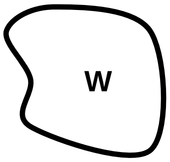
3.4 Post Construction Stormwater Control Fact Sheets (PTP)

Post Construction Stormwater Control Practices	PTP-03 Wet Ponds



Symbol

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Description

Wet ponds are detention ponds containing a permanent pool (or micropool) that allows the treatment of stormwater runoff, while also contributing to the aesthetic value. Wet 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.

The different types of wet ponds consist of the following components: a sediment forebay, a 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.

The five types of wet ponds addressed in this fact sheet include the following:

- Wet ponds;
- Wet extended detention ponds;
- Micropool extended detention ponds;
- Pocket ponds; and
- Multiple pond systems.

Applications

Wet ponds are well-suited for several stormwater water quality benefits, including the following items:

- Areas where high particulate control is needed
- Suitable for large, regional tributaries with sufficient drainage area and/or hydrology to support a permanent pool.
  - Minimum contributing drainage area is 25 acres for wet ponds, wet ED ponds and multiple ponds
  - Minimum contributing drainage area is 10 acres for a micropool extended detention pond (must check that hydrology is capable of supporting water levels)
  - Minimum contributing drainage area is 5 acres for pocket ponds (must check that hydrology is capable of supporting water levels).
- Provides multiple benefits for passive recreation such as bird watching, and wildlife habitat
- Capable of controlling both stormwater quantity and quality issues

Wet ponds also have features that limit where this practice may be used.

- Typically, wet ponds are not feasible for dense or urban land uses due to large land requirements and areas with steep or unstable slopes.
- These ponds have the potential for nuisance insects or odor.
- There are possible safety concerns related to the structure and to maintaining a permanent pool of water.
- Wet ponds may cause increased water temperature, including the potential for downstream thermal impact.

Wet Pond Variations

This practice includes five variations of wet ponds. Each of these types is discussed briefly, and design information specific to a type is also included in the fact sheet.

- **Wet Ponds**

Figure PTP-03- 1 Wet Pond.
Source, Stormwater Managers Resource Center, www.stormwatercenter.net

Wet ponds maintain a permanent pool to treat incoming stormwater, and require a contributing drainage area of 25 acres or greater. 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 based on the water quality volume calculation; and a temporary, or "live," storage area provided above the permanent pool to accommodate larger flows and control erosion. During storm events, runoff displaces the water existing in the permanent pool.

Wet ponds provide for the controlled release of Q_{P25} and Q_{P100} through the spillway outlets. The WQ_v is maintained within the pond's permanent pool (i.e., there is no spillway opening included to control the release of WQ_v). See Figures PTP-03-3 and PTP-03-4 for schematics of a typical wet pond.

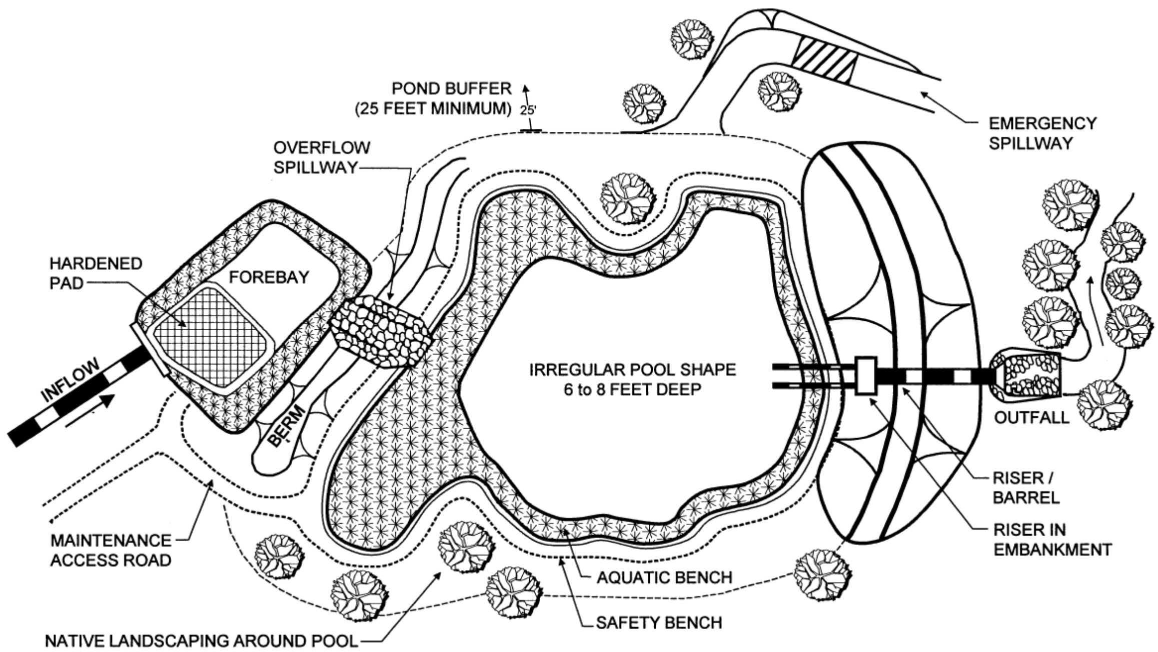


Figure PTP-03- 2 Plan View of Wet Pond
Source, Georgia Stormwater Management Manual

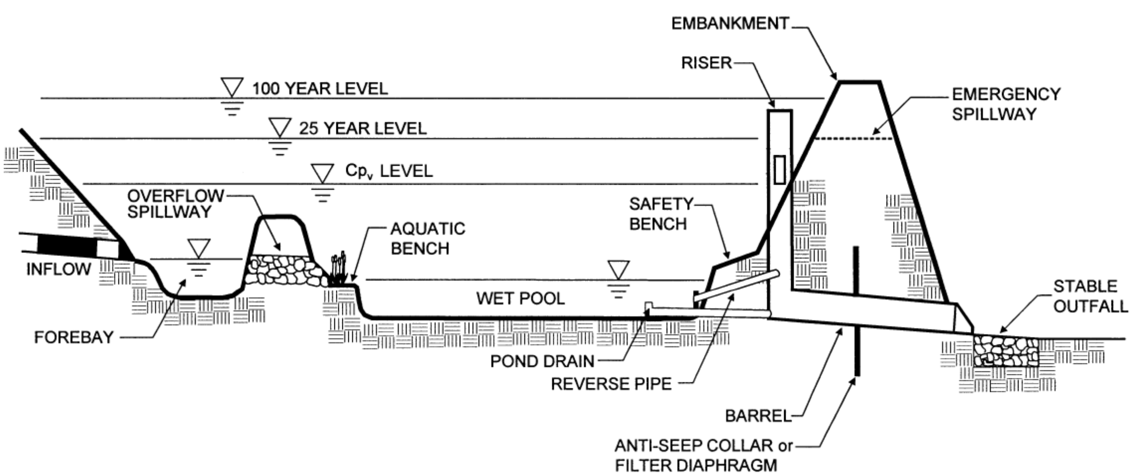


Figure PTP-03- 3 Profile View of Wet Pond.
Source, Georgia Stormwater Management Manual

Wet Pond Variations

➢ **Wet Extended Detention Pond**

Figure PTP-03- 4 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 between the permanent pool and the extended detention area. This wet pond type requires a minimum of 25 acres of contributing drainage 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. See PTP-03-03 and PTP-03-04 for schematics of a typical wet ED pond.

The wet ED pond is similar to the wet pond in that both pond types provide for the controlled release of Q_{P25} and Q_{P100} through the spillway outlets. However, the wet ED pond also includes a spillway outlet at the top of the permanent pool to allow the controlled release of 50% of WQ_v. The permanent pool will be set to hold 50% of WQ_v, with the remainder of WQ_v released through the spillway outlet at the top of the permanent pool. Figures PTP-03-6 and PTP-03-7 show schematics for wet ED ponds.

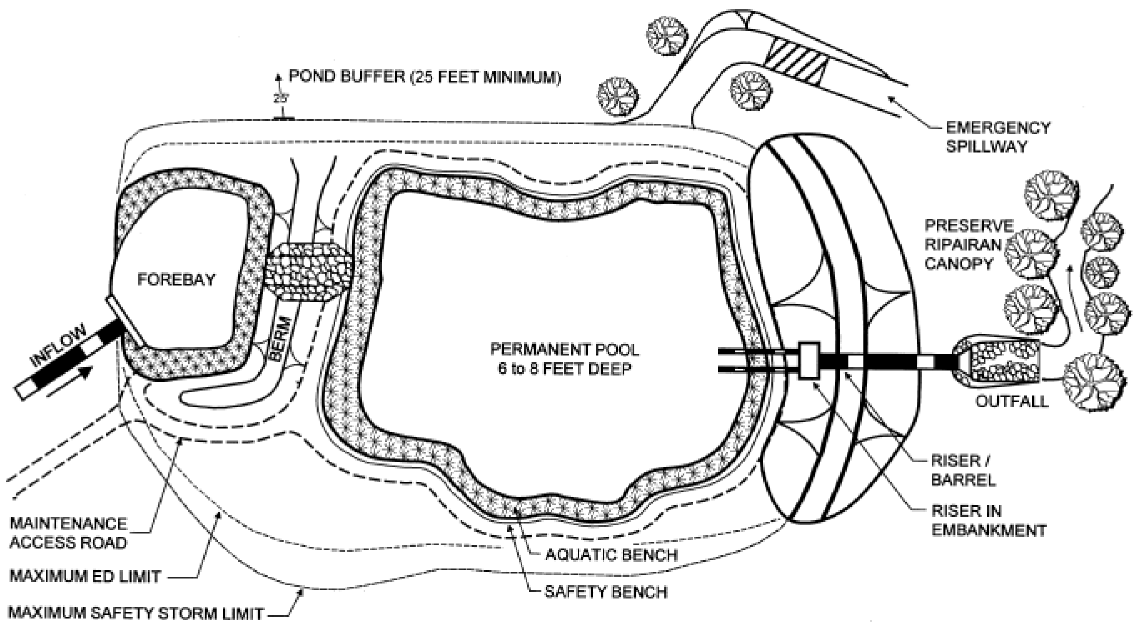


Figure PTP-03- 5 Cross-Section View of Wet Extended Detention Pond.
Source, Minnesota Stormwater Management Manual

