PDHonline Course C196 (2 PDH)

Stormwater Control Practices

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2012

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PROTECTING WATER QUALITY

A field guide to erosion, sediment and stormwater best management practices for development sites in Missouri and Kansas.

REVISED
JANUARY 2011

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ABC's of BMP's LLC, and
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Vegetative Buffer Strip

Figure 6.86 Vegetative buffer strips slow surface runoff, reduce sedimentation and help capture pollutants. Depending on the choice of plant materials, they can be low maintenance areas (mow once or twice a year) or provide habitat for wildlife.

Practice Description

A vegetative buffer strip is a wide belt of vegetation designed to provide infiltration, intercept sediment and other pollutants and reduce stormwater flow and velocity. Vegetative buffer strips are similar to grassed swales except they are designed to accept only overland sheet flow. They cannot treat high velocity flows. Surface runoff must be evenly distributed across the vegetative buffer strip. After a channel forms in the vegetative buffer strip, it is no longer effective.

Vegetative buffer strips can consist of grass, woody vegetation or other erosion resistant plants. They can be used adjacent to impervious surfaces and next to stream corridors or wetlands to slow the flow and help remove sediment from runoff. They can also be used in conjunction with infiltration basins, infiltration trenches or alongside streams to provide water quality treatment for post-construction.

Recommended Minimum Requirements

Prior to start of construction, vegetative buffer strips should be designed by a qualified professional. The site superintendant and field personnel should refer to plans and specifications throughout the construction process. The vegetative buffer strip should be built according to planned alignment, grade and cross section. Should any field adjustment to the design and installation be needed, a qualified professional should be consulted in the modification to the original design or specification.

Drainage Area

Less than 5 acres.

Location

Adjacent to low or medium density residential areas on gently sloping ground (less than 5 percent), with length of strip running along the contour, along the perimeter of a site, or any available vegetated area or area capable of being vegetated.

Vegetation

A mix of erosion resistant plants that form a dense mat and effectively bind the soil (see Permanent Seeding).

Slope

Uniform, even and relatively flat (5 percent or less) with a level spreading device (level lip, weir, etc.) across the top edge of the vegetative buffer strip.

Minimum Width

Should conform to those in Table 6.16.

Minimum Length

At least as long as the contributing runoff area, but no less than 50 feet plus 4 feet for each one percent increase in slope.

Table 6.16 Minimum Width of Vegetative Buffer Strip

Slope of Land	Width of Vegetative Buffer Strip	Width of Vegetative Buffer Strip
(Percent)	**For Grassed Areas (ft.)**	**For Forested Areas (ft.)**
0	10	25
2	12	29
4	14	33
6	16	37
8	18	41
10	20	45
15	25	55

Construction

Site Preparation

- Natural wooded strips in addition to grass strips should be considered. At the start of development, designate, identify and fence off any areas to be preserved. Avoid storing debris from clearing and grubbing activities and other construction waste material in these areas during construction.
- If a vegetative buffer strip is constructed, clear and grub the vegetative buffer strip area before the impervious area is completed.

Grading

- If the adjacent area does not meet the buffer on a uniform contour, grade a swale along the contour directly adjacent to the top edge of the vegetative buffer strip. The swale will serve as a "level spreader" to collect overland flow and distribute the runoff evenly to the vegetative buffer strip. By discharging to the vegetative buffer strip uniformly along the top of the strip, rill and gully formation due to concentration of flow is minimized.
- Line the swale with rock or other erosion resistance material.
- Sod or seed, fertilize and protect the vegetative buffer strip area with an appropriate rolled erosion control product per the specifications.

  Note: Some fertilizing activities may be prohibited near wetlands and other eco-sensitive areas. Consult a qualified professional if needed.
- Vegetated buffer strips should be protected from excessive sediment laden storm water runoff during construction operations because excess sediment will kill the vegetation. This protection can be in the form of silt fence or other sediment control best management practices placed at the top of the slope to pretreat runoff headed for the buffer strip. If excessive sediment is deposited in the buffer strip, appropriate measures should be taken to reestablish the vegetative strip, including complete regrading and reseeding or sodding of the area.

