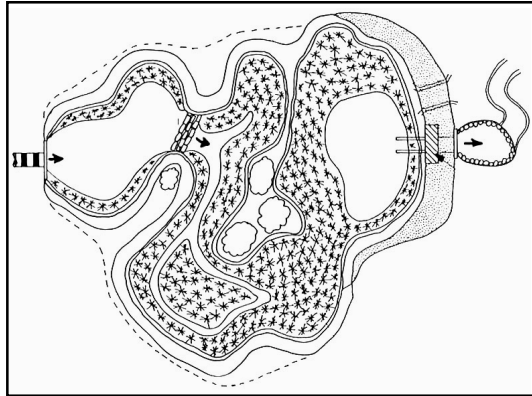


# Constructed Wetlands

## Stormwater Wetlands



### Description

Stormwater wetlands are constructed wetland systems designed to maximize the removal of pollutants from stormwater runoff via several mechanisms: microbial breakdown of pollutants, plant uptake, retention, settling and adsorption. Stormwater wetlands temporarily store runoff in shallow pools that support conditions suitable for the growth of wetland plants. Stormwater wetlands also promote the growth of microbial populations which can extract soluble carbon and nutrients and potentially reduce BOD and fecal coliform levels concentrations.

Like detention basins and wet ponds, stormwater wetlands may be used in connection with other BMP components, such as sediment forebays and micropools. These engineered wetlands differ from wetlands constructed for compensatory storage purposes and wetlands created for restoration. Typically, stormwater wetlands will not have the full range of ecological functions of natural wetlands; stormwater wetlands are designed specifically for flood control and water quality purposes. Similar to wet ponds, stormwater wetlands require relatively large contributing drainage areas and/or dry weather base flow. Minimum contributing drainage areas should be at least ten acres, although pocket type wetlands may be appropriate for smaller sites if sufficient ground water flow is available.

The use of stormwater wetlands is limited by a number of site constraints, including soils types, depth to groundwater, contributing drainage area, and available land area. Soils, depth to bedrock, and depth to water table must be investigated before designing and siting stormwater wetlands. Medium-fine texture soils (such as loams and silt loams) are best to establish vegetation, retain surface water, permit groundwater discharge, and capture pollutants. At sites where infiltration is too rapid to sustain permanent soil saturation, an imper-

### Purpose

	<b>Water Quantity</b>
Flow attenuation	■
Runoff volume reduction	▣
	<b>Water Quality</b>
<b>Pollution prevention</b>	
Soil erosion	N/A
Sediment control	N/A
Nutrient loading	N/A
<b>Pollutant removal</b>	
Total suspended sediment (TSS)	■
Total phosphorus (P)	▣
Nitrogen (N)	▣
Heavy metals	▣
Floatables	▣
Oil and grease	■
<b>Other</b>	
Fecal coliform	■
Biochemical oxygen demand (BOD)	■

■	Primary design benefit
▣	Secondary design benefit
□	Little or no design benefit

# Constructed Wetlands

## Stormwater Wetlands

---

meable liner may be required. Where the potential for groundwater contamination is high, such as runoff from sites with a high potential pollutant load, the use of liners should be required.

### **Advantages**

- Improvements in downstream water quality.
- Settlement of particulate pollutants.
- Reduction of oxygen-demanding substances and bacteria from urban runoff.
- Biological uptake of pollutants by wetland plants.
- Flood attenuation.
- Reduction of peak discharges.
- Enhancement of vegetation diversity and wildlife habitat in urban areas.
- Aesthetic enhancement and valuable addition to community green space.
- Relatively low maintenance costs.

### **Limitations**

- Release of nutrients in the fall.
- May be difficult to maintain vegetation under a variety of flow conditions.
- Geese may become undesirable year-round residents if natural buffers are not included in the wetland design.
- May act as a heat sink, and can discharge warmer water to downstream water bodies.
- Depending upon design, larger land requirements than for other BMPs.
- Until vegetation is well established, pollutant removal efficiencies may be lower than anticipated.
- Relatively high construction costs in comparison to other BMPs.

## Requirements

### **Design**

A site appropriate for a stormwater wetland must have adequate water flow and appropriate underlying soils. Baseflow from the drainage area or groundwater must be sufficient to maintain a shallow pool in the wetland and support the vegetation, including species susceptible to damage during dry periods. Underlying soils that are NRCS Types B, C or D will have only small infiltration losses. Sites with type A (sandy) soils have high infiltration rates and may require a geotextile liner or a 15 centimeter (6 inch) layer of clay. After excavation and grading of a basin, at least 10 centimeters (4 inches) of soil should be applied to the site. This material, which may be the previously-excavated soil or other suitable material, is needed to provide a substrate in which vegetation can become established.

# Constructed Wetlands

## Stormwater Wetlands

### Wetland Treatment

The design criteria for stormwater wetlands are the same as those for active settling ponds. They can be designed to meet particle size removal efficiencies and treatment volume criteria. However, care must be taken to design the wetland so that the bounce in the pool is compatible with the wetland vegetation. The bounce must be considered in addition to any discharge requirements for particle size, flood control or downstream erosion control settling ponds with special attention to keeping solids from overtaking the vegetation.

