Constructed Stormwater Wetland (CSW)

Constructed Wetland at Hank Aaron Stadium; Mobile, AL

Synonyms: Constructed wetland, stormwater wetland, pocket wetland, traditional constructed stormwater wetland, shallow marsh wetland

Constructed stormwater wetlands (CSWs) are created wetland areas designed to treat stormwater and function similarly to natural wetlands. These systems use complex biological, chemical, and physical processes to cycle nutrients, and breakdown other pollutants for treatment of stormwater runoff.

Site Selection

Quantity Control	yes
Drainage Area	med - large
Space Required	med - large

Works with:

Steep Slopes	---
Shallow Water Table	✔
Poorly Drained Soils	✔

General Significance

Construction Cost	med-high
Maintenance	med
Community Acceptance	med
Habitat	high
Sun / Shade	either

Natural wetlands are often referred to as “nature’s kidneys” due to their ability to transform or filter compounds. CSWs mimic the filtration and cleansing capabilities of natural wetlands while providing temporary storage of stormwater above the permanent pool elevation (PPE) and because of this, are often used for water quantity control. These systems are large (unless a small CSW/pocket wetland is used) and use shallow pools, complex microtopography, and both aquatic and riparian vegetation to effectively treat stormwater. The use of CSWs or any other SCM does not promote the discharge of stormwater into natural wetlands.

Advantages:

- Visual amenity for natural community greenspace
- Enhanced biodiversity and ecological benefits to urban areas
- Flood attenuation for improved water quality, reduced erosion, and downstream habitat
- Reduced peak flows downstream assist with decreased sediment loads entering streams and a reduction of downstream bank erosion
- Filtration of pollutants and nutrient uptake from plants further improves water quality
- Relatively low maintenance costs

Limitations:

- Requires more surface area than some other conventional stormwater practices; not suitable for space-limited ultra-urban environments
- May release nutrients in the fall
- May be difficult to establish plants under a variety of flow conditions
- Geese may become undesirable residents if natural buffers are not included in the design
- If not designed properly, water leaving the system may have higher temperatures
- Until vegetation is established, pollutant removal efficiency rates may be lower than anticipated
- Higher construction costs when compared with other practices

Site Selection

CSWs are not typically recommended for ultra-urban developments because they usually require more surface area (SA) than conventional stormwater control measures (SCMs). However, they may be suited to large residential, suburban, or commercial developments where space is not limited.

Evaluating Soils: Use the USDA Web Soil Survey to identify soil map units and to make initial interpretations for potential uses and limitations of a site. However, since most soil map units have inclusions of other soils that may be quite different, detailed evaluations should be made at the proposed site by a professional soil scientist or soil classifier. On-site evaluations should properly identify a soil or the hydrologic soil group (HSG) and the final decision for use should be made based on the detailed determination of soil series or HSG. For a detailed list of HSG properties, see Table A.3 in Appendix A on Stormwater Hydrology.

In-Situ Soil: CSWs are appropriate for the USDA hydrologic soil group (HSG) C and D soils that have slow to very slow infiltration rates. Other soils may also work with the addition of a clay or synthetic liner or may be perched.

USDA's online Web Soil Survey (http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm) can be used as a guide to determine the needed soil information for the site, such as the hydrologic soil group (HSG) and depth to water table.

Compaction Guidelines

****based on soil permeability***

0.06 - 0.2"/hr - minimal compaction necessary

0.2 - 0.6"/hr - compaction necessary

>0.6"/hr - needs importation of clay and/or liner

Depth to Groundwater: CSWs are well suited for areas where the depth to groundwater is two feet or less. Excavation to the seasonally high water table may be used to maintain the permanent pool elevation (PPE) in the wetland.

Continuous Flow: CSWs are more easily sited in areas where sufficient water or continuous base flow is present to maintain the PPE in the wetland.

Sizing: A minimum drainage area of 10 acres is recommended for a CSW and 5 acres or less is recommended for a small CSW. The wetland footprint will be approximately 3 - 5% of the contributing drainage area.

Commercial or Industrial Sites: If CSWs are sited adjacent to commercial or industrial land uses, contributing pollutants have the potential to harm fish and wildlife populations over time as these pollutants accumulate.

Perching/Liners: CSWs sited in areas with HSG B or where the seasonaly high water table is not near the ground

Table 4.2.1
Site Selection: Constraints and Limitations for Constructed Stormwater Wetlands

Drawdown	Appropriate locations should draw down 2 – 5 days.
Slope	No more than 8% is conducive for a CSW.
Utilities	Call 811 before construction to locate utilities (For more information, visit: www.al1call.com).
Minimum Head	There must be an elevation difference of 2 - 5' from inflow to outflow to ensure water movement throughout the wetland.
High Sediment loads	Drainage Areas under construction or with high sediment loads should be avoided.
Non-native Invasive Vegetation	Non-native, invasive vegetation can be difficult to eradicate. See Vegetation in Appendix D for more information on nonnative, invasive plant removal.
Continuous Flow	Continuous flow is necessary to maintain the permanent pool elevation (PPE) in the wetland.

surface can be perched using a clay or synthetic liner. The clay or synthetic liner should have an infiltration rate of less than 0.01”/hr to keep water from percolating into the surrounding soil. Synthetic liners are considered more expensive and more likely to become damaged compared to clay liners. Perching is generally more risky as perched wetlands rely solely on stormwater to maintain the PPE and extended drought conditions can result in vegetation losses. With or without a liner, soil compaction may be necessary to achieve the desired infiltration rate (See callout box for **Compaction Guidelines**).

Common Constructed Wetland Variations

Traditional Constructed Stormwater Wetlands: CSWs have large surface areas and require a reliable source of base flow or groundwater supply to maintain hydrology to support emergent wetland plants. Deep water zones are concentrated in the forebay, deep pools, and outlet pool. The traditional CSW design is presented in this handbook. All other variations only differ slightly from this design.

Small CSW/Pocket Wetlands: Small CSWs follow the traditional CSW design, but treat much smaller drainage areas (5-10 acres) and are smaller systems. These systems are perfect when all site conditions are met for a CSW, but constraints limit the SA footprint. Water levels tend to fluctuate the most in a small CSW, making it more of a risk in areas prone to extreme drought conditions.

Retention Basins: Retention basins are similar to the traditional design with the exception of additional storage above the marsh. This increase in the temporary pool depth for additional vertical storage and a slightly smaller footprint limits vegetation selection, thus reducing some pollutant removal and available habitat.

Pond/Wetland Systems: These systems utilize two cells for treatment. A wet pond is used to reduce sediment and incoming velocities before entering a shallow marsh wetland. The pollutant removal capability of this system is less than the traditional CSW design.

Gravel-based Wetlands: This rock filter design variation uses one or more wetland treatment cells filled with gravel. The primary contributors of pollutant removal for these systems are algae and microorganism growth that occurs on the gravel.

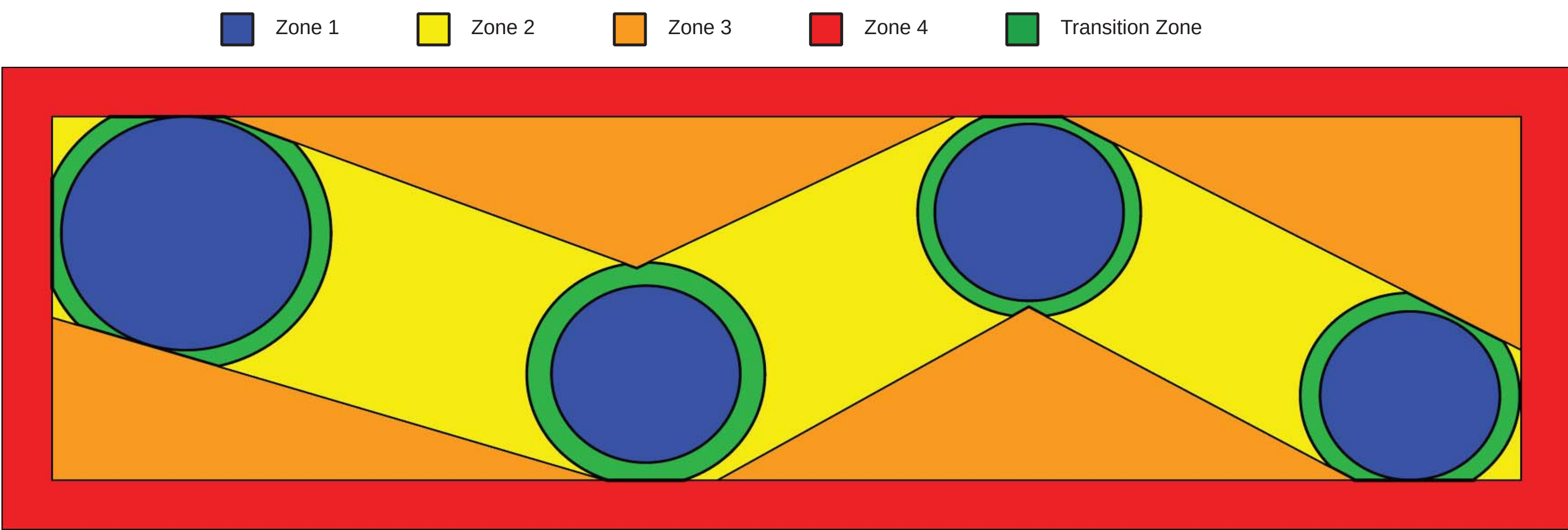
In-line and off-line wetlands: Inline and offline wetlands are not recommended due to their potential to degrade stream habitat and quality. In-line wetlands are wetlands constructed in the stream channel. Off-line wetlands divert stream flow into a constructed wetland and then release it back into the stream. The water source for a CSW should be a combination of stormwater and groundwater interception.