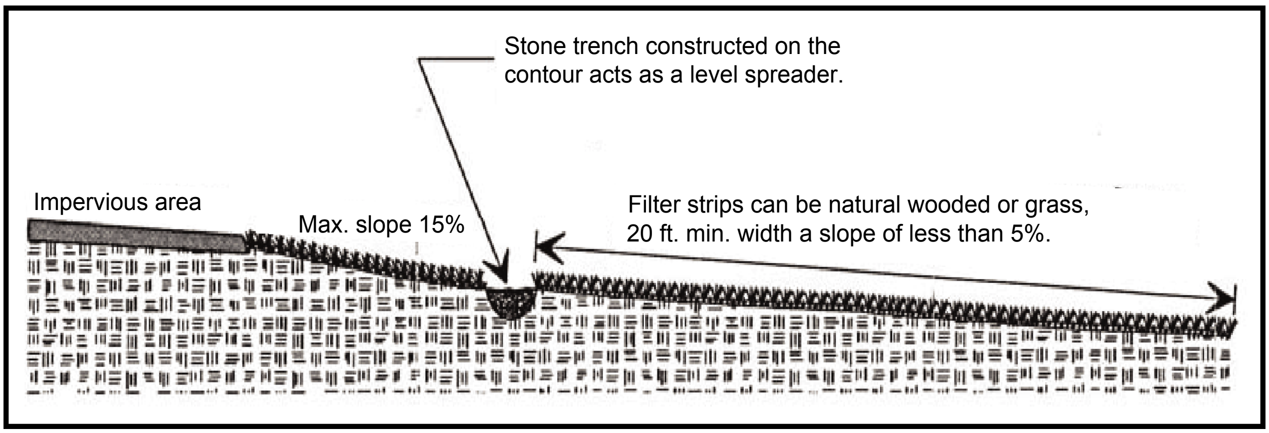

Figure 6.87 Vegetative Buffer Strip

Erosion Control

- Minimize the size of all disturbed areas and stabilize as soon as each phase of construction is complete.
- Direct all overland flow to the vegetative buffer strip or the level spreading swale at low velocities.

Safety

- Store all construction materials and waste material well away from the vegetative buffer strip.
- Follow all local, state and federal guidelines in constructing utility trenches. If utility lines are buried beneath the vegetative buffer strip, do not perform final grading until all trench settlement has taken place. Prior to excavation activities of any type, call 1-800-DIG-RITE (344-7483) to obtain utility locations.
- Provide temporary fencing and warning signs until vegetation is established.

Construction Verification

Check the finished grades and configuration of all earthwork, level spreaders and diversions.

Maintenance, Inspection and Removal

- Check for eroded channels in the vegetative buffer strip after every storm event. Fix eroded areas and reseed, mulch and fertilize the affected area. Modify the Storm Water Pollution Prevention Plan to prevent further issues.
- Apply fertilizer in accordance with soil test recommendations and always consider application timing and rates that will protect water quality – i.e. do not apply more than is necessary and do not apply when rain will likely carry fertilizer off to the stream system. Excessive fertilizer can cause a change in pH that allows heavy metals and other toxic compounds to become mobile and available for uptake by aquatic plants and animals. The change in pH can also prohibit nutrient uptake by the targeted vegetation.
- Remove sediment deposits accumulating in the vegetative buffer. This should be done very carefully to avoid damage to the vegetation.
- Protect new plantings from livestock or wildlife.
- Mow grass strips to a height of 6- to 12-inches two to three times a year to suppress weeds and woody vegetation unless natural, woody vegetation is indicated on the plan.
- Repair foot paths and traffic ruts.
- Remove the temporary vegetative bufferstrip and stabilize the site prior to filing *Form H: Request for Termination of a General Permit*, Form--MO 780-1409 (see Chapter One - Missouri Permit Requirements).