Factors which increase the settling rate of suspended solids in stormwater wetlands include:

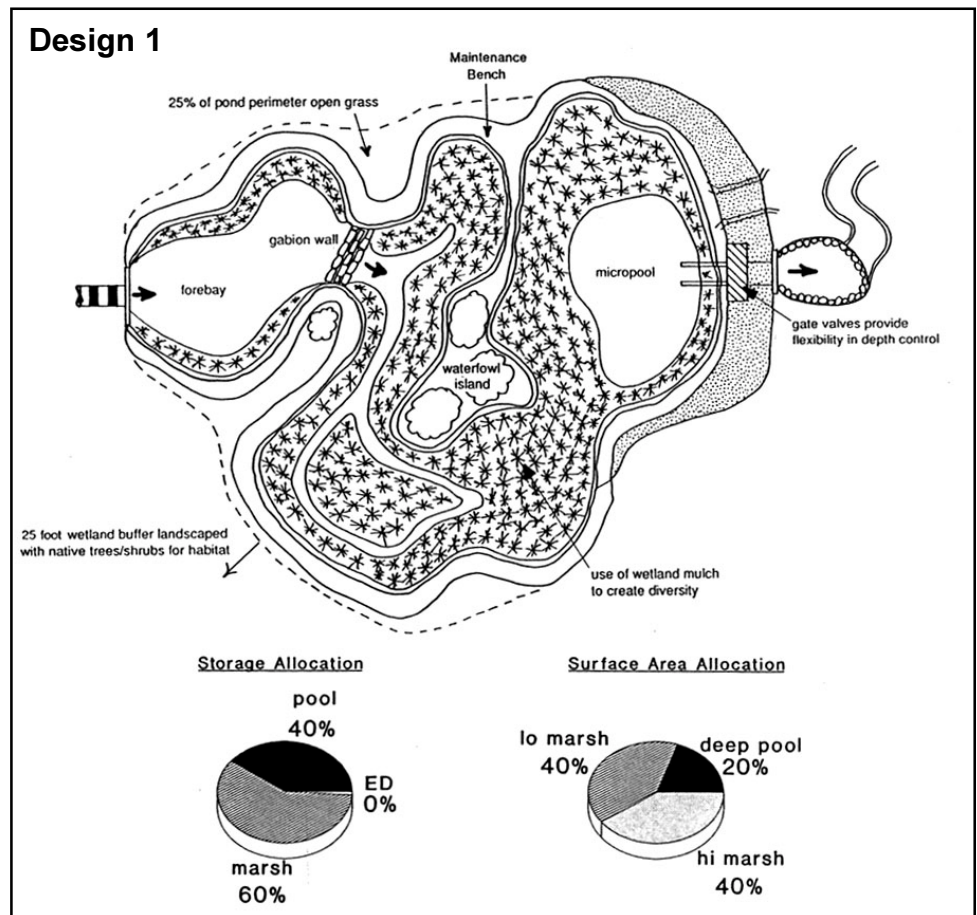
- Laminar settling in zero-velocity zones created by plant stems
- Anchoring of sediments by root structure, helping to prevent scour in shallow areas
- Increased biological activity removing dissolved nutrients
- Increased biological floc formation.

### Basic Stormwater Wetland Design Types

Design criteria and other considerations for the following four wetland types are summarized in Table 2.

#### Design 1: Shallow Marsh System (Fig. 1)

- Shallow marsh systems are configured with different low marsh and high marsh areas, which are referred to as cells (see Fig. 5). They also include a forebay for coarse particulate settlement before the wetland cell and a micropool at the outlet.
- Shallow marshes are designed with sinuous pathways to increase retention time and contact area.
- Most shallow marsh



**Figure 1. Shallow Marsh System**

Source: Schueler, 1992.

# Constructed Wetlands

## Stormwater Wetlands

ATTRIBUTE	DESIGN No. 1 SHALLOW MARSH	DESIGN No. 2 POND/ WETLAND	DESIGN No. 3 ED WETLAND	DESIGN No. 4 POCKET WETLAND
POLLUTANT REMOVAL CAPABILITY	moderate, reliable removal of sediments and nutrients	moderate to high, reliable removal of nutrients and sediment	moderate, less reliable removal of nutrients	moderate, can be subject to resuspension and groundwater displacement
LAND CONSUMPTION	high, shallow marsh storage consumes space	moderate, as vertical pool substitutes for marsh storage	moderate, as vertical ED substitutes for marsh storage	moderate, but can be shoehorned in site
WATER BALANCE	dry weather baseflow normally recommended to maintain water elevations. Groundwater not recommended as the primary source of water supply to wetland			water supply provided by excavation to groundwater
<u>WETLAND AREA</u> <u>WATERSHED AREA</u>	minimum ratio of .02	minimum ratio of .01	minimum ratio of .01	minimum ratio of .01
CONTRIBUTING WATERSHED AREA	DA of 25 acres or greater, with dry weather Q	DA of 25 acres or greater, with dry weather Q	minimum of ten acres required for ED	1 to 10 acres
DEEP WATER CELLS	forebay, channels micropool	pond micropool	forebay micropool	micropool, if possible
OUTLET CONFIGURATION	reversed slope pipe extending from riser, withdrawn approximately one foot below normal pool. Pipe and pond drain equipped with gate valve			broad crested wier with half round trash rack, and pond drain
SEDIMENT CLEANOUT CYCLE (approximate)	cleanout of forebay every 2-5 years	cleanout of pond every ten years	cleanout of forebay every 2 to 5 years.	cleanout of wetland every 5 to 10 years, onsite disposal and stockpile mulch
NATIVE PLANT DIVERSITY	high, if complex microtopography is present	high, with sufficient wetland complexity and area	moderate, fluctuating water levels impose physiological constraints	low to moderate, due to small surface area and poor control of water levels
WILDLIFE HABITAT POTENTIAL	high, with complexity and buffer	high, with buffer, attracts waterfowl	moderate, with buffer	low, due to small area and low diversity

**Table 1: Wetland Characteristics**

Source: Schueler, 1992.

