Constructed Stormwater Wetland

Practice Description

Stormwater wetlands provide an efficient biological method for removing a wide variety of pollutants (e.g. suspended solids, nutrients (nitrogen, N, and phosphorus, P), heavy metals, toxic organic pollutants, and petroleum compounds) in a managed environment.

Compared with wet ponds, sand filters, bioretention areas, and other stormwater BMPs, wetlands have the best median removal rate for total suspended solids (TSS), nitrate-nitrogen, ammonia-nitrogen, total phosphorus (TN), phosphate-phosphorus, and some metals. Stormwater wetlands can also be used to reduce pollution associated with high levels of fecal coliform and other pathogen contamination. Wetlands temporarily store stormwater runoff in shallow pools that support emergent and riparian vegetation. The storage, complex microtopography, and vegetative community in stormwater wetlands combine to form an ideal matrix for the removal of many pollutants. Stormwater wetlands can also effectively reduce peak runoff rates and stabilize flow to adjacent natural wetlands and streams.

Wetlands are effective sedimentation devices and provide conditions that facilitate the chemical and biological processes that cleanse water. Pollutants are taken up and transformed by plants and microbes, immobilized in sediment, and released in reduced concentrations in the wetland's outflow, as shown in Figure 1.

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

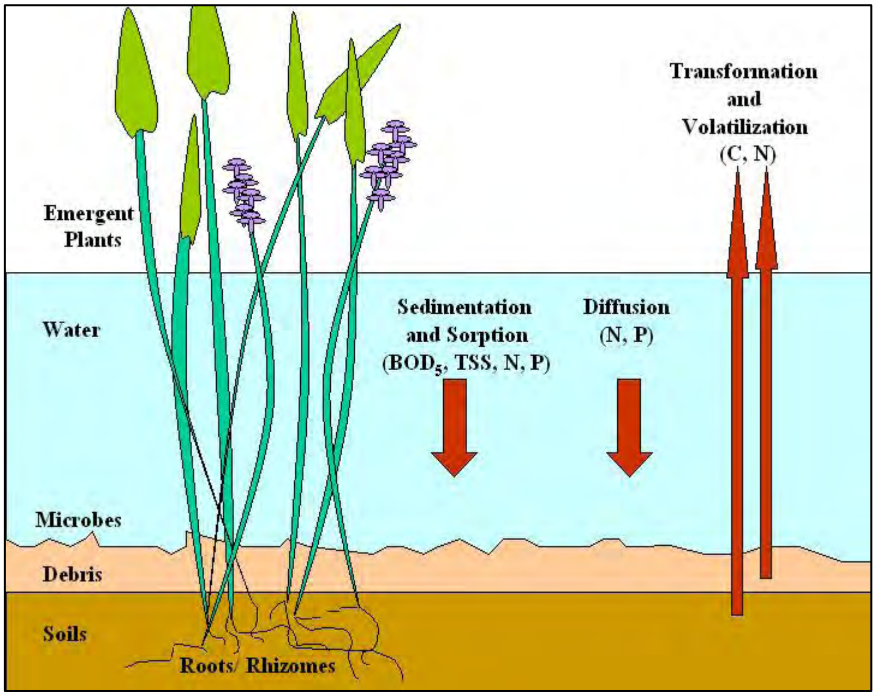


Figure 1 Wetland Microbes, Plants and Soil Transform and Take up Pollutants from Stormwater

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

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

Long-term data from stormwater wetlands indicate that treatment performance for parameters such as 5-day biochemical oxygen demand (BOD5), TSS, and TN typically does not deteriorate over the life of a stormwater wetland. The dissolved oxygen (DO) concentration in wetland outflows may be below 1.0 mg/L. Higher DO concentrations can be achieved by incorporating aeration techniques such as turbulent or cascading discharge zones, or mechanical mixing.

Planning Considerations

Stormwater wetlands occupy somewhat more surface area than a wet detention pond, but have the potential to be better integrated aesthetically into a site design because of the abundance of aquatic vegetation. Stormwater wetlands require a drainage area sufficiently large, or adequate groundwater or surface water supplies, to provide year-round hydration. In sloping terrain, wetland cells can be arranged in series on terraces.

Stormwater wetlands are appropriately located at the lower parts of the development site. Careful planning is needed to be sure that sufficient water will be retained to sustain good wetland plant growth. Since water depths are shallower than in wet detention ponds, water loss by evaporation is an important concern.

Stormwater wetlands are designed in such a way that the distance the water flows from the entrance to the exit is maximized. This allows for sufficient contact time for pollutant removal.

Design Criteria

Converting Erosion- and Sediment-Control Devices

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

Siting Considerations

In addition to the restrictions and modifications to adapting stormwater wetlands to different regions and land uses, designers need to ensure that this management practice is feasible at the site in question. The following section provides basic guidelines for siting wetlands.

Drainage Area

Wetlands need sufficient drainage area to maintain the permanent pool. In humid regions, this is typically about 25 acres, but a greater area may be needed in regions with less rainfall.

Slope

Wetlands can be used on sites with an upstream slope of up to about 15 percent. The local slope should be relatively shallow, however. While there is no minimum slope requirement, there does need to be enough elevation drop from the inlet to the outlet to ensure that hydraulic conveyance by gravity is feasible (generally about 3 to 5 feet).

Soils/Topography

Wetlands can be used in almost all soils and geology.

Nutrient Reduction

The wetland substrate contains a mixture of sediment, plants, water, and detritus that collectively remove multiple pollutants through a series of complementary physical, chemical, and biological processes. Stormwater wetlands are effective at reducing TSS, TN, and TP.

Some wetlands can be constructed as a pond/wetland system. In these cases, part of the BMP is a pond and part of it is a wetland. These systems are slightly less effective at nitrogen removal than wetland-only designs. In some cases, the pond/wetland systems provide additional benefits that warrant a less effective nitrogen removal BMP and therefore should be considered based on the priority of pollutant removal.

Design Considerations

Design is a six-step process:

1) Understand basic layout concepts

2) Determine the volume of water to treat

3) Determine surface area and depth of each wetland zone

4) Select the soil media type

5) Select the appropriate outlet structure

6) Select plants

Step 1: Understand Basic Layout Concepts

Stormwater Wetland Components

Stormwater wetlands consist of six primary components. Figure 2 provides a conceptual diagram, and brief descriptions are given below.

1. **Inlet**: This is where water enters the wetland. The inlet can be a swale, a pipe, a diverter box, sheet flow, or other method of transporting water to the wetland.

2. **Deep Pool:** This zone consists of permanent deep pools of water that retain water even during drought. Deep pools in a stormwater wetland are one of two types:

a. *Forebay:* The forebay is a deep pool that directly follows the inlet provides two important functions: (1) dissipates runoff velocity and energy and (2) collects gross solids and sediment to ease maintenance of the BMP. The forebay essentially acts as a pretreatment device for the stormwater wetland. The water flows out of the forebay and into the wetland. The entrance to the forebay is deeper than the exit of the forebay. This design will dissipate the energy of the water entering the system, and will also ensure that large solids settle out.