Troubleshooting

Consult with a design professional if any of the following occur:

- Variations in topography on-site indicate vegetative buffer strip will not function as intended.
- Design specifications for fill, rock, sod, seed, mulch or fertilizer cannot be met; substitution may be required. Unapproved substitutions could lead to the vegetative buffer strip not operating as designed after construction activities have been completed.
- Naturally vegetated areas intended for use as buffer strips have been damaged or inadvertently reduced in width.

Common Problems and Solutions

Problem	Solution
Inadequate vegetation causing erosion of vegetative buffer strip due to too great a length of overland flow, too great a slope or high flow rates due to a drainage area greater than 5 acres.	Repair erosion damage and reevaluate erosion protection measures.
Inadequate vegetation causing erosion of vegetative buffer strip due to malfunctioning irrigation or lack of proper watering to establish the vegetation.	Repair erosion damage and possible irrigation issues, provide sufficient water for plant establishment and reevaluate erosion protection measures.
Settlement of soil in utility trenches or settlement of fill creates ponding within the vegetative buffer strip.	Fill low areas and regrade to provide proper drainage.
Uneven slope or debris clogging the trench at top of vegetative buffer strip creates a diversion of flow around vegetative buffer strip.	Remove debris and regrade as needed to provide proper drainage.
Sediment and debris clogging upper end of vegetative buffer strip creates a reduction in flow across vegetative buffer strip.	Replace clogged portion of vegetative buffer strip.

Dewatering

Figure 6.88 Use of a dewatering bag where storm water is pumped into a geotextile bag. The sediment stays in the bag while the storm water is allowed to flow out through the small voids in the material. Source: ACF Environmental Inc.

Practice Description

Dewatering is a commonly required practice occurrence after a storm event on a construction site. Dewatering is performed in excavated work areas such as utility trenches and footings to clear the area of storm water so work can be performed. It may also be required on sediment traps or basins that are designed to pond water to make storage room for additional storm water during the next rain event. It is also performed in excavated work areas such as utility trenches and footings to clear the area of storm water so work can be performed.

Dewatering can be performed with a suction pump or other device such as a skimmer. Dewatering of storm water from sediment traps or basins must be limited to removing only the top or surface water containing the least amount of sediment. When dewatering with a pump, the water should be pumped into a device such as a geotextile bag or temporary sediment trap to remove or settle the sediment and allow the treated or clearer storm water to be discharged.

Recommended Minimum Requirements

It is best if the stored storm water in the trap or basin has been allowed to sit a minimum of 24 hours after the storm event. Depending on the types of soils and high clay content, additional settling time may be necessary before dewatering the trap or basin. If the intake must be close to the bottom of the excavated area it should be protected with a cloth or geotextile sock to reduce the amount of sediment particles exiting through the hose.

Water must be withdrawn from the top of the basin or treated through a geotextile bag or other treatment system before the storm water is allowed to leave the site.

Maintenance, Inspection and Removal

- Maintain the pump in proper operating condition and make sure the pump does not cause pollution to the surrounding area from fuels, oils, greases or other operating fluids. Monitor the dewatering and discontinue when the discharge begins to contain heavier sediment loads.
- Remove the temporary device and stabilize the site prior to filing *Form H - Request for Termination of a General Permit*, Form--MO 780-1409 (see Chapter 1 -Missouri Permit Requirements) for termination of permit coverage.

Troubleshooting

- Make sure the sediment has a proper settling time and sediment laden water is not discharging from the construction site.
- Make sure the geotextile bag (if used) is the proper size for the amount and velocity of flow going into the bag.
- Make sure the geotextile bag is located where it can be accessed for removal. The bag can be heavy, particularly when sediment is wet.
- It is also a good idea to have the dewatering bag placed so the discharged storm water can flow over a vegetated buffer strip or other area of vegetation, if possible.