# Constructed Wetlands

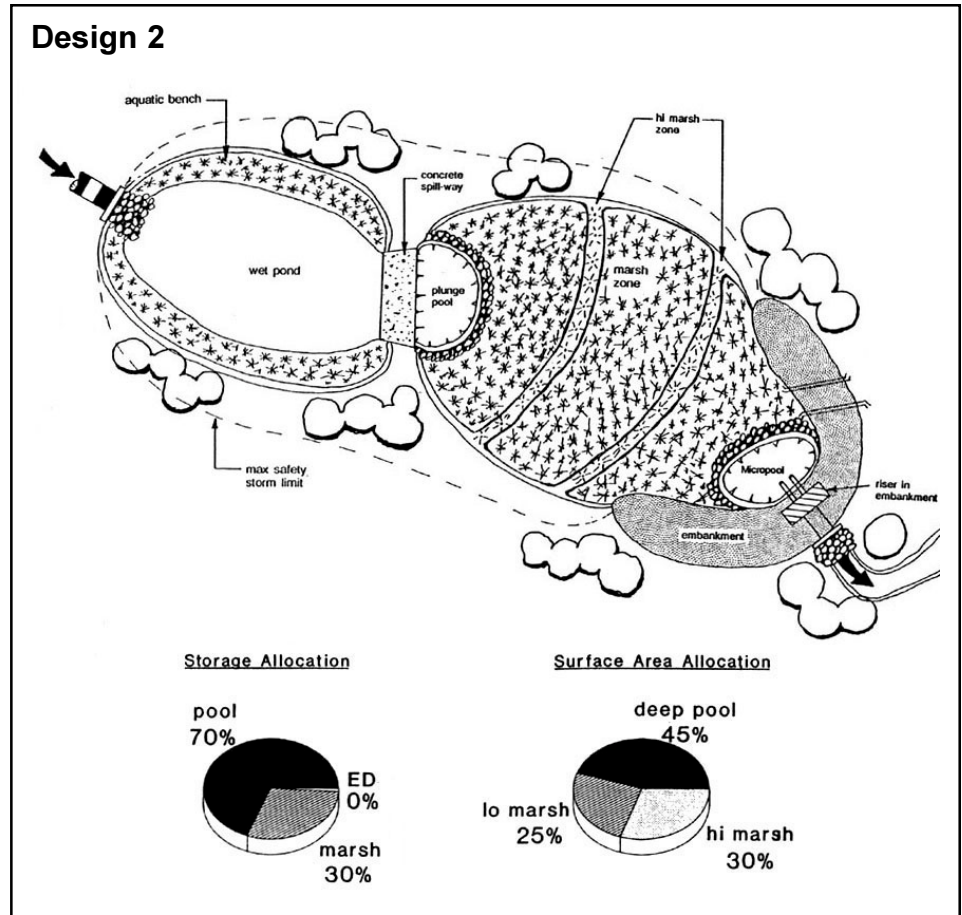
## Stormwater Wetlands

systems consist of pools ranging from 6 to 18 inches during normal conditions.

- Shallow marshes may require larger contributing drainage areas than other systems, as runoff volumes are stored primarily within the marshes, not in deeper pools where flow may be regulated and controlled over longer periods of time.

### Design 2: Pond/Wetland Systems (Fig. 2)

- Multiple cell systems, such as pond/wetland systems, utilize at least one pond component in conjunction with a shallow marsh component.
- The first cell is typically the wet pond which provides for particulate pollutant removal. The wet pond is also used to reduce the velocity of the runoff entering the system.



**Figure 2. Pond/Wetland System**

Source: Schueler, 1992.

- The shallow marsh provides additional treatment of the runoff, particularly for soluble pollutants. These systems require less space than the shallow marsh systems and generally achieve a higher pollutant removal rate than other stormwater wetland systems.

### Design 3: Extended Detention Wetlands (Fig. 3)

- Extended detention wetlands provide a greater degree of downstream channel protection. These systems require less space than the shallow marsh systems, since temporary vertical storage is substituted for shallow marsh storage.
- The additional vertical storage area also provides extra runoff detention above the normal elevations.
- Water levels in the extended detention wetlands may increase by as much as three feet after a storm event and return gradually to normal within 24 hours of the rain event.

