9. Stormwater Wetlands

Description

Stormwater wetlands are constructed systems that mimic the functions of natural wetlands and use physical, chemical, and biological processes to treat stormwater pollution.

Stormwater Wetlands

Regulatory Credits*		Feasibility Considerations	
Pollutant Removal			
85%	Total Suspended Solids	High	Land Requirement
40%	Total Nitrogen	Med	Cost of Construction
40%	Total Phosphorus	Med	Maintenance Burden
Water Quantity		Med-High	Treatable Basin Size
yes	Peak Runoff Attenuation	Med	Possible Site Constraints
yes	Runoff Volume Reduction	Med	Community Acceptance

* Stormwater wetlands that are designed as part of a pond/wetland system will receive variable credit. See Section 9.2.

Advantages

- Creates a shallow matrix of sediment, plants, water, and detritus that collectively removes multiple pollutants through a series of complementary physical, chemical, and biological processes.
- Best BMP design for maximum TSS, nitrogen, and phosphorus removal while also providing stormwater volume control.
- Aesthetically pleasing when properly maintained and can be sited in both low- and high-visibility areas.
- Can provide an excellent habitat for wildlife and waterfowl.

Disadvantages

- Occupies more land than other stormwater BMPs such as detention basins.
- Needs to meet critical water balance requirements to stay healthy and properly functioning.
- Poorly maintained stormwater wetlands can be colonized by invasive species that out-compete native wetlands plants. Removal of invasive plants is difficult and labor intensive and may need to be done repeatedly.

Major Design Elements

Required by the NC Administrative Rules of the Environmental Management Commission. Other specifications may be necessary to meet the stated pollutant removal requirements.	
1	Sizing shall take into account all runoff at ultimate build-out including off-site drainage.
2	Side slopes stabilized with vegetation shall be no steeper than 3:1.
3	Wetland shall be located in a recorded drainage easement with a recorded access easement to a public ROW.
4	The wetland must drawdown in 2-5 days.
5	Flow through the wetland shall not be short-circuited and shall be made as lengthy as possible.
6	A forebay is required.
7	A vegetated filter strip is not required for overflows or discharges from a constructed stormwater wetland (except for within ½ mile of and draining to SA waters or unnamed tributaries of SA waters). For SA waters in Phase II areas, criteria in S.L. 2006-246 Section 9(h) must still be met.
Required by DWQ policy. These are based on available research, and represent what DWQ considers necessary to achieve the stated removal efficiencies.	
8	Sizing of the wetland is based on storage volume requirements as described in this section.
9	The minimum treatment volume for a stormwater wetland shall be 3,630 ft^3. Lesser volumes will be approved on a case-by-case basis.
10	Maximum shallow land depth (temporary pool) shall be one (1) foot.
11	Minimum length to width ratio shall be 1.5:1, however, 3:1 is preferred.
12	The wetland must be stabilized within 14 days of construction.
13	The PPE must be maintained by installation of a natural or synthetic liner with a maximum infiltration rate of 0.01 in/hr beneath the entire bottom of deep pools and shallow water areas to prevent excessive seepage unless shallow groundwater is present and the PPE is located within 6-inches of the SHWT. In this case, only lining of deep pools may be required. At least 4-inches of appropriate topsoil must be added to the liner to support plant growth.
14	Cattails are not to be planted.

9.1. General Characteristics and Purpose

Stormwater wetlands provide an efficient biological method for removing a wide variety of pollutants, (e.g. suspended solids, nutrients (nitrogen and phosphorus), heavy metals, toxic organic pollutants, and petroleum compounds) in a managed environment. Compared with wet ponds, sand filters, bio-retention areas, and other stormwater BMPs, wetlands have the best median removal rate for total suspended solids, nitrate-nitrogen, ammonia-nitrogen, total phosphorus, phosphate-phosphorus, and some metals. Stormwater wetlands can also be used to reduce pollution associated with high levels of fecal coliform and other pathogen contamination. Wetlands temporarily store stormwater runoff in shallow pools that support emergent and riparian vegetation. The storage, complex microtopography, and vegetative community in stormwater wetlands combine to form an ideal matrix for the removal of many pollutants. Stormwater wetlands can also effectively reduce peak runoff rates and stabilize flow to adjacent natural wetlands and streams. Figure 9-1 shows examples of stormwater wetlands.

Wetlands are effective sedimentation devices and provide conditions that facilitate the chemical and biological processes that cleanse water. Pollutants are taken up and transformed by plants and microbes, immobilized in sediment, and released in reduced concentrations in the wetland's outflow as shown in Figure 9-2.

Plants improve water quality by slowing water flow and settling solids, transforming or immobilizing pollutants, and supplying reduced carbon and attachment area for microbes (bacteria and fungi). Dense strands of vegetation create the quiescent conditions that facilitate the physical, chemical, and biological processes that cleanse the stormwater. Many herbaceous wetland plants die annually. Because the dead plant material requires months or years to decompose, a dense layer of plant litter accumulates in the wetland. Like the living vegetation, the litter creates a substrate that supports bacterial growth and physically traps solids.

