4.3.1 Stormwater Ponds

General Application Stormwater 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

DESIGN GUIDELINES:

- Minimum contributing drainage area of 25 acres; 10 acres for micropool ED pond.
- A sediment forebay or equivalent upstream pre-treatment must be provided.
- Minimum length to width ratio for the pond is 1.5:1.
- Maximum depth of the permanent pool shall not exceed 8 feet.
- Side slopes to the pond shall not exceed 3:1 (h:v) on one side of the pond to facilitate access. Slopes as steep as 2:1 will be allowed for other areas, with proper stabilization.

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.
- Pond drainage can be difficult for low relief terrain.

MAINTENANCE REQUIREMENTS:

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

STORMWATER MANAGEMENT SUITABILITY

- ✓ **Water Quality**
- ✓ **Channel Protection**
- ✓ **Overbank Flood Protection**
- ✓ **Extreme Flood Protection**

Accepts runoff from SPAP land uses: *Yes*

(2' distance required to water table)

FEASIBILITY CONSIDERATIONS

M-H	**Land Requirement**
L	**Capital Cost**
L	**Maintenance Burden**

Residential/Subdivision Use: *Yes*

Drainage Area: *10-25 acres min.*

Soils: *Hydrologic group 'A' and 'B' soils may require pond liner*

L=Low **M**=Moderate **H**=High

POLLUTANT REMOVAL

H	**Total Suspended Solids**
M	**Nutrients**: Total Phosphorus / Total Nitrogen
M	**Metals**: Cadmium, Copper, Lead, and Zinc
M	**Pathogens**: Coliform, Streptococci, E.Coli

OTHER CONSIDERATIONS

- Outlet clogging
- Safety bench
- Landscaping

4.3.1.1 General Description

Stormwater ponds (also referred to as retention ponds, wet ponds, or wet extended detention ponds) 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 pond, 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 control. The upper stages of a stormwater pond are designed to provide extended detention of the downstream channel protection volume (CPv), as well as conventional detention for overbank flood protection (Qp_2, Qp_{10}, and Qp_{25}) and extreme flood protection (Qp_{100}).

Stormwater ponds are among the most cost-effective and widely used stormwater practices. A well-designed and landscaped pond can be an aesthetic feature on a development site when planned and located properly.

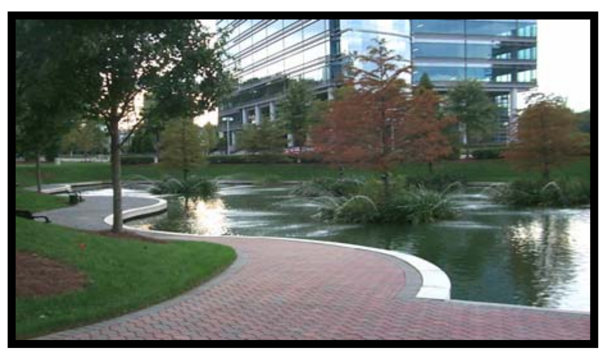
There are several variations of stormwater pond design, the most common of which include the wet pond, the wet extended detention pond, and the micropool extended detention pond. In addition, multiple stormwater ponds can be placed in series or parallel to increase total suspended solids (TSS) removal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

Figure 4-10. Stormwater Pond Examples

Wet Pond

Wet Extended Detention Pond

Micropool Extended Detention Pond



Multiple Pond System

- **Wet Pond** – Wet ponds are stormwater basins constructed with a permanent (dead storage) pool of water equal to the WQv. Stormwater runoff is added to 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) Pond** – A wet extended detention pond is a wet pond 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 pond, but consumes less space.
- **Micropool Extended Detention (ED) Pond** – The micropool extended detention pond is a variation of the wet ED pond where only a small "micropool" is maintained at the outlet to the pond. 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 Pond System** – A multiple pond 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 Stormwater Management Suitability

Stormwater ponds are designed to control both stormwater quantity and quality, and therefore, provide a comprehensive stormwater management BMP. Thus, a stormwater pond can be used to address the minimum design standards for water quality, channel protection and flood protection for a given drainage area.

<u>Water Quality Volume (WQv)</u>
Ponds 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 pond. 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.

<u>Channel Protection Volume (CPv)</u>
A portion of the storage volume above the permanent pool in a stormwater pond can be used to provide control of the CPv. This is accomplished by capture of the stormwater runoff from the 1-year, 24-hour storm event, and release of that runoff over a minimum 24-hour and a maximum of a 72-hour period, measured from centroid to centroid (extended detention).

<u>Overbank Flood Protection (up to Qp_{25}) and Extreme Flood Protection (Qp_{100})</u>
A stormwater pond can also provide storage above the permanent pool/water surface level to reduce the post-development peak flow of the 2-year, 10-year, 25-year and 100-year storms to pre-development levels (detention).

4.3.1.3 Pollutant Removal Capabilities

All of the stormwater pond 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 ponds 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, 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 – 80%
- Total Phosphorus – 55%

- Total Nitrogen – 30%
- Pathogens – 70% (if no resident waterfowl population is present)
- Heavy Metals – 50%

For additional information and data on pollutant removal capabilities for stormwater ponds, 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.

