Bowling Green, Kentucky
Stormwater Best Management Practices (BMPs)
Stormwater Pollution Treatment Practices (Structural)

PTP-03

Activity: Stormwater Ponds

W

SP

PLANNING CONSIDERATIONS:

Design Life:
Life

Acreage Needed:
Moderate to High

Estimated Unit Cost:
Low

Annual Maintenance:
Low

Target Pollutants; Pollutant Removal

Total Suspended Solids (TSS); 80%
Nutrients – Total Phosphorous/Total Nitrogen; 50/30%
Metals – Cadmium, Copper, Lead, and Zinc; 50%
Pathogens – Coliform, Streptococci, E.Coli; 70%

Description

Stormwater ponds are detention ponds containing a permanent pool (or micropool) that allows the treatment of stormwater runoff, while also contributing to the aesthetic value. Stormwater ponds addressed in this fact sheet include micropool extended detention ponds, wet ponds, wet extended detention ponds, multiple pond systems, and pocket ponds.

Stormwater ponds enhance water quality through settling and biological uptake, and offer a control for sediment, heavy metals, and floatables. They also may provide benefits in reducing impacts due to nutrients, oxygen demanding substances, oil and grease, and bacteria and viruses.

Stormwater ponds consist of the following components: a sediment forebay, permanent pool, runoff control volume storage, and a shallow littoral zone, or aquatic bench, along the edge of the permanent pool. Other design considerations include an emergency spillway, maintenance access and landscaping.

Suitable Applications

- Areas where high particulate control is needed
- Suitable for large, regional tributaries; minimum contributing drainage area is 25 acres, or 10 acres for a micropool extended detention pond
- Provides multiple benefits for passive recreation such as bird watching, and wildlife habitat
- To control both stormwater quantity and quality issues

Typically, stormwater ponds are not feasible for dense or urban land uses due to large land requirements and areas with steep or unstable slopes.

Activity: Stormwater Ponds	PTP-03

Approach

- Wet Pond

Wet ponds are stormwater basins with rooted wetland vegetation along the perimeter. The permenant pool of water (below the weir crest, culvert, or inlet) provides a quiescent volume for continued settling of particulate contaminants and uptake of dissolved contaminants by aquatic plants between storms.

- Wet Extended Detention Pond

A wet extended detention pond combines a permenant pool and extended detention area to treat stormwater runoff. Storage for the water quality volume is split evenly between the permanent pool and the extended detention storage, which requires less space than a wet pond. During storm events, water is detained above the permanent pool, and released over time. Keep in mind that vegetation planted in the extended detention zone should withstand both wet and dry conditions.

- Micropool Extended Detention Pond

This extended detention pond is modified with a micropool to prevent resuspention of sediment particles and clogging of the low flow orifice. These ponds are often used in retrofit situations. Keep in mind that vegetation planted in the extended detention zone should withstand both wet and dry conditions.

- Multiple Pond Systems

A multiple pond system can have a high pollutant removal capacity compared to other stormwater ponds. The multiple pond system incorporates two or more storage cells, elongating the flow path, which is a key component in pollutant removal.

- Pocket Ponds

Pocket ponds are typically used on smaller sites and drain smaller drainage areas. They maintain a permanent pool through a connection with the groundwater. These stormwater ponds have less pollutant removal capacity, but are often used in situations where space is not available for a larger pond. These ponds also do not have the added aquatic habitat benefits of larger ponds. Pocket ponds should not be used in areas where pollutants may contaminate the groundwater or drinking water supplies.

Maintenance

Frequently (3-4 times a year)

- Clean and remove debris from inlet and outlet structures
- Remove floatables and sediment build-up
- Mow side slopes

As Needed

- Repair undercut or eroded areas
- Inspect at least annually and after large rain events
- Pond vegetation need to be trimmed or harvested as appropriate, grassy areas frequently mowed and repairs made to signage, walkways, picnic tables, or any other public recreation equipment.

Maintenance (cont.)

Annual

- Remove invasive vegetation and remove side slopes.
- Inspect for damage to the embankment and inlet/outlet structures.
- Monitor and record for sediment accumulation.

Sediment Removal

- The sediment accumulation rate is dependant on a number of factors including watershed size, facility sizing, construction upstream, industrial or commercial activities upstream, etc. Sediment contents should removed and disposed of properly.
- Most sediment collected is innocuous (free of pollutants other than "clean" soil) and can be used as fill material, cover or land spreading. It is important that this material not be placed in a way that will promote or allow resuspension in storm runoff. The sediment should not be placed within the high water level area of the stormwater pond or another BMP, creek, waterway, buffer, runoff conveyance device, or other infrastructure. Some demolition or sanitary landfill operators will allow the sediment to be disposed at their facility for use as cover.
- Sediment should be removed when 10 to 15% of the storage capacity has been lost.

Inspection Checklist

- ☐ Mosquitoes can be a concern for stormwater ponds, and mosquito population growth could have health concerns as well as impact maintaining oxygen in ponds. Consulting the local health department or spraying as necessary to reduce mosquito population growth may be necessary.
- ☐ In cases where a stormwater pond is used for large detention facilities, the structural integrity of the impounding embankment should also be evaluated. The embankment should be protected against catastrophic dam failure.
- ☐ Maintenance of vegetation
- ☐ Inlet pipe condition
- ☐ Evidence of scouring
- ☐ Removal of trash and sediments

Wet Pond

Wet Pond

Source, Stormwater Managers Resource Center, www.stormwatercenter.net

Wet ponds maintain a permanent pool to treat incoming stormwater. Treatment occurs through settlement of suspended particles and uptake of dissolved contaminants by aquatic plants between storm events. Wet ponds are constructed with two storage areas. A permanent pool, or "dead" storage area is based on the water quality volume calculation. During storm events, runoff displaces the water existing in the permanent pool. A temporary or "live" storage area can be provided above the permanent pool to accommodate larger flows and control erosion. See PTP-03-01and PTP-03-02 for a schematic of a typical wed pond.

