12.0 Constructed Wetlands

Definition: Practices that mimic natural wetland areas to treat urban stormwater by incorporating permanent pools with shallow storage areas. Constructed Wetlands are explicitly designed to provide stormwater detention for larger storms (Cv and Fv) above the RPv storage. Design variants include:

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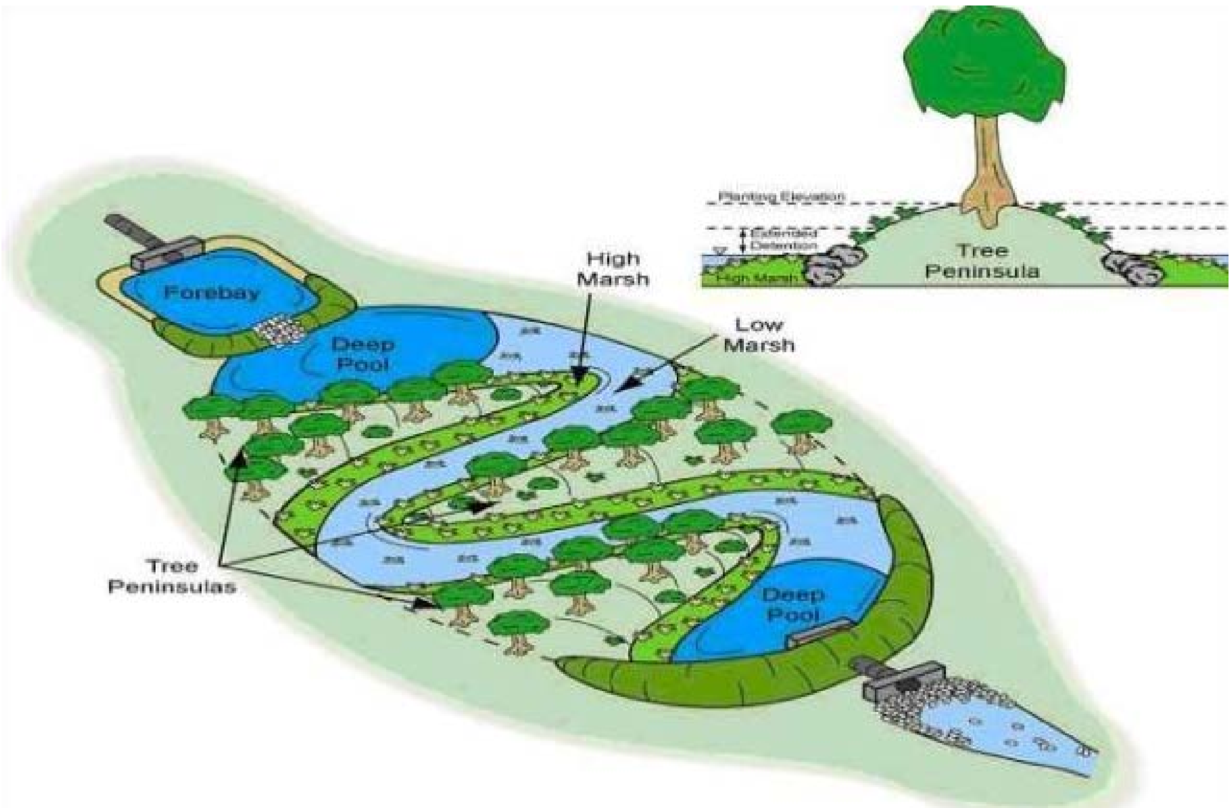
- 12-A Traditional Constructed Wetlands
- 12-B Wetland Swales
- 12-C Ephemeral Constructed Wetlands
- 12-D Submerged Gravel Wetland (to be added at a later date)

Constructed Wetlands are shallow depressions that receive stormwater inputs for water quality treatment. The majority of the wetland surface area is covered by shallow (<1' deep) wetland area, with greater depths in the forebay and pools within the wetland. Wetlands possess variable microtopography to promote dense and diverse wetland cover. Runoff from each new storm displaces runoff from previous storms, and the long residence time allows multiple pollutant removal processes to operate. The wetland environment provides an ideal environment for gravitational settling, biological uptake, and microbial activity.

The Constructed Wetlands design variants all share commonalities, but are also unique in their performance credits. None of the design variants receive any retention allowance, though they all have pollutant reduction capabilities. Traditional Constructed Wetlands (12-A), should be considered for use after all other upland runoff reduction opportunities have been exhausted and there is still a remaining treatment volume or runoff from larger storms (i.e. 10-year, 100-year or flood control events) to manage. Both Wetland Swales (12-B) and Ephemeral Constructed Wetlands (12-C) can provide some runoff reduction credits, particularly in well drained soils. Submerged Gravel Wetlands are to be added at a later date, and will only provide pollution reduction credits.

Constructed Wetlands have both community and siting criteria (see *Section 12.3 Wetland Feasibility Criteria*) that should be considered before incorporating the stormwater practice onsite.

Figure 12.1. Typical Traditional Constructed Wetland Plan View



12.1 Wetland Stormwater Credit Calculations

Stormwater wetlands receive 0% retention credit (R_v) and pollutant removals are outlined in **Table 12.1**. As a treatment practice, the wetland must be sized according to the standards outlined in Section 12.6 to receive full pollutant removal credit.

