTENANCE ACCESS

- A minimum 20' wide maintenance right-of-way or drainage easement shall be provided for the organic filter from a driveway, public or private road. The maintenance access easement shall have a maximum slope of no more than 15% and shall have a minimum unobstructed drive path having a width of 12 feet, appropriately stabilized to withstand maintenance equipment and vehicles. Adequate access must be provided to the filter bed. Facility designs must enable maintenance personnel to easily remove and replace upper layers of the filter media.

I. SAFETY FEATURES

- Where necessary, surface organic filter facilities can be fenced to prevent access.
- Inlets and outlets shall be designed and maintained so as not to permit access by children.

J. LANDSCAPING

- Organic filters can be designed with a grass cover to aid in pollutant removal and prevent clogging. The grass should be capable of withstanding frequent periods of inundation and drought.

K. ADDITIONAL SITE-SPECIFIC DESIGN CRITERIA AND ISSUES

Physiographic Factors - Local terrain design constraints

- Low Relief – Use of an organic filter may be limited by low head
- High Relief – Filter bed surface must be level
- Karst – Use liner or impermeable membrane to seal bottom earthen surface of the organic filter or use watertight structure

Special Downstream Watershed Considerations

- Wellhead Protection – Reduce potential groundwater contamination (in required wellhead protection areas) by preventing infiltration of hotspot runoff. May require liner for type "A" and "B" soils; Pretreat hotspots; provide 2 to 4 foot separation distance from water table.

4.4.1.6 Design Procedures

Step 1. Compute runoff control volumes

Calculate WQv and CPv in accordance with the guidance presented in Chapter 3. Consult local regulations for peak discharge control (i.e., detention) requirements.

Step 2. Determine if the development site and conditions are appropriate for the use of organic filter.

Consider the subsections 4.4.1.4 and 4.4.1.5.K. Check with Northeast Tennessee Regional Stormwater Planning Group and other agencies as appropriate to determine if there are any additional restrictions and/or surface water or watershed requirements that may apply.

Step 3. Compute WQv peak discharge (Q_{wq})

The peak rate of discharge for water quality design storm is needed for sizing of off-line diversion structures (see Chapter 3 for more information on this calculation).

(a) Using WQv, compute CN

(b) Compute time of concentration using TR-55 method

(c) Determine appropriate unit peak discharge from time of concentration

(d) Compute Q_{wq} (in inches) from unit peak discharge, drainage area, and WQv

Step 4. Size flow diversion structure, if needed

A flow regulator (or flow splitter diversion structure) should be supplied to divert the WQv to the organic filter facility. Size low flow orifice, weir, or other device to pass Q_{wq}.

Step 5. Size filtration basin chamber

The filter area is sized using the following equation (based on Darcy's Law):

$$A_f = (WQv)\,(d_f) / [(k)\,(h_f + d_f)\,(t_f)]$$

where:

WQv = water quality volume (ft^3)
A_f = surface area of filter bed (ft^2)
d_f = filter bed depth

(at least 1.5 feet, no more than 2 feet)
k = coefficient of permeability of filter media (ft/day)
(use 3.5 ft/day for sand)
(use 2.0 ft/day for peat)
(use 8.7 ft/day for leaf compost)
h_f = average height of water above filter bed (ft)
(1/2 h_{max}, which varies based on site but h_{max} is typically ≤ 6 feet)
t_f = design filter bed drain time (days)
(1.67 days or 40 hours is required maximum time)

Set preliminary dimensions of filtration basin chamber.

Step 6. Size sedimentation chamber

The sedimentation chamber shall be sized to at least 25% of the computed WQv and have a length-to-width ratio of 2:1. The Camp-Hazen equation is used to compute the required surface area:

$$A_s = -(Q_o/w) * \text{Ln}(1-E)$$

where:
A_s = sedimentation basin surface area (ft^2)
Q_o = rate of outflow = the WQv (ft^3) / 86400 seconds
w = particle settling velocity (ft/sec)
E = trap efficiency

Assuming:
- 90% sediment trap efficiency (0.9)
- particle settling velocity (ft/sec) = 0.0033 ft/sec for imperviousness (I) ≥ 75%
- particle settling velocity (ft/sec) = 0.0004 ft/sec for imperviousness (I) < 75%
- average of 24 hour holding period

Then:
A_s = (0.0081) (WQv) ft^2 for I ≥ 75%
A_s = (0.066) (WQv) ft^2 for I < 75%

Set preliminary dimensions of sedimentation chamber.

Step 7. Compute V_{min}

$$V_{min} = 0.75 * WQv$$

Step 8. Compute storage volumes within entire facility and sedimentation chamber orifice size

Use the following equation:

$$V_{min} = 0.75\ WQv = V_s + V_f + V_{f\text{-}temp}$$

(1) Compute V_f = water volume within filter bed/gravel/pipe = $A_f * d_f * n$
Where: n = porosity = 0.4 for most applications

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

(3) Compute V_s = volume within sediment chamber = $V_{min} - V_f - V_{f\text{-}temp}$

(4) Compute h_s = height in sedimentation chamber = V_s/A_s

(5) Ensure h_s and h_f fit available head and other dimensions still fit – change as necessary in design iterations until all site dimensions fit.

(6) Size orifice from sediment chamber to filter chamber to release V_s within 24-hours at average

release rate with 0.5 h_s as average head.

(7) Design outlet structure with perforations allowing for a safety factor of 10.

(8) Size distribution chamber to spread flow over filtration media – level spreader weir or orifices.

Step 9. Design inlets, pretreatment facilities, underdrain system, and outlet structures

See design criteria above for more details.

Step 10. Compute overflow weir sizes

1. Size overflow weir at elevation h_s in sedimentation chamber (above perforated stand pipe) to handle surcharge of flow through filter system from 25-year storm.

2. Plan inlet protection for overflow from sedimentation chamber and size overflow weir at elevation h_f in filtration chamber (above perforated stand pipe) to handle surcharge of flow through filter system from 25-year storm (see example).

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4.4.1.7 Maintenance Requirements and Inspection Checklist

Note: Section 4.4.1.7 must be included in the Operations and Maintenance Plan that is recorded with the deed.

Regular inspection and maintenance is critical to the effective operation of an organic filter as designed. It is the responsibility of the property owner to maintain all stormwater BMPs in accordance with the minimum design standards and other guidance provided in this manual. The local municipality has the authority to impose additional maintenance requirements where deemed necessary.

This page provides guidance on maintenance activities that are typically required for organic filters, along with a suggested frequency for each activity. Individual organic filters may have more, or less, frequent maintenance needs, depending upon a variety of factors including the occurrence of large storm events, overly wet or dry (i.e., drought) regional hydrologic conditions, and any changes or redevelopment in the upstream land use. Each property owner shall perform the activities identified below at the frequency needed to maintain the organic filter in proper operating condition at all times.

Inspection Activities	Suggested Schedule
• A record should be kept of the dewatering time (i.e., the time required to drain the filter bed completely after a storm event) for an organic filter to determine if maintenance is necessary. The filter bed should drain completely in about 40 hours after the end of the rainfall. • Check to ensure that the filter surface does not clog after storm events.	After Rain Events
• Check the contributing drainage area, facility, inlets and outlets for debris. • Check to ensure that the filter surface is not clogging.	Monthly
• Check to see that the filter bed is clean of sediment and the sediment chamber is not more than 50% full of sediment or the sediment accumulation is not more than 6 inches, whichever is less sediment. Remove sediment as necessary. • Make sure that there is no evidence of deterioration, spalling, bulging, or cracking of concrete. • Inspect inlets, outlets and overflow spillway to ensure good condition and no evidence of erosion. • Check to see if stormwater flow is bypassing the facility. • Ensure that no noticeable odors are detected outside the facility.	Annually
Maintenance Activities	**Suggested Schedule**
• Mow and stabilize (prevent erosion, vegetate denuded areas) the area draining to the organic filter. Collect and remove grass clippings. Remove trash and debris. • Ensure that activities in the drainage area minimize oil/grease and sediment entry to the system.	Monthly
• Check to see that the filter bed is clean of sediment and the sediment chamber is not more than 50% full of sediment or the sediment accumulation is not more than 6 inches, whichever is less sediment. Remove sediment as necessary. • Repair or replace any damaged structural parts. • Stabilize any eroded areas.	Annually
• If filter bed is clogged or partially clogged, manual manipulation of the surface layer of filter media may be required. Remove the top few inches of filter media, roto-till or otherwise cultivate the surface, and replace with media meeting the design specifications. • Replace any filter fabric that has become clogged.	As needed

The Northeast Tennessee Regional Stormwater Planning Group encourages the use of the inspection checklist that is presented on the next page to guide the property owner in the inspection and maintenance of organic filters. The local municipality can require the use of this checklist or other form(s) of maintenance documentation when and where deemed necessary in order to ensure the long-term proper operation of the organic filter. Questions regarding stormwater facility inspection and maintenance should be referred to the local municipality of the Northeast Tennessee Regional Stormwater Planning Group.

INSPECTION CHECKLIST AND MAINTENANCE GUIDANCE (continued)
ORGANIC FILTER INSPECTION CHECKLIST

Location: ____ Owner Change since last inspection? Y N

Owner Name, Address, Phone: ____

Date: ___________ Time: ______________ Site conditions:____

Inspection Items	Satisfactory (S) or Unsatisfactory (U)	Comments/Corrective Action
Organic Filter Inspection List		
Complete drainage of the filter in about 40 hours after a rain event?		
Clogging of filter surface?		
Clogging of inlet/outlet structures?		
Clogging of filter fabric?		
Filter clear of debris and functional?		
Leaks or seeps in filter?		
Obstructions of spillway(s)?		
Animal burrows in filter?		
Sediment accumulation in filter bed (less than 50% is acceptable)?		
Cracking, spalling, bulging or deterioration of concrete?		
Erosion in area draining to organic filter?		
Erosion around inlets, filter bed, or outlets?		
Pipes and other structures in good condition?		
Undesirable vegetation growth?		
Other (describe)?		
Hazards		
Have there been complaints from residents?		
Public hazards noted?		

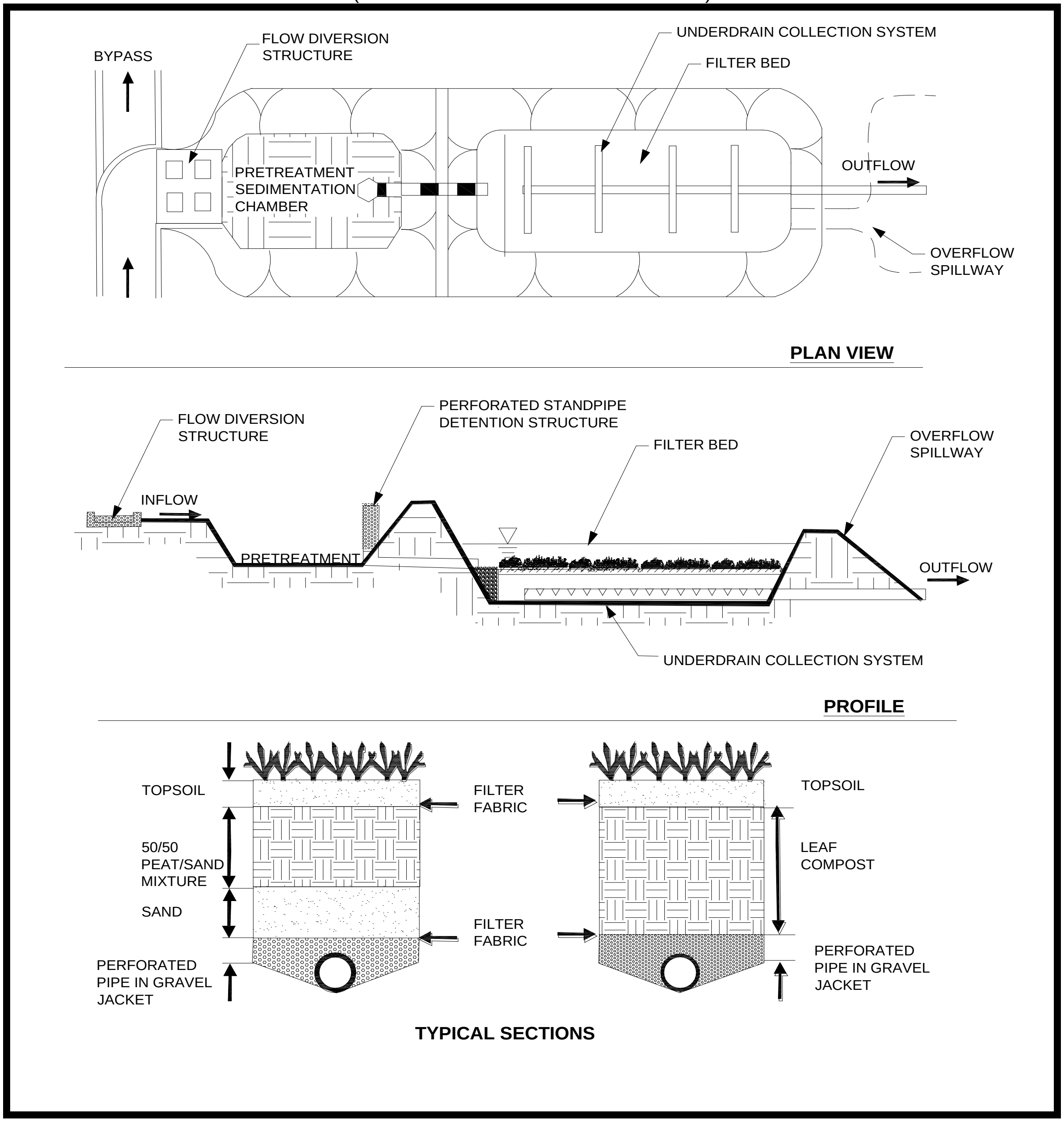
If any of the above inspection items are **UNSATISFACTORY**, list corrective actions and the corresponding completion dates below:

Corrective Action Needed	Due Date

Inspector Signature:________________________________ Inspector Name (printed)____________________________

4.4.1.8 Example Schematic

Figure 4-58. Schematic of an Organic Filter
(Source: Center for Watershed Protection)



4.4.1.9 References

AMEC. *Knox County Stormwater Management Manual Volume 2, Technical Guidance*.

AMEC. *Metropolitan Nashville and Davidson County Stormwater Management Manual, Volume 4 Best Management Practices.* 2006.

Atlanta Regional Council (ARC). *Georgia Stormwater Management Manual Volume 2 Technical Handbook.* 2001*.*

Maryland Department of the Environment. *Maryland Stormwater Design Manual, Volumes I and II.* Prepared by Center for Watershed Protection (CWP). 2000.

Minnesota Pollution Control Agency. *Minnesota Stormwater Manual.* Accessed January 2006. http://www.pca.state.mn.us/water/stormwater/stormwater-manual.html

Washington State Department of Ecology. *Stormwater Management Manual for Western Washington.* 2000.

4.4.1.10 Suggested Reading

Bell, W., L. Stokes, L.J. Gavan, and T. Nguyen. *Assessment of the Pollutant Removal Efficiencies of Delaware Sand Filter BMPs.* City of Alexandria, Department of Transportation and Environmental Services, Alexandria, VA, 1995.

California Storm Water Quality Task Force. *California Storm Water Best Management Practice Handbooks.* 1993.

City of Austin, TX. *Water Quality Management.* Environmental Criteria Manual, Environmental and Conservation Services, 1988.

City of Sacramento, CA. *Guidance Manual for On-Site Stormwater Quality Control Measures.* Department of Utilities, 2000.

Claytor, R.A., and T.R. Schueler. *Design of Stormwater Filtering Systems.* The Center for Watershed Protection, Silver Spring, MD, 1996.

Horner, R.R., and C.R. Horner. *Design, Construction, and Evaluation of a Sand Filter Stormwater Treatment System, Part II: Performance Monitoring.* Report to Alaska Marine Lines, Seattle, WA, 1995.

Metropolitan Washington Council of Governments (MWCOG). *A Current Assessment of Urban Best Management Practices: Techniques for Reducing Nonpoint Source Pollution in the Coastal Zone.* March, 1992.

Northern Virginia Regional Commission (NVRC). *The Northern Virginia BMP Handbook.* Annandale, VA, 1992.

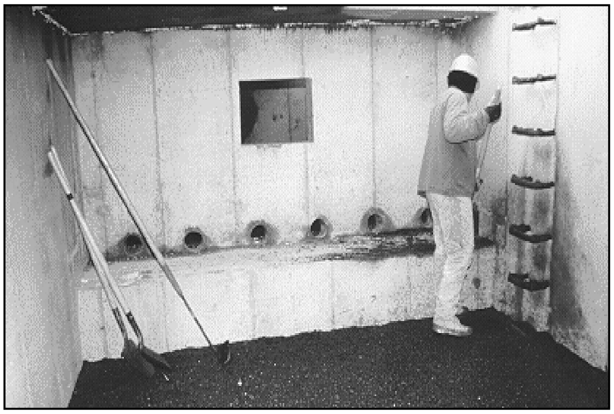
Schueler, T.R. *Developments in Sand Filter Technology to Improve Stormwater Runoff Quality.* Watershed Protection Techniques 1(2):47-54, 1994.

US EPA. *Storm Water Technology Fact Sheet: Sand Filters.* EPA 832-F-99-007, Office of Water. 1999.

Young, G.K., S. Stein, P. Cole, T. Kammer, F. Graziano, and F. Bank. *Evaluation and Management of Highway Runoff Water Quality.* FHWA-PD-96-032. Federal Highway Administration, Office of Environment and Planning, 1996.

4.4.2 Underground Sand Filter

Limited Application
Water Quality BMP



Description: The underground sand filter is a design variation of the surface sand filter, where the sand filter chambers and media are located in an underground vault.

KEY DESIGN CONSIDERATIONS

DESIGN GUIDELINES:

- Maximum contributing drainage area of 2 acres
- Typically requires 2 to 6 feet of head
- Precast concrete shells available, which decrease construction costs
- Underdrain required

ADVANTAGES / BENEFITS:

- High pollutant removal
- Applicable to small drainage areas
- Good for highly impervious areas
- Good retrofit capability

DISADVANTAGES / LIMITATIONS:

- High maintenance burden
- Not recommended for areas with high sediment content in stormwater or clay/silt runoff areas
- Possible odor problems
- Should be installed after site construction is complete

MAINTENANCE REQUIREMENTS:

- Inspect for clogging – rake first inch of sand
- Remove sediment from forebay/chamber
- Replace sand filter media as needed

STORMWATER MANAGEMENT SUITABILITY

Stormwater Quality:	**Yes**
Channel Protection:	✷
Detention/Retention:	**No**

Accepts hotspot runoff: *Yes, but requires impermeable liner and two feet of separation distance to water table when used in hotspot areas.*

COST CONSIDERATIONS

Land Requirement:	**Low**
Capital Cost:	**High**
Maintenance Burden:	**High**

LAND USE APPLICABILITY

Residential/Subdivision Use:	**No**
High Density/Ultra Urban Use:	**Yes**
Commercial/Industrial Use:	**Yes**

POLLUTANT REMOVAL

Total Suspended Solids:	**80%**

✷ in certain situations

4.4.2.1 General Description

The underground sand filter is a design variant of the surface sand filter. The underground sand filter is an enclosed filter system typically constructed just below grade in a vault along the edge of an impervious area such as a parking lot. The system consists of a sedimentation chamber and a sand bed filter. Runoff flows into the structure through a series of inlet grates located along the top of the control. Underground sand filters are best used for high-density land uses or ultra-urban applications where space for surface stormwater controls is limited. Figure 4-59 presents an example of an underground sand filter.

Figure 4-59. Example of an Underground Sand Filter

Multiple configurations have been developed for underground filters including the DC filter and the Delaware filter. The DC filter is intended to treat stormwater that is conveyed by a storm drain system. The Delaware filter (also known as the perimeter sand filter) is designed to collect flow directly from impervious surfaces and is well suited for installation along parking areas. Both systems operate in the same manner.

The underground sand filter is a three-chamber system. The initial chamber is a sedimentation (pretreatment) chamber that temporarily stores runoff and utilizes a wet pool to capture sediment. The sedimentation chamber is connected to the sand filter chamber by a submerged wall that protects the filter bed from oil and trash. The filter bed is 18 to 24 inches deep and may have a protective screen of gravel or permeable geotextile to limit clogging. The sand filter chamber also includes an underdrain system with inspection and clean out wells. Perforated drain pipes under the sand filter bed extend into a third chamber that collects filtered runoff. Flows beyond the filter capacity are diverted through an overflow weir.