Common Problems and Solutions

Problem	Solution
Pump loses suction – pump has lost its prime.	Reprime pump and begin dewatering activities.
Pump hose becomes clogged - the protective sock at the end of the hose has become saturated with sediment.	Clean or replace sock and keep the end off the bottom of the trap or basin and out of sediment laden water.
Erosion around the dewatering bag caused by locating the bag on an unstable surface.	Stop dewatering and move the bag to a stable (non-erodible) surface and continue the dewatering process.

Sediment Basin

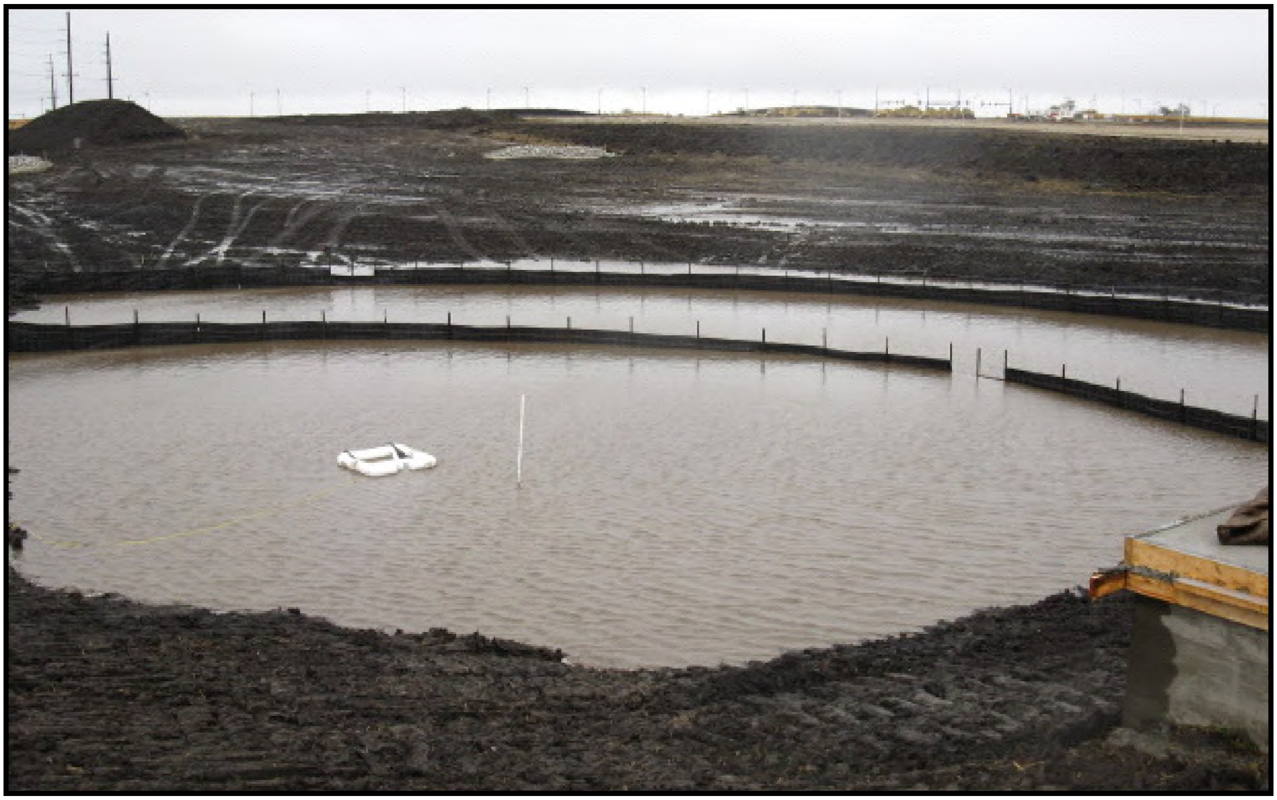

Figure 8.89 A sediment basin can be used to pretreat sediment-laden water before it discharges from the construction site. Source: BFA Inc.

Practice Description

A sediment basin is a temporary pond constructed to contain sediment-laden storm water for an extended period of time prior to the storm water discharging from the basin. A sediment basin is temporary and should be removed or retrofitted prior to any final construction activities that would make these features a permanent detention or retention pond, after the entire contributing drainage area is stabilized.