Table 12.1-A Traditional Constructed Wetlands Performance Credits

Runoff Reduction	
Retention Allowance	0%
RPv -A/B Soil	0%
RPv - C/D Soil	0%
Cv	0%
Fv	0%
Pollutant Reduction	
TN Reduction	30% Removal Efficiency
TP Reduction	40% Removal Efficiency
TSS Reduction	80% Removal Efficiency

Table 12.1-B Wetland Swale Performance Credits

Runoff Reduction	
Retention Allowance	0%
RPv -A/B Soil	15% Annual Runoff Reduction
RPv - C/D Soil	10% Annual Runoff Reduction
Cv	1% of RPv Allowance
Fv	0%
Pollutant Reduction	
TN Reduction	100% of Load Reduction + 20% Removal Efficiency
TP Reduction	100% of Load Reduction + 30% Removal Efficiency
TSS Reduction	100% of Load Reduction + 60% Removal Efficiency

Table 12.1-C Ephemeral Constructed Wetland Performance Credits

Runoff Reduction***	
Retention Allowance	0%
RPv -A/B Soil	40% Annual Runoff Reduction
RPv - C/D Soil	10% Annual Runoff Reduction
Cv	1% of ~~Rpv~~ RPv Allowance
Fv	0%
Pollutant Reduction	
TN Reduction	100% of Load Reduction + 20% Removal Efficiency
TP Reduction	100% of Load Reduction + 30% Removal Efficiency
TSS Reduction	100% of Load Reduction + 60% Removal Efficiency

*****NOTE:** An Ephemeral Constructed Wetland constructed in accordance with the Sediment and Stormwater Plan Review Policy and Procedures for Poultry House Projects as a forebay having a volume equivalent to the full RPv shortfall volume is given full volume reduction credit. The Department will monitor the performance of the ephemeral constructed wetland forebays at these poultry house projects and may adjust the volume reduction credit as necessary.

12.2 Stormwater Wetlands Design Summary

Table 12.2 summarizes design criteria for stormwater wetlands. For more detail, consult Sections 12.3 through 12.7. Sections 12.8 and 12.9 describe practice construction and maintenance criteria.

Table 12.2 Stormwater Wetland Design Summary

<table>
<tr><td>Feasibility
(Section 12.3)</td><td colspan="2">• Requires a water balance calculation for drainage areas less than 5 acres.
• Consumes about 10% of CDA.
• Contributing slopes <8%.
• Setbacks from property lines, buildings, septic fields, and wells.
• Typically located in HSG C and D soils, or in areas of high groundwater.
• Avoid construction within jurisdictional wetlands. Jurisdictional determinations and permits maybe required. Evaluate impacts to downstream waters, including existing wetlands.</td></tr>
<tr><td>Conveyance
(Section 12.4)</td><td colspan="2">• Max. 1% slope within wetland cells.
• Max. 1 foot drop between wetlands cells.
• Removable flashboard risers recommended to set pool elevation.</td></tr>
<tr><td>Pretreatment
(Section 12.5)</td><td colspan="2">• Sediment Forebay at Piped Inlets (Reference Wet Pond specification for additional information).</td></tr>
<tr><td>Sizing
(Section 12.6)</td><td colspan="2">• RPv event: Max. 12” above the normal pool elevation (no more than 6” after 48hrs, except 12-C)
• Fv event: Max. 2.5 ft above the normal pool elevation.
• Min. 1 ft of freeboard from the design high water surface elevation to the nearest structure, roadway, etc (can be outside the extents of the facility).
• 15% to 35% of the total water storage must be provided within the permanent pools (12-A only).</td></tr>
<tr><td rowspan="2">Geometry</td><td>Traditional Constructed Wetland (12-A)
• 2:1 overall flow path to linear length ratio.
• 0.5:1 shortest flow path to overall length.
• Max. 20% of the contributing may enter with less than a 1:1 ratio of flow path to overall length.
• Side slopes 4:1 or flatter..
• Deep Pool depth minimum 18”; 22” if no groundwater source.
• Create microtopography within the wetland</td><td>Wetland Swale (12-B):
• Min. 1’ bottom width, max 6’.
• Min. 4’ wide bench set at 1-yr elevation.
• Side slopes 3:1 or flatter.
• Max. 1% avg. slope (increased if checkdams are used)
• Seasonal high groundwater may intersect the low flow channel to promote aquatic vegetation.
• Min. 100’ length</td></tr>
<tr><td>Ephemeral Constructed Wetland (12-C)
• Side slopes 4:1 or flatter.
• Groundwater below bottom of wetland (seasonal high groundwater may intersect).</td><td>Submerged Gravel Wetland (12-D)
• To be added at a later date.</td></tr>
<tr><td>Landscaping
(Section 12.7 and Landscaping Criteria Specification)</td><td colspan="2">• Min. 75% Native Species planted.
• Match Plants to Inundation Zones.
• Integrate trees into design (not for Wetland Swale, 12-B).
• Min. 4 aggressive colonizer species.
• Reference Landscape Criteria Specification for additional information.</td></tr>
</table>

FEQ July 2016

12.3 Wetland Feasibility Criteria

Constructed wetland designs are subject to the following site constraints:

Adequate Water Balance. Traditional Constructed Wetlands (12-A) must have enough water supplied from groundwater, runoff or baseflow so that the permanent pools are designed to not go dry after a 30-day summer drought. A simple water balance calculation must be performed using the equation provided in *Section 12.6. Water Balance Testing* for drainage areas less than 5 acres.