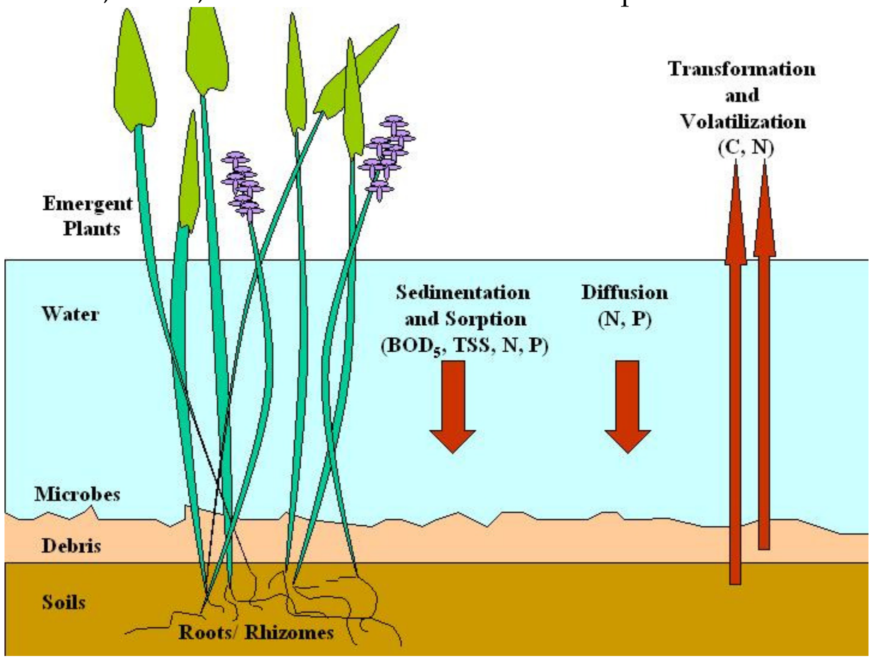
Microorganisms, adhering to vegetation, roots, and sediment in the wetland, can decompose organic compounds and convert significant quantities of nitrate directly to nitrogen gas. Large amounts of nitrogen and phosphorus also can be incorporated in new soil and in the extra biomass of the wetland vegetation. Transformations can take place through both aerobic and anaerobic processes. For these reasons, maintaining the health of the vegetative community is critical for effective pollutant removal.

The ability of the emergent plants to settle and stabilize suspended solids in sediments and reduce resuspension is important. The settling characteristic allows the wetland to remove pollutants such as phosphorus, trace metals, and hydrocarbons that are typically adsorbed to the surfaces of suspended particles.

Figure 9-1
Stormwater Wetlands, Washington, DC & Raleigh, NC

Long-term data from stormwater wetlands indicate that treatment performance for parameters such as 5-day biochemical oxygen demand (BOD_5), total suspended solids (TSS), and total nitrogen (TN) typically does not deteriorate over the life of a stormwater wetland. The dissolved oxygen (DO) concentration in wetland outflows may be below 1.0 mg/L. Higher DO concentrations can be achieved by incorporating aeration techniques such as turbulent or cascading discharge zones, or mechanical mixing.

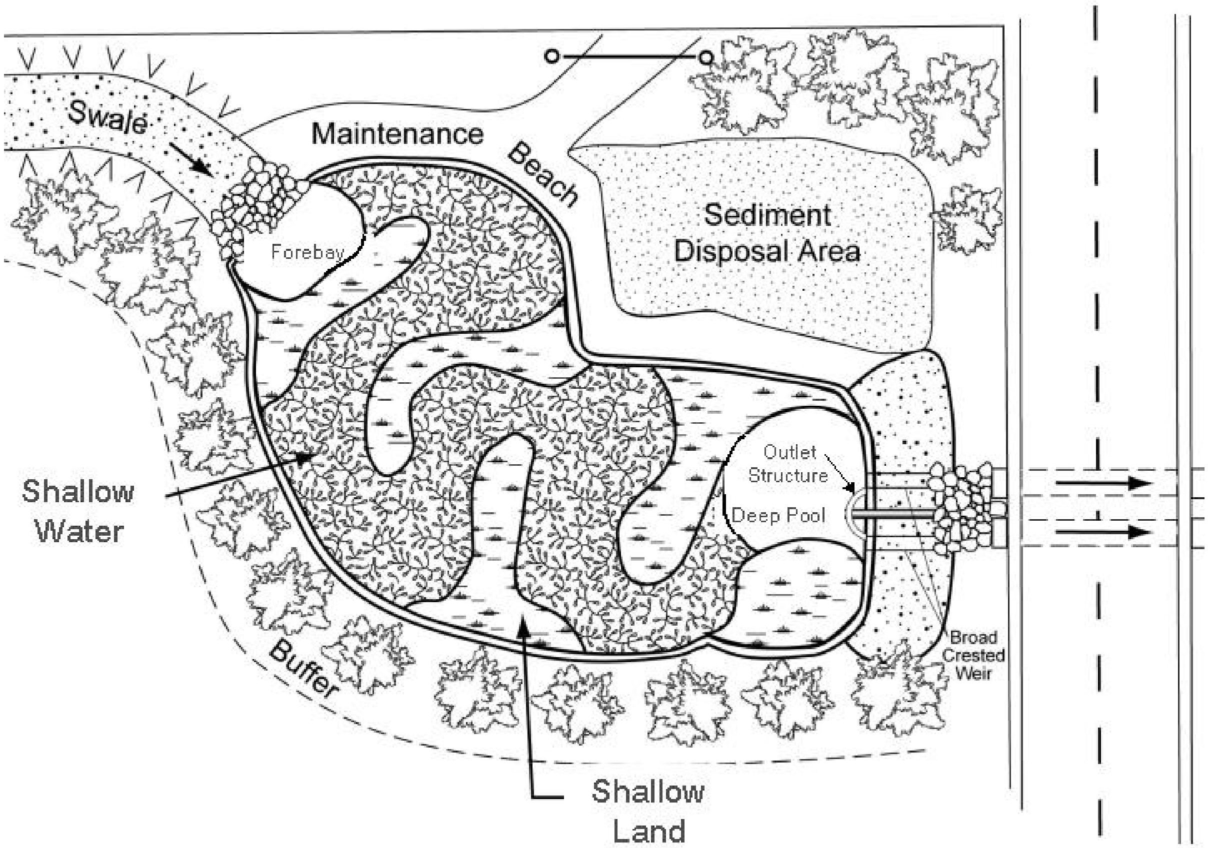
Figure 9-2
Wetland Microbes, Plants, and Soil Transform and Take Up Pollutants from Stormwater



Stormwater wetlands occupy somewhat more surface area than a wet detention pond, but have the potential to be better integrated aesthetically into a site design because of the abundance of aquatic vegetation. Stormwater wetlands require a drainage area sufficiently large, or adequate groundwater or surface water supplies, to provide year-round hydration. In sloping terrain, wetland cells can be arranged in series on terraces. Stormwater wetlands are appropriately located at the lower parts of the development site. Careful planning is needed to be sure that sufficient water will be retained to sustain good wetland plant growth. Since water depths are shallower than in wet detention ponds, water loss by evaporation is an important concern.

