C-4. Stormwater Wetland

Design Objective

Stormwater wetlands are constructed systems that mimic the functions of natural wetlands and use physical, chemical, and biological processes to treat stormwater. A stormwater wetland is designed to capture the design storm and release it slowly over a period of two to five days via a properly designed outlet structure. The wetland shall be designed in a manner that protects the device, the areas around the device and the receiving stream from erosion. Stormwater 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.

Design Volume

The design volume for a wetland is the volume that can be retained for a two to five-day period between the temporary pool elevation and the permanent pool elevation.

Important Links

Rule 15A NCAC 2H .1054. MDC for Stormwater Wetlands
SCM Credit Document, C-4. Credit for Stormwater Wetlands

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Figure 1: Stormwater Wetland Example - Plan View

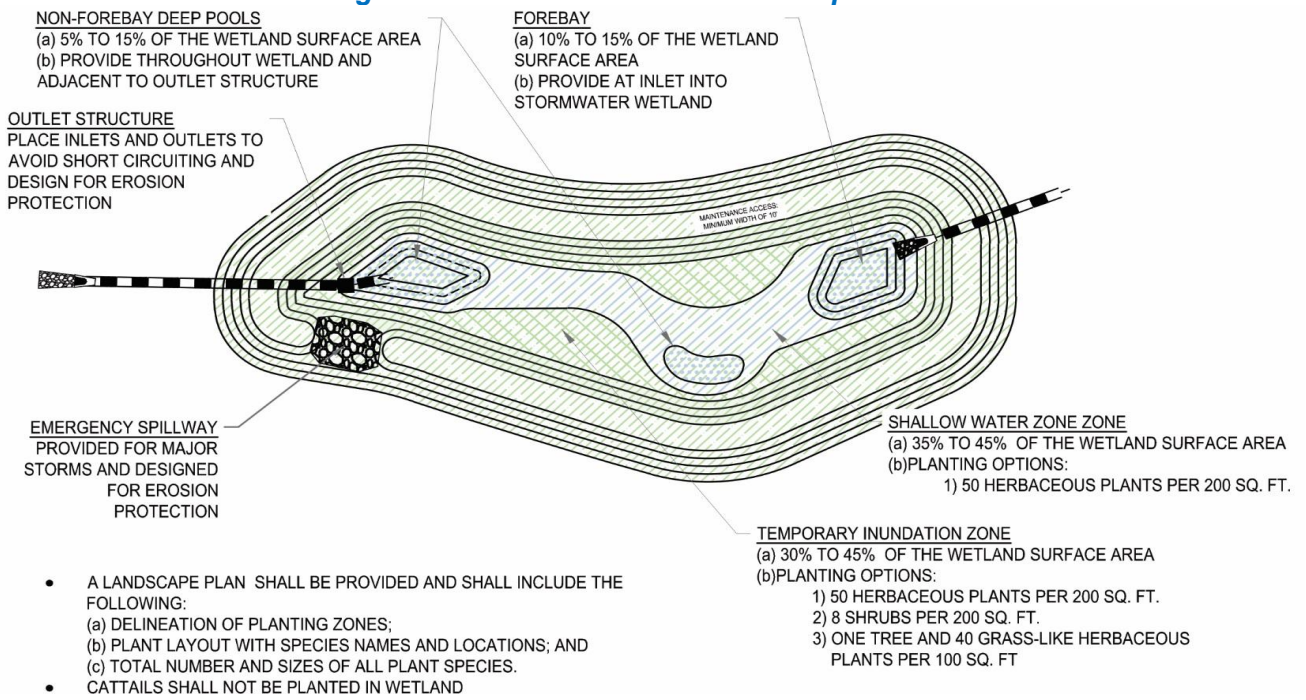


Figure 2: Stormwater Wetland Example – Schematic Cross-Section

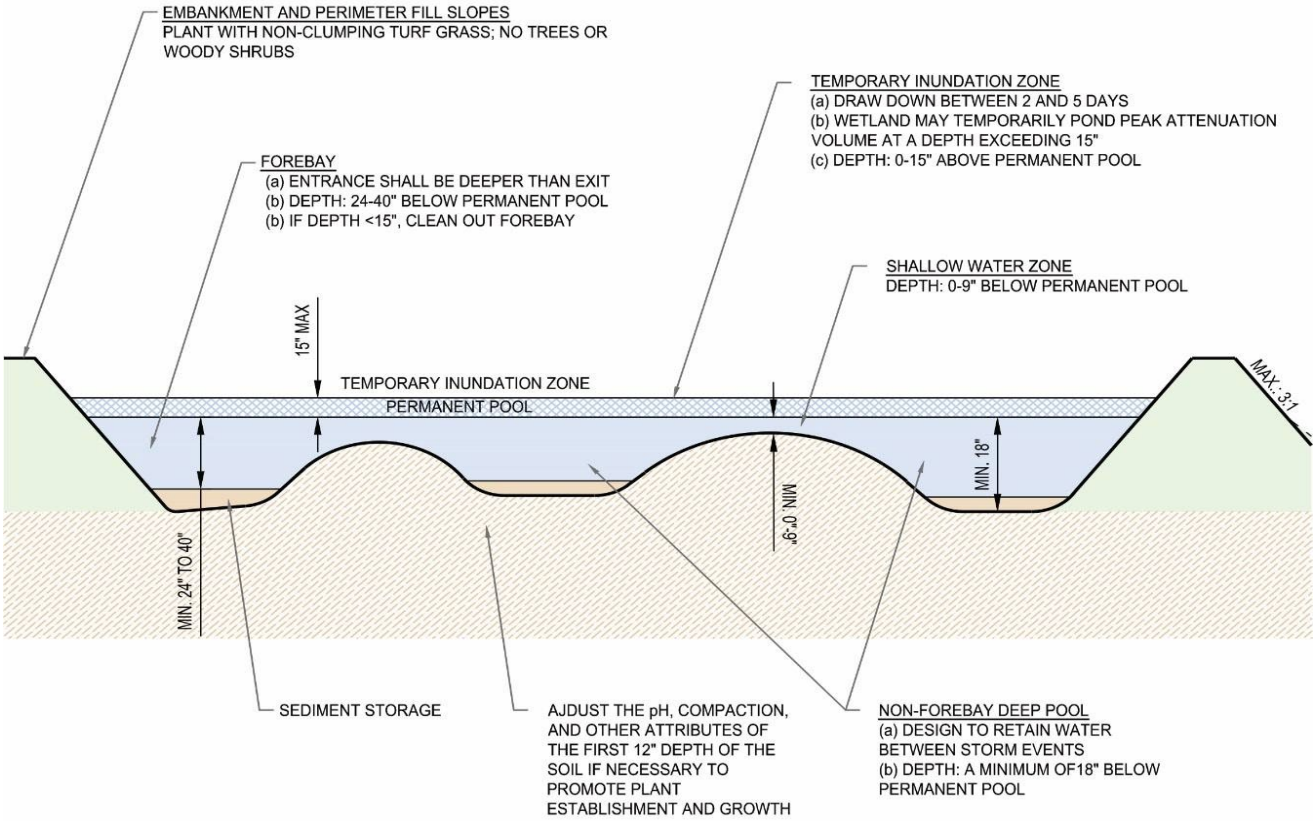
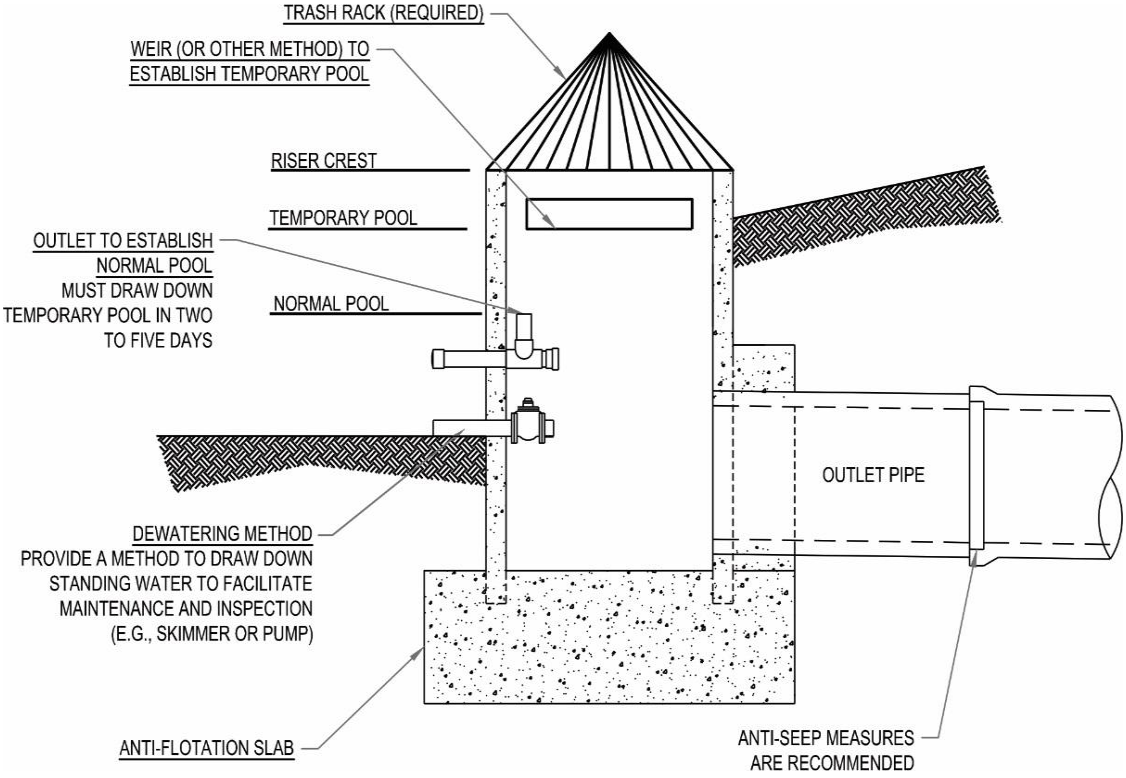


Figure 3: Stormwater Wetland Example - Riser



Guidance on MDC

WETLAND MDC 1. TEMPORARY PONDING DEPTH.
The ponding depth for the design volume shall be a maximum of 15 inches above the permanent pool.