Contributing Drainage Area (CDA). The contributing drainage area must be large enough to sustain a permanent water level within the stormwater wetland. If the only source of wetland hydrology is stormwater runoff, then typically more than 2 to 3 acres of drainage area is needed to maintain constant water elevations. Smaller drainage areas are acceptable if the bottom of the wetland intercepts the groundwater table or if the designer and the landowner are willing to accept periods of relative dryness (i.e., Ephemeral Constructed Wetlands, 12-C), and the plant species are chosen to accommodate this design variable.

Space Requirements. Constructed Wetlands normally require a footprint that takes up about 10% of the contributing drainage area, depending on the average depth of the wetland.

Site Topography. Wetlands are best applied when the grade of contributing slopes is less than 8%. Reference ***Specification 6.0. Restoration Practices*** for additional information on a step pool approach to Constructed Wetlands that can be applied on steep sloped areas.

Available Hydraulic Head. The permanent pool elevation is typically fixed by the elevation of the existing downstream conveyance system to which the wetland will ultimately discharge. Because the storage needed for storm events in Constructed Wetlands is shallow, the amount of head needed is typically less than for Wet Ponds, usually a minimum of 2 to 4 feet.

Minimum Setbacks. Local ordinances and design criteria should be consulted to determine minimum setbacks to property lines, structures, utilities, and wells. As a general rule, the edges of Constructed Wetlands should be located at least 20 feet away from property lines, 25 feet from building foundations, 100 feet from septic system fields, and 150 feet from public and private water supply wells.

Depth to Water Table. The depth to the groundwater table is not a major constraint for Constructed Wetlands, since a high water table can help maintain the permanent pool elevation. However, designers should keep in mind that high groundwater inputs may reduce pollutant removal rates, increase excavation costs and reduce the storage volume. For Ephemeral Constructed Wetlands, 12-C, the normal groundwater elevation shall be below the bottom of the wetland, though the seasonal high groundwater may fluctuate within the storage area.

Soils. Soil tests must be conducted to determine the infiltration rates and other subsurface properties of the soils underlying the proposed wetland. Highly permeable soils will make it difficult to maintain a healthy permanent pool. Underlying soils of Hydrologic Soil Group (HSG) C or D should be adequate to maintain a permanent pool. Most HSG A soils and HSG B soils are only suitable for variants 12-B or 12-C.

Use of, or Discharges to, Natural Wetlands. Constructed wetland should be constructed off-line from and designed to avoid impacts to federal or state jurisdictional waters, including perennial and intermittent streams and ditches, and tidal and non-tidal wetlands. Constructed wetlands may not be located within or otherwise impact federal or state jurisdictional waters without first obtaining a permit from the appropriate agency. Designers should request a jurisdictional determination from the federal regulatory agency (U.S. Army Corps of Engineers, Philadelphia District, 215-656-6728) and the state regulatory agency (Delaware Department of Natural Resources and Environmental Control, Wetland and Subaqueous Lands Section, 302-739-9943) to ensure that all federal and state jurisdictional areas are identified. An environmental consultant can be hired to assist with the determination.

Community and Environmental Concerns. In addition to the community and environmental concerns that can exist for Wet Ponds, Constructed Wetlands can generate the following, which must be addressed during design:

- **Aesthetics and Habitat.** Constructed Wetlands can create wildlife habitat and can also become an attractive community feature. Designers should think carefully about how the wetland plant community will evolve over time, since the future plant community may not resemble the one initially planted. A management plan must be put in place to help control noxious weeds and threatening invasive species from colonizing the wetlands.
- **Existing Forests.** Given the large footprint of a Constructed Wetland, there is a chance that the construction process may result in extensive tree clearing. The designer should preserve mature trees during the facility layout, and he/she should consider creating a wooded wetland (see Cappiella et al., 2006) to reduce clearing. Any felled trees, including the root wad, can be placed in the Constructed Wetland to provide wildlife habitat, bank stabilization, and shade.
- **Safety Risk.** Constructed Wetlands are generally safer than Wet Ponds due to their reduced depth, although forebays and deep micropools should be designed with aquatic benches to reduce safety risks.
- **Mosquito Risk.** Mosquito control can be a concern for Constructed Wetlands if they are under-sized or have a small contributing drainage area. Deepwater zones serve to keep mosquito populations in check by providing habitat for fish and other pond life that prey on mosquito larvae. Few mosquito problems are reported for well designed, properly-sized and frequently-maintained Constructed Wetlands; however, no design can eliminate them completely. Simple precautions can be taken to minimize mosquito breeding habitat within constructed wetlands (e.g., constant inflows, benches that create habitat for natural predators, and constant pool elevations –MSSC, 2005). Wetland Swales, due to the lack of deeper pools, may have higher

mosquito populations, and should have limited residential applicability.

12.4 Wetland Conveyance Criteria

The longitudinal slope profile within individual wetland cells should generally be flat from inlet to outlet, at 1% maximum. The recommended maximum elevation drop between wetland cells should be 1 foot or less.

While many different options are available for setting the normal pool elevation, it is strongly recommended that removable flashboard risers be used, given their greater operational flexibility to adjust water levels following construction (see Hunt et al, 2007). A weir or spillway can also be designed to accommodate passage of the larger storm flows at relatively low ponding depths.

12.5 Wetland Pretreatment Criteria

Sediment regulation is critical to sustain Constructed Wetlands. Consequently, a forebay shall be located at the inlet, and a micropool pool shall be located at the outlet. Forebays are designed in the same manner as Wet Ponds. Reference the design criteria below for additional information.