Stormwater wetlands are designed in such a way that the distance that the water flows from the entrance to the exit is maximized. This allows for sufficient contact time for pollutant removal. Figure 9-3 shows an example of how a wetland can be configured to maximize the distance that the water flows.

Figure 9-3
Stormwater Wetland*
From Design of Stormwater Wetland Systems, Adapted from Schueler, 1992



* *Additional deep pools are encouraged throughout the wetland.*

9.2. Meeting Regulatory Requirements

To obtain a permit to construct a stormwater wetland in North Carolina, the stormwater wetland must meet all of the Major Design Elements that are listed at the beginning of this section. In-stream impoundments are not allowed for creating BMPs.

Some wetlands can be constructed as a pond/wetland system. In these cases, part of the BMP is a pond and part of it is a wetland. The nitrogen removal rate for a pond/wetland system can range from 25-40%. The removal rate for a specific pond/wetland system design is prorated, depending on the ratio of permanent treatment volume that is allocated between the pond and the wetland. If 100% of the volume is allocated to the pond, the removal rate is 25% (as in a wet detention basin design). If 100% of the volume is allocated to the wetland, the removal rate is 40% (as in a wetland design). The removal rate is linearly interpolated between these two values. For instance, if the permanent treatment volume were allocated to be 33% a pond and 67% a wetland, the resulting removal rate would be 35%.

Pollutant Removal Calculations
The pollutant removal calculations for Stormwater Wetlands are as described in Section 3.4, and use the pollutant removal rates provided in Table 4-2 in Section 4.0. Construction of a stormwater wetland also passively lowers nutrient loading since it is counted as pervious surface when calculating nutrient loading. Further enhancing the passive reduction of nutrient loading is the fact that the surface area of any permanent water surface contributes no pollutant runoff (an export coefficient of 0.0 lb/ac/yr).

Volume Control Calculations
Stormwater wetlands can typically be designed with enough storage to provide active storage control, calculations for which are provided in Section 3.4. They will also provide some passive volume control capabilities by providing pervious surface, and therefore reducing the total runoff volume to be controlled.

9.3 Design

Design is a six-step process:
1.) Understand basic layout concepts
2.) Determine the volume of water to treat
3.) Determine surface area and depth of each wetland zone
4.) Select the soil media type
5.) Select the appropriate outlet structure
6.) Select plants

Converting Sediment and Erosion Control Devices
Often, the same basin can be used during construction as a sediment and erosion control device and later converted to a stormwater wetland. Before conversion, all accumulated sediment must be removed and properly disposed of, then the appropriate modifications to the basin depth, geometry, and hydrology, as well as inlet and outlet structures, etc., must be made.

9.3.1 Step 1: Understand Basic Layout Concepts

Stormwater Wetland Components
Stormwater wetlands consist of six primary components:

1. **Inlet**: This is where water enters the wetland. The inlet can be a swale, a pipe, a diverter box, sheet flow, or other method of transporting water to the wetland. Some examples are provided in Figure 9-4.

2. **Deep Pool**: This zone consists of permanent deep pools of water that retain water even during drought. Deep pools in a stormwater wetland are one of two types:
   a. Forebay: The forebay is a deep pool that directly follows the inlet provides two important functions: (1) dissipates runoff velocity and energy and (2) collects gross solids and sediment to ease maintenance of

the BMP. The forebay essentially acts as a pretreatment device for the stormwater wetland. The water flows out of the forebay and into the wetland. The entrance to the forebay is deeper than the exit of the forebay. This design will dissipate the energy of the water entering the system, and will also ensure that large solids settle out.

b. Non-Forebay Deep Pools: Other deep pools in the wetland are always full of water and are areas where rooted plants do not live. Submerged and floating plants may be used in this area, except around the wetland outlet device. The deep pool at the outlet should be non-vegetated to prevent clogging. Deep pools provide additional pollutant removal and storage volume as well as habitat for aquatic wildlife such as the mosquito-eating fish. Include a deep pool next to the outlet structure in order to allow for proper drawdown.

3. **Shallow water**, "low marsh": Shallow water includes all areas inundated by the permanent pool to a depth of 3"-6" with occasional drying during periods of drought. The shallow water zone provides a constant hydraulic connection between the inlet and outlet structure of the stormwater wetland. The top of the shallow water zone represents the top of the permanent pool elevation (PPE). Herbaceous plants, shown in Table 9-1 are recommended for this area because they are more efficient in the pollutant removal process and less likely to encourage mosquito growth.

4. **Shallow land**, "high marsh" or "temporary inundation zone": This zone provides the temporary storage volume of the stormwater wetland. The top of the shallow land zone represents the top of the temporary pool elevation (TPE). The shallow land is wet only after a rain event, and rooted plants live in this zone. See Table 9-1 at the end of this Section for plant selection. Shallow land in a wetland provides pollutant uptake, shade, and wildlife habitat and should be planted with vegetation able withstand irregular inundation and occasional drought.

5. **Upland**: These areas are never wet, are not a required element of wetland design, and can be eliminated if space is of concern. They may serve as an amenity or provide access for maintenance. Some wetlands have upland areas as an island in the center of the wetland.

6. **Outlet**: The outlet structure consists of a drawdown orifice placed at the top of the shallow water elevation so that stormwater accumulating in the shallow land area will be able to slowly drawdown from the wetland. The outlet structure may also be designed to pass larger storm events, which will have a higher flow outlet at the proper elevation.

Surrounding Soils, Groundwater and Liners

A primary cause of failure of stormwater wetlands is failure to maintain the PPE at the design elevation (Figure 9-5). Site soils and groundwater elevation heavily influence the way in which stormwater wetlands may be constructed and their ultimate success or failure.