The temporary ponding depth for the design volume may not exceed 15 inches in order to protect the health of the plants and the integrity of the soils. The design volume is the volume generated based on the water quality event.

An adjustable outlet device is highly recommended. Adjustable outlet devices allow the owner/operator of the stormwater wetland to easily correct any construction errors in the wetland depth. In addition, an adjustable outlet device allows the owner/operator to hold the ponding depth to a lower level (no less than four inches) during the first growing season to allow the plants to become established. This practice increases the survivability of the plants. However, the outlet must be brought up to the design ponding depth within the first year after construction to ensure that the entire design storm is treated. Restoring the ponding depth must be in the construction contract and the responsible person must be named. Figure 5 shows two examples of adjustable outlet structures in a stormwater wetland.

Figure 4: Two Examples of Adjustable Outlets

WETLAND MDC 2. PEAK ATTENUATION DEPTH.
The wetland may be designed to temporarily pond peak attenuation volume at a depth exceeding 15 inches.

Additional depth may be provided for peak attenuation. The storm size for peak attenuation is not specified; it must be determined by the applicant and will likely be based on local peak attenuation requirements.

WETLAND MDC 3. SURFACE AREA.
The surface area shall be sufficient to limit the ponding depth to 15 inches or less. The surface area specifications in Wetland MDC (6) through (9) are based on the wetland at its temporary ponding depth.

The minimum wetland surface area at temporary pool shall be determined by dividing the design volume in cubic feet by 1.25 feet (the maximum allowed ponding depth for the temporary pool). The designer may make the wetland larger (with a shallower ponding depth).

WETLAND MDC 4. SOIL AMENDMENTS.
The pH, compaction, and other attributes of the first 12-inch depth of the soil shall be adjusted if necessary to promote plant establishment and growth.

A soil analysis should be conducted within the stormwater wetland to determine the viability of soils for healthy vegetation growth. Imported or in-situ soils may be amended with organic material, depending on soil analysis results, to enhance suitability as a planting media. More guidance on soil amendments can be found in Part A-2 of this manual. Native plants grown in topsoil typically do not need fertilization or lime.

WETLAND MDC 5. LOCATION OF INLET(S) AND OUTLET.
The inlet(s) and outlet shall be located in a manner that avoids short circuiting.

Stormwater wetlands shall be designed in manner that maximizes the flow path from the inlet or inlets to the outlet. This allows for sufficient contact time for pollutant removal. Figure 1 at the beginning of this chapter shows how the flow path can be enhanced with additional sinuosity by proper grading. Figure 11 on page 25 also shows a good example of extending the flow path.

WETLAND MDC 6. FOREBAY.
A forebay shall be provided at the inlet to the stormwater wetland. The forebay shall comprise 10 to 15 percent of the wetland surface area. The forebay depth shall be 24 to 40 inches below the permanent pool elevation. The forebay entrance shall be deeper than the forebay exit. If sediment accumulates in the forebay in a manner that reduces its depth to 15 inches, then the forebay shall be cleaned out and returned to its design state.

The forebay is a deep pool immediately at the inlet that dissipaters energy and promotes settling of large particles, which eases maintenance of the stormwater wetland. Making the forebay entrance deeper than the exit increases its effectiveness at dissipating energy and settling solids. Deep pools are best colonized by plants with submerged roots. Deep pools slow flow velocities and trap sediment, absorb nutrients in the water column, improve oxidation, and create habitat for wildlife and mosquito predators such as frogs, fish, and dragonfly nymphs during dry times.

WETLAND MDC 7. NON-FOREBAY DEEP POOLS.
Deep pools shall be provided throughout the wetland and adjacent to the outlet structure to prevent clogging. The non-forebay deep pools shall comprise 5 to 15 percent of the wetland surface area and shall be designed to retain water between storm events. The deep pools at their deepest points shall be at least 18 inches below the permanent pool elevation.

Stormwater wetlands should be designed with non-forebay deep pools that retain some water. These pools provide habitat for *gambusia* fish and other predators (Figure 5), which prey upon mosquito larvae. 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 in A or B soils should be lined to prevent infiltration and ensure that they stay wet between storm events.

Figure 5: Gambusia fish

Site soils and groundwater elevation strongly influence the way stormwater wetlands should be constructed and their ultimate success or failure. A soils report with a determination of the seasonal high water table (SHWT) and in-situ soil permeability should be prepared. If the SHWT is not located near ground surface and the wetland will be located in A or B soils, a clay or geomembrane liner should be installed in the deep pools and shallow water areas to sustain the permanent pool of water. Figure 6 shows a stormwater wetland in Garner, NC that has been negatively impacted by infiltration.

Figure 6: Stormwater Wetland Impacted by Infiltration

WETLAND MDC 8. SHALLOW WATER ZONE.
The shallow water zone shall comprise 35 to 45 percent of the wetland surface area. The shallow water zone shall be zero to nine inches below the permanent pool elevation.

Shallow water includes all areas inundated by the permanent pool to a depth of zero to nine inches with occasional drying during periods of drought. Shallower depths may be preferable, as it may make it easier to establish vegetation. 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.