12.6 Wetland Design Criteria

Variant 12-A, Traditional Constructed Wetlands:

Wetland Sizing. Traditional Constructed Wetlands provide water quality enhancement for stormwater volumes remaining after upstream practices have provided runoff reduction. Additionally, stormwater wetlands can be sized to control flows from the Cv and Fv storms. The available storage volume of storm events in Constructed Wetlands is equal to the volume provided above the permanent pool, or the normal water surface elevation. The permanent pool volume, or the volume below the normal water surface elevation, must account for a minimum of 15 to 35% of the total storage volume to maintain a healthy system.

The Constructed Wetland must be sized so that the 1-year RPv event has a maximum ponding depth of 12” above the normal water surface elevation, in order to reduce impact on the aquatic plantings. In addition, the RPv must be attenuated for a minimum of 24-hours, although no more than 6” of water can be ponded for more than 48 hours. The 100-year Fv event has a maximum ponding depth of 2.5 feet above the normal water surface elevation. Additionally, 1 foot of freeboard above the Fv or largest design storm water surface elevation must be provided to the surrounding roadways and structures requiring a Certificate of Occupancy. The extents of the Fv or highest design storm must be clearly denoted on the Sediment and Stormwater Management

Plans.

Internal Design Geometry. Traditional Constructed Wetlands can be designed in several ways, all of which promote diverse emergent and aquatic vegetation, as well as anaerobic and aerobic conditions within the water to promote pollutant removal. In all cases, varied topography within each component of the wetland is encouraged to provide diverse ecology (e.g., hummocks, forested peninsulas, horizontal tree stumps, boulders, etc). Research and experience have shown that the internal design geometry and depth zones are critical in maintaining the pollutant removal capability and plant diversity of stormwater wetlands. Wetland performance is enhanced when the wetland has multiple cells, longer flowpaths, and a high ratio of surface area to volume.

Whenever possible, constructed wetlands should be irregularly shaped with long, sinuous flow paths. The total length of the flow path compared to the linear length through the wetland area, must be a minimum ratio of 2:1. In addition, the ratio of the shortest flow path through the system (due to an inlet located near the outlet) to the overall length must be at least 0.5:1. The drainage area served by any inlets located less than a 0.5:1 ratio shall constitute no more than 20% of the total contributing drainage area.

One continuous winding system can be designed that distributes the runoff through wetland areas and deeper permanent pools. The flow through the system shall be limited to maximum of 1% average slope excluding any drops or riffles. At least one shallow wetland area and one permanent pool area must be provided, but there is no maximum on how many times the systems can be alternated. See below for more detailed information on the various components.

If a more varied range in elevation is desired, a more step pool approach can be taken, where the different cells can be separated in elevation by bio or compost logs, sand berms anchored with rocks/boulders, or other stabilized protection. Forested peninsulas can also be extended across 95% of the width of the wetland, creating two separate zones. Riffles, or rock lined slopes of maximum 8%, can also be used to adjust the grades. The maximum elevation difference between the various cells shall be 1 foot.

Inundation Zones.

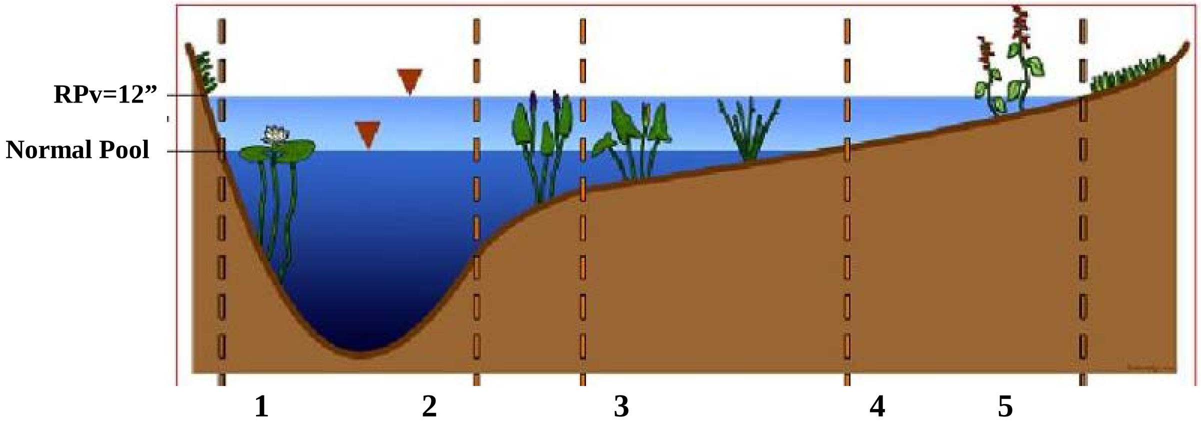


Figure 12.4. Traditional Constructed Wetland Inundation Zones: (1) Deep Pool (depth -36 to -18 inches), (2) Transition Zone (depth -18 to -6 inches), (3) Low Marsh Zone (depth -6 inches to normal pool), (4) High Marsh Zone (normal pool to +12 inches), and (5) Floodplain (+12 to +30 inches) (adapted from Hunt et al,. 2007).

Zone 1:

- ***Forebays.*** For all designs a forebay must be included at all pipe inlets to provide sedimentation prior to the runoff entering the main wetland system. The forebay must be 3 to 4 foot deep and follow the forebay specifications as described in ***Specification 13 – Wet Ponds***. The forebay will allow for easier access of accumulated sediments rather than being dispersed throughout the wetland system. In some instances, it might be desired to direct water from a Wet Pond to a wetland system, in which case a specified forebay is not necessary since one is provided in the Wet Pond.