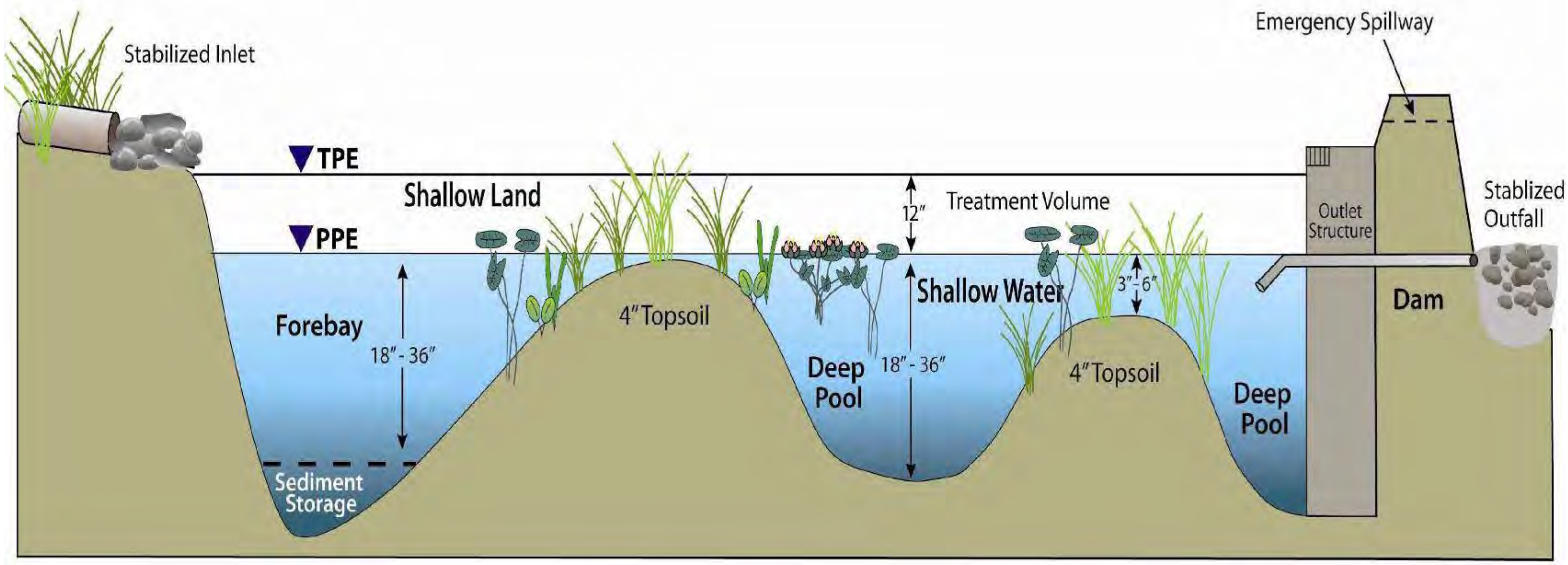
b. *Non-Forebay Deep Pools*: Other deep pools in the wetland are always full of water and are areas where rooted plants do not live. Submerged and floating plants may be used in this area, except around the wetland outlet device. The deep pool at the outlet should be non-vegetated to prevent clogging.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

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

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

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

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



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

Figure 2 Constructed Stormwater Wetland Conceptual Diagram

Step 2: Determine the Volume of Water to Treat

Water Treatment Volume

A wetland is intended to treat the first flush (1″-1.5″) of a particular design storm. The Simple Method in Appendix A details the volumetric calculation.

Contributing Drainage

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

Siting Issues

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

Pretreatment Options

Wetlands and pond/wetland systems require the use of a forebay for pretreatment.

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

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

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

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

a. <u>Determine Required Surface Area of Entire Wetland and Each Wetland Zone</u>:

Two factors determine the surface area:

1) The watershed runoff volume that is to be contained (Q_{Volume}), and

2) The depth of water that plants can sustain for several days in the shallow land area (D_{Plants}), the depth of the temporary pool, up to 12 inches (Hunt and Doll, 2000).

The total surface area of the wetland is determined by the quotient of these variables. The surface area of each wetland zone is a percentage of the total required surface area.

Calculations for determining the surface areas of the various wetland zones are provided below.

• *Surface Area*: The total surface area of the wetland is

$$\frac{Q_{Volume}(ft^3)}{D_{Plants}(ft)} = \_\_\_ \text{ (SF)}$$

(Note: D_{Plants} can be up to 12 inches.) This surface area, in square feet (SF), is distributed to the various wetland zones as outlined below:

- Deep Pools: Ideally, several deep pools should be provided throughout the wetland.
  - Non-Forebay: 5-10% of wetland surface
  - Forebay: 10% of wetland surface
- Shallow Water (low marsh): 40% of wetland surface.
- Shallow Land (high marsh): 30-40% of wetland surface (maximize if pathogens are target pollutant).
- Upland: This is an optional design element. If upland area is included, it will not replace any of the required calculated surface area.

b. Design Depth of Each Wetland Zone: Determine the appropriate depth for each wetland zone. The following depths are recommended for each wetland zone as illustrated in Figure 2:

- Deep Pools:
  - Non-Forebay: 18-36” (include one at the outlet structure for proper drawdown).
  - Forebay: 18-36” plus additional depth for sediment accumulation (deepest near inlet to dissipate energy, more shallow near the exit).
- Shallow Water (low marsh): 3-6”. A primary cause of wetland failure is designing this layer to be too deep.
- Shallow Land (high marsh): Up to 12”. This is the depth, D_{Plants}, used in the surface area calculation, and is also the depth of the temporary pool.
- Upland: Up to 4 feet above the shallow land zone.

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

Step 4: Select the Soil Media Type

A soil analysis should be conducted within the stormwater facility area to determine the viability of soils to ensure healthy vegetation growth and to provide adequate infiltration rates through the topsoil. For wetlands designed to utilize a clay or synthetic liner, at least four (4) inches of quality topsoil shall be added to the top of the liner to support plant growth. Imported or in situ soils may be amended with organic material, depending on soil analysis results, to enhance suitability as a planting media.

Step 5: Select the Appropriate Outlet Structure

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

An ideal outlet structure should contain the following features:

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

Overflow Structure Maintenance Considerations

Stormwater wetland maintenance must be considered when designing outlet structures. Occasionally, wetlands may require complete drawdown. The structures in Figure 3 show the low-capacity drawdown orifice, the high-capacity overflow, and a manually operated valve for maintenance purposes. Alternatively, a flashboard riser can be used to draw water down for maintenance, as shown in Figure 4.

Figure 3 Outlet Structures with Manual Drawdown Valve for Maintenance

Figure 4 Outlet Structure with Flashboard Riser for Maintenance (Photos Courtesy of NC State Science House & BAE)

One method to help ensure that the drawdown orifice does not clog is to turn the orifice downward below the normal pool as shown in Figure 5. This prevents floating debris or vegetation from clogging the orifice. The site in Figure 5 has been drained for maintenance.

Figure 5 Outlet Structure with Down-Turned Drawdown Orifice

The overflow structure should be located near the edge of the wetland so that it can be accessed easily for maintenance, as shown in Figure 6.

Figure 4 Outlet Structure Near Wetland Edge, Orifice Easily Accessible for Maintenance

Overflow structures that are several feet into the wetland, as shown in Figure 7, are difficult to reach and likely will not be maintained.

Figure 5 Outlet Structure Not Near Wetland Edge, Orifice *Not* Easily Accessible for Maintenance

Step 6: Select Plants

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

Shrubs and wetland plants should be designed to minimize solar exposure of open water areas. A landscape plan should be prepared by a qualified design professional that outlines the methods to be used for maintaining wetland plant coverage.