WETLAND MDC 9. TEMPORARY INUNDATION ZONE.
The temporary inundation zone shall comprise 30 to 45 percent of the wetland surface area. The temporary inundation zone shall be between 0 and 15 inches above the permanent pool elevation.

The temporary inundation zone holds water only after rain events, and rooted plants live in this zone. The plants and soils in the temporary inundation zone remove pollutants via filtering and biological processes and provide shade for the stormwater wetland. Plants should be carefully selected for this zone to ensure survival during both wet and dry conditions. Soil bioengineering

techniques, such as the use of fascines, stumps or logs, and coconut fiber rolls, can be used to create and reinforce the temporary inundation zone in areas of the stormwater wetland that may be subject to high flow velocities.

WETLAND MDC 10. DRAWDOWN TIME.
The design volume shall draw down to the permanent pool level between two and five days.

Besides drawing the design volume down in two to five days, the outlet in a stormwater wetland should be accessible to operators and resistant to clogging. In addition, the outlet structure shall have a bypass structure for larger storm events, and may, if the applicant so chooses, be designed to attenuate peak flows. The orifice may also include 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.

It is also recommended that the outlet structure be easily adjusted to allow the owner/operator to correct water levels as needed. Water levels may need to be lowered during and following plant installation.

Figure 7 shows the drawdown orifice, the overflow for larger storm events, and a manually operated valve for maintenance. One method to prevent clogging in the drawdown orifice is to turn the orifice downward below the normal pool. This prevents floating debris or vegetation from clogging the orifice.

Figure 7: Outlet Structure

If the wetland is 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 to protect trout.

The overflow structure should be located near the edge of the wetland so that it can be accessed easily for maintenance. Overflow structures that are several feet into the wetland are difficult to reach and likely will not be maintained. See Figure 8.

Figure 8: How to Plan for Outlet Structure Maintenance

WETLAND MDC 11. PROTECTION OF THE RECEIVING STREAM.
The wetland shall discharge the runoff from the one-year, 24-hour storm in a manner that minimizes hydrologic impacts to the receiving channel.

Eventually, there will be more technical information available on this MDC. For now, it is being researched at NCSU.

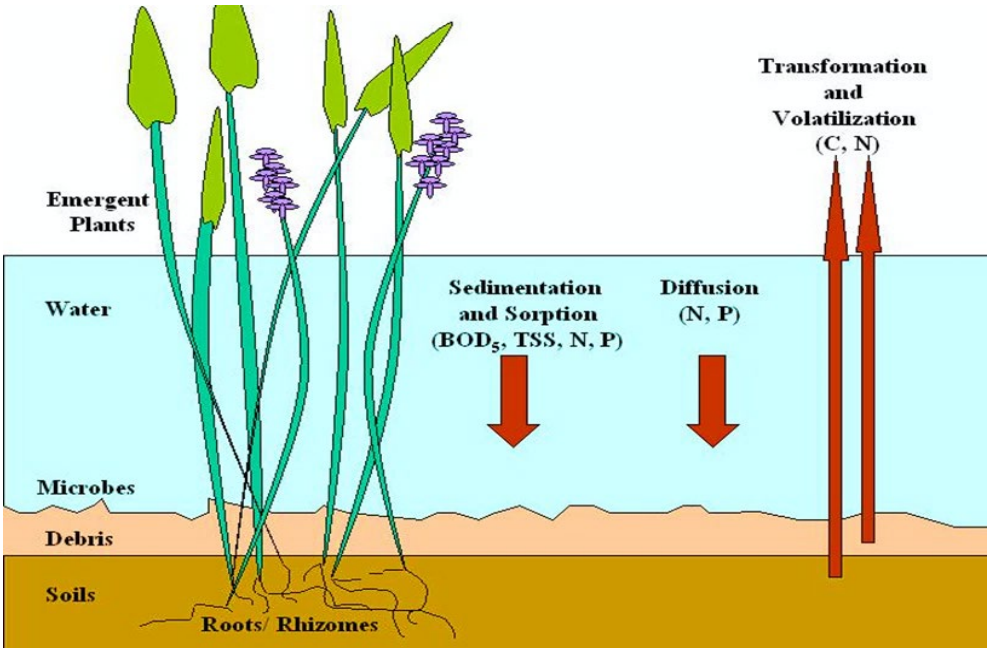
WETLAND MDC 12. LANDSCAPING PLAN.
A landscape plan prepared by a licensed professional shall be provided and shall include the following:
(a) delineation of planting zones;
(b) plant layout with species names and locations; and
(c) total number and sizes of all plant species.

Plants improve water quality by slowing velocity, which settles solids. Plants also supply carbon sources and habitat for microbes that decompose organic compounds and convert significant quantities of nitrate directly to nitrogen gas. Many herbaceous wetland plants die back during the winter. This creates a dense layer of plant litter that also provides a substrate that traps solids and supports microbial growth.