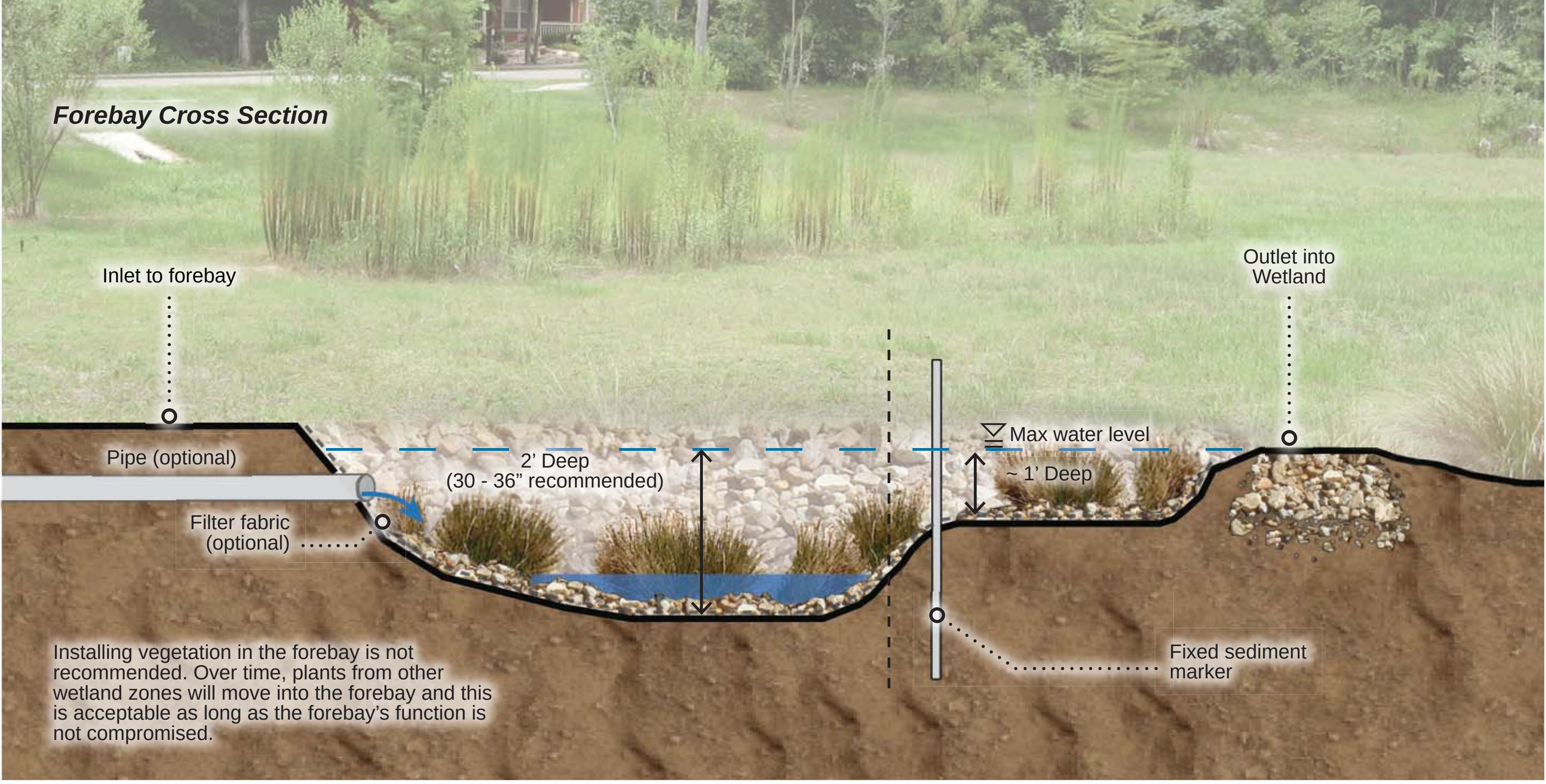
Design

CSWs have many components and zones; therefore, planning and site layout is even more critical for this practice compared to smaller stormwater control measures (SCMs). Components of a CSW include the forebay, inlet, deep pools (Zone 1), shallow water (Zone 2), transition zone, shallow land (Zone 3), upland (Zone 4), and the outlet structures.

The distance that stormwater travels from the entrance to the exit of the CSW should be maximized so that contact time in the wetland is increased to allow for greater pollutant removal. Flow paths can be enhanced using parallel berms and deep pools that are perpendicular to the flow path direction to slow water and increase residence time.

The wetland design should account for maintenance access to plants, forebay, deep pools, outlet pool, and the outlet structure. Since heavy equipment is necessary to clean out the forebay and deep pools, consideration should be given for a maintenance access road wide enough for vehicles to safely turn around.





Components

Zone 1 (Deep Pools)

The total deep pools topographic zone should be divided into several deep pools with one at the inlet (forebay) and outflow (outlet pool) and the rest dispersed between these pools. Deep pools allow for sediment deposition, energy dissipation, and nitrate treatment. Deep pools are designed to hold water throughout the year and can provide habitat for fish and other aquatic organisms during a drought. Deep pools can be planted with floating or submerged plants that grow in standing water.

Inlet: The inlet is the structure where flow or stormwater enters the CSW and should be designed to handle the runoff entering the system. Inlets may be in the form of a swale, pipe, diverter box, or sheet flow device such as a grassed filter strip. The velocity of flow entering the inlet should be considered. Any conveyance bends that could cause erosion or turbidity should be avoided. Erosion and scour should be minimized through the use of armor or vegetation.

Safety Precautions

Safety should be considered due to deep standing water conditions. Creative engineering and design techniques should be used to discourage children from entering the wetland area unless a site goal is to use the wetland as an educational tool. Observation decks, walking paths, and other safe viewing areas may be included in the design to prevent injuries. Trash racks, grates, or pipes may need to be sized such that children cannot enter them. Check local regulations to determine that appropriate safety precautions have been met.

Forebay: The forebay is a pool located at the inlet of the wetland system. It is deepest at the point of runoff entry and shallowest at the exit point. This design dissipates energy throughout the forebay and provides diffuse flow into the CSW.The primary function of the forebay is to allow large debris and sediment to settle out so that pools and ecologically sensitive areas are not clogged, flow velocity is not decreased, and sheet flow is created over the weir into the flow path throughout the wetland. CSW forebays are not vegetated and can be up to 36" deep.

Deep pools: Vegetated deep pools occur between the forebay and outlet pool. Vegetated deep pools are planted with submerged, floating, and occasionally emergent plants. These pools can provide continuous habitat for mosquito predators, such as fish, that require flooded conditions for survival. Dispersing deep pools throughout the wetland decreases distances fish must travel.

Outlet Pool: The outlet pool should not be vegetated to minimize clogging. A clogged outlet structure can result in extended flooding throughout the wetland and decreased drawdown time to the PPE. Decreased drawdown time is detrimental to wetland plants in Zone 3 (shallow land).

Transition Zone

The transition zone is located between the deep pools (excluding the forebay) and the shallow water zone. The transition from these two zones should be a gentle slope and hold 6 – 9" of water at the PPE. Similarly to deep pool vegetation, few plants can tolerate the transition zone due to the increased water depth present in this zone.

Zone 2

Shallow Water: The shallow water zone (also called low or shallow marsh) includes all land within the wetland that has a constant level of 3 – 6" of water when the wetland is at its PPE. Occasional drying in this zone may occur during periods of extreme drought, but should not occur on a regular basis. The purpose of the shallow water zone is to provide a continuous hydraulic connection between the inlet and outlet structures and, during low flows, the shallow water channel should convey water from the inlet to the outlet pool. The water surface level in this zone is considered the PPE. Rooted herbaceous vegetation tolerant of constant inundation is planted in this zone.

Zone 3

Shallow Land: The shallow land zone (also called the high marsh) is the temporary inundation zone that provides necessary storage during and after a rainfall event. This zone functions similarly to a floodplain in a natural wetland. The highest elevation of this zone is referred to as the temporary pool elevation (TPE). Rooted vegetation that is tolerant of temporary flooding and drought is present in this zone. The shallow land zone provides some shade, pollutant uptake, and wildlife habitat.

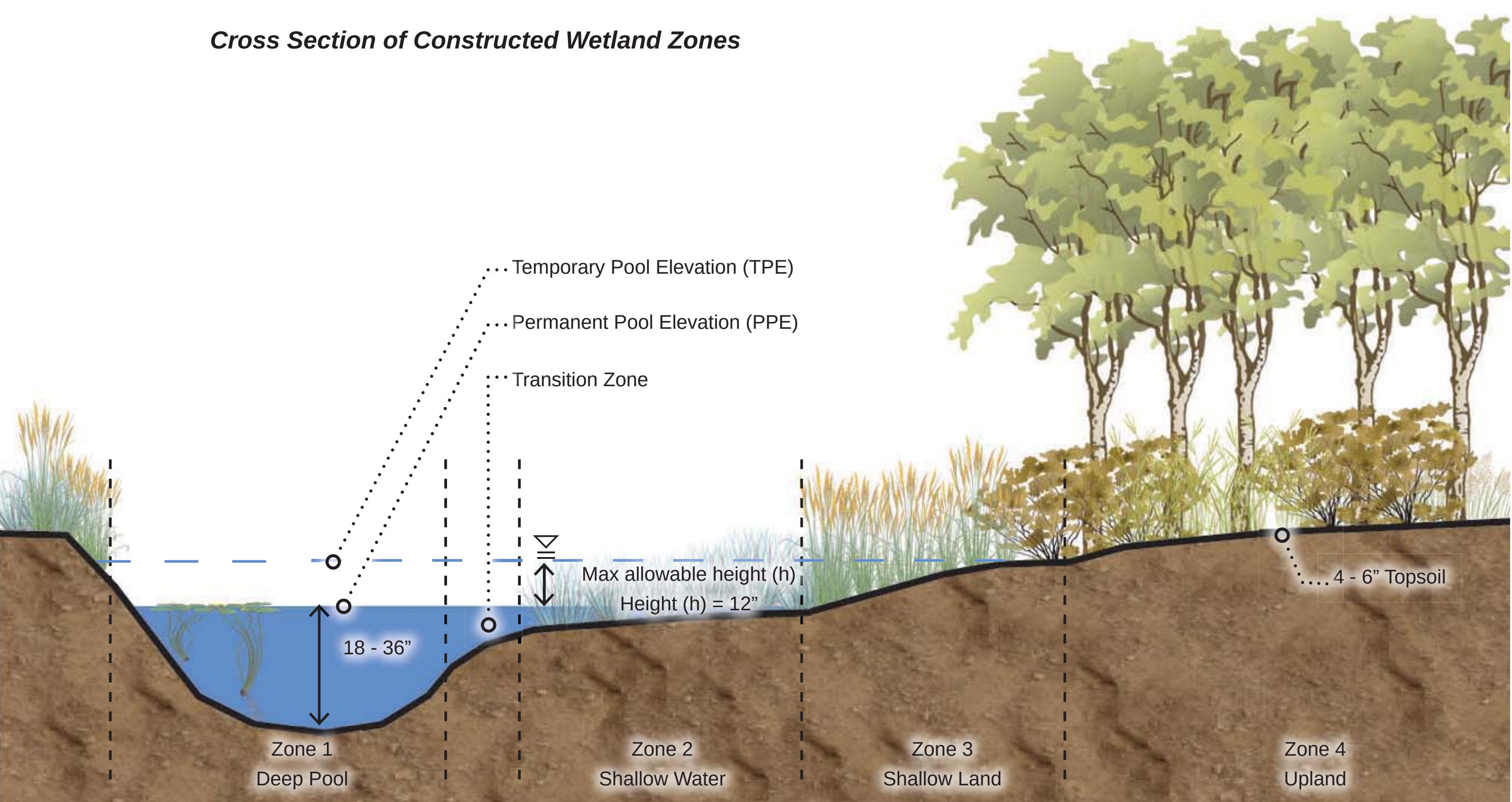
Zone 4

Upland: The upload zone is rarely wet and is not required for a CSW design, especially when space constraints exist. In some cases, an existing buffer can be utilized as the upland zone in the design. The upland zone can aid in tying the CSW to adjacent land, can be used for maintenance access, or to house an observation deck. This zone should not have a slope steeper than 3:1 in order to reduce erosion, allow for maintenance, and to support vegetation.