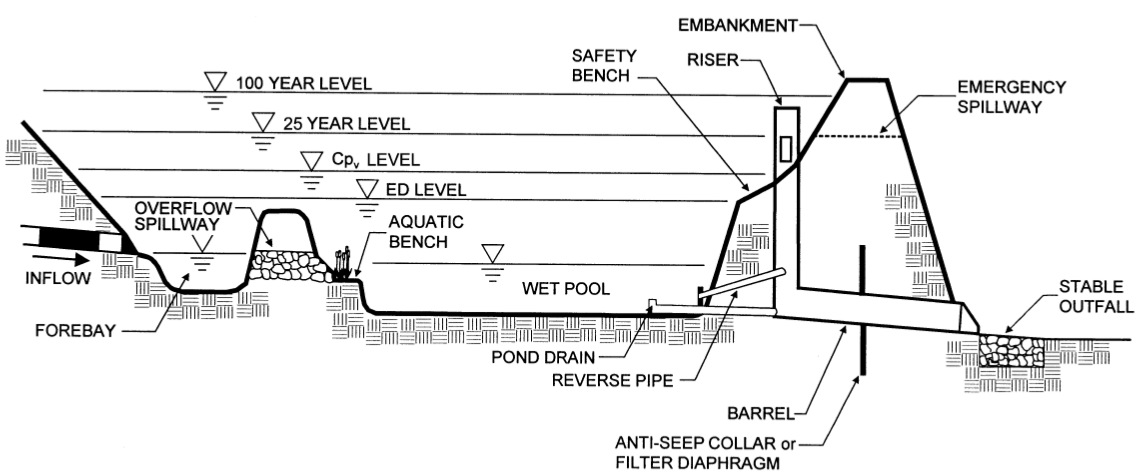


Figure PTP-03- 6 Profile View of Wet Extended Detention Pond.
Source, Georgia Stormwater Management Manual

Micropool Extended Detention Pond

Figure PTP-03- 7 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 smaller micropool near the pond outlet helps prevent resuspension. The outlet structure is designed to detain the water quality volume for 24 hours and prevents resuspension 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 or may be undesirable, such as where there are potential thermal impacts to receiving streams, safety concerns in residential areas, or where the contributing drainage area is smaller than what is needed to support a larger wet pond type. See PTP-03-9 and PTP-03-10 for schematics of a micropool ED pond.

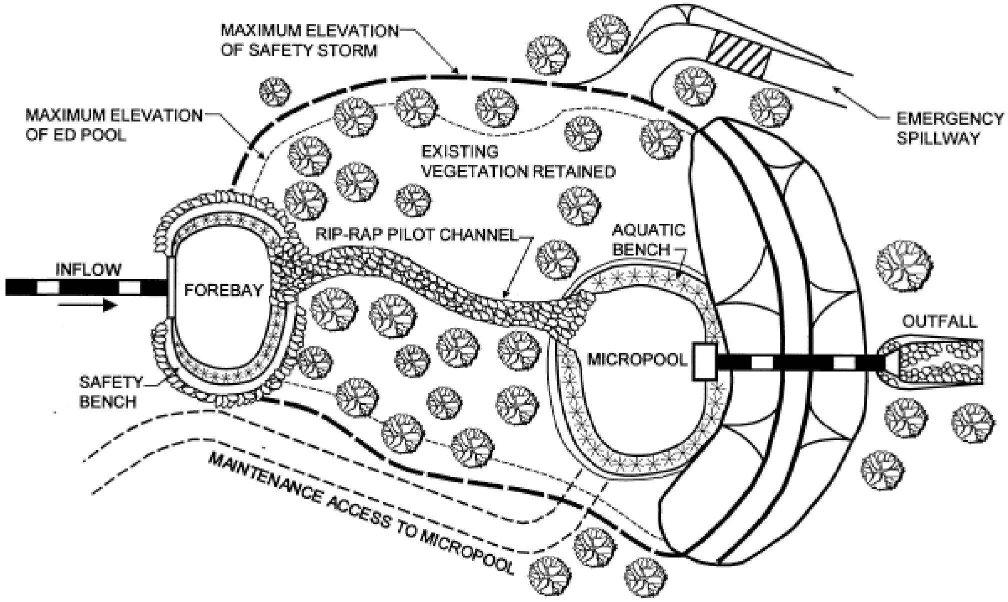


Figure PTP-03- 8 Plan View of Micropool Extended Detention Pond.
Source: Georgia Stormwater Management Manual

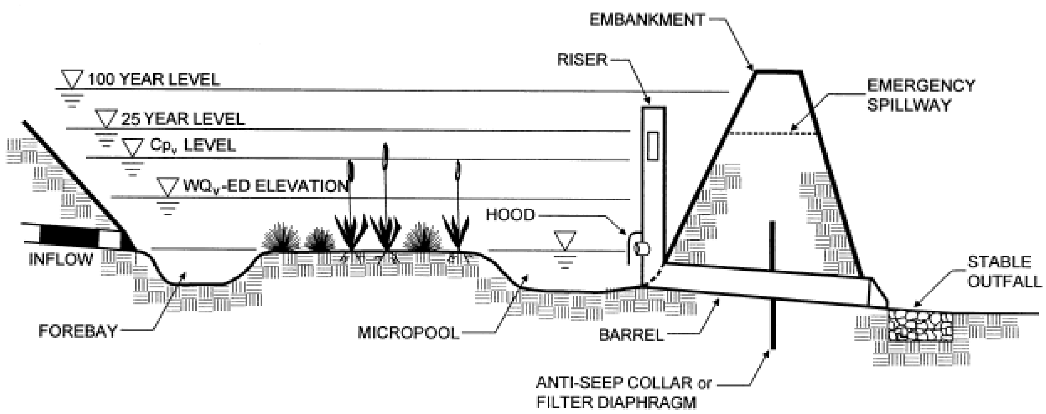


Figure PTP-03- 9 Profile View of Micropool Extended Detention Pond.
Source: Georgia Stormwater Management Manual

Pocket Ponds

Figure PTP-03- 10 Pocket Pond.
Source, Stormwater Managers Resource Center, www.stormwatercenter.net

Pocket ponds are small wet ponds that have smaller contributing drainage areas than other wet pond types. The minimum recommended contributing drainage is 10 acres. These ponds often have little or no baseflow for sustaining water elevations during dry weather, and the permanent pool water elevations rely on a locally high water table or intercepting groundwater. Due to the smaller contributing drainage areas, the pocket pond design should include water balance calculations to assess whether the site's hydrology can sustain a wet pond, including consideration of drought conditions. For land uses where the area draining to the pond may contaminate drinking water supplies, interception of groundwater as a part of stormwater treatment should be avoided (including installation of pocket ponds).

Even though pocket ponds may be well-suited for use for smaller sites where larger wet pond types cannot be used, pocket ponds do have limitations that must be considered in the design. Pocket ponds can be more prone to clogging due to the small size and fluctuating water levels. These fluctuating water levels may also cause other nuisance conditions such as odor and insect habitat when the permanent pool level is diminished.

Pocket ponds should include similar components to those used for other wet pond types even though the pond size will be smaller. The permanent pool for pocket ponds is similar to the micropool for the micropool ED ponds. This permanent pool (micropool) is maintained at the outlet. The outlet structure is designed to detain the water quality volume for 24 hours and prevents resuspension of sediment particles and clogging of the low flow orifice. See Figures PTP-03-12 and PTP-03-13 for pocket pond schematics.

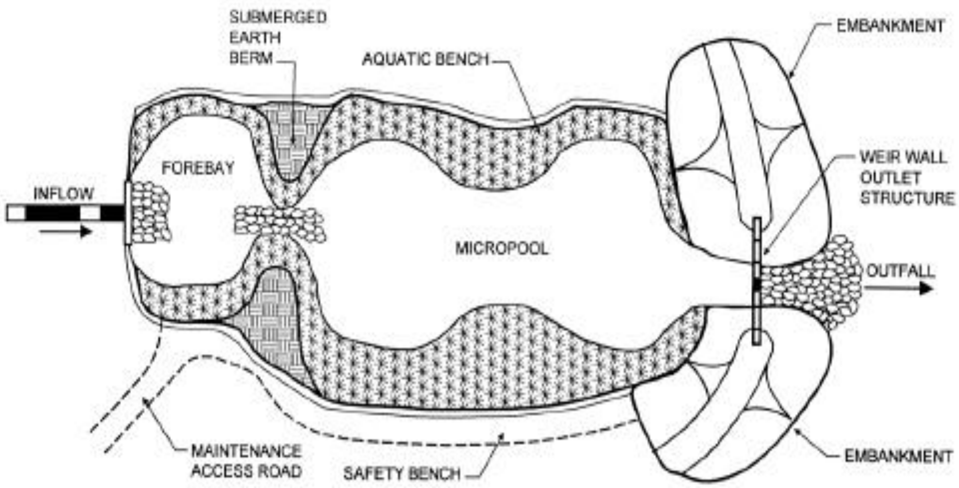


Figure PTP-03- 11 Plan View of Pocket Pond.
Source: Maryland Stormwater Design Manual

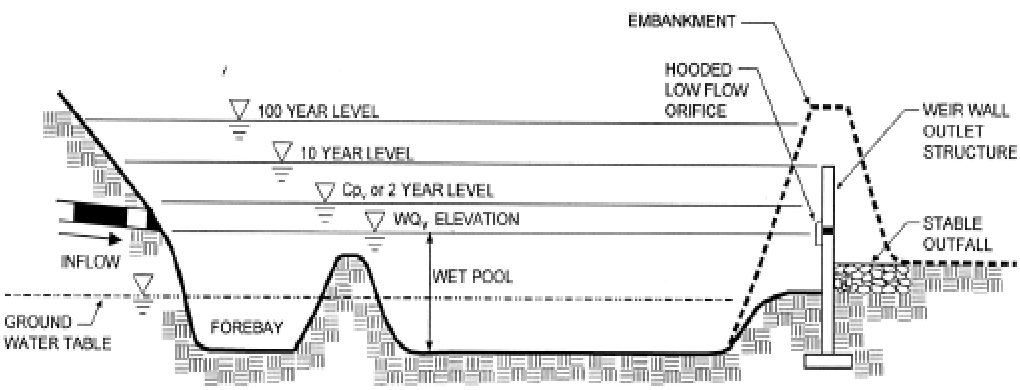


Figure PTP-03- 12 Profile View of Pocket Pond.
Source: Maryland Stormwater Design Manual

Multiple Ponds

Figure PTP-03- 13 Multiple Ponds.
Source, Stormwater Managers Resource Center, www.stormwatercenter.net

A multiple pond system combines one or more wet pond types so that flow passes through the wet ponds in succession. This system increases sediment and pollutant removal from the incoming stormwater. The use of a forebay prior to the first pond can be critical to allowing heavier materials to settle out in the forebay and reducing required maintenance in the wet ponds. Two drawbacks for this multiple pond system would be the required space for multiple ponds and the need to inspect and maintain more than one structure. Using more than one pond must also consider how the permanent pools will be sustained in all wet ponds given the contributing drainage area and water balance. Figures PTP-03-15 and PTP-03-16 show schematics for a two-cell multiple pond system.