Design Criteria

The following sizing design considerations should be made for wet ponds:

- The permanent pool should have a hydraulic residence time of at least 2 to 4 weeks
- The maximum depth of the permanent pool is generally less than 8 feet, although greater depths are possible with artificial mixing or aerators at maximum depth. The objective is to avoid thermal stratification that could result in odor problems associated with anaerobic conditions. Gentle artificial mixing may be needed in small ponds because they are effectively sheltered from the wind. Minimum depth of the pool should be 3 to 4 feet. Greater depths near the outlet may allow water to cool and minimize thermal impacts to receiving streams.
- The outlet of the facility should be restricted so as to detain a treatment design storm in a "live" pool on top of the permanent pool for 24 to 60 hours. The effect of restricting the outflow is to reduce the overflow rate during the storm reducing downstream erosion, flood control and slightly increasing the capture of settleable solids.
- Water quality detention ponds should be sized to collect the first flush of stormwater runoff. The first flush of stormwater consists of pollutants deposited on exposed areas that become entrained as stormwater washes through the catchment. This initial stormwater quantity containing the high initial pollutant load is called the "first flush". For this area, the first flush is generally the first 0.5 to 1.1 inches of runoff over the tributary area.

Wet Pond (cont.)

- About 10 to 25% of the surface area determined in the above procedure should be devoted to the forebay. The forebay can be distinguished from the remainder of the pond by one of several means: a lateral sill with rooted wetland vegetation, two ponds in series, differential pool depth, rock-filled gabions or retaining wall, or a horizontal rock filter placed laterally across the pond. A baffle box or water quality inlet(s) can be used in lieu of a forebay.
- Side slopes should be 6:1 (H:V) or flatter to provide a littoral shelf and safety bench from the side of the facility out to a point 2 to 3 feet below the permanent pool elevation. Side slopes above the littoral zone should be no steeper than 4:1 (H:V). Side slopes below the littoral zone can be 2:1 (H:V) to maximize permanent pool volumes where needed. A short (1.0 ft) drop-off can be constructed at the edge of the pond to control the potential breeding of mosquitoes.
- The contours and shape of the permanent pool should be irregular to compliment natural landscaping.
- Pretreatment – Facilities that receive stormwater from contributing areas with greater than 50 percent impervious surface or that are a potential source of oil and grease contamination (hotspots) must include a baffle, skimmer, and grease trap to prevent these substances from being discharged from the facility.
- The permanent pool may be excavated into bedrock for a wet or dry detention pond, but the cost may be prohibitive. Furthermore, if there is highly fractured bedrock or karst topography, then the modification of a detention pond should be carefully considered because it may not hold water and the additional water flow and/or weight could intensify karst activity.
- The interaction with other utilities must be considered as it may not be practical to develop a permanent pool in an area that is needed by another utility. Furthermore, the cost of designing around utilities or utility relocation must be considered.
- A 5:1 (H:V) access must be considered to account for maintenance crews and public interaction. Maintenance crews must have access to the site for proper maintenance. Ponds that are not designed with access for maintenance crews often become more of a nuisance than a beneficial part of a stormwater management program. It may also be desirable to encourage or discourage access for the public. Public education and recreation may be facilitated by access to the pond, provided public safety is sufficiently addresses.
- Design to minimize short-circuiting by including energy dissipaters on inlets, shape the pond with at least a 3:1 length to width ratio, and locate the inlets as far away from the outlet as possible. It should be noted that a length to width ratio of up to 7:1 is preferred. The inlet and outlet can be placed at the same end if baffling is installed to direct the water to the opposite end before returning to the outlet. If topography or aesthetics requires the pond to have an irregular shape, the pond area and volume should be increased to compensate for the dead spaces.

Wet Pond (cont.)

- Except for very small facilities, include a forebay, baffle box, or other pretreatment BMP to facilitate maintenance. However, note that a forebay will require less frequent maintenance.
- To maintain the wet pool to the maximum extent possible, excessive losses by infiltration through the bottom must be avoided. Depending on the soils, this can be accomplished by compaction, incorporating clay into the soil, or an artificial liner.
- Place an antiseep collar around the outlet pipe with an earthen embankment.
- The outlet should incorporate an antivortex device if the facility is large (a 100-year storm must safely pass through or around the device).
- The slope of an earthen embankment should be vegetated to avoid erosion. Drought tolerant groundcover species should be used if irrigation can not occur during the summer.
- Ponds that serve smaller local site runoff do not offer as much recreational benefit as ponds serving larger regional runoff. Regional facilities can often be landscaped to offer recreational and aesthetic benefits. Jogging and walking trails, picnic areas, ball fields, and canoeing or boating are some of the typical uses. For example, portions of the facility used for flood control can be kept dry, except during floods, and can be used for exercise areas, soccer fields, or football fields. Wildlife benefits can also be provided in the form of islands or preservation zones, which allow a view of nature within the park schemes.
- The public's safety must be a foremost consideration. For the design of wet detention ponds, this usually takes place in the grading, fencing, landscaping, pipe cover, grating and signage. The most important design feature affecting public safety during a pond's operation is grading. The contours of the pond should be designed to eliminate "drop-offs". When possible, terraces or benches are used to transition into the permanent pool. Within the permanent pool, it is desirable to have a wet terrace 12 to 18 inches below the normal pool level.

Outlet Design

- Proper hydraulic design of the outlet is critical to achieving good performance of the stormwater pond. The two most common outlet problems that occur are: 1) the capacity of the outlet is too great resulting in partial filling of the basin shorter drawdown time and reduced pollutant removal and 2) the outlet clogs because it is not adequately protected against trash and debris. To avoid these problems, two alternative outlet types are recommended for use: 1) V-notch weir, and 2) perforated riser. The V-notch weir will not clog as easily, and should be designed to extend at least 12 inches below the normal pool. The perforated riser allows flow to enter at varying depths to provide internal flow control at varying depths and treatment volumes. The number of perforations per row is a function of the outlet sizing for the pond.