For these reasons, planning and maintaining the health of the stormwater wetland plants is crucial. See Figure 9 for a summary of the how plants, microbes and soil contribute to the

function of stormwater wetlands. Having a dense stand of healthy plants is more important to wetland functioning than the specific plant species that are present, as long as they are ecologically appropriate. The best species are native, non-invasive plants with high colonization and growth rates. Species that will persist structurally through the winter are an important consideration. Examples include woody shrubs and some sedges and rushes. In addition, the plant should be robust in periodically flooded environments that may dry out during periods of drought.

Figure 9: Stormwater Wetland Microbes, Plants, and Soil



The landscaping plan should be prepared by a qualified design professional licensed in North Carolina should include the following:

(a) delineation of planting zones (required);
(b) total quantity of plants needed, a list of species that would be acceptable in each planting zone (see Tables 1-3), and minimum number of distinct species to be installed in each planting zone (required);
(c) species used in SCMs should be, at a minimum, native to NC and grown in a nursery located in NC or within 200 miles of the SCM. In addition, it is preferable for the plants to be grown from seed collected within NC or contiguous states.
(d) minimum size requirements for plants (required);
(e) at least two sources for the plant material, from within the project's ecoregion;
(f) sequence and timing for preparing wetland bed (including soil amendments, initial fertilization, and watering, as needed); and
(g) specification of supplementary plantings to replenish losses.

At a minimum, species utilized in stormwater wetlands should be:

- Native to the ecoregion of the wetland being constructed and sourced from a nursery no further south than USDA Hardiness Zone 8b to ensure greater survivability of the planting;
- Straight species, rather than cultivated varieties of native plants; and
- Adapted to the water level zone into which they will be installed.

WETLAND MDC 13. SHALLOW WATER PLANTINGS.
The shallow water zone shall be planted with a minimum of three diverse species of herbaceous, native vegetation at a minimum density of 50 plants per 200 square feet (equivalent to 2 foot on center spacing).

The shallow water zone includes all areas that are inundated by the normal pool to a depth up to 9 inches. This zone does become drier during periods of drought. Shallow water zones, such as littoral shelves should be vegetated with emergent plants and provide some of the best treatment zones in the wetland.

Another way to think of this MDC is that it is equivalent to one plant per every 4 square feet. However, wetland plants are most likely to survive if planted in the shallowest 0-6" of the shallow water zone. Therefore, DEQ encourages concentrating the plant coverage in the shallowest 0-6" at a higher density to achieve an average density across the shallow water zone of one plant per 4 square feet.

In addition to plant density, the designer should also consider the following when designing shallow water plantings:

- HITTING THE DEPTH CORRECTLY. It is very important to hit the required 0-9" depth for the shallow water zone correctly because plants installed there will not survive if the soils are dry or if the plants are covered by more than 9" of water.
- NUMBER OF PLANT SPECIES. At least six different species of plants should be installed in the stormwater wetland. A greater diversity of plant species will increase the resilience of the wetland to changing environmental conditions.
- CONTAINER SIZE. In most cases, plants installed in stormwater wetlands are grown in containers holding 3.6 to 6.8 cubic inches of media (for example, and not limited to, 72, 50 and IP 110). Other container sizes or bare root stock may be appropriate for some species and conditions.
- PLANT HEIGHT. Plants that grow in shallow water (water's edge to 6" below normal water level) must have at least 3" of above-water foliage when installed. This can be achieved by adjusting the water level of the wetland to accommodate plans with shorter foliage or by specifying that plants must have at least a 9" foliage height when installed in this zone.
- TIMING OF INSTALLATION. Installation is generally considered safe from the average last spring frost for the wetland location until several weeks before the average first fall frost for the wetland location. It is difficult to guarantee survivability for herbaceous plants installed during the dormant season.

The plant species listed in Tables 1-3 below have performed well in NC stormwater wetlands and can be reliably propagated in wetland plant nurseries. These lists are not exhaustive. Personal experience, many excellent publications, and recommendations from wetland scientists, landscape architects, and wetland plant growers may reveal additional useful species. The icons denote if the species provide a food source for butterflies/moths (), bees () and birds ().

Table 1: Plants for Shallow Water Zone

Botanical Name	Common Name	Ideal Depth	Notes
Acorus americanus	Sweetflag	0-2”	
Canna flaccida	Yellow canna	0-2”	
Dulichium arundinaceum	Three-way sedge	0-6	
Eleocharis acicularis and *Eleocharis quadrangulata*	Needle spikerush and Squarestem spikerush	0-9” 1-12	.
Iris virginica	Virginia iris	0-2”	
Juncus effusus	Common rush	0-2”	
Lilaeopsis carolinensis and *Lilaeopsis chinensis*	Carolina grasswort and Eastern grasswort	0-9”	Several inches tall, native only to coastal plain.
Nelumbo lutea	American lotus	1”-3’	Robust water-lily type that will spread.
Nuphar lutea ssp. advena	Yellow pond-lily	1”-3’	A water-lily type species that will spread.
Nymphaea odorata	American white waterlily	1”-3”	A water-lily that will spread.
Orontium aquaticum	Golden club	0-6”	