For all stormwater wetland designs, a soils report with a determination of the seasonal high water table (SHWT) and in-situ soil permeability must be included and submitted to DWQ. Two options exist for the wetland designer:

(1) If the wetland intersects the shallow groundwater table, groundwater may be utilized to maintain the PPE at the design elevation. In this case, DWQ requires that the PPE be no more than six (6) inches above or below the SHWT. DWQ may require installation of an impermeable liner beneath deep pools depending on soil permeability.

(2) If the SHWT is not present near ground surface, and the stormwater wetland is to be perched above the water table, or located in highly permeable soils like gravelly sands or fractured bedrock, DWQ requires installation of an impermeable soil/clay/geomembrane liner with an infiltration rate of less than 0.01 in/hr beneath the entire bottom of deep pools and shallow water areas to sustain the permanent pool of water.

Note that at least four inches of topsoil is required for both lined and unlined wetlands. See Section 9.3.4 for further details on soil requirements.

Figure 9-4

Wetland Inlet Device Examples: Culvert and Rip-Rap Channel

(Courtesy of Sharon Schulze, NC State Science House)

Figure 9-5
Failure to Maintain PPE at Design Elevation in Wetland (Garner, NC)

Figure 9-6
Algal Growth in Large Open Water Areas from High Nutrient Loading

9.3.2 Step 2: Determine the Volume of Water to Treat

Water Treatment Volume
A wetland is intended to treat the first flush (1"-1.5") of a particular design storm. The Simple Method in Section 3.3.1 of this Manual details the volumetric calculation.

Contributing Drainage
There is no minimum or maximum for the drainage area. Instead, any drainage area that contributes a minimum volume of 3,630 cubic feet is allowed. Smaller volumes will be allowed on a case-by-case basis, though supporting calculations such as a water balance or other justification will be required.

Siting Issues
Stormwater wetlands should not be located within existing jurisdictional wetlands or constructed as in-stream impoundments. If there are industrial or commercial land uses in the drainage area, accumulated pollutants may eventually increase environmental risk to wildlife (Figure 9-6). Typical pollutant loads found in residential and commercial settings are unlikely to cause this problem.

Pretreatment Options
Wetlands and pond/wetland systems require the use of a forebay for pretreatment (see Section 5.4 for forebay design).

9.3.3 Step 3: Determine Surface Area and Depth of Each Wetland Zone

Flow paths from inlet to outlet points within stormwater wetlands should be maximized. Internal berms and irregular shapes are often used to achieve recommended flow paths. The minimum length to width ratio shall be 1.5:1, however, 3:1 is highly recommended. Narrow, deep-water zones should be constructed at the wetland inlet and outlet to evenly distribute flow. Inlets also may incorporate pipe manifolds to enhance flow distribution. Deep-water zones perpendicular to the flow direction, and internal berms parallel to the flow, can also be used to reduce the potential for short-circuiting.

The total surface area of the deep pool topographic zone should be broken into several micropools that are well dispersed throughout the wetland so that the distances for fish to travel within the shallow water zone to reach the entire wetland is minimized. One deep pool should be located at the entrance of the wetland and one should be located at the exit. Other deep pools can be dispersed throughout the wetland.

The geometric calculations for wetlands are provided below. As opposed to many other types of BMP designs, the permanent volume of water contained in the stormwater wetland is not part of the design calculations, but is merely a result of the breakdown of natural or engineered hydrologic zones and their respective depths.

a. Determine Required Surface Area of Entire Wetland and Each Wetland Zone: Two factors determine the surface area, 1.) The watershed runoff volume that is to be contained (Q_{Volume}), and 2.) The depth of water that plants can sustain for several days in the shallow land area (D_{Plants}), the depth of the temporary pool, up to 12 inches (Hunt, Doll, 2000). The total surface area of the wetland is determined by the quotient of these variables. The surface area of each wetland zone is a percentage of the total required surface area. Calculations for determining the surface areas of the various wetland zones are provided below.

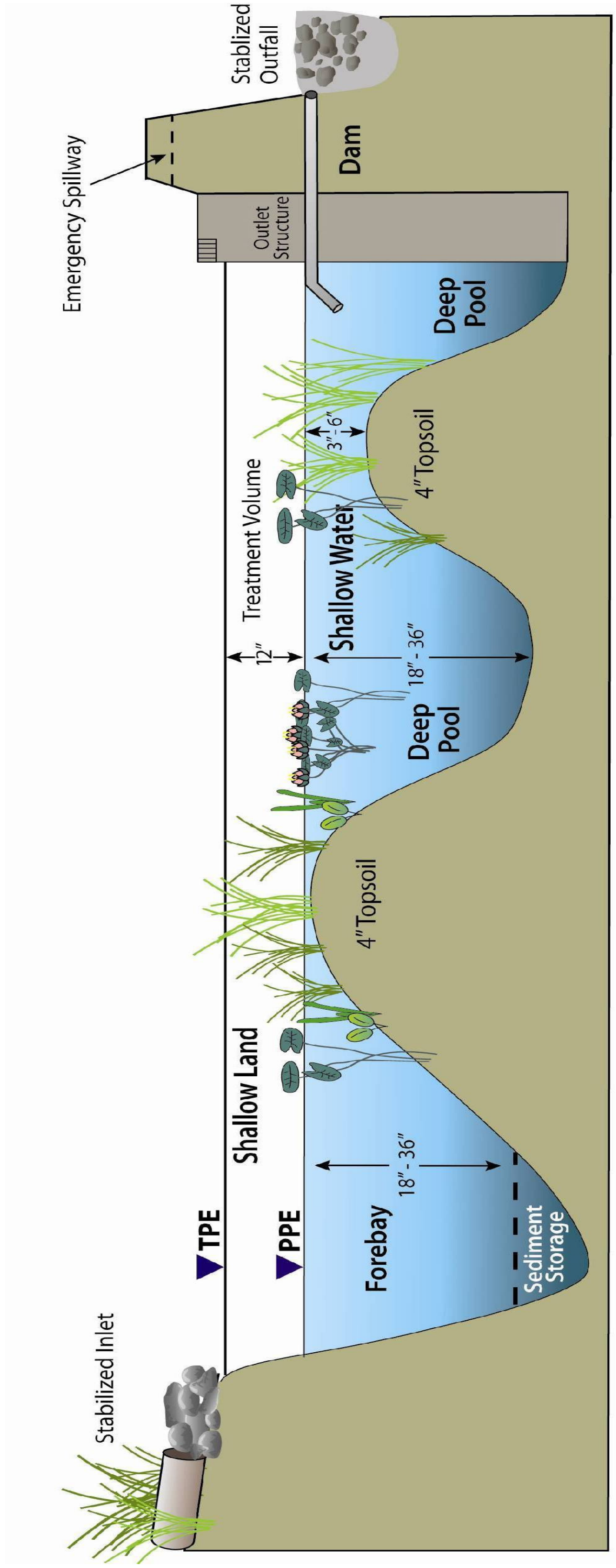
- *Surface Area*: The total surface area of the wetland is $\frac{Q_{Volume}(ft^3)}{D_{Plants}(ft)}$ = ___ (SF).

