5.4.2 Wet Pond

Description: Wet ponds consist of a permanent pool of standing water that promotes pollutant removal through gravitational settling, biological uptake and microbial activity. Runoff from each new storm enters the pond and partially displaces pool water from previous storms. The pool also acts to minimize re-suspension of sediments and other pollutants deposited during prior storms. When sized properly, wet ponds have a permanent pool residence time that ranges from many days to several weeks, which allows numerous pollutant removal mechanisms to operate.

Figure 1: Wet pond with permanent pool storage and temporary detention in a residential setting (Source: SMART Center).

Feasibility:
- Contributing impervious drainage area of 10-25 acres.
- Available space

Key Design Criteria:
- **Space required:** typically 1%-3% of the CDA.
- Other design criteria include soils, landscaping/plant selection, slope, outlet structure and safety.

Site Constraints:
- **Available hydraulic head:** 6-8 feet
- **Soils:** HSG C and D to maintain permanent pool; HSG A and B need a liner.
- **Minimum setbacks from:**
  Property lines: 20 feet
  Building foundations: 25 feet
  Septic system and private wells: 100 feet
- **Karst:** not recommended in or near karst terrain

Maintenance:
- Remove debris and blockages
- Repair undercut, eroded, and bare soil areas
- Mowing embankment
- Forebay Sediment Removal
- Repair pipes as needed

Advantages:
- Maximize nutrient removal
- Ponds do not consume a large area relative to the drainage size of the watershed
- Can be used as an aesthetic amenity
- Increased biodiversity
- Reduces channel/stream erosion
- Opportunity for multiple use

Disadvantages:
- There is no runoff volume reduction credit for this SCM because of limited infiltration
- Project may be required to comply with TN Safe Dam regulation
- Large space requirement
- Safety concerns
- Not to be used in areas of high groundwater table

Design Checklist:
- ❑ Check soil type and depth to water table and bedrock, and determine whether liner is needed
- ❑ Determine which design is suitable for the project.
- ❑ Check Wet Pond sizing guidance.
- ❑ Select erosion control measures
- ❑ Prepare landscape plan

1. Design

Designers should note that a wet pond is typically the final element in the "roof-to-stream pollutant removal "sequence" and provides no volume reduction credit, and **should therefore be considered only if there is remaining pollutant removal or Channel Protection Volume to manage after all other upland runoff reduction options have been considered and properly evaluated.**

In instances where a wet pond is proposed as an aesthetic amenity, the design parameters contained here represent good engineering design to maintain a healthy pond. The treatment volume requirements for water quality and detention requirements for channel protection may be more economically met through the upstream runoff reduction practices; however, the basic wet pond features related to aesthetics (pool volume and geometry) and safety (aquatic and safety benches, side slopes, maintenance, etc.) remain as important neighborhood or site design features.

There is no runoff volume reduction credit for wet ponds since the runoff reduction pathways of infiltration and extended filtration are generally limited. The wet pond functions as a basin that generally discharges a volume equivalent to the entire inflow runoff volume.

1.1 Design Guidance

Single Pond Cell (with forebay) or a Multiple Cell Design (see **Section 1.8**)
Length/Width ratio OR Flow path = 2:1 or more; Length of shortest flow path/overall length = 0.8 or more (see **Section 1.6**)
Standard aquatic benches or wetlands more than 10% of pond area (see **Section 1.6**)
Turf in pond, trees, shrubs, and herbaceous plants in pond buffers; Shoreline landscaping to discourage geese (see **Section 1.10**)
Aeration (preferably bubblers that extend to or near the bottom or floating islands (see **Section 1.11**)

1.2 Physical Feasibility

Space Required	The surface area of a wet pond will normally be at least 1% to 3 % of its contributing drainage area, depending on the impervious cover, pond geometry, etc.
Contributing Drainage Area (CDA)	A contributing drainage area of 10 to 25 acres or more is typically recommended for wet ponds to maintain a healthy permanent pool. Wet ponds can still function with drainage areas less than 10 acres, but designers should be aware that these "pocket" ponds will be prone to clogging and experience extreme fluctuations in seasonal water levels and be susceptible to creating nuisance conditions. A water balance should be calculated to assess whether the wet pond will draw down by more than 2 feet after a 30-day summer drought (see **Section 1.5**).
Available Hydraulic Head	The depth of a wet pond is usually determined by the hydraulic head available on the site. The bottom elevation is normally the invert of the existing downstream conveyance system to which the wet pond discharges. Typically, a minimum of 6 to 8 feet of head are needed for a wet pond to function.
Minimum Setbacks	Local subdivision and zoning ordinances and design criteria should be consulted to determine minimum setbacks for impoundments to property lines, structures, and wells. Generally, wet ponds should be set back at least 20 feet from property lines, 25 feet from building foundations, 50 feet from septic system fields and 100 feet from private wells. Setbacks are measured from the toe of the embankment on the downstream side and the design high water on the upstream side.