4.3.1.4 Application and Site Feasibility Criteria

Stormwater ponds are generally applicable to most types of new development and redevelopment, and can be used in both residential and nonresidential areas. Ponds can also be used in retrofit situations. The following criteria should be evaluated to ensure the suitability of a stormwater pond for meeting stormwater management objectives on a site or development.

General Feasibility

- Suitable for use in residential subdivisions and in non-residential areas.
- Suitable for high density/ultra-urban areas, however, land requirements may preclude their use.
- Suitable for use as a regional stormwater control measure (i.e., controlling runoff from more than one site).

Physical Feasibility - Physical Constraints at Project Site

- Drainage Area: A minimum of 25 acres is needed for wet ponds and wet ED ponds to maintain a permanent pool; 10 acres minimum for micropool ED ponds. The Director may approve a smaller drainage area with an adequate water balance and anti-clogging device.
- Space Required: Approximately 2 to 3% of the contributing drainage area is typically required for most stormwater ponds.
- Site Slope: In general, stormwater ponds can be used on sites that have an upstream slope of up to 15%.
- Minimum Head: Six to eight feet of elevation difference is needed from the inflow of the pond to the outflow.
- Minimum Depth to Water Table: If used on a site with an underlying water supply aquifer (but not within a designated wellhead protection zone) or when treating a land use that requires a Special Pollution Abatement Permit, a separation distance of 2 feet is required between the bottom of the pond and the elevation of the seasonally high water table, as determined through geotechnical data collection or historical data.
- Soils: Underlying soils of hydrologic group “C” or “D” are typically adequate to maintain a permanent pool. Stormwater ponds constructed in group “A” soils and some group “B” soils may require a pond liner. Evaluation of underlying soils should be based upon an actual subsurface analysis and permeability tests.

4.3.1.5 Planning and Design Standards

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

A. LOCATION AND SITING

- Stormwater ponds must have a minimum contributing drainage area of 25 acres or more for a wet pond or wet ED pond to maintain a permanent pool. For a micropool ED pond, the minimum drainage area is 10 acres. The Director may consider allowing the use of a stormwater pond 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). In such situations, the Director may require calculation of a water balance for the pond (see Chapter 3 for details). It is important that ponds that serve smaller drainage areas have an adequate anti-clogging device provided for the pond outlet.
- Although not required, Knox County recommends that stormwater ponds be located where the topography allows for maximum runoff storage at minimum excavation or embankment construction costs. When locating a stormwater pond, 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 ponds shall not be located on unstable slopes or slopes greater than 15%.
- Stormwater ponds 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.
- Each stormwater pond 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 pond design. The easement limit should be located no closer than 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 downgradient from a land use that must obtain a Special Pollution Abatement Permit, then the minimum 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 pond 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 pond 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 pond inlet (unless the inlet provides less than 10% of the total inflow to the pond);
  - (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 pond side slopes are 4:1 or greater); and,

(8) Appropriate native landscaping.

C. PHYSICAL SPECIFICATIONS / GEOMETRY

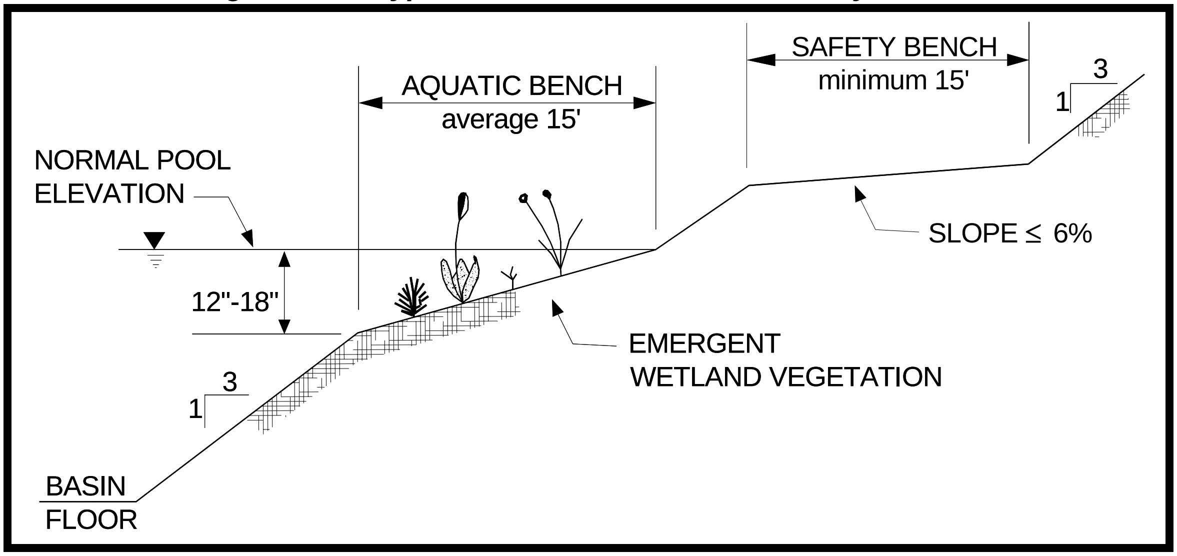
In general, pond designs are unique for each site and application. However, there are a number of geometric ratios and limiting depths for pond design that must be observed for adequate pollutant removal, ease of maintenance, and improved safety.