Peltandra virginica	Arrow arum	-0-12”	Spreads vigorously.
Pontederia cordata	Pickerelweed	0-12”	Spreads vigorously.
Sagittaria latifolia	Broadleaf arrowhead	0-6”	Spreads vigorously.
Sagittaria lancifolia	Bulltongue arrowhead	2-6”	Native only to coastal plain. Spreads vigorously.
Saururus cernuus	Lizard’s tail	0-6”	Spreads vigorously.
Schoenoplectus americanus *Schoenoplectus pungens*	Chairmaker’s bulrush Common threesquare	0-2”	Not native to mountains.
Schoenoplectus tabernaemontani	Softstem bulrush	0-6”	Spreads vigorously.
Scirpus cyperinus *Scirpus expansus*	Wool grass Sedge/Woodland bulrush	0-2”	
Sparganium americanum	American bur-reed	0-6”	Spreads vigorously.
Zizaniopsis miliacea	Giant cutgrass	2-6”	Not native to mountains. Foliage present all year.Spreads vigorously.

WETLAND MDC 14. TEMPORARY INUNDATION ZONE PLANTINGS.
The temporary inundation zone shall be planted according to one of the following options:

(a) a minimum of three diverse species of herbaceous, native vegetation at a minimum density of 50 plants per 200 square feet (equivalent to 2-foot on center spacing);
(b) a minimum of eight shrubs per 200 square feet (equivalent to 5 foot on center spacing); or
(c) a minimum of one tree and a minimum of 40 grass-like herbaceous plants per 100 square feet.

The temporary inundation zone stabilizes the slopes and optimizes pollutant removal during storm events. Shallow land zones should be planted with wetland vegetation capable of growing in alternating dry and inundated conditions. The temporary inundation zone should be planted with vegetation that can withstand irregular inundation and occasional drought.

Table 2: Herbaceous Plants for the Temporary Inundation Zone

Botanical Name	Common Name	Notes
Andropogon glomeratus	Bushy Beardgrass Bushy Bluestem	
Amsonia tabernaemontana	Eastern blue star	
Asclepias incarnata	Swamp Milkweed	Not found in mountains. 
Carex amphibola *Carex cherokeensis* *Carex crinita* *Carex glaucescens* *Carex gravi* *Carex intumescens* *Carex lupulina* *Carex lurida* *Carex stricta* *Carex vulpinoidea*	Creek sedge Cherokee sedge Fringed Sedge Southern waxy sedge Gray's sedge Bladder sedge Hop sedge Lurid Sedge Tussock Sedge Fox Sedge	
Chasmanthium latifolium *Chasmanthium laxum*	River Oats Slender woodoats	
Chelone glabra	White Turtlehead	Not found in mountains. 
Cladium jamaicense	Saw grass	
Conoclinium coelestinum	Blue Mistflower	
Coreopsis lanceolata *Coreopsis tinctoria*	Tickseed	
Dulichium arundinaceum	Three-way sedge	
Echinacea purpurea	Purple cone flower	
Elymus canadensis *Elymus hystrix* *Elymus virginicus*	Wildrye	
Eupatorium perfoliatum	Boneset	
Eutrochium dubium (syn. *Eupatorium dubium*)	Coastal Joe Pye Weed	

Eutrochium fistulosum (syn *Eupatorium fistulosum*) *Eutrochium maculatum* (syn. *Eupatorium maculatum*)	Hollow Stemmed Joe Pye Weed Spotted Joe Pye Weed	
Gallardia pulchella	Blanket flower	
Helenium autumnale	Sneezeweed	
Helianthus angustifolius	Swamp Sunflower	
Heliopsis hellianthoides	False sunflower	
Hibiscus coccineus *Hibiscus laevis* *Hibiscus moscheutos*	Scarlet Rosemallow Halberldeaf Rosemallow Marsh Hibiscus	Not found in mountains 
Juncus effusus *Juncus coriaceus* *Juncus tenuis*	Common Rush Leathery rush Path Rush	Evergreen 
Kosteletskya pentacaropos (syn. *Kosteletskya virginica*)	Saltmarsh Mallow	Coastal plain only 
Liatris spicata	*Blazing star/Dense blazing star*	
Lobelia cardinalis *Lobelia elongata*	Cardinal Flower Blue lobelia	*L. elongate* not found in mountains 
Monarda fistulosa *Monarda didyma*	Bee balm	
Muhlenbergia capillaris	Purple Muhly	Not found in mountains, Coastal plain genetic origin preferred 
Panicum rigidulum (syn. Coleataenia rigidula) *Panicum virgatum*	Redtop panicgrass Switchgrass	
Ratibida pinnata	Gray-headed coneflower	
Rhynchospora colorata	Starrush Whitetop	
Saururus cernuus	Lizard's tail	
Erianthus brevibarbis (syn. *Saccharum brevibarbe*) *Erianthus giganteus* (syn. Saccharum *giganteum*)	Narrow Plume Grass Sugar Cane Plumegrass	
Scirpus atrovirens	Green Bulrush	

Scirpus cyperinus	Wool grass	
Silphium perfoliatum	Cup plant	
Solidago canadensis *Solidago rugosa* *Solidago sempervirens*	Goldenrod	
Syphyotrichum lateriflorum *Syphyotrichum laeva* laeve *Syphyotrichum novae-angliae* *Syphyotrichum oblongifolium*	Calico aster Smooth aster New England aster Aromatic aster	
Verbena hastata	Swamp Verbena	
Vernonia noveboracensis	Ironweed	