Depth-to-Water Table and Bedrock	Shallow water table or depth to bedrock may make excavation difficult and expensive. Groundwater inputs can also reduce the pollutant removal rates of wet ponds. Refer to Chapter 3.3 for design variations when encountering high water table, bedrock, or karst topography.
Soils	Highly permeable soils make it difficult to maintain a constant level for the permanent pool. Soil explorations should be conducted at proposed pond sites to identify soil infiltration and the presence of karst topography. Underlying soils of Hydrologic Soil Group (HSG) C or D should be adequate to maintain a permanent pool. Most group A soils and some group B soils will require a liner in order to maintain the permanent pool. A wet pond should be the option of last resort if karst topography is present. Refer to Chapter 3.3 and Appendix B for additional guidance when designing near karst topography. At a minimum, an impermeable clay or (preferably) geosynthetic liner will be required. Geotechnical explorations should also be conducted at the proposed pond embankment to properly design the embankment cut-off trench and fill material.
Karst	Wet ponds are not recommended in or near karst terrain. An alternative practice or combination of practices should be employed at the site.
Trout Streams	The use of wet ponds in watersheds containing trout streams is strongly discouraged because the discharge can cause stream temperature warming.
Use of or Discharges to Natural Wetlands	It can be tempting to construct a wet pond within an existing natural wetland, but wet ponds cannot be located within jurisdictional waters, including wetlands, without obtaining a section 404 permit from the appropriate state or federal regulatory agency. In addition, the designer should investigate the wetland status of adjacent areas to determine if the discharge from the wet pond will change the hydroperiod of a downstream natural wetland (see Cappiella et al., 2006b, for guidance on minimizing stormwater discharges to existing wetlands).
Perennial streams	Locating wet ponds on perennial streams is typically not allowed and will require both a Section 401 and Section 404 permit from the appropriate state or federal regulatory agency.

1.3 Design Applications

Wet ponds are applicable for most land uses and are best suited for larger development projects due to the large footprint required. While the pollutant reduction credit of a wet pond may be adequate to achieve compliance, it is recommended to use upland runoff reduction SCMs such as rooftop disconnections, small-scale infiltration, rainwater harvesting, bioretention, grass channels and dry swales that reduce runoff volume at its source (rather than merely treating runoff at the terminus of the storm drain system). Upland runoff reduction practices can be used to satisfy some or all of the water quality requirements at many sites, which can help to reduce the footprint and volume of wet ponds.

The use of upland runoff reduction features may give designers the flexibility to select the most practical design configuration. The design configurations, as illustrated in Figure 2, below include:

- Wet pond with 100% of the permanent pool in a single cell.
- Wet Extended Detention and/or multi-cell wet pond meeting additional requirements for pond geometry, landscaping, etc.
- Pond/Wetland Combination (see Section 5.4.11 for additional guidance on the design of the wetland element).

1.4 Typical Details

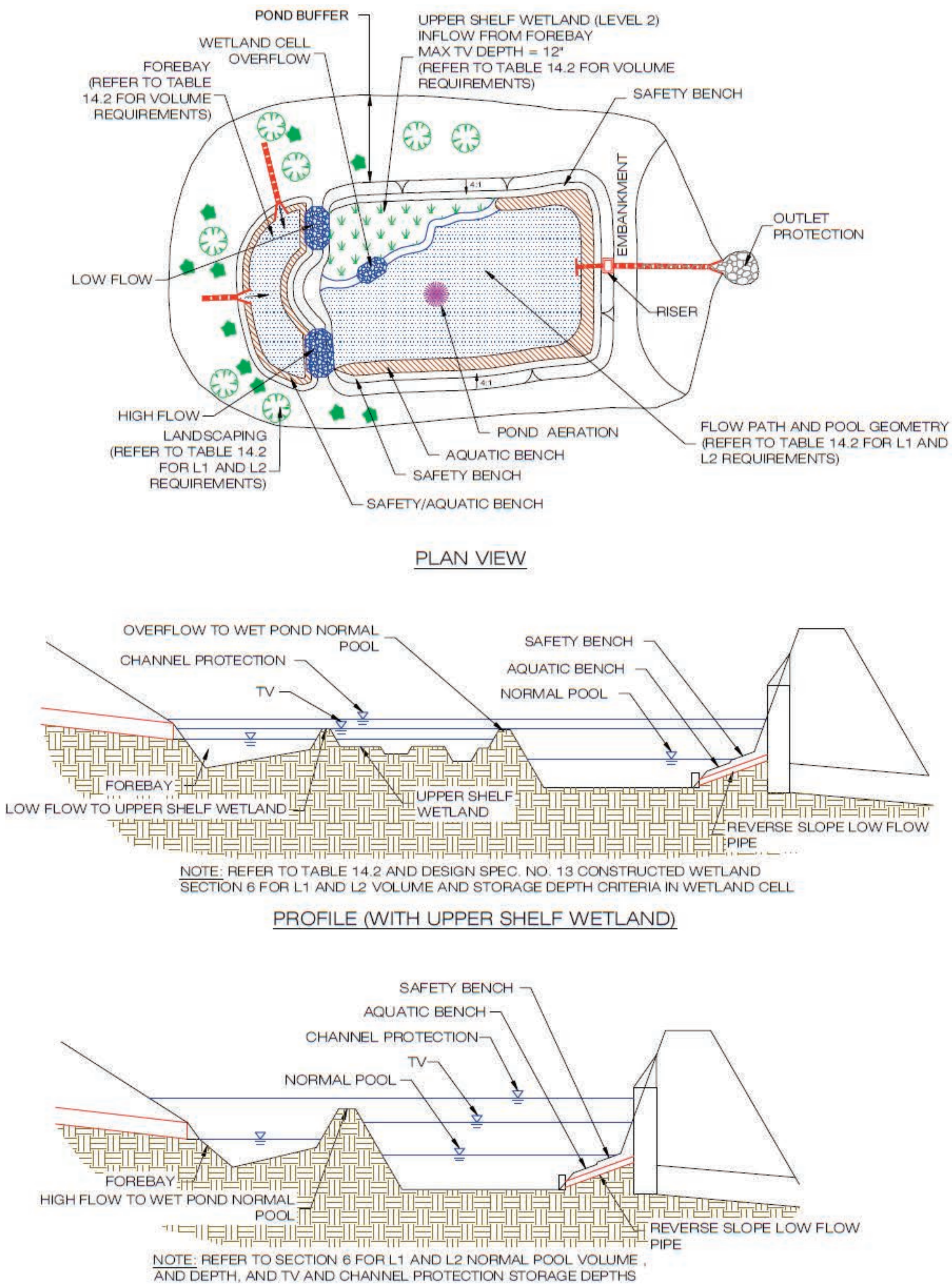

Figure 2: Wet Pond Design Schematics (Source: Virginia).