Outlet Structure

The outlet structure for the CSW serves three primary functions: 1) to contain the water quality volume within the wetland, 2) to release water when a rain event exceeds the first flush, and 3) to allow for manipulation of the pool elevation in order to conduct maintenance activities and therefore, should be easily accessed. The outlet contains a drawdown orifice that is placed at the top of the TPE or at lower depths to either prevent clogging or to release water at a cooler temperature. This allows the temporary pool to slowly draw down from the wetland, but still retains stormwater within the wetland for a minimum of 48 hours. There should not be public access to end walls at outfall pipes since CSWs are designed to pass large rain events and can be safety hazards. These areas may require fencing or warning signs for safety depending on the location of the wetland and responsible entity.

Cross Section of Constructed Wetland Zones



Design Guidance

1. **Determine Volume of Runoff Treated**

The volume of water typically treated by the CSW is based on the first flush of the design storm, see Appendix A on Stormwater Hydrology for more information on first flush. The volume of water below the PPE is constant and remains at all times, except during extreme drought. The first flush, or design storm volume, is the volume of water stored within the PPE and the TPE. The volume of runoff treated by a CSW is determined by two different methods, depending on the amount of impervious cover and land use.

- For areas with connected impervious and mixed land uses, the volume of runoff is calculated using the **Discrete Curve Number Method**.

  Variables needed for use in the **Discrete Curve Number Method** include: **drainage area, pervious and impervious land area, curve numbers (CN), maximum potential retention after rainfall begins (S), precipitation depth (P), and runoff depth (Q)**. The Discrete Curve Number Method is outlined in EQNs 4.2.1 and 4.2.2. For more information on the Discrete Curve Number Method and other methodologies, see Stormwater Hydrology in Appendix A.

  A runoff depth is calculated for each land use with a different corresponding **CN (pervious) and pervious cover**.

  The **total volume treated, calculated in acre inches (ac-in)**, is determined by multiplying runoff depth, **Q (in)** by area, **A (ac)** for all surfaces, pervious (different land uses) and impervious. To determine the volume in cubic feet, use EQN 4.2.3.

  The **Composite Curve Number Method** is used for areas with minimal impervious cover and a single land use. The same variables used for the Discrete Curve Number Method are used for the **Composite Curve Number Method: drainage area, pervious and impervious land area, curve numbers (CN), maximum potential retention after rainfall begins (S), precipitation depth (P), and runoff depth (Q)**. The two areas (one pervious and one impervious) are multiplied by their corresponding CNs to calculate a product, as shown in EQN 4.2.4.

  A **composite curve number (CCN)** can be calculated using the two products, as shown in EQN 4.2.5, where **TA is total area.**

  The **CCN** is then used in calculating the **retention after rainfall begins (S) and runoff depth (Q)**, shown in EQNs 4.2.1 and Y.2. Once runoff depth is determined in inches it can be multiplied by **TA** to determine a total volume in ac-in, which is converted into cubic feet using EQN 4.2.3.

  It is important to note that to calculate the overall surface area of the wetland, it is best for volume to remain in ac-in.

EQN 4.2.1

$$S = \left(\frac{1000}{CN}\right) - 10$$

EQN 4.2.2

$$Q = \frac{\left[P - (0.2S)\right]^2}{P + 0.8S}$$

EQN 4.2.4

$$Product_{impervious} = A_{impervious} * CN$$

$$Product_{pervious} = A_{pervious} * CN$$

EQN 4.2.5

$$CCN = \frac{(Product_{impervious} + Product_{pervious})}{TA}$$

EQN 4.2.3

$$Volume = \_\_\_\_\_\_\_\_ ac - in * 3630 = \_\_\_\_\_\_\_\_ ft^3$$

2. **Determine SA and Zone Depth**

Since the CSW is designed to hold approximately the first inch of rainfall from the entire drainage area, the SA is calculated as the volume (ac-in) divided by the allowable height (in), as shown in EQN 4.2.6. A **maximum allowable height of 12" for TPE** is recommended. Once SA is calculated, it is converted to square feet by multiplying the SA in acres by the conversion factor 1ac = 43560 ft^2.

The flow path from the inlet to outlet points within the CSW should be maximized in order to maximize the retention time within the system. Often, berms and irregular shapes can be used to obtain the optimal flow path. A 3:1 minimum length to width ratio is suggested.

Even though flow path and retention time is to be maximized, it is crucial to reduce the potential for cutoffs or changes in flow path to reduce nick points or weak areas in the topography that allow for water to short circuit the desired flow path. Deep water zones perpendicular to the flow direction and internal berms parallel to overall flow are recommended.

In contrast to other SCMs, the permanent volume of water, or water below the PPE, will remain in the CSW at all times, and is not part of the design calculations. This pool is maintained through natural or engineered hydrologic zones that are dependent on characteristics such as HSG, saturated hydraulic conductivity (K_{sat}), wetland liners, depth to water table, and many other factors.

The SA of each zone within in the CSW is a percentage of the total SA. Table 4.2.2 contains a recommended distribution for SAs of individual zones. This distribution can vary depending on targeted treatment pollutant to be treated.

Deep Pools (Zone 1): A deep pool should be located at the inlet (see Forbay Cross Section) and another at the outlet (outlet pool). A water balance using monthly rates for rainfall, infiltration, and evapotranspiration can be used to verify the depth of water in Zone 1. Conducting a water balance will help the designer to verify the probability of water following a month long drought, with the exception of extended drought periods.

Shallow Water Zone (Zone 2): This zone should not be designed too deep; this will help ensure plant survivability and habitat.

Shallow Land (Zone 3): The depth of shallow land is equal to or less than the **maximum allowable height (h)** used in the SA calculation, EQN 4.2.7. This depth will also set the elevation of the TPE and is the maximum storage volume in the CSW at any given time. If the CSW targets pathogens, the shallow land zone should comprise a large portion (40% of the total SA) of the wetland to allow for pathogen die off from ultra-violet light exposure.

EQN 4.2.6

$$SA = V / h$$

EQN 4.2.7

$$Q = N * \left[C_d * A * (2 * g * H)^{0.5}\right]$$

Table 4.2.2
Recommended Distribution for Surface Areas of Individual Zones

Zone	Surface Area Recommendation	Recommended Water Depth
Zone 1, Deep Pools	20 - 25% of total surface area (10% allocated to forebay, remaining to other deep pools)	18 - 36"
Zone 2, Shallow Water	40% of total surface area	3 - 6"
Zone 3, Shallow Land	30 - 40% of total surface area	12" at TPE
Zone 4, Upland	This zone is optional and is not included in the surface area calculation. Determine the amount of area remaining in overall site and use this area for upland.	This zone is rarely wet.

3. **Determine the Appropriate Outlet Structure**

This practice is unique because the outlet structure has both low and high capacity features.

High Capacity: The high capacity feature is used to bypass storms that are in excess of the first flush volume.

Low Capacity: The low capacity feature is used as a drawdown structure to slowly release the volume of water within the temporary pool over 2 – 5 days.

Examples of outlet structures are shown in Table 4.2.3. Manual drawdown valves or flashboard risers can be installed to drain the wetland for maintenance purposes.

For ease of maintenance, trash racks are recommended for weir boxes and metal mesh is recommended for drawdown orifices to prevent clogging of the outlet structure. The drawdown orifice should be turned downward toward the permanent pool to ensure that it does not clog; this will help to prevent "floatables" from clogging the orifice.

Orifice (low capacity): Factors such as the **number of orifices (N), the coefficient of discharge (C_d), area of orifice(s) [(A) (ft^2)] and driving head [(H) (ft)]**, affect the flow that will exit the system via the drawdown orifice, and ultimately the time required to draw down the temporary pool. The flow rate leaving the orifice can be calculated using the Orifice Equation, EQN 4.2.7, where **g** is **Gravity (32.2ft/s²) and maximum head is equal to the depth of the temporary pool**.

The orifice flow rate determines how quickly the temporary pool will drain, with a target of 2 - 5 days drawdown time. To calculate the drawdown time, EQN 4.2.8 is used.

In EQN 4.2.8, **V** is the **volume calculated in EQN 4.2.3, Q is the flow rate calculated in EQN 4.2.7, and time is in seconds**. A simple conversion can be used to determine if the temporary pool will drain within five days.

Weir (high capacity): The Weir Equation, EQN 4.2.9, can be used to determine the flow rate over a broad-crested weir or the top of a broad-crested weir box outlet structure. Characteristics of the weir, such as the **weir coefficient (C_w - 3.0 for broad-crested weirs), the length of the weir [(L) (ft)], and the driving head [(H) (ft)] are used in EQN 4.2.9.**

It is important to check the capacity of the network that the overflow will enter after leaving the CSW. It should be verified that the system can handle the peak flow and maximum flows anticipated from the high capacity weir.

Table 4.2.3

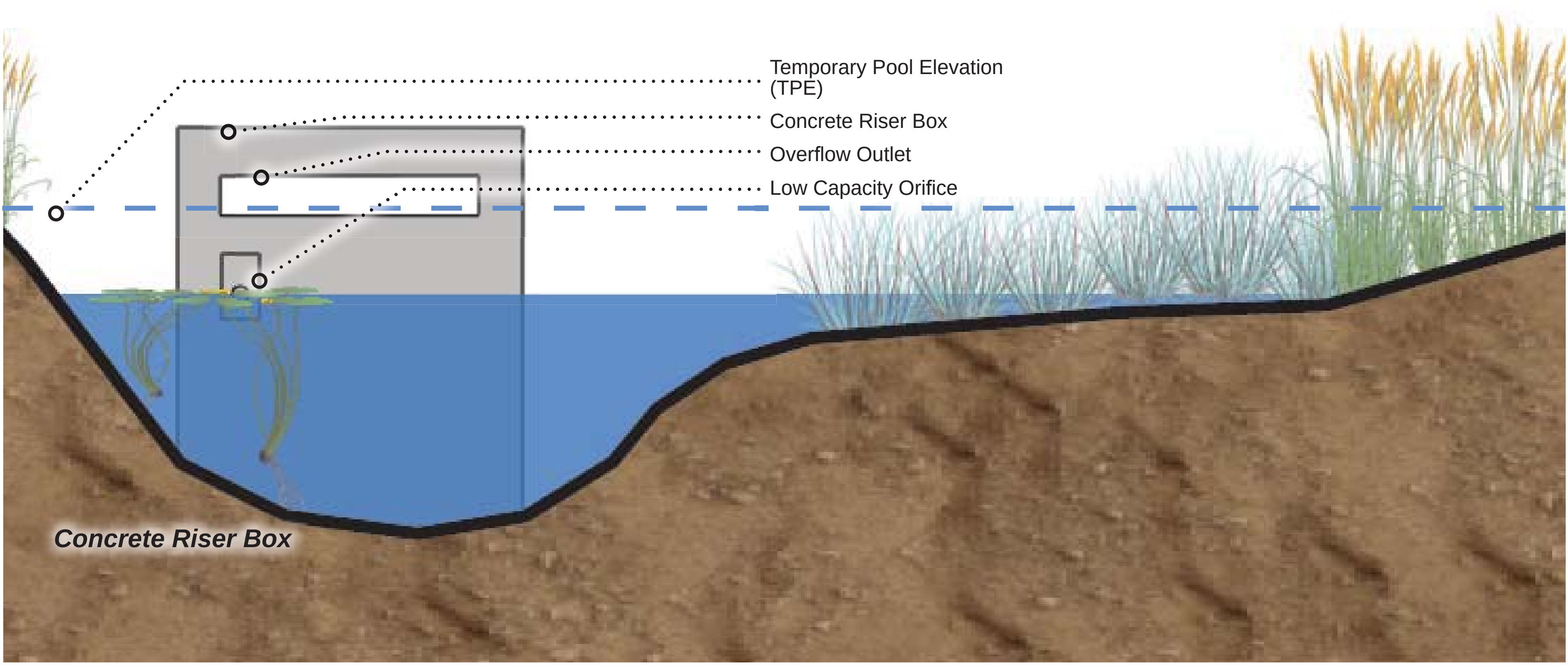
High-capacity	Low-capacity
weir box	drawdown orifice
broad-crested weir	
broad-crested spillway	

