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Stormwater Wetlands

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As our population has grown, so have our towns and cities. This growth, or urbanization, has led to an increase in watersheds that are covered with impervious surfaces. Lands that were once forests and fields are now buildings, parking lots, and roads. Because of this, rain that once infiltrated the ground or was evapotranspired back into the atmosphere now becomes runoff. This stormwater runoff either flows over the land or is directed to inlets in the storm sewer system, where it quickly is routed to receiving water bodies such as streams, reservoirs, and lakes. Stormwater runoff is untreated, so any debris or contaminants it picks up along the way, such as nutrients from fertilizers, oil and grease from parking lots, or pathogens from animal wastes, are also carried to these water bodies.

Stormwater should not be routed to natural wetlands. Doing so can alter the hydrology of natural wetlands causing changes in vegetation and habitat.

Stormwater best management practices (BMPs) are used to help mitigate the impact of stormwater runoff on water quality by reducing pollutant loads through physical, chemical and/or biological processes. One of the most effective BMPs at improving stormwater quality is the stormwater wetland (Figure 1).

Benefits of Stormwater Wetlands

Stormwater wetlands offer a number of benefits, such as pollutant removal, peak discharge control, wildlife habitat, educational opportunities, and aesthetics.

Pollutant Removal

Stormwater wetlands remove pollutants through sedimentation, filtration, adsorption, biological uptake, and chemical precipitation. The slow-moving waters in stormwater wetlands allow coarse particles, litter, and other debris to settle out of suspension. The dense vegetation in stormwater wetlands filters the water, aiding in particulate removal. Adsorption occurs when pollutants such as soluble phosphorus or dissolved metals come into contact with soil particles and organic matter. Plants, algae, and microorganisms remove nutrients such as nitrogen and phosphorus. However, these nutrients will return to the water and soil columns unless the vegetation is periodically harvested. Lastly, chemical precipitation occurs when two pollutants (e.g. iron and aluminum) react to form an insoluble precipitant.

The ability of stormwater wetlands to improve water quality depends on the targeted pollutants as removal efficiencies vary (Table 1). Removal efficiencies are highest for total suspended solids and bacteria and lowest for soluble phosphorus and total nitrogen.

Figure 1. Stormwater wetlands, such as this one at McConnell Springs in Lexington, Ky., help improve stormwater quality while providing an educational opportunity for citizens.

Table 1. Pollutant removal efficiencies (%) for stormwater wetlands.

Pollutant	Median Value
Total suspended solids (n = 37)[1]	72
Total phosphorus (n = 37)	48
Soluble phosphorus[2] (n = 26)	25
Total nitrogen (n = 24)	24
Nitrogen as nitrate and nitrite (n = 33)	67
Zinc (n = 19)	42
Copper (n = 12)	47
Bacteria[3] (n = 3)	78

Source: The National Pollutant Removal Performance Database.
[1] n indicates number of studies evaluated
[2] orthophosphorus and dissolved phosphorus
[3] fecal streptococci, enterococci, fecal coliform, E. coli, and total coliform

Peak Discharge Control

Stormwater wetlands help attenuate peak discharges by providing storage for runoff and reducing flow velocities. Stormwater wetlands are generally designed so they can store the first inch of rainfall in order to capture the first flush. The first flush is the initial runoff from a storm event. This initial runoff contains the highest concentrations of pollutants as it is the first runoff to essentially wash off the land. Flow velocities are reduced as runoff passes through the dense wetland vegetation. The outlet structure on a stormwater wetland also helps control peak discharges. The designer needs to consider outlet type, size, and elevation.

Habitat

Stormwater wetlands provide habitat for many types of wildlife including birds, reptiles, amphibians, dragonflies, and fish (Figure 2). Some wildlife spend their entire lives in a wetland setting while others only use them for a portion of their life cycle, such as during breeding.

Figure 2. Stormwater wetlands provide habitat to many types of wildlife.

Figure 3. Stormwater wetlands are outdoor classrooms for students of all ages.

Educational Opportunities

Stormwater wetlands are great educational opportunities for communities (Figure 3). These stormwater controls can serve as valuable teaching tools for schoolchildren as well as college students and the general public. Stormwater wetlands are outdoor classrooms that provide opportunities for hands-on learning experiences in a wide-range of academic subjects.

Aesthetics

Stormwater wetlands are a method of wildscaping that bring the tranquility of nature to an urban environment. Through proper maintenance, a stormwater wetland can serve as a unique landscape element through which to showcase uncommon vegetation. Community amenities such as walking trails and picnic shelters can be erected adjacent to stormwater wetlands (Figure 4).