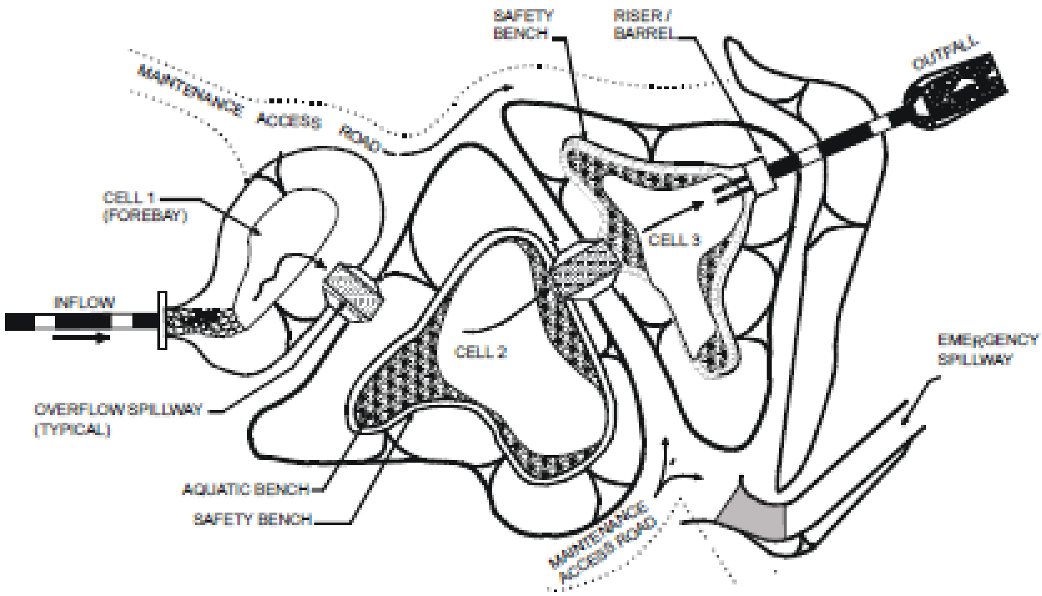


Figure PTP-03- 14 Plan View of Multiple Pond System.
Source: Maryland Stormwater Design Manual

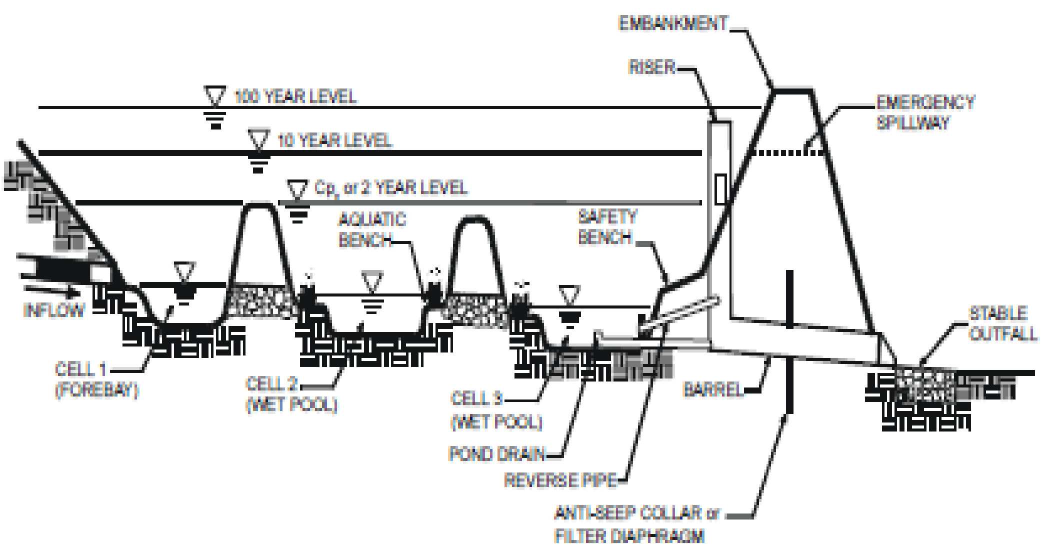


Figure PTP-03- 15 Profile View of Multiple Pond System
Source: Maryland Stormwater Design Manual

Maintenance

Maintenance Plan

A site-specific maintenance plan describing maintenance responsibilities should be developed. that addresses the following items:

- Maintenance access for appropriate equipment, vehicles, and personnel
- Vegetation maintenance schedule that includes mowing multiple times per year
- Inspection checklist
- Maintenance agreement between the facility owner and the City with these items:
  - Sediment removal from sedimentation chamber when sediment depth is ½ of the total depth to the outlet, or is greater than 1.5 feet (whichever is less)
  - Clean and/or repair sediment chamber outlet devices if drawdown times exceed 48 hours 36 hours
  - Trash and debris should be removed as necessary
- Properly dispose of any material generated during maintenance activities.

Monthly to Quarterly or After Major Storms (>1")

Check that the maintenance access is free and clear.

- Inspect low flow orifices and all pipes for clogging.
- Check the pond area for debris, bare soil areas and undesirable vegetation.
  - The minimum mowing requirements for mown slopes will be a spring mowing and a fall mowing.
  - Remove debris.
  - Repair undercut, eroded and bare soil areas.
- Look for damaged safety measures or other dangerous items.

Semi-Annual to Annual

- Ensure that the pond's mechanical components (if any) are functional. Repair broken mechanical components if needed.
- Remove invasive vegetation.
- Monitor and record sediment accumulation.
- Pond vegetation needs to be trimmed or harvested as appropriate.

1-3 Years

- Inspect riser, barrel and embankment for damage. Make any needed repairs.
- Inspect all pipes.
- Monitor sediment deposition in the pond and in the forebay. Remove sediment from the forebay and the pond when needed.

Maintenance	**5-25 Years** ➢ Use remote television inspection of the reverse slope pipes, underdrains or other hard-to-access piping. If needed, replace or repair pipes. **Embankment** The pond embankment and/or riser will require inspection by a qualified professional (e.g., structural engineer, geotechnical engineer, etc.) who has experience in the construction, inspection and repair of these features.

Inspection Checklist

All appropriate items should be checked on the inspection checklist. If an applicable item does not meet the condition on the checklist

Monthly

- ❑ Maintenance access is free and clear
- ❑ Low flow orifice(s) and pipes are free from clogging.
- ❑ Pond areas are free of debris.
- ❑ Pond areas do not have any bare soil areas.
- ❑ Pond areas do not include any undesirable vegetation (i.e., woody vegetation near the embankment, etc.).
- ❑ Check water depth in pond to see if water level has dropped below the permanent pool (look for a fully visible low flow outlet).
  - If the pond water depth is below the permanent pool level, inspector should work to determine why water level has dropped below the permanent pool level (drought conditions or problems with pond).
  - Where low permanent pool levels may produce nuisance insect or odor conditions, the owner should work toward counteracting these conditions until the permanent pool level is restored.
- ❑ There are no damaged safety measures or other dangerous items at the pond.

Semi-Annual to Annual

- ❑ The pond's mechanical components (if any) are functional.
- ❑ The pond's vegetation has been harvested as appropriate.

1-3 Years

- ❑ The riser, barrel and embankment were inspected for damage and do not require repairs.
- ❑ All pipes were inspected and do not require repairs or replacement.
- ❑ The sediment deposition in the pond and in the forebay was checked, and, if needed, sediment was removed from these areas.

5-25 Years

- ❑ Use remote television inspection of the reverse slope pipes, underdrains or other hard-to-access piping. If needed, replace or repair pipes.

Design Criteria

General Design

- A minimum separation distance between the pond and the groundwater table and/or an impervious liner may be required for ponds where source water protection is required or for contributing drainage areas designated as "hot spot" landuses.
- The maximum depth of the pond should not exceed 10 feet.
- For karst areas, it is recommended that ponds use an impermeable liner and include a minimum three foot separation from the barotic rock layer.
- A landscaping plan must address how the pond and the surrounding areas will be stabilized and how vegetation will be established. This plan should include maintenance actions and schedules for the vegetation.

Pre-treatment

- Facilities that receive stormwater from contributing areas with over 50% 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.
- Require pre-treatment measures such as other water quality BMPs and/or forebay(s). For areas receiving drainage from potential "hot spot" areas, the pre-treatment measures may require an impermeable liner and/or other separation to keep stormwater separated from groundwater.
- The forebay depth should be 4-6 feet deep.
- A sediment forebay sized to 10% of the pond area 0.1 inches per impervious acre of contributing drainage should be provided for all wet ponds
- Direct vehicle/equipment access should be required for forebays to allow for sediment removal and maintenance.
- The forebay may be separated from the remainder of the pond by one of several means: an earthen berm, a concrete weir, gabion baskets, 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.
- If appropriate, a baffle box or water quality inlet(s) can be used in lieu of a forebay.
- The bottom of the forebay may be hardened using concrete, asphalt or grouted riprap to make sediment removal easier.

Inlet and Outlet Structures

- All extended detention wet ponds and pocket ponds must have a low flow orifice capable of releasing the 50% of WQ_v in the temporary storage area over at least 24 hours. The remaining 50% of WQ_v is in the pond's permanent pool.
- The water quality protection orifice must meet the following criteria:
  - The minimum diameter for the water quality protection orifice without internal orifice protection is 3 inches.

   - The orifice should be protected from clogging by an acceptable external trash rack.
   - The orifice diameter may be reduced to 1 inch if internal orifice protection is used (e.g., an overperforated vertical stand pipe with 0.5-inch orifices or slots that are protected by wirecloth and a stone filtering jacket).
   - Adjustable gate valves may also be used to achieve this equivalent diameter.

- The minimum diameter for the water quality protection orifice without internal orifice protection is 3 inches. The orifice should be protected from clogging by an acceptable external trash rack. The orifice diameter may be reduced to 1 inch if internal orifice protection is used (e.g., an over perforated vertical stand pipe with 0.5-inch orifices or slots that are protected by wire cloth and a stone filtering jacket). Note that a 3 inch diameter orifice or larger is preferred. Adjustable gate valves may also be used to achieve this equivalent diameter.
- All wet pond types must also include an outlet structure that is sized for Q_{P25} control (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 are not acceptable.
- An emergency spillway is to be included in the stormwater pond design to safely pass the extreme flood flow (Q_{P100}). The spillway prevents pond water levels from overtopping the embankment and causing structural damage. The emergency spillway must be designed to State of Kentucky guidelines for dam safety and must be located so that downstream structures will not be impacted by spillway discharges.
- Inflow channels are to be stabilized with flared riprap aprons, or the equivalent.
- Pond outlets must be designed to prevent discharge of floating debris.
- Burying all pipes below the frost line can prevent frost heave and pipe freezing.
- The outflow riser should be located so that short-circuiting between inflow points and riser does not occur.
- Riprap, plunge pools or pads, or other energy dissipators are to be placed at the end of the outlet to prevent scouring and erosion. Large facility outlets may also require an anti-vortex device.