EQN 4.2.8

$$\frac{Volume}{Flow\ rate} = Time$$

EQN 4.2.9

$$Q = C_w * L * H^{1.5}$$



Constructed Stormwater Wetland Design Example

This design example below is for a **small CSW** that was planned for a site in Auburn, Alabama. The site conditions reflected ideal circumstances for a CSW with one exception; the location had a relatively small **total drainage area of 1.5 acres**. The soil on site is a Kinston silt clay loam series that has moderate permeability but is considered to be moderate to poorly-drained, which classified the soil as a HSG D. **For this design example numbers are rounded to two significant digits**

1. **Determine Volume of Runoff Treated**

EQNs 4.2.1 and Y.2 are used to determine the runoff depth based on land use areas and the corresponding CNs. In addition to being a relatively small site, the site is predominately pervious with **1.2 acres of pervious land**; however, this land is in poor condition. Using the NRCS Curve Number Table A.4 found in Stormwater Hydrology in Appendix A, **a CN for the pervious land cover is determined to be 89**. For all **impervious areas** consisting of parking lot, paved surfaces, and driving lanes, a **CN of 98** is assigned. The **precipitation depth (P)** desired for the water quality storm event in the Auburn area is **1.25”**.

EQN 4.2.1

$$S = \left(\frac{1000}{CN}\right) - 10$$

EQN 4.2.2

$$Q = \frac{\left[P - (0.2S)\right]^2}{P + 0.8S}$$

Using the provided CNs, precipitation depth, and Equations, the following runoff depths are determined:

Parking lot: S=0.20, Q= 1.04”, 0.09”

Poor Condition Pervious Area: S=1.24, Q= 0.45”, 0.04”

The **total volume (ac-in)** treated is determined by multiplying **runoff depth [(Q (in)] by area [(A) (ac)]** for all surfaces, pervious (different land uses) and impervious. To determine the runoff volume, the calculated runoff depths (Q) are multiplied by their respective areas and summed.

Parking lot: 1.04in*0.3=0.31 ac-in

Pervious Area: 0.45in*1.2=0.45 ac-in

Total runoff volume: 0.76 ac-in

To calculate the **volume in cubic feet**, use **EQN 4.2.3** to determine a volume of 2758.8 ft^3 or 2758 ft^3.

EQN 4.2.3

$$Volume = \_\_\_\_\_\_ \; ac\text{-}in * 3630 = \_\_\_\_\_\_ \; ft^3$$

For areas with minimal impervious cover and a single land use, the **Composite Curve Number Method** should be used. However, this site has a single dominant pervious land use and the **impervious area is 20% of the total drainage area**, so the **Discrete Curve Number Method** is used.

However, to illustrate the **Composite Curve Number Method**, it is used in this example to calculate the desired volume of treatment. Using **EQN 4.2.4**, the land use areas are multiplied by their corresponding CNs to calculate a product.

EQN 4.2.4

$$Product_{impervious} = A_{impervious} * CN$$

$$Product_{pervious} = A_{pervious} * CN$$

$$Product_{impervious} = 0.3*98 = 29.4$$

$$Product_{pervious} = 1.2*89 = 106.8$$

Continued on next page

A **composite curve number (CCN)** can be calculated using the two products, as shown in **EQN 4.2.5**, where **TA** is the **total area**.

EQN 4.2.5

$$CCN = \frac{(Product_{impervious} + Product_{pervious})}{TA}$$

$$CCN = \frac{(29.4 + 106.8)}{1.5} = 90.8 \approx 91$$

The **CCN** is then used in calculating the **retention after rainfall begins (S) and runoff depth (Q)**, shown in **EQNs 4.2.1 and Y.2**.

EQN 4.2.1

$$S = \left(\frac{1000}{CN}\right) - 10$$

EQN 4.2.2

$$Q = \frac{[P - (0.2S)]^2}{P + 0.8S}$$

S=0.99, Q= 0.54", 0.05'

Multiplying the **runoff depth (Q)** by the **TA** gives a runoff volume in ac-in. The total volume equals 0.81 ac-in. The volume can be **converted into cubic feet using EQN 4.2.3**. The total treatment volume is 2940.3 ft^3.

Since this site has 20% impervious cover, the **Discrete Curve Number Method** volume calculation of 0.76 ac-in or 2759 ft^3 will be used.

2. Determine Surface Area and Zone Depth

Since the CSW is designed to hold approximately the first inch of rainfall (first flush) from the entire drainage area, the SA is calculated as the **volume (ac-in) divided by the allowable height (in)**, as shown in **EQN 4.2.6**. The **maximum allowable height (h)** used for this site location is **9"**.

EQN 4.2.6

$$SA = V / h$$

$$SA = \frac{(0.76ac\text{-}in)}{9in} = 0.08ac = 3678.4ft^2$$

To convert SA calculated using EQN 4.2.6 into square feet, multiply the SA in acres by the conversion factor 1ac = 43560 ft^2.

Next, the SAs and depths of each zone are determined. For the example, the recommendations from Table 4.2.2 are followed (All areas for zones are rounded to the nearest whole foot).

Deep Pools, Zone 1: 25% of the total SA (10% allocated to forebay, remaining to other deep pools)

Zone 1:

10% = 368 ft^2 in forebay ~radius of 11'

15% = 552 ft^2 allocated to other deep pools, with recommended depths of 18"

Continued on next page

Shallow Water, Zone 2: 40% of total SA

40% = 1472 ft^2 for shallow water (Zone 2), with recommended depths ranging from 3-6"

Shallow Land, Zone 3: 30 - 40% of the total SA

30% = 1104 ft^2 for shallow land (Zone 3), with recommended depth equal to the maximum allowable height of 9".

Upland, Zone 4: This zone is optional and is not included in the surface area calculation. Determine the amount of area remaining in the overall site and use this area for upland. The area at the site for the proposed small CSW is approximately 5000 ft^2; therefore, the remaining 1321 ft^2 will be used to connect Zone 3 to an Upland area (Zone 4).

A liner is not necessary for this site; however, proper documentation of soil media type is strongly recommended.

3. Determine the Appropriate Outlet Structure

This site is adjacent to a riparian buffer and a manufactured weir box is not necessary. A combination of high-capacity and low-capacity outlets is used to drain into the densely vegetated riparian buffer. For this site, a drawdown orifice is used to set the PPE and to draw down the temporary pool. The orifice is designed using **EQN 4.2.7** and the following characteristics are used:

N = 1, C_d = 0.6, g = 32.2, H = 0.75', and A= 0.003 ft^2 (¾" diameter pipe).

EQN 4.2.7

$$Q = N * [C_d * A * (2 * g * H)^{0.5}]$$

$$Q = 1 * [0.6 * 0.003 * (2 * 32.2 * 0.75)^{0.5}] = 0.01 cfs$$

The orifice flow rate determines how quickly the temporary pool will drain, with a target of 2 - 5 days drawdown time. To **calculate the drawdown time, EQN 4.2.8** is used.

The **volume is 2759 ft^3** and **flow rate** was calculated as **0.204 cfs**.

EQN 4.2.8

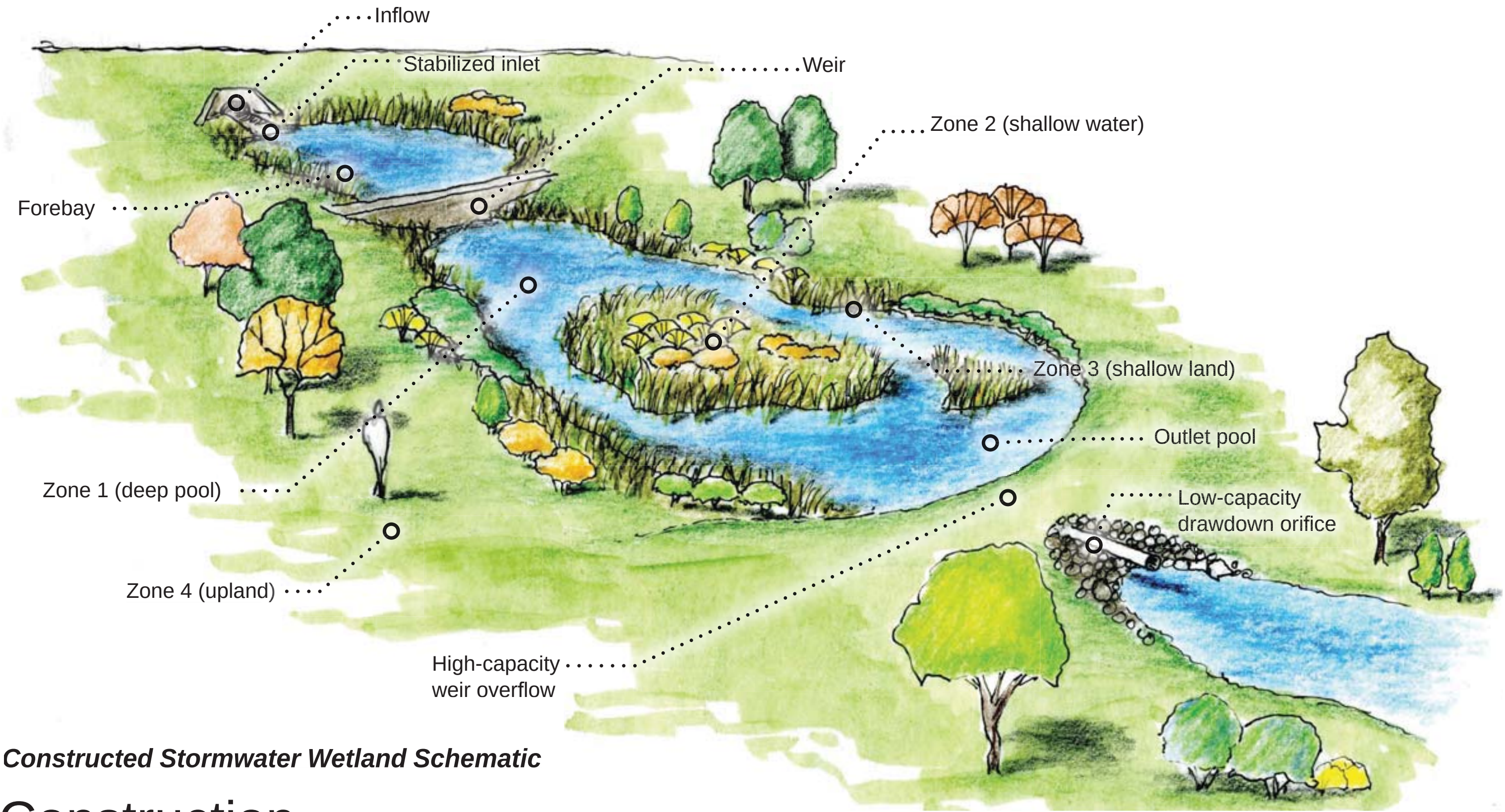
$$\frac{Volume}{Flow\ rate} = Time$$

$$\frac{2759 ft^3}{0.01 ft^3/s} = Time = 275900 s = 76.6\ hrs = 3.2\ days$$

The high capacity weir should be sized to handle the peak flow event and the **length of the weir** can be determined using **EQN 4.2.9**.