This practice applies where other erosion control measures are insufficient to prevent off-site sedimentation. The purpose of a sediment basin is to detain sediment-laden runoff from disturbed areas in wet storage long enough for most of the sediment to settle out.

Recommended Minimum Requirements

Prior to the start of construction, sediment basins should be designed by a registered design professional. Plans and specifications should be referred to by the site superintendent and field personnel throughout the construction process and anytime maintenance practices are required.

Build the sediment basin according to planned grades and dimensions.

Dam Height

10 feet or less.

Contributing Drainage Area

On project sites greater than 10 acres, contributing area is limited to 20 acres or less.

Structure Life

Limited to 10 years.

Detention

At least 24 hours or per local requirements.

Storage Volume

Minimum of 3,600 cubic feet per acre of contributing drainage area (pervious or impervious).

Trap Efficiency

The length to width ratio of the basin should be 2:1 or greater; 5:1 is optimal to capture fine sediments. Locate the inlet as far as possible upstream from the outlet.

Short Circuiting

Design the inflow to the pond as far away from the discharge point as possible. If not possible, design a baffle, weir or wall between the inflow and outflow to increase distance and travel time so there is maximum settling time prior to storm water discharge.

Embankment

- Top Width: At least 6 feet.
- Side Slopes: 2.5:1 or flatter; 3:1 where maintained by tractor or other equipment.
- Settlement: Allow for at least 10 percent.
- Fill material: Stable moist soil compacted in lifts less than 8 inches.

Anti-seep Devices

Either of the following is recommended:

- Use at least two watertight anti-seep collars around the outlet conduit; collars should project 1- to 3-feet from the pipe.
- A sand diaphragm (see Glossary).

Risers

- Hold risers in place with an anchor or large foundation to keep them from becoming buoyant.
- Install appropriate inlet protection on the riser.
- Pipe size for the primary conduit should restrict discharge into the natural drainage area at a rate and volume of storm water that meets the local regulatory requirements and the design plan.

Emergency Spillway

- Constructthe spillway in undisturbed soil in a location that will not erode the dam.
- Cross Section: Trapezoidal-shaped with side slopes of 3:1 or flatter
- Control Section: Level, straight and at least 20 feet long. The spillway should have a minimum width of 10 feet.
- Stabilization: Stabilize with vegetation, erosion control blankets or other erosion control stabilization practices. Install rip-rap, turf reinforcement mats, transition mat or other appropriate material to finished grade if the spillway is not to be vegetated.