Table 3: Shrubs for the Temporary Inundation Zone

Botanical Name	Common Name
Aesculus pavia *Aesculus sylvatica*	Red buckeye Painted buckeye
Alnus serrulata	Tag alder/Hazel alder
Amelanchier arborea	Downy service-berry
Amelanchier canadensis	Canadian serviceberry
Aronia arbutifolia	Red Chokeberry
Callicarpa americana	Beautyberry
Ceonothus americanus	New Jersey tea
Cephalanthus occidentalis	Common button bush
Clethra alnifolia	Summersweet clethra
Cornus amomum	Silky dogwood
Cyrilla racemiflora	Swamp cyrilla (ti-ti)

Diospyros virginiana	Persimmon 
Eubotrys racemosus	Fetterbush/Swamp dog hobble 
Hamamelis virginiana	Witchhazel 
Hypericum densiflorum	Dense hypericum 
Ilex decidua	Possum haw 
Ilex glabra	Inkberry 
Ilex verticillata	Winterberry 
Ilex vomitoria	Yaupon holly 
Itea virginica	Virginia sweetspire 
Lindera benzoin	Northern spicebush 
Leucothoe fontanesiana *Leucothoe axillaris*	Highland doghobble  Coastal doghobble
Lyonia lucida	Fetterbush 
Rhododendron viscosum *Rhododendron atlanticum*	Swamp azalea  Dwarf azalea
Physocarpus opulifolius	Ninebark 
Rosa palustris	Swamp rose 
Salix caroliniana *Salix serica*	Carolina willow  Silky willow
Sambucus canadensis (syn. *S. nigra* ssp. *canadensis)*	American black elderberry 
Spiraea tomentosa	Hardhack/Steeple bush 
Styrax americanus	American snowbell 
Symphoricarpos orbiculatus	Coralberry 
Vaccinium arboreum *Vaccinium ~~corymobosum~~ corymbosum* *Vaccinium fuscatum*	Farkleberry  Highbush blueberry Black highbush blueberry

Viburnum dentatum	Arrowwood viburnum
Viburnum prunifolium	Blackhaw viburnum
Viburnum nudum	Possumhaw viburnum
Xanthorhiza simplicissima	Yellowroot

WETLAND MDC 15. DAM STRUCTURE AND PERIMETER FILL SLOPES.
On the dam structure and perimeter fill slopes, non-clumping turf grass shall be provided, and trees and woody shrubs shall not be allowed.

The turf areas on the dam structure and perimeter fill slopes should be stabilized within 14 days after the end of construction. The stabilization might be the final vegetation or a temporary stabilization measure until the vegetation becomes established.

WETLAND MDC 16. NO CATTAILS.
Cattails shall not be planted in the wetland.

At first glance, cattails, with their long, thick leaves and their decorative brown seed heads are interesting and attractive in a stormwater wetland. However, cattails are very invasive (250,000 seeds per seed head) and can quickly take over an entire stormwater wetland, outcompeting other plants and eventually reducing the storage capacity of the wetland. Matted cattails detritus also provides excellent mosquito habitat. The plants in Tables 1-3 above are just as impressive and not invasive.

Figure 10: Cattails

WETLAND MDC 17. TRASH RACK.
A trash rack or other device to trap debris shall be provided on piped outlet structures.

See Part A-3 for more information on how to select a trash rack.

Recommendations

WETLAND RECOMMENDATION 1: SUFFICIENTLY LARGE DRAINAGE AREA
It is recommended to have a drainage area of at least two acres to provide year-round hydration for wetland plants to grow and thrive.

Stormwater wetlands often thrive better when they have a sufficiently large drainage area (two acres or more) to provide year-round hydration, particularly when they are installed in A or B

soils. Since water depths are shallower than in wet detention ponds, water loss by evaporation is an important concern.

WETLAND RECOMMENDATION 2: DEEP ZONE PLANTINGS.
Deep zone plantings are not required, but the designer may use them if desired for aesthetic purposes. They may not be planted in the deep zone adjacent to the outlet structure to prevent clogging.

Table 4: Floating Aquatic Plants for the Deep Zone

Botanical Name	Common Name
Nymphaea odorata	White water lily
Nelumbo lutea	American lotus
Nuphar lutea ssp. *advena*	Yellow Pond-lily

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.

Maintenance

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.

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. Important operation and maintenance procedures:

1. Immediately following construction of the stormwater wetland, conduct bi-weekly inspections and water wetland plants bi-weekly until vegetation becomes established (commonly six weeks).
2. Before and immediately after plant installation, monitor water level and adjust to ensure that plants are not completely inundated.
3. No portion of the stormwater wetland will be fertilized after the first initial fertilization that is required to establish the wetland plants.

4. Stable groundcover will be maintained in the drainage area to reduce the sediment load to the wetland.
5. At least once annually a dam safety expert will inspect the embankment. Any problems that are found will be repaired immediately.

After the stormwater wetland is established, it shall be inspected **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 shall be kept in a known set location and shall be available upon request.