EQN 4.2.9

$$Q = C_w * L * H^{1.5}$$



Constructed Stormwater Wetland Schematic

Construction

Planning: A well-planned construction schedule and construction oversight can minimize mistakes that negatively impact wetland functions. Construction discharge permit coverage may be required and should be considered early in the planning process. The designer and contractor should make a site visit so that logistics, sequencing, safety concerns, and techniques can be discussed to minimize costs and maximize efficiency.

Surveying: Before excavation, utilities should be marked and the construction surveying and staking of the layout completed to identify the zones of the wetland. During construction, elevations of graded features should be checked often so that wetland vegetation zones do not remain too dry or too wet.

For more information on soil test protocols, go to the Alabama Cooperative Extension System website at www.aces.edu/pubs/docs/A/ANR-0006-A/ANR-0006-A.pdf. Soil samples can be sent to the Auburn University Soil Testing Lab (www.aces.edu/anr/soillab/) or to other soil testing facilities to be analyzed.

Excavation: The outlet structure should be constructed first to control the water level in the wetland during construction. Excavation should begin at the outlet and move backwards toward the inlet. Tracked excavators are recommended, especially on wet sites. Toothed buckets are recommended to avoid smearing and unintended soil compaction. A hydraulic thumb attachment for the bucket is especially useful for removing debris, placing structures, and scarifying soil surfaces.

Compaction: Care should also be taken to ensure the appropriate level of soil compaction meets the requirements of the wetland design after construction is finished. During construction, the wetland base soil may need to be tamped to prevent excessive seepage. See call out box for **Compaction Guidelines** in the Site Selection Section.

Surface Scarification: Following excavation and soil amendment placement, the site should be prepped for permanent vegetation installation. Use a hydraulic thumb to rough up the soil. Scarification, chiseling, or ripping the top layer of soil is recommended especially if unintentional compaction occurred during construction or the site has suffered drought conditions. Scarification will help plants establish by providing an environment conducive to root growth.

Topsoil: At least 4” of topsoil should be added to all systems (including lined systems) regardless of the hydrologic soil group (HSG). Grading should take into account the 4” layer of topsoil to be added to the subsurface grade. Topsoil on site may be stockpiled for final grading. Harvesting topsoil on site is less expensive, but may result in the introduction of nonnative, invasive plants if they were present prior to construction.

Soil Testing: Before planting, a routine soil test should be performed to determine any nutrient and lime recommendations needed for plant establishment. Any organic matter incorporation, topsoil, clay liner components, or lime should be installed or mixed during or immediately following excavation.

Fertilizing: CSWs tend to lose organic matter during construction and excavation, and adding nutrients back into the soil is important not only for plant establishment, but for performance. A one-time fertilizer application (top dressed on soil surface) prior to planting may be needed to aid in plant establishment, but ongoing fertilization should not be required.

Please review proper sediment control practices in the Alabama Handbook for Erosion Control, Sediment Control and Stormwater Management on Construction Sites and Urban Areas

(http://swcc.alabama.gov/pages/erosion_handbook.aspx).

Geotextile Fabric: The inlet and forebay should be stabilized with a layer of non-woven geotextile fabric and riprap to dissipate energy from stormwater.

Stabilization: The wetland must be stabilized using permanent seed and appropriate mulch cover as soon as possible, but no later than 13 days from when the site is no longer undergoing active construction. A wetland hydroseed mix is recommended for initial stabilization. Soil scarification to half an inch will help promote quick germination. Once erosion and sediment control measures are installed, they should be inspected following rainfall events to ensure that they are functioning properly.

Retrofits: CSWs are an alternative retrofit option for sediment and erosion control basins used in construction when sediment is removed, properly disposed of, and the appropriate modifications are made to the basin. Retrofits can sometimes make sizing the stormwater wetland difficult due to lack of available space. In these cases, a bypass is needed so the wetland is not inundated with too large of a volume of stormwater, which can damage or "blow out" vegetation. A good rule of thumb is that a bypass is needed if the available space to retrofit is less than 67% of the total SA needed for an appropriately sized wetland.

Vegetation

Permanent vegetation should be installed when construction is complete. Ideal plants for CSWs are native perennials and shrubs with dense root systems to trap sediments and solids. Plants must be tolerant of the stress of flooding and drying associated with these systems. Native plants that colonize quickly should be used. Nonnative, invasive species should never be planted as these can result in dense monocultures that do not foster insect, animal, or plant diversity. If an upland area exists on site, trees may be salvaged to maintain a buffer surrounding the wetland area. Vegetation zones should be staked, flagged, or marked using marking paint for ease of plant installation. See Table 4.2.4 for recommended planting season guidelines for each wetland zone.

Seeding: Seeding of the wetland alone is not recommended due to poor success rates and slow establishment. Established plants can be obtained from nurseries that carry native wetland vegetation.

Plant Sizes: Recommended herbaceous plants should be a minimum of 4" tall, shrubs in a minimum of 1-gallon containers, and trees in a minimum of 3-gallon containers. It should be noted that using larger container plants can yield quicker establishment, but installing larger plants is more expensive and can be time consuming.

Plant Installation: In many cases, using a hydraulic auger attachment to drill holes for 3-gallon plants can speed the process, but attention should be paid to the amount of compaction that this equipment may cause.

Planting Time: Time of year plays an important role in plant establishment. Most herbaceous wetland plants establish best when planted at the onset of the growing season and should be installed from April to mid-June. Wetland plants need an entire growing season to accumulate root reserves needed to survive the upcoming winter. Trees and shrubs are best planted from November to mid-March. An early planting date allows plants to get acclimated before the heat and drought of summer begins.

Water Level During Establishment: Soil should be kept moist without the presence of flooded conditions at planting

Table 4.2.4

Plant Type	Recommended Planting Season
Deep pool plants, Zone 1	Spring or after last frost, preferably not in Summer*
Herbaceous wetland plants, Zones 2 and 3	Spring or after last frost, preferably not in Summer*
Shrubs and trees, Zones 3 and 4	Winter (when dormant), Spring or after last frost, Fall, preferably not in Summer*

* A fall planting season is recommended for coastal CSWs.

and for the first six weeks. Cyclic flooding or occasional inundation followed by aerated conditions is helpful when establishing vegetation in these systems. The soil should never completely dry out during plant establishment. Water levels throughout the wetland can be manipulated using the outlet device to ensure that plants establish before receiving large quantities of stormwater. A common mistake made is assuming wetland plants can immediately withstand flooded conditions when plants lack developed root systems and structural adaptations against waterlogged conditions. Leaves, stems, and other plant parts must be held above the water surface to avoid plant drowning (unless a submerged plant).

Plant Spacing: Plant spacing is a very important factor in a CSW vegetation plan. Planting at greater densities is more expensive, but will result in a more rapidly colonized wetland and can reduce the chance for invasive species colonization. If > 60% plant cover is desired following the first growing season, herbaceous plants should be spaced at a minimum of 3’ apart. However, for quicker herbaceous plant cover, spacing as close as 1.5 - 2’ apart is recommended. Planting herbaceous plants 3’ apart may result in a fully colonized wetland after two years of growth while planting 6’ apart may require two or more growing seasons before considered fully functional. Planting broad-leaved emergent plants (*Sagittaria* sp. and *Pontederia* sp.) too far apart can result in the invasion and colonization of undesirable plants such as cattails (*Typha latifolia*). Shrubs should be spaced at a maximum of 5’ apart, but 3’ is preferred. Trees will volunteer in the CSW, and only 2 – 4 trees/10,000 ft^2 are recommended. Plant spacing recommendations from other LID manuals and available research have been synthesized and compiled in Table 4.2.11.

Shading: Though some shading is desired to reduce water temperatures and to improve habitat for fish and macroinvertebrates, trees should not be clustered together and should only be planted around the perimeter of the wetland to reduce shading and discourage mosquito growth.

Nuisance Species: Cattails should never be planted in the CSW. Although cattails are native to Alabama, they are considered invasive and once they invade, can quickly form dense mats, choking out other native vegetation. Monocultures such as cattails decrease habitat for native wildlife resulting in decreased diversity and species richness. Canada geese are a nuisance to newly establishing plants since they dig up and disturb seedlings and increase nutrients and fecal coliforms in the wetland. Geese are attracted to open water areas and a well-designed upland area can discourage them from settling in the wetland.

The following plant lists are not exhaustive and other plants may be appropriate for use in CSWs in Alabama. Extension specialists, horticulturists, or wetland scientists should be consulted for plant recommendations outside this plant list.

Table 4.2.5
Deep Pools, Zone 1 Plant List

Botanical Name	Common Name	Habit	Prefers	Comments
Nelumbo lutea	American lotus	aquatic herb, floating	sun	Very cold and heat tolerant; once established this plant needs lots of space
*Nuphar lutea**	spadderdock	aquatic herb, floating	part shade	Can be hard to establish; attracts birds; spreads by rhizomes; colonizing
*Nymphaea odorata**	American water lily	aquatic herb, floating	sun to shade	Can be hard to establish; waterfowl eat the buoyant seeds; good fish cover; colonizing
Vallisneria americana	American eelgrass	aquatic herb, submerged	sun to part shade	Grows in stoloniferous clumps; good food source for turtles and other aquatic wildlife

* Transition zone plant.

Deep pool (Zone 1) plants are floating or submerged plants that have an obligate wetland indicator status and grow under continuously standing water conditions. Obligate plants always occur as hydrophytes (water loving plants) in their native habitats. The depth of water ranging from 18 - 36” severely limits the number of native species that can grow in these conditions. The purpose of vegetated deep pools is to absorb nutrients from the water column, encourage sediment deposition, improve dissolved oxygen concentrations, and provide habitat or food sources for aquatic life.