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

- Delineation of planting (pondscaping) zones;
- Selection of corresponding plant species;
- A minimum of ten (10) different species total, of which at least five (5) are emergent species, with no more than 30% of a single species;
- Buffers are recommended as centipede grass;
- Minimum plant quantities and sizes per 200 ft^2 of shallow water area: 50 herbaceous plants of at least 4-cubicinch container (equivalent to 2 ft on center minimum; 1.5 ft on center recommended)
- Minimum plant quantities and plant sizes per 200 ft^2 of shallow land area:

  50 herbaceous plants of at least 4-cubic inch container, OR

  8 shrubs of at least 1-gallon container (equivalent to 5 ft on center minimum; 3 ft on center recommended), OR

  1 tree of at least 3-gallon container and 40 grass-like herbaceous plants of at least 4-cubic inch container
- Source of plant materials (wetland seed mixes are not allowed);
- Planting layout;
- Sequence and timing for preparing wetland bed (including soil amendments, initial fertilization, and watering, as needed);
- Growing medium specifications (soil specifications); and
- Specification of supplementary plantings to replenish losses.

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

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

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

Table 1: Wetland Plant Recommendations

DEEP POOL

Botanical Name	**Common Name**
Floating Aquatic Plants	
Lemna spp.	Duckweed
Nelumbo lutea	American lotus
Nuphar lutea ssp. *polysepala*	Rocky Mtn Pond-lily
Nuphar lutea ssp. *advena*	Yellow Pond-lily
Submerged Aquatic Plants	
Eleocharis acicularis	Needle spikerush
Eleocharis quadrangulata	Squarestem spikerush
Elodea canadensis	Canadian waterweed
Elodea nuttallii	Western waterweed

SHALLOW WATER

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

SHALLOW LAND	
Botanical Name	**Common Name**
Herbaceous Plants	
Asclepias incarnata	Swamp Milkweed
Carex tenera	Quill sedge
Chelone glabra	White Turtlehead
Eupatoriadelphus dubius	Dwarf Joe Pye Weed
Eupatoriadelphus fistulosus	Joe Pye Weed
Eupatoriadelphus maculatus	Spotted trumpetweed
Hibiscus coccineus	Scarlet rose mallow
Hibiscus laevis	Halberdleaf rosemallow
Kosteletzkya virginica	Seashore Mallow
Lobelia cardinalis	Cardinal flower
Lobelia elongata	Longleaf lobelia
Lobelia siphilitica	Great blue Lobelia
Rhynchospora colorata	Starrush whitetop
Saccharum baldwinii	Narrow plumegrass
Shrubs	
Aronia arbutifolia	Red Chokeberry
Cephalanthus occidentalis	Common Buttonbush
Clethra alnifolia	Sweet pepperbush
Cornus amomum	Silky dogwood
Cyrilla racemiflora	TiTi
Gordonia lasianthus	Bushy St. Johnswort
Hypericum densiflorum	Possumhaw
Ilex deciduas	Inkberry
Ilex glabra	InkberryVirginia Sweetspire
Itea virginica	Swamp Rose
Rosa palustris	Creeping Blueberry
Vaccinium crassifolium	Possumhaw
Viburnum nudum var. nudum	Loblolly Bay

Design Variations

There are several variations of the wetland design. The designs are characterized by the volume of the wetland in deep pool, high marsh, and low marsh, and whether the design allows for detention of small storms above the wetland surface.

Shallow Marsh

In the shallow marsh design, most of the wetland volume is in the relatively shallow high marsh or low marsh depths. The only deep portions of the shallow wetland design are the forebay at the inlet to the wetland and the micropool at the outlet. One disadvantage to this design is that, since the pool is very shallow, a large amount of land is typically needed to store the water quality volume (i.e., the volume of runoff to be treated in the wetland).

Extended Detention Wetland

This design is the same as the shallow marsh, with additional storage above the surface of the marsh. Stormwater is temporarily ponded above the surface in the extended detention zone for 12 to 24 hours. This design can treat a greater volume of stormwater in a smaller space than the shallow wetland design. In the extended detention wetland option, plants that can tolerate wet and dry periods should be specified in the extended detention zone.

Pond/Wetland System

The pond/wetland system combines the wet pond design (see *Wet Pond Practice*) with a shallow marsh. Stormwater runoff flows through the wet pond and into the shallow marsh. Like the extended detention wetland, this design requires less surface area than the shallow marsh because some of the volume of the practice is in the relatively deep (i.e., 6-8 feet) pond.

Pocket Wetland

This design is very similar to the pocket pond (see *Wet Pond Practice*). In this design, the bottom of the wetland intersects the groundwater, which helps to maintain the permanent pool. Some evidence suggests that groundwater flows may reduce the overall effectiveness of stormwater-management practices (Brown and Schueler, 1997). This option may be used when there is not significant drainage area to maintain a permanent pool.

Gravel-Based Wetlands

In this design, runoff flows through a rock filter with wetland plants at the surface. Pollutants are removed through biological activity on the surface of the rocks and pollutant uptake by the plants. This practice is fundamentally different from other wetland designs because, while most wetland designs behave like wet ponds with differences in grading and landscaping, gravel-based wetlands are more similar to filtering systems.

Construction Considerations

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

Inlet and outlet channels should be protected from scour that may occur during periods of high flow. Standard erosion-control measures should be used. *Volume 1 - Erosion and Sediment Control Manual* can provide information on erosion- and sediment-control techniques.

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

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

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

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

Safety Considerations

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

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

Common Problems

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

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

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

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

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

Maintenance

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

Dry Detention Pond

Practice Description

As the name of this BMP implies, these basins are typically dry between storm events. A low-flow outlet slowly releases water retained over a period of days. This BMP can be applied in residential, industrial, and commercial developments where sufficient space is available. The primary purpose of dry extended detention basins is to attenuate and delay stormwater runoff peaks. They are appropriate where water quality issues are secondary to managing peak runoff, since the overall pollutant removal efficiency of dry extended detention basins is low. Dry extended detention basins are not intended as infiltration or groundwater recharge measures

Planning Considerations

Dry detention ponds have traditionally been one of the most widely used stormwater best management practices. In some instances, these ponds may be the most appropriate best management practice. However, they should not be used as a “one size fits all: solution. If pollutant removal efficiency is an important consideration, dry detention ponds may not be the most appropriate choice. Dry detention ponds require a large amount of space to build. In many instances, smaller sized best management practices are more appropriate alternatives (see *Grassed Swales, Infiltration Basin, Infiltration Trench, Pervious Asphalt Pavement*, *Bioretention (Rain Gardens), Permeable Interlocking Concrete Paving,* or *Green Roofs*).

Design Criteria

Converting Sediment and Erosion Control Devices

Sediment basins that are used during construction can be converted into dry extended detention basins after the construction is completed. If used during construction as a sediment basin, the basin must be completely cleaned out, graded, and vegetated within 14 days of completion of construction.

Siting Considerations

Designers need to ensure that the dry detention pond is feasible at the site in question. This section provides basic guidelines for siting dry detention ponds.

Drainage Area

Dry extended detention basins can be utilized on very large sites, but often reach limitations around 25 acres or more. The most common limitation is the bottom of the basin approaching groundwater.

Slope

Dry detention ponds can be used on sites with slopes up to about 15 percent. The local slope needs to be relatively flat, however, to maintain reasonably flat side slopes in the practice. There is no minimum slope requirement, but there does need to be enough elevation drop from the pond inlet to the pond outlet to ensure that flow can move through the system.

Soils/Topography

Dry detention ponds can be used with almost all soils and geology, with minor design adjustments for regions of karst topography or in rapidly percolating soils such as sand. In these areas, extended detention ponds should be designed with an impermeable liner to prevent groundwater contamination or sinkhole formation.

Ground Water

Except for the case of hot spot runoff, the only consideration regarding groundwater is that the base of the extended detention facility should not intersect the groundwater table. A permanently wet bottom may become a mosquito breeding ground. Research in southwest Florida (Santana et al., 1994) demonstrated that intermittently flooded systems, such as dry extended detention ponds, produced more mosquitoes than other pond systems, particularly when the facilities remained wet for more than 3 days following heavy rainfall.