Permanent Pool

- The permanent pool's contours and shape should be irregular to compliment natural landscaping.
- The permanent pool may be excavated into bedrock for a wet pond
- The maximum permanent pool depth is generally less than 8 feet. Deeper depths may allow thermal stratification and anaerobic conditions to occur, causing odor problems if no artificial mixing or aerators are used.

Design Criteria

- Greater depths near the outlet may allow water to cool and minimize thermal impacts to receiving streams.
- Minimum depth of the permanent pool should be 3 to 4 feet.

Embankment

- Vegetated embankments shall be less than 20 feet in height and shall have side slopes no steeper than 2:1 (horizontal to vertical) although 3:1 is preferred. 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 Kentucky guidelines for dam safety.
- Seepage control or anti-seep collars should be provided for all outlet pipes.
- A minimum of 1 foot of freeboard must be provided for earthen embankments.
- Earthen embankment slopes should be vegetated to avoid erosion. Drought tolerant groundcover species should be used if irrigation cannot occur during the summer.

Maintenance and Safety

- Adequate maintenance access such as a maintenance access bench must be provided for all wet ponds. The access bench is a shallow slope area adjacent to the pond that will be used for equipment access.
- The forebay of the pond should include a fixed vertical sediment depth marker securely installed in the forebay. This marker will be used as an indicator for when sediment removal is needed in the forebay. Sediment removal should occur for forebay areas every 2-7 years or after 50% of the total forebay storage capacity is filled with sediment.
- The riser should be planned for future maintenance, lessening the clogging potential, planning access for inspections and maintenance, and safety from improper access by children and/or vandals.
- Public safety must be considered in every aspect of the pond design.
- Dam safety regulations must be strictly followed in pond design and maintenance to ensure that downstream property and structures are adequately protected.
- OSHA safety procedures must be followed for maintenance activities in enclosed areas, such as outlet structures.
- All wet ponds must include a drain and written procedures for draining the pond.

Multiple Pond Systems

- Performance is enhanced by using multiple treatment cells, longer flowpaths and high surface area to volume ratios.
- For separating multiple ponds, a berm or simple weir is preferred rather than using pipes because pipes have higher freezing potential.

Design Components

Pre-Treatment

- Wet ponds require pre-treatment measures such as other water quality BMPs and/or forebay(s). For pre-treatment areas receiving drainage from potential "hot spot" areas, the pre-treatment measures may require an impermeable liner and/or other separation to keep stormwater separated from groundwater.
- A sediment forebay sized to 0.1 inches per impervious acre of contributing drainage should be provided for wet ponds that are in a treatment train with off-line water quality treatment structural controls. This forebay may be a small pool separated from the pond area by barriers such as earthen berms, concrete weirs or gabion baskets.
- Direct vehicle/equipment access should be required for forebays to allow for sediment removal and maintenance.
- The bottom of the forebay may be hardened using concrete, asphalt or grouted riprap to make sediment removal easier.
- The forebay outlets should include non-erosive conditions as flows move from the forebay to the pond.
- Channels used to convey runoff to the pond should be stabilized to reduce the sediment loads.
- The forebay of the pond should include a fixed vertical sediment depth marker securely installed in the forebay. This marker will be used as an indicator for when sediment removal is needed in the forebay. Sediment removal should occur for forebay areas every 2-7 years or after 50% of the total forebay storage capacity is filled with sediment.
- Removed sediment from pond areas that do not receive runoff from confirmed hotspots is generally not considered toxic or hazardous material, and can be safely disposed by land application or land filling. For sediment from runoff from hotspot areas, sediment testing may be necessary prior to disposal.

Inlet and Outlet Structures

- For extended detention ponds and pocket ponds, the low flow orifice must be capable of releasing 50% of WQ_v over at least 24 hours.
- For a wet pond, the outlet structure is sized for Q_{P25} control (based upon hydrologic routing calculations) and can consist of a weir, orifice, outlet pipe, combination outlet, or other acceptable control structure that is not easily clogged.
- The water quality 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 (e.g., an overperforated vertical stand pipe with 0.5-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.

Design Components

- The two most common outlet problems that occur are: 1) the outlet capacity is too great, resulting in partial filling of the pond, 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, providing 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.
- An emergency spillway may be required in wet pond designs to safely pass the extreme flood flow. The spillway prevents pond water levels from overtopping the embankment and causing structural damage. The emergency spillway must be designed to State of Kentucky guidelines for dam safety and must be located so that downstream structures will not be impacted by spillway discharges.
- Inflow channels are to be stabilized with flared riprap aprons, or the equivalent.
- The principal spillway opening should not permit entry by small children, and endwalls above pipe outfalls greater than 48 inches in diameter should be fenced to prevent a hazard.
- Pond outlets must be designed to prevent discharge of floating debris. The recommended approach is to equip the principal spillway openings with removable trash racks to prevent clogging by large debris and to restrict riser access for safety. U. S. EPA guidance for controlling floatables suggests that openings in the range of 1.5 inches are both cost-efficient and effective in removing floatables and large solids.
- The riser should be planned for future maintenance, lessening the clogging potential, planning access for inspections and maintenance, and safety from improper access by children and/or vandals.
- OSHA safety procedures must be followed for maintenance activities in enclosed areas, such as outlet structures.
- The recommended approach for limiting riser access is to install lockable manhole covers and manhole steps within easy reach of valves and other controls. These measures will allow maintenance access and help prevent unauthorized access.
- For spillway outlets, flared pipe sections that discharge at or near the downslope invert or a step-pool arrangement are recommended rather than headwalls at the spillway outlet.
- Burying all pipes below the frost line can prevent frost heave and pipe freezing.
- A riser or an alternative method may be used for the pond's principal spillway.
  - For perforated risers, the minimum opening diameter should be ½ inch and the minimum pipe diameter is 8 inches.

Design Components

- The low flow orifice for the riser must be adequately protected from clogging. This protection may be an acceptable external trash rack (recommended minimum orifice diameter of 3 inches) or a smaller orifice diameter may be used along with internal orifice protection (recommended minimum diameter of 1 inch).
- One example alternative method would be to use a broad crested, rectangular, V-notch or proportional weir, protected by a half-round CMP.

- The outflow riser should be located so that short-circuiting between inflow points and the riser does not occur.
- Where standard weirs are used, the minimum slot width is 3 inches. This is particularly important for tall slots.
- The pond must include an emergency spillway to pass storm events in excess of the pond's hydraulic design. The emergency spillway must be stabilized to prevent erosion, must comply with state dam safety requirements and must be located so that downstream structures will not be impacted by spillway discharges. If the emergency spillway crosses the maintenance access for the pond, materials meeting the appropriate load requirements must be selected.
- Riprap, plunge pools or pads, or other energy dissipators are to be placed at the end of the outlet to prevent scouring and erosion. If the pond discharges to a channel with dry weather flow, care should be taken to minimize tree clearing along the downstream channel, and to reestablish a forested riparian zone in the shortest possible distance.
- For outlets, it is recommended that a stilling pond or outlet protection be used to reduce outflow velocities to non-erosive velocities (3.5 to 5.0 fps).

Pond

- Wet ponds require a minimum contributing drainage area and may also require water balance calculations to confirm that a wet pond can be supported at the location.
  - Minimum contributing drainage area is 25 acres for wet ponds, wet ED ponds and multiple ponds
  - Minimum contributing drainage area is 10 acres for a micropool extended detention pond (must check that hydrology is capable of supporting water levels)
  - Minimum contributing drainage area is 5 acres for pocket ponds (must check that hydrology is capable of supporting water levels).
- 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.

Design Components

- For outlets, it is recommended that a stilling pond or outlet protection be used to reduce outflow velocities to non-erosive velocities (3.5 to 5.0 fps).
- Dam safety regulations must be strictly followed in pond design and maintenance to ensure that downstream property and structures are adequately protected.
- Public safety must be considered in every aspect of the pond design.
- The minimum length to width ratio for the pond is 1.5:1.
- It is recommended that the pond's footprint cover approximately 1-3% of the contributing drainage area.
- Adequate maintenance access must be provided for all wet pond types. One approach for this is to incorporate an access bench (a shallow slope area adjacent to the pond) that will be used for equipment access.
    - The recommended access bench width is 10 feet (minimum 8 feet).
    - The maximum access bench cross-slope should be 0.06:1 (V:H) or 6%.
    - Use a maximum bench slope of 0.15:1 (V:H).
    - The bench should be appropriately stabilized for vehicle and equipment access.
    - This bench may also consider extending to other areas such as forebays, inlet and outlet, and should also consider the need for vehicle turn around space.
    - Access benches are not needed for ponds with side slopes that are 1:4 (V:H) or flatter.
    - The recommended maintenance access will connect with a maintenance right-of-way or easement (if needed) that will extend from the pond to a public or a private road.
- A minimum separation distance between the pond and the groundwater table and/or an impervious liner may be required for ponds where source water protection is required or for contributing drainage areas designated as "hot spots".
- A site-specific geotechnical investigation should be conducted.
- Side slopes should not exceed 1V:3H.
- The slopes immediately adjacent to the pond should be less than 25% but greater than 0.5-1% to maintain positive drainage toward the pond.
- Wet ponds are sized to store all of WQ_v in the permanent pool and to temporarily store the volume of runoff required to provide overbank flood (Q_{P25}) protection (i.e., reduce the post-development peak flow of the 25-year storm event to the pre-development rate), and control the peak flow for the 100-year storm (Q_{P100}) if required.
- Wet ED ponds, micropool ED ponds and pocket ponds are designed to store 50% of WQ_v in the permanent pool and the remainder of WQ_v in temporary storage for at least 24 hours. These ponds can also provide additional storage volume for normal detention (peak flow reduction) for Q_{P25} and Q_{P100}. Routing calculations must be used to demonstrate adequate storage volume.