Table 4.2.6
Shallow Water, Zone 2 Plant List

Botanical Name	Common Name	Habit	Prefers	Comments
Carex crinita	fringed sedge	Grass like, evergreen	part shade	Can be divided; colonizing
Hibiscus moscheutos	rose mallow	herbaceous perennial	sun to part shade	Attracts birds, hummingbirds, and ducks
Iris virginica	Southern blue flag iris	herbaceous perennial	sun	Do not plant the nonnative invasive yellow flag iris (I. pseudacorus); I. versicolor is the Northern blue flag iris
Juncus effusus	Common rush	Grass like, evergreen	sun to part shade	Can be divided; colonizing
Peltandra virginica	arrow arum	herbaceous perennial	part shade	Attracts birds, not eaten by muskrats or geese
*Pontederia cordata**	pickerelweed	herbaceous perennial	sun to part shade	Attracts dragonflies, attracts ducks, reliable colonizer
Sagittaria lancifolia	bulltongue arrowhead	herbaceous perennial	sun	Attracts ducks; colonizing
Sagittaria latifolia	duck potato	herbaceous perennial	sun to part shade	Starchy rhizomes attract ducks and snapping turtles; colonizing; high nutrient uptake
Saururus cernuus	lizard tail	herbaceous perennial	part shade to shade	Colonizing; dominates during drought; attracts wood ducks
Schoenoplectus americanus	three square	herbaceous perennial	sun to part shade	Seeds eaten by waterfowl
*Schoenoplectus tabernaemontani**	softstem bulrush	grass like perennial	sun	Seeds eaten by waterfowl; nesting cover
Scirpus cyperinus	woolgrass	herbaceous perennial	sun	Seeds eaten by waterfowl; colonizing
Sparganium americanum	bur-reed	herbaceous perennial	sun to part shade	Tolerates flowing water

* Transition zone plant.

Plants in the Shallow Water Zone (Zone 2) also have an obligate wetland indicator status. This zone holds approximately 3 – 6" of water at all times unless subject to a drought. This zone is typically a channel that connects deep pools to the outlet. A common concern with Zone 2 is that plants in this zone may not be suited to occasional drought. However, even in drought conditions, most CSWs will contain water within a foot below the soil surface and most plant roots in this zone can intercept this water to survive during drought conditions.

Zone 2 plants are herbaceous, considered more efficient in pollutant removal, and are less likely to promote mosquito proliferation. These plants are obligate, emergent plants that always occur as hydrophytes in their native habitats. The use of emergent plants can also reduce algal blooms in deep pools. Zone 2 provides habitat for mosquito predators that can control mosquito populations through a natural means. Emergent plants in this zone will migrate throughout the wetland based on plant successional patterns, or changes to vegetation present in the plant community over time. Some species may be eliminated all together and others may dominate certain areas of the wetland based on the conditions they most prefer.

The transition zone connects Zone 1 to Zone 2 and holds approximately 6 – 9" of water at all times. Some plants for Zone 2 are appropriate for the transition zone and are noted in the plant list.

Table 4.2.7
Shallow Land, Zone 3 Plant List

Botanical Name	Common Name	Habit	Prefers	Comments
Acorus americanus	sweetflag	herbaceous perennial	sun	Does not colonize quickly
Alnus serrulata	hazel alder	deciduous shrub	sun to shade	Colonizes easily; fixes nitrogen
Asclepias incarnata	swamp milkweed	herbaceous perennial	sun to part shade	Attracts butterflies
Cephalanthus occidentalis	buttonbush	deciduous shrub	part shade to shade	Good for fringe of zone 2; attracts bees, birds eat fruit
Chelone glabra	white turtlehead	herbaceous perennial	sun to shade	Attracts butterflies and hummingbirds
Clethra alnifolia	summersweet clethra	deciduous shrub	sun to part shade	Moderate growth rate
Conoclinium coelestinum	mistflower	herbaceous perennial	sun to part shade	Attracts birds and butterflies
Cornus amomum	silky dogwood	deciduous shrub	part shade to shade	Attracts butterflies; birds eat berries
Cyrilla racemiflora	swamp titi	deciduous tree	part shade	Fruit attracts birds and small mammals; bee attractant
Eragrostis spectabilis	purple love grass	native grass	sun	Compact native grass
Eupatoriadelphus fistulosis	Joe Pye weed	herbaceous perennial	sun to part shade	Attracts butterflies and birds
Fothergilla gardenii	dwarf witch alder	deciduous shrub	part shade	Can be damaged by prolonged flooding; good for the edge of the wetland
Helianthus angustifolius	swamp sunflower	herbaceous perennial	part shade	Seeds attract birds; white tail deer browse
Ilex glabra	inkberry	evergreen shrub	sun to part shade	Attracts birds
Ilex verticillata	winterberry	deciduous tree	sun to part shade	Attracts birds and butterflies
Ilex decidua	possumhaw	deciduous tree	sun to part shade	Used as a nesting site by birds; fruit attracts birds and small mammals
Ilex vomitoria	dwarf yaupon holly	evergreen shrub	sun to part shade	Birds and small mammals eat fruit
Itea virginica	sweetspire	deciduous shrub	sun to part shade	Medium to fast growth rate
Lindera benzoin	spicebush	deciduous shrub	sun to part shade	Attracts birds
Lobelia cardinalis	cardinal flower	herbaceous perennial	sun to shade	Butterfly and hummingbird attractant; self sows

Continued on next page

Botanical Name	Common Name	Habit	Prefers	Comments
Magnolia virginiana	sweetbay magnolia	evergreen to semi-evergreen tree	part shade	Attracts sweetbay silkmoths; moderate growth rate
Morella cerifera	wax myrtle	evergreen shrub	sun to part shade	Attracts butterflies and birds; fixes nitrogen
Muhlenbergia capillaris	muhly grass	native grass	sun to part shade	Flood and drought tolerant
Panicum virgatum	switchgrass	native grass	sun to part shade	Flood and drought tolerant
Stokesia laevis	Stoke's aster	herbaceous perennial	sun to part shade	Attracts butterflies
Tradescantia virginiana	spiderwort	herbaceous perennial	sun to shade	Attracts bees
Vernonia gigantea	giant ironweed	herbaceous perennial	sun to shade	Attracts bees
Vernonia novenboracensis	New York ironweed	herbaceous perennial	sun	Attracts birds and butterflies
Viburnum dentatum	witherod	deciduous shrub	sun to shade	Attracts butterflies
Viburnum nudum	possumhaw	deciduous shrub	sun to part shade	Berries consumed by birds
Viburnum obovatum	Walter's viburnum	evergreen shrub	part shade	Berries consumed by birds

Plants in the Shallow Land Zone (Zone 3) are herbaceous plants or shrubs that have a facultative or facultative wet wetland indicator status. Facultative plants can occur as hydrophytes (water loving plants) or non-hydrophytes (plants intolerant of flooding). Plants in this area should be placed in a manner that discourages public access because this zone is a critical habitat area for wildlife. However, this zone can also be used for strategic maintenance access. Establishing plants in Zone 3 can be difficult due to alternating hydroperiods (periods of time this zone remains wet) of flooded and drought conditions based on stormwater runoff entering the wetland. Plants should have robust root systems that can stabilize the area to minimize erosion that may occur after a heavy rain. Vegetation for this zone should have high wildlife value, provide food, and shelter to insects (not mosquitoes), birds (not Canada geese, See Nuisance Species), and other desirable small animals.

Vegetation Design Guidelines

- A vegetation plan should include delineated planting zones with a corresponding plant species list, plant establishment schedule, plant maintenance guidelines, and the nursery where plants will be ordered.
- Construction sequencing should be outlined as it relates to plant installation.
- Details for any necessary plant replacement should be outlined.
- If plant establishment and survival is a concern, two thirds of plants can be installed the first year followed up by installation of the last third in the second year. The last third of plants can be planted in areas of the wetland that may not have established or need additional vegetation for adequate cover.
- The plant list should include a minimum of at least ten different total species, with five of these being emergent wetland plants, and no more than 30% of one species in the entire wetland. These are minimum guidelines, and more plant diversity is encouraged.

Table 4.2.8
Upland, Zone 4 Plant List

Botanical Name	Common Name	Habit	Prefers	Comments
Asimina parviflora	dwarf paw paw	deciduous shrub	shade	Fruit attracts small mammals
Callicarpa americana	beautyberry	deciduous shrub	sun to part shade	Attracts birds, rodents, butterflies and deer
Calycanthus floridus	sweetshrub	deciduous shrub	part shade	Colonizing, very insect and disease resistant, adapted to many soils
Cercis canadensis	redbud	deciduous tree	part shade to shade	Attracts birds
Cornus florida	dogwood	deciduous tree	part shade to shade	Fruit attracts birds, small mammals, and deer
Echinacea purpurea	purple coneflower	herbaceous perennial	sun to part shade	Self sows; attracts butterflies and hummingbirds
Fagus grandifolia	American beech	deciduous tree	part shade to shade	Nuts attract birds, rodents, mammals; used as a nesting site and larval host for moths
Fraxinus americana	white ash	deciduous tree	sun to shade	Seeds attract birds, used as larval host for butterflies; used as a nesting site and for cover
Liriodendron tulipifera	tulip poplar	deciduous tree	sun to shade	Used as a nesting site, attracts butterflies, hummingbirds, and birds
Pinus taeda	loblolly pine	evergreen tree	part shade	Fast growing, used as a nesting site, seeds attract birds and small mammals
Quercus alba	white oak	deciduous tree	sun to shade	Acorns attract birds and rodents, attracts butterflies, and used as a larval host
Rudbeckia fulgida	orange coneflower	herbaceous perennial	sun to part shade	Self sows; spreads by offsets; attracts birds
Tilia americana	basswood	deciduous tree	sun to shade	Attracts bees and butterflies

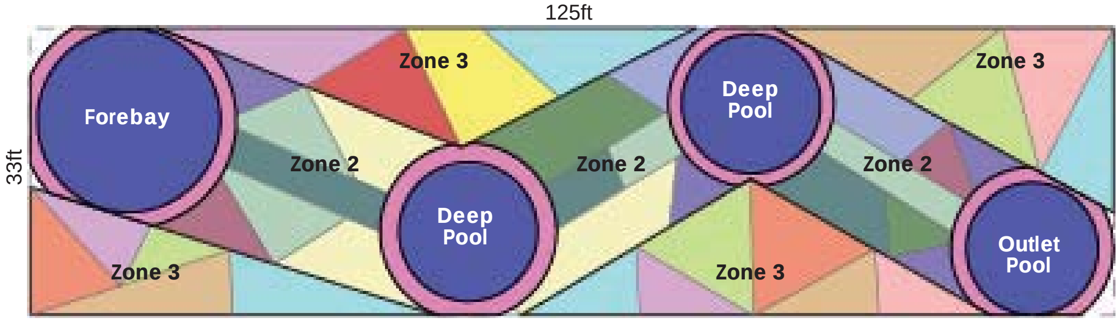
Upland (Zone 4) plants have either a facultative upland or upland wetland indicator status. Upland plants are almost always found in dry areas, but facultative upland plants can be found as hydrophytes (water loving plants), although they usually occur in uplands. Many plants are tolerant of conditions present in the upland zone and because of this, the upland zone provides much biodiversity to the wetland and can provide nesting sites and other valuable wildlife habitat, food sources, and shade.