Wet Pond
(cont.)

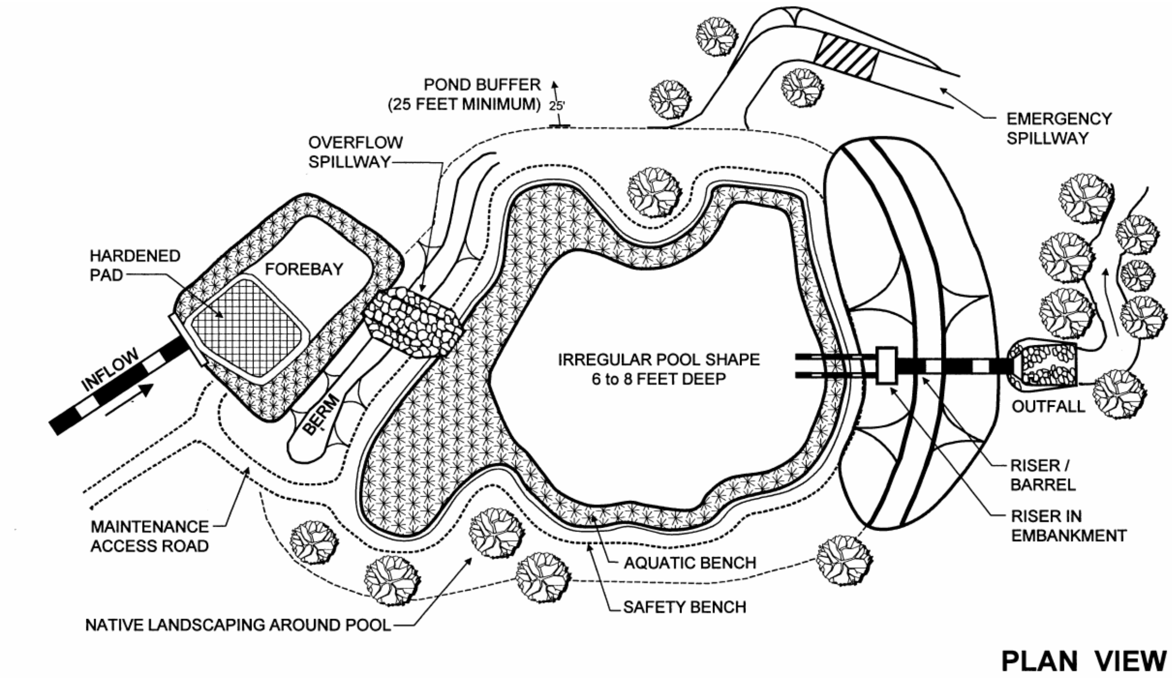

Figure PTP-03-01
Source, Georgia Stormwater Management Manual

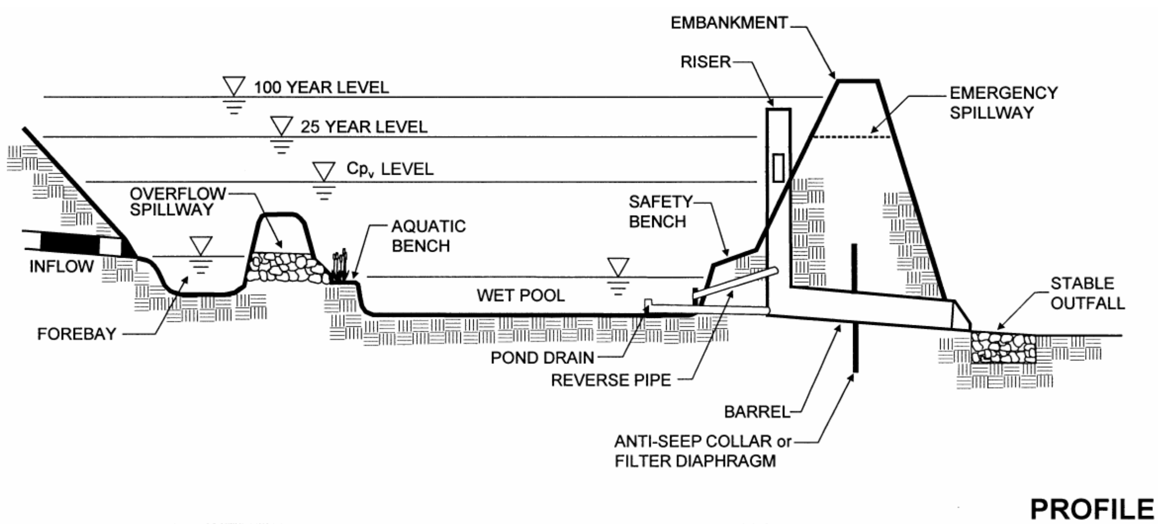

Figure PTP-03-02
Source, Georgia Stormwater Management Manual

Activity: Stormwater Ponds / Wet Extended Detention Pond	PTP-03.2

Wet Extended Detention Pond

Wet Extended Detention Pond
Source, Stormwater Managers Resource Center, www.stormwatercenter.net

A wet extended detention (ED) pond is a wet pond where the basin is designed to hold the water quality volume divided evenly permanent pool and the extended detention area. During a rain event, water is held in the extended detention area and released over a 24 hour period. Wet ED ponds typically have smaller land area requirements compared to wet ponds.

The permanent pool volume for a micropool extended detention pond should be sized to contain 50% of the water quality treatment volume. See PTP-03-03 and PTP-03-04 for a schematic of a typical wet ED pond. See Wet Pond for more detailed design parameters.

Wet Extended Detention Pond (cont.)