- ***Deep Pools.*** The volume of water stored in the deep pools, also referred to as micropools, must be at least 15% of the total water storage volume. At least two deep pools in addition to the forebay must be provided, one of which must be located prior to the outlet location to provide for additional sediment deposition. Deep pools can help to provide fish habitat, cooler water temperatures, energy dissipation, and sedimentation. These interior deep pools range from -18 inches to -36 inches in depth below the normal pool elevation, and must be designed to remain permanently saturated. If groundwater will not support the permanent pool elevation in the summer months, then the minimum deep pool elevation should be lowered to -22 inches. The deep pools must be hydraulically connected within the water flow path. The deep pools shall be designed with a slope not steeper than 3:1.

Zone 2: Transition Zone. Zone 2 is only allowed as a short transition zone between the deeper pools and the low marsh zone, and ranges from -6 to -18 inches below the normal pool elevation. In general, this transition zone must have a maximum slope of 3:1, or flatter, from the deep pool to the low marsh zone. It is advisable to install biodegradable erosion control fabrics or similar materials during construction to prevent erosion or slumping of this transition zone.

Zone 3: Low Marsh Zone. Most of the wetland surface area will exist between the two marsh zones, zones 3 and 4. The low marsh zone ranges from 6 inches below the normal pool elevation to the normal pool elevation. It should therefore normally be saturated, and planted with species that thrive in this wet condition. The slope within the low marsh zone shall not be steeper than 4:1. Since this zone provides essential wetland function in between storm events, it should have a surface area between 75 and 125% of the high marsh zone surface area.

Zone 4: High Marsh Zone. The upper end of the marsh zone is the high marsh zone, which ranges from the normal pool elevation to +12 inches, allowing the RPv to inundate to the top of the high marsh zone. Where conditions allow, the RPv ponding depth should be reduced to be closer to 6”, which will increase the plant survivability. The slope within the high marsh zone shall not be steeper than 4:1, and typically much flatter marsh zones are designed to increase storage.

Zone 5: Floodplain. Any storm events above the RPv event, should inundate into the floodplain area. A low floodplain should range between +12 and +18 inches above the normal water surface elevation, and be planted with plants suited for infrequent to temporary saturations, depending on weather patterns. An upper floodplain of elevations ranges +18 to +30 inches provides storage for the higher storm events, including the Fv. The two floodplains areas can be combined for smaller drainage areas less than 10 acres. Also, if the Constructed Wetland is connected to a Wet Pond then the Wet Pond can be utilized for the storage of the higher storm events, and the floodplain storage within the Constructed Wetland can be reduced. The slope within the floodplain shall not be steeper than 4:1, and typically much flatter floodplains are designed to increase storage.

Vegetated Perimeter. A minimum 50 foot wide vegetated perimeter around the wetland area must be planted with appropriate grasses, trees and shrubs (the emergency spillway shall either be grass or riprap). Existing vegetation can and should remain in the perimeter area, so long as noxious species are eradicated and invasive species are controlled.

Water Balance Testing. Traditional Constructed Wetlands can be scaled to accommodate small drainage areas, although it is necessary to calculate a water balance when the contributing drainage area is less than 5 acres (Refer to ***Specification 13. Wet Ponds***).

Similarly, if the hydrology for the permanent pools is not supplied by groundwater or dry weather flow inputs, a simple water balance calculation must be performed, using **Equation 12.2** (Hunt et al., 2007)**,** to assure the deep pools will not go completely dry during a 30 day summer drought.

Equation 12.2. The Hunt Water Balance Equation for Acceptable Water Depth in a Stormwater Wetland

$$DP = RF_m * EF * WS/WL - ET - INF - RES$$

Where:
- DP = Depth of pool, inches
- RF_m = Monthly rainfall during drought, inches (assume 1 inch, or use historically data)
- EF = Fraction of rainfall that enters the stormwater wetland (Rational runoff coefficient)
- WS/WL = Ratio of contributing drainage area to the normal pool wetland surface area
- ET = Summer evapotranspiration rate, inches (assume 7 inches)
- INF = Monthly infiltration loss (assume 7.2 inches, or 0.01 inch/hour for 30 days, unless a higher infiltration rate is known)
- RES = Reservoir of water for a factor of safety, inches (assume 6 inches)

Variant 12-B, Wetland Swales:

Wetland Swale Sizing. Wetland swales are designed similar to traditional vegetated swales in that they should convey the Cv and Fv events with non-erosive velocities and should fully contain the Cv event (no freeboard required). If the Fv event is not contained within the swale top of bank, then the area of inundation or alternate route shall be noted. The RPv water surface elevation shall not pond more than 6 inches above the normal water surface elevation. There is no minimum or maximum drainage area, though typically swales are designed for less than 5 acres of contributing area.

Internal Geometry. Wetland swales should be designed as a two stage system. The low flow channel requires a minimum width of 1 foot, and should be designed with a permanent to semi-permanent water elevation of 4 to 6 inches. This can be accomplished through inception with the seasonal high groundwater or through the use of check dams or other control structures that back the water up to that level during wet conditions. The low flow channel should support plants that tolerate mostly wet conditions. The width of the low flow channel should be maximum 6 feet to prevent additional low flow channels from forming within (or braiding); very large drainage areas may require increased widths, but typically the low flow channel will fall in the 2 to 4 foot width range. To increase functionality, the low flow channel should be meandered within the total confines of the Wetland Swale (i.e., the top of bank does not need to meander, but the low flow channel should).