- Permanent pool volume shall be sized as follows:
  - Standard wet ponds: 100% of the water quality treatment volume (1.0 X WQv);
  - Wet ED ponds: 50% of the water quality treatment volume (0.5 X WQv);
  - Micropool ED ponds: 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 pond 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, ponds should be wedge-shaped when possible so that flow enters the pond and gradually spreads out, improving the sedimentation process. Baffles, pond shaping or islands can be added within the permanent pool to increase the flow path.
- Maximum depth of the permanent pool shall not exceed 8 feet to avoid stratification and anoxic conditions. The Director may approve a greater depth in the event that measures are taken that will eliminate the possibility of such conditions and safety precautions are adequately considered. 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 pond, 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 pond to facilitate access for maintenance and repair. The remainder of the pond 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 ponds, the safety bench shall extend no less than 15 feet outward from the normal water edge to the toe of the pond side slope. The slope of the safety bench shall not exceed 6%. The requirements for a safety bench may be waived if pond 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 pond 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 pond. In some design configurations, the pretreatment volume may be located within the permanent pool.

Figure 4-11. Typical Stormwater Pond Geometry Criteria



- The 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.
- 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 pond can be partially submerged. Exit velocities of discharges from the forebay to the pond must be non-erosive.

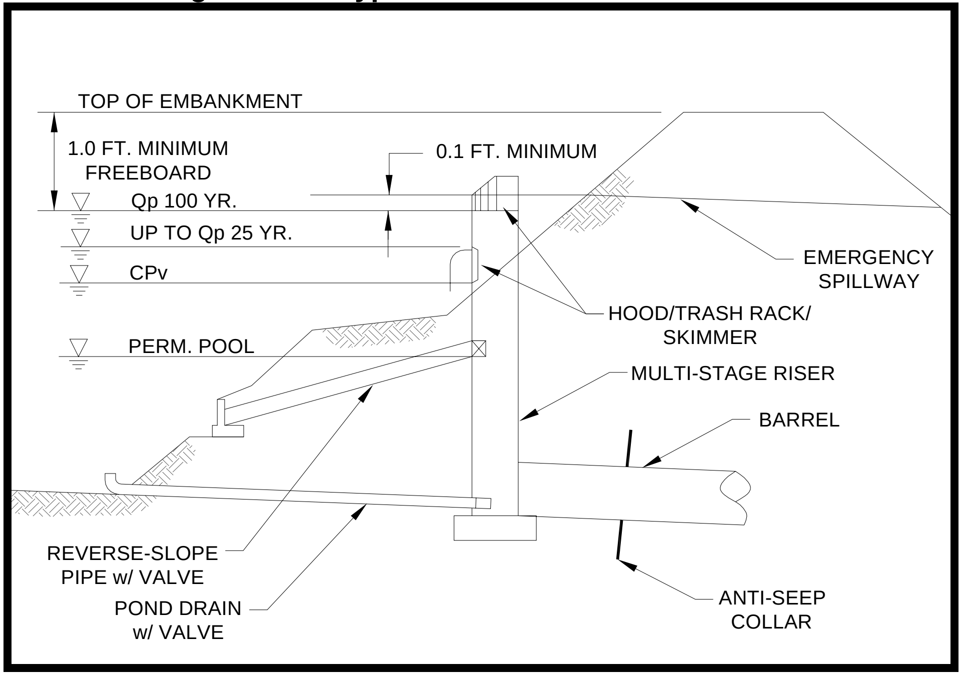
E. OUTLET STRUCTURES

- Flow control from a stormwater pond 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 pond 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 may be located within the pond embankment for maintenance access, safety and aesthetics, unless flow distribution or the potential for erosion around the rise exists. The outlet barrel shall be of reinforced concrete.
- A number of outlets at varying depths in the riser provide internal flow control for routing of the WQv, CPv, Qp_2, Qp_{10}, Qp_{25} and Qp_{100}. The number of orifices can vary and is usually a function of the pond design.

  For example, a wet pond riser configuration is typically comprised of a channel protection (CPv) outlet (usually an orifice), an overbank flood protection (Qp_2, Qp_{10}, Qp_{25}) outlet (often a slot or weir), and the extreme flood protection (Qp_{100}) outlet. 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 pond, it simply displaces that same volume through the channel protection orifice. Thus an off-line wet pond providing *only* water quality treatment can use a simple overflow weir as the outlet structure.

  In the case of a wet ED pond or micropool ED pond, 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

Figure 4-12. Typical Pond Outlet Structure



prevent floatables from clogging the pipe and to avoid discharging warmer water at the surface of the pond. 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.

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 pond) and channel protection outlet shall be fitted with adjustable slide gates or another mechanism that can be used to adjust detention time.
- Higher flows (Qp_2, Qp_{10}, Qp_{25}, 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 pond outlet discharges immediately to a channel that carries dry weather flow, care shall be taken to minimize disturbance along the downstream channel, and to reestablish a forested riparian zone in the shortest possible distance. See Chapter 7 (Stormwater Drainage Design) for more guidance on outlet designs and Chapter 6 (Water Quality Buffers) for rules and regulations pertaining to encroachments in a water quality buffer.
- Each pond shall have a bottom drain pipe with an adjustable slide gate that can completely or partially drain the pond within 24 hours.
- Ponds shall not be drained until at least 24 hours after the completion of a rain event, so that water quality and channel protection objectives can be met.