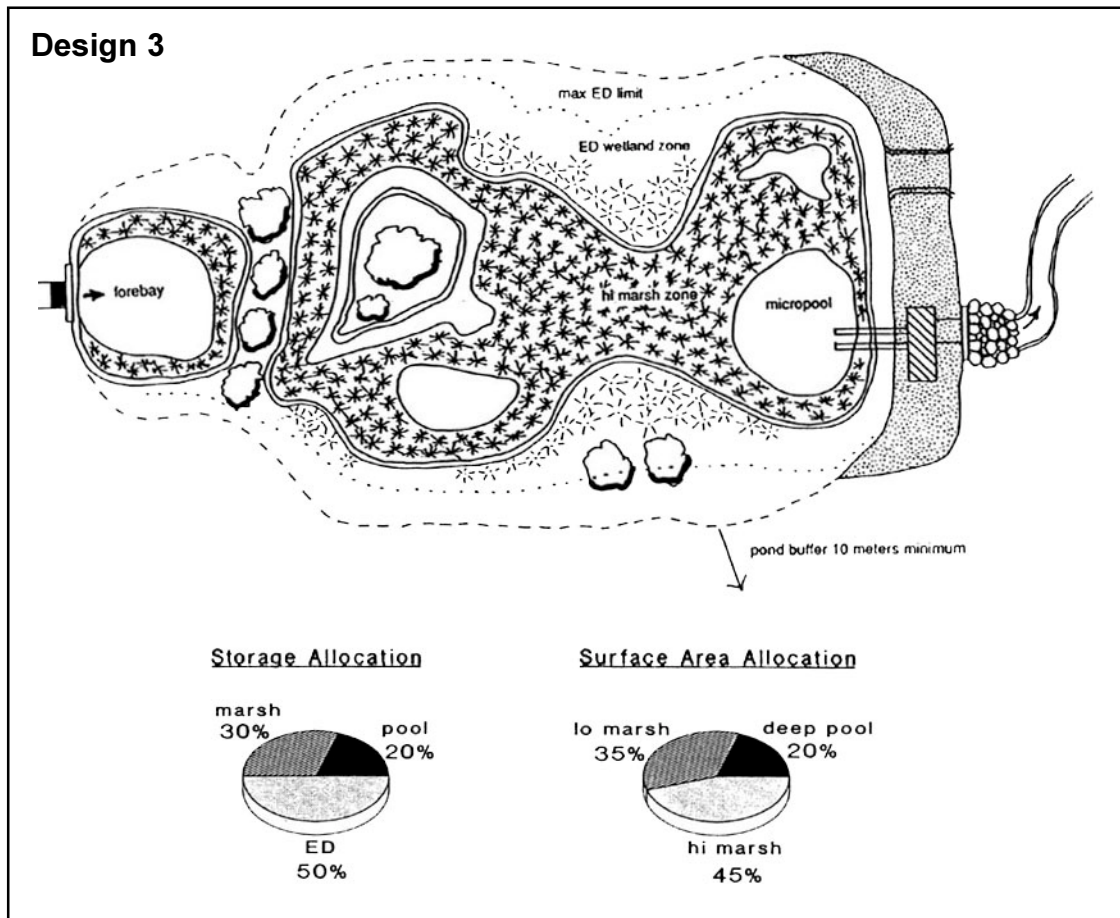


# Constructed Wetlands

## Stormwater Wetlands

### Requirements

**Design** (continued)



**Figure 3. Extended Detention Wetland System**

Source: Schueler, 1992.

- The vegetated area in extended detention wetlands expands from the normal pool elevation to the maximum surface water elevation.
- Wetlands plants that tolerate intermittent flooding and dry periods should be selected for the extended detention area above the shallow marsh elevations.

#### Design 4: Pocket wetlands ( Fig. 4)

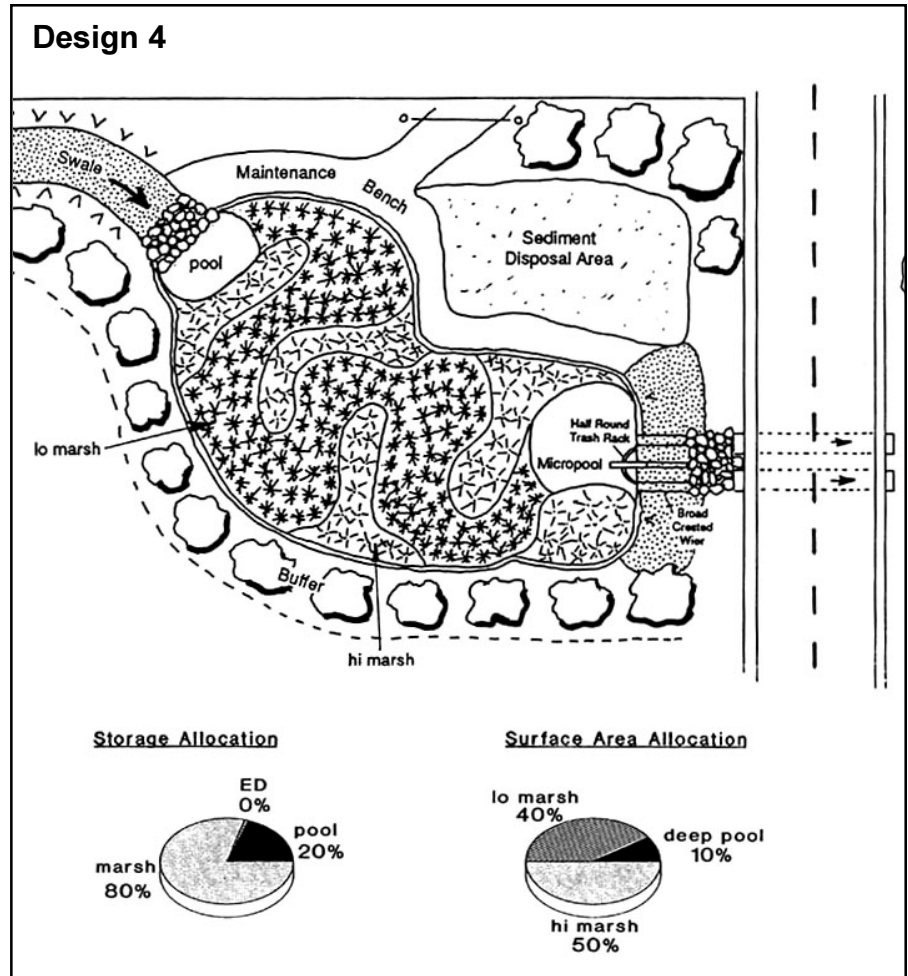
- These systems may be utilized for smaller sites of one to ten acres.
- To maintain adequate water levels, pocket wetlands are generally excavated down to the groundwater table.
- Pocket wetlands which are supported exclusively by stormwater runoff generally will have difficulty maintaining marsh vegetation due to extended periods of drought.