1.5 Design Calculations

1.5.1 Sizing

A wet pond is comprised of a permanent pool, multiple permanent pool cells, or a combination of the permanent pool and extended detention storage. The design goal is two-fold: 1) store the pollutant removal volume in the permanent pool, and 2) provide temporary storage above the permanent pool elevation for attenuation of large storm events. The permanent pool volume must be equal to 100% of the treatment volume. Stormwater runoff from the representative storm event displaces water already in the pool. See Chapter Section 5.4.1 Dry Detention for sizing specifications for temporary storage above permanent pool elevation. Research has demonstrated that larger wet ponds with longer residence times enhance algal uptake and nutrient removal rates (CWP 2008), therefore oversizing this practice is allowed as long as adequate water balance estimates are determined and the design minimizes nuisance species and safety concerns.

Sizing using the TNRRAT is strongly encouraged. If alternative sizing methods are employed, then it is up to the designer to justify the appropriateness of the selected method and provide sufficient design calculations to support the design.

Other Design Variants: Wet ponds can be designed to promote runoff volume reduction through water reuse (e.g., pumping pond water back into the contributing drainage area for use in seasonal landscape irrigation). While this practice is not common, it has been applied to golf course ponds, and accepted computational methods are available (Wanielista and Yousef, 1993 and McDaniel and Wanielista, 2005). It is recommended that designers be allowed to take credit for annual runoff reduction achieved by pond water reuse, as long as acceptable modeling data is provided for documentation.

Treatment Volume Storage. The permanent pool volume equal to the Treatment Volume can consist of the forebay (or multiple forebays as needed) and the main pool. A minimum depth of 4 feet and a maximum depth of 6 feet are recommended. The minimum depth encourages proper mixing while a maximum depth helps to minimize stratification and an imbalance between pool volume and surface area.

The wet pond can consist of multiple cells or an extended detention (ED) storage above the permanent pool. When incorporating multiple cells, wet ponds with a single inflow point and forebay may count the forebay as one cell; (however, multiple forebays do not count as multiple cells). The remaining Runoff Reduction Volume should be divided among the remaining cells and may include a wetland cell and a deep pool cell.

Maximum Extended Detention Levels. The maximum extended detention volume may not extend more than 12 inches above the wetland cell permanent pool at its maximum water surface elevation. The maximum ED and channel protection detention levels can be up to 5 feet above the wet pond permanent pool.

Water Balance Testing. A water balance calculation is recommended to document that sufficient inflows to the pond exist to compensate for combined infiltration and evapotranspiration losses during a 30-day summer drought without creating unacceptable drawdowns (Equation 1, adapted from Hunt et al., 2007). The recommended minimum pool depth to avoid nuisance conditions may vary; however, it is generally recommended that the water balance maintain a minimum 24-inch reservoir.

Water Balance Equation for Acceptable Water Depth in a Wet Pond

Equation 1

$$DP > ET + INF + RES - MB$$

Where:

- ***DP*** = Average design depth of the permanent pool (inches)
- ***ET*** = Summer evapotranspiration rate (inches) (assume 8 inches)
- ***INF*** = Monthly infiltration loss (assume 7.2 @ 0.01 inch/hour)
- ***RES*** = Reservoir of water for a factor of safety (assume 24 inches)
- ***MB*** = Measured baseflow rate to the pond, if any (convert to inches)

Design factors that will alter this equation are the measurements of seasonal base flow and infiltration rate. The use of a liner could eliminate or greatly reduce the influence of infiltration. Similarly, land use changes in the upstream watershed could alter the base flow conditions over time.

Translating the baseflow to inches refers to the depth within the pond. Therefore, the following equation can be used to convert the baseflow, measured in cubic feet per second (ft^3/s), to pond-inches:

Equation 2

$$\text{Pond inches} = ft^3/s * (2.592E6) * (12''/ft) / \text{SA of Pond } (ft^2)$$

Where:

- ***2.592E6*** = Conversion factor: ft^3/s to ft^3/month
- ***SA*** = surface area of pond in ft^2

1.6 Internal Design Geometry

Side Slopes. Side slopes for the wet pond should generally have a gradient of 4:1 to 5:1. The mild slopes promote better establishment and growth of vegetation and provide for easier maintenance and a more natural appearance.

Long Flow Path. Wet pond designs should have an irregular shape and a long flow path from inlet to outlet to increase water residence time and pond performance. In terms of flow path geometry, there are two design considerations: (1) the overall flow path through the pond, and (2) the length of the shortest flow path (Hirschman et al., 2009).

- The overall flow path can be represented as the length-to-width ratio OR the flow path ratio. These ratios must be at least 2L:1W. Internal berms, baffles, or vegetated peninsulas can be used to extend flow paths and/or create multiple pond cells.
- The shortest flow path represents the distance from the closest inlet to the outlet. The ratio of the shortest flow to the overall length must be at least 0.5. In some cases – due to site geometry, storm sewer infrastructure, or other factors – some inlets may not be able to meet these ratios. However, the drainage area served by these "closer" inlets should constitute no more than 20% of the total contributing drainage area.

Safety Features. Several design features of impounding structures are intended to provide elements of safety. The perimeter of all pool areas greater than 4 feet in depth must be surrounded by two benches, as follows:

- A ***Safety Bench*** is a minimum 10-foot wide bench with a minimal cross slope (2%) located immediately above and adjacent to the permanent pool. A safety bench is not necessary if the stormwater pond side slopes above the permanent pool are 5H:1V or flatter.
- An ***Aquatic Bench*** is a shallow area just inside the perimeter of the normal pool that promotes growth of aquatic and wetland plants. The bench also serves as a safety feature, reduces shoreline erosion, and conceals floatable trash. The aquatic bench extends 10 feet inward from the permanent pool shoreline, from a depth of 0 to 18 inches (maximum) below the normal pool water surface elevation.