See the design procedures in 4.3.1.6 as well as in Volume 2, Chapter 3 for additional information and specifications on pond routing and outlet operations.

F. EMERGENCY SPILLWAY

- An emergency spillway shall be included in the stormwater pond design, sized to safely pass the Qp_{100}. The spillway prevents pond 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 pond 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 ponds, the safety bench shall extend no less than 15 feet outward from the normal water edge to the toe of the pond 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 pond for the purpose of safety management.
- All outlet structures shall be designed so as not to permit access by children. Knox County encourages the posting of warning signs near the pond to prohibit swimming and fishing in the facility.

I. LANDSCAPING

- Aquatic vegetation can play an important role in pollutant removal in a stormwater pond. In addition, vegetation can enhance the appearance of the pond, stabilize side slopes, serve as wildlife habitat, and can temporarily conceal unsightly trash and debris. Therefore, wetland plants should be encouraged in a pond design, along the aquatic bench (fringe wetlands), the safety bench and side slopes (ED ponds), 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.
- Native species of fish can be stocked in a pond to aid in mosquito prevention. Knox County 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.

- Water quality buffers, as defined and described in Volume 2, Chapter 6 of this manual, are not required for stormwater ponds 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 Volume 2, 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 pond.

Physiographic Factors - Local terrain design constraints:

- Low Relief – Maximum normal pool depth is limited; providing pond 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 pond liner; group “B” soils may require infiltration testing.

Wellhead Protection

- Reduce potential groundwater contamination in wellhead protection areas by preventing infiltration of runoff from areas that require a Special Pollution Abatement Permit, 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 pond from water table shall be provided.

4.3.1.6 Design Procedures

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

Step 1. Compute runoff control volumes

Calculate WQv, CPv, Qp_2, Qp_{10}, Qp_{25}, and Qp_{100}, in accordance with the guidance presented in Volume 2, Chapter 3.

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

Consider the Application and Site Feasibility Criteria in sections 4.3.1.4 and 4.3.1.5.

Step 3. Confirm additional design criteria and applicability

Consider any special site-specific design conditions/criteria from subsection 4.3.1.5. Check with Knox County Engineering, 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 pond. 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 Pond: Size permanent pool volume to 1.0 WQv less any forebay storage volume.

Wet ED Pond: 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 Pond: 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 pond location and preliminary geometry. Conduct pond grading design and determine storage available for permanent pool (and water quality extended detention if wet ED pond or micropool ED pond)

This step involves initially designing the grading of the pond (establishing contours) and determining the elevation-storage relationship for the pond. See subsection 4.3.1.5 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 pond) based on volumes calculated earlier.

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

Wet Pond: The CPv elevation is determined from the stage-storage relationship and the orifice is then sized to detain the channel protection storage volume for a 24-hour period, measured from centroid to centroid. 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. Orifice diameters less than three inches must employ internal orifice protection (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 slide gates can also be used to achieve this equivalent diameter.

Wet ED Pond and Micropool ED Pond: 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 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. Orifice diameters less than three inches must employ internal orifice protection (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 slide gates 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 detain the channel protection storage volume for a 24-hour period, measured from centroid to centroid.

Step 8. Calculate Qp_2, Qp_{10}, Qp_{25} and Qp_{100} release rates and water surface elevations

Set up a stage-storage-discharge relationship for the control structure for the extended detention (CPv) requirement, the 2, 10, and 25-year storms, and the 100-year storm orifices.

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

Using the 100-year water surface elevation, set the top of the embankment elevation, and size the emergency spillway, ensuring safe passage of the Qp_{100}. Set the invert elevation of the emergency spillway 0.1 foot above the 100-year water surface elevation.

Step 10. Investigate potential pond hazard classification

The design and construction of stormwater management ponds 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 4.3.1.5-D through H for more details.

Step 12. Design vegetation

A vegetation scheme for a stormwater pond and its buffer should be prepared to indicate how aquatic and terrestrial areas will be stabilized and established with vegetation.

See subsection 4.3.1.5-I for more details.

4.3.1.7 Maintenance Requirements and Inspection Checklist

Note: Section 4.3.1.7 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 stormwater ponds 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. 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 stormwater ponds, along with a suggested frequency for each activity. Individual stormwater ponds 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: 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 pond or contributing drainage area as such changes may affect pond 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 pond 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 pond, 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 ponds 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 is required prior to sediment disposal when the pond receives discharge from a land use that requires a SPAP. Dispose of sediments per Section 10.3.	5 to 7 years or after 50% of the total forebay capacity has been lost
• Monitor sediment accumulations, and remove sediment when the pond volume has become reduced significantly or the pond is not providing a healthy habitat for vegetation and fish (if used). Discharges of pond water may be considered an illegal discharge, as per the Knox County Stormwater Management Ordinance. Care should be exercised during pond drawdowns to prevent downstream discharge of sediments, anoxic water, or high flows with erosive velocities. Knox County should be notified before draining a stormwater pond.	10 to 20 years or after 25% of the permanent pool volume has been lost

Knox County 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 ponds. The Director 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 pond. Questions regarding stormwater facility inspection and maintenance should be referred to the Knox County Department of Engineering and Public Works, Stormwater Management Division.