Design Considerations

Specific designs may vary considerably, depending on site constraints or preferences of the designer or community. Some features, however, should be incorporated into most dry extended detention pond designs. These design features can be divided into five basic categories: pretreatment, treatment, conveyance, maintenance reduction, and landscaping.

Pretreatment

A forebay is highly recommended at the inlet of a dry extended detention basin to trap incoming sediment if the design flow to the facility is over 10 acre-inches. A forebay is recommended on all other dry detention basins. With heavy, coarse sediment confined to the forebay area, maintenance is made simpler and less costly and the life of the BMP is extended.

To prevent resuspension of trapped sediment and scour during high flows, the energy of the influent flow must be controlled. This can be in the form of a forebay as mentioned above, a plunge pool, riprap, or other energy-dissipating and erosion-control measures.

Treatment

Treatment design features help enhance the ability of a stormwater management practice to remove pollutants. Designing dry ponds with a high length-to-width ratio (i.e., at least 1.5:1) and incorporating other design features to maximize the flow path effectively increases the detention time in the system by eliminating the potential of flow to short-circuit the pond. Designing ponds with relatively flat side slopes can also help to lengthen the effective flow path. Finally, the pond should be sized to detain the volume of runoff to be treated for between 12 and 48 hours.

Length, Width, Depth and Geometry

The volume of a dry extended detention basin is driven exclusively by the volume of stormwater that is required to be captured. Once that volume is calculated, the dimensional aspect of the basin is mostly site driven. Below are some dimensional and layout requirements:

- The maximum depth shall be 10 feet.
- A minimum of 1 foot of freeboard shall be provided between the design flow pool elevation and the emergency overflow invert.

- The minimum flow length-to-width ratio shall be 1.5:1, but 3:1 is recommended. The basin width should preferably expand as it approaches the outlet.
- Side slopes of the basin shall be no steeper than 3H:1V if stabilized by vegetation.
- In addition to detention volume, design must provide for sediment storage equal to 25 percent of detention volume. If it is known that the upstream drainage basin will contribute high sediment loads (e.g. construction) over several years, then additional sediment storage should be provided.

By causing turbulence and eddies in the flow, flow short-circuiting can interfere with the function of the basin outlet system and should therefore be minimized. The most direct way of minimizing short-circuiting is to maximize the distance between the riser and the inlet. Larger length-to-width ratios should be used if sedimentation of particulates during low flows is desirable. Irregularly shaped basins appear more natural. If a relatively long, narrow facility is not suitable at a given site, baffles constructed from gabions or other materials can be placed in the basin to lengthen the flowpath.

A sinuous low-flow channel should be constructed through the basin to transport dry-weather flows and minor storm flows. Preferably, the channel would be grass lined and sloped at approximately 2 percent to promote drainage of the basin between storms. The entire bottom of the basin should drain toward the low-flow channel.

Conveyance

Conveyance of stormwater runoff into and through the dry pond is a critical component. Stormwater should be conveyed to and from dry ponds safely in a manner that minimizes erosion potential. The outfall of pond systems should always be stabilized to prevent scour. To convey low flows through the system, designers should provide a pilot channel. A pilot channel is a surface channel that should be used to convey low flows through the pond. In addition, an emergency spillway should be provided to safely convey large flood events. To help mitigate the warming of water at the outlet channel, designers should provide shade around the channel at the pond outlet.

Outlet Design

In addition to meeting specific hydraulic requirements for runoff detention and peak attenuation, outlets also must be functionally simple and easy to maintain. Below are design requirements and guidelines for dry extended detention basin outlets:

- Basin design should include a small permanent pool near the outlet orifice to reduce clogging and keep floating debris away from the outlet.
- Basin design must include a drain that will completely empty the basin for clean-out.

- Durable materials such as reinforced concrete or plastic are preferable to corrugated metal in most instances.
- The riser should be placed in or at the face of the embankment to make maintenance easier and prevent flotation problems.
- Erosion protection measures should be used at the basin discharge point.
- To prevent piping and internal erosion problems around the spillway/outlet conduit through an embankment system, a filter diaphragm and drainage system is recommended.

Maintenance Reduction

Regular maintenance activities are needed to maintain the function of stormwater practices. In addition, some design features can be incorporated to ease the maintenance burden of each practice. In dry detention ponds, a "micropool" at the outlet can prevent resuspension of sediment and outlet clogging. A good design includes maintenance access to the forebay and micropool.

Another design feature that can reduce maintenance needs is a non-clogging outlet. Typical examples include a reverse-slope pipe or a weir outlet with a trash rack. A reverse slope pipe draws from below the permanent pool extending in a reverse angle up to the riser and determines the water elevation of the micropool. Because these outlets draw water from below the level of the permanent pool, they are less likely to be clogged by floating debris.

Landscaping

When choosing vegetation for a dry extended detention basin, consideration must be given to the wildflowers or grasses specified because of the frequent inundations, warm and cold seasons, as well as salt and oil loading. Additionally, the plants should not be fertilized except for a one-time application after seeding. Mowing should be minimal. It has been found that a wet meadow mix or Bermuda grass typically performs well in those locations with the climate able to support it.

The dry extended detention basin must be stabilized within 14 days after the end of construction. The stabilization might be the final vegetation or a temporary stabilization measure until the vegetation becomes established.

Design Variations

Tank Storage

Another variation of the dry detention pond design is the use of tank storage. In these designs, stormwater runoff is conveyed to large storage tanks or vaults underground. This practice is most often used in the ultra-urban environment on small sites where no other opportunity is available to provide flood control. Tank storage is provided on small areas because underground storage for a large drainage area would generally be costly. Because the drainage area contributing to tank storage is typically small, the outlet diameter needed to reduce the flow from very small storms would very small. A very small outlet diameter, along with the underground location of the tanks, creates the potential for debris being caught in the outlet and resulting maintenance problems. Since it is necessary to control small runoff events (such as the runoff from a 1-inch storm) to improve water quality, it is generally infeasible to use tank storage for water quality and generally impractical to use it to protect stream channels.

Common Problems

Although dry detention ponds are widely applicable, they have some limitations that might make other stormwater management options preferable:

- Dry detention ponds have only moderate pollutant removal when compared to other structural stormwater practices, and they are ineffective at removing soluble pollutants.
- Dry extended detention ponds may become a nuisance due to mosquito breeding if improperly maintained or if shallow pools of water form for more than 7 days.
- Although wet ponds can increase property values, dry ponds can actually detract from the value of a home.
- Dry detention ponds on their own only provide peak flow reduction and do little to control overall runoff volume, which could result in adverse downstream impacts.

Maintenance

– The drainage area will be managed to reduce the sediment load to the dry extended detention basin.

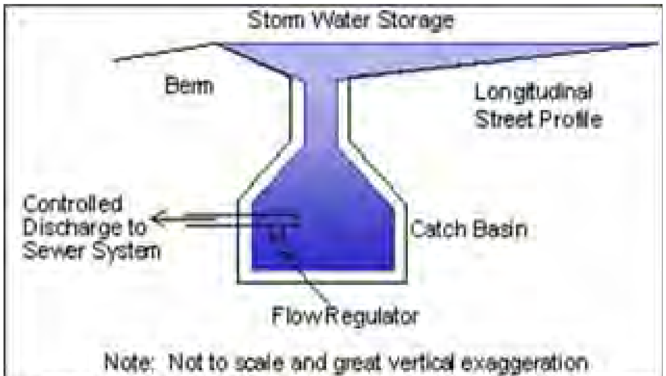
– Immediately after the dry extended detention basin is established, the vegetation will be watered twice weekly, if needed, until the plants become established (commonly six weeks).