Vegetation Design Example

The following recommendations are based on a small CSW that is 125' x 33'. Vegetation for this small CSW should be native and low maintenance. The SA breakdown is as follows:

Table 4.2.9

Zone	Description	Radius (if applicable)
Forebay, Zone 1	411ft^2	~ 11ft
Outlet Pool, Zone 1	200ft^2	~ 8ft
Deep Pool, Zone 1	410ft^2, ~ 200ft^2 per pool for 2 pools	~ 8ft each
Shallow Water, Zone 2	1,646ft^2	
Shallow Land, Zone 3	1,234ft^2	



A drawing or sketch of the CSW drawn to scale is needed to layout the vegetation plan. A specific plant list can be made using the above plants lists for each zone.

Most small CSWs cannot accommodate large trees. Ornamental plants that attract butterflies may be desired if the CSW will be located in a highly visible area. Plants that tolerate the transition zone should be noted and placed appropriately between Zones 1 and 2. Moreover, plants that establish quickly or colonize should be prioritized to reduce the chance for nonnative invasives to move into the wetland area. Plants such as *Sparganium americanum* that tolerate flowing water should be placed appropriately in the path of flowing water in Zone 2.

Table 4.2.10
Design Example Plant List

Zone 1	Zone 2	Zone 3
Nelumbo lutea	*Carex crinata*	*Conoclinium coelestinum*
	Hibiscus moscheutos	*Eupatoriadelphus fistulous*
	Iris virginica	*Lindera benzoin*
	Juncus effusus	*Lobelia cardinalis*
	Pontederia cordata *	*Ilex glabra*
	Sagittaria latifolia	*Ilex vomitoria*
	Saururus cernuus	*Itea virginica*
	Sparganium americanum	*Viburnum nudum*

* Transition Zone Plant

Option 1: Calculating Plant Quantity Based on a Drawing

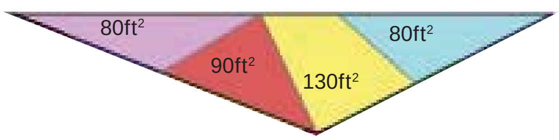
Outline where each species will be planted on a layout plan. Each zone can be divided into geometric shapes to calculate areas (See next page). Use the plant list for each zone to place plants throughout the zone. If plants prefer part shade, be sure that these will be shaded from afternoon sun by taller plants when established.

Continued on next page

Table 4.2.11
Plant Spacing Recommendations

Plant Type	Recommended Quantities	Recommended On-Center Spacing
Floating plants for deep pools, Zone 1	6/100 ft^2	8’
Herbaceous plants for shallow water and shallow land, Zones 2 and 3	25/100 ft^2	2’
Shrubs and small trees for shallow land and upland, Zones 3 and 4	4/100 ft^2	12.5’
Trees for upland, Zone 4	1/200 ft^2	100’

A portion of zone 3 will be used as an example for how to calculate plant quantity:



Quantities can be calculated based on the recommended spacing for each plant type as shown in Table 4.2.11. Quantities shown below are suggested for maximum cover and establishment; however, depending on the vegetation budget, quantities may be more or less per square foot.

Ilex glabra has 80 ft^2 that it will inhabit. Based on 4/100 ft^2 planting recommendations, a quantity is determined:
80 ft^2 * 4 ÷ 100 ft^2 = 3.24, so **3 plants**

Eupatoriadelphus fistulosus has 90 ft^2 that it will inhabit. Based on 25/100 ft^2 planting recommendations, a quantity is determined:
90 ft^2 * 25 ÷ 100 ft^2 = 22.5, so **22 plants**

Itea virginica has 130 ft^2 that it will inhabit. Based on 4/100 ft^2 planting recommendations, a quantity is determined:
130 ft^2 * 4 ÷ 100 ft^2 = 5.2, so **5 plants**

Conoclinium coelestinum has 80 ft^2 that it will inhabit. Based on 25/100 ft^2 planting recommendations, a quantity is determined:
80 ft^2 * 25 ÷ 100 ft^2 = 20, so **20 plants**

The same process should be followed to calculate quantities for the remainder of the vegetation plan

Option 2: Create a Landscape Drawing

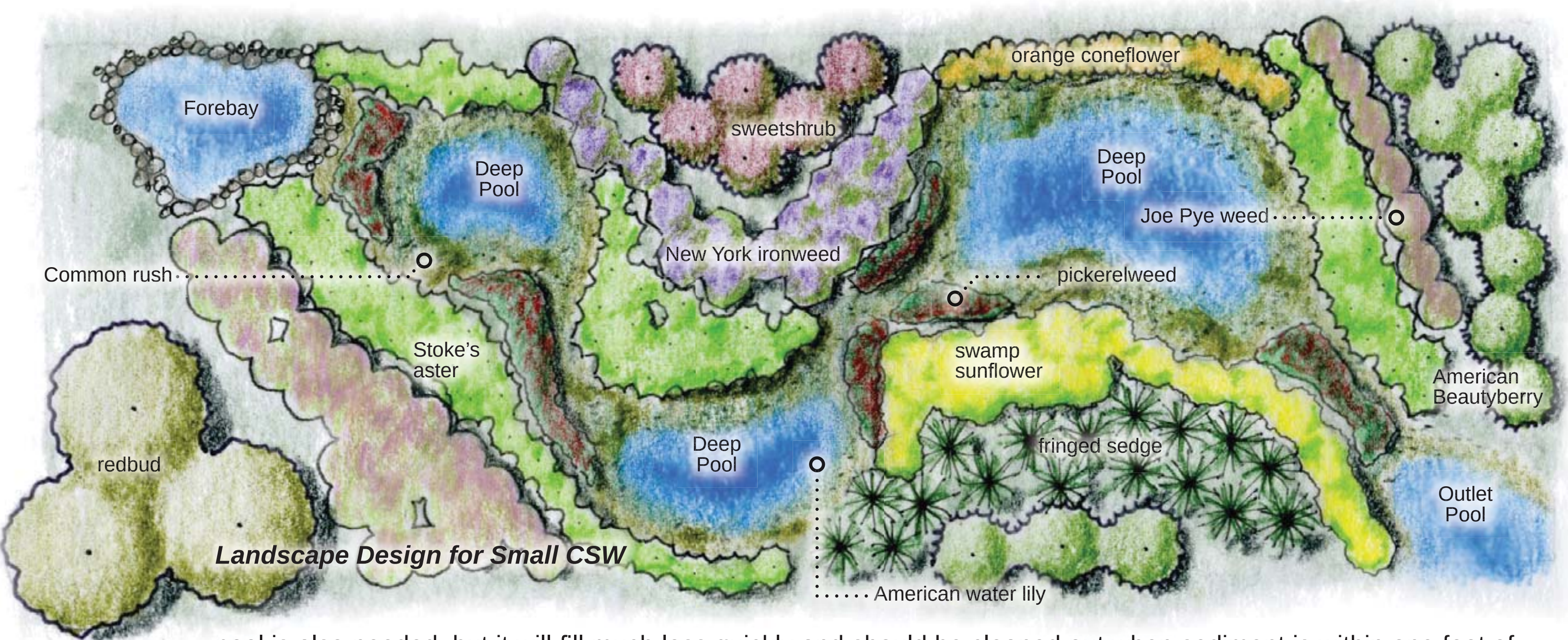
This option is only appropriate for a small CSW draining < 1.5 acres.

This drawing, on next page, is made to scale, shows each individual plant, and is similar to a conventional landscape plan. Much like Option 1, the zones should be drawn on the plan based on the square feet per zone. After creating a plant list, each plant can be added using a circle template. The circle template is used to show the plant’s size at maturity, which will help to avoid overcrowding of plants.

Maintenance

CSWs can function effectively for 20 years or longer if designed and maintained properly. Most maintenance tasks for CSWs focus on efficient hydraulic flow, plant health, aesthetics, safety, and mosquito control.

Sediment Removal: Sediment depth in the forebay should be measured and recorded consistently at the same time of year using a rod or other measuring tool. A fixed sediment marker can be installed to determine when dredging is necessary. Sediment removal is recommended when the functionality of the forebay has diminished, when it is half full, or when the average depth of sediment is within a foot of the water surface. Sediment removal from the outlet



pool is also needed, but it will fill much less quickly and should be cleaned out when sediment is within one foot of the water surface.

Clogged Outlet Structure: The outlet structure should be monitored monthly and after storm events. A clogged outlet structure can result in extended flooding throughout the wetland and decreased drawdown time to the PPE. Decreased drawdown time is detrimental to wetland plants in Zone 3 (shallow land). Floating trash and plant debris can easily clog smaller diameter orifices, and the addition of a trash rack or grate can facilitate easier clean out. A clogged orifice can damage wetland vegetation because the temporary pool will not draw down in the recommended 2 - 5 days. Storage volume for later storms is lost when the temporary pool is full. Turning the drawdown orifice pipe downward below the PPE can decrease maintenance frequency and ensure that it is not clogged with floating vegetation, debris, or other trash. It is important that only maintenance professionals have access to drawdown orifice pipes.

Removed Sediment Disposal: Once removed, sediment can be land applied on the banks of the wetland (Zone 4), and should be immediately stabilized using permanent seed and appropriate mulch cover. If the wetland receives runoff from a commercial or industrial setting, the sediment may be hazardous and will need to be tested. Upon the need to dispose of any potentially contaminated or hazardous sediment, the ADEM Environmental Services Branch should be contacted for guidance associated with the requirements for waste determination and disposal procedures. For more information, please call 334-271-7700 or 1-800-533-2336.

Emergency Spillway: The embankment, dam, and emergency spillway should be free of any woody vegetation. When vegetation is found growing on these structures, it should be removed. The dam can be mowed to retard growth. Plants growing on the dam can be controlled using a systemic herbicide; this may be a labor-intensive task and a professional may be required to complete the job especially if a pesticide applicator's permit is needed for commercial applications.

Plant Inspections: Plant establishment and care should be a priority as they are critical to maximizing wetland functions. The task of plant establishment and maintenance should be carefully outlined prior to construction of the wetland area. Weekly plant inspections may be necessary during the first six weeks following planting, followed by bi-weekly inspections for the remainder of the first growing season to observe plant growth and soil moisture levels.

Water Level in the CSW: Naturally lower water levels throughout the wetland during the first growing season (spring and summer) allows new plants to take advantage of more oxygen (decreased oxygen causes stress to plants) in the rootzone resulting in increased SA coverage by plants. Water levels can be raised during the winter months since plant roots require less oxygen for metabolism during this time. If conditions are dry, plants may require irrigation during establishment and access to a water source or a water truck should be considered during planning.

Surface Area Coverage: Plant SA coverage in the 90 - 95% range is preferred and in general, higher SA coverage is better. Following the second growing season, if plant cover has not reached a minimum of 70%, additional plant installation is needed. Plant succession (changes in species present on the plant community is a natural occurrence, but can also be indicative of a problem. When invasive plants move into the established wetland, it is often a sign that conditions in the wetland are no longer favorable for the native plants that were previously established. For example, when submerged aquatic plants disappear, it may be a sign of diminished water clarity, increased sediment, or high turbidity since these plants rely on light penetration throughout the water column for survival.