INSPECTION CHECKLIST AND MAINTENANCE GUIDANCE (continued)
STORMWATER POND 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?		
Pipes in good condition?		
Slide gate operation?		
Pond 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 pond?		
Headwalls and endwalls in good condition?		
Encroachment by other activities?		
Evidence of sediment accumulation?		
Dry Pond 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)____________________________

4.3.1.8 Example Schematics

The example schematics for stormwater wet ponds 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 Pond
(Source: adapted from CWP, 2005)

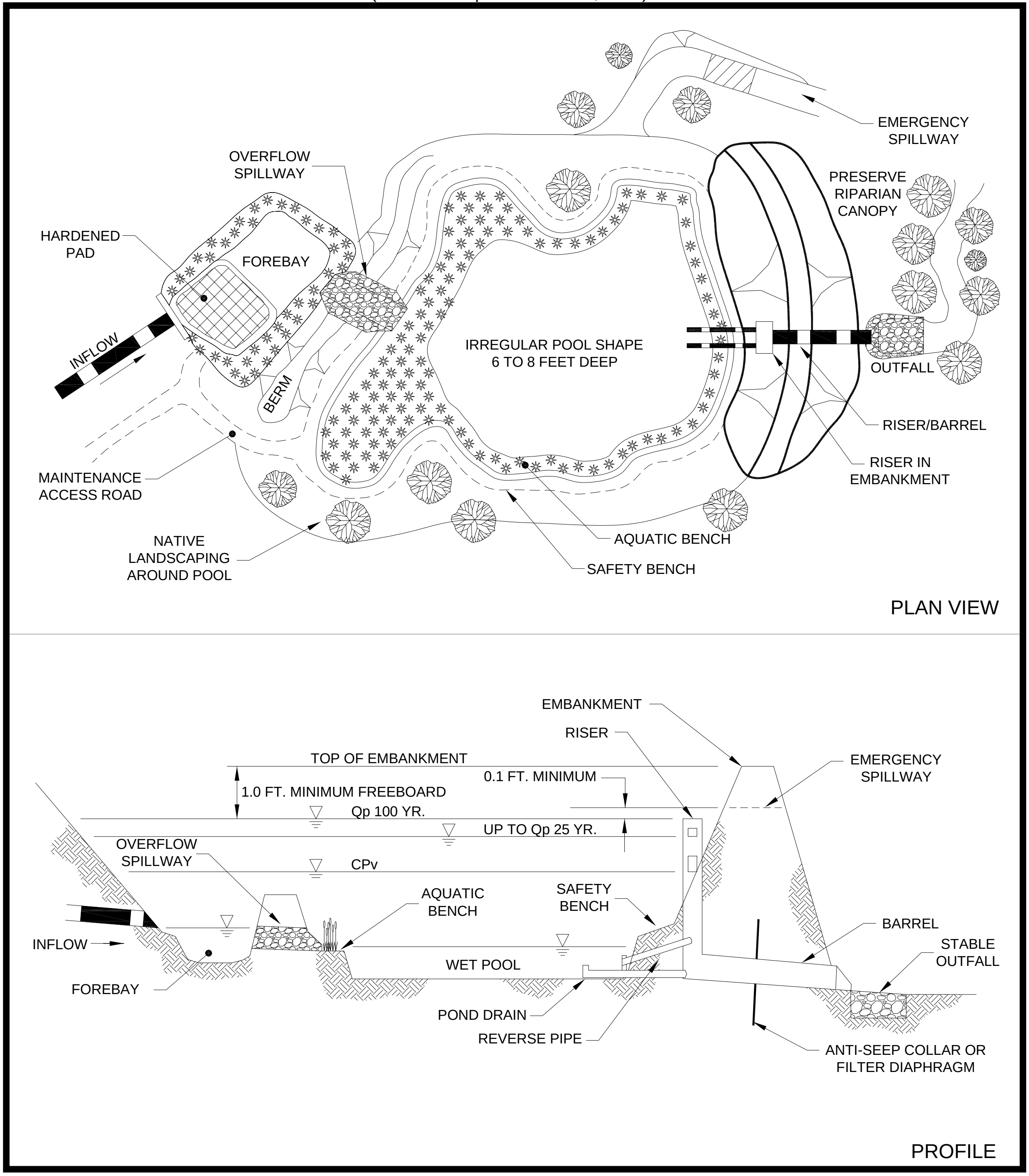


Figure 4-14. Schematic of a Wet Extended Detention Pond
(Source: adapted from CWP, 2005)