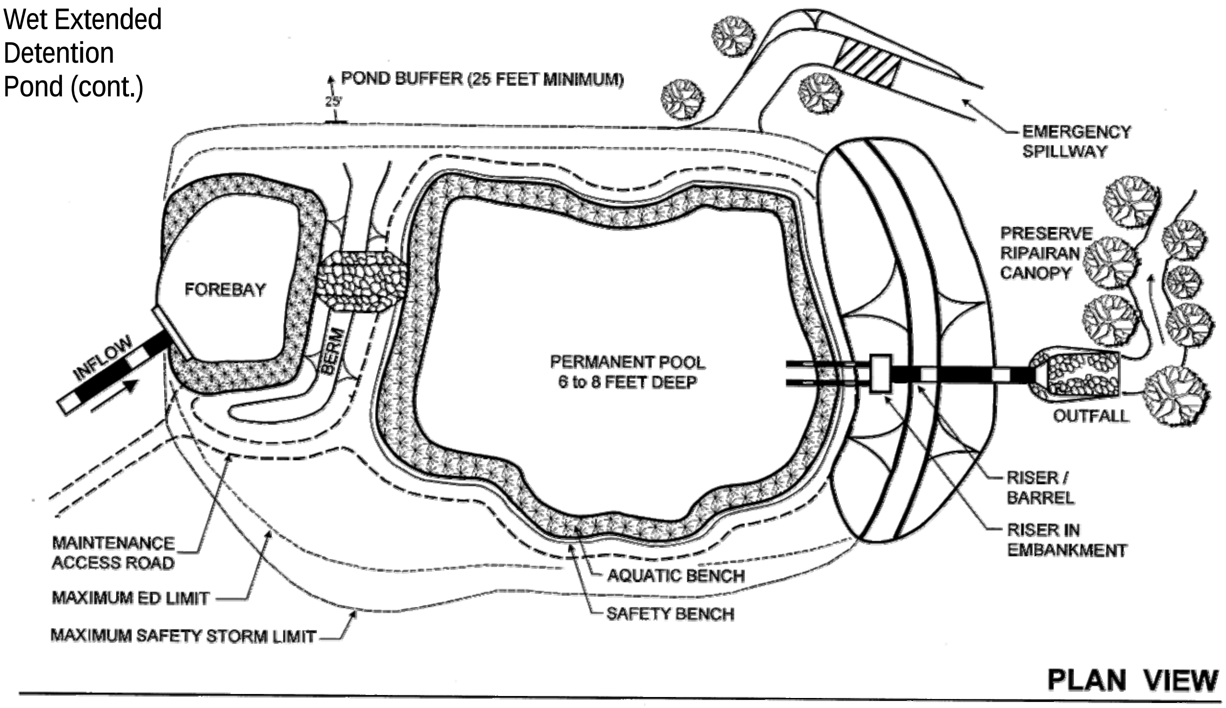

Figure PTP-03-03

Source, Georgia Stormwater Management Manual

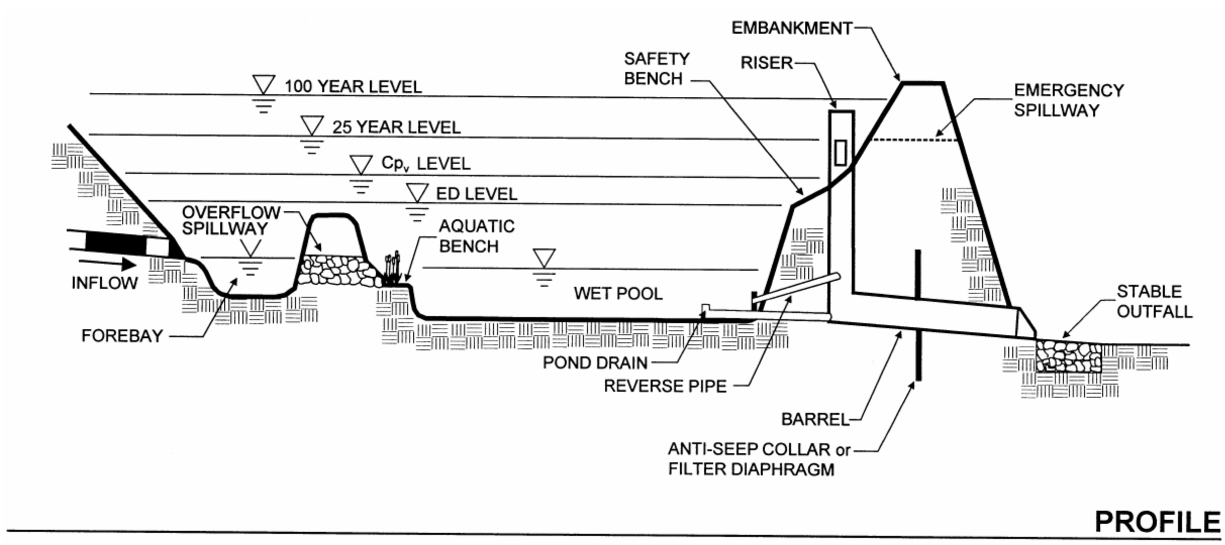

Figure PTP-03-04

Source, Georgia Stormwater Management Manual

Activity: Stormwater Ponds / Micropool Extended Detention Pond	PTP-03.3

Micropool Extended Detention Pond

Micropool Extended Detention Pond
Source, Stormwater Managers Resource Center, www.stormwatercenter.net

A micropool extended detention pond is a basin where a small micropool is permanently maintained at the outlet. The outlet structure is designed to detain the water quality volume for 24 hours and prevents resuspention of sediment particles and clogging of the low flow orifice.

Larger stormwater ponds provide more pollutant removal efficiency than micropool extended detention ponds. However, micropools are ideal for areas where large open stormwater ponds cannot be used. Large open stormwater ponds may be undesirable due to thermal impacts on receiving streams, safety concerns in residential areas, or limited contributing drainage area.