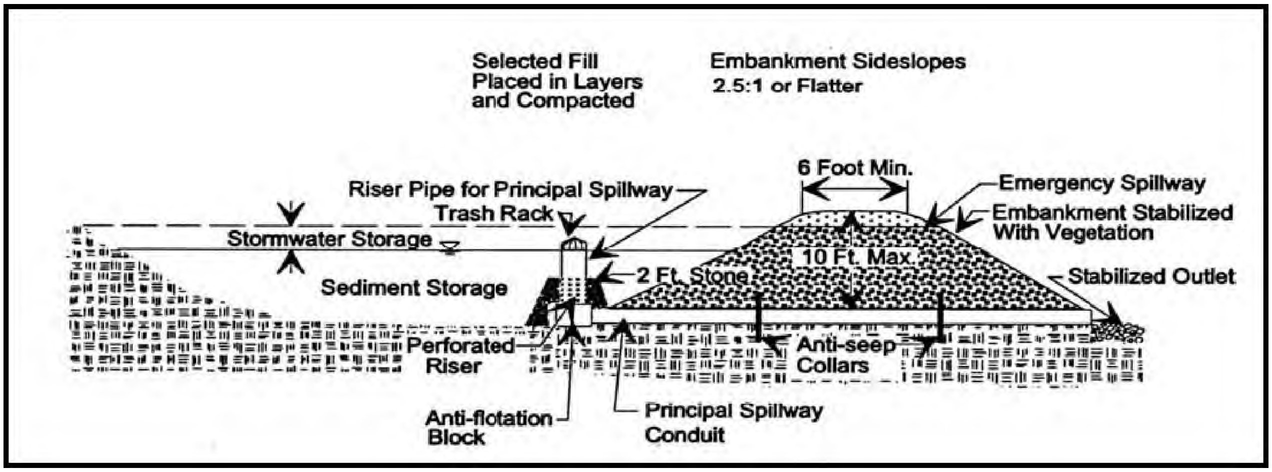

Figure 6.90 Typical Sediment Basin

Construction

Locate the sediment basin as close to the sediment source as possible, considering soil type, pool area, dam length, spillway conditions and proximity of sensitive habitats.

Site Preparation

- Prior to excavation activities of any type, call 1-800-DIG-RITE (344-7483) to obtain utility locations.
- Follow all federal, state and local requirements for impoundments. Clear, grub and strip the dam foundation, removing all woody vegetation, rocks and other objectionable material.
- Dispose of trees, limbs, logs and other debris in designated disposal areas.
- Excavate the foundation (outlet apron first), stockpiling any surface soil having high amounts of organic matter for later use.

Principal Spillway

- Construct a level sediment pool bottom to aid in sediment clean out. Situate the spillway barrel (pipe) and riser on a firm, even foundation. Prepare the pipe bedding.
- Place a 4-inch layer of moist, clayey, workable soil (not pervious material such as sand, gravel or silt) around the barrel, and compact with hand tampers to at least the density of the foundation soil. Don’t raise the pipe from the foundation when compacting under the pipe haunches.

  Perforate the lower half of the riser with 1/2-inch diameter holes spaced 3 inches apart or use a manufactured perforated riser.
- Embed the riser at least 12 inches into concrete, which serves as an anti-flotation block. The weight of the concrete should balance the buoyant force acting on the riser.

$$\text{Buoyant Force} = \text{Volume of Riser} \times 62.4\ \text{lbs/ft}^3$$

- Surround the riser with 2- to 3-inch diameter clean stone to the height of the perforations on the riser. The stone footprint diameter should be 2 feet for every 1 foot of height.
- Place a domed inlet protector or steel trash rack around the riser inlet. The inlet protection should include overflow design. Trash rack openings should be no more than 4- to 6-inches square.
- At the pipe outlet, install a riprap apron at least 5 feet wide and 10 feet long to a stable grade.

Embankment

- Scarify the foundation of the dam before placing fill.
- Use fill from predetermined borrow areas. It should be clean, stable soil free of roots, woody vegetation, rocks and other debris; and must be wet enough to form a ball without crumbling, yet not so wet that water can be squeezed out.
- Place the most permeable soil in the downstream toe and the least permeable in the center portion of the dam.
- Compact the fill material in 6- to 8-inch continuous lifts over the length of the dam.
- Protect the spillway barrel with 2 feet of fill compacted with hand tampers before traversing over the pipe with equipment.

Emergency Spillway

- Construct and compact the dam to an elevation 10 percent above the design height to allow for settling.
- Place a reference stake indicating the sediment clean out elevation (50 percent of design elevation).
- Construct the spillway in undisturbed soil around one end of the embankment and locate it so that any flow will return to the receiving channel without damaging the embankment.

Stabilize the spillway as soon as grading is complete with vegetation, erosion control blankets or other erosion control stabilization practice; install riprap, TRM, transition mat or other appropriate material to finished grade if the spillway is not to be vegetated.

Erosion Control

- Minimize the size of all disturbed areas. Vegetate and stabilize all disturbed areas as soon as construction is complete.
- Divert runoff from undisturbed areas away from the basin.
- Use temporary diversions to prevent surface water from running onto disturbed areas.
- Divert sediment-laden storm water runoff to the upper end of the sediment basin (as far from the outlet or spillway as possible) to improve trap effectiveness. A forebay may also be incorporated at the basin inlet to dissipate energy.
- Direct all runoff into the basin at a low velocity (channel slope less than one percent).
- Vegetate and stabilize all disturbed areas immediately after construction.