# Constructed Wetlands

## Stormwater Wetlands

### General Design Considerations

- Sediment forebays are recommended to decrease the velocity and sediment loading to the wetland. The forebays provide the additional benefits of creating sheet flow, extending the flow path, and preventing short circuiting. The forebay should contain at least 10 percent of the wetland's treatment volume and should be 4 to 6 feet deep. The forebay is typically separated from the wetland by gabions, gravel/riprap or by an earthen berm.
- The wetland design should include a buffer to separate the wetland from surrounding land. Buffers may alleviate some potential wetland nuisances, such as accumulated floatables, odors and or geese.
- A buffer of 25 feet is recommended, plus an additional 25 feet when wildlife habitat is of concern. Leaving trees undisturbed in the buffer zone will minimize the disruption to wildlife and reduce the chance for invasion of nuisance vegetation such as cattails and primrose willow.
- Above ground berms or high marsh wedges should be placed at approximately 50 foot intervals, at right angles to the direction of the flow to increase the dry weather flow path within the stormwater wetland.
- Before the outlet, a four- to six-foot deep micropool (having a capacity of at least ten percent of the total treatment volume), should be included in the design to prevent the outlet from clogging. A reverse slope pipe or a hooded, broad crested weir is the recommended outlet control (See Figure 3b Wet Ponds BMP).
- The outlet from the micropool should be located at least one foot below the normal pool surface. To prevent clogging, trash racks or hoods should be installed on the riser (See Figure 3b Wet Ponds BMP).
- To facilitate access for maintenance, the riser should be installed within the embankment (See Figure 3b in Wet Ponds BMP).



**Figure 4. Pocket Wetland System**

Source: Schueler, 1992.

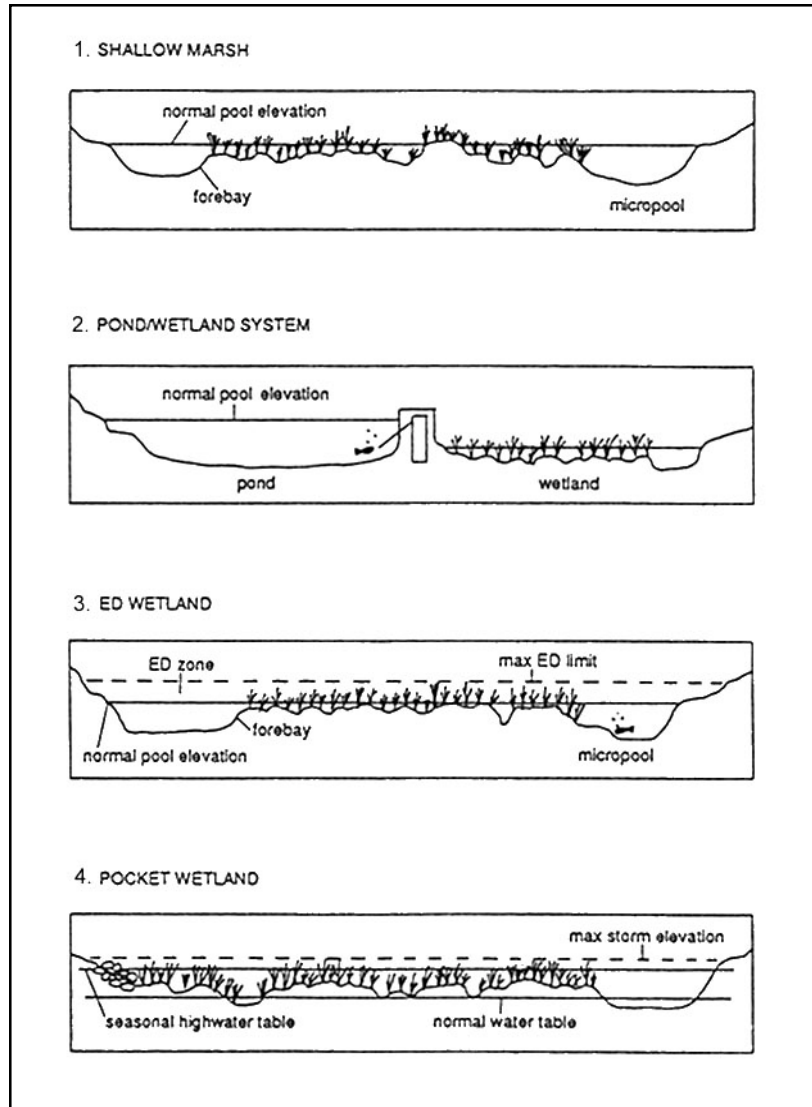
# Constructed Wetlands

## Stormwater Wetlands

### Requirements

#### Design (continued)

- Install a bottom drain pipe with an inverted elbow to prevent sediment clogging in order to completely drain the stormwater wetland for emergency purposes or routine maintenance (See Figure 3b Wet Ponds BMP).
- Fit both the outlet pipe and the bottom drain pipe with adjustable valves at the outlet ends to regulate flows (See Figure 3b Wet Ponds BMP).
- Surround all deep-water cells with a safety bench having a minimum width of ten feet and a depth of zero to 18 inches below pool's normal water level.
- Remember that wetland treatment systems' effectiveness in removing urban pollutants depends on the system's physical characteristics, such as wetland-size-to-watershed-size ratio, runoff residence time in the wetland and water budget.
- In general, as the wetland-to-watershed area ratio increases, the average runoff residence time increases and the effectiveness of the wetland for pollutant removal also increases.
- Prepare a water budget to demonstrate that the water supply to the stormwater wetland is greater than the expected loss rate.