Design Components

- The maximum depth of the pond should not exceed 10 feet.
- The elevation difference from the site inflow to outflow is recommended to be 6-10 feet. However, lower heads may also work for smaller sites.
- The recommended pond side slopes would be 1:3 (V:H).
- Construction inspections are needed to confirm that the pond is being built by the approved design and specifications. Use a detailed inspection checklist that includes sign-offs by qualified individuals at critical construction stages to check that the contractor's plan interpretation is acceptable to the project's designer.
- Areas above the normal high water elevations of the pond should be sloped toward the pond to allow drainage and to prevent standing water. Carefully finish grading to avoid creation of upland surface depressions that may retain runoff. The pond bottom should be graded toward the outlet to prevent standing water conditions. A low flow or pilot channel across the pond bottom from the inlet to the outlet (often constructed with riprap) helps convey low flows and prevent standing water conditions.
- For karst areas, it is recommended that ponds use an impermeable liner and include a minimum three foot separation from the barotic rock layer. Liner options include a layer of 6-12 inches of clay soil including bentonite (minimum 15% passing the #200 sieve and a maximum permeability of 1X 10^{-5} cm/sec), a 30 mL polyliner or another approved engineering design.
- A landscaping plan should describe how the pond and surrounding areas will be stabilized, how vegetation will be established, how these areas will be maintained and maintenance schedules.
    - Rooted wetland vegetation should be planted along the pond's perimeter.
    - Keep in mind that vegetation planted in the extended detention zone should be able to withstand both wet and dry conditions.
- All wet ponds must include a drain and written procedures for draining the pond.

Embankment

- Vegetated embankments shall be less than 20 feet in height and shall have side slopes no steeper than 2:1 (horizontal to vertical) although 3:1 is preferred. 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 Kentucky guidelines for dam safety.
- Seepage control or anti-seep collars should be provided for all outlet pipes.
- A minimum of 1 foot of freeboard must 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.
- For earthen embankments, suitable soils must be used to construct the embankment.
- Woody vegetation should not be planted or allowed to grow within 15 feet of the embankment toe and within 25 feet of the inlet and outlet structures.

Design Components

Multiple Pond Systems

- Performance is enhanced by using multiple treatment cells, longer flowpaths and high surface area to volume ratios.
- For separating multiple ponds, a berm or simple weir is preferred rather than using pipes because pipes have higher freezing potential.

Design Procedure

Step 1 – Make a preliminary judgment as to whether site conditions are appropriate for the use of a type of wet pond, and identify the function of the pond in the overall treatment system. This includes performing an initial suitability screening for the site.

- Consider basic issues for initial suitability screening, including:
    - Site drainage area
    - Site topography and slopes
    - Soil characteristics
    - Depth to water table and bedrock
    - Presence of active karst features and/or wetlands
    - Post-development landuse (Is it a potential "hot spot" landuse?)
- Determine how the type of wet pond will fit into the overall stormwater treatment system.
    - Keep in mind that other water quality BMPs may be used upslope of the pond that may reduce the required pond size.
    - Decide where on the site the pond is most likely to be located.

Step 2 – Confirm design criteria, site constraints and applicability.

- Determine the design criteria that will be used.
    - Local construction and stormwater requirements
    - State stream construction permitting (if in a floodplain area)
    - State dam safety guidance (for ponds with embankments)
    - Any other criteria or restrictions that apply
- Determine any constraints the site will place on the pond such as:
    - Available contributing drainage area
    - Limited amount of space and surface area available for treatment
    - High water table
    - Active karst areas

Design Procedure

- Determine the TSS reduction provided, using the equations below for weighted TSS reduction, $TSS_{weighted}$, and TSS treatment train, TSS_{train}. The minimum TSS reduction required for the site is 80% and can be weighted for the site.

$$\%TSS_{\text{weighted}} = \frac{\sum_{n}^{1}(TSS_1 A_1 + TSS_2 A_2 + \ldots + TSS_n A_n)}{\sum_{n}^{1}(A_1 + A_2 + \ldots + A_n)}$$

Where runoff is treated by two or more BMPs in series, the TSS reduction provided is calculated with the following equation for a treatment train:

$$TSS_{train} = A + B - \frac{(A \times B)}{100}$$

Where A is the TSS reduction provided by the first BMP and B is the TSS reduction provided by the next BMP.

Step 3 –Confirm site suitability, including field verification of site suitability.

- The field verification should be conducted by a qualified geotechnical professional.
- The recommended minimum is one soil boring per acre with a minimum of three soil borings or pits dug at the same location as the proposed pond. The borings or pits will be used to verify soil types and to determine the depth to groundwater and bedrock.
- The recommended minimum depth of the soil borings or pits is five feet below the bottom elevation of the proposed pond.
- Perform water balance calculations, if needed. A water balance is recommended where there is a need to document sufficient inflows to support a wet pond type. The water balance considers the site's ability to maintain a constant permanent pool during prolonged dry weather conditions. Use the following steps to perform water balance calculations:
    - Check maximum drawdown during periods of high evaporation and during an extended period of no appreciable rainfall to ensure that wetland vegetation will survive.
    - The change in storage within a pond = inflows – outflows.
    - Potential inflows: runoff, baseflow and rainfall (ground water and surface water).
    - Potential outflows: Infiltration, surface overflow and evapotranspiration.
    - For some wet pond types, some assumptions can help simplify the water balance since only the permanent pool volume is being evaluated. . The validity of these assumptions need to be verified for each design and wet pond type.
        - Assume no inflow from baseflow,

Design Procedure

- Assume no outflow losses for infiltration
- Assume no outflow losses for surface overflows

- In equation format, the water balance based on the contributing drainage area is as follows:

$$\Delta SP = RO + B + RF - I - SO - ET$$

Where:

ΔSP = change in pond storage, inches

RO = runoff, inches

B = baseflow, inches

RF = rainfall, inches

I = infiltration, inches

SO = surface overflow, inches

ET = evapotranspiration, inches

- For testing a site's suitability for a wet pond type, the critical issue is maintaining a minimum permanent pool depth to avoid nuisance conditions such as insect conditions or odor. The water balance equation may be modified to calculate the required design depth for the permanent pool by considering 30-day summer drought conditions. In equation format, the 30-day water balance based on the contributing drainage area is as follows:

$$DP > ET_S + I_S + RES + B_S$$

Where:

DP = Average design depth of the permanent pool, inches

ET_S = Summer evapotransipration amount, inches

I_S = Summer infiltration amount, inches

RES = Pond's water reservoir for a factor of safety (assume 24 inches)

B_S = Summer baseflow amount, inches

Design Procedure

Step 4 – Compute runoff control volumes, permanent pool volume and peak flows. Refer to Section 2.4.7 for more information on these values.

➢ Calculate the Permanent Pool Volume (V_{PP}).

$$V_{PP} = 0.5inches * A_W * \frac{1ft}{12in}$$

Where:

V_{PP} = Permanent Pool Volume, acre-feet

A_W = total watershed area draining to the pond, acres

➢ Calculate the Water Quality Volume (WQ_V).

$$\boldsymbol{WQ_v = [P\ Rv)(A)]/12}$$

Where:

P = is the average rainfall, (inches)

R_V = 0.05 + 0.009(I), where I is the percent impervious cover

A = the area of imperviousness, (acres)

➢ Calculate the Peak Flow for the 25 year storm (Q_{P25}).

➢ Calculate the Peak Flow for the 100 year storm (Q_{P100}).

If the pond will be used as the only BMP for rate control for larger storms, the pond should be designed to treat the entirety of each of these runoff control volumes. If other BMPs will be used to control portions of these runoff control volumes, the portion handled by other BMPs may be subtracted from the appropriate volumes to determine the volumes to be controlled in the pond.

Note: Steps 5 – 12 may be iterative to achieve a pond design that meets the required performance and the site constraints.

Step 5 – Determine the pond location and preliminary geometry.

➢ Use the following steps to develop the preliminary grading plan for the pond.

- Locate the pond at the site's lowest elevation area that is not in a jurisdictional wetland or active karst area. Provide space around the pond for maintenance access (minimum width of 8 feet, recommended minimum width of 10 feet).
- Establish a primary outlet elevation (normal water level) and/or a pond bottom elevation.
- Provide storage for the permanent pool below the primary outlet elevation in the main pond area.

Design Procedure

- The permanent pool should include an aquatic bench extending into the pool and an access bench extending out of the pool.
- Provide storage based on the water quality volume (WQ_V), volume for the Peak Flow (V_{P25}) and volume for the Extreme Flood Peak Flow (V_{P100}). The pond must be able to contain the first two volumes, and must be designed to pass the extreme flood peak flow.
- Considering the desired pond footprint during the WQ_V, V_{P25} and V_{P100} design storms, allocate storage volume above the riser bottom orifice for WQ_V, V_{P25} and V_{P100}, respectively. While developing the grading plan, consider the desired (or required) length to width ratio and side slopes based on the Design Criteria and Design Components information.
- Once the preliminary grading plan has been developed, determining the associated stage-storage relationship for water surface elevations through the maximum expected levels.

➢ Use the average end area method to calculate the approximate storage at a given stage (elevation). The area within each of the closed contour lines on the pond's grading plan is measured. The average area is calculated between two adjacent contours. The average areas are then multiplied by the elevation difference to calculate the approximate volume between the two contours.

$$\boldsymbol{V_{1-2} = \frac{A_1 + A_2}{2} \times (E_2 - E_1)}$$

Where:

V_{1-2} = the volume between contour 1 and contour 2 (acre-feet)

A_1 and A_2 = the areas within closed contours 1 and 2, respectively (acres)

E_1 and E_2 = the elevations of contours 1 and 2, respectively (feet)

The cumulative pond volume above the bottom of the pond can be calculated by adding the incremental volumes. The stages (elevations) and the corresponding storages can be used to develop a stage-storage-discharge table as the outlet structures are designed. This is an iterative process that may require revising the preliminary grading plan and recalculating the stage-storage relationship until all of the items in Design Criteria and Design Components are satisfied.

Design Procedure

STEP 6 – Determine the pre-treatment volume for the sediment forebay.

- Where there are no adequate upstream treatment BMPs, a sediment forebay or a similarly performing treatment system is recommended at each inlet to the pond that conveys 10% or more of the total design inflow.
- The recommended forebay volume is 10% of the WQ_v with a depth of 4-6 feet. More shallow depths increase the potential for sediment resuspension in the forebay.
- Both the storage volume of the forebay and the storage volumes for other water quality BMPs upstream in the treatment train count toward the required water quality volume, and may be subtracted from the total water quality volume required.

STEP 7 – Size and design the outlet structures.