At the water surface elevation of the RPv event (within +/- 0.1'), a shallow floodplain bench shall be provided, which alleviates shear stress on the sides of the banks. The total bench width should be minimum 4 feet and is generally split on either side of the low flow channel, though the dimensions can alter as the low flow channel meanders through the swale section, with increased bench widths on the inside of a curve. Vegetation planted on the benches should also support wet periods, though will be inundated less frequently then the plants in the low flow channel.

Deep pools should not be incorporated into the Wetland Swales for safety purposes, as most people assume swales are traversable and would not suspect a deep portion. The average groundwater elevation must be below the bottom of the Wetland Swale; only the seasonal high groundwater may intersect the bottom.

Side Slopes. The Wetland Swales shall not have a steeper slope than 3:1.

Longitudinal Slope: The maximum longitudinal slope is an average of 1%. Grade breaks similar to variant 12-A can be used as necessary.

Vegetated Perimeter. A minimum 10 foot wide vegetated perimeter on both sides of the wetland swale must be planted with appropriate grasses, trees and shrubs. Existing vegetation can and should remain in the perimeter area, so long as invasive species are eradicated and invasive species are controlled.

Variant 12-C, Ephemeral Constructed Wetlands:
Wetland Sizing. Ephemeral Constructed Wetlands are designed without a permanent pool, since the intent is for them to be wet only in the spring and fall months. The Fv water surface shall be maximum 30 inches above the ground surface, and the RPv event must pond between 6-inches and 1-foot of water. An emergency spillway must be provided for the 100-year and larger events, but traditionally no other outlets are provided. If freezing in the winter is a concern, or for maintenance purposes, a drain pipe can be provided, but the Ephemeral Constructed Wetland should only be drained in late November after amphibian breeding seasons. The wetland can be modeled with the design infiltration rate, and is allowed to hold the RPv event for greater than 48 hours.

Internal Geometry. Ephemeral Constructed Wetlands should mimic those found naturally, which typically are ponded low areas. These shallow areas fill up with runoff during wet conditions, and will dry up during periods of little to no rain. These fluctuations typically provide more diversity in vegetation and animals. The shallow ponded area must be planted with a variety of vegetation that can tolerate both wet and dry conditions.

The seasonal high groundwater may fluctuate into the bottom of the Ephemeral Constructed Wetland, but the average groundwater elevation shall be below the wetland bottom. The wetland shall be modeled with the seasonal high groundwater if it does intersect the wetland bottom.

Depending on the existing grades, an embankment may be required to contain the wetland pool. If so, a core trench shall extend down to a limiting layer or minimum 4 feet below ground surface, which will help prevent lateral migration of water through the embankment, compromising the construction.

For Ephemeral Constructed Wetlands functioning as forebays on poultry house projects, forebays located in HSG C/D should be no deeper than 1’ as measured from the invert of the overflow weir to the bottom of the forebay. Forebays located in HSG A/B should be no deeper than 2’ as measured from the invert of the overflow weir to the bottom of the forebay.

Side Slopes. The side slopes of the buffer area and within the wetland should be 4:1 or flatter.

Vegetated Perimeter. A minimum 50 foot wide vegetated perimeter around the wetland area must be planted with appropriate grasses, trees and shrubs (the emergency spillway shall either be grass or riprap). Existing vegetation can and should remain in the perimeter area, so long as noxious species are eradicated and invasive species are controlled.

Constructed Wetland Material Specifications:
Wetlands are generally constructed with materials obtained on-site, except for the plant materials, inflow and outflow devices (e.g., piping and riser materials), possibly stone for inlet and outlet stabilization, and stabilization fabric for lining banks or berms. In some instances clay may need to be imported to provide a permanent pool elevation in certain areas of the constructed wetland that may not otherwise support a permanent pool. Plant stock should be nursery grown, unless otherwise approved by the local regulatory authority, and should be healthy and vigorous native species free from defects, decay, disfiguring roots, sun-scald, injuries, abrasions, diseases, insects, pests, and all forms of infestations or objectionable disfigurements, as determined by the local regulatory authority.

12.7 Wetland Landscaping Criteria

A landscaping plan is required for all Constructed Wetlands and must be prepared by a licensed professional knowledgeable in wetland species. The plan shall outline a detailed schedule for the care, maintenance and possible reinstallation of vegetation in the wetland and its buffer, particularly for the first 10 years of establishment.

The plan should outline a realistic, long-term planting strategy to establish and maintain desired wetland vegetation. The plan should indicate how wetland plants will be established within each inundation zone (e.g., wetland plants, seed-mixes, volunteer colonization, and tree and shrub stock) and whether soil amendments are needed to get plants started. Reference the **Landscaping Criteria Appendix** for additional Constructed Wetland landscaping specifications.

For Ephemeral Constructed Wetlands functioning as forebays on poultry house projects, since the forebay is likely to be subjected to prolonged periods of saturation especially on HSG C/D soils, the recommendations for Zone 4, High Marsh may be used to select plant materials for the forebay area under those soil conditions.

12.8. Wetland Construction Sequence

The construction sequence for the wetland variants depends on site conditions, design complexity, and the size and configuration of the proposed facility. The following two-stage construction sequence is recommended for installing a wetland facility and establishing vigorous plant cover.

Stage 1 Construction Sequence: Wetland Facility Construction.