  (Note: D_{Plants} can be up to 12 inches.) This surface area, in square feet (SF), is distributed to the various wetland zones as outlined below:
  - Deep Pools: Ideally several deep pools should be provided throughout the wetland.
    - Non-Forebay: 5-10% of wetland surface
    - Forebay: 10% of wetland surface
  - Shallow Water (low marsh): 40% of wetland surface.
  - Shallow Land (high marsh): 30-40% of wetland surface (maximize if pathogens are target pollutant).
  - Upland: This is an optional design element. If upland area is included, it will not replace any of the required calculated surface area.

b. Design Depth of Each Wetland Zone: Determine the appropriate depth for each wetland zone. DWQ recommends the following depths for each wetland zone as illustrated in Figure 9-7:
- Deep Pools:
  - Non-Forebay: 18-36" (include one at the outlet structure for proper drawdown).
  - Forebay: 18-36" plus additional depth for sediment accumulation (deepest near inlet to dissipate energy, more shallow near the exit).
- Shallow Water (low marsh): 3-6". A primary cause of wetland failure is designing this layer to be too deep.
- Shallow Land (high marsh): Up to 12". This is the depth, D_{Plants}, used in the surface area calculation, and is also the depth of the temporary pool.
- Upland: Up to 4 feet above the shallow land zone.

c. Double Check the Volume: Ensure that the volume of the shallow land section can accommodate the treatment volume necessary for the wetland (as was calculated in Step 2). The shallow land zone acts as the temporary pool and contains the treatment volume after a rain event.

Figure 9-7
Stormwater Wetland Conceptual Diagram



Note: Depending on site soils and groundwater elevations, a clay or synthetic liner may be required to maintain PPE at design elevation.

9.3.4 Step 4: Select the Soil Media Type

Stormwater wetlands are appropriate for NRCS type C and D soils. A soil analysis should be conducted within the stormwater facility area to determine the viability of soils to assure healthy vegetation growth and to provide adequate infiltration rates through the topsoil. For wetlands designed to utilize a clay or synthetic liner, at least four (4) inches of quality topsoil shall be added to the top of the liner to support plant growth. Imported or in-situ soils may be amended with organic material, depending on soil analysis results, to enhance suitability as a planting media. See Section 6.5 of this Manual for full details on soil media requirements, specifications and amendments.

9.3.5 Step 5: Select the Appropriate Outlet Structure

The outlet design must be accessible to operators, easy to maintain, and resistant to fouling by floating or submerged plant material or debris. Wetlands should have both low- and high-capacity outlets. High-capacity outlets, such as weir boxes or broad-crested spillways, should be provided unless bypasses are provided for storms in excess of the first flush volume. The low-capacity outlet is typically a drawdown orifice and should be able to draw down the temporary pool within 2-5 days. Multiple-outlet structures are often used to balance the volume control requirements and maintenance needs. Additionally, designers can choose to install manual drawdown valves or flashboard risers (also called sliding weir plates) so that maintenance personnel can drain the wetland for maintenance purposes. If installed, drawdown valves should be secured so that only intended personnel can access them. Also, trash racks are recommended on the outlet structure to keep floating plants from clogging the outlet.

An ideal outlet structure should contain the following features:

- High-capacity weir box overflow;
- Low-capacity drawdown sized to drawdown the temporary pool (shallow land zone) in 2-5 days; and
- Easy accessibility for operation and maintenance.

Overflow Structure Maintenance Considerations

Stormwater wetland maintenance must be considered when designing outlet structures. Occasionally wetlands may require complete drawdown. The structures in Figure 9-8 show the low-capacity drawdown orifice, the high-capacity overflow, and a manually operated valve for maintenance purposes. Alternatively, a flashboard riser can be used to draw water down for maintenance, as shown in Figure 9-9.

Figure 9-8
Outlet Structures with Manual Drawdown Valve for Maintenance

Figure 9-9
Outlet Structures with Flashboard Riser for Maintenance
(Courtesy NC State Science House and BAE)

One method to help ensure that the drawdown orifice does not clog is to turn the orifice downward below the normal pool as shown in Figure 9-10. This prevents floating debris or vegetation from clogging the orifice. If the wetland is located in trout-sensitive waters, consider extending the orifice to close to the bottom of the drawdown structure among a pile of riprap. This will ensure that cooler water enters the stream in an effort to protect trout, which thrive in cold water. The site in Figure 9-10 has been drained for maintenance.

Figure 9-10
Outlet Structure With Down-Turned Drawdown Orifice

The overflow structure should be located near the edge of the wetland so that it can be accessed easily for maintenance, as shown in Figure 9-11. Overflow structures that are several feet into the wetland, as shown in Figure 9-12, are difficult to reach and likely will not be maintained.