– No portion of the dry extended detention pond will be fertilized after the first initial fertilization that is required to establish the vegetation.

– The vegetation in and around the basin should be maintained at a height of approximately six inches.

– Once a year, a dam safety expert will inspect the embankment.

In-Line Storage



Catch basins can be equipped with flow restrictors to temporarily detain storm water in the conveyance system

Source: EPA

Practice Description

In-line storage refers to a number of practices designed to use the storage within the storm drain system to detain flows. While these practices can reduce storm peak flows, they are unable to improve water quality and offer limited protection of downstream channels. Hence, the U.S. Environmental Protection Agency does not recommend using these practices in many circumstances. Storage is achieved by placing devices in the storm drain system to restrict the rate of flow. Devices can slow the rate of flow by backing up flow, as in the case of a dam or weir, or through the use of vortex valves (devices that reduce flow rates by creating a helical flow path in the structure). A description of various flow regulators is included in Urbonas and Stahre (1990).

Planning Considerations

In-line storage practices serve a similar purpose as traditional detention basins (see *Dry Detention Ponds Practice*). These practices can act as surrogates for aboveground storage when little space is available for aboveground storage facilities.

Design Criteria

Flow regulators cannot be applied to all storm drain systems. In older cities, the storm drain pipes may not be oversized, and detaining stormwater within them would cause upstream flooding. Another important issue in siting these practices is the slope of the pipes in the system. In areas with very flat slopes, restricting flow within the system is likely to cause upstream flooding because introducing a regulator into the system will cause flows to back up a long distance before the regulator. In steep pipes, on the other hand, a storage flow regulator cannot utilize much of the storage available in the storm drain system.

Common Problems

In-line storage practices only control stormwater quantity and are not efficient at improving runoff water quality.

Without proper design, these practices often cause upstream flooding.

Maintenance

Flow regulators require very little maintenance because they are designed to be “self-cleaning,” much like the storm drain system. In some cases, flow regulators may be modified based on downstream flows, new connections to the storm drain, or the application of other flow regulators within the system. For some designs, such as check dams, regulations will require only moderate construction in order to modify the structure’s design.

Wet Pond

Practice Description

Wet ponds (a.k.a. stormwater ponds, wet retention ponds, wet extended detention ponds) are constructed basins that have a permanent pool of water throughout the year (or at least throughout the wet season). In wet detention basins, a permanent pool of standing water is maintained by the riser—the elevated outlet of the wet detention basin. Water in the permanent pool mixes with and dilutes the initial runoff from storm events. Wet detention basins fill with stormwater and release most of the mixed flow over a period of a few days, slowly returning the basin to its normal depth.

Runoff generated during the early phases of a storm usually has the highest concentrations of sediment and dissolved pollutants. Because a wet detention basin dilutes and settles pollutants in the initial runoff, the concentration of pollutants in the runoff released downstream is reduced. Following storm events, pollutants are removed from water retained in the wet detention basin. Two mechanisms that remove pollutants in wet detention basins include settling of suspended particulates and biological uptake, or consumption of pollutants by plants, algae, and bacteria in the water. However, if the basin is not adequately maintained (e.g., by periodic excavation of the captured sediment), storm flows may re-suspend sediments and deliver them to the stream.

Planning Considerations

Wet detention basins are applicable in residential, industrial, and commercial developments where enough space is available. Wet detention basins are sized and configured to provide significant removal of pollutants from the incoming stormwater runoff. The permanent pool of water is designed for a target total suspended solids removal efficiency according to the size and imperviousness of the contributing watershed. Above this permanent pool of water, wet detention basins are also designed to hold the runoff volume required by the stormwater regulations, and to release it over a period of 2 to 5 days. As a result, most of the suspended sediment and pollutants attached to the sediment settle out of the water. In addition, water is slowly released so that downstream erosion from smaller storms is lessened.

Design Criteria

Converting Erosion- and Sediment-Control Devices

Wet detention basins are typically part of the initial site clearing and grading activities and are often used as sediment basins during construction of the upstream development. Volume 1 contains design requirements for sediment basins required during construction. A sediment basin typically does not include all the engineering features of a wet detention basin, and the design engineer must ensure that the wet detention basin includes all the features identified in this section, including the full sizing as a wet detention basin. If the wet detention basin is used as a sediment trap during construction, all sediment deposited during construction must be removed, erosion features must be repaired, and the vegetated shelf must be restored, before operation as a stormwater BMP begins.

Siting Considerations

Because large storage volumes are needed to achieve extended detention times, wet detention basins require larger land areas than many other BMPs. Wet detention basins may not be suitable for projects with very limited available land. Permanent retaining walls may be used to obtain the required design volumes while reducing the footprint that would otherwise be required for earthen construction. Retaining walls utilized to contain the permanent pool must not reduce the required 10′ width of the vegetated shelf, and must not extend to a top elevation above the lowest point of the vegetated shelf. Retaining walls utilized to contain the temporary pool must not reduce the required 10′ width of the vegetated shelf, and must not be in contact with the stormwater stored up to the temporary pool elevation. Two retaining walls may be used, as shown in Figure 1. Or, the design may be altered to contain only one of the two shown.

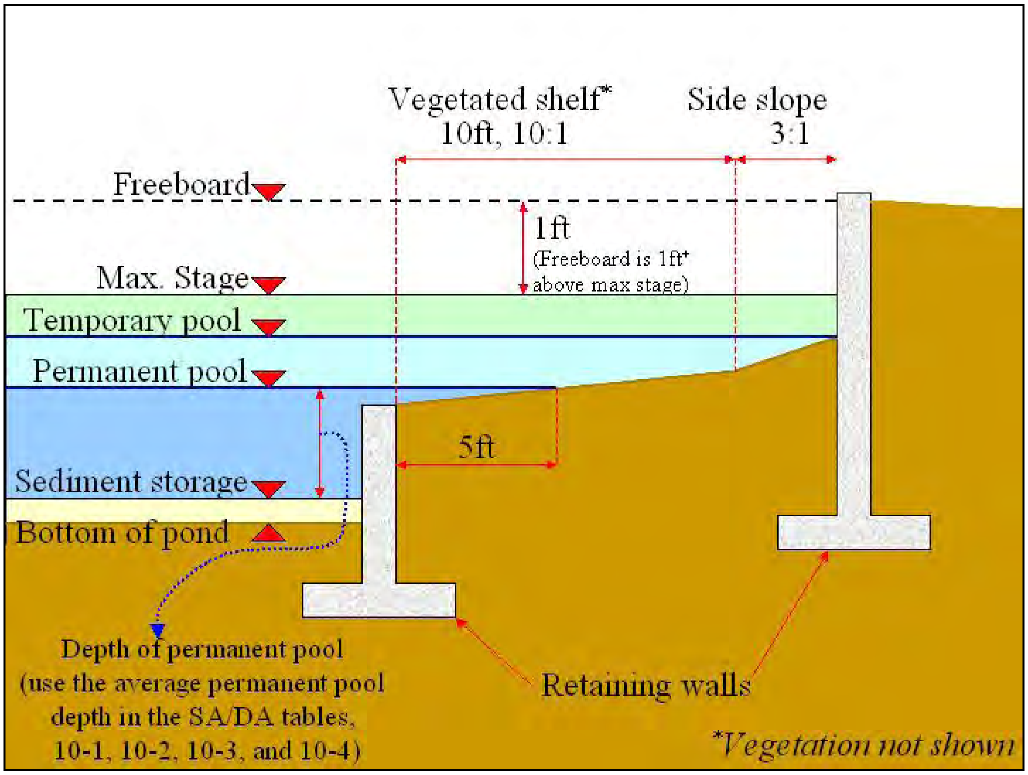


Figure 1 Alternative Wet Pond Design: Retaining Wall Option

Drainage Area

Wet ponds need sufficient drainage area to maintain the permanent pool. In humid regions, this is typically about 25 acres, but a greater area may be needed in regions with less rainfall. BMPs that focus on source control, such as bioretention, should be considered for smaller drainage areas.