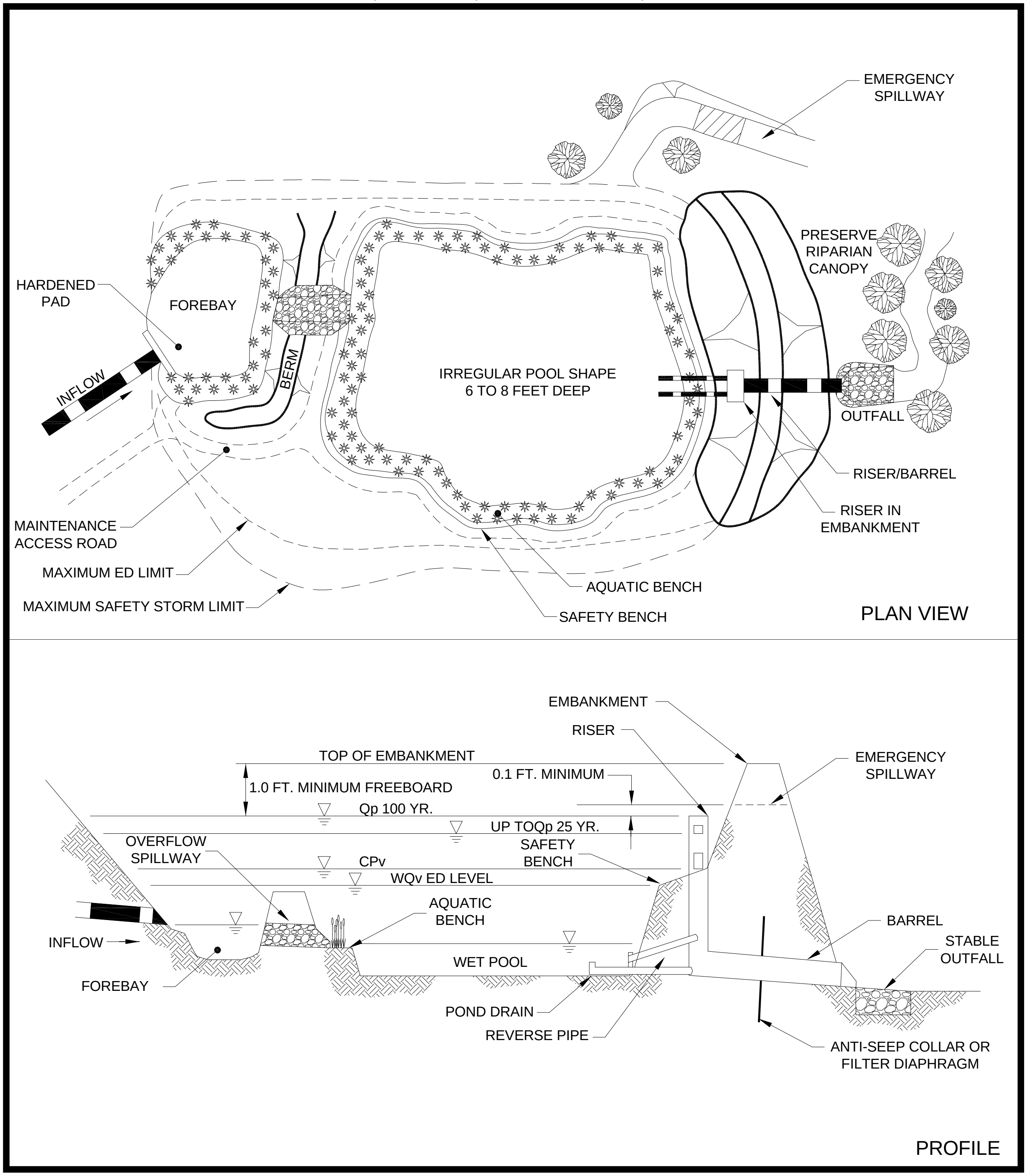


Figure 4-15. Schematic of a Micropool Extended Detention Pond
(Source: adapted from CWP, 2005)