The permanent pool volume for a micropool extended detention pond should be sized to contain 0.1 inch per impervious acre of contributing drainage. See PTP-03-05 and PTP-03-06 for schematics of a micropool ED pond. See Wet Pond for more detailed design parameters.

Micropool Extended Detention Pond (cont.)

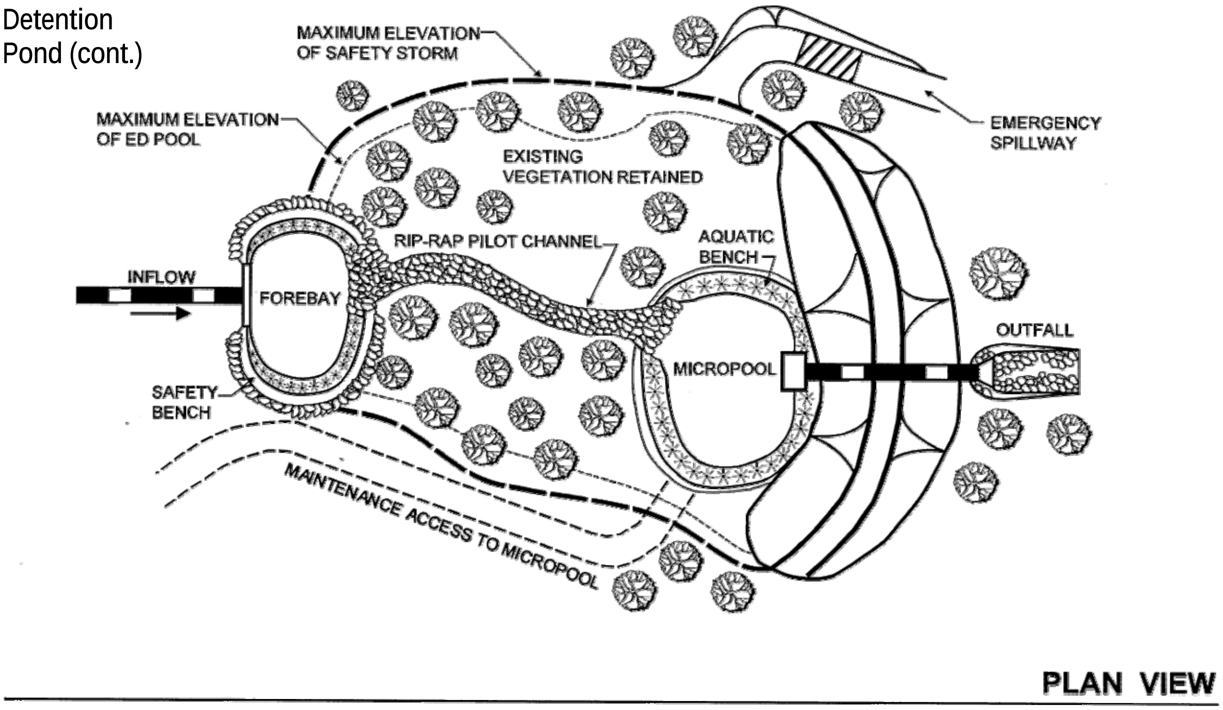

Figure PTP-03-05
Source, Georgia Stormwater Management Manual

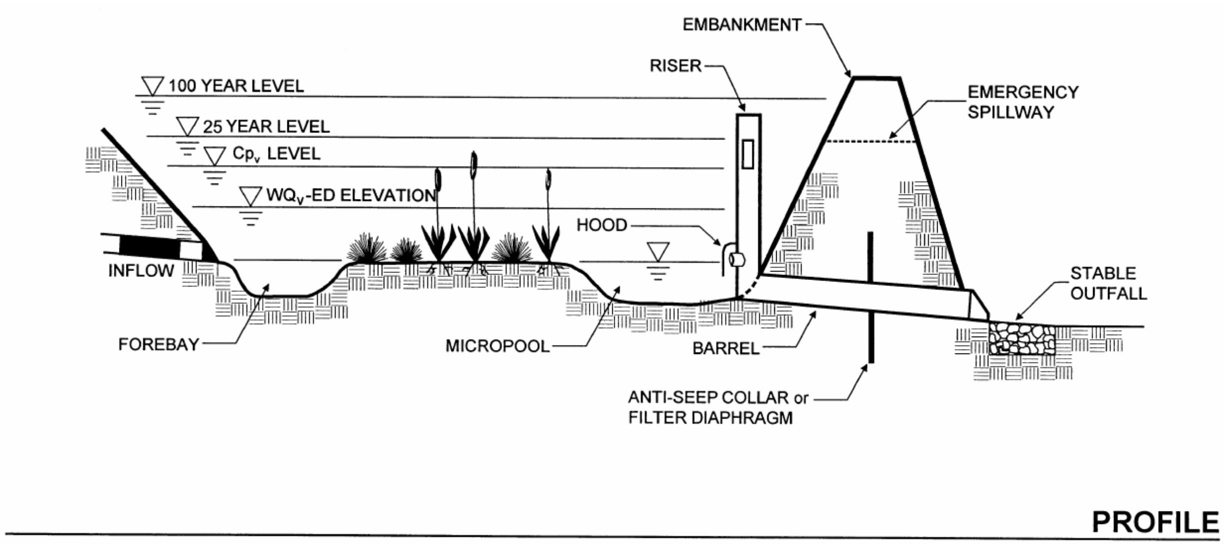

Figure PTP-03-06
Source, Georgia Stormwater Management Manual

Activity: Stormwater Ponds / Multiple Pond System	PTP-03.4

Multiple Pond System

Multiple Pond System
Source, Stormwater Managers Resource Center, www.stormwatercenter.net

A multiple pond system provides water quality treatment as well as water quantity storage facilities through the use of multiple cells. The combination of two or more stormwater ponds in series can extend the pollutant removal pathway and treatment time and improve downstream channel protection.