Figure 9-11
Outlet Structure Near Wetland Edge, Orifice Easily Accessible for Maintenance

Figure 9-12
Outlet Structure Not Near Wetland Edge, Orifice *Not* Easily Accessible for Maintenance

9.3.6 Step 6: Select Plants

High pollutant removal efficiencies in a stormwater wetland depend on a dense cover of emergent plant vegetation. Although various plant types differ in their abilities to remove pollutants from the water column, in general, the specific plant species do not appear to be as important for stormwater wetland functioning as plant growth survival and plant densities (Kadlec and Knight 1996). In particular, species should be used that have high colonization and growth rates, can establish large areas that continue through the winter dormant season, have a high potential for pollutant removal, and are very robust in continuously or periodically flooded environments. Non-invasive species should be used. Native species are preferred.

Shrubs and wetland plants should be designed to minimize solar exposure of open water areas (particularly critical in mountain settings to prevent thermal pollution of trout waters). A landscape plan prepared by a qualified design professional licensed in North Carolina must be provided to document the methods to be used for establishing and maintaining wetland plant coverage.

A stormwater wetland facility consists of the area of the wetland, including bottom and side slopes, plus maintenance/access buffers around the wetland. Minimum elements of a stormwater wetland landscape plan include:

- Delineation of planting (pondscaping) zones;
- Selection of corresponding plant species;
- A minimum of ten (10) different species total, of which at least five (5) are emergent species, with no more than 30% of a single species;
- Buffers are recommended as Centipede grass;

- Minimum plant quantities and sizes per 200 ft^2 of shallow water area:
  - 50 herbaceous plants of at least 4 cubic-inch container (equivalent to 2 ft on center minimum; 1.5 ft on center recommended)
- Minimum plant quantities and plant sizes per 200 ft^2 of shallow land area:
  - 50 herbaceous plants of at least 4 cubic-inch container, *OR*
  - 8 shrubs of at least 1-gallon container (equivalent to 5 ft on center minimum; 3 ft on center recommended), *OR*
  - 1 tree of at least 3 gallon container *and* 40 grass-like herbaceous plants of at least 4 cubic-inch container
- Source of plant materials (*wetland seed mixes are not allowed*);
- Planting layout;
- Sequence and timing for preparing wetland bed (including soil amendments, initial fertilization, and watering, as needed);
- Growing medium specifications (soil specifications); and
- Specification of supplementary plantings to replenish losses.

Soil bioengineering techniques, such as the use of fascines, stumps or logs, and coconut fiber rolls, can be used to create shallow land cells in areas of the stormwater wetland that may be subject to high flow velocities. The landscape plan should also provide elements that promote greater wildlife and waterfowl use within the wetland and buffers, as well as aesthetic considerations. For instructions regarding landscape plan requirements, please refer to Chapter 6 Landscape and Soil Specifications.

Five (5) or more species of emergent wetland plants should be selected in order to optimize treatment processes as well as to promote ecological mosquito control (i.e., attract a variety of predator insects for natural mosquito control). Use of trees and shrubs should be limited if mosquitoes are of concern, and are best planted around the perimeter of the wetland. Cattails **shall not** be planted as they can quickly take over and choke out other plants in the wetland which will limit biodiversity, and ultimately lead to mosquito infestation.

Plant recommendations are listed in Table 9-1. The list of plant species is not exhaustive, and additional wetland plant species may be suitable that are not shown below. There are many excellent plant references in publication as well as recommendations from wetland scientists and landscape architects.

Table 9-1
Stormwater Wetland Plant Recommendations

DEEP POOL

Botanical Name	Common Name
Floating Aquatic Plants	
Lemna spp.	Duckweed
Nelumbo lutea	American lotus
Nuphar lutea ssp. *polysepala*	Rocky Mtn Pond-lily
Nuphar lutea ssp. *advena*	Yellow Pond-lily

Submerged Aquatic Plants	
Eleocharis acicularis	Needle spikerush
Eleocharis quadrangulata	Squarestem spikerush
Elodea canadensis	Canadian waterweed
Elodea nuttallii	Western waterweed

SHALLOW WATER

Botanical Name	Common Name
Herbaceous Plants	
Acorus subcordatum	Sweetflag
Alisma subcordatum	Water plantain
Hydrolea quadrivalvis	Waterpod
Iris virginica	Blue flag iris
Juncus effusus var. pylaei or solutus	Soft rush
Ludwigia spp.	Primrose willow
Peltandra virginica	Arrow arum
Pontederia cordata	Pickerelweed
Sagittaria latifolia	Duck Potato
Sagittaria lancifolia	Bulltongue
Saururus cernuus	Lizard's tail
Schoenoplectus tabernaemontani	Soft stem bulrush
Schoenoplectus americanus	Three-square bulrush
Schoenoplectus pungens var. pungens	
Scirpus cyperinus	Woolgrass
Zizaniopsis miliacea	Giant cutgrass

SHALLOW LAND

Botanical Name	Common Name
Herbaceous Plants	
Asclepias incarnata	Swamp Milkweed
Carex tenera	Quill sedge
Chelone glabra	White Turtlehead
Eupatoriadelphus dubius	Dwarf Joe Pye Weed
Eupatoriadelphus fistulosus	Joe Pye Weed
Eupatoriadelphus maculatus	Spotted trumpetweed
Hibiscus coccineus	Scarlet rose mallow
Hibiscus laevis	Halberdleaf rosemallow
Kosteletzkya virginica	Seashore Mallow
Lobelia cardinalis	Cardinal flower
Lobelia elongata	Longleaf lobelia
Lobelia siphilitica	Great blue Lobelia
Rhynchospora colorata	Starrush whitetop
Saccharum baldwinii	Narrow plumegrass
Shrubs	
Aronia arbutifolia	Red Chokeberry
Cephalanthus occidentalis	Common Buttonbush
Clethra alnifolia	Sweet pepperbush