- Both the safety bench and the aquatic bench should be landscaped with vegetation that hinders or prevents access to the pool. Thick shoreline vegetation also serves to discourage geese.
- The principal spillway opening must be designed and constructed to prevent access by small children.
- End walls above pipe outfalls greater than 48 inches in diameter must be fenced to prevent a fall hazard. Local stormwater program should be consulted.
- An emergency spillway and associated freeboard must be provided in accordance with applicable local or state dam safety requirements. The emergency spillway must be located so that downstream structures will not be impacted by spillway discharges.
- Warning signs prohibiting swimming should be posted.

1.7 Required Geotechnical Testing

Soil borings should be conducted within the footprint of the proposed embankment, in the vicinity of the proposed outlet structure, and in at least two locations within the proposed wet pond treatment area. Soil boring data is needed to (1) determine the physical characteristics of the excavated material to determine its adequacy as structural fill or other use, (2) determine the need and appropriate design depth of the embankment cut-off trench; (3) provide data for structural designs of the outlet works (e.g., bearing capacity and buoyancy), (4) determine the depth to groundwater and bedrock and (5) evaluate potential infiltration losses (and the potential need for a liner).

1.8 Pretreatment Forebay

Sediment forebays are considered to be an integral design feature to maintain the longevity of all wet ponds. A forebay must be located at each major inlet to trap sediment and preserve the capacity of the main treatment cell. A major inlet is defined as one that carries runoff from 10% or more of the total contributing area. Pre-treatment and inlet design must be sufficient as to not create erosion potential and to maximize sediment deposition. See Section 5.5 for design guidance on inlets and pre-treatment.

1.9 Conveyance and Overflow

Internal Slope. The longitudinal slope of the pond bottom should be at least 0.5% to 1%.

Principal Spillway. The principal spillway shall be designed with acceptable anti-flotation, anti-vortex and trash rack devices. The spillway must generally be accessible from dry land.

Non-Clogging Low Flow Orifice. A low flow orifice must be provided that is adequately protected from clogging by either an acceptable external trash rack or by internal orifice protection that may allow for smaller diameters. Orifices less than 3 inches in diameter may require extra attention during design, to minimize the potential for clogging. There are many design options including, but not limited to:

- A submerged reverse-slope pipe that extends downward from the riser to an inflow point 1 foot below the normal pool elevation.
- Alternative methods may employ a broad crested rectangular or V-notch (or proportional) weir, protected by a half-round CMP that extends at least 12 inches below the normal pool elevation.

Emergency Spillway. Wet ponds must be constructed with overflow capacity to pass the 100-year design storm event through either the Primary Spillway (with two feet of freeboard to the settled top of embankment) or a vegetated or armored Emergency Spillway (with at least one foot of freeboard to the settled top of embankment).

Pond Drain. Wet ponds should be equipped with a drain pipe that can completely or partially drain the permanent pool. In cases where a low level drain is not feasible (such as in an excavated pond, or a pond in the coastal plain where a low level outlet is available), a pump wet well should be provided to accommodate a temporary pump intake when needed to drain the pond.

- The drain pipe should have an upturned elbow or protected intake within the pond, to prevent sediment deposition, and a diameter capable of draining the pond within 24 hours.
- The pond drain must be equipped with an adjustable valve located within the riser, where it will not be normally inundated and can be operated in a safe manner.

Adequate Outfall Protection. The design must specify an outfall that will be stable for the maximum (pipe-full) design discharge (the 10-year design storm event or the maximum flow when surcharged during the emergency spillway design event, whichever is greater). The channel immediately below the pond outfall must be modified to prevent erosion and conform to natural dimensions in the shortest possible distance. Outlet protection should be provided consistent with state or local guidance.

Inlet Protection. Inlet areas should be stabilized to ensure that non-erosive conditions exist during storm events up to the overbank flood event (i.e., the 10-year storm event). Inlet pipe inverts should generally be located at or slightly below the permanent pool elevation.

Dam Safety Permits. Wet ponds with high embankments or large drainage areas and impoundments may be regulated under the Tennessee Safety Dam Act.

1.10 Landscaping and Planting Plan

A landscaping plan must be provided that indicates the methods used to establish and maintain vegetative coverage in the pond and its buffer. Minimum elements of a plan include the following:

- Delineation of pondscaping zones within both the pond and buffer
- Selection of corresponding plant species
- The planting plan
- The sequence for preparing the wetland benches (including soil amendments, if needed)
- Sources of native plant material
- The landscaping plan should provide elements that promote diverse wildlife and waterfowl within the stormwater wetland and buffers. **However, to the extent possible, the aquatic and safety benches should be planted with dense shoreline vegetation to help establish a safety barrier, as well as discourage resident geese.**
- Woody vegetation may not be planted or allowed to grow within 15 feet of the toe of the embankment nor within 25 feet from the principal spillway structure.
- A vegetated buffer of native plants that requires minimal maintenance should be provided that extends at least 25 feet outward from the maximum water surface elevation of the wet pond. Permanent structures (e.g., buildings) should not be constructed within the buffer area. Existing trees should be preserved in the buffer area during construction.
- The soils in the stormwater buffer area are often severely compacted during the construction process, to ensure stability. The density of these compacted soils can be so great that it effectively prevents root penetration and, therefore, may lead to premature mortality or loss of vigor. As a rule of thumb, planting holes should be three times deeper and wider than the diameter of the root ball for ball-and-burlap stock, and five times deeper and wider for container-grown stock.
- Avoid species that require full shade, or are prone to wind damage. Extra mulching around the base of trees and shrubs is strongly recommended as a means of conserving moisture and suppressing weeds.