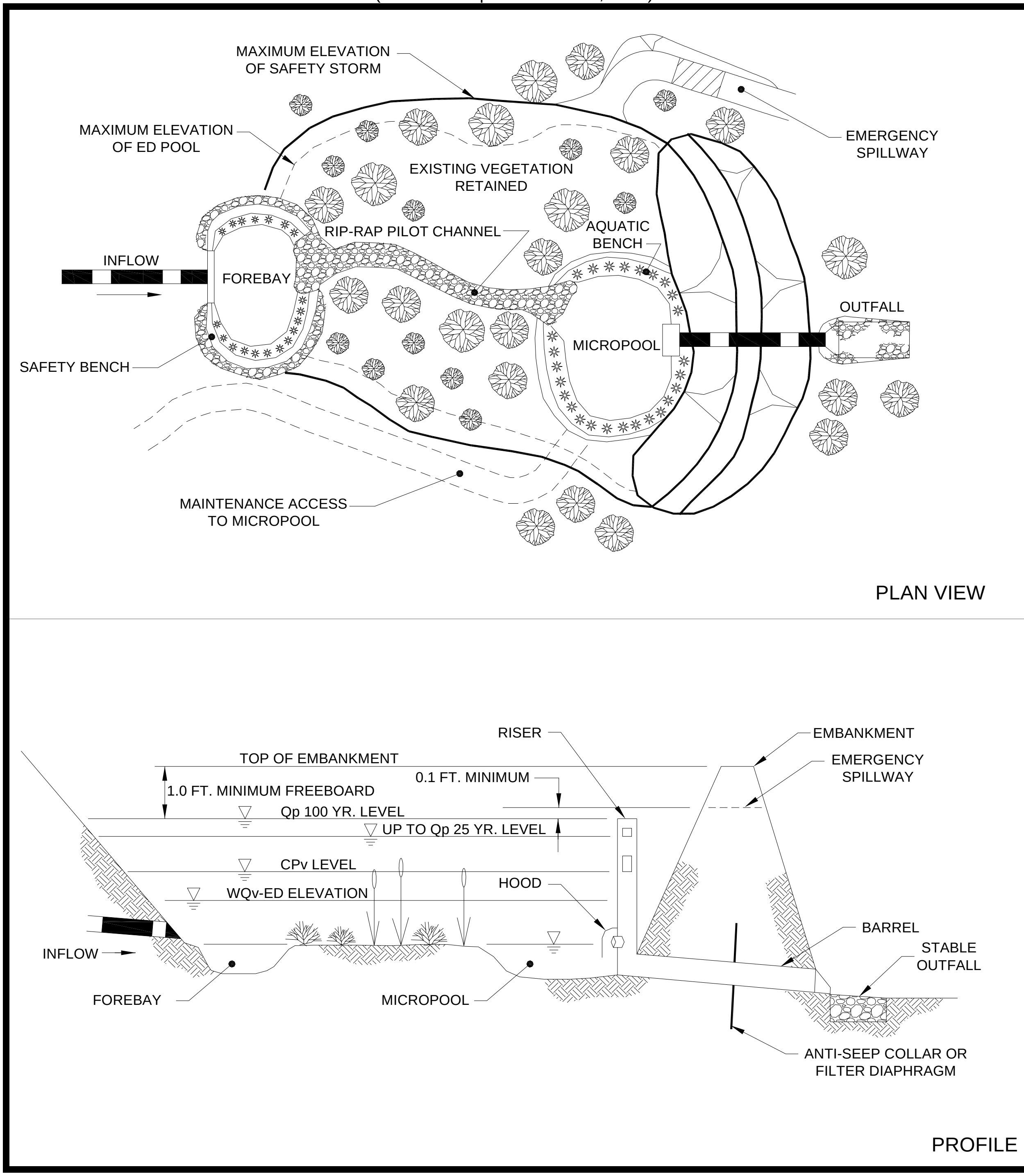
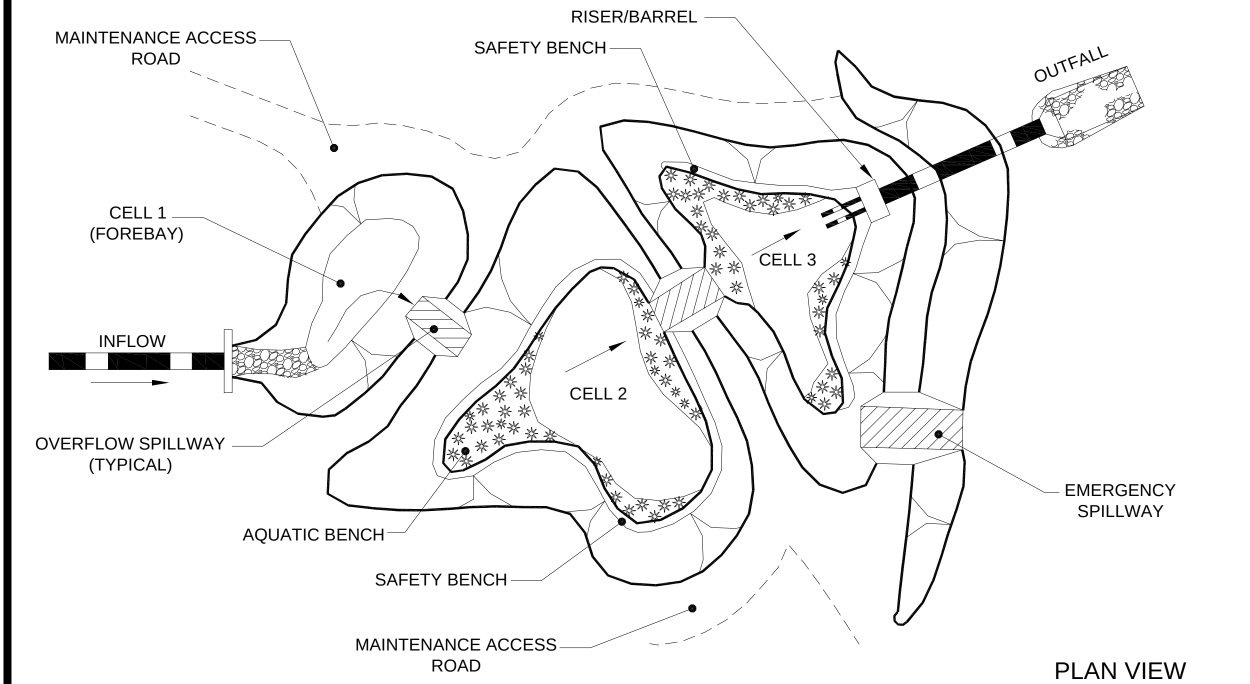
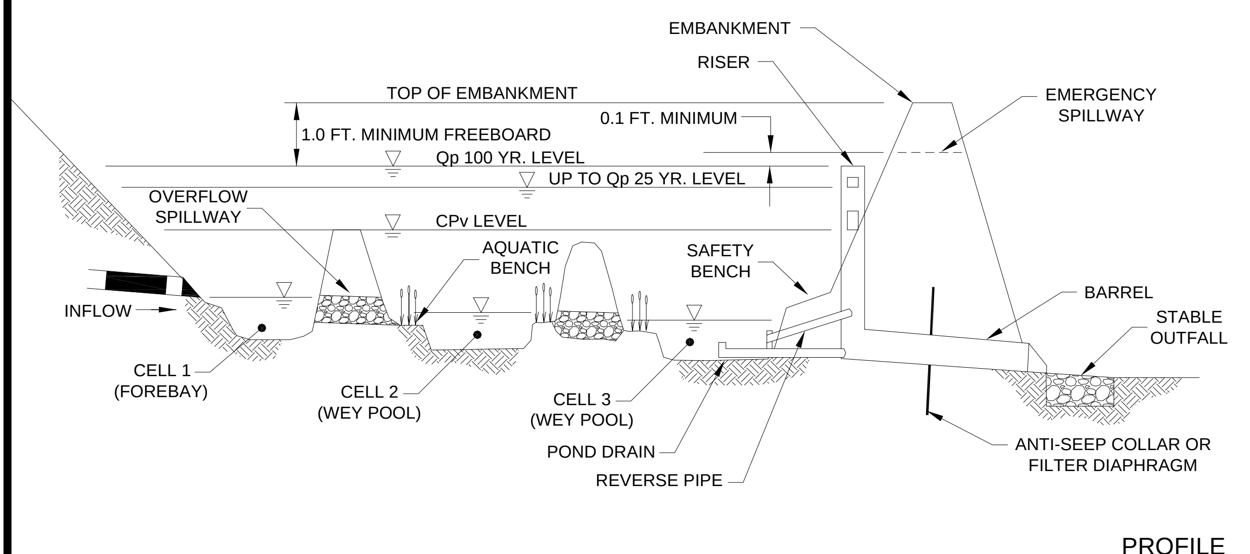