Slope

Wet ponds can be used on sites with an upstream slope up to about 15 percent. The local slope should be relatively shallow, however. Although there is no minimum slope requirement, there does need to be enough elevation drop from the pond inlet to the pond outlet to ensure that water can flow through the system.

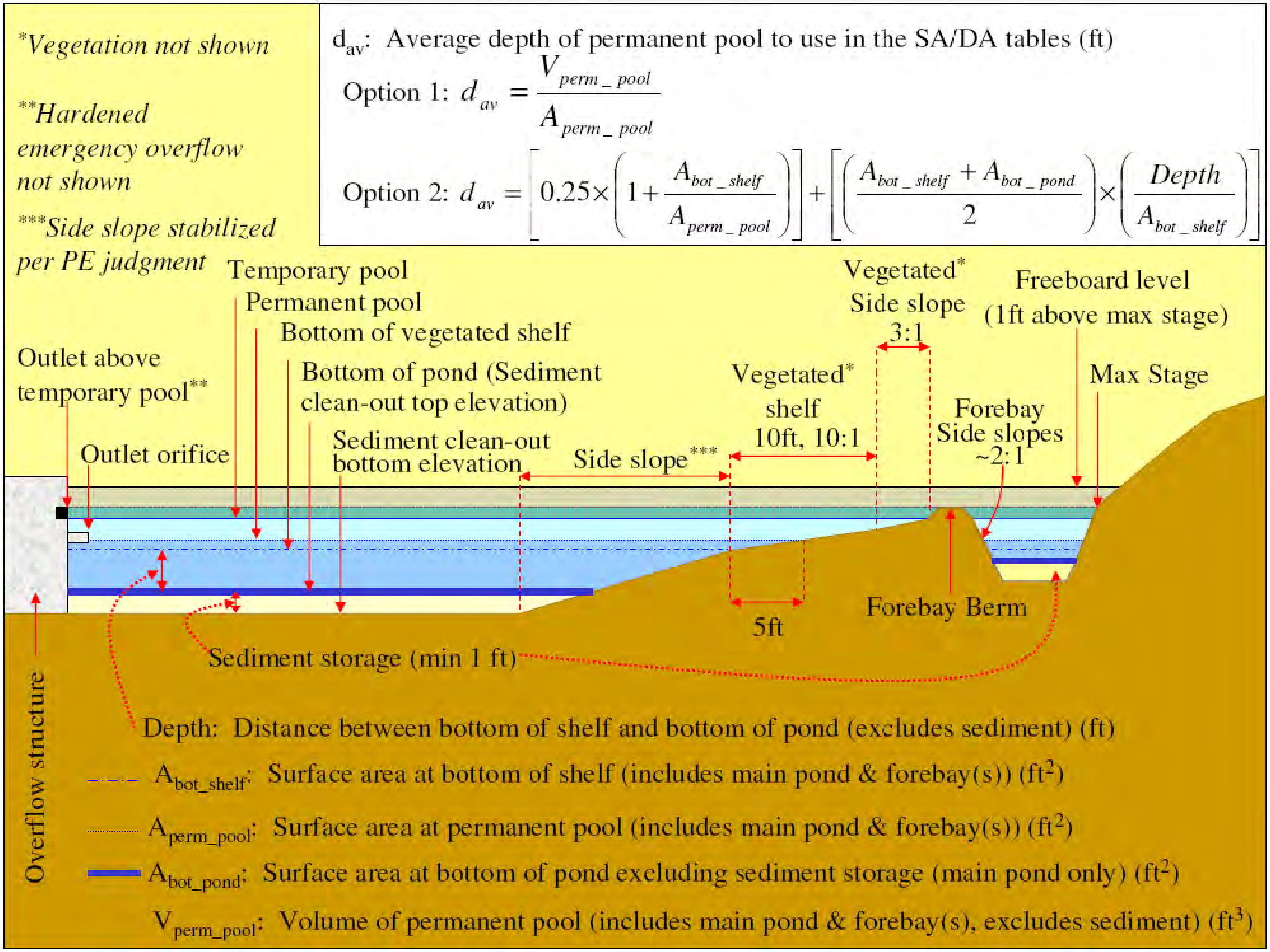


Figure 2 Basic Wet Detention Basin Elements: Cross Section

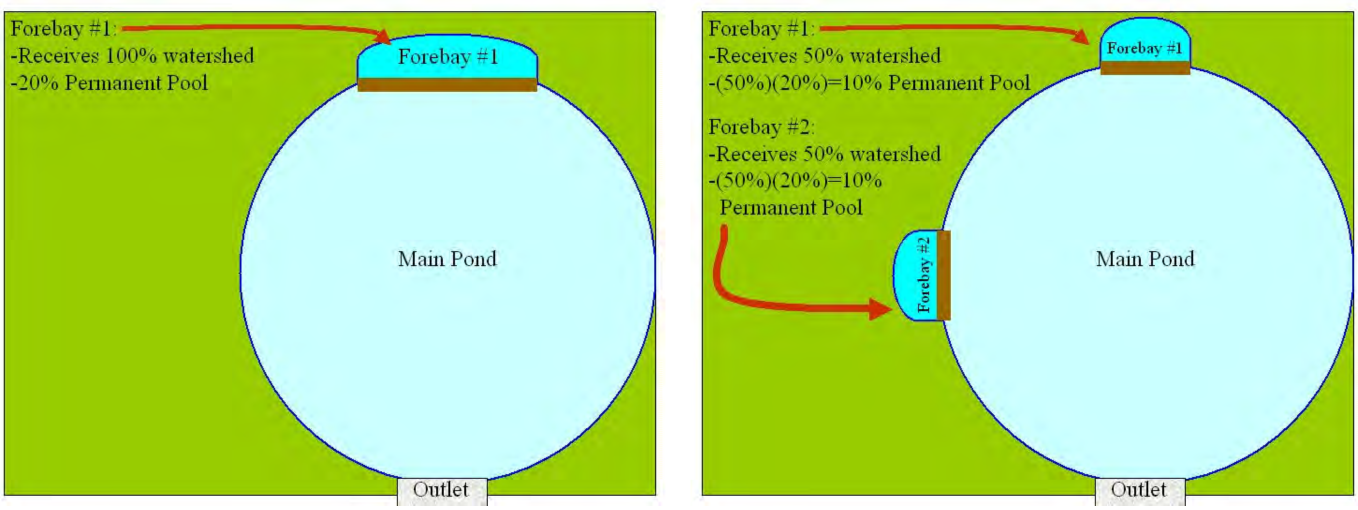
Design Considerations

Specific designs may vary considerably, depending on site constraints or preferences of the designer or community. There are some features, however, that should be incorporated into most wet pond designs. These design features can be divided into five basic categories: pretreatment, treatment, conveyance, maintenance reduction, and landscaping.