Due to its location below the surface, underground sand filters have a high maintenance burden and should only be used where adequate inspection and maintenance can be ensured.

4.4.2.2 Stormwater Management Suitability

Underground sand filter systems are designed primarily as <u>off-line</u> systems for treatment of the water quality volume. They are not useful for flood protection and will typically need to be used in conjunction with another structural BMP, such as a conventional detention basin that can provide downstream channel protection, overbank flood protection, and extreme flood protection. Further, underground sand filter facilities utilized on-line must provide flow diversion and/or be designed to safely pass extreme storm flows and protect the filter bed and facility. Under certain circumstances, underground sand filters can provide limited runoff quantity control, particularly for smaller storm events.

Water Quality (WQv)
In underground sand filter systems, stormwater pollutants are removed through a combination of gravitational settling, filtration and adsorption. The filtration process effectively removes suspended solids and particulates, biochemical oxygen demand (BOD), fecal coliform bacteria, and other pollutants.

Channel Protection (CPv)
For smaller sites, an underground sand filter may be designed to capture the entire channel protection volume (CPv) in either an off- or on-line configuration. Given that an underground sand filter system is typically designed to completely drain over 40 hours, the channel protection design requirement for extended detention of the 1-year, 24-hour storm runoff volume can be met. For larger sites or where only the WQv is diverted to the underground sand filter facility, another structural control must be used to provide extended detention of the CPv.

4.4.2.3 Pollutant Removal Capabilities

Underground sand filters are presumed to be able to remove 80% of the total suspended solids (TSS) load in typical urban post-development runoff when sized, designed, constructed and maintained in accordance with the recommended specifications. Undersized or poorly designed underground sand filters can reduce TSS removal performance.

Additionally, research has shown that use of underground sand filters will have benefits beyond the removal of TSS, such as the removal of other pollutants (i.e. phosphorous, nitrogen, fecal coliform and heavy metals), as well, which is useful information should the pollutant removal criteria change in the future. The following design pollutant removal rates are conservative average pollutant reduction percentages for design purposes derived from sampling data.

For additional information and data on pollutant removal capabilities for underground sand filters, see the National Pollutant Removal Performance Database (2nd Edition) available at www.cwp.org and the International Stormwater Best Management Practices (BMP) Database at www.bmpdatabase.org.

4.4.2.4 Application and Site Feasibility Criteria

Underground sand filter systems are well-suited for highly impervious areas where land available for structural BMPs is limited. Underground sand filters should primarily be considered for new construction or retrofit opportunities for commercial, industrial, and institutional areas where the sediment load is relatively low, such as: parking lots, driveways, loading docks, gas stations, garages, airport runways/taxiways, and storage yards.

To avoid rapid clogging and failure of the filter media, the use of underground sand filters should be avoided in areas with less than 50% impervious cover, or high sediment yield sites with clay/silt soils.

The following basic criteria should be evaluated to ensure the suitability of an underground sand filter facility for meeting stormwater management objectives on a site or development.

General Feasibility

- Not suitable for use in a residential subdivision
- Suitable for use in high density/ultra-urban areas
- Not suitable for use as a regional stormwater control. On-site applications are typically most feasible.

Physical Feasibility - Physical Constraints at Project Site

- Drainage Area – 2 acres maximum for an underground sand filter

- Space Required – Function of available head at site
- Minimum Head – The surface slope across the filter location should be no greater than 6%. The elevation difference needed at a site from the inflow to the outflow is 2-6 feet.
- Minimum Depth to Water Table – If used on a site with an underlying water supply aquifer, a separation distance of 2 feet is required between the bottom of the sand filter and the elevation of the seasonally high water table to prevent groundwater contamination.
- Soils – Not recommended for clay/silt drainage areas that are not stabilized.

Other Constraints / Considerations

- Aquifer Protection – Do not allow infiltration of filtered hotspot runoff into groundwater

4.4.2.5 Planning and Design Standards

The following standards shall be considered **minimum** design standards for the design of underground sand filters. Underground sand filters that are not designed to these standards will not be approved. The local municipality shall have the authority to require additional design conditions if deemed necessary.

A. CONSTRUCTION SEQUENCING

- Ideally, the construction of an underground filter shall take place **after** the construction site has been stabilized.
- In the event that the underground sand filter is not constructed after site stabilization, care shall be taken during construction to minimize the risk of premature failure of the organic filter due to deposition of sediments from disturbed, unstabilized areas.
- Diversion berms and erosion prevention and sediment controls shall be maintained around the filter during all phases of construction. No runoff or sediment shall enter the sand filter area prior to completion of construction and the complete stabilization of construction areas.
- Underground sand filters shall not be used as a temporary sediment trap for construction activities.
- During and after excavation of the underground sand filter area, all excavated materials shall be placed downstream, away from the sand filter, to prevent redeposit of the material during runoff events.

B. LOCATION AND SITING

- Underground sand filter systems are generally applied to land uses with a high percentage of impervious surfaces. Sand filters shall not be utilized for sites that have less than 50% impervious cover. Any disturbed or denuded areas located within the area draining to and treated by the underground sand filter shall be stabilized prior to construction and use of the sand filter.
- Delaware underground sand filters are typically sited along the edge, or perimeter, of an impervious area such as a parking lot.
- DC underground sand filters are installed within the storm drain system.
- Underground sand filter systems shall be designed for intermittent flow and must be allowed to drain and re-aerate between rainfall events. They shall not be used on sites with a continuous flow from groundwater, sump pumps, or other sources.

C. PHYSICAL SPECIFICATIONS / GEOMETRY

- The entire treatment system (including the sedimentation chamber) must temporarily hold at least 75% of the WQv prior to filtration. Figures 4-60 and 4-61 illustrate the distribution of the treatment volume (0.75 WQv) among the various components of the underground sand filters, including:
  - V_w – wet pool volume within the sedimentation basin
  - V_f – volume within the voids in the filter bed

- V_{temp} – temporary volume stored above the filter bed
- A_s – the surface area of the sedimentation basin
- A_f – surface area of the filter media
- h_f – average height of water above the filter media (1/2 h_{temp})
- d_f – depth of filter media

- The sedimentation chamber shall be sized to at least 50% of the computed WQv.
- The filter area shall be sized based on the principles of Darcy's Law. A coefficient of permeability (k) of 3.5 ft/day for sand shall be used. The filter bed shall be designed to completely drain in 40 hours or less.
- The filter media shall consist of an 18-inch to 24-inch layer of clean washed medium aggregate concrete sand (ASTM C-33) on top of the underdrain system. Figure 4-62 illustrates a typical media cross section.
- The filter bed shall be equipped with a 6-inch perforated pipe underdrain (PVC AASHTO M 252, HDPE, or other suitable pipe material) in a gravel layer. The underdrain shall have a minimum grade of 1/8-inch per foot (1% slope). Holes shall be 3/8-inch diameter and spaced approximately 6 inches on center. Gravel shall be clean-washed aggregate with a maximum diameter of 3.5 inches and a minimum diameter of 1.5 inches with a void space of about 40%. Aggregate contaminated with soil shall not be used.

Figure 4-60. Underground (DC) Sand Filter Volumes
(Source: Center for Watershed Protection)

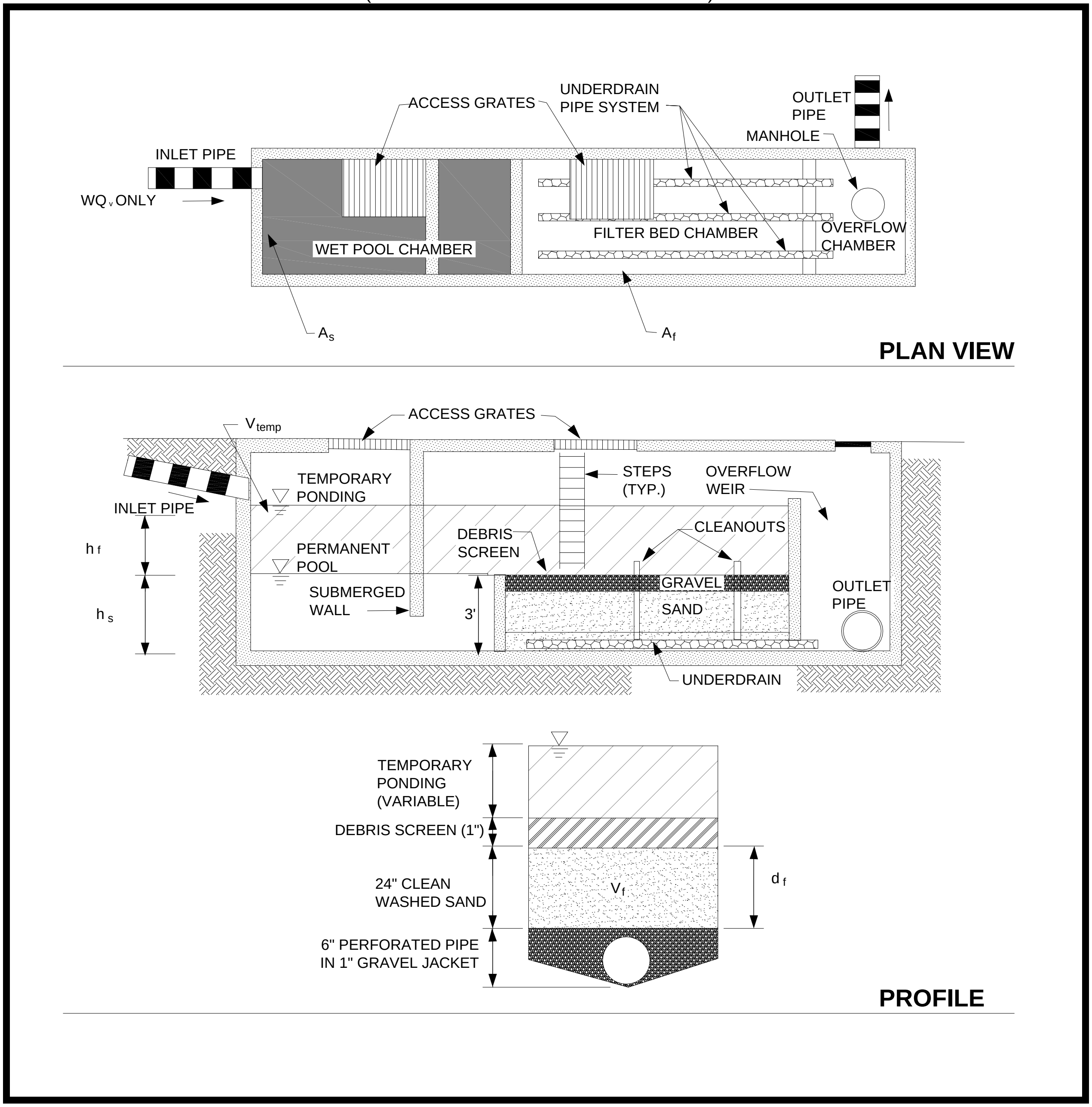


Figure 4-61. Perimeter Sand Filter Volumes
(Source: Claytor and Schueler, 1996)

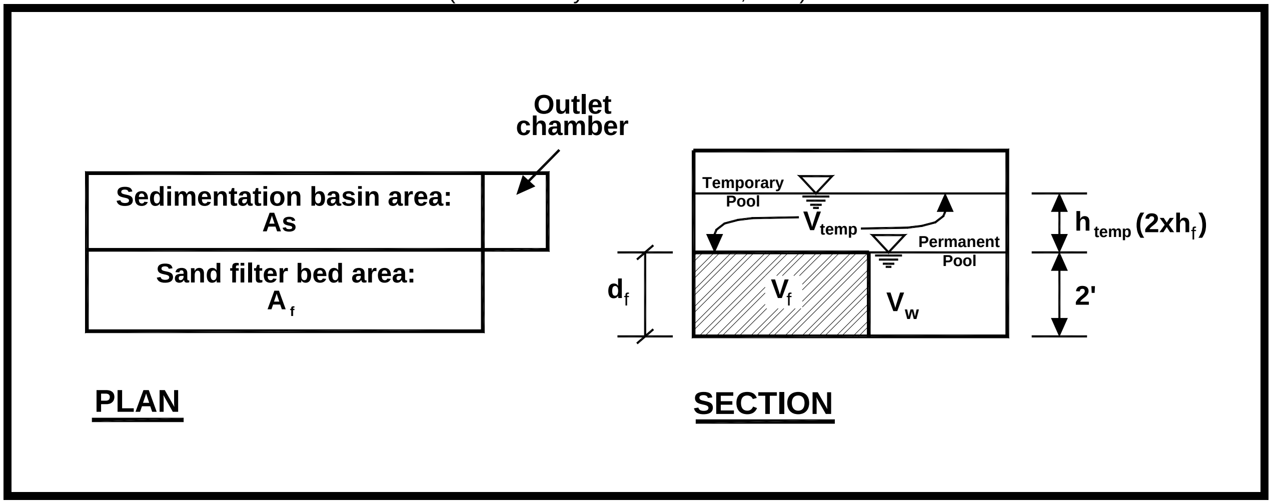
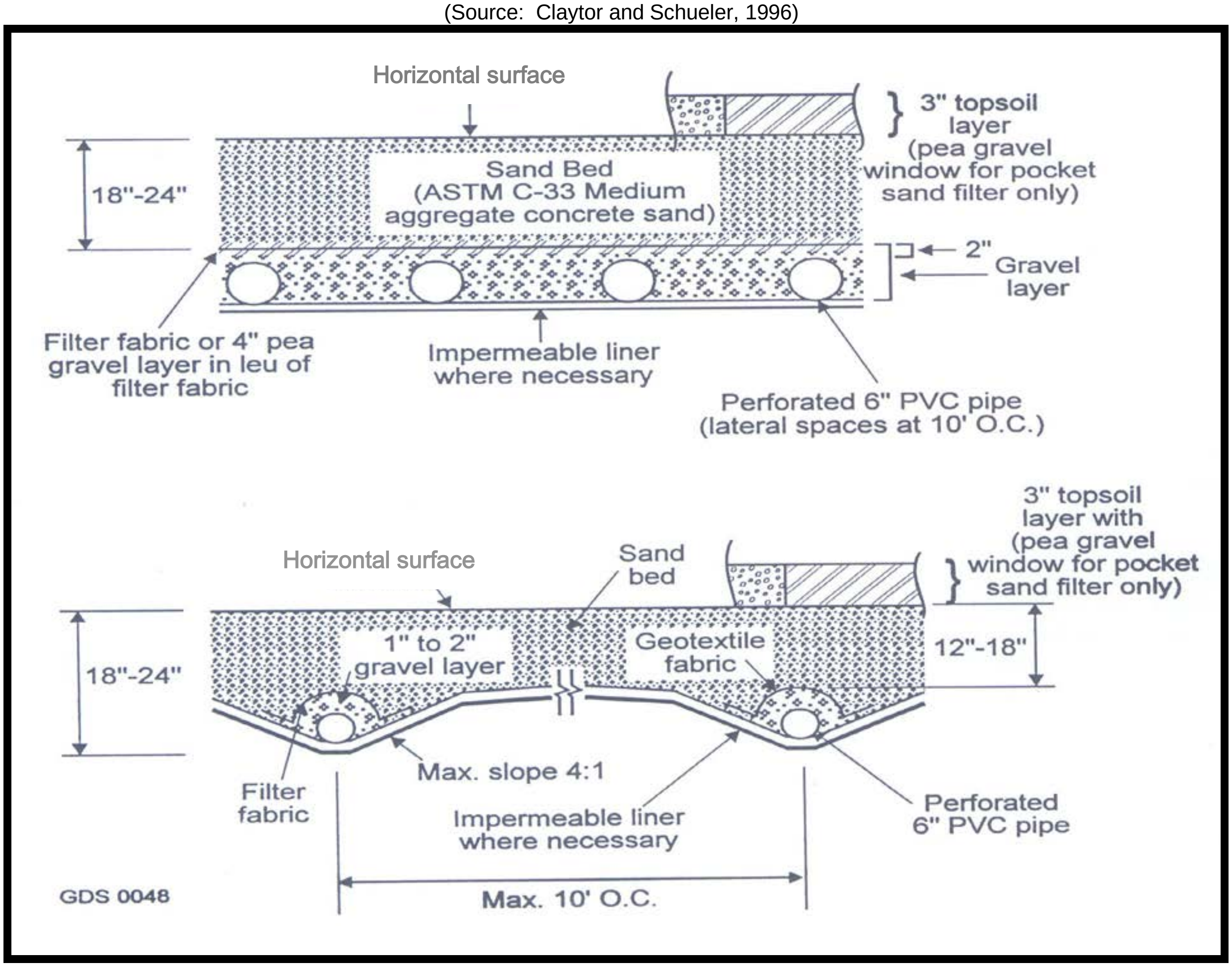


Figure 4-62. Typical Sand Filter Media Cross Sections
(Source: Claytor and Schueler, 1996)



D. OUTLET STRUCTURES

- An outlet pipe shall be provided from the underdrain system to the facility discharge. Due to the slow rate of filtration, outlet protection is generally unnecessary (except for emergency overflows and spillways). However, the design shall ensure that the discharges from the underdrain system occur in a non-erosive manner.

E. EMERGENCY SPILLWAY

- An emergency bypass spillway or weir must be included in the underground sand filter design to safely pass flows that exceed the WQv (and CPv if the filter is utilized for channel protection purposes

F. MAINTENANCE ACCESS

- A minimum 20' wide maintenance right-of-way or drainage easement shall be provided for an underground sand filter from a driveway, public or private road. The maintenance access easement shall have a maximum slope of no more than 15% and shall have a minimum unobstructed drive path having a width of 12 feet, appropriately stabilized to withstand maintenance equipment and vehicles. Adequate access must be provided to the grates of the filter bed. Facility designs must enable maintenance personnel to easily remove and replace upper layers of the filter media.

G. SAFETY FEATURES

- Inlets, access grates and outlets shall be designed and maintained so as not to permit access by children. Inlet and access grates to the underground sand filters may be locked.

4.4.2.6 Design Procedures

Step 1. Compute runoff control volumes

Calculate WQv, CPv in accordance with the guidance presented in Chapter 3.

Step 2. Determine if the development site and conditions are appropriate for the use of an underground sand filter.

Consider the subsection 4.4.2.4. Check with Northeast Tennessee Stormwater Planning Group and other agencies as appropriate to determine if there are any additional restrictions and/or surface water or watershed requirements that may apply.

Step 3. Compute WQv peak discharge (Q_{wq})

The peak rate of discharge for water quality design storm is needed for sizing of off-line diversion structures (see Chapter 3 for more information on this calculation).

(a) Using WQv, compute CN
(b) Compute time of concentration using TR-55 method
(c) Determine appropriate unit peak discharge from time of concentration
(d) Compute Q_{wq} in inches from unit peak discharge, drainage area, and WQv.

Step 4. Size flow diversion structure, (if needed)

If a diversion structure is utilized, a flow regulator should be supplied to divert the WQv to the underground sand filter facility. Size low flow orifice, weir, or other device to pass Q_{wq}.

Step 5. Size filtration basin chamber

The filter area is sized using the following equation (based on Darcy's Law):

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

where:

A_f = surface area of filter bed (ft^2)

WQv = water quality volume (ft^3)
d_f = filter bed depth (1.5 ft)
(at least 18 inches, no more than 24 inches)
k = coefficient of permeability of filter media (ft/day)
(use 3.5 ft/day for sand)
h_f = average height of water above filter bed (ft)
(1/2 h_{max}, which varies based on site but h_{max} is typically $\leq$ 6 feet)
t_f = design filter bed drain time (days)
(1.67 days or 40 hours is required maximum time)

Set preliminary dimensions of filtration basin chamber.

Step 6. Size sedimentation chamber

Depending on the type of underground sand filter system utilized, the sedimentation chamber shall be sized to at least 50% of the computed WQv and have a length-to-width ratio of 2:1. The Camp-Hazen equation is used to compute the required surface area:

$$A_s = -(Q_o/w) * \text{Ln}(1-E)$$

where:
A_s = sedimentation basin surface area (ft^2)
Q_o = rate of outflow = the WQv (ft^3) / 86400 seconds
w = particle settling velocity (ft/sec)
E = trap efficiency

Assuming:
- 90% sediment trap efficiency (0.9)
- particle settling velocity (ft/sec) = 0.0033 ft/sec for imperviousness ≥ 75%
- particle settling velocity (ft/sec) = 0.0004 ft/sec for imperviousness < 75%
- average of 24 hour holding period

Then:
A_s = (0.0081) (WQv) ft^2 for I $\geq$ 75%
A_s = (0.066) (WQv) ft^2 for I < 75%

Set preliminary dimensions of sedimentation chamber.