Figure 4-16. Schematic of a Multiple Pond System

(Source: adapted from CWP, 2005)



PLAN VIEW



4.3.1.9 Design Forms

Knox County recommends the use of the following design procedure forms when designing a stormwater wet pond. Proper use and completion of the form may allow a faster review of the Stormwater Management Plan by Knox County Engineering.

Design Procedure Form: Stormwater Ponds

PRELIMINARY HYDROLOGIC CALCULATIONS

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

1b. Estimate CPv — CPv = ________ acre-ft

1c. Estimate storage volumes
 Estimate storage volume required for 2-year storm — 2-year storage = ________ acre-ft
 Estimate storage volume required for 10-year storm — 10-year storage = ________ acre-ft
 Estimate storage volume required for 25-year storm — 25-year storage = ________ acre-ft
 Estimate storage volume required for 100-year storm — 100-year storage = ________ acre-ft

STORMWATER POND DESIGN

2. Is the use of a stormwater pond appropriate? — ***See subsections 4.3.1.4 and 4.3.1.5 - ,***

3. Confirm additional design criteria and applicability. — ***See subsection 4.3.1.5 - 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 Pond — V_{pool}=1.0(WQv)-Vol_{pre} — V_{pool}= ________ acre-ft

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

 Micropool ED Volume — 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 Ponds (continued)

7. WQv and CPv 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. Refer to Chapter 3, Section 3.3.2.3 for guidance)	
Establish CPv top elevation using stage-storage curve	CPv WSEL= ________ ft-NGVD
Estimate orifice size	CPv orifice diameter = ________ inches
Perform hydrograph routing to check detention time	centroid-centroid det. = ________ hours
Iterate to final orifice size	Final CPv orifice diameter = ________ inches

8. Calculate Qp_2, Qp_{10}, Qp_{25} and Qp_{100} release rates and WSEL — 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_2=pre-dev. Peak discharge - (WQv-ED release + CPv-ED release)	Qp_2= ________ cfs
Qp_{10}=pre-dev. Peak discharge - (WQv-ED release + CPv-ED release)	Qp_{10}= ________ cfs
Qp_{25}=pre-dev. Peak discharge - (WQv-ED release + CPv-ED release)	Qp_{25}= ________ cfs
Qp_{100}=pre-dev. Peak discharge - (WQv-ED release + CPv-ED release)	Qp_{100}= ________ 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 in Chapter 7**

9. Size emergency spillway using the Qp_{100}	$Q_{ES}=Qp_{100}$ ________ cfs
and set top of embankment elevation and	$WSEL_{100}$= ________ ft
emergency spillway elevation based on	$El_{embank}=WSEL_{100+}1.0$ ________ ft
$WSEL_{100}$	$El_{ES}=WSEL_{100}+.01$ feet ________ 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 Section 4.3.1.5 - D through H**
12. Design vegetation according to guidance in Chapter 6	
13. Verify peak flow control, water quality drawdown time and channel protection detention time	

4.3.1.10 References

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*

4.3.1.11 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.

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 Ponds for Urban Stormwater Management.* University of Central Florida, 1989.

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