- The pond must include the following outlet stages in the pond design. It is possible to design one device to meet all required stages.
- The assumed water quality volume (low flow) outlet is an orifice at the bottom of the riser designed to release WQ_v with an average detention time of 24 hours. After designing the low flow orifice, the design should be checked to verify that the release rate is no greater than 5.66 cfs/acre of pond surface area.
- The following outlet equations are based on assumptions about the outlet structure type that will be used to control flows at various stages. If a different structure type is selected, the designer must use specific equations for structure type to determine the stage-discharge relationships. However, the general design approach will remain the same even if a different outlet structure type is used for the pond calculations.
- The average release rate of WQ_v (Q_{WQ_avg}) is calculated using the following equation:

$$Q_{WQ\_avg} = \frac{WQ_v}{t_{WQ}}$$

Where:

t_{WQ} = the intended WQ_v detention time (seconds)

WQ_v = water quality volume (cubic feet)

Q_{WQ_avg} = average release rate of WQ_v (cfs)

- From the stage-storage table, find the elevation associated with WQ_v. Calculate the approximate average head (in feet) on the water quality outlet (h_{wq_avg}) using the following equation:

$$h_{wq\_avg} = \frac{E_{WQ} - E_{PermPool}}{2}$$

Design Procedure

Where:

E_{WQ} = the WQ_v pool elevation (feet)

$E_{PermPool}$ = the permanent pool elevation (feet) at the invert of the water quality orifice.

- Calculate the required orifice cross-sectional area indirectly by using the orifice equation.

$$Q_{WQ\_avg} = CA_{WQ}\sqrt{2gh_{wq\_avg}}$$

Where:

C = the orifice coefficient (0.6 is typically used, but not apply for all cases)

A_{WQ} = the orifice area (square feet)

g = gravitational acceleration (32.2 feet/s^2)

- Calculate the control for the 25-year, 24-hour runoff peak flow (Q_{P25}). The calculation procedures will be similar to those used for the low flow orifice except that any higher outflow openings (i.e., perforated riser openings, weir, orifices, etc.) would be included as well. The combined outflow from all openings must be such that the post-development Q_{P25} does not exceed the pre-development Q_{P25}.
- The combined outflow from the low flow orifice and any higher outflow openings is calculated by adding together the discharges from each structures associated with a given head value and a specified pond water surface elevation.
- Calculate the required control for water quantity management. See Section 2.4.7. At minimum, Q_{p100} must be able to be safely passed through the pond with 1-2 feet of freeboard below the top of the embankment. Check with local officials and/or state dam safety personnel to determine whether Q_{p100} may be passed using only a principal spillway, or if a combination of a principal spillway and emergency spillway will be required. If an emergency spillway is required, the spillway type is often a broad-crested weir or similar structure that is not easily obstructed. The combined outflow through all spillway openings is calculated by adding together the discharges for each opening associated with a given head value and a specified water surface elevation.
- Using the determined opening and spillway information, incorporate the outlet structures into the pond design. Keep in mind that the spillway design must also consider using measures such as removable trash racks to prevent the discharge of floating debris.

STEP 8 – Design the spillways and embankments.

- All spillway and embankment design must meet any applicable state and/or local criteria.
- The emergency spillway must be stabilized.

Design Procedure

- The embankments must be overfilled by at least 5% to allow for settling.
- The minimum embankment with is 6 feet. A wider embankment width may be preferred for maintenance access.
- All embankments must be adequately stabilized with appropriate non-woody vegetation or other measures.
- The embankment and spillway side slopes should be no steeper than 1:3 (V:H).
- Using the determined opening and spillway information, incorporate the outet structures into the pond design. Keep in mind that the spillway design must also consider using measures such as removable trash racks to prevent the discharge of floating debris.

STEP 9 – Design the inlets.

- If inflow inlet pipes are used, it is recommended that the pipes be buried below the frost line.
- Inlet design should consider preventing or reducing scour by including riprap or flow diffusion devices such as plunge pools or berms.

STEP 10 – Design the sediment forebay.

- The sediment forebay size was determined in Step 6.
- The bottom of the forebay may be hardened using concrete, asphalt or grouted riprap to make sediment removal easier.
- The forebay outlets should include non-erosive conditions as flows move from the forebay to the pond.
- The forebay of the pond should include a fixed vertical sediment depth marker securely installed in the forebay. This marker will be used as an indicator for when sediment removal is needed in the forebay. Sediment removal should occur for forebay areas every 2-7 years or after 50% of the total forebay storage capacity is filled with sediment.

STEP 11 – Design the maintenance access and safety features.

- Maintenance access and safety features should meet the requirements included in the Design Criteria and Design Component sections.
- Any additional safety features or signage should be added as appropriate.
- Dam safety regulations must be strictly followed in pond design and maintenance to ensure that downstream property and structures are adequately protected.
- OSHA safety procedures must be followed for maintenance activities in enclosed areas, such as outlet structures.

STEP 12 – Check the expected pond performance against regulatory requirements.

- The pond design should be re-checked to confirm that the pond meets the flow control requirements.

Design Procedure

- The average detention time for WQ_v is 12 hours. The release rate for WQ_v should not exceed 5.66 cfs per acre of pond area.
- Post-development Q_{P25} is no more than the pre-development Q_{P25}.
- If required, post-development Q_{p100} is no greater than the pre-development Q_{p100}.
- If required, the post-development Q_{p100} must be able to be safely passed through the pond while maintaining 1-2 feet of freeboard below the top of the embankment.
- Any other requirements for state dam safety.
- The % TSS removal for the treatment train (upstream water quality BMPs and pond) must be 80% or greater.

STEP 13 – Prepare the vegetation and landscaping plan.

The vegetation and landscaping plan should include soil preparation information, vegetation type and vegetation maintenance. The plan should include information about where woody vegetation is not appropriate (i.e., embankment areas, near spillways where access may be affected, etc.). The plan should also include information about reapplying stabilization measures to areas where vegetation growth is sparse.

STEP 14 – Prepare the operation and maintenance plan.

The operation and maintenance plan should include maintenance information and inspection checklists similar to those discussed in this practice's fact sheet.

STEP 15 – Complete the Design Summary Table.

Design Parameter	Required Size	Actual Size
Pond Type		
WQv		
WQv Elevation		
Forebay		
Outlet		

Example Design

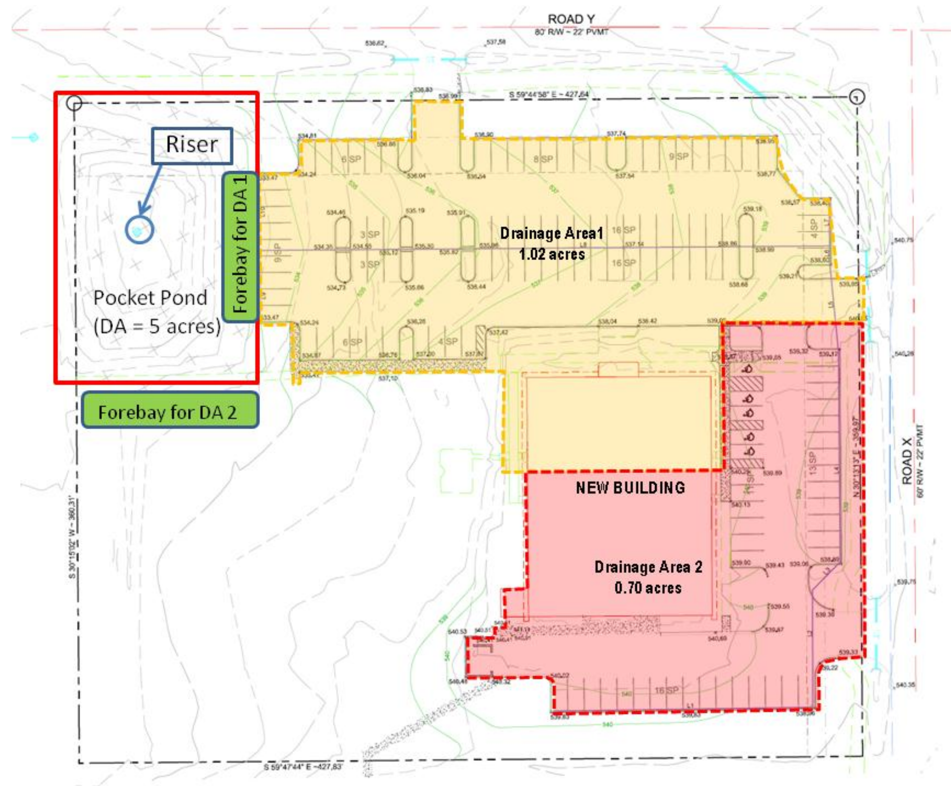
Proposed development of an undeveloped site into an office building and associated parking.

Base Data	**Hydrologic Data**
Site Area = 3.54 ac	Pre Post
Total drainage area = 5.0 ac	CN 71 89
Soils Type "C"	
Pre-Development	**WQ_v Depth** = 1.1 in
Impervious Area = 0 ac; or I = 0%	
Meadow (CN = 71)	**Precipitation**
	I_{WQ} 2.45 in/hr
Post-Development	
Impervious Area = 1.72 ac; or I = 1.72/3.54 = 49%	2yr, 24hr 3.54 in
Open Space, Fair (CN = 79)	25yr, 24hr 5.88 in
Paved parking lots, roofs, driveways, etc. (CN =98)	100yr, 24hr 7.43 in

This example focuses on the design of a pocket pond to meet the water quantity control requirements and to also be a part of the treatment train for the site's water quality treatment requirements. This example design focuses on water quality volume (WQ_v) control only. However, similar design procedures would be used to design for the other water quantity control requirements. The primary functions of the pocket pond are to provide water quality treatment of stormwater and to provide large storm attenuation.

Example Design

Problem: Design a post-construction stormwater water quality and quantity pocket pond for this site. The pocket pond will be constructed to meet the required detention standards and will provide 80% TSS reduction for the site. There are two impervious drainage areas for the site, and stormwater from both areas will drain to the pocket pond. The total watershed drainage area, A_w, to the pond is 5 acres. Try designing the pocket pond for this site.



Step 1 – Make a preliminary judgment as to whether site conditions are appropriate for the use of a pocket pond, and identify the function of the pond in the overall treatment system. This includes performing an initial suitability screening for the site.

- Consider basic issues for initial suitability screening, including:
  - The total drainage area to the pond is 5 acres (A_w).
  - The site's topography and slopes show that the northwest corner of the site is the preferred pond location.
  - The site has type "C" soils
  - The depth to the water table and bedrock show that the northwest corner of the site is a suitable location for a pocket pond.
  - There are active karst areas on the site. The pond will be located away from the active karst areas.
  - The proposed development is a commercial office building with associated parking.