Cornus amomum	Silky dogwood
Cyrilla racemiflora	TiTi
Gordonia lasianthus	Loblolly Bay
Hypericum densiflorum	Bushy St. Johnswort
Ilex deciduas	Possumhaw
Ilex glabra	Inkberry
Itea virginica	Virginia Sweetspire
Rosa palustris	Swamp Rose
Vaccinium crassifolium	Creeping Blueberry
Viburnum nudum var. nudum	Possumhaw

9.4 Construction

The wetland must be stabilized within 14 days of construction. Consider construction sequencing so that vegetation can be planted and the wetland brought online within 14 days. Plants may need to be watered during this time if the device is not brought online the same day. Stabilization may be in the form of final vegetation plantings or a temporary means until the vegetation becomes established. A good temporary means of stabilization is a wet hydroseed mix. For rapid germination, scarify the soil to a half-inch prior to hydroseeding.

Inlet and outlet channels should be protected from scour that may occur during periods of high flow. Standard erosion control measures should be used. The Land Quality Section of the North Carolina Department of Environment and Natural Resources and the U.S. Department of Agriculture Natural Resource Conservation Service (NRCS) can provide information on erosion and sediment control techniques.

The stormwater wetland should be staked at the onset of the planting season. Water depths in the wetland should be measured to confirm the original planting zones. At this time, it may be necessary to modify the planting plan to reflect altered depths or the availability of wetland plant stock. Surveyed planting zones should be marked on an "as-built" or record design plan and located in the field using stakes or flags.

The wetland drain should be fully opened for no more than 3 days prior to the planting date (which should coincide with the delivery date for the wetland plant stock) to preserve soil moisture and workability.

The most common and reliable technique for establishing an emergent wetland community in a stormwater wetland is to transplant nursery stock obtained from local aquatic plant nurseries. The optimal period for transplanting extends from early April to mid-June so that the wetland plants will have a full growing season to build the root reserves needed to survive the winter. However, some species may be planted successfully in early fall. Contact your nursery well in advance of construction to ensure that they will have the desired species available.

Post-nursery care of wetland plants is very important in the interval between delivery of the plants and their subsequent installation because they are prone to desiccation. Stock should be frequently watered and shaded.

Safety Considerations

The permanent pool of water presents an attractive play area to children and thus may create safety problems. Engineering design features that discourage child access are recommended. Trash racks and other debris-control structures should be sized to prevent entry by children. Other safety considerations include using fences around the spillway structure, embankment, and stormwater wetland slopes; using shallow safety benches around the stormwater wetland; and posting warning signs.

Fencing of stormwater wetlands is not generally aesthetically pleasing but may be required by the local review authority. A preferred method is to engineer the contours of the stormwater wetland to eliminate dropoffs and other safety hazards as discussed above. Riser openings must restrict unauthorized access. Endwalls above pipe outfalls greater than 48 inches in diameter must be fenced to prevent falls.

9.5. Maintenance

The following section contains information on maintenance issues common to wetlands and a sample O&M agreement required by DWQ for installation of a stormwater wetland BMP.

9.5.1 Common Maintenance Issues

Please refer to Section 7.0, General BMP Maintenance, for information on types of maintenance activities, typical frequency, and specific maintenance tasks that are common to all BMPs. The following information details maintenance specific to stormwater wetlands.

The landscape professional managing the wetland must understand the biological requirements of the plants and manage water levels appropriately to provide for their needs. For example, growing conditions are most critical during seed germination and early establishment. However, optimum conditions are not always required once the vegetated community becomes established.

Although wetland plants require water for growth and reproduction, they can be killed by drowning in excessively deep water. Usually, initial growth is best with transplanted plants in wet, well-aerated soil. Occasional inundation followed by exposure to air of the majority of the vegetation enables the plants to obtain oxygen and grow optimally. Conversely, frequent soil saturation is important for wetland plant survival.

If a minimum coverage of 70 percent is not achieved in the planted wetland zones after the second growing season, supplemental planting should be completed. Coverage of 90 to 95 percent is desirable.

Dramatic shifts can occur as plant succession proceeds. The plant community reflects management and can indicate problems or the results of improvements. For example, a requirement of submerged aquatic plants, such as pondweed (*Potamogeton spp.*), is light penetration into the water column. The disappearance of these plants may indicate inadequate water clarity. The appearance of invasive species or development of a monoculture is also a sign of a problem with the aquatic/soil/vegetative requirements. For instance, many invasive species can quickly spread and take over a wetland. If cattails become invasive, they can be removed by a licensed aquatic pesticide applicator by wiping aquatic glyphosate, a systemic herbicide, on the cattails.

Unlike maintenance requirements for wet or dry stormwater ponds, sediment should only be selectively removed from stormwater wetlands, primarily from the forebay. Sediment removal disturbs stable vegetation cover and disrupts flowpaths through the wetland. The top few inches of sediment should be stockpiled so that it can be replaced over the surface of the wetland after the completion of sediment removal to re-establish the vegetative cover using its own seed bank. Accumulated sediment should be removed from around inlet and outlet structures.

9.5.2 Sample Operation and Maintenance Provisions

I will keep a maintenance record on this BMP. This maintenance record will be kept in a log in a known set location. Any deficient BMP elements noted in the inspection will be corrected, repaired or replaced immediately. These deficiencies can affect the integrity of structures, safety of the public, and the removal efficiency of the BMP.

Important maintenance procedures:

- Immediately following construction of the stormwater wetland, bi-weekly inspections will be conducted and wetland plants will be watered bi-weekly until vegetation becomes established (commonly six weeks).
- No portion of the stormwater wetland will be fertilized after the first initial fertilization that is required to establish the wetland plants.
- Stable groundcover will be maintained in the drainage area to reduce the sediment load to the wetland.
- Once a year, a dam safety expert should inspect the embankment.