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

Table 6: Sample Operation and Maintenance Provisions for Stormwater Wetlands

SCM element:	Potential problems:	How to remediate the problem:
The entire wetland	Trash/debris is present.	Remove the trash/debris.
The 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.
Inlet device	The inlet pipe is clogged (if applicable).	Unclog the pipe. Dispose of the sediment in a location where it will not cause impacts to streams or the SCM.
	The inlet pipe is cracked or otherwise damaged (if applicable).	Repair or replace the pipe.
	Erosion is occurring in the swale (if applicable).	Regrade the swale if necessary 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 of less than 15” or 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 SCM.
	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 30% 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 30% of the deep pool and shallow water areas.	Remove the invasive plants by hand or by wiping them with pesticide (do not spray) – consult a professional.
	The temporary inundation zone 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.
	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 SCM.
Embankment	A tree has started to grow on the embankment.	If tree is <6” in diameter, remove the tree. If the tree is >6” in diameter, consult a dam safety specialist to remove the tree.
	An annual inspection by an 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 and repair any holes or erosion.

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 SCM.
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.	Repair the damage and improve the flow dissipation structure.
	Discharges from the wetland are causing erosion or sedimentation in the receiving water.	Contact the local NCDQ Regional Office.

Old Versus New Design Standards

The following is a summary of some of the changes in stormwater wetland design standards between the archived version of the BMP Manual and the current MDC for stormwater wetlands. It is intended to capture the highlights only; any stormwater wetland MDC that are not captured in this table are still required per 15A NCAC 02H .1054.

	Old manual requirements	New MDC
Drawdown time for the design volume	2-5 days	2-5 days
Sizing	Based on the surface area needed to pond water 12”	Based on the surface area needed to pond water 15”
SHWT requirements	Permanent pool shall be within 6” of the SHWT (either above or below) or a liner shall be provided	No requirements regarding SHWT
Required spacing for herbaceous plants	Required to be 2 foot on center	Should be 2 foot on center average, may distribute throughout the planting zone to avoid the deepest areas of the wetland.

Required size for plants	Specific minimum pot sizes were specified	The manual suggests containers holding 3.6 to 6.8 cubic inches of media (for example, and not limited to, 72, 50 and IP 110) but allows for other container sizes or bare root stock for some species and conditions when appropriate.
Plant lists	Plant recommendations were limited.	A much more extensive list of plants is provided based on advice from NC growers and other plant experts in NC.
Minimum length to width ratio	1.5:1 with 3:1 recommended	Specific ratio not given; instead, inlet(s) and outlet shall be located to avoid short circuiting.
Forebay design	Not specified	Forebay should be deeper at the entrance, shallower at the exit.
Trash rack	Not required	Trash rack or other device to exclude trash from the outlet structure required.

References for Plant Wildlife Value

American Wildlife and Plants: A Guide To Wildlife Food Habits, Alexander C. Martin, Herbert S. Zim and Arnold L. Nelson (1989) ISBN 10: 0486207935 / ISBN 13: 9780486207933

Caterpillars of Eastern North America: A Guide to Identification and Natural History, David L. Wagner, Princeton Field Guides, 2005 ISBN-10: 0691121443

Department of Ecology, State of Washington, "An On-line Version of an Aquatic Plant Identification Manual for Washington's Freshwater Plants at http://www.ecy.wa.gov/programs/wq/plants/plantid2/categories.html (Accessed December 12, 2017).

Florida Native Plant Society "Learn About Native Plants" at http://www.fnps.org/natives/natives (Accessed December 12, 2017).

Forest Plants of the Southeast and their Wildlife Uses, James H. Miller and Karl V. Miller, University of Georgia Press, 2005. ISBN: 0820327484

Illinois Wildflowers maintained by Dr. John Hilty at http://www.illinoiswildflowers.info/index.htm (Accessed October 13 and December 12, 2017).

Ladybird Johnson Wildflower Center Plant Database (Accessed October 10 and December 12, 2017) https://www.wildflower.org/plants/result.php?id_plant=chgl2

Landscaping for Wildlife with Native Plants, Chris Moorman, Mark Johns, Liessa Thomas Bowen, North Carolina State University Cooperative Extension Service, 2002. https://content.ces.ncsu.edu/landscaping-for-wildlife-with-native-plants

Personal Observations, Shannon Currey, Hoffman Nursery, Rougemont, NC.

Personal Observations, staff of North Carolina Botanical Garden, Chapel Hill, NC. (Mike Kunz, NCBG)

USDA Natural Resources Conservation Service Plant Fact Sheets https://www.nrcs.usda.gov/Internet/FSE_PLANTMATERIALS/publications/lapmcfs7566.pdf

Wildflowers and Plant Communities of the Southern Appalachian Mountains and Piedmont, *A Naturalist's Guide to the Carolinas, Virginia, Tennessee, and Georgia*, Timothy P. Spira, 2011. ISBN: 978-0-8078-7172-0

Photo Gallery

Figure 11: View of Wetland with Long Flow Path (Caldwell Co. Photo by Seth Nagy)

Figure 12: Stormwater Wetlands, Washington, DC & Raleigh, NC