The permanent pool volume for a multiple pond system should be sized according to the specific cell types used. See PTP-03-07 and PTP-03-08 for schematics of a typical multiple pond system. See Wet Pond for more detailed design parameters.

Multiple Pond System (cont.)

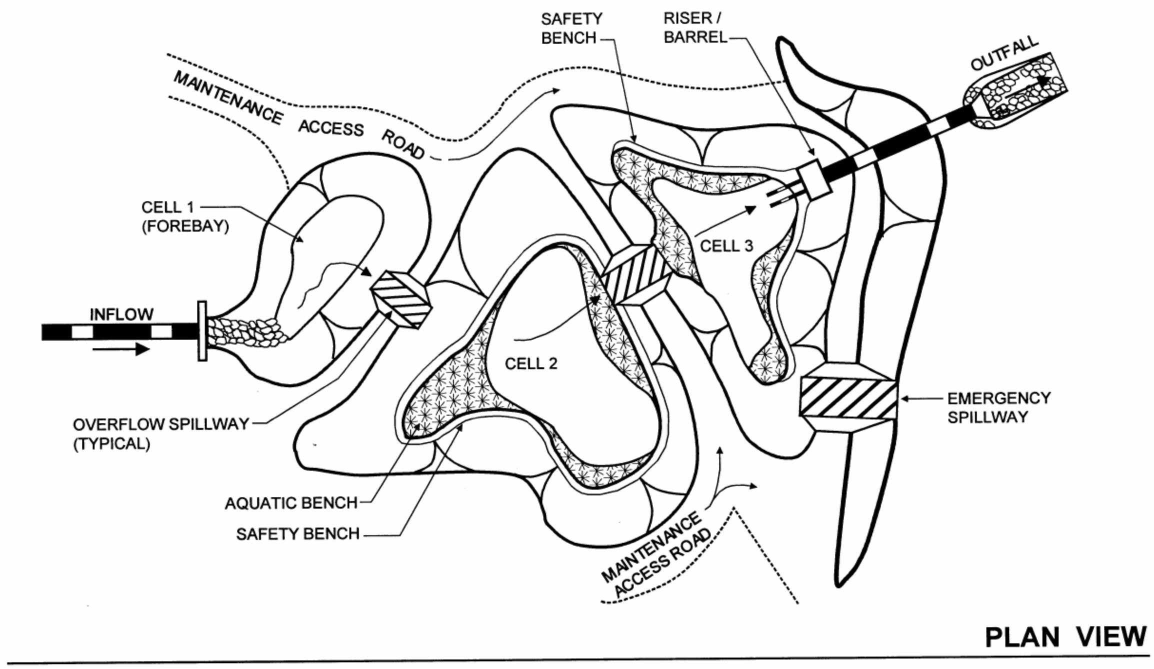

Figure PTP-03-07
Source, Georgia Stormwater Management Manual

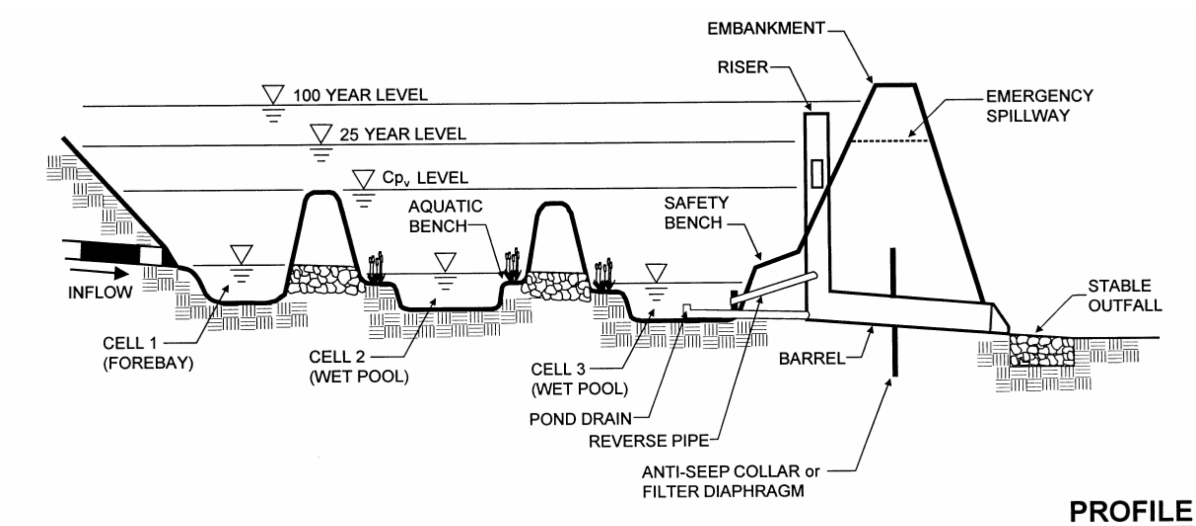

Figure PTP-03-08
Source, Georgia Stormwater Management Manual

Pocket Pond

Multiple Pond System
Source, Stormwater Managers Resource Center, www.stormwatercenter.net

Pocket ponds are designed to have smaller contributing drainage areas than traditional stormwater ponds. This results in little or no base flow during dry weather. Normal pool elevations are maintained through interaction with the water table. Pocket ponds do not have the pollutant removal capabilities that traditional stormwater ponds do, but they may be better suited for a location with limited available land area. If excavation to groundwater could impact drinking water supplies due to surrounding land use drainage, avoid connecting the pond to groundwater sources. See PTP-03-09 and PTP-03-10 for schematics of a typical pocket pond. See Wet Pond for more detailed design parameters.

Pocket Pond
(cont.)