Step 7. Compute V_{min}

$$V_{min} = 0.75 * WQv$$

Step 8. Compute storage volumes within entire facility and sedimentation chamber orifice size

***Underground (D.C.) sand filter*:**

$$V_{min} = 0.75\ WQv = V_s + V_f + V_{f\text{-}temp}$$

(1) Compute V_f = water volume within filter bed/gravel/pipe = $A_f * d_f * n$
Where: n = porosity = 0.4 for most applications

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

(3) Compute V_s = volume within sediment chamber = $V_{min} - V_f - V_{f\text{-}temp}$

(4) Compute h_s = height in sedimentation chamber = V_s/A_s

(5) Ensure h_s and h_f fit available head and other dimensions still fit – change as necessary in design iterations until all site dimensions fit.

(6) Size orifice from sediment chamber to filter chamber to release V_s within 24-hours at average release rate with 0.5 h_s as average head.

(7) Design outlet structure with perforations allowing for a safety factor of safety times the orifice capacity.

(8) Size distribution chamber to spread flow over filtration media – level spreader weir or orifices.

***Underground perimeter (Delaware) sand filter*:**

(1) Compute V_f = water volume within filter bed/gravel/pipe = $A_f * d_f * n$
where: A_f = surface area of filter bed (ft^2)
d_f = filter bed depth (1.5 ft)
(at least 18 inches, no more than 24 inches)
n = porosity = 0.4 for most applications

(2) Compute V_w = wet pool storage volume A_s * 2 feet minimum

(3) Compute V_{temp} = temporary storage volume = $V_{min} – (V_f + V_w)$

(4) Compute h_{temp} = temporary storage height = $V_{temp} / (A_f + A_s)$

(5) Ensure $h_{temp} \geq 2 * h_f$, otherwise decrease h_f and re-compute. Ensure dimensions fit available head and area – change as necessary in design iterations until all site dimensions fit.

(6) Size distribution slots from sediment chamber to filter chamber.

Step 9. Design inlets, underdrain system, and outlet structures

See design criteria above for more details.

Step 10. Compute overflow weir sizes

***Underground (D.C.) sand filter*:**

$$V_{min} = 0.75\ WQv = V_s + V_f + V_{f\text{-}temp}$$

(1) Compute V_f = water volume within filter bed/gravel/pipe = $A_f * d_f * n$
where: n = porosity = 0.4 for most applications

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

(3) Compute V_s = volume within sediment chamber = $V_{min} - V_f - V_{f\text{-}temp}$

(4) Compute hs = height in sedimentation chamber = Vs/As

(5) Ensure hs and hf fit available head and other dimensions still fit – change as necessary in design iterations until all site dimensions fit.

(6) Size orifice from sediment chamber to filter chamber to release Vs within 24-hours at average release rate with 0.5 hs as average head.

(7) Design outlet structure with perforations allowing for a safety factor of times the orifice capacity.

(8) Size distribution chamber to spread flow over filtration media – level spreader weir or orifices.

Underground perimeter (Delaware) sand filter: Size overflow weir at end of sedimentation chamber to handle excess inflow, set at WQv elevation.

4.4.2.7 Maintenance Requirements and Inspection Checklist

Note: Section 4.4.2.7 must be included in the Operations and Maintenance Plan that is recorded with the deed.

Regular inspection and maintenance is critical to the effective operation of an underground sand filter as designed. It is the responsibility of the property owner to maintain all stormwater BMPs in accordance with the minimum design standards and other guidance provided in this manual. The local municipality has the authority to impose additional maintenance requirements where deemed necessary.

This page provides guidance on maintenance activities that are typically required for underground sand filters, along with a suggested frequency for each activity. Individual filters may have more, or less, frequent maintenance needs, depending upon a variety of factors including the occurrence of large storm events, overly wet or dry (i.e., drought) regional hydrologic conditions, and any changes or redevelopment in the upstream land use. Each property owner shall perform the activities identified below at the frequency needed to maintain the sand filter in proper operating condition at all times.

Inspection Activities	Suggested Schedule
• A record should be kept of the dewatering time (i.e., the time required to drain the filter bed completely after a storm event) for a sand filter to determine if maintenance is necessary. The filter bed should drain completely in about 40 hours after the end of the rainfall. • Check to ensure that the filter surface does not clog after storm events.	After Rain Events
• Check the contributing drainage area, facility, inlets and outlets for debris. • Check to ensure that the filter surface is not clogging.	Monthly
• Check to see that the filter bed is clean of sediment, and the sediment chamber is not more than 50% full or 6 inches, whichever is less, of sediment. Remove sediment as necessary. • Make sure that there is no evidence of deterioration, spalling, bulging, or cracking of concrete. • Inspect grates of sand filter (perimeter and Delaware). • Inspect inlets, outlets and overflow spillway to ensure good condition and no evidence of erosion. • Check to see if stormwater flow is bypassing the facility (if so designed). • Ensure that no noticeable odors are detected outside the facility.	Annually
Maintenance Activities	**Suggested Schedule**
• Mow and stabilize (prevent erosion, vegetate denuded areas) the area draining to the underground sand filter. Collect and remove grass clippings. Remove trash and debris. • Ensure that activities in the drainage area minimize oil/grease and sediment entry to the system. • If permanent water level is present (perimeter and Delaware).in sand filter, ensure that the chamber does not leak, and normal pool level is retained.	Monthly
• Check to see that the filter bed is clean of sediment, and the sediment chamber is not more than 50% full or 6 inches, whichever is less, of sediment. Remove sediment as necessary. • Repair or replace any damaged structural parts. • Stabilize any eroded areas.	Annually
• If filter bed is clogged or partially clogged, manual manipulation of the surface layer of sand may be required. Remove the top few inches of sand, roto-till or otherwise cultivate the surface, and replace media with sand meeting the design specifications. • Replace any filter fabric that has become clogged.	As needed

The Northeast Tennessee Regional Stormwater Planning Group encourages the use of the inspection checklist that is presented on the next page to guide the property owner in the inspection and maintenance of underground sand filters. The local municipality can require the use of this checklist or other form(s) of maintenance documentation when and where deemed necessary in order to ensure the long-term proper operation of the underground sand filter. Questions regarding stormwater facility inspection and maintenance should be referred to the local municipality of the Northeast Tennessee Regional Stormwater Planning Group.

INSPECTION CHECKLIST AND MAINTENANCE GUIDANCE (continued)
UNDERGROUND SAND FILTER INSPECTION CHECKLIST

Location: ____ Owner Change since last inspection? Y N

Owner Name, Address, Phone: ____

Date: ___________ Time: ______________ Site conditions:______________________________________

Inspection Items	Satisfactory (S) or Unsatisfactory (U)	Comments/Corrective Action
Underground Sand Filter Inspection List		
Complete drainage of the filter in about 40 hours after a rain event?		
Clogging of filter surface?		
Clogging of inlet/outlet structures?		
Clogging of filter fabric?		
Filter clear of debris and functional?		
Leaks or seeps in filter?		
Obstructions of spillway(s)?		
Animal burrows in filter?		
Sediment accumulation in filter bed (less than 50% is acceptable)?		
Cracking, spalling, bulging or deterioration of concrete?		
Erosion in area draining to sand filter?		
Erosion around inlets, filter bed, or outlets?		
Pipes and other structures in good condition?		
Undesirable vegetation growth?		
Other (describe)?		
Hazards		
Have there been complaints from residents?		
Public hazards noted?		

If any of the above inspection items are **UNSATISFACTORY**, list corrective actions and the corresponding completion dates below:

Corrective Action Needed	Due Date

Inspector Signature:_________________________________ Inspector Name (printed)____________________________

4.4.2.8 Example Schematics

Figure 4-63. Schematic of an Underground (D.C.) Sand Filter
(Source: Center for Watershed Protection)

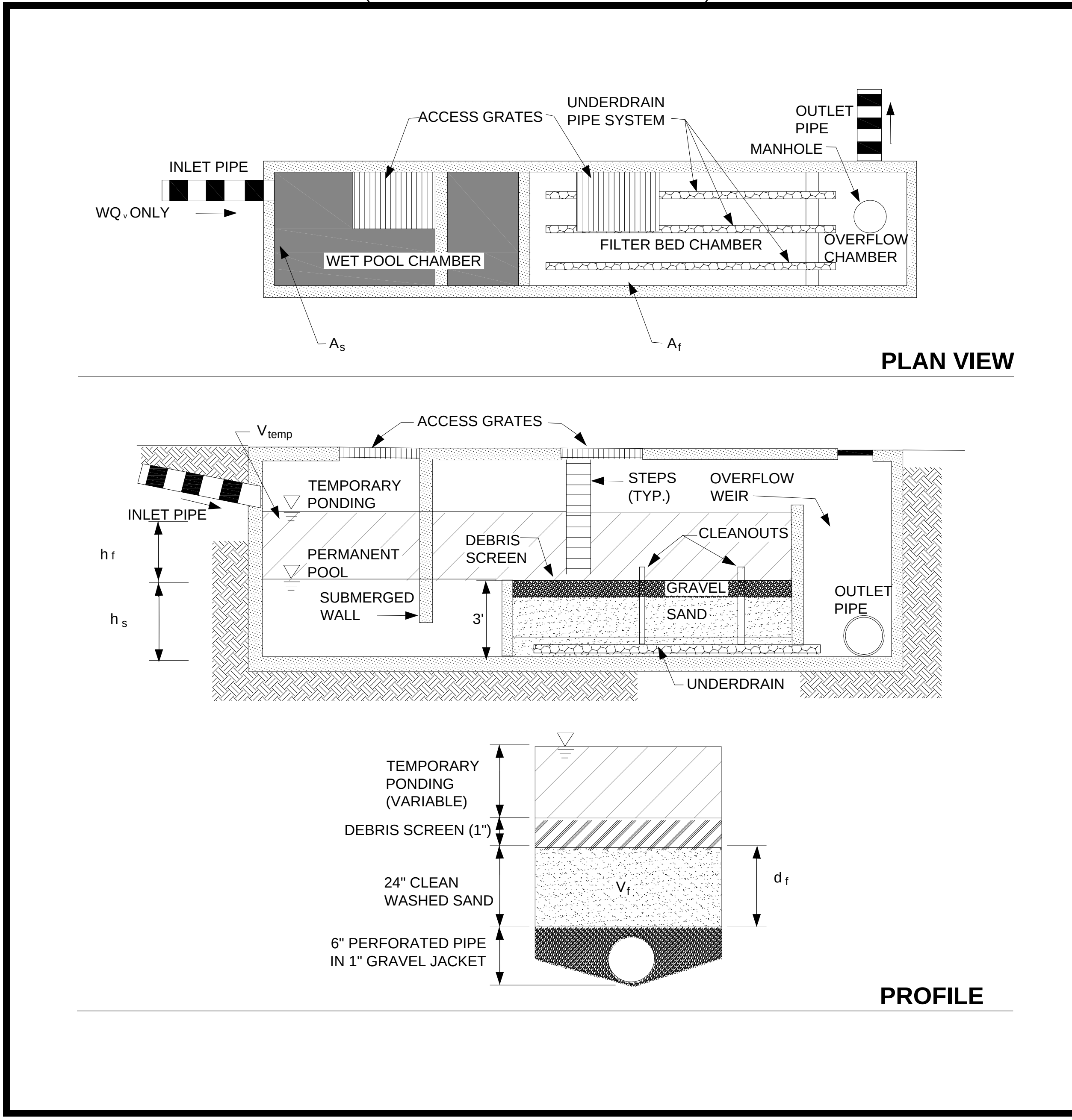
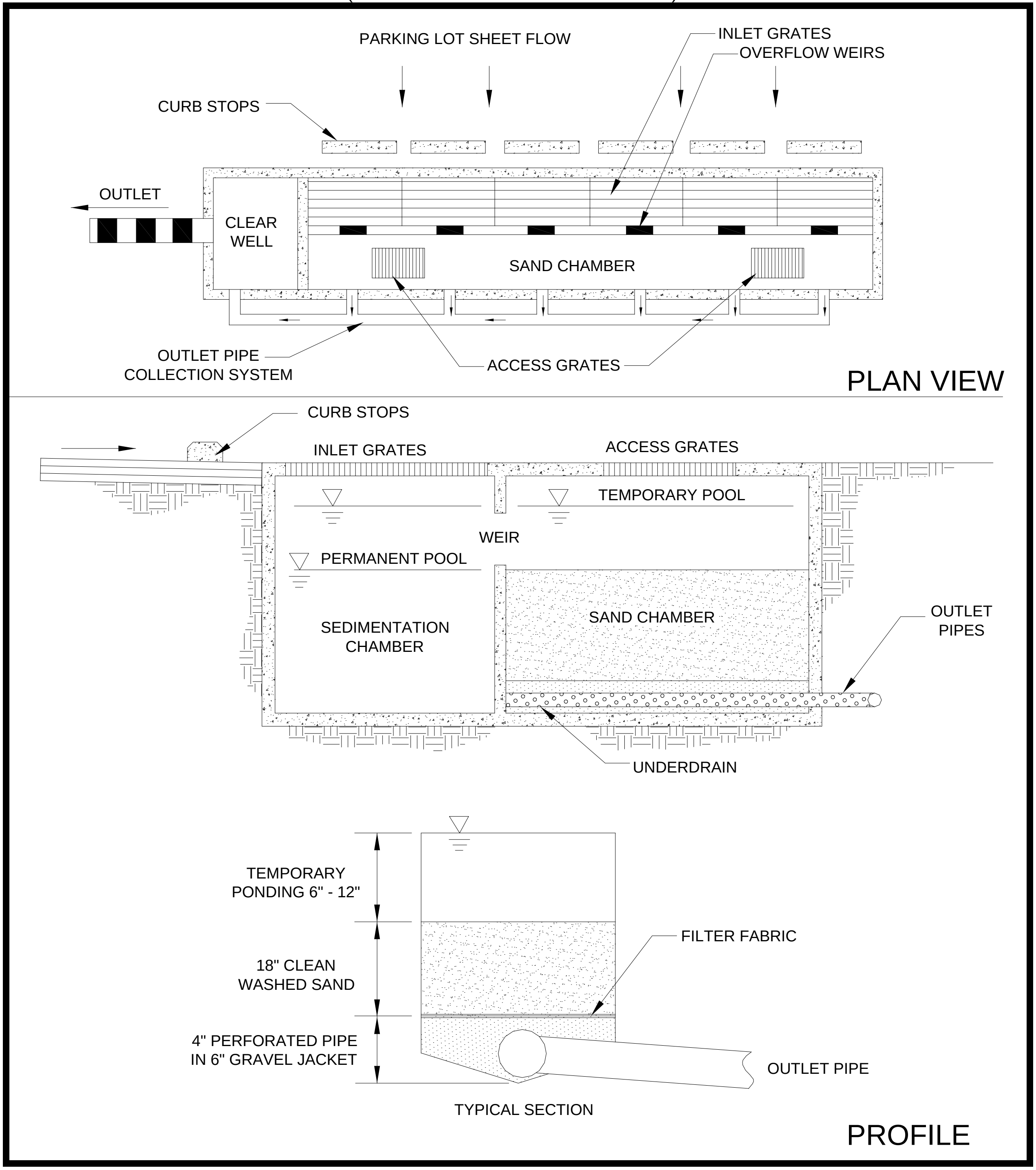


Figure 4-64. Schematic of a Perimeter (Delaware) Sand Filter
(Source: Center for Watershed Protection)



4.4.2.9 References

AMEC. *Knox County Stormwater Management Manual Volume 2, Technical Guidance*.

AMEC. *Metropolitan Nashville and Davidson County Stormwater Management Manual Volume 4 Best Management Practices.* 2006.

Atlanta Regional Council (ARC). *Georgia Stormwater Management Manual Volume 2 Technical Handbook*. 2001.

Brown, W., and T. Schueler. *The Economics of Stormwater BMPs in the Mid-Atlantic Region.* Prepared for Chesapeake Research Consortium, Edgewater, MD, by the Center for Watershed Protection, Ellicott City, MD, 1997.

Center for Watershed Protection (CWP). *Design of Stormwater Filtering Systems.* Prepared for the Chesapeake Research Consortium, Solomons, MD, and U.S. EPA Region 5, Chicago, IL, by the Center for Watershed Protection, Ellicott City, MD, 1996.

Center for Watershed Protection (CWP). *Multi-Chamber Treatment Train developed for stormwater hot spots.* Watershed Protection Techniques 2(3):445-449, 1997.

Maryland Department of the Environment (MDE). *Maryland Stormwater Design Manual.* 2000. Available at: http://www.mde.state.md.us/programs/waterprograms/sedimentandstormwater/stormwater_design/index.asp.

Minnesota Pollution Control Agency. *Minnesota Stormwater Manual.* Accessed January 2006. http://www.pca.state.mn.us/water/stormwater/stormwater-manual.html

New Jersey Department of Environmental Protection. *Stormwater Best Management Practices Manual.* 2004.

Schueler, T. *Developments in Sand Filter Technology to Improve Stormwater Runoff Quality.* Watershed Protection Techniques 1(2):47-54, 1994.

StormwaterAuthority.com. *Sand and Organic Filters.* Accessed January 2006. www.stormwaterauthority.com

4.4.2.10 Suggested Reading

Bell, W., L. Stokes, L.J. Gavan, and T. Nguyen. *Assessment of the Pollutant Removal Efficiencies of Delaware Sand Filter BMPs.* City of Alexandria, Department of Transportation and Environmental Services, Alexandria, VA, 1995.

California Storm Water Quality Task Force. *California Storm Water Best Management Practice Handbooks,* 1993.

City of Austin, TX. *Water Quality Management.* Environmental Criteria Manual, Environmental and Conservation Services, 1988.

City of Sacramento, CA. *Guidance Manual for On-Site Stormwater Quality Control Measures.* Department of Utilities, 2000.

Claytor, R.A., and T.R. Schueler. *Design of Stormwater Filtering Systems.* The Center for Watershed Protection, Silver Spring, MD, 1996.

Horner, R.R., and C.R. Horner. *Design, Construction, and Evaluation of a Sand Filter Stormwater Treatment System. Part II: Performance Monitoring.* Report to Alaska Marine Lines, Seattle, WA, 1995.

Metropolitan Washington Council of Governments (MWCOG). *A Current Assessment of Urban Best Management Practices: Techniques for Reducing Nonpoint Source Pollution in the Coastal Zone,* March, 1992.

Northern Virginia Regional Commission (NVRC). *The Northern Virginia BMP Handbook.* Annandale, VA, 1992.

US EPA. *Storm Water Technology Fact Sheet: Sand Filters.* EPA 832-F-99-007, Office of Water, 1999.

Young, G.K., S. Stein, P. Cole, T. Kammer, F. Graziano, and F. Bank. *Evaluation and Management of Highway Runoff Water Quality.* FHWA-PD-96-032, Federal Highway Administration, Office of Environment and Planning, 1996.

4.4.3 Submerged Gravel Wetland

Limited Application Water Quality BMP

Description: Submerged gravel wetlands are one or more cells filled with crushed rock designed to support wetland plants. Stormwater flows subsurface through the root zone of the constructed wetland where pollutant removal takes place.

KEY DESIGN CONSIDERATIONS

DESIGN GUIDELINES:

- Intended for space-limited applications
- High removal rates for sediment, Biochemical Oxygen Demand, and fecal coliform bacteria
- Max drainage area ≤ 5 acres

ADVANTAGES / BENEFITS:

- High TSS removal
- Generally requires low land consumption, and can fit within an area that is typically devoted to landscaping
- High pollutant removal capabilities are expected; however, limited performance data exist
- Can be located in low-permeability soils with a high water table

DISADVANTAGES / LIMITATIONS:

- High maintenance burden
- Not recommended for areas with high sediment content in stormwater or clay/silt runoff areas
- Should be installed after site construction is complete

MAINTENANCE REQUIREMENTS:

- Periodic sediment removal required to prevent clogging of gravel base

STORMWATER MANAGEMENT SUITABILITY

Stormwater Quality:	**Yes**
Channel Protection:	**No**
Detention/Retention:	**No**

Accepts hotspot runoff: *Yes, but requires an impermeable liner and two feet of separation distance to water table when used in hotspot areas.*

COST CONSIDERATIONS

Land Requirement:	**Low**
Capital Cost:	**High**
Maintenance Burden:	**High**

LAND USE APPLICABILITY

Residential/Subdivision Use:	**No**
High Density/Ultra Urban Use:	**Yes**
Commercial/Industrial Use:	**Yes**

POLLUTANT REMOVAL

Total Suspended Solids:	**80%**

4.4.3.1 General Description

The submerged gravel wetland system consists of one or more treatment cells that are filled with crushed rock or gravel and is designed to allow stormwater to flow subsurface through the root zone of the constructed wetland. The outlet from each cell is set at an elevation to keep the rock or gravel submerged. Wetland plants are rooted in the media, where they can directly take up pollutants. In addition, algae and microbes thrive on the surface area of the rocks. In particular, the anaerobic conditions on the bottom of the filter can foster the denitrification process. Although widely used for wastewater treatment in recent years, only a handful of submerged gravel wetland systems have been designed to treat stormwater. Mimicking the pollutant removal ability of nature, this structural control relies on the pollutant-stripping ability of plants and soils to remove pollutants from runoff.