Site Selection

One of the first steps in designing a stormwater wetland is selecting the appropriate installation site. The two biggest factors to consider when locating a stormwater wetland are water availability and topography.

Water Availability

It is important that the stormwater wetlands have water for most—if not all—of the year to support the types of vegetation and wildlife that live in the wetland. If the site contains permeable soils, such as sand, a high water table is needed to maintain adequate wetland conditions. The base elevation of the stormwater wetland generally should be 6 to 12 inches below the seasonally low water table depth. In some instances, a liner may be used; however, this is an added expense. If the site contains clayey soils, the wetland may be designed above the water table, provided the contributing drainage area is sufficient. The size of the stormwater wetland will depend in part on the amount of impervious area in the watershed.

Topography

Like natural wetlands, stormwater wetlands are more easily sited on flatter terrain. Flatter terrain means that a larger stormwater wetland can be constructed, if desired, as compared to steeper terrain. With steeper terrain, stormwater wetland size is limited.

Stormwater Wetland Components

Stormwater wetlands are constructed wetlands comprised of deep and shallow pools, marsh land, and dense, rooted vegetation (Figure 5). These wetlands also have a forebay at the inlet and a micropool at the outlet.

Forebay

A forebay is designed to promote the settling of coarse sediment particles by dissipating energy and slowing down the flow. This is accomplished by using a 4- to 6-foot deep micropool at the inlet of the wetland. Sediments and other debris are collected in the forebay, allowing for easier maintenance. The forebay also helps distributes stormwater inflows more evenly across the wetland. The forebay is typically sized to accommodate 10 percent of the water quality volume (WQV). The WQV is the portion of the average annual stormwater runoff that should be captured and treated in order to remove the most pollutants. Typically, this is 80 percent to 90 percent of the average annual runoff. Requirements vary among jurisdictions, so it is important to check your local stormwater management manual for specifics related to WQV calculations.

Micropool

Similar to the forebay, the micropool is designed to settle sediment particles out of suspension prior to the outlet. The micropool also allows for the discharge of deeper, cooler waters. Since the water depth in a stormwater wetland is mostly shallow and the surface area is large, thermal pollution is a concern. By discharging waters near the bottom of the micropool, the thermal impacts to receiving streams are lessened. Also, the placement of a deep pool near the outlet helps inhibit the growth of vegetation, which can clog the outlet structure. Like the forebay, the micropool is typically sized to accommodate 10 percent of the WQV.

Low-Marsh Zone

The low-marsh zone is the portion of the stormwater wetland that has water at a depth of 6 to 18 inches, at low flow,

Figure 4. A walking trail surrounds this stormwater wetland in Boone, N.C.

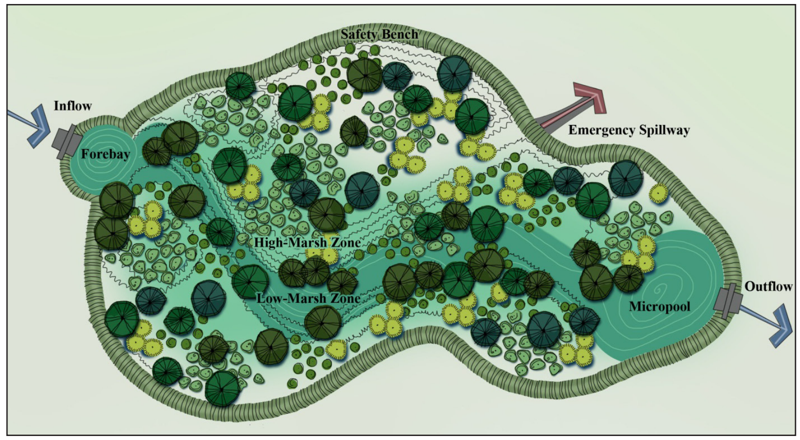

Figure 5. Stormwater wetlands are comprised of a forebay; low-marsh and high-marsh zones with dense, rooted vegetation; micropool; safety bench; primary outlet; and emergency spillway.

and supports emergent wetland vegetation. This vegetation is critical to the effectiveness of stormwater wetlands in removing pollutants such as nutrients. The low-marsh zone is often constructed as a sinuous channel through the wetland connecting the forebay to the micropool. This zone typically accounts for 35 percent to 45 percent of the wetland's surface area.

High-Marsh Zone

The high-marsh zone is designed to support a larger diversity of wetland vegetation and wildlife. This zone has a water depth of 0 to 6 inches at low flow, meaning that much of the zone is dry except during storm events. The high-marsh zone typically accounts for 35 percent to 45 percent of the wetland's surface area.