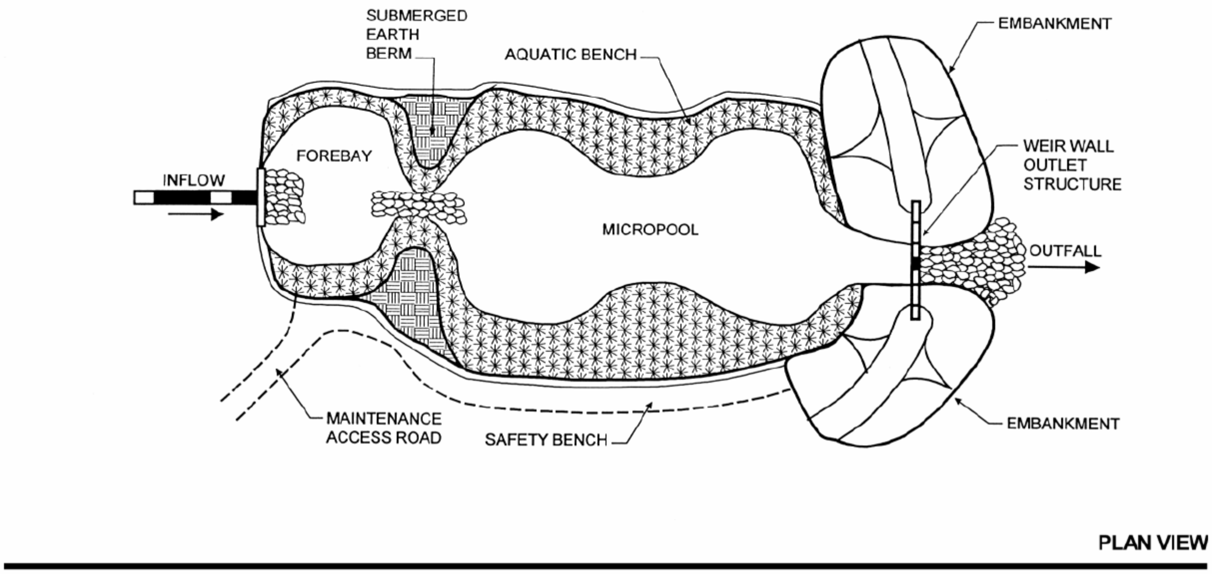

Figure PTP-03-09
Source, Maryland Stormwater Design Manual

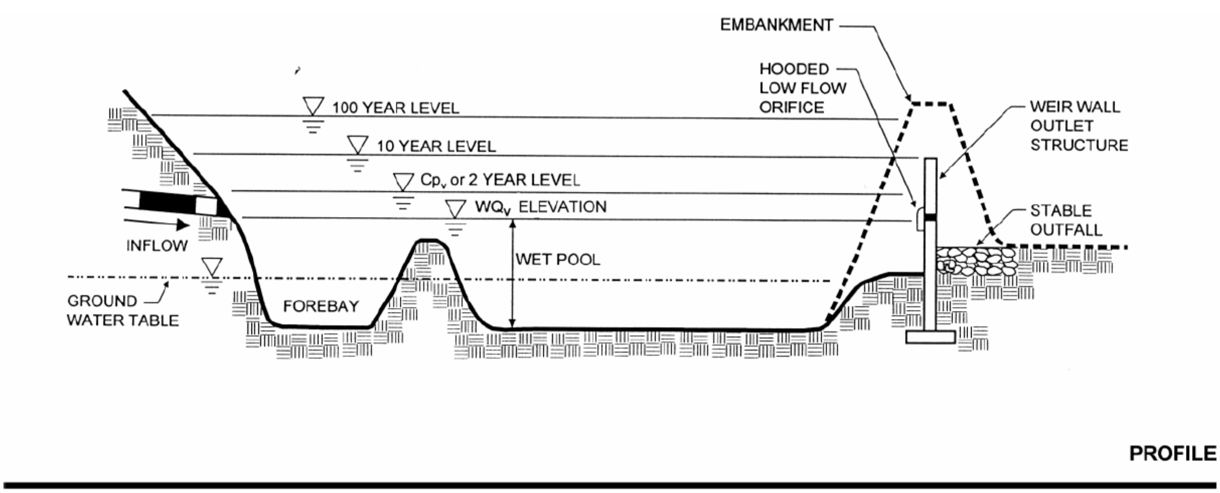

Figure PTP-03-10
Source, Maryland Stormwater Design Manual

Stormwater Pond Design Procedures

Step 1. Compute runoff control volumes.

Calculate the Water Quality Volume (WQ_v), Channel Protection Volume (Cp_v) Overbank, Flood Protection Volume (Q_p), and Extreme Flood Volume (Q_f). See Section 1.6.

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

- Determine if adequate space for access and safety benching exists.
- Determine if hot spot pretreatment of specific land use is required.

Other considerations include:
- Type of development?
- Greater than 25 acre watershed?
- Stable slopes < 15% Grade?
- Does pond location utilize natural topography at site and setback requirements for stormwater pond facilities?
- Are utilities located outside pond site?

Step 3. Confirm local design criteria and applicability.

Consider any special site-specific design conditions/criteria such as soils, topography constraints, groundwater, and downstream conditions. Check with local officials and other agencies to determine if there are any restrictions and/or surface water or watershed requirements that may apply.

Step 4. Determine pretreatment volume.

A sediment forebay must be 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 inches per impervious acre 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 WQ_v for subsequent calculations.

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

- Wet Pond: Size permanent pool volume to 1.0 WQ_v
- Wet ED Pond: Size permanent pool volume to 0.5 WQ_v. Size extended detention volume to 0.5 WQ_v.
- Micropool ED Pond: Size permanent pool volume to 25 to 30% of WQ_v. Size extended detention volume to remainder of WQ_v.
- Pocket Pond: Dependent on ground water connection.

Step 6. Determine pond location and preliminary geometry.