After the stormwater wetland is established, I will inspect it **monthly and within 24 hours after every storm event greater than 1.0 inches (or 1.5 inches if in a Coastal County)**. Records of operation and maintenance will be kept in a known set location and will be available upon request.

Inspection activities shall be performed as follows. Any problems that are found shall be repaired immediately.

Table 9-2
Sample Operation and Maintenance Agreement for Stormwater Wetlands

BMP element:	Potential problem:	How to remediate the problem:
Entire BMP	Trash/debris is present.	Remove the trash/debris.
Perimeter of wetland	Areas of bare soil and/or erosive gullies have formed.	Regrade the soil if necessary to remove the gully, and then plant a ground cover and water until it is established. Provide lime and a one-time fertilizer application.
	Vegetation is too short or too long.	Maintain vegetation at an appropriate height.
Inlet device: pipe or swale	The pipe is clogged (if applicable).	Unclog the pipe. Dispose of the sediment offsite.
	The pipe is cracked or otherwise damaged (if applicable).	Replace the pipe.
	Erosion is occurring in the swale (if applicable).	Regrade the swale if necessary to smooth it over and provide erosion control devices such as reinforced turf matting or riprap to avoid future problems with erosion.
Forebay	Sediment has accumulated in the forebay to a depth that inhibits the forebay from functioning well.	Search for the source of the sediment and remedy the problem if possible. Remove the sediment and dispose of it in a location where it will not cause impacts to streams or the BMP.
	Erosion has occurred.	Provide additional erosion protection such as reinforced turf matting or riprap if needed to prevent future erosion problems.
	Weeds are present.	Remove the weeds, preferably by hand. If a pesticide is used, wipe it on the plants rather than spraying.
Deep pool, shallow water and shallow land areas	Algal growth covers over 50% of the deep pool and shallow water areas.	Consult a professional to remove and control the algal growth.
	Cattails, phragmites or other invasive plants cover 50% of the deep pool and shallow water areas.	Remove invasives by physical removal or by wiping them with pesticide (do not spray) – consult a professional.
	Shallow land remains flooded more than 5 days after a storm event.	Unclog the outlet device immediately.
	Plants are dead, diseased or dying.	Determine the source of the problem: soils, hydrology, disease, etc. Remedy the problem and replace plants. Provide a one-time fertilizer application to establish the ground cover if necessary.

Table 9-2, continued

Sample Operation and Maintenance Agreement for Stormwater Wetlands

BMP element:	Potential problem:	How to remediate the problem:
Deep pool, shallow water and shallow land areas (con't)	Best professional practices show that pruning is needed to maintain optimal plant health.	Prune according to best professional practices.
	Sediment has accumulated and reduced the depth to 75% of the original design depth of the deep pools.	Search for the source of the sediment and remedy the problem if possible. Remove the sediment and dispose of it in a location where it will not cause impacts to streams or the BMP.
Embankment	A tree has started to grow on the embankment.	Consult a dam safety specialist to remove the tree.
	An annual inspection by appropriate professional shows that the embankment needs repair.	Make all needed repairs.
	Evidence of muskrat or beaver activity is present.	Consult a professional to remove muskrats or beavers.
Micropool	Sediment has accumulated and reduced the depth to 75% of the original design depth.	Search for the source of the sediment and remedy the problem if possible. Remove the sediment and dispose of it in a location where it will not cause impacts to streams or the BMP.
OUTLET STRUCTURE	Clogging has occurred.	Clean out the outlet device. Dispose of the sediment off-site.
	The outlet device is damaged	Repair or replace the outlet device.
Receiving water	Erosion or other signs of damage have occurred at the outlet.	Contact the NC Division of Water Quality 401 Oversight Unit at 919-733-1786.

September 28, 2007 Changes:

1. Major Design Elements:
    a. Reformatted to include numbered requirements.
    b. Specified that the requirement to drain down within 2 and 5 days is required by the Administrative Code. The Code makes this requirement for wet ponds, and it has been applied to wetlands in this case because this design element is parallel between wet ponds and wetlands.
    c. For clarification, "of drainage" was removed from, "The minimum treatment volume for a stormwater wetland shall be 3,630 ft^3 of drainage. Lesser volumes will be approved on a case-by-case basis."
    d. For clarification, "ponding depth" was replaced with "shallow land depth" in the phrase, "Maximum ponding depth shall be 1 foot."
    e. Specified that cattails are not to be planted.
    f. Added, "A forebay is required," per 15A NCAC 02H .1008(e)(6).
    g. Added, "Overflows shall pass through a minimum 30 feet long vegetative filter, 50-foot filter is required for some projects," per 15A NCAC 02H .1008(c)(4) and 15A NCAC 02H .1005(b)(iii).
2. 9.3.1: Clarified that the shallow land topographic zone (zone 3) shall contain the entire treatment volume. Directed readers to Figures 9-7a and 9-7b for further clarification.
3. 9.3.3: Clarified the surface area calculation section to specify that the temporary pool can be up to 12 inches deep, and is contained in the shallow land topographic zone.
4. 9.3.3: Clarified that more than four inches of topsoil above the clay liner is acceptable.
5. Figure 9-7a and 9-7b: Added clarification of the division between the temporary and permanent pools.
6. Figure 9-14: Deleted for clarification.
7. Table 9-2: Deleted the requirement to remove sediment from the forebay when it fills 25% of the forebay.

July 10, 2009 Changes:

1. Various changes throughout the chapter to layout, terminology, wording, photos, illustrations, and order of topics.
2. Replaced Figure 9-7a and Figure 9-7b with new Figure 9-7.
3. Clarified options for maintaining PPE with SHWT or natural/synthetic liner.
4. Added more photos throughout chapter for clarification.
5. Updated planting density requirements and recommended plant species list.
6. Updated sample O&M agreement.
7. Increased total phosphorus removal credit to 40%.
8. Clarified surface area and depth design procedures.
9. Emphasized use of forebay as pretreatment device
10. Removed requirement of one (1) foot soil between liner and planting media.
11. Clarified grass buffer requirements.