Table 4.2.12
Maintenance Schedule

Task	How Often	Comments
Erosion Inspection	During and after major storm events for first 2 years, annually thereafter	Ruts, holes, or gullies should be repaired with soil and vegetation cover.
Inspection	After 0.5” or greater rainfall event	Visually inspect all components including forebay, weir, embankment, orifices, or channels where applicable.
Plant Inspection	Weekly for first 6 weeks, then bi-weekly for rest of first growing season; once to twice per year thereafter	Plants should be inspected and irrigated (if necessary) weekly for the first 6 weeks following plant installation. Following the first growing season, plants should be inspected twice per year for the first 3 years and once annually thereafter.
Inspect for/Remove Pests	When the wetland is visited	Inspect for beavers, muskrats, or other pests that may inhibit flow patterns or clog the wetland. A professional trapper may need to be hired.
Dam/Embankment Inspection	Annually	A dam safety expert should inspect the embankment.
Trash Removal	Twice a year, once a week, or once a month depending on location	Trash or debris should be removed from the entire wetland area. Trash should be removed from any trash grates or debris collection mechanisms. Trash removal frequency should be tailored to the site and adjacent land use. CSWs draining commercial areas may require more frequent trash cleanup.
Remove Woody Vegetation from Dam Face	Annually	All woody plants should be removed from the dam face or emergency spillway. A dam safety expert may need to be consulted.
Sediment Removal from the Forebay	When the forebay is half full or within 1’ of surface	Sediment removal may be more frequent if construction is underway in the drainage area.
Sediment Removal from Deep Pools	When they are half full or within 1’ of surface	Deep pools should be dredged before a shift in vegetation or aquatic life occurs due to increased flooding within the wetland.
Sediment Removal from the Outlet Pool	When the outlet pool is half full or within 1’ of surface	Sediment in the outlet pool can inhibit water from leaving the CSW, creating unintentional extended flooded conditions.
Measure Sediment in Forebay	Minimum of once a year	A rod or other tool can be used to check sediment accumulation depth.
Removal of Invasive Plants	Twice a year during the first 2 years, once a year (in spring) thereafter	Weeds or other invasive plants should be removed as they crowd and rob native plants of water, sunlight, and nutrients. Invasive species removal will decrease in frequency when native plants have dominated the CSW.
Replanting	Following the second growing season if necessary	If SA coverage has not reached a minimum of 70% following the second growing season, additional planting may be necessary.
Inspect/Unclog Orifice or Outlet Device	Once per month or following a 2” rain event	The outlet structure is clogged when Zone 3 remains flooded for more than 5 days. Check for trash in the drawdown orifice.

Invasive Plants: Invasive plants can be spread through seeds or other vegetative parts. When invasive plant species become established, their seeds can be easily discharged from the wetland to spread these species downstream. Certain native species may also become noxious. For example, cattails that establish themselves in CSWs adjacent to commercial or residential settings should be removed immediately due to threats of mosquitoes and decreased plant diversity. If caught early, hand removal may prove effective. However, it is very difficult to remove a large clump of cattails by hand and if any portion of the plant is left, the plant will regenerate. In this case, a systemic herbicide such as glyphosate labeled for aquatic use should be wiped onto the foliage. See Appenix D on Vegetation for more information on using herbicides.

Nuisance Species Damage: Animals such as muskrats and beavers can damage the CSW. Muskrats feed on vegetation, and these discarded plant pieces can clog the orifice. Holes burrowed by muskrats in the outlet pool can result in increased turbidity of water leaving the system. Holes burrowed into the dam can diminish its structural integrity and be a safety issue. Muskrat holes should be filled during site visits. Beavers are also known to be attracted to flowing water and can become a nuisance because they remove woody vegetation from the perimeter of the wetland and build dams throughout, which can raise water levels and damage vegetation. If muskrats or beavers become problematic, a professional trapper or relocator may be needed.

Maintenance History: Maintenance records should be kept at a single location throughout the life of the practice. Datasheets or checklists should be used for each inspection during site visits. Problems noted during inspections should be immediately repaired. Maintenance professionals should note erosion, channelization, bank stability, and any sediment accumulation during inspections. It is also important to note plant distribution and wildlife presence. See Table 4.2.12 Maintenance Schedule for additional recommendations.

Pollutant Removal

Table 4.2.13
Pollutant Removal Table

Sediment	Nutrients		Metals	Pathogens
	N	P		
a.85%	40%	40%	No Data	No Data
b.80%	30%	40%	50%	70%
c.80%	30%	40%	50%	70%*
d.80%	30%	40%	50%	70%*

a. NCDENR, 2007
b. City of Auburn, 2011
c. Georgia Manual, 2001
d. Iowa State University, 2009
* If no resident waterfowl are present

Like a natural wetland, plants in a CSW are vital to system processes. When designed and constructed properly, CSWs have the best median pollutant removal rates for total suspended solids (TSS), nitrate-nitrogen, ammonia-nitrogen, total phosphorus, phosphate-phosphorus, and metals compared with bioretention and other stormwater control measures (SCMs). The ability of CSWs to effectively treat TSS, nutrients, and the biochemical oxygen demand (BOD) does not decrease over the life of the wetland. The CSW can be designed to meet particle size removal efficiencies and treatment volume criteria.

Nutrients: Nutrient transformations occur in both aerobic and anaerobic processes within the CSW. The four wetland zones offer both aerobic and anaerobic soil conditions along with the organic matter or topsoil layer that provides exchange sites necessary for nutrient removal. In Zone 1, the deep pools promote an anaerobic environment associated with increased denitrification (nitrogen reduction). Transitional zones aid in nutrient removal through nitrification and denitrification cation processes. Shallow water zones have higher oxygen concentrations compared to deep pools and promote nitrification through aerobic processes.

Total Suspended Solids: Plant stems and pool variations create a slower laminar flow that allows the settling of particulates and sediment. This allows the CSW to treat pollutants such as phosphorus, trace metals, and hydrocarbons that are adsorbed to sediment, suspended solids, or to plant tissues. Reduction of total suspended solids (TSS) is generally at least 80% unless the CSW is undersized or has been improperly designed.

Undersized Wetlands: Undersized wetlands may increase the velocity of inflow and may cause re-suspension of sediments and decreased removal of attached pollutants.

Dissolved Oxygen: Water discharged from these systems may contain low concentrations of dissolved oxygen (DO) (<1 mg/L). If this is a concern for downstream water bodies, an aerating structure may be included to create turbulence and increased DO concentrations of water exiting the wetland.

Temperature: If temperature is a concern, the drawdown orifice should draw from the bottom of the outlet structure to ensure that the coolest water is discharged. This can be especially important in protecting aquatic animal communities that require cooler water temperatures.

Vegetation: CSW plants provide attachment areas and habitat for microorganisms that serve as filtering mechanisms and aid in denitrification. Emergent plants aid in trapping and stabilizing sediment to reduce resuspension of TSS and can attract mosquito predators to inhibit mosquito growth. Plant roots assist in microbial breakdown or the chemical transformation of organic matter, heavy metals, and pesticides by releasing oxygen from their roots to create oxidized sediment surrounding their root systems. The rich organic layer formed through plant decomposition fosters beneficial bacterial growth and traps solids. In order to increase pollutant removal potential, it is important to consider and maintain both the health and diversity of plants in these systems.

References

Alabama Department of Environmental Management. National Pollutant Discharge Elimination System (NPDES) Construction, Noncoal/Nonmetallic Mining And Dry Processing Less Than Five Acres, Other Land Disturbance Activities, And Areas Associated With These Activities. Field Operations Division – Water Quality Program. Chapter 335-6-12.

Bonilla-Warford, C.M. and J.B. Zedler. 2002. Potential for Using Native Plant Species in Stormwater Wetlands. Environmental Management. 29:3.

Burchell, M.R., W.F. Hunt, K.L. Bass, and J. Wright. 2010. Stormwater Wetland Construction Guidance. North Carolina Cooperative Extension. AG-588-13.

Carleton, J. N. T.J. Grizzard, N. Godrej, and H. Post . 2001. Factors affecting the performance of stormwater treatment wetlands. Water Research, 35(6), 1552-1562.

Carr, D. and B. Rushton. 1995. Integrating a Herbaceous Wetland into Stormwater Management. Southwest Florida Water Management District Stormwater Research Program.

Center for Watershed Protection. 1995. Pollutant Dynamics Within Storm Water Wetlands: I. Plant Nutrient Uptake. Techniques, Vol. 1, No.4. Silver Spring, MD.

City of Auburn Stormwater Manual. 2011

Dodson, R.D. 1999. Stormwater Pollution Control: Municipal, Industrial, and Construction NPDES Compliance. Second Edition. McGraw-Hill, New York.

Georgia Stormwater Management Manual. 2001.

Hammer, D.A. (Ed.). 1989. Constructed Wetlands for Wastewater Treatment. Lewis Publishers, Chelsea, MI.

Hunt, W.F., C.S. Apperson, and W.G. Lord. 2005. Mosquito Control for Stormwater Facilities. North Carolina Cooperative Extension. AG-588-4.

Hunt, W.F. and B. Doll. 2000. Designing Stormwater Wetlands for Small Watersheds. North Carolina Cooperative Extension. AG-588-2.

Hunt, W.F. and W.G. Lord. 2006. Maintenance of Stormwater Wetlands and Wet Ponds. North Carolina Cooperative Extension. AG-588-07.

Hunt, W.F., M.R. Burchell, J.D. Wright, and K.L. Bass. 2007. Stormwater Wetland Design Update: Zones, Vegetation, Soil, and Outlet Guidance. North Carolina Cooperative Extension. AG-588-12.

Jones, M.P. and W.F. Hunt. 2007. Stormwater BMPs for Trout Waters. North Carolina Cooperative Extension. AG-588-10.

Iowa State University. 2009. Iowa Stormwater Management Manual, Ch 2H-1: General Information for Stormwater Wetlands. Transportation Institute, Ames, IA.

Kadlec, R.H. and R.L. Knight. 1996. Treatment Wetlands. Lewis Publishers, Boca Raton, FL.

Lichvar, R.W. and P. Minkin. 2008. Concepts and procedures for updating the national wetland plant list. U.S. Army Corps of Engineers, Engineer Research and Development Center, ERDC/CRREL TN-08-3.

Moore, T.L. and W.F. Hunt. 2011. Stormwater Wetlands and Ecosystem Services. North Carolina Cooperative Extension. AG-588-22.

North Carolina Department of the Environment and Natural Resources. 2007. Stormwater Best Management Practices Manual, Ch 9: Stormwater Wetlands (Chapter revised 2009). North Carolina Division of Water Quality, Raleigh, NC.

Pennsylvania Stormwater Best Management Practices Manual. 2006. Appendix B Pennsylvania Native Plants.

Stevens, M. and C. Hoag. 2000. Broad-Leaved Cattail. US Department of Agriculture, Natural Resources Conservation Service, Aberdeen, ID.

United States Department of Agriculture and Natural Resources Conservation Service. 1996. Guidelines for Establishing Aquatic Plants in Constructed Wetlands. NRCS, Athens, GA.

US Environmental Protection Agency. 1999. Stormwater Technology Fact Sheet: Storm Water Wetlands. Office of Water, Washington, D.C.

US Environmental Protection Agency. 1996. Protecting Natural Wetlands: A Guide to Stormwater Best Management Practices. Office of Water, Washington, D.C.

::This page::
::intentionally left blank::