For more guidance on planting trees and shrubs in wet pond buffers, see Appendix D of this manual.

1.11 Maintenance Features

The following wet pond maintenance criteria should be addressed during the design, in order to facilitate on-going maintenance:

- ***Maintenance Access.*** Good access is needed so crews can remove sediments, make repairs and preserve pond treatment capacity.
  - Adequate maintenance access must extend to the forebay, safety bench, riser, and outlet structure and must have sufficient area to allow vehicles to turn around.
  - The riser should be located within the embankment for maintenance access, safety and aesthetics. Access to the riser should be provided by lockable manhole covers and manhole steps within easy reach of valves and other controls.

- Access roads must (1) be constructed of materials that can withstand the expected frequency of use, (2) have a minimum width of 12 feet, and (3) have a profile grade that does not exceed 15%. Steeper grades are allowable if appropriate stabilization techniques are used, such as a gravel road.
- A maintenance right-of-way or easement must extend to the stormwater pond from a public or private road.

- ***Pond Aerators.*** Electric or mechanical aeration is used to place as much oxygen into contact with water as economically practical. This can be accomplished by mixing large quantities of water (both volume and total surface area) with atmospheric oxygen. Aerators can be utilized on a continuous, seasonal, or temporary basis as needed to maintain minimum oxygen levels. Several different types and scales of aeration devices are available. Most aeration equipment will require electricity at the pond bank.

1.12 Wet Pond Material Specifications

Wet ponds are generally constructed with materials obtained on-site, except for the plant materials, inflow and outflow devices (e.g., piping and riser materials), possible stone for inlet and outlet stabilization, filter fabric for lining banks or berms, and a liner when required.

- ***Liners.*** When a stormwater pond is located over highly permeable soils or fractured bedrock, a liner may be needed to sustain a permanent pool of water. If geotechnical tests confirm the need for a liner, acceptable options include the following: (1) a clay liner following the specifications outlined in **Table 1** below; (2) a 30 mil poly-liner; (3) bentonite; (4) use of chemical additives; or (5) an engineering design, as approved on a case-by-case basis by the local review authority. A clay liner should have a minimum thickness of 12 inches with an additional 12-inch layer of compacted soil above it, and it must meet the specifications outlined in **Table 1**. Other synthetic liners can be used if the designer can supply supporting documentation that the material will achieve the required performance.

Table 1: Clay Liner Specifications (Source: VADCR, 1999).

Property	Test Method	Unit	Specification
Permeability	ASTM D-2434	Cm/sec	1 x 10^{-6}
Plasticity Index of Clay	ASTM D-423/424	%	Not less than 15
Liquid Limit of Clay	ASTM D-2216	%	Not less than 30
Clay Particles Passing	ASTM D-422	%	Not less than 30
Clay Compaction	ASTM D-2216	%	95% of standard proctor density

1.13 Regional & Special Case Design Adaptations

Karst Terrain

Designers should always conduct geotechnical investigations in areas of karst terrain to assess this risk and rule out the presence of karst during the project planning stage. If these studies indicate that less than 3 feet of vertical separation exists between the bottom of the ED pond and the underlying soil-bedrock interface, ED ponds should not be used due to the risk of sinkhole formation, groundwater contamination, and frequent facility failures (see Appendix B). At a minimum, designers must specify the following:

- A minimum of 6 feet of unconsolidated soil material exists between the bottom of the basin and the top of the karst layer.
- Maximum temporary or permanent water elevations within the basin do not exceed 6 feet.

- Annual maintenance inspections must be conducted to detect sinkhole formation. Sinkholes that develop should be reported immediately after they have been observed, and should be repaired, abandoned, adapted or observed over time following the guidance prescribed by the appropriate local or state groundwater protection authority (see Chapter 3.3 and Appendix B)
- A liner is installed that meets the requirements outlined in Table 2.

Table 2: Required Groundwater Protection Liners for Ponds in Karst Terrain (WVDEP, 2006 and VADCR, 1999).

Situation	Criteria
Pond not excavated to bedrock	24 inches of soil with a maximum hydraulic conductivity of 1 x 10-5 cm/sec.
Pond excavated to or near bedrock	24 inches of clay[1] with a maximum hydraulic conductivity of 1 x 10-6 cm/sec.
Pond excavated to bedrock within a wellhead protection area, in a recharge area for a domestic well or spring, or in a known faulted or folded area	Synthetic liner with a minimum thickness of 60 mil.

1 Clay properties as follows:
Plasticity Index of Clay = Not less than 15% (ASTM D-423/424)
Liquid Limit of Clay = Not less than 30% (ASTM D-2216)
Clay Particles Passing = Not less than 30% (ASTM D-422)

Steep Terrain

The use of wet ponds is highly constrained at development sites with steep terrain. Some adjustment can be made by terracing pond cells in a linear manner, using a 1- to 2-foot armored elevation drop between individual cells. Terracing may work well on longitudinal slopes with gradients up to approximately 10%.

Cold Climate and Winter Performance

Pond performance decreases when snowmelt runoff delivers high pollutant loads. Ponds can also freeze in the winter, which allows runoff to flow over the ice layer and exit without treatment. Inlet and outlet structures close to the surface may also freeze, further diminishing pond performance. Salt loadings are higher in cold climates due to winter road maintenance. The following design adjustments are recommended for wet ponds installed in higher elevations and colder climates:

- Treat larger runoff volumes in the spring by adopting seasonal operation of the permanent pool (see MSSC, 2005).
- Plant salt-tolerant vegetation in pond benches.
- Do not submerge inlet pipes, and provide a minimum 1% pipe slope to discourage ice formation.
- Locate low flow orifices so they withdraw at least 6 inches below the typical ice layer.
- Place trash racks at a shallow angle to prevent ice formation.
- Oversize riser and weir structures to avoid ice formation and pipe freezing.
- If winter road sanding is prevalent in the contributing drainage area, increase the forebay size to accommodate additional sediment loading.