Conduct pond grading and determine storage available for permanent pool (and water quality extended detention if wet ED pond or micropool ED pond). This step involves initially grading the pond (establishing contours) and determining the elevation-storage relationship for the pond.

- Include safety and aquatic benches and access.
- Set WQ_v permanent pool elevation (and WQ_v-ED elevation for wet ED and micropool ED pond) based on volumes calculated earlier.

Stormwater Pond Design Procedures (cont.)

Step 7. Compute extended detention orifice release rate(s) and size(s), and establish Cp_v Elevation. See Section 1.6.

Wet Pond: The Cp_v 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 (12-hour extended detention may be warranted in some cold water streams). 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 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 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. Adjustable gate valves can also be used to achieve this equivalent diameter. The Cp_v 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 (12-hour extended detention may be warranted in some cold water streams).

Step 8. Calculate Q_{p25} (25-year storm) release rate and water surface elevation.

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).

Size emergency spillway, calculate 100-year water surface elevation, set top of embankment elevation, and analyze safe passage of the Extreme Flood Volume (Q_f). At final design, provide safe passage for the 100-year event.

Step 10. Investigate potential pond hazard risks and regulatory classifications.

Step 11. Design pretreatment, sediment forebay(s), outlet structures, maintenance access, and safety features. See Design Criteria for more details.

Step 12. Design Outlet Structures

Two types of outlet structures are recommended here, including a V-notch weir and a perforated riser pipe.

Stormwater Pond Design Procedures (cont.)

Flow Control Using a "V" Notch Weir

- The outlet control "V" notch weir should be sized using the following formula (Brater and King, 1976). See Figure PTP-03-11

$$Q = 2.5 * H^{5/2} \tan\left(\frac{\theta}{2}\right)$$

Where:
- Q = discharge, cfs
- θ = notch angle, degrees
- H = head or elevation of water over the weir, ft

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

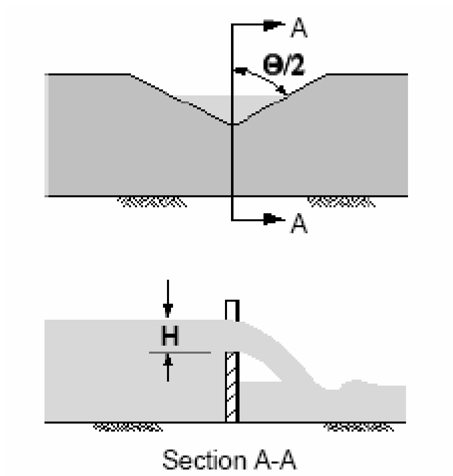

Figure PTP-03-11
Source, Georgia Stormwater Management Manual

Flow Control Using a Single Orifice

- For a single orifice, use the standard orifice equation below (See Figure PTP-03-12):

$$Q = CA(2gH)^{0.5}$$

Where:
- Q = the orifice flow discharge (cfs)
- C = discharge coefficient
- A = cross-sectional area of the orifice or pipe, ft^2
- G = acceleration due to gravity (32.2 ft/s^2)
- D = diameter of orifice or pipe, ft
- H = effective head on the orifice, from the center of the orifice to the water surface

Stormwater Pond Design Procedures (cont.)

- Typicall discharge coefficients include 0.6 where the material is thinner than the orifice diameter with sharp edges, 0.8 where material is thicker than the orifice diameter, and 0.92 if the edges are rounded.

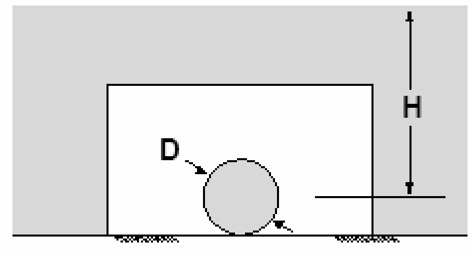

Figure PTP-03-12
Source, Georgia Stormwater Management Manual

Flow Control Using a Perforated Riser

- A perforated riser is a special case of orifice flow. Flow is controlled at an orifice plate at the bottom of the riser or in the outlet pipe just downstream from the elbow at the bottom of the riser. It is key that the perforations are sized such that they convey more flow than the orifice plate. For outlet control using the perforated riser as the outflow control, the single orifice design can be modified as follows.
- This design incorporates flow control for the small storms in the perforated riser but also provides an overflow outlet for large storms. If properly designed, the facility can be used for both water quality and drainage control by: 1) sizing the perforated riser as indicated for water quality control; 2) sizing the outlet pipe to control peak outflow rate from the 2-year storm; and 3) using a spillway in the pond berm to control the discharge from larger storms up to the 100-year storm.
- Calculate the total flow capacity of the perforated section using the following equation (McEnroe, 1988):

$$Q = C_p \frac{2A_p}{3H_s}\sqrt{2g}H^{3/2}$$

Where:
- Q = discharge, cfs
- C_p = discharge coefficient for perforations, typically 0.61
- A_p = cross-sectional holes, ft^2
- H_s = distance from S/2 below the lowest row of holes to S/2 above the top row, ft (See Figure PTP-03-13)

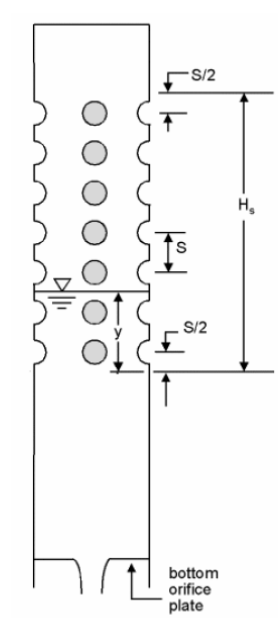

Figure PTP-03-13
Source, Georgia Stormwater Management Manual

Stormwater Pond Design Procedures (cont.)

Step 13. Prepare Vegetation and Landscaping Plan.

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