4.4.3.2 Stormwater Management Suitability

Submerged gravel wetlands are designed as off-line systems for treatment of the water quality volume. They are not useful for flood protection and will need to be used in conjunction with another structural BMP, such as a conventional detention basin that can provide downstream channel protection, overbank flood protection, and extreme flood protection. All submerged gravel wetlands must provide flow diversion to protect the gravel bed.

Water Quality (WQv)
In submerged gravel wetlands, stormwater runoff flows through a gravel filter with wetland plants at the surface. Pollutants are removed through biological activity on the surface of the gravel and pollutant uptake by the plants. This practice is fundamentally different from other wetland designs because while most wetland designs behave like wet ponds, with differences in grading and landscaping, gravel wetlands are similar to filtering practices. The filtration process effectively removes suspended solids and particulates, biochemical oxygen demand (BOD), fecal coliform bacteria, and other pollutants.

Channel Protection (CPv)
The WQv is diverted to the submerged gravel wetland; therefore, it requires the use of another structural BMP to provide CPv extended detention.

4.4.3.3 Pollutant Removal Capabilities

The pollution removal efficiency of the submerged gravel wetland is similar to a typical wetland. Due to the settling environment of the gravel media, recent data show a TSS removal rate in excess of the 80% goal. Therefore the total suspended solids design pollutant removal rate of 80% is a conservative average pollutant reduction percentage for design purposes derived from sampling data, modeling and professional judgment.

For additional information and data on pollutant removal capabilities for submerged gravel wetlands, see the National Pollutant Removal Performance Database (2nd Edition) available at www.cwp.org and the International Stormwater Best Management Practices (BMP) Database at www.bmpdatabase.org.

4.4.3.4 Application and Site Feasibility Criteria

Submerged gravel wetlands are well-suited for highly impervious areas where land available for structural BMPs is limited. Submerged gravel wetlands should primarily be considered for new construction or retrofit opportunities for commercial, industrial, and institutional areas where the sediment load is relatively low, such as: parking lots, driveways, loading docks, gas stations, garages, airport runways/taxiways, and storage yards.

To avoid clogging, the use of submerged gravel wetlands should be avoided in areas with less than 50% impervious cover, or high sediment yield sites with clay/silt soils.

The following basic criteria should be evaluated to ensure the suitability of a submerged gravel wetland for meeting stormwater management objectives on a site or development.

General Feasibility

- Suitable for use in high density/ultra-urban areas
- Not suitable for use in a residential subdivision
- Not suitable for use as a regional stormwater control. On-site applications are typically most feasible.

Physical Feasibility - Physical Constraints at Project Site

- Drainage Area – 5 acres maximum for a submerged gravel wetland. Submerged gravel wetland systems need sufficient drainage area to maintain vegetation. See subsection 3.1.8 for guidance on performing a water balance calculation.
- Space Required – Function of drainage area and available head at site.
- Minimum Head – The local slope should be relatively flat (<2%). While there is no minimum slope requirement, there does need to be enough elevation drop from the inlet to the outlet to ensure that hydraulic conveyance by gravity is feasible (generally about 3 to 5 feet).
- Pretreatment – Submerged gravel wetland designs shall include a sediment forebay or other equivalent pretreatment measures to prevent sediment or debris from entering and clogging the gravel bed.
- Minimum Depth to Water Table – Unless they receive hotspot runoff, submerged gravel wetland systems can be allowed to intersect the groundwater table. If a submerged gravel wetland receives hotspot runoff and has an underlying water supply aquifer, a separation distance of 2 feet is required between the bottom of the gravel and the elevation of the seasonally high water table to prevent groundwater contamination.
- Soils – Not recommended for clay/silt drainage areas that are not stabilized.

Other Constraints / Considerations

- See subsection 4.3.4 (*Stormwater Wetlands*) for additional planning and design guidance.

4.4.3.5 Planning and Design Standards

The following standards shall be considered **minimum** design standards for the design of submerged gravel wetlands. Submerged gravel wetlands that are not designed to these standards will not be approved. The local municipality shall have the authority to require additional design conditions if deemed necessary.

A. LOCATION AND SITING

- Submerged gravel wetlands shall have a contributing drainage area of 5 acres or less.
- Submerged gravel wetlands are generally applied to sites that have greater than 50% impervious cover. Any disturbed or denuded areas located within the area draining to and treated by the submerged gravel wetland shall be stabilized prior to construction and use of the submerged gravel wetland.

Manufactured (i.e., Proprietary) Submerged Gravel Wetlands:

- A manufacturer of a treatment system utilizing a submerged gravel wetland is identified below. Manufactured submerged gravel wetlands should be selected on the basis of good design, suitability for the desired pollution control goals, durabilty, ease of installation, ease of maintenance, and reliability. The product listed below is not the only product available, nor should its presence in this manual be construed as an endorsement of this product. It is merely shown as a manufactured submerged gravel wetland that is known to operate in the southeast.

StormTreat	www.stormtreat.com

B. PRETREATMENT / INLETS

- Sediment regulation and removal is critical to sustain submerged gravel wetlands. A gravel wetland facility shall have a sediment forebay or equivalent upstream pretreatment.
- A sediment forebay is designed to remove incoming sediment from the stormwater flow prior to dispersal into the wetland. The forebay shall consist of a separate cell, formed by an acceptable barrier. A forebay shall be provided at each inlet, unless the inlet provides less than 10% of the total design storm inflow to the gravel wetland facility.
- The forebay shall be sized to contain 0.1 inches per impervious acre (363 ft^3) of contributing drainage and shall be no more than 4 to 6 feet deep. The pretreatment storage volume is part of the total WQv design requirement and may be subtracted from the WQv for wetland storage sizing.
- A fixed vertical sediment depth marker shall be installed in the forebay to measure sediment deposition over time. The bottom of the forebay may be hardened (e.g., using concrete, paver blocks, etc.) to make sediment removal easier.
- Inflow channels shall be stabilized with flared riprap aprons, or the equivalent. Exit velocities from the forebay to the wetland shall be non-erosive.

C. OUTLET STRUCTURES

- An outlet pipe shall be provided from the submerged gravel wetland to the facility discharge. The design shall ensure that the discharges occur in a non-erosive manner.

D. MAINTENANCE ACCESS

- A minimum 20' wide maintenance right-of-way or drainage easement shall be provided to a submerged gravel wetland from a driveway, public or private road. The maintenance access easement shall have a maximum slope of no more than 15% and shall have a minimum unobstructed drive path having a width of 12 feet, appropriately stabilized to withstand maintenance equipment and vehicles.

E. LANDSCAPING

- A landscaping plan shall be developed that indicates the methods used to establish and maintain wetland coverage. Minimum considerations of the plan include: selection of plant species, planting plan and sources of plant material. More information on wetland plants can be found at the following websites:
  - http://wetlands.fws.gov/
  - http://www.npwrc.usgs.gov/resource/plants/floraso/species.htm
  - http://www.tva.gov/river/landandshore/stabilization/plantsearch.htm

4.4.3.6 Design Procedures

Step 1. Compute runoff control volumes

Calculate WQv and CPv in accordance with the guidance presented in Chapter 3. Consult local regulations for peak discharge control (i.e., detention) requirements.

Step 2. Determine if the development site and conditions are appropriate for the use of a stormwater wetland

Consider the subsections 4.4.3.4 and 4.4.3.5-A (Location and Siting).

Step 3. Confirm design criteria and applicability

Check with the local municipality of the Northeast Tennessee Regional Stormwater Planning Group, TDEC, or other agencies to determine if there are any additional restrictions and/or surface water or watershed requirements that may apply to the site.

Step 4. Compute WQv peak discharge (Q_{wq})

The peak rate of discharge for the water quality design storm is needed for sizing the off-line diversion structures (see Chapter 3 for more information on this calculation).

(a) Using WQv, compute CN

(b) Compute time of concentration using TR-55 method

(c) Determine appropriate unit peak discharge from time of concentration

(d) Compute Q_{wq} in inches from unit peak discharge, drainage area, and WQv.

Step 5. Size flow diversion structure

A flow regulator should be supplied to divert the WQv to the submerged gravel wetland. Size low flow orifice, weir, or other device to pass Q_{wq}.

Step 6. Determine pretreatment volume

A sediment forebay is provided at each inlet, unless the inlet provides less than 10% of the total design storm inflow to the gravel wetland. The forebay shall be sized to contain 0.1 inches per impervious acre (363 ft^3) of contributing drainage and shall be 4 to 6 feet deep. The forebay storage volume counts toward the total WQv requirement and may be subtracted from the WQv for subsequent calculations.

Step 7. Design inlets, sediment forebay(s), outlet structures, maintenance access, and safety features.

See subsection 4.4.3.5 for more details.

Step 8. Design landscape plan

A landscape plan for a stormwater wetland shall be prepared to indicate how it will be stabilized and established with vegetation. See subsection 4.4.3.5-E (Landscaping) for more details.

4.4.3.7 Inspection and Maintenance Requirements

Note: Section 4.4.3.7 must be included in the Operations and Maintenance Plan that is recorded with the deed.

Regular inspection and maintenance is critical to the effective operation of a submerged gravel wetland as designed. It is the responsibility of the property owner to maintain all stormwater BMPs in accordance with the minimum design standards and other guidance provided in this manual. The local municipality has the authority to impose additional maintenance requirements where deemed necessary.

This page provides guidance on maintenance activities that are typically required for submerged gravel wetlands, along with a suggested frequency for each activity. Individual gravel wetlands may have more, or less, frequent maintenance needs, depending upon a variety of factors including the occurrence of large storm events, overly wet or dry (i.e.., drought) regional hydrologic conditions, and any changes or redevelopment in the upstream land use. Each property owner shall perform the activities identified below at the frequency needed to maintain the gravel wetlands in proper operating condition at all times.

Inspection Activities	**Suggested Schedule**
• Ensure that inlets and outlets to each submerged gravel wetland cell are free from debris and not clogged.	Monthly
• Check for sediment buildup in gravel bed.	Annually
Maintenance Activities	**Suggested Schedule**
• If sediment buildup is preventing flow through the wetland, remove gravel and sediment from cell. Replace with clean gravel and replant vegetation.	As needed
• Ensure that inlets and outlets to each submerged gravel wetland cell are free from debris and not clogged.	Monthly
• Check for sediment buildup in gravel bed.	Annually

The Northeast Tennessee Regional Stormwater Planning Group encourages the use of the inspection checklist that is presented on the next page to guide the property owner in the inspection and maintenance of submerged gravel wetlands. The local municipality can require the use of this checklist or other form(s) of maintenance documentation when and where deemed necessary in order to ensure the long-term proper operation of the submerged gravel wetland. Questions regarding stormwater facility inspection and maintenance should be referred to the local munipality of the Northeast Tennessee Stormwater Planning Group.

INSPECTION CHECKLIST AND MAINTENANCE GUIDANCE (continued)
SUBMERGED GRAVEL WETLAND INSPECTION CHECKLIST

Location: ____ Owner Change since last inspection? Y N

Owner Name, Address, Phone: ____

Date: ___________ Time: ______________ Site conditions:____

Inspection Items	Satisfactory (S) or Unsatisfactory (U)	Comments/Corrective Action
Wetland Area		
Healthy vegetation?		
Animal burrows present?		
Erosion in drainage area feeding wetland?		
Other (describe)?		
Inlet/Outlet Structures and Channels		
Clear of debris and functional?		
Trash rack clear of debris and functional?		
Sediment accumulation?		
Condition of concrete/masonry?		
Metal pipes in good condition?		
Control valve operation?		
Drain valve operation?		
Outfall channels function, not eroding?		
Other (describe)?		
Sediment Forebays		
Evidence of sediment accumulation?		
Wetland Vegetation Areas		
Vegetation adequate?		
Undesirable vegetation growth?		
Hazards		
Have there been complaints from residents?		
Public hazards noted?		

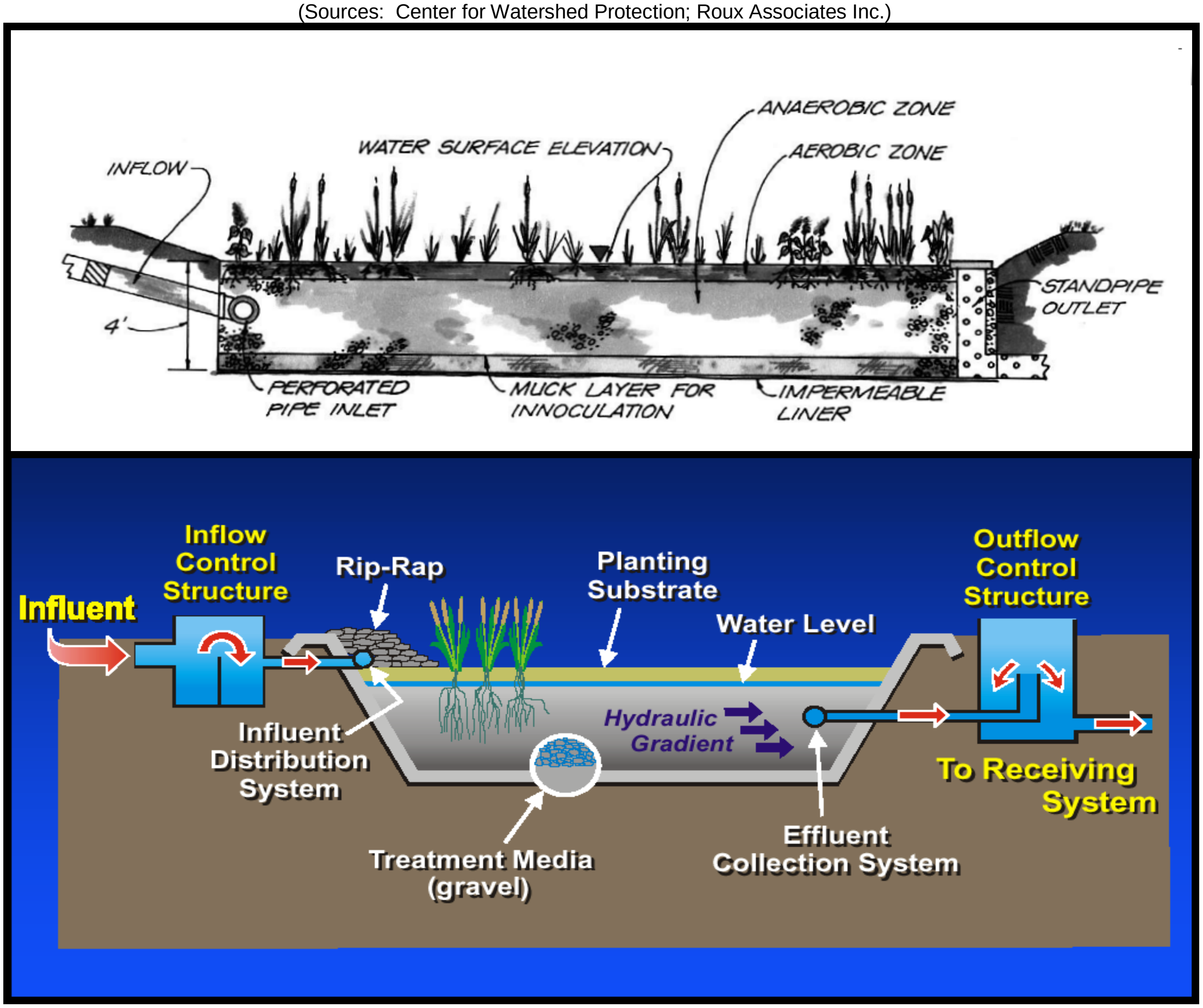
If any of the above inspection items are **UNSATISFACTORY**, list corrective actions and the corresponding completion dates below:

Corrective Action Needed	Due Date

Inspector Signature:_________________________________ Inspector Name (printed)____________________________

4.4.3.8 Example Schematic

Figure 4-65. Schematics of Submerged Gravel Wetland Systems
(Sources: Center for Watershed Protection; Roux Associates Inc.)



4.4.3.9 References

AMEC. *Knox County Stormwater Management Manual Volume 2, Technical Guidance*.

Atlanta Regional Council (ARC). *Georgia Stormwater Management Manual Volume 2 Technical Handbook.* 2001.

Center for Watershed Protection (CWP). *Design of Stormwater Filtering Systems.* Prepared for the Chesapeake Research Consortium, Solomons, MD, and U.S. EPA Region 5, Chicago, IL, by the Center for Watershed Protection, Ellicott City, MD, 1996.

Center for Watershed Protection. *Manual Builder.* Stormwater Manager's Resource Center, Accessed July 2005. *www.stormwatercenter.net*

Maryland Department of the Environment (MDE). *Maryland Stormwater Design Manual.* 2000. Available at: http://www.mde.state.md.us/programs/waterprograms/sedimentandstormwater/stormwater_design/index.asp.

New Jersey Department of Environmental Protection. *Stormwater Best Management Practices Manual.* 2004.

Northern Virginia Planning District Commission (NVPDC). Northern Virginia BMP Handbook. Annadale, Virginia: November 1992.

Schueler, T.R. Design of Stormwater Wetland Systems: Guidelines for Creating Diverse and Effective Stormwater Wetland Systems in the Mid-Atlantic Region. Washington, D.C.: Metrolpolitan Washington Council of Governments (MWCOG), October, 1992.

4.4.3.10 Suggested Reading

Adams, L., Dove L.E., D.L. Leedy, and T. Franklin. *Urban Wetlands for Stormwater Control and Wildlife Enhancement – Analysis and Evaluation.* Urban Wildlife Research Center, Columbia, Maryland, 1983.

California Storm Water Quality Task Force. *California Storm Water Best Management Practice Handbooks.* 1993.

City of Austin, TX. *Water Quality Management.* Environmental Criteria Manual, Environmental and Conservation Services, 1988.

City of Sacramento, CA. *Guidance Manual for On-Site Stormwater Quality Control Measures.* Department of Utilities, 2000.

Claytor, R.A., and T.R. Schueler. *Design of Stormwater Filtering Systems.* The Center for Watershed Protection, Silver Spring, MD, 1996.

US EPA. *Storm Water Technology Fact Sheet: Storm Water Wetlands.* EPA 832-F-99-025, Office of Water, 1999.

Faulkner, S. and C. Richardson. *Physical and Chemical Characteristics of Freshwater Wetland Soils.* Constructed Wetlands for Wastewater Treatment, ed. D. Hammer, Lewis Publishers, 831 pp, 1991.

Guntenspergen, G.R., F. Stearns, and J. A. Kadlec. *Wetland Vegetation.* Constructed Wetlands for Wastewater Treatment, ed. D. A. Hammer, Lewis Publishers, 1991.

Metropolitan Washington Council of Governments (MWCOG). A Current Assessment of Urban Best Management Practices: Techniques for Reducing Nonpoint Source Pollution in the Coastal Zone. March, 1992.

4.4.4 Alum Treatment System

Limited Application Water Quality BMP

Description: Alum treatment systems provide chemical treatment of stormwater runoff by means of adding liquid aluminum sulfate (alum) to sediment-laden runoff. The alum combines with suspended solids, phosphorus and heavy metals causing them to settle-out of suspension.

KEY CONSIDERATIONS

DESIGN GUIDELINES:

- Intended for areas requiring regional stormwater treatment from a piped stormwater drainage system where general application BMPs are not feasible.
- Typical drainage area > 50 acres.
- Typically consists of mechanical/electrical dosing system, chemical storage facilities, a downstream settling pond and floc drying beds.

ADVANTAGES / BENEFITS:

- High pollutant removal capability.
- Can be used as a regional stormwater treatment BMP.

DISADVANTAGES / LIMITATIONS:

- High capital, operations and maintenance costs.
- Requires more frequent maintenance than most other stormwater treatment controls.
- Generally, not cost effective for small sites.
- Potential for stormwater quality impacts must be evaluated prior to design/use of the system.

MAINTENANCE REQUIREMENTS:

- Requires trained system operator.
- Restock chemicals frequently.
- Inspect and maintain all components on a frequent, routine basis.
- Remove floc build-up from settling pond.