Linear Highway Sites

Wet ponds are poorly suited to treat runoff within open channels located in the highway right of way, unless storage is available in a cloverleaf interchange or in an expanded right-of-way. Guidance for pond construction in these areas is provided in Profile Sheet SR-5 in Schueler et al (2007).

2. Construction

2.1 Construction Sequence

The following is a typical construction sequence to properly install a wet pond. The steps may be modified to reflect different wet pond designs, site conditions, and the size, complexity and configuration of the proposed facility.

Step 1: Install E&S Controls prior to construction, including temporary de-watering devices and stormwater diversion practices. All areas surrounding the pond that are graded or denuded during construction must be planted with turf grass, native plantings, or other approved methods of soil stabilization.

Step 2: Use of Wet Pond as an E&S Control. A wet pond may serve as a sediment basin during project construction. If this is done, the volume should be based on the more stringent sizing rule (erosion and sediment control requirement vs. water quality treatment requirement). Installation of the permanent riser should be initiated during the construction phase, and design elevations should be set with final cleanout of the sediment basin and conversion to the post-construction wet pond in mind. The bottom elevation of the wet pond should be lower than the bottom elevation of the temporary sediment basin. Appropriate procedures should be implemented to prevent discharge of turbid waters when the basin is being converted into a wet pond.

Step 3: Stabilize the Drainage Area. Wet ponds should only be constructed after the contributing drainage area to the pond is completely stabilized. If the proposed pond site will be used as a sediment trap or basin during the construction phase, the construction notes should clearly indicate that the facility will be de-watered, dredged and re-graded to design dimensions after the original site construction is complete.

Step 4: Assemble Construction Materials on-site, make sure they meet design specifications, and prepare any staging areas.

Step 5: Clear and Strip the project area to the desired sub-grade.

Step 6: Excavate the Core Trench and Install the Spillway Pipe.

Step 7: Install the Riser or Outflow Structure, and ensure the top invert of the overflow weir is constructed level at the design elevation.

Step 8: Construct the Embankment and Any Internal Berms in 8- to 12-inch lifts, or as directed by geotechnical recommendations, and compact as required with appropriate equipment.

Step 9: Excavate/Grade until the appropriate elevation and desired contours are achieved for the bottom and side slopes of the pond.

Step 10: Construct the Emergency Spillway in cut or structurally stabilized soils.

Step 11: Install Outlet Protection, including emergency and primary outlet apron protection.

Step 12: Stabilize Exposed Soils with temporary seed mixtures appropriate for the pond buffer. All areas above the normal pool elevation should be permanently stabilized by hydroseeding or seeding over straw.

Step 13: Plant the Pond Buffer Area, following the pondscaping plan (See Section 1.10).

2.2 Construction Inspection

Multiple inspections are critical to ensure that stormwater ponds are properly constructed. Inspections are recommended during the following stages of construction:

- Pre-construction meeting
- Initial site preparation (including installation of E&S controls)
- Excavation/Grading (interim and final elevations)
- Installation of the embankment, the riser/primary spillway, and the outlet structure
- Implementation of the pondscaping plan and vegetative stabilization
- Final inspection (develop a check list for facility acceptance)

An example of a construction phase inspection checklist for wet ponds is available in Section 5 of this specification.

In order to facilitate and anticipate maintenance, contractors should measure the actual constructed pond depth at three areas within the permanent pool (forebay, mid-pond and at the riser), and they should mark and geo-reference them on an as-built drawing. This simple data set will enable maintenance inspectors to determine pond sediment deposition rates in order to schedule sediment cleanouts.

3. Maintenance

3.1 Agreements

The Tennessee MS4 permit specifies the circumstances under which a maintenance agreement must be executed between the owner and the local stormwater management authority, and sets forth inspection requirements, compliance procedures if maintenance is neglected, notification of the local program upon transfer of ownership, and right-of-entry for local program personnel.

- Restrictive covenants or other mechanism enforceable by the local stormwater program must be in place to help ensure that wet ponds are maintained, as well as to pass the knowledge along to any subsequent property owners.
- Access to wet ponds should be covered by a drainage easement to allow access by the local stormwater program staff to conduct inspections and perform maintenance when necessary.
- All wet ponds must include a long term maintenance agreements consistent with the provisions of the local stormwater program and must include the recommended maintenance tasks and a copy of an annual inspection checklist.
- The maintenance agreement should also include contact information for owners to get local or state assistance to solve common nuisance problems, such as mosquito control, geese, invasive plants, vegetative management and beaver removal.

3.2 First Year Maintenance Operations

Successful establishment of wet ponds requires that the following tasks be undertaken during the first year following construction.

Initial Inspections. It is recommended that for the first six months following construction, the site should be inspected at least twice after storm events that exceed a 1/2-inch of rainfall.

Planting of Aquatic Benches. The aquatic benches should be planted with emergent wetland species, following the planting recommendations contained in Stormwater Treatment Wetland section (5.4.11).

Spot Reseeding. Inspectors should look for bare or eroding areas in the contributing drainage area or around the pond buffer, and make sure they are immediately stabilized with grass cover.

Watering. Trees planted in the pond buffer need to be watered during the first growing season. In general, consider watering every 3 days for first the month, and then weekly during the remainder of the first growing season (April - October), depending on rainfall.