**Figure 5: Comparative Profiles of the Four Stormwater Wetland Designs**

Source: Schueler, 1992.

### Wetland Size

The stormwater wetland should be designed to store the water quality treatment volume as required by the local permitting agency. The Metropolitan Council of Governments (Schueler, 1992) has developed guidelines for constructing wetland stormwater basins (see Table 3). Those guidelines recommend a wetland surface area of 1 to 2 percent of the watershed area, depending on the nature of the watershed and the design of the facility.



# Constructed Wetlands

## Stormwater Wetlands

DESIGN CRITERIA	DESIGN No. 1 SHALLOW MARSH	DESIGN No. 2 POND/ WETLAND	DESIGN No. 3 ED WETLAND	DESIGN No. 4 POCKET WETLAND
<b>Wetland/Watershed Ratio</b>	0.2	.01	.01	.01 (target)
<b>Minimum Drainage Area</b>	25 ac.	25 ac.	10 ac.	1-10 ac.
<b>Length to Width Ratio (minimum)</b>	1:1	1:1	1:1	1:1 (target)
<b>Extended Detention</b>	No	No	Yes	No
<b>Allocation of Treatment Volume (pool, marsh, ED)</b>	40/60/0	70/30/0	20/30/50	20/80/0
<b>Allocation of Surface Area (deep, lo, high)</b>	20/40/40	45/25/30	20/35/45	10/40/50
<b>Cleanout Frequency</b>	2-5 yrs	10 yrs	2-5 yrs	10 yrs
<b>Forebay</b>	Required	No	Required	Optional
<b>Micropool</b>	Required	Required	Required	Optional
<b>Outlet Configuration</b>	reverse-slope pipe or hooded broad crest weir	same	same	hooded broad crested weir
<b>Propagation Technique</b>	Mulch or Transplant	Mulch or Transplant	Mulch or Transplant	Volunteer
<b>Buffer (feet)</b>	25 to 50	25 to 50	25 to 50	0 to 25
<b>Pondscaping Plan Requirements</b>	Emphasize wildlife habitat marsh micro- topography, buffer	Emphasize wildlife habitat and hi marsh wedges	Emphasize stabilization of ED zone, project pondscaping zones	pondscaping plan optional

**Table 2: Wetland Design Criteria**

Source: Schueler, 1992.

# Constructed Wetlands

## Stormwater Wetlands

---

### Requirements

#### Design (continued)

During dry weather, flow must be adequate to provide a baseflow and to maintain the vegetation. The flow path should be maximized to increase the runoff's contact time with plants and sediments.

#### Outlet Design

- Extended detention design criteria are strongly recommended for the outlet structure design (see Extended Detention).
- An orifice or other outlet structure can be used to restrict the discharge to the required flow. Because of the abundance of vegetation in the wetland, a trash guard should be used to protect the orifice.
- A trash guard large enough so that velocities through it are less than 2 fps will reduce clogging problems.
- Flow from the wetland should be conveyed through an outlet structure that is located within the deeper areas of the wetland. Discharging from the deeper areas using a reverse slope pipe prevents the outlet from becoming clogged. A micropool just prior to the outlet will also prevent outlet clogging.
- The micropool should contain approximately 10 percent of the treatment volume and be 4 to 6 feet deep.
- An adjustable gate-controlled drain capable of dewatering the wetland within 24 hours should be located within the micropool.
- A typical drain may be constructed with an upward-facing inverted elbow. The dewatering feature eases planting and follow-up maintenance.

#### Wetland Vegetation

(See Figure 6 for techniques to enhance wildlife habitat in stormwater wetlands.)

- Vegetation can be established by three methods: allowing volunteer vegetation to become established (not recommended) planting nursery vegetation and seeding.
- A higher diversity wetland can be established when nursery plants are used. Vegetation from a nursery should be planted during the growing season—not during late summer or fall—to allow vegetation time to store food reserves for their dormant period.
- Select species adaptable to the broadest ranges of depth, frequency and duration of inundation (hydroperiod). Match site conditions to the environmental requirements of plant selections. Take into account hydroperiod and light conditions.
- Give priority to species that have already been used successfully in constructed wetlands and that are commercially available.
- Allowing species transmitted by wind and water fowl to voluntarily become establish in the wetland is unpredictable.
- Wetlands established with volunteers are usually characterized by low plant diversity with monotypic stands of exotic or invasive species.