Example Design

- Determine how the pocket pond will fit into the overall stormwater treatment system.
  - The proposed pocket pond will be the primary BMP for TSS removal. No other water quality BMPs will be installed at the site.
  - The northwest corner of the site is the best candidate location for the pocket pond.
  - The stormwater from the two impervious areas on the site will be conveyed through pipes or other stabilized conveyances into the pocket pond.
  - Two separate sediment forebays (one to the east of the pond and a second to the south of the pond) will be used as pre-treatment for the runoff from each impervious area as well as pervious areas draining to the pond. These forebays will reduce maintenance requirements for the pocket pond since other water quality BMPs will not be used upstream of the pond. All pervious site areas as well as all contributing pervious off-site drainage areas will be well-stabilized with vegetative cover.

Step 2 – Confirm design criteria, site constraints and applicability.

- The following minimum criteria will be used in the design.
  - The pocket pond must meet the following criteria:
    - The WQ_v must have an average detention time of 24 hours.
    - The post-development 25-year peak flow (Q_{P25}) discharged from the pond must be no greater than the pre-development 25-year peak flows (Q_{P25}).
    - For this location, the City is not requiring that the 100-year peak flow to be controlled by the pocket pond, but is requiring the pond to be able to safely pass the 100-year peak flow through the principal spillway.
    - The pocket pond is the primary water quality BMP for meeting the City's requirement for % TSS removal.
  - The site is not within a floodplain area, and does not require state permitting for floodplain construction.
  - The pond is bounded on two sides by existing streets, and will not require an embankment (i.e., the pond is excavated). Therefore, no state dam safety approvals are needed.
  - The outlet structure will be an improved sinkhole and will require registration as such.
- The following items are the site constraints related to the pond:
  - The proposed pond location is bounded on two sides (north and west) by existing streets. The design for high flow conditions must consider street flooding potential.
  - The proposed pond's principal spillway discharge will not impact roads or buildings downstream (and also off-site).

Example Design

- Determine the TSS reduction provided, using the equations below for weighted TSS reduction, $TSS_{weighted}$. The pocket pond BMP has an estimated 80% TSS removal. All runoff from impervious surfaces goes to the pocket pond.

$$\%TSS_{weighted} = \frac{(80 * 1.02\ acres) + (80 * 0.70\ acres)}{1.72\ acres} = 80\% \checkmark$$

Step 3 –Confirm site suitability, including field verification of site suitability.

- The site geotechnical investigation showed that proposed pond location was suitable for installing a pocket pond and that the nearby sinkhole drainage is not expected to adversely affect the ability to maintain a permanent pool here.
- The soil borings indicated that the underlying soils in the vicinity of the proposed pocket pond had limited infiltration capacity and that the high water elevation allowed a minimum 3-foot separation between the bottom of the pond and the high water elevation.
- No impermeable layers/lenses or bedrock was encountered during the geotechnical field evaluation of the site.
- The pond site's water balance will be based on 30-day drought conditions, and will check that the pond site is capable of supporting a wet pond.
    - The site's summer evapotranspiration (ET_s) amount is assumed at 8 inches
    - The summer infiltration (I_s) amount for the site is assumed at 7.2 inches
    - The pond water reservoir (RES) for factor of safety is assumed at 24 inches.
    - The site's summer baseflow (B_s) amount was measured, but the average design depth of the permanent pool did not include baseflow here for a conservative estimate of the average design depth.

$$DP > ET_s + I_s + RES + B_s$$

$$DP > 8\ inches + 7.2\ inches + 24\ inches + 0\ inches$$

$$DP > 39.2\ inches = 3.27\ feet$$

Step 4 – Compute runoff control volumes and peak flows. Refer to Chapter 2 and Appendix B for more information on these values.

- Calculate the Permanent Pool Volume (V_{PP}). Use A_W = 5 acres.

$$V_{PP} = 0.5\ inches * 5\ acres * \frac{1\ ft}{12\ inches} = 0.208\ acre - feet = 9075\ ft^3$$

- Calculate the Water Quality Volume (WQ_V).

Total Site WQ_v:

$$WQ_v = [(P\ R_v)(A)]/12$$

Example Design

Where:

P = 1.1 inches

$R_v = 0.05 + 0.009(I)$

I = 49

$R_v = 0.05 + 0.009(49) = 0.491$

A = 1.72 acres

WQ_v = (1.1in x 0.491 x 1.72ac)/12 = 0.077 acre-ft = **3373** ft^3

- For the Example Design, the proposed pocket pond will be assumed to be the only rate control for the site (i.e., assumes that no other BMPs reduce the runoff control volumes that are to be handled by the pocket pond).

Note: Steps 5 – 12 may be iterative to achieve a pond design that meets the required performance and the site constraints.

First Iteration

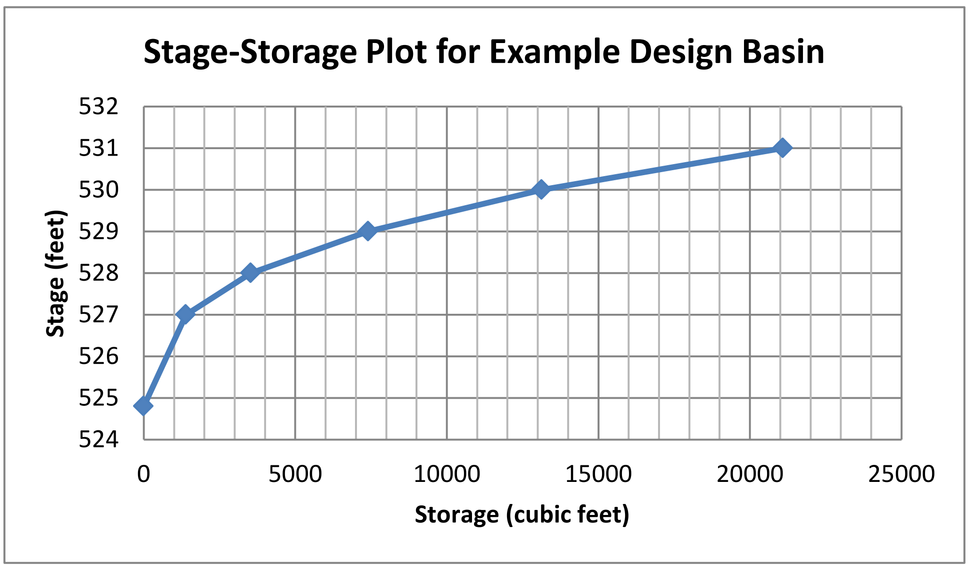
Step 5 – Determine the pond location and preliminary geometry.

- These items were used to develop the preliminary grading plan for the pond.
  - The pond's lowest elevation is not in a jurisdictional wetland. The maintenance access for the pond will be on the eastern side of the pond near the parking area. Additionally, the pond side slopes here are approximately 1.4% or 1:7 (V:H).
  - The pond bottom elevation is at 524.80 feet. This elevation will also be the invert for the permanent pool.
  - The pond is assumed to have sufficient storage for all required controlled discharges.
  - The outlet riser is centrally located in the pond, and cannot be moved farther away from the pond inlets due to the existing roadways nearby. The central riser location helps maximize the available length to width ratio.

Example Design

The proposed stage-storage relationships for the pond are summarized in the table and chart shown below:

Elevation E (ft)	Area A (square feet)	Average Area between Elevations	Average Area (ft^2)	Depth (Elevation Difference)	Incremental Volume (ft^3)	Cumulative Volume (ft^3)
524.8	0	NA – pond bottom	NA – pond bottom	NA – pond bottom	0	0
527	1266	524.8 ft & 527 ft	633	2.2	1392.6	1392.6
528	3024	527 ft & 528 ft	2145	1	2145	3537.6
529	4709	528 ft & 529 ft	3866.5	1	3866.5	7404.1
530	6744	529 ft & 530 ft	5726.5	1	5726.5	13130.6
531	9169	530 ft & 531 ft	7956.5	1	7956.5	21087.1



- One assumption for the pocket pond design is that 50% of WQ_v will be stored in the permanent pool. This means the added total storage for the permanent pool and the temporarily detained portion of WQ_v is about 10,762 ft^3 (Vpp + [50%WQ_v]). From the stage-storage plot (or linear interpolation from the table values), this total volume would be at approximate stage of 529.6 feet – about 1.4 feet from the top pond elevation.

- If a design objective is to control peak flows for larger storm events, the pond size will need to be increased to detain the added volume.

Example Design

- For the purposes of this Example Design, the detention storage for the larger storm events will be ignored and the pond footprint will not be enlarged.

➢ The expected permanent pool depth of 4.5 feet is greater than the permanent pool depth based on 30-day drought conditions (3.27 feet) from Step 3.

➢ The primary outlet elevation will be at the top of the permanent pool storage. From the stage-storage information, the primary outlet elevation is at 529.3 ft.

STEP 6 – Determine the pre-treatment volume for the sediment forebay.

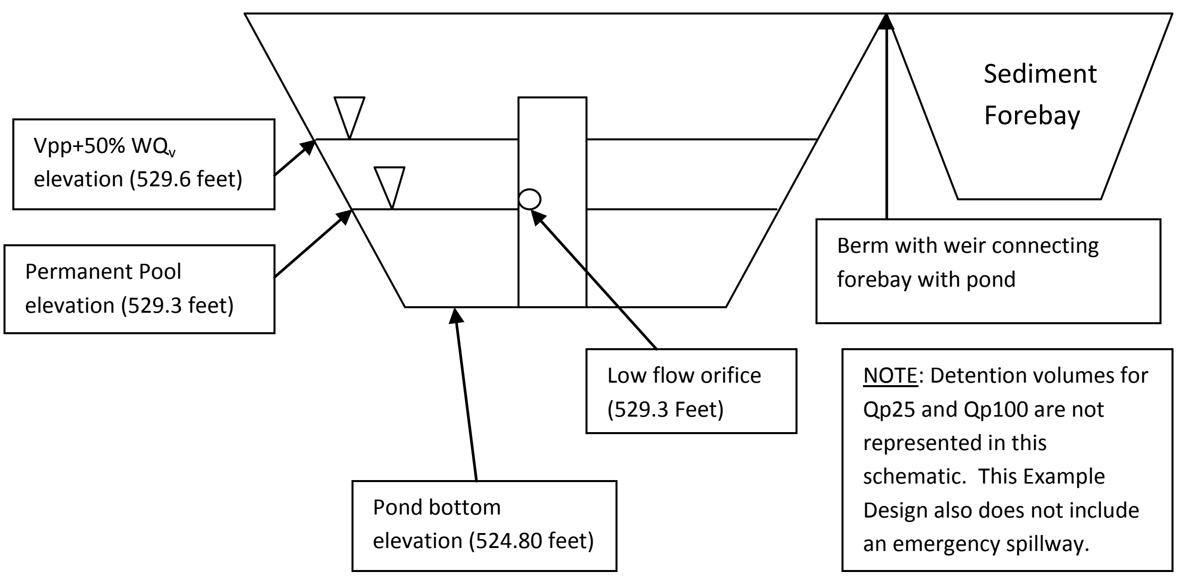
➢ This design example includes two sediment forebays – one for each of the two impervious drainage areas. These forebays do not include any added sediment load for pervious site areas (i.e., pervious areas are well-stabilized).