3.3 Maintenance Inspections

Maintenance of a wet pond is driven by annual inspections that evaluate the condition and performance of the pond, including the following:

- Measure sediment accumulation levels in the forebay.
- Monitor the growth of wetland plants, trees and shrubs planted. Record the species and their approximate coverage, and note the presence of any invasive plant species.
- Inspect the condition of stormwater inlets to the pond for material damage, erosion or undercutting.
- Inspect the banks of upstream and downstream channels for evidence of sloughing, animal burrows, boggy areas, woody growth, or gully erosion that may undermine embankment integrity.

- Inspect the pond outfall channel for erosion, undercutting, rip-rap displacement, woody growth, etc.
- Inspect the condition of the principal spillway and riser for evidence of spalling, joint failure, leakage, corrosion, etc.
- Inspect the condition of all trash racks, reverse-sloped pipes, or flashboard risers for evidence of clogging, leakage, debris accumulation, etc.
- Inspect maintenance access to ensure it is free of woody vegetation, and check to see whether valves, manholes and locks can be opened and operated.
- Inspect internal and external side slopes of the pond for evidence of sparse vegetative cover, erosion, or slumping, and make needed repairs immediately.

Based on inspection results, specific maintenance tasks will be triggered. An example maintenance inspection checklist for Wet Ponds can be found in Appendix F.

3.4 Common Ongoing Maintenance Tasks

Maintenance is needed so stormwater ponds continue to operate as designed on a long-term basis. Routine stormwater pond maintenance, such as removing debris and trash, is needed several times each year (See Table 3). More significant maintenance (e.g., removing accumulated sediment) is needed less frequently but requires more skilled labor and special equipment. Inspection and repair of critical structural features (e.g., embankments and risers) needs to be performed by a qualified professional engineer who has experience in the construction, inspection, and repair of these features.

The maintenance plan should clearly outline how vegetation in the pond and its buffer will be managed or harvested in the future. Periodic mowing of the stormwater buffer is only required along maintenance rights-of-way and the embankment. The remaining buffer can be managed as a meadow (mowing every other year) or forest. The maintenance plan should schedule a shoreline cleanup at least once a year to remove trash and floatables.

Table 3: Typical Wet Pond Maintenance Tasks and Frequency.

Maintenance Items[1]	Frequency[1]
• Remove debris and blockages • Repair undercut, eroded, and bare soil areas	Quarterly or after major storms (>1 inch of rainfall)
• Mowing embankment	Twice a year
• Shoreline cleanup to remove trash, debris and floatables • A full maintenance inspection • Open up the riser to access and test the valves • Repair broken mechanical components, if needed	Annually
• Pond buffer and aquatic bench reinforcement plantings	One time – during the second year following construction
• Forebay Sediment Removal	Every 5 to 7 years
• Repair pipes, the riser and spillway, as needed	From 5 to 25 years
1 Maintenance items and required frequency should be verified with local requirements	

3.5 Sediment Removal

Frequent sediment removal from the forebay is essential to maintain the function and performance of a wet pond. For planning purposes, maintenance plans should anticipate cleanouts approximately every 5 to 7 years, or when inspections indicate that 50% of forebay sediment storage capacity has been filled. Absent an upstream eroding channel or other source of sediment, the frequency of sediment removal should decrease as the drainage area stabilizes. The designer should also check to see whether removed sediments can be spoiled on-site or must be hauled away. Sediments excavated from wet ponds are not usually considered toxic or hazardous. They can be safely disposed of by either land application or land filling. Sediment testing may be needed prior to sediment disposal if the wet pond serves a hotspot land use.

4. Community & Environmental Concerns

Wet ponds can generate the following community and environmental concerns that need to be addressed during design.

Aesthetic Issues. Many residents feel that wet ponds are an attractive landscape feature, promote a greater sense of community and are an attractive habitat for fish and wildlife. Designers should note that these benefits are often diminished where wet ponds are under-sized or have small contributing drainage areas.

Existing Wetlands. A wet pond should never be constructed within an existing natural wetland. Discharges from a wet pond into an existing natural wetland should be minimized to prevent pollution damage and changes to its hydroperiod.

Existing Forests. Construction of a wet pond may involve extensive clearing of existing forest cover. Designers can expect a great deal of neighborhood opposition if they do not make a concerted effort to save mature trees during pond design and construction.

Stream Warming Risk. Wet ponds can warm streams by 2 to 10 degrees Fahrenheit, although this may not be a major problem for degraded urban streams. To minimize stream warming, landscaping plans for wet ponds should emphasize shading with a combination of emergent vegetation and overstory shading. When all upgradient runoff reduction options have been exhausted, designers should utilize the multiple cells, and not the ED option..

Safety Risk. Pond safety is an important community concern. Gentle side slopes and safety benches should be provided to avoid potentially dangerous drop-offs, especially where wet ponds are located near residential areas.

Mosquito Risk. Mosquitoes are not a major problem for larger wet ponds (Santana et al., 1994; Ladd and Frankenburg, 2003, Hunt et al, 2005). However, fluctuating water levels in smaller or under-sized wet ponds could pose some risk for mosquito breeding. Mosquito problems can be minimized through simple design features and maintenance operations described in MSSC (2005).

Geese and Waterfowl. Wet ponds with extensive managed turf and shallow shorelines can attract nuisance populations of resident geese and other waterfowl, whose droppings add to the nutrient and bacteria loads, thus reducing the removal efficiency for those pollutants. Several design and landscaping features can make wet ponds much less attractive to geese (see Schueler, 1992).

Harmful Algal Blooms. Designers are cautioned that recent research on wet ponds in the coastal plain has shown that some ponds can be hotspots or incubators for algae that generate harmful algal blooms (HABs). The type of HAB may include cyanobacteria, raphidophytes, or dinoflagellates, and the severity appears to be related to environmental conditions and high nutrient inputs. Given the known negative effects of HABs on the health of shellfish, fish, wildlife and humans, this finding is a cause for concern for coastal stormwater managers.