Step 1: Stabilize Drainage Area. Constructed wetlands should only be constructed after the contributing drainage area to the wetland is completely stabilized. If the proposed wetland 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 2: Assemble Construction Materials on-site, make sure they meet design specifications, and prepare any staging areas.

Step 3: Install Erosion and Sediment (E&S) Controls prior to construction, including temporary dewatering devices, sediment basins, and stormwater diversion practices. All areas surrounding the wetland that are graded or denuded during construction of the wetland are to be planted with turf grass, native plant materials or other approved methods of soil stabilization. In some cases, a phased or staged E&S Control plan may be necessary to divert flow around the stormwater wetland area until installation and stabilization are complete.

Step 4: Excavate the Core Trench for the Embankment and Construct the Embankment (if required). Install the Outlet Pipe and Emergency Spillway.

Step 5: Install the Riser or Outflow Structure and ensure that the top invert of the overflow weir is constructed level and at the proper design elevation (flashboard risers are strongly recommended by Hunt et al, 2007).

Step 6: Clear and Strip the wetland project area to the desired sub-grade.

Step 7: Construct any Internal Berms in 8 to 12-inch lifts and compacted with appropriate equipment.

Step 8: Excavate/Grade until the appropriate elevation and desired contours are achieved for the bottom and side slopes of the wetland. This is normally done by "roughing up" the interim elevations with a skid loader or other similar equipment to achieve the desired topography across the wetland. Spot surveys should be made to ensure that the interim elevations are 3 to 6 inches below the final elevations for the wetland.

Step 9: Install Micro-Topographic Features and Soil Amendments within wetland area. Since most stormwater wetlands are excavated to sub-soil, they often lack the nutrients and organic matter needed to support vigorous growth of wetland plants. It is therefore essential to add compost, topsoil or wetland mulch to all depth zones in the wetland. The importance of soil amendments in excavated wetlands cannot be over-emphasized; poor plant survival and sparse wetland plant coverage are likely if soil amendments are not added. The planting soil should be a high organic content loam or sandy loam, placed by mechanical methods, and spread by hand. Planting soil depth should be at least 4 inches for shallow wetlands. No machinery should be allowed to traverse over the planting soil during or after construction. Planting soil should be tamped, but it should not be overly compacted.

Step 10: Stabilize Exposed Soils above the normal pool elevation with permanent seed mixtures appropriate for a wetland environment by hydro-seeding or seeding under straw per the Landscape Plan. Temporary seed, such as annual rye or winter wheat, can be used to stabilize the soil but permanent species must then be planted or seeded at a later date. Stabilization matting shall be utilized in Wetland Swales, 12-B, and in all areas of concentrated flow and/or slopes at 3:1 or steeper.

Step 11: Post Construction Verification: After soil stabilization, but prior to planting individual species, perform a post construction verification of the constructed wetland. This will confirm the planting zones and normal pool elevation based on the outlet elevation. Three cross-sections (forebay, mid-wetland, and prior to the principal spillway) shall be measured, marked, and geo-referenced on the post construction verification survey document. This will enable maintenance reviewers to determine sediment deposition rates in order to schedule sediment cleanouts. Any embankments shall be verified per the requirements in ***Specification 13. Wet Ponds***.

Stage 2 Construction Sequence: Establishing the Wetland Vegetation.

Step 12: Open Up the Wetland Connection (if desired). Once the final grades are attained, the pond and/or contributing drainage area connection can be opened to allow the wetland cell to fill up to the normal pool elevation. Gradually inundate the wetland to minimize erosion of unplanted features. If the wetland area is connected than it will need to be dewatered to the lowest planting elevation (i.e., the low marsh zone) prior to planting.

Step 13: Finalize the Wetland Landscaping Plan (if needed). At this stage the engineer, landscape architect, and wetland expert work jointly to refine the initial wetland landscaping plan *after* the Constructed Wetland has been constructed and the normal pool elevation has been established if there have been any changes to the planting zones from the initial design. This can allow the designer to select appropriate species and additional soil amendments, based on field confirmation of soils properties and the actual depths and inundation frequencies occurring within the wetland, and also confirm plant availability

Step 14: Measure and Stake Planting Depths at the onset of the planting season. Depths in the wetland should be measured to the nearest inch to confirm the original planting depths of the planting zone. Surveyed planting zones should be marked on the post construction verification, and their locations should also be identified in the field, using stakes or flags. If necessary, dewater to the bottom of the low marsh zone prior to staking and planting.

Step 15: Propagate the Constructed Wetland. Three techniques are used in combination to propagate the emergent community over the wetland bed:

1. *Initial Planting of Container-Grown Wetland Plant Stock.* The transplanting window extends from early April to mid-June. Planting after these dates is quite chancy, since emergent wetland plants need a full growing season to build the root reserves needed to get through the winter. If at all possible, the plants should be ordered at least 6 months in advance to ensure the availability and on-time delivery of desired species.
2. *Broadcasting Wetland Seed Mixes*. The higher wetland elevations should be established by broadcasting wetland seed mixes to establish diverse emergent wetlands. Seeding of wetland seed mixes as a ground cover is recommended for all zones above 3 inches below the normal pool elevation. Hand broadcasting or hydroseeding can be used to spread seed, depending on the size of the wetland cell.
3. *Allowing "Volunteer Wetland Plants to Establish.*. The establishment of volunteer species should be encouraged with the exception of noxious weeds and invasives. Typically if properly managed, the constructed wetland will fill out with volunteer species and establishment of the planted and seeded species within 3 to 5 years.