Pretreatment

Forebays are highly recommended on all inlets to a wet detention basin. A properly engineered forebay can concentrate large particle-size sediment for easier removal, and can dissipate the incoming flow energy prior to the stormwater entering the main part of the BMP. The dissipation of incoming flow energy reduces re-suspension of settled material in the main pool, and it reduces the likelihood of erosion features within the BMP. Also, the forebay itself should be configured for energy dissipation within the forebay to avoid re-suspension of large-particle settled material previously captured in the forebay. One of several engineering means of energy dissipation is to have the inlet pipe submerged below the permanent forebay pool level, provided that the inlet placement does not serve to re-suspend previously captured sediment.

It is recommended that the design volume for the forebay be approximately 20% of the total calculated permanent pool volume. The main pool of the permanent pool would then account for approximately 80% of the design volume. If the pond has more than one forebay, the total volume of the forebays should equal 20% of the permanent pool volume. In this case, each forebay should be sized as in Figures 3–5.



Figures 3–4 Forebay Sizing Examples (continued)

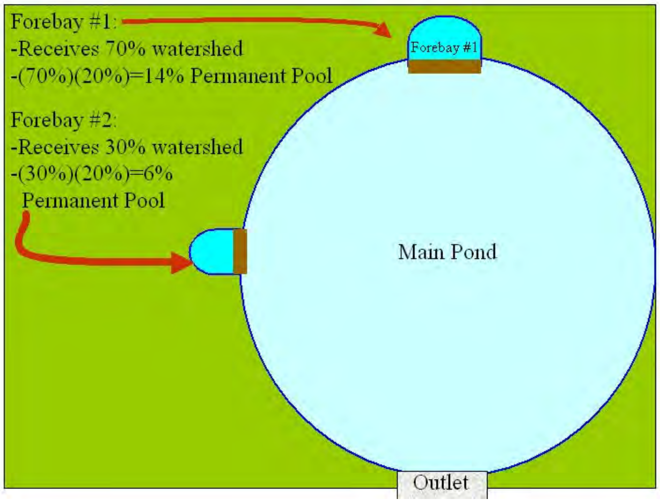


Figure 5 Forebay Sizing Examples (concluded)

Treatment

Treatment design features help enhance the ability of a stormwater management practice to remove pollutants. The purpose of most of these features is to increase the amount of time that stormwater remains in the pond.

One technique of increasing the pollutant removal of a pond is to increase the volume of the permanent pool. Typically, ponds are sized to be equal to the water quality volume (i.e., the volume of water treated for pollutant removal). Designers may consider using a larger volume to meet specific watershed objectives, such as phosphorus removal in a lake system. Regardless of the pool size, designers need to conduct a water balance analysis to ensure that sufficient inflow is available to maintain the permanent pool.

Other design features do not increase the volume of a pond, but can increase the amount of time stormwater remains in the practice and eliminate short-circuiting. Ponds should always be designed with a length-to-width ratio of at least 1.5:1. In addition, the design should incorporate features to lengthen the flow path through the pond, such as underwater berms designed to create a longer route through the pond. Combining these two measures helps ensure that the entire pond volume is used to treat stormwater. Another feature that can improve treatment is to use multiple ponds in series as part of a "treatment train" approach to pollutant removal. This redundant treatment can also help slow the rate of flow through the system. Additionally, a vegetated buffer with shrubs or trees around the pond area should provide shading and consequent cooling of the pond water.

If designers of wet ponds are anticipating ponds that stratify in the summer, they might want to consider installing a fountain or other mixing mechanism. This will ensure that the full water column remains oxic.

Conveyance

Length, Width (Area), Depth, Geometry

Depth is an important engineering design criterion because most of the pollutants are removed through settling. Very shallow basins may develop currents that can re-suspend materials; on the other hand, very deep wet detention basins can become thermally stratified and/or anoxic and release pollutants back into the water.

The engineering design of a wet detention basin must include a 10-foot-wide (minimum) vegetated shelf around the full perimeter of the basin. The inside edge of the shelf shall be no deeper than 6″ below the permanent pool level, and the outside edge shall be 6″ above the permanent pool level. For a 10′ wide shelf, the resulting slope is 10:1. With half the required shelf below the water (maximum depth of 6 inches), and half the required shelf above the water, the vegetated shelf will provide a location for a diverse population of emergent wetland vegetation that enhances biological pollutant removal, provides a habitat for wildlife, protects the shoreline from erosion, and improves sediment trap efficiency. A 10′ wide shelf also provides a safety feature prior to the deeper permanent pool.

Short-circuiting of the stormwater must be prevented. The most direct way of minimizing short-circuiting is to maximize the length of the flow path between the inlet and the outlet: basins with long and narrow shapes can maximize the length of the flow path. Long and narrow but irregularly shaped wet detention basins may appear more natural and therefore may have increased aesthetic value. If local site conditions prohibit a relatively long, narrow facility, baffles may be placed in the wet detention basin to lengthen the stormwater flow path as much as possible. Baffles must extend to the temporary pool elevation or higher. A minimum length-to-width ratio of 1.5:1 is required, but a flow path of at least 3:1 is recommended. Basin shape should minimize dead storage areas and, where possible, the width should expand as it approaches the outlet.

Although larger wet detention basins typically remove more pollutants, a threshold size seems to exist above which further improvement of water quality by sedimentation is negligible. The permanent pool volume within a wet detention basin is calculated as the total volume beneath the permanent pool water level, and above the sediment storage volume, including any such volume within the forebay.

Outlet Design

The outlet device shall be designed to release the temporary pool volume (minimum required treatment volume as calculated by the Simple Method) over a period of 48 to 120 hours (2 to 5 days). Longer detention times typically do not improve settling efficiency significantly, and the temporary pool volume must be available for the next storm. In addition, prolonged periods of inundation can adversely affect the wetland vegetation growing on the vegetated shelf.

In addition to being designed to achieve the 2- to 5-day drawdown period, outlets also must be functionally simple and easy to maintain. One possible configuration option of the outlet piping that simplifies maintenance and reduces the potential for obstruction is the submerged orifice arrangement shown in Figure 6.

Durable materials, such as reinforced concrete, are preferable to corrugated metal in most instances. The riser should be placed in or at the face of the embankment. By placing the riser close to the embankment, maintenance access is facilitated and flotation forces are reduced. The design engineer must present flotation force calculations for any outlet design subject to flotation forces.

Emergency overflow spillways must be designed with hardened materials at the points where extreme conditions might compromise the integrity of the structure.