5. Wet Pond Checklist Example

Sample Construction Inspection Checklist for Wet Ponds: The following checklist provides a basic outline of the anticipated items for the construction inspection of a wet pond. Inspectors should review the plans carefully, and adjust these items and the timing of inspection verification as needed to ensure the intent of the design and the inspection is met.

Pre-Construction Meeting

- ❑ Pre-construction meeting with the contractor designated to install the wet pond has been conducted.
- ❑ Identify the tentative schedule for construction and verify the requirements and schedule for interim inspections and sign-off.
- ❑ Subsurface investigation and soils report supports the placement of a wet pond in the proposed location.
- ❑ Impervious cover has been constructed/installed and area is free of construction equipment, vehicles, material storage, etc.
- ❑ All pervious areas of the contributing drainage areas have been adequately stabilized with a thick layer of vegetation and erosion control measures have been removed.
- ❑ Certification of Stabilization Inspection: Inspector certifies that the drainage areas are adequately stabilized in order to convert the sediment pond or trap (if used for sediment control) into a permanent wet pond.

Construction of Wet Pond Embankment and Principal Spillway

- ❑ Stormwater has been diverted around or through the area of the wet pond embankment to a stabilized conveyance; and perimeter erosion control measures to protect the facility during construction have been installed.
- ❑ Materials for construction of the embankment and principal spillway are available and meet the specifications of the approved plans.
- ❑ Construction of key trench, principal spillway, including the riser and barrel, anti-seepage controls, outlet protection, etc., is built in accordance with approved plans.
- ❑ Geotechnical analysis and approval of the core (if required) and embankment material has been provided, and the material has been placed in lifts and compacted in accordance with the approved plans.
- ❑ Certification of Embankment and Principal Spillway Inspection: Inspector certifies that each element of the embankment and principal spillway has been constructed in accordance with the approved plans.

Excavation of Wet Pond

- ❑ Excavation of the wet pond geometry (including bottom width, side slopes, check dams, weir overflow and outlet protection, etc.) achieves the elevations in accordance with approved plans.
- ❑ Excavation of internal micro-topographic features: deep pool, forebays, etc., is in accordance with approved plans.
- ❑ Impermeable liner, when required, meets project specifications and is placed in accordance with manufacturer's specifications.
- ❑ Certification of Excavation Inspection: Inspector certifies that the excavation has achieved all the appropriate grades, grade transitions, and wet pond geometry as shown on the approved plans.

Landscaping Plan and Stabilization

- ❑ Exposed soils on pond side slopes above permanent pool elevation are stabilized with specified seed mixtures, stabilization matting, mulch, etc., in accordance with approved plans.
- ❑ Appropriate number and spacing of plants are installed and protected on the aquatic bench and pond buffer in accordance with the approved plans.
- ❑ All erosion and sediment control practices have been removed.
- ❑ Follow-up inspection and as-built survey/certification has been scheduled.
- ❑ GPS coordinates have been documented for the wet pond installation.

REFERENCES

Cappiella, K., T. Schueler and T. Wright. 2006. Urban Watershed Forestry Manual: Part 2: Conserving and Planting Trees at Development Sites. USDA Forest Service. Center for Watershed Protection. Ellicott City, MD.

Cappiella, K., L. Fraley-McNeal, M. Novotney and T. Schueler. 2008. "The Next Generation of Stormwater Wetlands." Wetlands and Watersheds Article No. 5. Center for Watershed Protection. Ellicott City, MD.

Hunt, W., C. Apperson, and W. Lord. 2005. Mosquito Control for Stormwater Facilities. Urban Waterways. North Carolina State University and North Carolina Cooperative Extension. Raleigh, NC.

Hunt, W., M. Burchell, J. Wright and K. Bass. 2007. Stormwater Wetland Design Update: Zones, Vegetation, Soil and Outlet Guidance.|| Urban Waterways. North Carolina State Cooperative Extension Service. Raleigh, NC.

Ladd, B and J. Frankenburg. 2003. Management of Ponds, Wetlands and Other Water Reservoirs. Purdue Extension. WQ-41-W.

McDaniel, J. and M. Wanielista. 2005. Stormwater Intelligent Controller System. Final Report to Florida DEP. University of Central Florida Stormwater Management Academy. http://www.floridadep.org/water/nonpoint/docs/nonpoint/Stormwater_I_ControllerFinalReport.pdf

Minnesota Stormwater Steering Committee (MSSC). 2005. Minnesota Stormwater Manual. Emmons & Oliver Resources, Inc. Minnesota Pollution Control Agency. St. Paul, MN.

Santana, F., J. Wood, R. Parsons, and S. Chamberlain. 1994. Control of Mosquito Breeding in Permitted Stormwater Systems. Southwest Florida Water Management District. Brooksville, FL.

Schueler, T, 1992. Design of Stormwater Wetland Systems. Metropolitan Washington Council of Governments. Washington, DC.

Schueler, T., D. Hirschman, M. Novotney and J. Zielinski. 2007. Urban Stormwater Retrofit Practices. Manual 3 in the Urban Subwatershed Restoration Manual Series. Center for Watershed Protection, Ellicott City, MD.

Virginia Department of Conservation and Recreation (VADCR). 1999. Virginia Stormwater Management Handbook. Volumes 1 and 2. Division of Soil and Water Conservation. Richmond, VA.

Virginia DCR Stormwater Design Specification No. 14: Wet Ponds Version 1.9. 2011.

Wanielista, M. and Y. Yousef. 1993. Design and analysis of irrigation ponds using urban stormwater runoff. ASCE Engineering Hydrology. P: 724-728.

West Virginia Department of Environmental Protection (WVDEP). 2006. West Virginia Erosion and Sediment Control Best Management Practice Manual. Division of Water and Waste Management.