# Constructed Wetlands

## Stormwater Wetlands

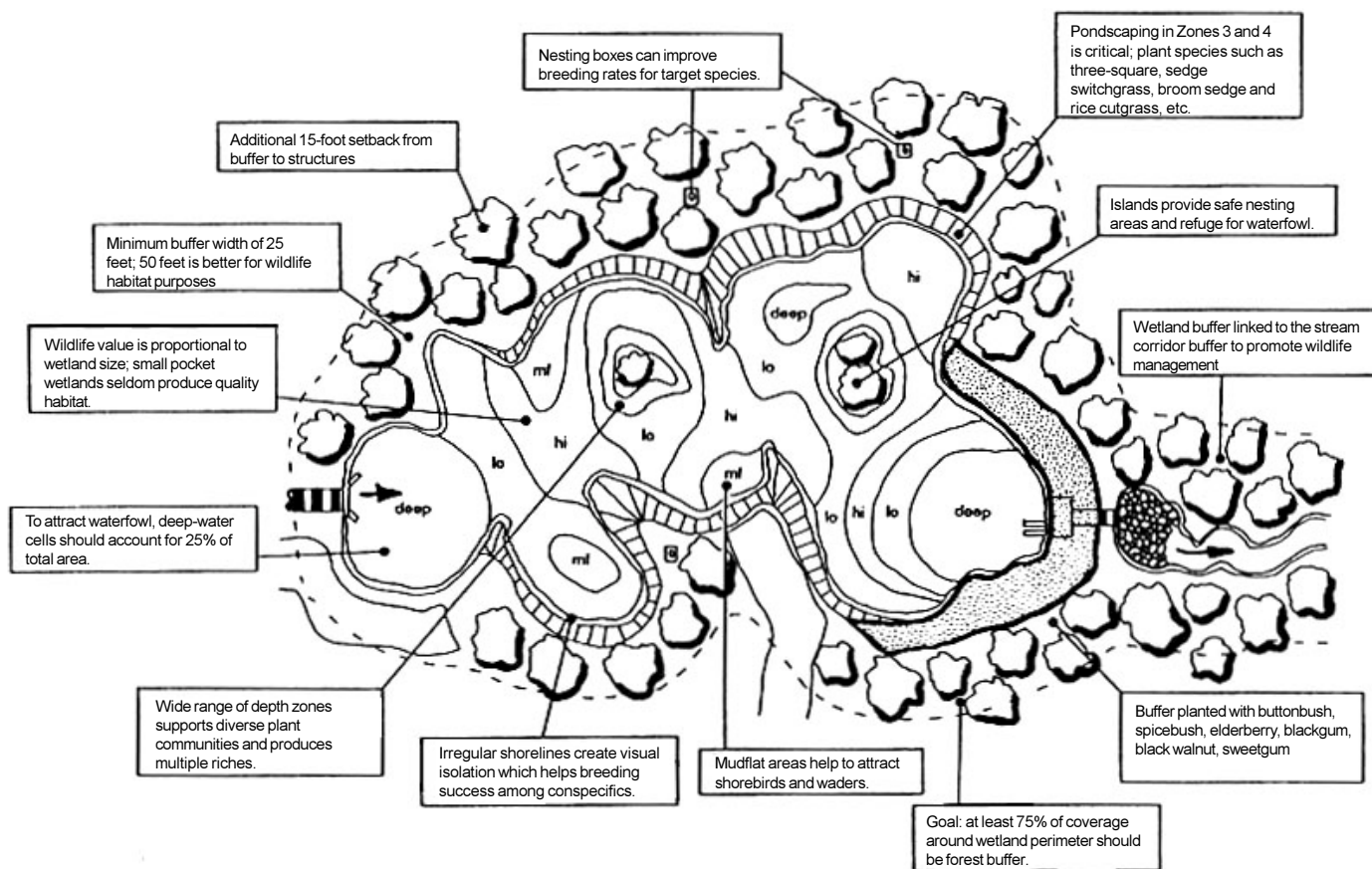
Sizing Criteria	DESIGN No.1 SHALLOW MARSH	DESIGN No.2 POND/ WETLAND	DESIGN No.3 ED WETLAND	DESIGN No.4 POCKET WETLAND
<b>Runoff Treatment Volume (<math>V_t</math>)</b>	Capture 90% of the Annual runoff volume from site $V_t = (1.25 \text{ inches}) (\text{Runoff Coefficient}) (\text{Site Area})$ Minimum $V_t$ of 0.25 watershed-inches			
<b>Wetland to Watershed Area Ratio</b>	.02	.01	.01	.01
<b>Allocation of Surface Area (%)</b>	20 - deep 40 - lo m. 40 - hi m.	45 - deep 25 - lo m. 30 - hi m.	20 - deep 35 - lo m. 45 - hi m.	10 - deep 40 - lo m. 50 - hi m.
<b>Allocation of Treatment Volume (%)</b>	40 - pool 60 - marsh 0 - ED	70 - pool 30 - marsh 0 - ED	20 - pool 30 - marsh 50 - ED	20 - pool 80 - marsh 0 - ED
<b>Flow Path</b> a. length to width ratio b. dry weather path	1:1 2:1	1:1 2:1	1:1 2:1	NA 2:1
<b>Water Balance</b>	Confirm inflow rate > 0.002 cfs/acre, compute water balance during dry weather			Confirm dry weather water table elevation in field
<b>Extended Detention</b>	Not Employed	Not Employed	EDv = 50% of $V_t$ 12 to 24 hrs ED range $\leq 3$ ft.	Not Employed

**Table 3: Wetland Sizing Criteria**

Source: Schueler, 1992.

# Constructed Wetlands

## Stormwater Wetlands



**Figure 6. Techniques for Enhancing Wildlife in Stormwater Wetlands.**

Source: Schueler, 1992.