STORMWATER MANAGEMENT SUITABILITY

Stormwater Quality:	**Yes**
Channel Protection:	**No**
Detention/Retention:	**No**

Accepts hotspot runoff: *No.*

COST CONSIDERATIONS

Land Requirement:	**Low**
Capital Cost:	**High**
Maintenance Burden:	**High**

LAND USE APPLICABILITY

Residential/Subdivision Use:	**No**
High Density/Ultra Urban Use:	**Yes**
Commercial/Industrial Use:	**Yes**

POLLUTANT REMOVAL

Total Suspended Solids:	**90%**

4.4.4.1 General Description

The process of alum (aluminum sulfate) treatment provides treatment of stormwater runoff from a piped stormwater drainage system entering a wet pond by injecting liquid alum into storm sewer lines on a flow-weighted basis during rain events. When added to runoff, liquid alum forms the harmless precipitates of aluminum hydroxide [$Al(OH)_3$] and aluminum phosphate [$AlPO_4$]. These precipitates combine with suspended solids, phosphorus and heavy metals, which then settle-out in a downstream capture pond.

An alum treatment system generally consists of three parts: a flow-weighted dosing system that fits inside a storm sewer manhole; remotely located alum storage tanks; and a downstream settling pond that allows the alum, pollutants and sediments to settle out. (Kurz, 1998). Disposal of the floc that settles in the downstream pond is critical, because of the concentration of dissolved chemicals, and also because bacteria and viruses remain viable in the floc layer (Kurz, 1998). In addition to the settling pond, a separate floc collection pump-out facility should be installed to further reduce the chance of resuspension and transport of floc to receiving waterbodies. The pump disposes the floc into the sanitary sewer system or onto nearby upland areas or sludge drying beds. Permits (from the local utility) will be required to pump to the sanitary sewer, however. The quantity of sludge produced at a site can be as much as 0.5 percent of the volume of water treated (Gibb et al., 1991). Figures 4-66 and 4-67 provide photographs of an alum treatment system settling pond and dosing/injection system, respectively.

Figure 4-66. Settling Basin for an Alum Treatment System
(Source: Georgia Stormwater Management Manual)

Figure 4-67. Dosing/Injection Components of an Alum Treatment System
(Source: Georgia Stormwater Management Manual)

The precipitate that is formed when alum is injected into the stormwater system is stable in sediments and will not re-dissolve due to changes in redox potential or pH under conditions normally found in surface water bodies. Laboratory or field testing may be necessary to verify feasibility and to establish design, maintenance, and operational parameters, such as the optimum coagulant dose required to achieve the desired water quality goals, chemical pumping rates and pump sizes.

Alum treatment systems can be expensive to construct and maintain. Capital construction costs depend primarily on the number of outfall locations treated rather than the size of the area draining to the system. Operations and maintenance expenses include costs for chemicals, power to the system, manpower for routine inspections and maintenance, and equipment renewal and replacement costs. In addition, regulatory agencies or wastewater utilities may require long-term monitoring of water quality downstream of alum treatment systems, which further increases maintenance costs.

4.4.4.2 Stormwater Management Suitability

Alum treatment systems are designed primarily for large watersheds. They are designed solely for the purpose of treating stormwater quality and do not have the ability to provide channel or flood protection.

4.4.4.3 Pollutant Removal Capabilities

The total suspended solids design pollutant removal rate of 90% is a conservative average pollutant reduction percentage for design purposes derived from sampling data, modeling and professional judgment.

For additional information and data on pollutant removal capabilities for alum treatment systems, see the National Pollutant Removal Performance Database (2nd Edition) available at www.cwp.org and the International Stormwater Best Management Practices (BMP) Database at www.bmpdatabase.org.

4.4.4.4 Application and Site Feasibility Criteria

The following basic criteria should be evaluated to ensure the suitability of an alum treatment system for meeting stormwater management objectives on a site or development.

General Feasibility

- Well-suited for large drainage areas that discharge into a closed body of water (e.g., an existing lake or pond).
- Suitable for use in high density/ultra-urban areas.
- Suitable for use as a regional stormwater control.

Physical Feasibility - Physical Constraints at Project Site

- Drainage Area – Typically 50 acres minimum for an alum treatment system.

4.4.4.5 Planning and Design Guidance

Alum treatment systems are fairly complex, and design details are beyond the scope of this manual. Further information can be obtained from the Internet and by contacting engineers who have designed and implemented successful systems. The local municipality shall have the authority to set the design conditions for alum treatment systems on a case-by-case basis.

The following information is provided as guidance for the design of alum treatment systems.

- Injection points should be 100 feet upstream of discharge points.
- Alum concentration is typically 10 μg/l.
- Alum treatment systems may need to control pH.
- For new basin design, the required size is approximately 1% of the drainage basin size, as opposed to 10 to 15% of the drainage basin area for a standard detention basin.
- No volume requirement is required when discharging into a closed body of water (e.g., an existing lake or pond).

4.4.4.6 Inspection and Maintenance Requirements

Note: Section 4.4.4.6 and the operation and maintenance document supplied by the alum system designer must be included in the Operations and Maintenance Plan that is recorded with the deed.

Regular inspection and maintenance is critical to the effective operation of an alum treatment system as designed. It is the responsibility of the property owner to maintain all stormwater BMPs in accordance with the minimum design standards and other guidance provided in this manual. The local municipality has the authority to impose additional maintenance requirements where deemed necessary.

This page provides guidance on maintenance activities that are typically required for alum treatment systems, along with a suggested frequency for each activity. Individual alum treatment systems may have more, or less, frequent maintenance needs, depending upon a variety of factors including the occurrence of large storm events, overly wet or dry (i.e., drought) regional hydrologic conditions, and any changes or redevelopment in the upstream land use. Each property owner shall perform the activities identified below at the frequency needed to maintain the alum treatment system in proper operating condition at all times. <u>Inspections and maintenance of the alum treatment system must be performed by a trained system operator.</u>

Inspection Activities	**Suggested Schedule**
• Dosing equipment – monitor dosage of alum and other chemicals. Also monitor the expected flows through the system. • Perform routine inspection of dosing equipment and pump-out facility to ensure that all equipment is in proper operating condition. • Inspect dosing equipment and storage facility for signs of leaks or spills. • Inspect chemical amounts and restock if needed. • Monitor pH and other parameters in the settling basin to determine potential negative impacts to receiving waters. • Inspect settling basin for signs of damage, impending failure, and poor water quality. • Inspect storage capacity of settling basin and floc drying beds (if used).	Monthly or more frequently
Maintenance Activities	**Suggested Schedule**
• Adjust the dosage of alum and other chemicals and possibly regulate flows through the basin to ensure proper dosage and delivery of runoff to the settling basin. • Perform maintenance and repair of pump equipment, chemical supplies and delivery system. • Dredge settling basin and properly dispose of accumulated floc.	As Needed

The Northeast Tennessee Regional Stormwater Planning Group encourages the use of the inspection checklist presented below for guidance in the inspection and maintenance of the alum treatment system. The local municipality can require the use of this checklist or other form(s) of maintenance documentation when and where deemed necessary in order to ensure the long-term proper operation of the treatment system. Owners of alum treatment systems are encouraged to provide additional inspection/maintenance items to ensure the long-term proper operation of the treatment system. Questions regarding inspection and maintenance should be referred to the local municipality of the Northeast Tennessee Stormwater Planning Group.

INSPECTION CHECKLIST FOR ALUM TREATMENT SYSTEMS

Location: ____ Owner Change since last inspection? Y N

Owner Name, Address, Phone: ____

Date: ___________ Time: ______________ Site conditions:____

Inspection Items	Satisfactory (S) or Unsatisfactory (U)	Comments/Corrective Action
Dosing System		
Dispensing proper dose?		
Signs of leaks or spills?		
In proper operating condition?		
Chemical Storage Facility		
Signs of leaks or spills?		
Proper delivery of chemicals to dosing system?		
In proper operating condition?		
Settling Pond		
pH and water quality condition?		
Erosion on embankment?		
Animal burrows in embankment?		
Cracking, sliding, bulging of dam?		
Blocked or malfunctioning drains?		
Leaks or seeps on embankment?		
Obstructions of spillway(s)?		
Clear of debris and functional?		
Sediment/floc accumulation?		
Condition of concrete/masonry?		
Metal pipes in good condition?		
Control valve operation?		
Pond drain valve operation?		
Channels/spillways function, not eroding?		
Other (describe)?		
Other (describe)?		
Hazards		
Have there been complaints from residents?		
Public hazards noted?		

If any of the above inspection items are **UNSATISFACTORY**, list corrective actions and the corresponding completion dates below:

Corrective Action Needed	Due Date

Inspector Signature:_________________________________ Inspector Name (printed)_____________________________

4.4.4.7 References

AMEC. *Knox County Stormwater Management Manual Volume 2, Technical Guidance*.

Atlanta Regional Council (ARC). *Georgia Stormwater Management Manual Volume 2 Technical Handbook.* 2001.

Gibb, A., B. Bennet, and A. Birkbeck. *Urban Runoff Quality and Treatment: A Comprehensive Review*. Prepared for the Vancouver Regional District, the Municipality of Surrey, British Columbia, Ministry of Transportation and Highways, and British Columbia Ministry of Advanced Education and Trainiing. Document No. 2-51-246(242), 1991.

Harper, H.H. and J.L. Kerr. *Design, Alum Treatment of Stormwater Runoff: The First Ten Years.* Environmental Research and Design, Orlando, Florida, 1996.

Kurz, R. *Removal of Microbial Indicators from Stormwater Using Sand Filtration, Wet Detention, and Alum Treatment Best Management Practices.* Southwest Florida Water Management District, Brooksville, Florida, 1998.

www.stormwaterauthority.org/assets/alum%20injection.pdf

4.4.4.8 Suggested Reading

Center for Watershed Protection. *Manual Builder.* Stormwater Manager's Resource Center. *www.stormwatercenter.net*

Maryland Department of the Environment. *Maryland Stormwater Design Manual, Volumes I and II.* Prepared by Center for Watershed Protection (CWP), 2000.

US EPA. *Storm Water Technology Fact Sheet: Sand Filters.* EPA 832-F-99-007. Office of Water. 1999.

Walker, W. *Phosphorus Removal by Urban Runoff Detention Basins.* Lake and Reservoir Management, North American Society for Lake Management, 314, 1987.

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4.4.5 Proprietary Structural BMPs

Limited Application
Water Quality BMP

Description: Proprietary systems are defined as manufactured stormwater treatment systems that are available from commercial vendors.

REASONS FOR LIMITED USE	STORMWATER MANAGEMENT SUITABILITY
Depending on the proprietary system, there may be: • Limited performance data • Application constraints • High maintenance requirements • Higher costs than other structural control alternatives	Stormwater Quality: ✷ Channel Protection: ✷ Detention/Retention: ✷
KEY CONSIDERATIONS	**LAND USE APPLICABILITY**
• Independent performance data must be available to prove a demonstrated capability of meeting stormwater management goal(s) • System or device must be appropriate for use in local conditions • Installation and operations/maintenance requirements must be understood by all parties approving and using the system or device in question	Residential/Subdivision Use: ✷ High Density/Ultra Urban Use: ✷ Commercial/Industrial Use: ✷ **POLLUTANT REMOVAL** Total Suspended Solids: ✷ ✷ Depends on the specific proprietary structural control.

Note: The city does not recommend any specific commercial vendors for proprietary systems. This subsection is being included in order to provide local municipalities with a rationale for approving the use of a proprietary system or practice.

4.4.5.1 General Description

There are many types of commercially-available proprietary stormwater structural controls for both water quality treatment and quantity control. These systems include:

- Hydrodynamic systems such as gravity and vortex separators
- Filtration systems
- Catch basin media inserts
- Chemical treatment systems
- Package treatment plants
- Prefabricated detention structures

Many proprietary systems are useful on small sites and space-limited areas where there is not enough land or room for other structural BMP alternatives. Proprietary systems can often be used in pretreatment applications in a treatment train. However, proprietary systems are often more costly than other alternatives and may have high maintenance requirements. Perhaps the largest difficulty in using a proprietary system is the lack of adequate independent performance data, particularly for use in local conditions. Below are general guidelines that should be followed before considering the use of a proprietary commercial system.

4.4.5.2 Guidelines for Using Proprietary Systems

In order for use as a limited application control, a proprietary system must have a demonstrated capability of meeting the stormwater management goals for which it is being intended. This means that the system must provide:

(1) Independent third-party scientific verification of the ability of the proprietary system to meet water quality treatment objectives and/or to provide water quantity control (channel or flood protection);

(2) Proven record of longevity in the field; and,

(3) Proven ability to function in local conditions (e.g., climate, rainfall patterns, soil types, etc.).

For a propriety system to meet item (1) listed above, the following monitoring criteria should be met for supporting studies:

- At least 15 storm events must be sampled
- The study must be independent or independently verified (i.e., may not be conducted by the vendor or designer without third-party verification)
- The study must be conducted in the field, as opposed to laboratory testing
- Field monitoring must be conducted using standard protocols which require proportional sampling both upstream and downstream of the device
- Concentrations reported in the study must be flow-weighted
- The propriety system or device must have been in place for at least one year at the time of monitoring

Although local data is preferred, data from other regions can be accepted as long as the design accounts for the local conditions.

The city may submit a proprietary system to further scrutiny based on the performance of similar practices. A poor performance record or high failure rate is valid justification for not allowing the use of a proprietary system or device. Consult the city for more information in regards to the use of proprietary structural stormwater controls.

4.4.6 Underground Detention

Limited Application Water Quality BMP

Description: Detention storage located in underground pipe systems or vaults designed to provide water quantity control through detention and/or extended detention of storm-water runoff.

KEY CONSIDERATIONS

DESIGN GUIDELINES:

- Maximum drainage area = 25 acres.
- Access point for maintenance required.
- Used downstream of a water quality BMP.

ADVANTAGES / BENEFITS:

- To be used for space-limited applications only.
- Good for retrofitting small urbanized lots.
- Concrete vaults or pipe systems can be used.
- Longevity is high, with proper maintenance.

DISADVANTAGES / LIMITATIONS:

- Controls for stormwater quantity only – not intended to provide water quality treatment.
- Dissolved pollutants are not removed.
- Frequent maintenance required.

MAINTENANCE REQUIREMENTS:

- Remove debris from inlet and outlet structures.
- Monitor sediment accumulation.
- Clean out sediment and floatable debris using catch basin cleaning equipment (vacuum pumps).

STORMWATER MANAGEMENT SUITABILITY

Stormwater Quality:	**No**
Channel Protection:	**Yes**
Detention/Retention:	**Yes**

Accepts hotspot runoff: *No.*

COST CONSIDERATIONS

Land Requirement:	**Med - High**
Capital Cost:	**Med - High**
Maintenance Burden:	**Med - High**

LAND USE APPLICABILITY

Residential/Subdivision Use:	**No**
High Density/Ultra Urban Use:	**No**
Commercial/Industrial Use:	**Yes**

POLLUTANT REMOVAL

Total Suspended Solids:	**Low**

4.4.6.1 General Description

Underground detention is typically utilized on sites where developable surface area is at a minimum. Underground detention facilities can be either box-shaped facilities constructed with reinforced concrete, facilities constructed with large diameter metal or plastic pipe or commercially-available proprietary underground systems. All methods serve as alternatives to surface dry detention for stormwater quantity control where there is not adequate land for a dry detention basin or multi-purpose detention area.

Underground detention can provide channel protection through extended detention of the channel protection volume and overbank flood control (and in some cases extreme flood) through normal detention. Basic storage design and routing methods are the same as for dry detention basins except that the bypass for high flows must be included in the design.

Due to the potential problems that local conditions present, the Northeast Tennessee Regional Stormwater Planning Group does not support the use of underground detention unless other peak discharge control options are deemed physically infeasible.

4.4.6.2 Pollutant Removal Capabilities

Underground detention facilities are not capable of significant pollutant removal. Therefore, because underground detention is not intended for water quality treatment, it must be used in a treatment train approach with other structural BMPs that provide treatment of the WQv. This will prevent the underground pipe systems or vaults from becoming clogged with trash or sediment and significantly reducing the maintenance requirements.

4.4.6.3 Planning and Design Standards

If underground detention is allowed by the local municipality, the following standards shall be considered **minimum** design standards for the design of underground detention. Underground detention that is not designed to these standards will not be approved. The local municipality shall have the authority to require additional design conditions if deemed necessary.

<u>A. LOCATION AND SITING</u>

- The maximum contributing drainage area to be served by a single underground detention vault or tank is 25 acres.
- Flood protection controls for peak discharge control should be designed as final controls for on-site stormwater. Therefore, underground detention will typically be located downstream of structural stormwater BMPs that are designed to provide treatment of the water quality volume (WQv) and channel protection volume (CPv).
- Underground detention shall be placed in a drainage easement that is recorded with the deed and shown on the plan. The drainage easement shall be located 15 feet from the outside limits of the underground detention structure. Minimum setback requirements for the easement shall be as follows unless otherwise specified by the Director:
    - ➢ From a public water system well – TDEC specified distance per designated category
    - ➢ From a private well – 50 feet; if the well is down gradient from a land use that must obtain a Special Pollution Abatement Permit, then the minimum setback is 250 feet
    - ➢ From a septic system tank/leach field – 50 feet
- The drainage easement shall be located 15 feet from the outside limits of the underground detention structure. The first floor elevation (FFE) for any structure adjacent to underground detention shall have an elevation no lower than 1 foot above the emergency spillway elevation.

<u>B. GENERAL DESIGN</u>

- Underground detention shall consist of the following elements, designed in accordance with the specifications provided in this section.

    (1) An outlet structure;

(2) An emergency spillway; and

(3) Maintenance access.

- Underground detention systems are sized to provide extended detention of the channel protection volume over 24 hours and temporarily store the volume of runoff required to provide locally regulated flood protection.
- Routing calculations must be used to demonstrate that the storage volume is adequate. See Chapter 3 for procedures on the design of detention storage.
- Adequate maintenance access must be provided for all underground detention systems. Access must be provided over the inlet pipe and outflow structure. Access openings can consist of a standard frame, grate and solid cover, or a removable panel. Vaults with widths of 10 feet or less should have removable lids.

C. PHYSICAL SPECIFICATIONS / GEOMETRY

- Underground detention vaults and tanks must meet structural requirements for overburden support and traffic loading if appropriate.
- Detention Vaults: Minimum 3,000 psi structural reinforced concrete may be used for underground detention vaults. All construction joints must be provided with water stops. Cast-in-place wall sections must be designed as retaining walls. The maximum depth from finished grade to the vault invert should be 20 feet.
- Detention Pipes: The minimum pipe diameter for underground detention is 36 inches.

D. INLET and OUTLET STRUCTURES

- A separate sediment sump or vault chamber sized to contain 0.1 inch per impervious acre (363 ft^3) of contributing drainage should be provided at the inlet for underground detention systems that are in a treatment train with off-line water quality treatment structural BMPs.
- For CPv control, a low flow orifice capable of releasing the channel protection volume over 24-72 hours must be provided. The channel protection orifice should have a minimum diameter of 3 inches and should be adequately protected from clogging by an acceptable external trash rack. The orifice diameter may be reduced to 1 inch if internal orifice protection is used (i.e., an over perforated vertical stand pipe with 0.5-inch orifices or slots that are protected by wire cloth and a stone filtering jacket). Adjustable gate valves can also be used to achieve this equivalent diameter.
- An additional outlet is sized for Overbank Flood Peak Flow control (based upon hydrologic routing calculations) and can consist of a weir, orifice, outlet pipe, combination outlet, or other acceptable control structure. See Chapter 3 for more information on the design of outlet works.
- Water shall not be discharged from underground detention in an erosive manner. Riprap, plunge pools or pads, or other energy dissipaters are to be placed at the end of the outlet to prevent scouring and erosion. If a pond outlet discharges immediately to a channel that carries dry weather flow, care should be taken to minimize disturbance along the downstream channel and streambanks, and to reestablish a forested riparian zone in the shortest possible distance (if the downstream area is located in a water quality buffer). See Chapter 7 for more guidance.

E. EMERGENCY SPILLWAY

- A high flow bypass shall be included in the underground detention design to safely pass Extreme Flood Peak Flows in the event of outlet structure blockage or mechanical failure. The bypass shall be located so that downstream structures will not be impacted by emergency discharges.

F. MAINTENANCE ACCESS

- A maintenance right-of-way or easement having a minimum width of 20 feet shall be provided from a driveway, public or private road. The maintenance access easement shall have a maximum slope of no more than 15% and shall have a minimum unobstructed drive path having a width of 12 feet, appropriately stabilized to withstand maintenance equipment and vehicles.