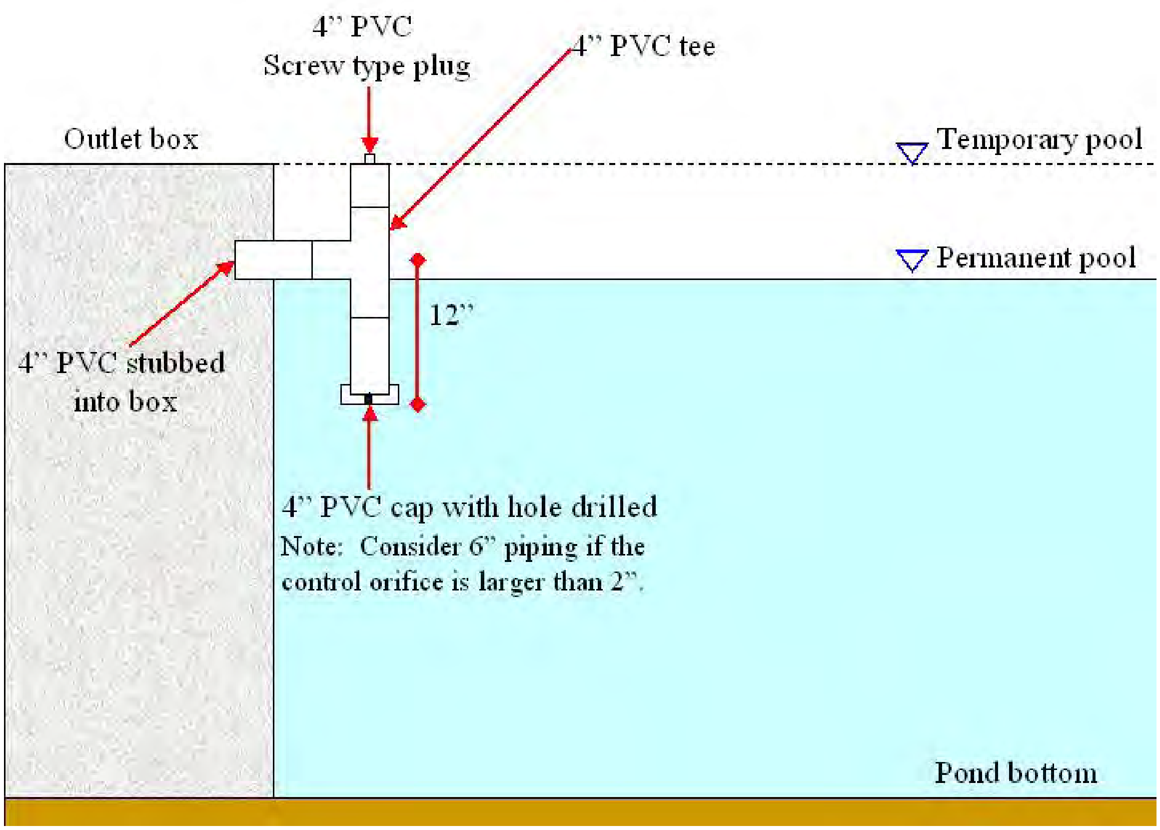


Figure 6

Typical Submerged Orifice Outlet Configuration

Maintenance Reduction

In addition to regular maintenance activities needed to maintain the function of stormwater practices, some design features can be incorporated to ease the maintenance burden of each practice. In wet ponds, maintenance reduction features include techniques to reduce the amount of maintenance needed, as well as techniques to make regular maintenance activities easier.

One potential maintenance concern in wet ponds is clogging of the outlet. Ponds should be designed with a non-clogging outlet such as a reverse-slope pipe, or a weir outlet with a trash rack. A reverse-slope pipe draws from below the permanent pool extending in a reverse angle up to the riser and establishes the water elevation of the permanent pool. Because these outlets draw water from below the level of the permanent pool, they are less likely to be clogged by floating debris. Another general rule is that no orifice should be less than 3 inches in diameter. (Smaller orifices are more susceptible to clogging.)

Design features are also incorporated to ease maintenance of both the forebay and the main pool of ponds. Ponds should be designed with maintenance access to the forebay to ease this relatively routine (5.7 year) maintenance activity. In addition, ponds should generally have a pond drain to draw down the pond for the more infrequent dredging of the main cell of the pond.

Fountains in the Wet Pond

Fountains are optional, decorative wet pond amenities. If they are included, they shall be designed as follows:

1. Ponds smaller than 30,000 ft^3 cannot have a fountain.

2. The fountain must draw its water from less than 2′ below the permanent pool surface.

3. Separated units (where the nozzle, pump and intake are connected by tubing) may be used only if they draw water from the surface in the deepest part of the pond.

4. The falling water from the fountain must be centered in the pond, away from the shoreline.

5. The maximum horsepower for the fountain's pump is based on the permanent pool volume, as described in Table 1. As an example, if the pond's volume is 350,000 cubic feet, the maximum pump horsepower for the fountain is 1.

Table 1
Fountain Pump Power Requirements

Minimum Pond Volume (ft^3)	Max Pump HP
30,000	1/8
40,000	1/6
60,000	1/4
80,000	1/3
125,000	1/2
175,000	3/4
250,000	1
450,000	2
675,000	3

Landscaping

Landscaping of wet ponds can make them an asset to a community and can also enhance the pollutant removal of the practice. A vegetated buffer should be preserved around the pond to protect the banks from erosion and provide some pollutant removal before runoff enters the pond by overland flow. In addition, ponds should incorporate an aquatic bench (i.e., a shallow shelf with wetland plants) around the edge of the pond. This feature may provide some pollutant uptake, and it also helps to stabilize the soil at the edge of the pond and enhance habitat and aesthetic value.

Construction Considerations

Even moderate rainfall events during the construction of a wet detention basin can cause extensive damage to it. Protective measures should be employed both in the contributing drainage area, and at the wet detention basin itself. Temporary drainage or erosion control measures should be used to reduce the potential for damage to the wet detention basin before the site is stabilized. The control measures may include stabilizing the surface with erosion mats, sediment traps, and diversions. Vegetative cover and the emergency spillway also should be completed as quickly as possible during construction.

The designer should address the potential for bedding erosion and catastrophic failure of any buried outlet conduit. A filter diaphragm and drain system should be provided along the barrel of the principal spillway to prevent piping. There has been an evolution in standard practice, and the accumulated evidence suggests that, in most circumstances, filter diaphragms are much superior to anti-seep collars in preventing piping. Filter diaphragms are preferred over the older design anti-seep collar.

If reinforced concrete pipe is used for the principal spillway, “O-ring” gaskets (ASTM C361) should be used to create watertight joints and should be inspected during installation.

Safety Considerations

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

Fencing of wet detention basins is not generally aesthetically pleasing but may be required by the local review authority. A preferred method is to engineer the contours of the wet detention basin to eliminate drop-offs and other safety hazards as discussed above. Riser openings must not permit unauthorized access. End walls above pipe outfalls greater than 48 inches in diameter should be fenced to prevent falls.

Design Variations

There are several variations of the wet pond design. Some of these design alternatives are intended to make the practice adaptable to various sites and to account for regional constraints and opportunities.

Wet Extended Detention Pond

The wet extended detention pond combines the treatment concepts of the dry extended detention pond and the wet pond. In this design, the water quality volume is split between the permanent pool and detention storage provided above the permanent pool. During storm events, water is detained above the permanent pool and released over 12 to 48 hours. This design has similar pollutant removal to a traditional wet pond and consumes less space. Wet extended detention ponds should be designed to maintain at least half the treatment volume of the permanent pool. In addition, designers need to carefully select vegetation to be planted in the extended detention zone to ensure that the selected vegetation can withstand both wet and dry periods.

Water Reuse Pond

Some designers have used wet ponds to act as a water source, usually for irrigation. In this case, the water balance should account for the water that will be taken from the pond. One study conducted in Florida estimated that a water reuse pond could provide irrigation for a 100-acre golf course at about one-seventh the cost of the market rate of the equivalent amount of water ($40,000 versus $300,000).

Common Problems

Limitations of wet ponds include:

- If improperly located, wet pond construction may cause loss of wetlands or forest.
- Wet ponds are often inappropriate in dense urban areas because each pond is generally quite large.
- Wet ponds may pose safety hazards.

Maintenance

– Immediately after the wet detention basin is established, the plants on the vegetated shelf and perimeter of the basin should be watered twice weekly, if needed, until the plants become established (commonly six weeks).

– No portion of the wet detention pond should be fertilized after the first initial fertilization that is required to establish the plants on the vegetated shelf.

– Stable groundcover should be maintained in the drainage area to reduce the sediment load to the wet detention basin.

- If the basin must be drained for an emergency or to perform maintenance, the flushing of sediment through the emergency drain should be minimized to the maximum extent practical.
- Once a year, a dam safety expert should inspect the embankment.