## Requirements Sequencing

- Sites must be carefully evaluated when planning stormwater wetlands. Soils, depth to bedrock, and depth to water table must be investigated before designing and siting stormwater wetlands. A “pondscaping plan” should be developed for each stormwater wetland.
- This plan should include hydrological calculations (or water budget), a wetland design and configuration, elevations and grades, a site/soil analysis, and estimated depth zones.
- The plan should also contain the location, quantity, and propagation methods for the stormwater wetland plants. Site preparation requirements, maintenance requirements and a maintenance schedule are also necessary components of the plan.
- The water budget should demonstrate that there will be a continuous supply of water to sustain the stormwater wetland. The water budget should be developed during site selection and checked after preliminary site design.



# Constructed Wetlands

## Stormwater Wetlands

---

- Drying periods of longer than two months have been shown to adversely effect plant community richness, so the water balance should confirm that drying will not exceed two months.
- After excavation and grading, the wetland should be kept flooded until planting.
- Six to nine months after being flooded and two weeks before planting, the wetland is typically drained and surveyed to ensure that depth zones are appropriate for plant growth. Revision may be necessary to account for any changes in depth.
- Next, the site is staked to ensure that the planting crew spaces the plants within the correct planting zone.

### **Maintenance**

Stormwater wetlands require routine maintenance. The small forebay should be dredged every other year to protect the wetland from excessive sediment buildup. Careful observation of the system over time is required. In the first three years after construction, twice-yearly inspections are needed during both the growing and non-growing season. Data gathered during these inspections should be recorded, mapped and assessed.

- The following observations should be made during the inspections:
  - Types and distribution of dominant wetland plants in the marsh.
  - The presence and distribution of planted wetland species.
  - The presence and distribution of invasive wetland species.
  - Signs that invasive species are replacing the planted wetland species.
  - Percentage of unvegetated standing water (excluding the deep water cells which are not suitable for emergent plant growth)
  - The maximum elevation and the vegetative condition in this zone, if the design elevation of the normal pool is being maintained for wetlands with extended zones.
  - Stability of the original depth zones and the microtopographic features, accumulation of sediment in the forebay and micropool, and survival rate of plants in the wetland buffer.
- Inspections should be conducted at least twice a year for the first three years and annually thereafter.
- Regulating the sediment input to the wetland is the priority maintenance activity.
- The majority of sediments should be trapped and removed before they reach the wetlands either in the forebay or in a pond component. Gradual sediment accumulation in the wetland results in reduced water depths and changes in the growing conditions for the emergent plants. Furthermore, sediment removal within the wetland can destroy the wetland plant community. Shallow marsh and extended detention wetland designs include forebays to trap sediment before reaching the wetland. These forebays should be cleaned out every other year.
- Pond/wetland system designs do not include forebays as the wet pond itself acts as an oversized forebay. Sediment cleanout of pond/wetland systems is needed every 10 years.

# Constructed Wetlands

## Stormwater Wetlands

---

### Requirements

#### **Maintenance** (continued)

- The key to using the wetland effectively is that the ponds must function so as not to destroy the wetland vegetation. Slight modification of operations and plantings may be necessary as operations proceed.
- Harvesting of wetland vegetation can also be considered to remove nutrients from the wetland system and to minimize nutrient release when vegetation dies in the autumn. This is not generally recommended, but in special cases it will remove the nutrients contained in the vegetation from the system. If vegetation is to be harvested, design features should be included that will allow the wetland to be dewatered (Schueler, October 1992).
- Maintenance requirements for constructed wetlands are particularly high while vegetation is being established (usually the first three years). This is likely to include removal of invasive species and replanting natives.
- Additional routine maintenance tasks, which can be conducted on the same schedule, include removing accumulated trash from trash racks, outlet structures and valves.

# Constructed Wetlands

## Stormwater Wetlands

---

### Sources

1. California Stormwater Quality Task Force. 1993. California Stormwater Best Management Practices Handbook. San Diego, CA.
2. Center for Watershed Protection. 2001. “Stormwater Wetland” fact sheet in *Stormwater Manager’s Resource Center*. [www.stormwatercenter.net](http://www.stormwatercenter.net). Ellicott City, MD.
3. Center for Watershed Protection. 1996. “Pollution Dynamics within Stormwater Wetlands: Organic Matter” in *Watershed Protection Techniques* Vol. 1, No. 4. Ellicott City, MD.
4. Center for Watershed Protection. 1996. “Comparative Pollutant Removal Capability of Stormwater Treatment Practices” in *Watershed Protection Techniques* Vol. 2, No. 4. Ellicott City, MD.
5. Environmental Protection Agency. 1999. “Storm Water Wetlands” Storm Water Technology Fact Sheet, Office of Water, Washington, D.C.
6. Environmental Protection Agency. 2000. “Free Water Surface Wetlands” Storm Water Technology Fact Sheet, Office of Water, Washington, D.C.
7. King County Department of Natural Resources. 1998. *Surface Water Design Manual*. Seattle.
8. Massachusetts Department of Environmental Protection. 1997. *Stormwater Management Volume Two: Stormwater Technical Handbook*. Boston.
9. Minnesota Pollution Control Agency. 2000. *Protecting Water Quality in Urban Areas: Best Management Practices for Dealing with Storm Water Runoff from Urban, Suburban and Developing Areas of Minnesota*. Minneapolis.
10. North Carolina University, Department of Environment and natural Resources. 1999. *Stormwater Best Management Practices*. Raleigh-Durham, N.C.
11. Schueler, T. R., Metropolitan Washington Council of Governments. 1992. *Design of Stormwater Wetland System: Guidelines for Creating Diverse and Effective Stormwater Wetlands in the Mid-Atlantic Region*. Washington, D.C.
12. Washington State Department of Ecology. 2000. *Stormwater Management in Washington*. Olympia.