Step 16: Install Goose Protection to Protect Newly Planted or Newly Growing Vegetation. This is particularly critical for newly established emergent and herbaceous plants, as predation by Canada geese can quickly decimate wetland vegetation. Goose protection can consist of netting, webbing, or string installed in a criss-cross pattern over the surface area of the wetland, above the level of the emergent plants.

Step 17: Plant the Wetland Floodplain and Buffer Area. This zone generally extends from 1 to 3 feet above the normal pool elevation. Consequently, plants in this zone are less frequently inundated but still must be able to tolerate periods of flooding and soil saturation. The buffer area can be planted with species that do not need wet conditions, and can be planted in the spring or fall.

Construction Reviews. Construction reviews are critical to ensure that the Constructed Wetlands are properly installed and established. Multiple site visits and reviews are recommended during the following stages of the wetland construction process:

- Pre-construction meeting
- Initial site preparation (including installation of project E&S controls)
- Excavation/Grading (e.g., interim/final elevations)

- Wetland installation (e.g., microtopography, soil amendments and staking of planting zones)
- Planting Phase (with an experienced landscape architect or wetland expert)
- Final Review (develop a punch list for facility acceptance)

12.9 Wetland Maintenance Criteria

An Operation and Maintenance Plan for the project will be approved by the Department or the Delegated Agency prior to project closeout. The Operation and Maintenance Plan will specify the property owner's primary maintenance responsibilities and authorize the Department or Delegated Agency staff to access the property for maintenance review or corrective action in the event that proper maintenance is not performed. Constructed Wetlands that are, or will be, owned and maintained by a joint ownership such as a homeowner's association must be located in common areas, community open space, community-owned property, jointly owned property, or within a recorded easement dedicated to public use.

Operation and Maintenance Plans should clearly outline how vegetation in the Constructed Wetland and its buffer will be managed or harvested in the future. Periodic mowing of the Constructed Wetland buffer is only required along the maintenance access 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.

Maintenance of a Constructed Wetland is driven by annual maintenance reviews that evaluate the condition and performance of the Constructed Wetland. Based on maintenance review results, specific maintenance tasks may be required. Additional reviews are required during the first two years of establishment.

First Two Years: The Constructed Wetland must be reviewed twice a year, once in the spring and once in the fall after a storm event that exceeds 1/2 inch of rainfall. This should be done for the first two years. Additional trips to the project site will be needed for watering, maintenance, etc which is described below.

- **Spot Reseeding.** Maintenance personnel should look for bare or eroding areas in the contributing drainage area, around the wetland buffer, and in the wetland cells, and make sure they are immediately stabilized with grass cover.
- **Watering.** Trees and shrubs planted in the buffer and on wetland islands and peninsulas need watering during the first growing season. In general, consider watering every three days for first month, and then weekly during the first growing season (April - October), depending on rainfall. In the summer months, and times of prolonged drought, all of the plantings may need watering to ensure survival.
- **Reinforcement Plantings.** Regardless of the care taken during the initial planting of the wetland and buffer, it is probable that some areas will remain non-vegetated and some species will not

survive. Poor survival can result from many unforeseen factors, such as predation, poor quality plant stock, water level changes, and drought. Thus, it is advisable to budget for an additional round of reinforcement planting after one or two growing seasons. Construction contracts should include a care and replacement warranty extending at least two growing seasons after initial planting, to selectively replant portions of the wetland that fail to fill in or survive. Close-out on the project will not occur until a minimum of 70% of the wetland area is permanently vegetated, which may take several growing seasons and additional plantings.

- **Invasive Species.** Designers should expect significant changes in wetland species composition to occur over time. Reviews should carefully track changes in wetland plant species distribution over time. Noxious plants and undesired invasive plants should be dealt with as soon as they begin to colonize the wetland. As a general rule, control of noxious weeds and undesirable invasive species (e.g., cattails and Phragmites) should commence as soon as they are spotted and before their coverage exceeds more than 5% of a wetland cell area. Herbicides must be applied by a Certified aquatic pesticide applicator through the Department of Agriculture and be aquatic safe (i.e., Glyphosate-based products). Extended periods of dewatering may also work, since early manual removal provides only short-term relief from invasive species. While it is difficult to exclude invasive species completely from stormwater wetlands, their ability to take over the entire wetland can be reduced if the designer creates a wide range of depth zones and a complex internal structure within the wetland.

Annual, On-going Maintenance: Managing vegetation is an important ongoing maintenance task at every Constructed Wetland and for each inundation zone.

- **Vegetation Management.** Thinning or harvesting of excess forest growth will be needed periodically to guide the forested wetland into a more mature state and prevent it from becoming overgrown. Thinning or harvesting operations should be scheduled to occur approximately 5 and 10 years after the initial wetland construction. Removal of woody species on or near the embankment, structural components such as inflow and outflow pipes, and maintenance access areas should be conducted every 2 years.
- **Mowing.** Regular mowing operations only need to occur along maintenance accessways, and should occur at minimum twice a year. Reference the Landscape Plan for additional requirements; some upland meadow areas may also require occasional mowing.
- **Sediment Removal.** Sediment removal in the pretreatment forebay must occur when 50% of total forebay capacity has been lost. The owner can plan for this maintenance activity to occur every 5 to 7 years.
- **Sediment Deposits.** Sediment removed from the forebay should be deposited in the designated maintenance set aside area for dewatering, prior to leveling and stabilization or removal from the site. Sediments excavated from Constructed Wetlands 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 contributing area serves a hotspot land use.

12.10 References

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