Outlets

The stormwater wetland has two outlets: a primary outlet and an emergency spillway. The primary outlet is designed to store water in the wetland except during storm events. During storm events, the primary outlet is designed to slowly release the stormwater. It is important to design the primary spillway so the water levels in the wetland can be temporarily lowered for maintenance and/or revegetation. Consideration should be given to the potential of the outlet freezing. The emergency spillway is designed to pass water from those infrequent but large storms so that the wetland is not damaged.

Table 2. Runoff control volumes for stormwater control design.

Sizing Criteria	Commonly Recommended Method
Water quality volume (WQV)	80% to 90% of the average annual rainfall
Channel protection volume (CPV)	1-year, 24-hour design storm
Overbank flood volume (OFV)	5- to 25-year, 24-hour design storm
Extreme flood-protection volume (EFV)	100-year, 24-hour design storm

Sources: Iowa Stormwater Management Manual, Lexington-Fayette Urban County Government Stormwater Manual, and Water Environmental Federation Manual of Practice No. 23.

Design Steps

When designing a stormwater wetland, consideration is given to the water quality volume (WQV), channel protection volume (CPV), overbank flood volume (OFV), and extreme flood-protection volume (EFV). Table 2 summarizes each of these design runoff volumes though state and municipal stormwater manuals may vary in recommendations. With the WQV, the goal is to treat the majority of the runoff pollutant load that occurs with smaller, more frequent storm events. For CPV, the goal is to extend detention of the runoff—or better, promote infiltration and evapotranspiration so velocities are reduced and less streambank erosion occurs. The goal of OFV retention is to maintain the peak flow or water surface elevation so flooding does not occur at down-gradient locations. With EFV, the goal is to minimize the damage to the wetland and other downstream stormwater control from large, rare flood events.

The main steps in designing a stormwater wetland are:

1. Calculate runoff volumes (WQV, CPV, OFV, and EFV) for the watershed.
2. Determine the surface area of the stormwater wetland.
3. Determine the forebay volume.
4. Determine the micropool volume.
5. Determine low-marsh and high-marsh volumes and surface areas.
6. Size the primary outlet and the emergency spillway.

Other general design recommendations are that a length-to-width ratio of 2:1 or greater should be used to provide sufficient stormwater retention time for treatment. Additionally, consideration should be given to a safety bench along the perimeter of the wetland, particularly near the deeper pools. This bench should have a width of at least 4 feet and a water depth of no more than 12 inches. From the safety bench to normal grade, the side slopes should be no steeper than 4:1 (H:V). Access should also be provided to the forebay and micropool at the outlet for periodic maintenance. In karst topography, an impermeable layer (e.g. clay layer or synthetic liner) is needed to prevent groundwater contamination and the formation of sinkholes. When designing a stormwater wetland, it is important to consult local design manuals regarding specifications and design requirements, as they are likely to vary.

Wetland Vegetation

One of the last steps in stormwater wetland design is selecting the wetland vegetation. This vegetation should be native to the area and should not grow aggressively. Also, it should tolerate the fluctuating water levels and poorer water quality associated with stormwater. The U.S. Army Corps of Engineers developed the National Wetlands Plant List, which is helpful when selecting vegetation. This list of wetland plants is also available through the U.S. Department of Agriculture Natural Resource Conservation Service. Some states also have lists of recommended wetland plants.

Inspection

Stormwater wetlands should undergo regular inspection the first year, particularly after storm events, to ensure they are functioning properly. If the stormwater wetland is performing well following the first year of operation, inspections can be spaced up to once every three years. If problems are noted, an inspection should be conducted every six months to one year.

Maintenance

Stormwater wetlands require periodic maintenance largely to replant vegetation, remove invasive species, and clean out the forebay and outlet micropool. Wetland vegetation should cover at least 50 percent of the surface area. If not, replanting is warranted. First though, the wetland's hydrology should be evaluated. Are there areas that have deeper water or more shallow water than planned? If the hydrology is the cause of poor vegetation survival, it must be fixed before replanting occurs.

Invasive vegetation, such as cattails, should be removed at least annually. Cattails and other invasive species spread quickly, and if not removed, will overtake a wetland. Often this means pulling the invasive plants by hand. However, aquatic safe herbicides are available for use in wetlands.

Sediment that has accumulated in the forebay and micropool requires periodic removal. Depending on the rate of sediment accumulation, the interval may be once every five or more years for the forebay and once every 20 years for the micropool. The remainder of the wetland should also be inspected for zones of sediment accumulation with removal occurring as needed.

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