- The maintenance access shall extend to the forebay (if included) and outlet works, and, to the extent feasible, be designed to allow vehicles to turn around.

4.4.6.4 Design Procedures

In general, site designers should perform the following design procedures when designing underground detention.

Step 1. Compute runoff control volumes.

Calculate WQv and CPv in accordance with the guidance presented in Chapter 3. Consult local regulations for peak discharge control (i.e., detention) requirements.

Step 2. Confirm design criteria and applicability.

Consider any special site-specific design conditions/criteria from subsection 4.4.6.3. Check with the Northeast Tennessee Regional Stormwater Planning Group, TDEC, or other agencies to determine if there are any additional restrictions and/or surface water or watershed requirements that may apply to the site.

Step 3. Calculate discharge release rates and water surface elevations.

Set up stage-storage-discharge relationships for the control structure for the 2, 10, 25 and 100-year storms.

Step 4. Design spillway(s)

Size emergency spillway (bypass) and analyze safe passage of the Extreme Flood. Set the emergency spillway elevation a minimum of 0.1 feet above the 100-year water surface elevation.

Step 5. Design inlets, outlet structures and maintenance access.

See subsection 4.4.6.3 for more details.

4.4.6.5 Maintenance Requirements and Inspection Checklist

Note: Section 4.4.6.5 must be included in the Operations and Maintenance Plan that is recorded with the deed.

Regular inspection and maintenance is critical to the effective operation of underground detention as designed. It is the responsibility of the property owner to maintain all stormwater BMPs in accordance with the minimum design standards and other guidance provided in this manual. The local municipality has the authority to impose additional maintenance requirements where deemed necessary.

This page provides guidance on maintenance activities that are typically required for underground detention, along with a suggested frequency for each activity. Individual underground detention locations may have more, or less, frequent maintenance needs, depending upon a variety of factors including the occurrence of large storm events, overly wet or dry (i.e., drought) regional hydrologic conditions, and any changes or redevelopment in the upstream land use. Each property owner shall perform the activities identified below at the frequency needed to maintain the pond in proper operating condition at all times.

Inspection Activities	**Suggested Schedule**
• After several storm events or an extreme storm event, inspect for: signs of clogging of the inlet or outlet structures and sediment accumulation.	As Needed
• Inspect for: trash and debris; clogging of the outlet structures and any pilot channels; excessive erosion; sediment accumulation in the basin and inlet/outlet structures; tree growth on dam or embankment; the presence of burrowing animals; standing water where there should be none; vigor and density of the grass turf on the basin side slopes and floor; differential settlement; cracking; leakage; and slope stability.	Semi-annually
• Inspect that the outlet structures, pipes, and downstream and pilot channels are free of debris and are operational. • Note signs of pollution, such as oil sheens, discolored water, or unpleasant odors. • Check for sediment accumulation in the facility. • Check for proper operation of control gates, valves or other mechanical devices.	Annually
Maintenance Activities	**Suggested Schedule**
• Perform structural repairs to inlet and outlets • Clean and remove debris from inlet and outlet structures.	Monthly or as needed
• Repair damage to inlet or outlet structures, control gates, valves, or other mechanical devices; repair undercut or eroded areas.	As Needed
• Monitor sediment accumulations, and remove sediment when the pond volume has become reduced significantly.	As Needed

The Northeast Tennessee Regional Stormwater Planning Group encourages the use of the inspection checklist that is presented on the next page to guide the property owner in the inspection and maintenance of underground detention facilities. The local municipality can require the use of this checklist or other form(s) of maintenance documentation when and where deemed necessary in order to ensure the long-term proper operation of the underground detention facilities. Questions regarding stormwater facility inspection and maintenance should be referred to the local municipality of the Northeast Tennessee Stormwater Planning Group.

INSPECTION CHECKLIST AND MAINTENANCE GUIDANCE (continued)
UNDERGROUND DETENTION INSPECTION CHECKLIST

Location: ____ Owner Change since last inspection? Y N

Owner Name, Address, Phone: ____

Date: ___________ Time: ______________ Site conditions:____

Inspection Items	Satisfactory (S) or Unsatisfactory (U)	Comments/Corrective Action
Inlet/Outlet Structures		
Clear of debris and functional?		
Trash rack clear of debris and functional?		
Sediment accumulation?		
Condition of concrete/masonry?		
Metal pipes in good condition?		
Control valve operational?		
Pond drain valve operational?		
Outfall channels function, not eroding?		
Other (describe)?		
Pond Bottom		
Excessive sedimentation?		

If any of the above inspection items are **UNSATISFACTORY**, list corrective actions and the corresponding completion dates below:

Corrective Action Needed	Due Date

Inspector Signature: ________________________________ Inspector Name (printed)____________________________

4.4.6.6 Example Schematics

Figure 4-68. Example Underground Detention Pipe System

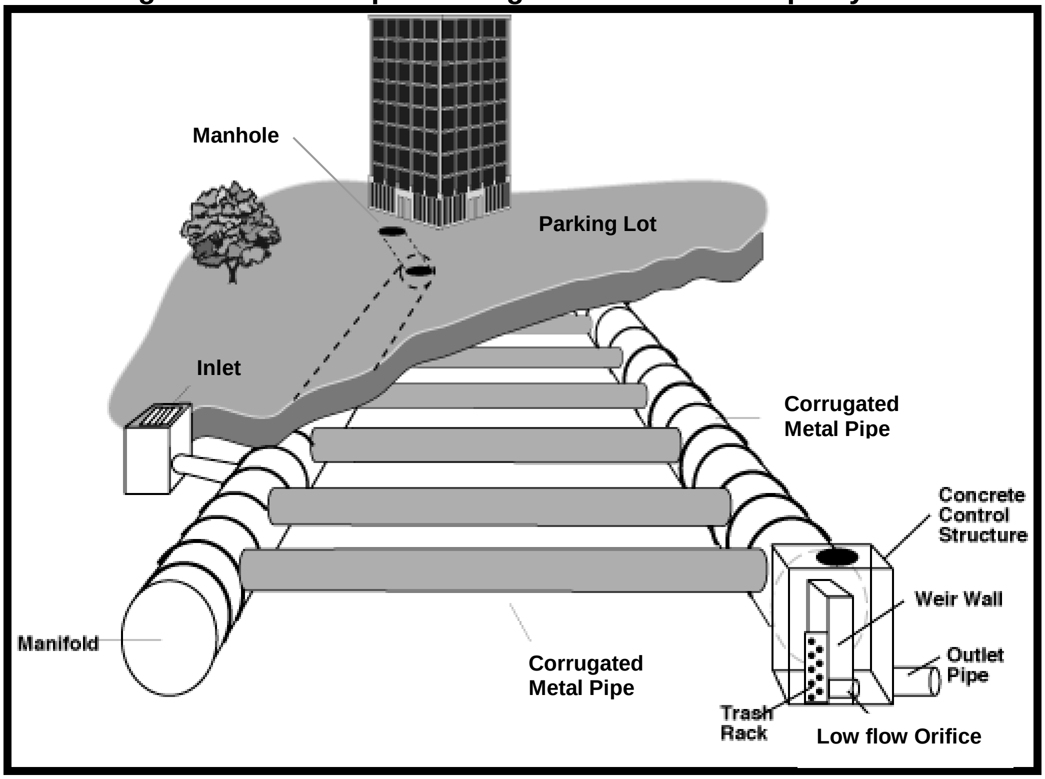
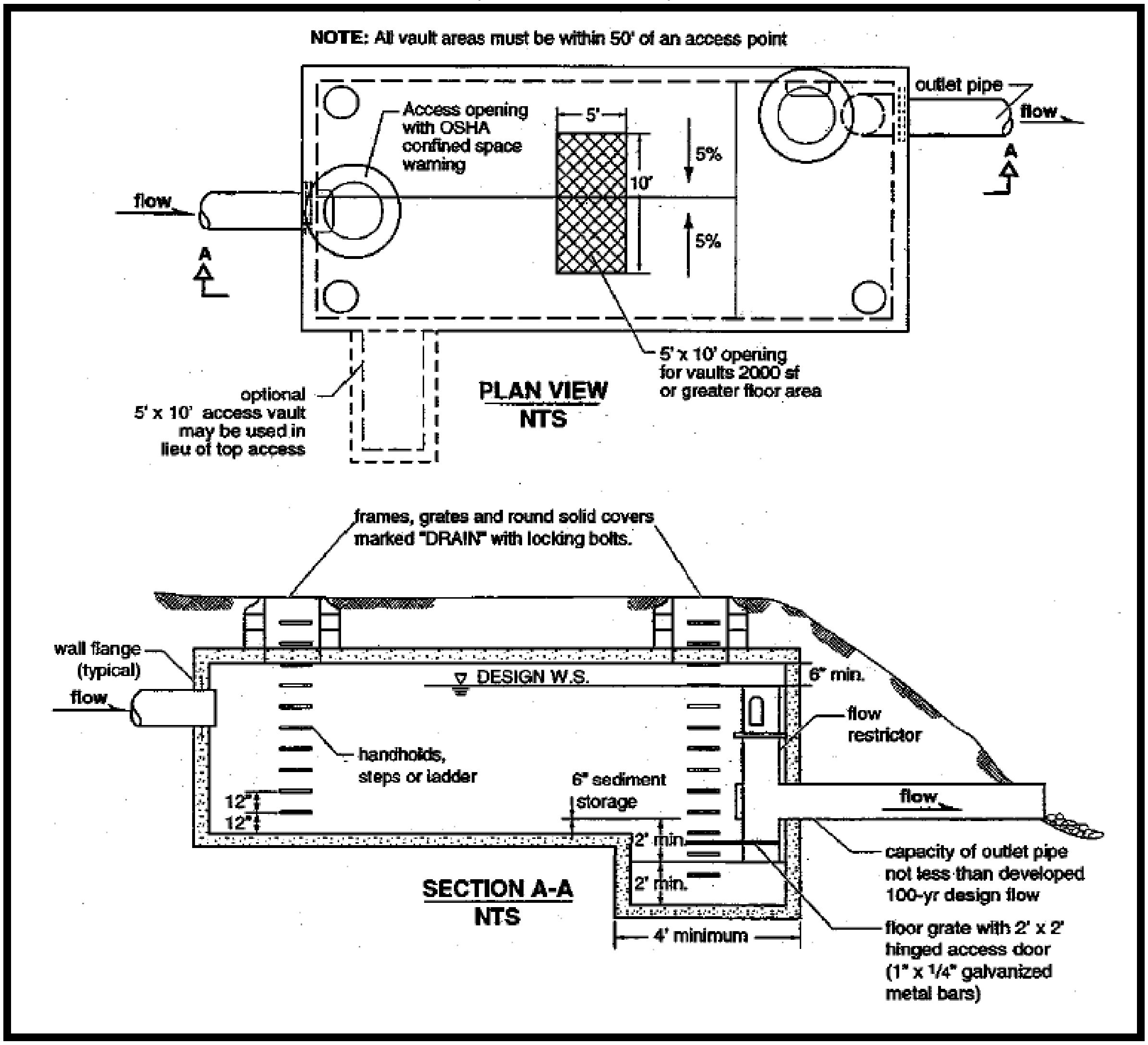


Figure 4-69. Schematic of a Typical Underground Detention Vault
(Source: WDE, 2000)



4.4.6.7 References

AMEC. *Knox County Stormwater Management Manual Volume 2, Technical Guidance*.

AMEC. *Metropolitan Nashville and Davidson County Stormwater Management Manual, Volume 4 Best Management Practices.* 2006.

Atlanta Regional Council (ARC). *Georgia Stormwater Management Manual Volume 2 Technical Handbook.* 2001*.*

Washington State Department of Ecology. *Stormwater Management Manual for Western Washington.* 2000.

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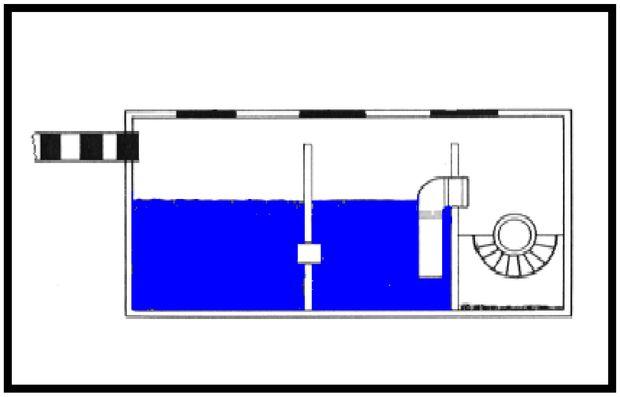
4.4.7 Oil-Grit (Gravity) Separator

Limited Application
Water Quality BMP



Description: The oil/grit separator is a device designed to remove settleable solids, oil and grease, debris and floatables from stormwater runoff. This is done through gravitational settling and trapping of pollutants. Oil-grit separators are also called gravity separators or oil/water separators.

KEY CONSIDERATIONS

DESIGN GUIDELINES:

- Maximum drainage area of 1 acre.
- Access for maintenance is required.
- Performance dependent on design and frequency of inspection and cleanout of unit.
- Openings to device must be 1/16 inch or less to prevent mosquito intrusion and breeding.
- Install as an off-line device unless separator can be sized to handle a small drainage area.
- Install inspection/collection manhole on downstream side to provide easy access for sampling of effluent.

ADVANTAGES / BENEFITS:

- Good for sites where larger, or above-ground BMPs are not an option, or for retrofitting small urbanized lots.
- Can be used as pretreatment for other BMPs.
- Longevity is high, with proper maintenance.
- Standardized designs allow for easy installation.

DISADVANTAGES / LIMITATIONS:

- Cannot alone achieve the 80% TSS removal target.
- Limited performance data.
- Dissolved pollutants are not removed.
- Frequent maintenance required.

MAINTENANCE REQUIREMENTS:

- Inspect the gravity separator unit.
- Clean out sediment, oil and grease, and floatable debris using catch basin cleaning equipment (vacuum pumps).

STORMWATER MANAGEMENT SUITABILITY

Stormwater Quality:	**Yes**
Channel Protection:	**No**
Detention/Retention:	**No**

Accepts hotspot runoff: *Yes, but two feet of separation distance required to water table when used in hotspot areas*

COST CONSIDERATIONS

Land Requirement:	**Low**
Capital Cost:	**Med - High**
Maintenance Burden:	**Med - High**

LAND USE APPLICABILITY

Residential/Subdivision Use:	**No**
High Density/Ultra Urban Use:	**Yes**
Commercial/Industrial Use:	**No**

POLLUTANT REMOVAL

Total Suspended Solids:	**40%**

4.4.7.1 General Description

Oil-grit separators (also called oil/water separators or gravity separators) are hydrodynamic separation devices that are designed to remove grit and heavy sediments, oil and grease, debris and floatable matter (e.g., litter) from stormwater runoff through gravitational settling and trapping. There are two basic types of oil-grit separators, as displayed in Figure 4-71, in Section 4.4.7.8. Conventional separators rely upon gravity, physical characteristics of oil and sediments, and good design parameters to achieve pollutant removal. Coalescing plate interceptor (CPI) separators contain closely-spaced plates which greatly enhance the removal efficiency for oils and greases. In addition, a wide variety of separator systems are commercially-available in a variety of layouts, for which vendors have design data and procedures. Example schematics for both types of oil-water separators are displayed in Section 4.4.7.8.

Conventional oil-grit separator units contain a permanent pool of water and typically consist of an inlet chamber, separation/storage chamber, a bypass chamber, and an access port for maintenance purposes. Runoff enters the inlet chamber where heavy sediments and solids drop out. Then the flow moves into the main separation chamber, where further settling of suspended solids takes place. Oil and grease are skimmed and stored in a waste oil storage compartment for future removal. After moving into the outlet chamber, the clarified runoff is then discharged to the site's stormwater conveyance system. Oil-grit separators are sized based on a design flow rate, the Water Quality Peak Flow Rate (Q_{wq}). This contrasts with most other stormwater structural controls, which are sized based on capturing and treating a specific volume.

CPI separators include coalescing tubes or plates that provide an additional media in which minute oil globules can agglomerate to aid in the separation process. Oil that agglomerates around the coalescing tubes/plates can easily be skimmed through the gravity process. CPI separators must be utilized in "hotspot" areas where oil, grease, or other petroleum products are potential pollutants (e.g., fueling areas, gas stations, etc.).

The performance of oil-grit separator systems is based primarily on the relatively low solubility of petroleum products in water and the difference between the specific gravity of water and the specific gravities of petroleum compounds. Separators are not designed to separate other products such as solvents, detergents, or dissolved pollutants. The typical oil-grit separator unit may be enhanced with a pretreatment swirl concentrator chamber, oil draw-off devices that continuously remove the accumulated light liquids, and flow control valves that regulate the flow rate into the unit. Separators are available as prefabricated proprietary systems from a number of different commercial vendors. Some of the enhancements added by commercial vendors are presented in the example schematics presented in section 4.4.7.8.

4.4.7.2 Stormwater Management Suitability

Oil-grit separators are designed solely as stormwater quality treatment and do not have the ability to provide channel protection or flood protection. An important consideration when designing an oil-grit separator system for a site is how to bypass large storm events that exceed the design flow capacity around the separator without damaging the unit, exceeding the design flow capacity, or resuspending collected pollutants. Since resuspension of accumulated sediments and oil droplets is possible during heavy storm events, oil-grit separator units are typically installed off-line with a bypass installed to minimize pollutant wash-out or resuspension.

Water Quality (WQv)
To treat stormwater runoff, oil-grit separators rely on gravity and trapping to filter pollutants. An oil-grit separator cannot alone achieve the 80% TSS removal criteria. Therefore, separators are frequently used as the upstream pretreatment measure in a series of BMPs, ahead of a detention basin or constructed wetland.

4.4.7.3 Pollutant Removal Capabilities

Testing of gravity separators has shown that they can remove between 40% and 50% of the TSS loading when used in an off-line configuration (Curran, 1996 and Henry, 1999). Gravity separators also provide removal of debris, hydrocarbons, trash and other floatables. They provide only minimal removal of nutrients and organic matter.

The total suspended solids design pollutant removal rate of 40% is a conservative average pollutant reduction percentage for design purposes derived from sampling data, modeling and professional judgment

4.4.7.4 Application and Feasibility Criteria

One of the most important selection criteria when considering an oil-grit separator is the long-term maintenance and operation costs, and the need for regular inspections and cleanout. Inspection and maintenance needs for such systems can be considered high relative to other stormwater BMPs. Therefore, the oil-grit separator system should only be constructed if the property owner or tenant of the site has both the physical and fiscal ability to perform regular inspection and maintenance of the system on a long-term basis. This is one of the constraints that will be considered by the local municipality when oil-grit separators are proposed as a BMP for a development or redevelopment site.

Oil-grit separators are best used in commercial, industrial and transportation land uses and are intended primarily as a pretreatment measure for high-density or ultra-urban sites, or for use in hydrocarbon hotspots, such as gas stations and areas with high vehicular traffic. However, separators cannot be used for the removal of dissolved or emulsified oils or for pollutants such as coolants, soluble lubricants, glycols and alcohols. Suitable applications of an oil-grit separator include:

- pretreatment for other structural controls;
- parking lots, streets, driveways, truck loading areas;
- runways, marinas, loading wharves;
- gasoline stations, refueling areas;
- automotive repair facilities, oil-change businesses, fleet maintenance yards;
- recycling or salvage yards which accept automotive equipment; and,
- commercial vehicle washing facilities.

4.4.7.5 Planning and Design Standards

Northeast Tennessee Regional Stormwater Planning Group's design standards for oil-grit (gravity) separators are presented below. Design specifications developed by a commercial vendor for prefabricated proprietary systems can also be utilized, but must be approved where such specifications differ and/or are less stringent from the standards presented below. The local municipality shall have the authority to require additional design conditions if deemed necessary.

A. LOCATION AND SITING

- Any individual oil-grit separator shall have a contributing drainage area no greater than 1 acre.
- It is desirable to maintain reasonable dimensions by bypassing larger storm flows in excess of the design flow rates. Thus, it is preferred that oil-grit separators be located off-line. An off-line separator can be an existing or proposed manhole with a baffle or other control (shown in Figure 4-71).
- Oil-grit separator systems can be installed in almost any soil or terrain. Since these devices are underground, appearance is not an issue and public safety risks are low.
- The design loading rate for oil-grit separators is low; therefore, they can only be cost-effectively sized to detain and treat the water quality volume, or other low flows if required by local municipalities. It is usually not economical or feasible to size an oil-grit separator to treat large design storms. Oil-grit separators require frequent maintenance for the life of the separator unit. Maintenance can be minimized (and performance can be increased) by careful planning and design, particularly upstream and downstream of the separator unit.