➢ The site's total sediment forebay storage should hold 10% of WQ_v, or about 338 ft^3.

➢ Forebay 1 receives drainage from Drainage Area 1 (1.02 acres). This forebay must be sized to hold 59% of the total forebay storage, or 200 ft^3 with a depth of 4 feet. The minimum surface area for Forebay 1 is 50 ft^2.

➢ Forebay 2 receives drainage from Drainage Area 2 (0.70 acres). This forebay must be sized to hold 41% of the total forebay storage, or 138 ft^3 with a depth of 4 feet. The minimum surface area for Forebay 2 is about 35 ft^2.

STEP 7 – Size and design the outlet structures.



➢ The assumed outlet structure will be a principal spillway riser that has a low flow orifice at the permanent pool elevation that will control the release of the detained portion of WQ_v. The example design will not include outlet calculations for the higher flow events.

➢ The low flow orifice design will release 50% of WQ_v with an average detention time of 24 hours.

Example Design

- The average release rate of the WQ_v (Q_{WQ_avg}) is calculated using the following equation:

$$Q_{WQ\_avg} = \frac{WQ_v}{t_{WQ}}$$

Where:

t_{WQ} = the intended WQ_v detention time = 24 hours = 86,400 seconds

WQ_v = 50% of WQ_v to be released = 1687 ft^3

Q_{WQ_avg} = average release rate of WQ_v (cfs)

$$Q_{WQ\_avg} = \frac{1687\ ft^3}{86400\ seconds} = 0.020\ cfs\ ✓$$

- From the stage-storage table, the elevation of the detained portion of WQ_v is at 529.6 feet.

  Calculate the approximate average head (in feet) on the water quality outlet (h_{wq_avg}) using the following equation:

$$h_{wq\_avg} = \frac{E_{WQ} - E_{PermPool}}{2}$$

Where:

E_{WQ} = 529.60 feet

$E_{PermPool}$ = 529.30 feet.

$$h_{wq\_avg} = \frac{0.60\ feet}{2} = 0.30\ feet ✓$$

- Calculate the required orifice cross-sectional area indirectly by using the orifice equation.

$$Q_{WQ\_avg} = CA_{WQ}\sqrt{2gh_{wq\_avg}}$$

Where:

Q_{WQ} = 0.020 cfs

C = the orifice coefficient (0.6 is typically used, but not apply for all cases)

A_{WQ} = the orifice area (square feet)

g = gravitational acceleration (32.2 feet/s^2)

Example Design

First, rearrange the orifice equation to solve for A_{WQ}.

$$A_{WQ} = \frac{Q_{wq\_avg}}{C\sqrt{2gh_{wq\_avg}}}$$

$$A_{WQ} = \frac{0.020\ cfs}{0.6\sqrt{2\left(32.2\frac{ft}{s^2}\right)(0.30\ feet)}} = 0.0076\ feet^2 ✓$$

- Calculate the orifice diameter using the following equation:

$$d_{WQ} = 2\sqrt{\frac{A_{WQ}}{\pi}}$$

Where:

d_{WQ} = the orifice diameter (feet)

$$d_{WQ} = 2\sqrt{\frac{0.0076\ ft^2}{3.14}} = 0.10\ feet ✓$$

$$d_{WQ} = 0.10\ feet = 1.18\ inches \approx 1\ inch$$

For the Example Design, the minimum allowed orifice diameter (1 inch) will be used. This device will require internal orifice protection. An alternate approach is to use an adjustable gate valve to achieve an equivalent orifice diameter.

- The rate of discharge for the orifice for any head value at the water quality orifice (h_{WQ}) can be calculated using:

$$Q_{WQ} = CA_{WQ}\sqrt{2gh_{WQ}}$$

Where:

Q_{WQ} = the orifice discharge rate at head h_{WQ} (cfs)

h_{WQ} = the head value above the water quality orifice (feet)

Using the range of values for h_{WQ} based on the elevations (E) up to E_{WQ} used in the pond's stage-storage relationship, the Q_{WQ} values are calculated for each corresponding value of h_{WQ}.

Elevation E (ft)	**h_{WQ} (feet)**	**Q_{WQ} (cfs)**
529.3	0	0
529.6	0.3	0.0144

Example Design

- Calculate the control for the 25-year, 24-hour runoff peak flow (Q_{P25}). The calculation procedures will be similar to those used for the low flow orifice except that any higher outflow openings (i.e., perforated riser openings, weir, orifices, etc.) would be included as well. The combined outflow from all openings must be such that the post-development Q_{P25} does not exceed the pre-development Q_{P25}.

  This Example Design will not include calculations for control for the 25-year, 24-hour peak flow. However, the pond's ability to meet the requirements for post-development Q_{P25} would need to be checked for an actual design.

- The combined outflow from the low flow orifice and any higher outflow openings is calculated by adding together the discharges from each structures associated with a given head value and a specified pond water surface elevation.

  The combined outflow would be calculated for all of the outflow openings to check that the pond meets the requirements for controlling the post-development Q_{P25}.

- Calculate the required control for the 100-year storm peak flow (Q_{p100}). If required, the post-development Q_{p100} must be no greater than the pre-development Q_{p100}. At minimum, Q_{p100} must be able to be safely passed through the pond with 1-2 feet of freeboard below the top of the embankment. Check with local officials and/or state dam safety personnel to determine whether Q_{p100} may be passed using only a principal spillway, or if an emergency spillway will be required. If an emergency spillway is required, the spillway type is often a broad-crested weir or similar structure that is not susceptible to obstruction. For calculating the combined outflow through all spillway openings, the combined outflow may be calculated by adding together the discharges for each opening associated with a given head value and a specified water surface elevation.

- Using the determined opening and spillway information, incorporate the outlet structures into the pond design. Keep in mind that the spillway design must also consider using measures such as removable trash racks to prevent the discharge of floating debris.

  The outlet openings and spillways are then added into the pond design. Other measures such as removable trash racks are also added to the design.

STEP 8 – Design the spillways and embankments.

- The Example Design pond will target passing all required flows through the principal spillway, and will not be required to include an emergency spillway.

STEP 9 – Design the inlets.

- The Example Design pond uses inflow inlet pipes from the upstream impervious areas to the pond. These inflow inlet pipes are designed to be buried below the frost line. The designer should consider winter freeze conditions and how the inlets would be affected since these discharge to a permanent pool.

Example Design

STEP 10 – Design the sediment forebays.

- The two sediment forebay sizes were determined in Step 6.
- The forebay bottoms will be hardened to allow for easier sediment removal.
- Each forebay will be equipped with a fixed vertical sediment depth marker to gauge when sediment removal is needed.

STEP 11 – Design the maintenance access and safety features.

- All maintenance access and safety features are designed in this step. The removable trash racks on the spillway riser will also function to prevent unauthorized access to the riser. The riser's pipe diameter will include bars across the pipe outlet to prevent unauthorized access if the pipe diameter is over 3 feet.

STEP 12 – Check the expected pond performance against regulatory requirements.

- The pond design should be re-checked to confirm that the pond meets the flow control requirements.
- The release rate for WQ_v should not exceed 5.66 cfs per acre of pond surface area. Calculate the flow rate and pond surface area associated with each available elevation and head value up to E_{WQ}. The maximum release rate for WQ_v will then be calculated using the pond surface area at each given elevation and head value, and the actual release rate will be compared with the maximum release rate.

Elevation E (ft)	h_{WQ} (feet)	Q_{WQ} (cfs)	Pond Surface Area at E (sq ft)	Pond Surface Area at E (acres)	Release rate (based on Q_{WQ} per acre of surface area) (cfs/acre)
529.3	0	0.000	0	0	0
529.6	0.3	0.014	1266	0.0291	0.49 ✓

The release rate in the last column of the table is checked to confirm whether the actual pond release rate exceeds 5.66 cfs per acre of surface area. All values are below the target value of 5.66 cfs per acre.

- The expected average detention time for WQ_v is 24 hours. Calculate the average release rate for the pond (Q_{WQ_avg}). Use WQ_v and Q_{WQ_avg} to calculate the actual average detention time for the pond. The required target detention time for WQ_v is 24 hours.

$$Q_{WQ\_avg} = \frac{0+0.014}{2} = 0.007 \text{ cfs}$$

$$t_{WQ} = \frac{WQ_v}{Q_{WQ\_avg}} = \frac{1686.5ft^3}{0.007cfs} = 240858 \text{ seconds} = 66.9 \text{ hours} ✓$$

Example Design

The actual value of t_{WQ} is over two times greater than the required 24 hours. The 1-inch diameter orifice used for the pond design is smaller than the calculated orifice size (diameter of 1.10 inches) from earlier in the Design Procedure. The smaller orifice gives a conservative design with a higher detention time for WQ_v. However, it may not be desirable to have an average detention time for the detained portion of WQv that exceeds 48 hours.

Second Iteration

If the calculated detention time for WQ_v is determined to be too long, a second iteration may be performed to attempt to improve the design. Examples of modifications that could help reduce the detention time for WQ_v include:

- Adjusting the pond configuration to try to get the detention time closer to 24 hours.
- Using an adjustable gate valve to allow the low flow orifice size to be increased above 1 inch.
- Subtracting the portions of WQ_v in the sediment forebays from the pond storage. This subtraction would decrease the required pond volume. It may also be desirable to increase the forebay sizes.

The Example Design will not include the final three design steps (Steps 13-15), but these steps would be incorporated into a full pond design.

STEP 13 – Prepare the vegetation and landscaping plan.

STEP 14 – Prepare the operation and maintenance plan.

STEP 15 – Complete the Design Summary Table.

Design Parameter	Required Size	Actual Size
Pond Type	Pocket Pond	
Vpp	10,762 ft^3 (Vpp + 50%WQ_v)	
Permanent Pool Elevation	529.3 ft	529.3 ft
WQv	3373 ft^3	3373 ft
WQv Elevation	529.6 ft	529.6 ft
Forebay	Forebay 1: 50ft^2 x 4ft Forebay 2: 35ft^2 x 4ft	Forebay 1: 10'x5'x4' Forebay 2: 7'x5'x4'
WQv orifice	1 inch	1 inch with hood