B. PHYSICAL SPECIFICATIONS / GEOMETRY

- Design procedures for commercially available oil-grit separators are usually given by the manufacturer in simplified tables or graphs based on field testing and observed pollutant removal rates. Pollutant removal rates higher than those indicated in Section 4.4.7.3 must be proven using the criteria for proprietary BMPs presented in Section 4.4.5 of this manual.
- Oil-grit separators must be constructed with watertight joints and seals.
- The separation chamber shall provide for three separate storage volumes, as follows:
  (1) A volume for separated oil storage at the top of the chamber;
  (2) A volume for settleable solids accumulation at the bottom of the chamber; and,
  (3) A volume required to give adequate flow-through detention time for separation of oil and sediment from the stormwater flow.
- Ideally, a gravity separator design will provide an oil draw-off mechanism to a separate chamber or storage area. This design is required where a gravity separator is utilized to treat oil, grease and/or petroleum hotspots.
- Oil-grit separators are typically designed to bypass runoff flows in excess of the water quality volume peak flow. Some designs have built-in high flow bypass mechanisms, whereas others require a diversion structure or flow splitter located upstream of the device in the drainage system. Bypass mechanisms must minimize potential for captured pollutants from being washed-out or resuspended by large flows. Regardless of the bypass mechanism, an adequate outfall/outlet must be provided for both the discharge from the separator itself, and the bypassed discharge. Runoff shall be discharged in a non-erosive manner.
- The device shall be designed such that the velocity through the separation chamber does not exceed the entrance velocity.
- A trash rack shall be included in the design to capture floating debris, preferably near the inlet chamber to prevent debris from becoming oil impregnated.
- The total wet storage of the gravity separator unit shall be no less than 400 cubic feet per contributing impervious acre.
- The theoretical sizing of a conventional oil-grit separator requires the use of Stokes Law for the computation of rise velocity of oil droplets:

Equation 4.4.7.1

$$V_p = \frac{1.79 \times 10^{-8} (S_w - S_p) D_p{}^2}{N}$$

where: V_p = upward rise velocity of petroleum droplet (ft/s)
S_w = specific gravity of water (0.998 to 1.000)
S_p = specific gravity of the petroleum droplet (typically 0.85 to 0.95)
D_p = diameter of petroleum droplet to be removed (microns)
N = absolute viscosity of water (poises)

The expected temperature is generally chosen for cold winter months. Typical values for the specific gravity and absolute viscosity of water at various temperatures are shown in the following table:

Temperature	S_w	N
32° F	0.999	0.01794
40° F	1.000	0.01546
50° F	0.999	0.01310
60° F	0.999	0.01129
70° F	0.998	0.00982

Sizing a Conventional Oil-Grit Separator:

- Using V_p above, a conventional oil-grit separator can be sized as follows:

Equation 4.4.7.2

$$D = \left(\frac{Q}{RV_H} \right)^{0.5}$$

Equation 4.4.7.3

$$W = RD$$

Equation 4.4.7.4

$$L = \frac{V_H D}{V_P}$$

Equation 4.4.7.5

$$V_H = \frac{V_P D}{L} = 15(V_P)$$

where: D = depth of unit (feet), generally between 3 and 8 feet
W = width of unit (feet), usually twice the depth
L = length of unit (feet), usually fifteen times the depth
Q = design flow rate (cfs), i.e., the water quality peak flow rate, Q_{wq}
R = width to depth ratio, generally a value of 2 is recommended
V_H = allowable horizontal velocity (ft/s), maximum 0.05 ft/s
V_p = upward rise velocity of oil droplet (ft/s)

- The total depth shall be adjusted by adding 1 foot of freeboard to the depth calculated using the equations above, or equations provided by a manufacturer.
- Top baffles should extend downward by 0.85D, and bottom baffles should extend upward by 0.15D, where D is the depth of the unit (in feet). The distribution baffle should be located at a distance of 0.10L from the inlet of the unity, where L is the length of the unit (in feet).

Sizing a Coalescing Plate Interceptor (CPI) Separator:

- CPI separators require considerably less space than a conventional separator to obtain the same effluent quality. A CPI separator is able to process smaller oil droplets by collecting them upon polyurethane plates or other materials. It is recommended that the design engineer consult vendors for a plate package that will meet site and flow criteria. Manufacturers will typically identify the capacity of various standard units.
- Using V_p above, a CPI separator can be sized as follows:

Equation 4.4.7.6

$$A_P = \frac{Q}{EV_P \cos(H)}$$

where: A_p = total surface area of coalescing plates (square ft)
Q = design flow rate (cfs), i.e., the water quality peak flow rate, Q_{wq}
E = efficiency of coalescent plates (typically 0.35 to 0.95)
V_p = upward rise velocity of oil droplet (ft/s)
H = angle of coalescing plates measured from horizontal (degrees), from 0° to 60°

- A plate angle of 45° to 60° is optimal, allowing sediment to slide off the plate and settle at the bottom of the chamber. At an angle of 0°, the plates would be horizontal and sediment will settle on the plates, reducing its effectiveness.
- Select a likely plate length and width, and then compute the number of plates needed using the following equation.

Equation 4.4.7.7

$$N = \frac{A_P}{W_P L_P}$$

where: N = number of plates required
A_p = total surface area of coalescing plates (ft^2)
W_p = width of plates (ft)
L_p = length of plates (ft)

- The space between the plates is usually about 1-inch. Placing plates closer together reduces the total required volume, but may instead allow debris such as twigs, plastics or paper to clog the plates.
- Calculate the chamber geometry and volume to contain the coalescing plates. Add a minimum of 1 foot below the plates to account for sediment storage. Add 6 to 12-inches above the plates for oil accumulation. Finally, add 1 foot above the oil accumulation allowance for freeboard.
- The CPI separator shall include a forebay chamber to collect floatable debris and evenly distribute flow if more than one plate is needed. Larger units may have a device to remove and store oil from the water surface, such as a skimmer or vacuum.

Manufactured (i.e., Proprietary) Oil-Grit Separators:

- Several manufacturers of oil-grit separators are identified in the references for this section. Manufactured separators should be selected on the basis of good design, suitability for the desired pollution control goals, durabilty, ease of installation, ease of maintenance, and reliability. The products listed in the reference section and/or shown in schematics are not the only products available, nor should their presence in this manual be construed as an endorsement of these products. They are merely shown as manufactured separators that are known to operate in Tennessee.
- Manufacturers generally provide design methods, installation guidelines, and proof of effectiveness for each application where used. These structures tend to include innovative methods of providing high flow bypass. However, it is incumbent upon the landowner to carefully investigate the suitability and overall trustworthiness of each manufacturer and/or subcontractor.

C. MAINTENANCE ACCESS

- A minimum 20 foot wide maintenance right-of-way or drainage easement shall be provided for the oil-grit separator from a driveway, public or private road. The maintenance access easement shall have a maximum slope of no more than 15% and shall have a minimum unobstructed drive path having a width of 12 feet, appropriately stabilized to withstand maintenance equipment and vehicles. The right-of-way shall be located such that maintenance vehicles and equipment can access the oil-grit separator.

4.4.7.6 Design Example

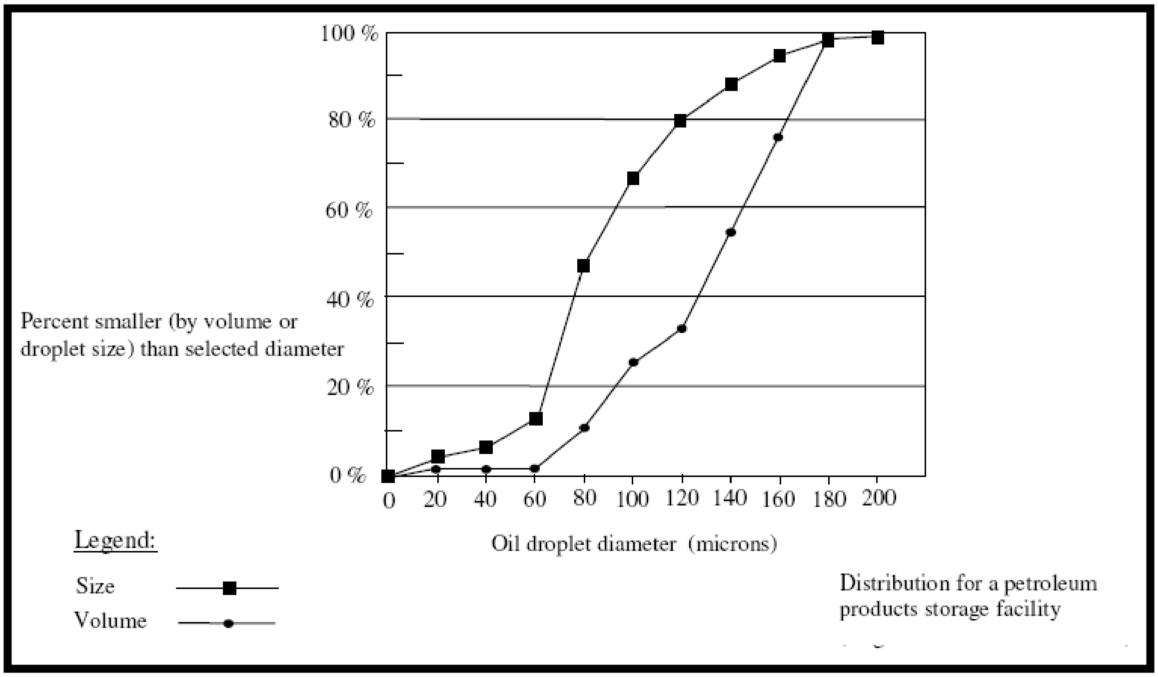
Basic Data

A conventional oil-grit separator unit is desired for use on a 1 acre parking lot.

- S_p = specific gravity of the petroleum droplet = 0.90
- V_p = 0.00080 ft/s for water temperature of 32°F (1 foot in 21 minutes)
- V_p = 0.00127 ft/s for water temperature of 60°F (1 foot in 13 minutes)
- Impervious percentage (I) = 90%
- Area (A) = 1 acre
- Time of concentration (t_c) = 6 minutes

Consider the effluent goal as 10 parts per million (ppm) and the design influent concentration is estimated to be 50 ppm (or equivalent to 50 mg/l), so that an oil removal efficiency of 80% is the desired target. From Figure 4-70 below, this can be achieved by removing all oil droplets with diameters of 90 microns or larger.

Figure 4-70. Typical Size and Volume Distribution of Oil Droplets
(Source: City of Knoxville, 2003)



<u>Step 1: Calculate the Water Quality Peak Flow Rate (Q_{wq}):</u>

(See Chapter 3 for equation information)
Compute the Runoff Peak Volume (Q_{wv}) in inches for 1.1-inch rainfall (P = 1.1):

Q_{wv} = PRv = 1.1Rv = 1.1(0.015 + (0.0092)(90)) = 0.93 inches

Compute modified CN:

$$CN = 1000/[10+5P+10\,Q_{wv} - 10(Q_{wv}^{\,2}+1.25Q_{wv}P)^{1/2}]$$
$$= 1000/[10+5(1.1)+10(0.93)-10(0.93^2+1.25(0.93)1.1)^{1/2}]$$
$$= 98.4 \quad \text{(Use CN = 98)}$$

For CN = 98 and an estimated time of concentration (t_c) of 6 minutes (0.1 hours), compute the Q_{wq} for a 1.1 inch storm.

I_a = 0.041 (from Table 3-13 in Chapter 3), therefore I_a/P = 0.041/1.1 = 0.037.

Using Figure 3-6 in Chapter 3, q_u can be estimated for a Type II storm as approximately 1000 csm/in or more (use 1000 csm/in because of limits in Figure 3-6).

q_u = 1000 csm/in, and therefore:

Q_{wq} = q_uA Q_{wv} = (1000 csm/in) (1.0ac/640ac/mi2) (0.93in) = 1.45 cfs

<u>Step 2: Size the oil-grit separator:</u>

The allowable horizontal velocity (V_H) is:

V_H = 15V_p = 15(0.00080) = 0.012 ft/s

Compute the required depth (D), width (W) and length (L) of the unit (R = 2):

D $= (Q_{wq}/RV_H)^{0.5} = (1.45/(2)(0.012))^{0.5} = 7.8$ ft
W $= RD = 2(7.8) = 14.8$ ft
L $= (V_H D)/V_p = (0.012x7.8)/0.00080 = 117$ ft

The very large size separator size (8' x 16' x 111') computed above is an indication of the fact that oil and water do not separate easily. By careful design of upstream and downstream reaches, it is possible to reduce turbulent flows, drop heights, mixing or swirling stormwater runoff, and excessive velocities. The large unit sized above also indicates the importance of subbasin size to unit size. It is important to keep drainage areas small (i.e., less than 1 acre); this will keep oil-grit separators to manageable sizes.

4.4.7.7 Maintenance Requirements and Inspection Checklist

Note: Section 4.4.7.7 must be included in the Operations and Maintenance Plan that is recorded with the deed.

Regular inspection and maintenance is critical to the effective use of oil-grit (gravity) separators as stormwater best management practices. It is the responsibility of the property owner to maintain all stormwater facilities in accordance with the minimum design standards and other guidance provided in this manual. The local municipality has the authority to impose additional maintenance requirements where deemed necessary.

This page provides guidance on maintenance activities that are typically required for oil-grit (gravity) separators, along with a suggested frequency for each activity. Individual gravity separators may have more, or less, frequent maintenance needs, depending upon a variety of factors including the occurrence of large storm events, overly wet or dry (i.e., drought) regional hydrologic conditions, and any changes or redevelopment in the upstream land use. Each property owner shall perform the activities identified below at the frequency needed to maintain oil-grit separators properly at all times.

Inspection Activities	Suggested Schedule
• Inspect the gravity separator unit for clogging, accumulated debris, sediment, and/or oil and grease.	Regularly (at least every three months)
Maintenance Activities	**Suggested Schedule**
• Clean out sediment, oil and grease, and floatables, using catch basin cleaning equipment (vacuum pumps). Manual removal of pollutants may be necessary.	As Needed

Additional Maintenance Considerations and Requirements

- Additional maintenance requirements for a proprietary system should be obtained from the manufacturer and included in the Operations and Maintenance Plan for the site.
- Consider using a licensed commercial subcontractor, who may have special equipment and abilities to perform periodic cleanout on oil-grit separators.
- Cleanout may require the implementation of confined-space procedures and equipment as required by OSHA regulations, such as non-sparking electrical equipment, oxygen meter, flammable gas meter, etc.
- Proper disposal of oil, solids and floatables removed from the gravity separator must be ensured. Floating oil, grease and petroleum substances removed using special vacuum hoses; should be treated as hazardous waste. Sediments may also contain heavy metals or other toxic substances and should be handled as hazardous waste.
- Removal of sediment depends upon accumulation rate, available storage, watershed size, nearby construction, industrial or commercial activities upstream, etc. The sediment composition should be identified by testing prior to disposal. Some sediment may contain contaminants for which the Tennessee Department of Environment and Conservation (TDEC) requires special disposal procedures. Consult TDEC's Division of Water Pollution Control if uncertain about what the sediments contain or if it is known to contain contaminants. Generally, give special attention or sampling to sediments accumulated in industrial or manufacturing facilities, fueling centers or automotive maintenance areas, large parking areas, or other areas where pollutants are suspected to accumulate.
- There is usually uncertainty about what types of oil or petroleum products may be encountered. A significant percentage of petroleum products are attached to fine suspended solids, and therefore, are not easily removed by settling.
- The local municipality encourages the use of the inspection checklist presented below for guidance in the inspection and maintenance of the oil-grit separator. Additional items should be added to the list, based on the inspection and maintenance information provided by the manufacturer of the separator unit. The local municipality can require the use of this checklist or other form(s) of maintenance documentation when and where deemed necessary in order to ensure the long-term proper operation of the unit. Questions regarding inspection and maintenance should be referred to the local municipality.

INSPECTION CHECKLIST: OIL-GRIT (OIL/WATER OR GRAVITY) SEPARATOR

Location: ____ Owner Change since last inspection? Y N
Type of Separator Unit (provide Manufacturer and Unit Name/ID if known): ______________________________
Owner Name, Address, Phone: ____
Date: __________ Time: ____________ Site conditions:____

Inspection Items	Satisfactory (S) or Unsatisfactory (U)	Comments/Corrective Action
Signs of clogging?		
Debris (trash) accumulation?		
Oil accumulation?		
Sediment accumulation?		
Standing water upstream of unit?		
Erosion downstream of unit?		
Other (describe)?		
Other (describe)?		
Other (describe)?		
Other (describe)?		
Hazards		
Have there been complaints from residents?		
Public hazards noted?		

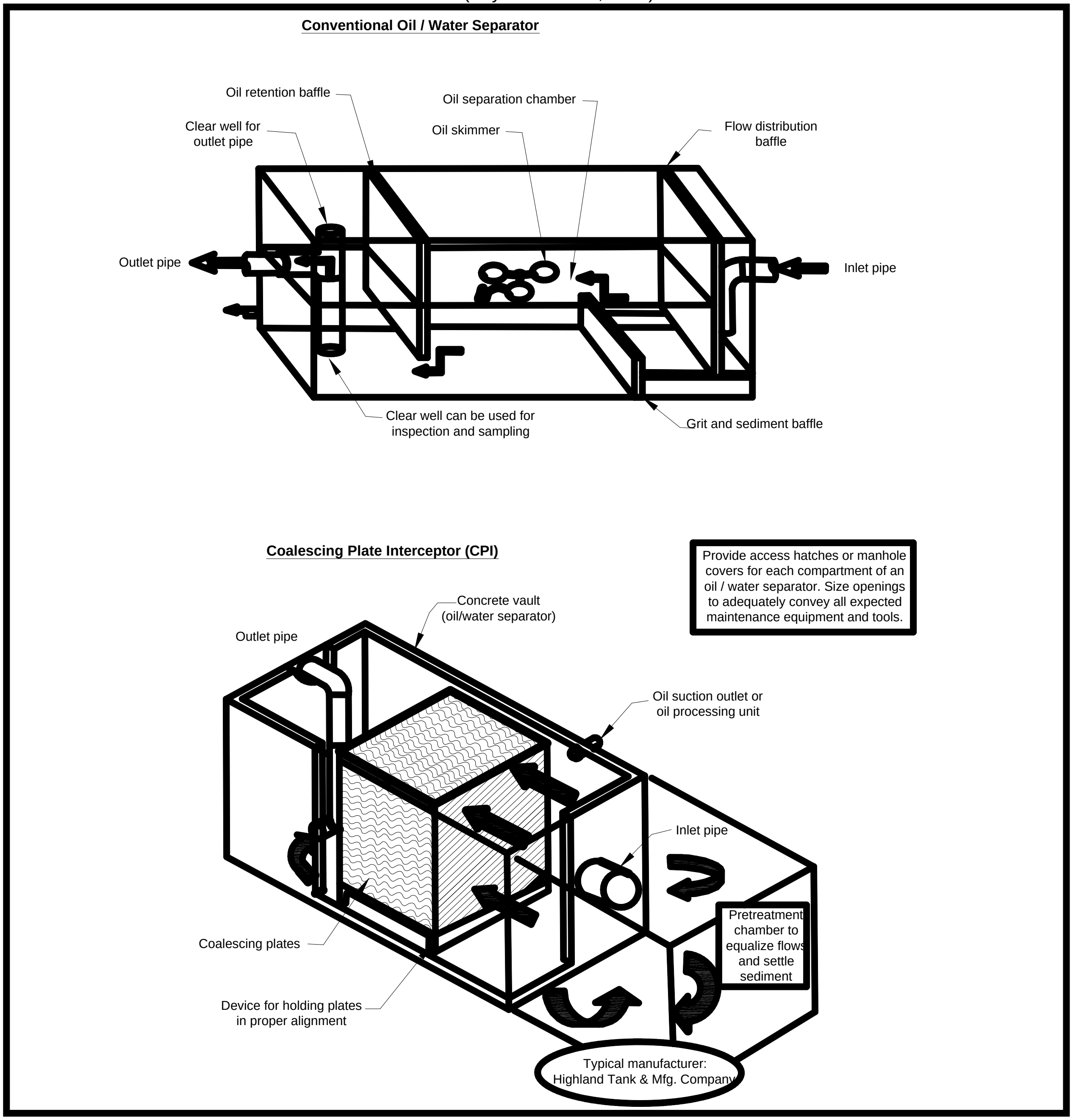
If any of the above inspection items are **UNSATISFACTORY**, list corrective actions and the corresponding completion dates below:

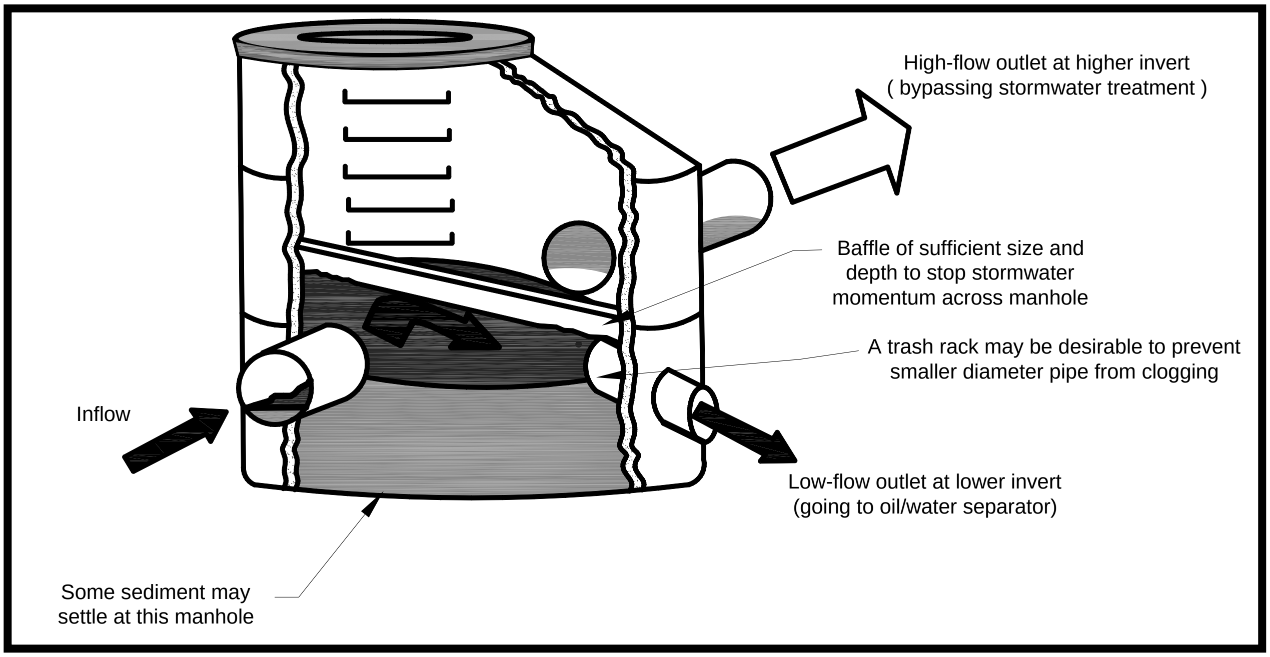
Corrective Action Needed	Due Date

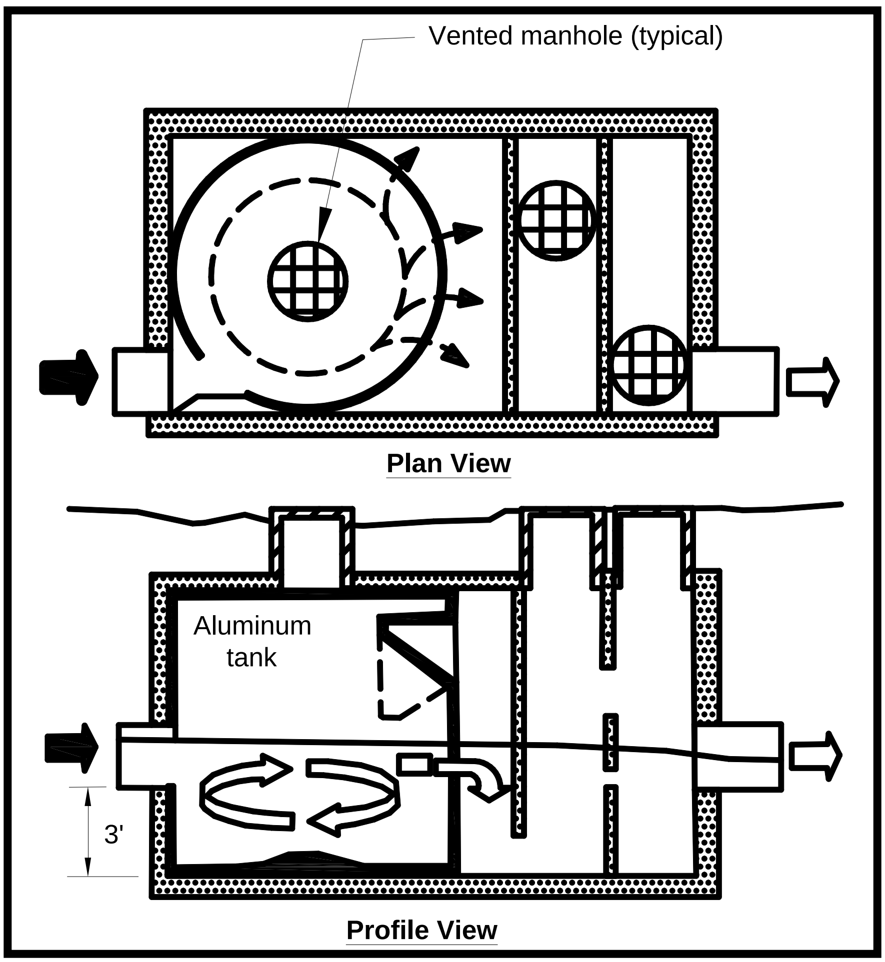
Inspector Signature:_____________________________ Inspector Name (printed)_____________________________

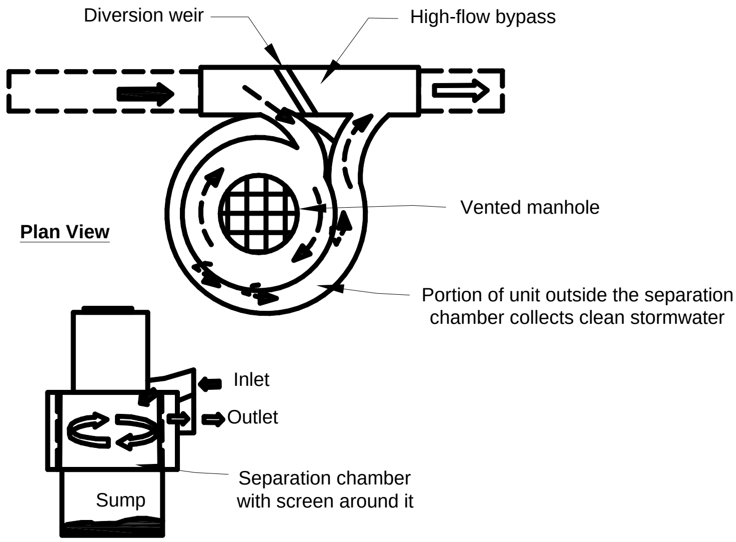
4.4.7.8 Example Schematics

Figure 4-71. Typical Oil-Grit (Oil/Water) Separators
(City of Knoxville, 2003)




High-flow outlet at higher invert
(bypassing stormwater treatment)
Baffle of sufficient size and
depth to stop stormwater
momentum across manhole
A trash rack may be desirable to prevent
smaller diameter pipe from clogging
Inflow
Low-flow outlet at lower invert
(going to oil/water separator)
Some sediment may
settle at this manhole

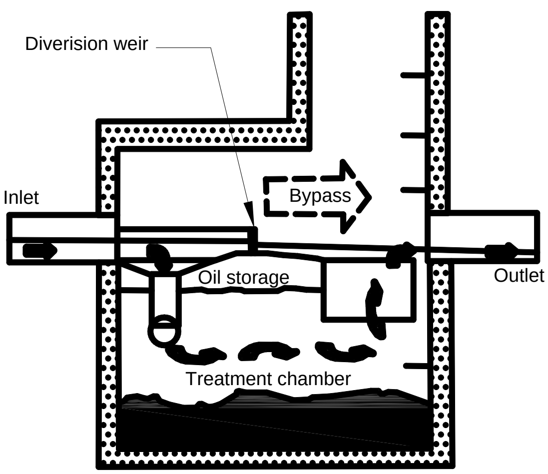

Vented manhole (typical)
Plan View
Aluminum
tank
3'
Profile View



Section View

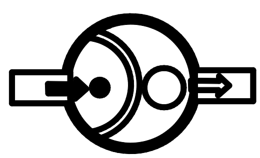
Notes:

1. This figure represents the continuous deflection stormwater treatment as manufactured by CDS Technologies. Units can also be retrofitted onto existing storm drains.
2. Units are manufactured from either fiberglass or precast concrete.
3. Manufacturer recommends the use of sorbent material within CDS separtion chamber to improve capture of oil and grease. Usage rate is typically several pounds of sorbent per acre per year.

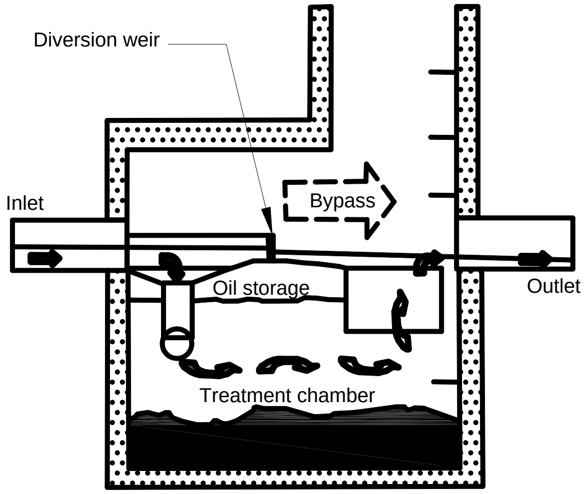


Notes:

1. This figure represents a single-unit system designed to process stormwater runoff on -line ,as manufactured by Stormceptor Corporation.
2. Unit consists of an insert placed into a standard concrete manhole. Basic size is 72" diameter, with larger sections used for the treatment chambers as needed.



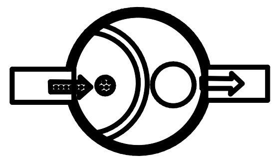
Plan view



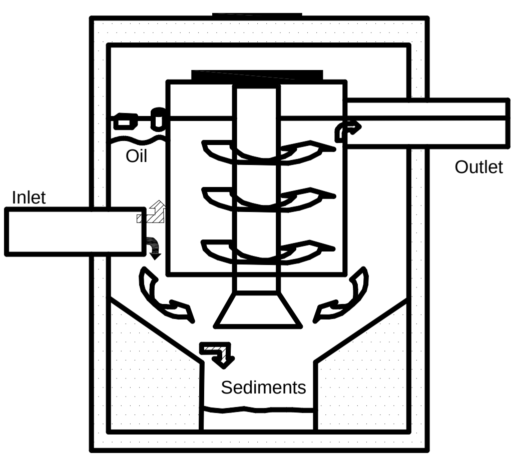
Notes:

1. This figure represents a single-unit system designed to process stormwater runoff on -line, as manufactured by Stormceptor Corporation.

2. Unit consists of an insert placed into a standard concrete manhole. Basic size is 72" diameter, with larger sections used for the treatment chambers as needed.



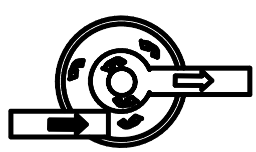
Plan view



Notes:

1. This figure shows a single unit to treat stormwater runoff, manufactured by H.I.L Technologies, Inc.

2. Unit consists of polyethylene components supported by a stainless frame, inserted into a standard concrete manhole. Concrete manhole sizes vary from 4' to 10'.



Plan view

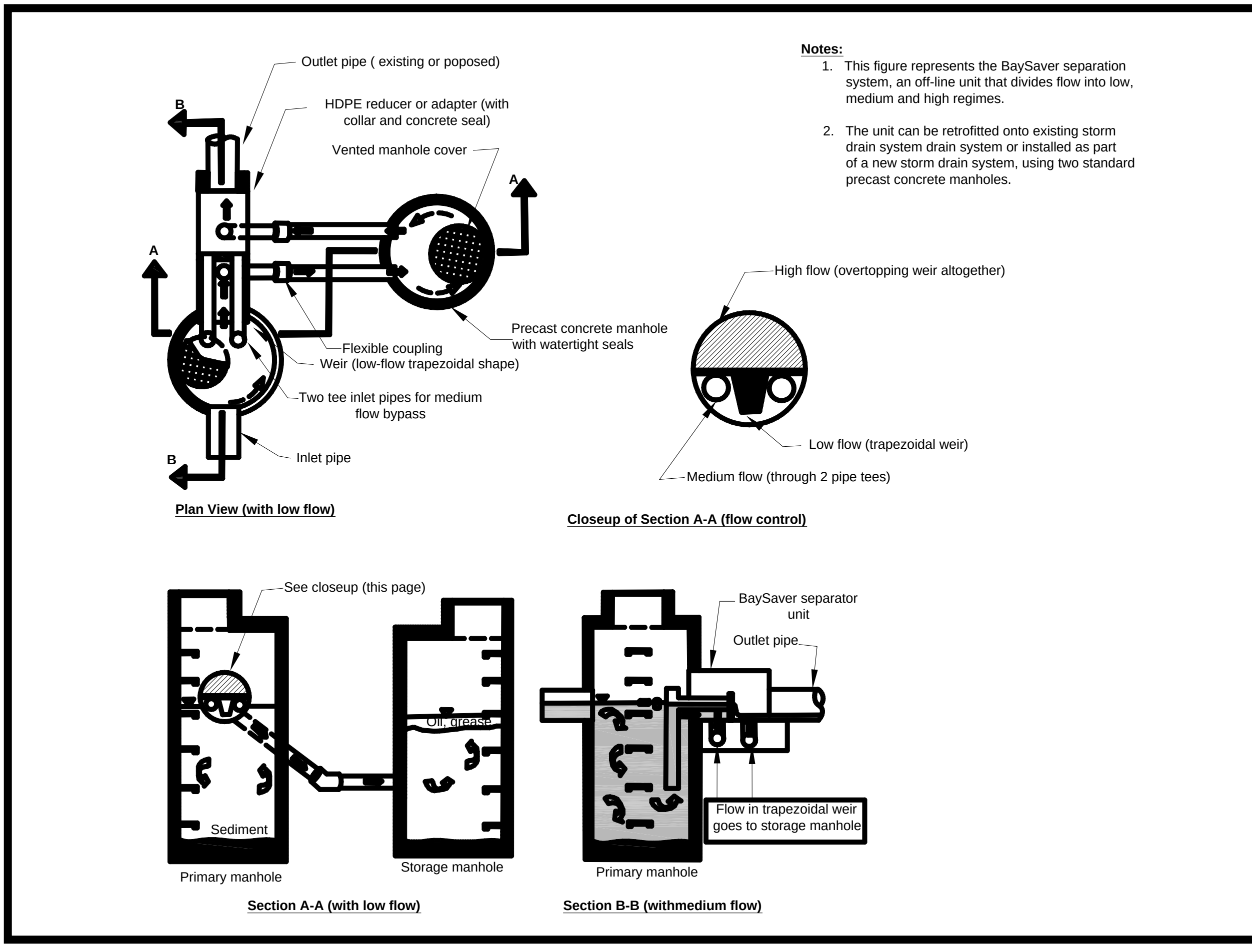
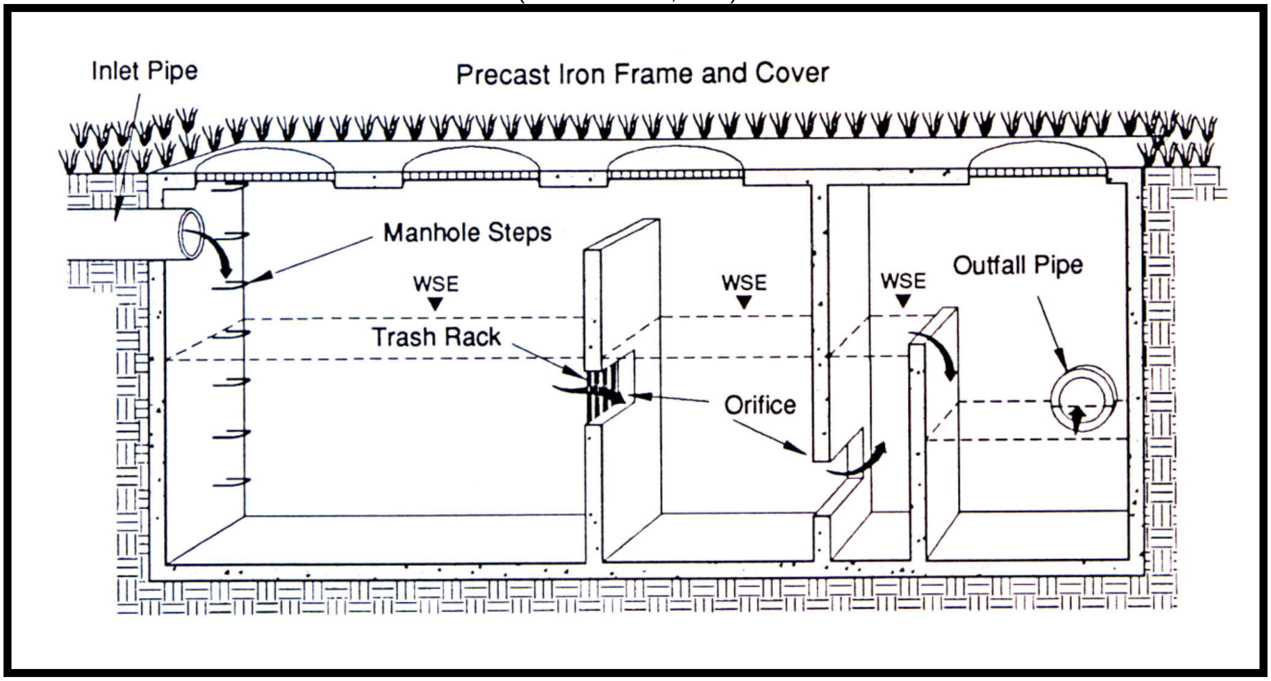

Outlet pipe (existing or poposed)
HDPE reducer or adapter (with collar and concrete seal)
Vented manhole cover
B
A
A
B
Flexible coupling
Weir (low-flow trapezoidal shape)
Precast concrete manhole with watertight seals
Two tee inlet pipes for medium flow bypass
Inlet pipe
Plan View (with low flow)
Notes:
1. This figure represents the BaySaver separation system, an off-line unit that divides flow into low, medium and high regimes.
2. The unit can be retrofitted onto existing storm drain system drain system or installed as part of a new storm drain system, using two standard precast concrete manholes.
High flow (overtopping weir altogether)
Low flow (trapezoidal weir)
Medium flow (through 2 pipe tees)
Closeup of Section A-A (flow control)
See closeup (this page)
Oil, grease
Sediment
Primary manhole
Storage manhole
Section A-A (with low flow)
BaySaver separator unit
Outlet pipe
Flow in trapezoidal weir goes to storage manhole
Primary manhole
Section B-B (withmedium flow)

Figure 4-72. Schematic of an Example Gravity (Oil-Grit) Separator
(Source: NVRC, 1992)



4.4.7.9 References

AMEC. *Knox County Stormwater Management Manual Volume 2, Technical Guidance*.

AMEC. *Metropolitan Nashville and Davidson County Stormwater Management Manual, Volume 4 Best Management Practices.* 2006.

Atlanta Regional Council (ARC). *Georgia Stormwater Management Manual Volume 2 Technical Handbook.* 2001.

City of Knoxville. *Knoxville Best Management Practices Manual.* City of Knoxville Stormwater Engineering Division, March 2003.

Metropolitan Council. *Minnesota Urban Small Sites BMP Manual.* Metropolitan Council Services, St. Paul Minnesota, 2001.

4.4.7.10 Suggested Reading

California Storm Water Quality Task Force. *California Storm Water Best Management Practice Handbooks,* 1993.

4.4.7.11 Oil/Grit Separator Manufacturers

Highland Tank (CPI unit)	www.highlandtank.com
Vortechnics, Inc.	www.vortechnics.com
CDS Technologies	www.cdstech.com.au/us/
Stormceptor Corporation	www.stormceptor.com
H.I.L. Technology, Inc.	www.hil-tech.com
BaySaver, Inc.	www.baysaver.com
Aquashield, Inc.	www.squashieldinc.com
Environment 21, LLC	www.env21.com

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