Safety

Because sediment basins that impound water are hazardous:

- Avoid steep slopes; slopes around the sediment basin should be 2.5:1 or flatter; 3:1 where maintained by tractor or other equipment.
- Fence the area and post warning signs if trespassing is likely.
- Drain the basin between storm events.

Construction Verification

Check the finished grades and configuration for all earthwork. Check elevations and dimensions of all pipes and structures.

Maintenance, Inspection and Removal

- Inspect the sediment basin weekly and after each storm event.
- Remove and properly dispose of sediment when it accumulates to one-half the design volume. Proper disposal of sediment may entail placement at a stock pile or other area up gradient of the pond. Spread it out to allow drying and then stabilize it.
- Check the embankment, emergency spillway and outlet for erosion damage, piping, settling, seepage or slumping along the toe or around the barrel and repair immediately.
- Remove trash and other debris from the riser, emergency spillway and pool area.
- Clean or replace the gravel around the riser if the sediment pool does not drain properly.
- Remove the basin after the drainage area has been permanently stabilized, inspected and approved. Do so by draining any water (see Dewatering), removing the sediment to a designated disposal area, smoothing the material to blend with the surrounding area; and then stabilize. If this temporary sediment basin is to be converted to a permanent storm water control measure, or SCM, such as a detention, retention or infiltration basin, refer to your plans and specifications. Make sure the site is entirely stabilized before the permanent device becomes operational (no sediment-laden water should be entering the SCM.)
- Remove the temporary device and stabilize the site prior to filing *Form H - Request for Termination of a General Permit*, Form--MO 780-1409 (see Chapter 1 -Missouri Permit Requirements) for termination of permit coverage.

Common Problems and Solutions

Problem	Solution
Seepage is encountered during construction.	It may be necessary to install drains.
Variations in topography on-site indicate sediment basin will not function as intended.	Consult with registered design professional.
Design specifications for fill, pipe, seed variety or seeding dates cannot be met.	Substitutions may be required. Unapproved substitutions could lead to failure.
Piping failure along conduit caused by improper compaction, omission of anti-seep collar, leaking pipe joints or use of unsuitable soil.	Repair embankment using proper construction methods and materials.
Erosion of spillway or embankment slopes caused by inadequate vegetation or improper grading and sloping.	Repair using proper grades and slopes. Stabilize with vegetation, erosion control blankets or other erosion control stabilization practices. install rip-rap, turf reinforcement mats, transition mat or other appropriate material to finished grade if the spillway is not to be vegetated.
Riser and barrel blocked with debris	Remove debris and install trash guard.

Problem	Solution
Overtopping of the principal and emergency spillway caused by undersized principal or spillway design.	Repair erosion damage and reevaluate spillway design.
Frequent operation of emergency spillway and increased erosion potential caused by lack of maintenance..	Clean the sediment out of the basin on a regular basis..
Frequent operation of emergency spillway and increased erosion potential caused by undersized principal spillway..	The sediment basin was designed wit insufficient volume. Enlarge the basin or install additional sediment traps upstream in thee watershed.
Slumping or settling of embankment caused by inadequate compaction or use of unsuitable soil..	Repair damage with suitable, well compacted material..
Slumping failure caused by steep slopes.	Flatten slopes.
Severe erosion below principal spillway caused by inadequate outlet protection.	Install adequate outlet protection.
Turbid water coming out of outfall pipe; small clay particles do not have sufficient time to settle out. The primary problem is that too much sediment is coming from above. Take needed steps to reduce thee overloading of sediment to the basin.	Consult with the registered design professional to pursue additional features such as installation of a pre-sediment basin, addition of bafflesor addition of particle curtains..

Do not apply water clarifying chemicals such as polymers to the final sediment basin. If the choice is made to use water clarifying chemicals earlier in the treatment process, see Chemical Application for Turbidity Reduction. Note any restrictions or controls required in federal, stateor local regulations.

Chemical Application for Turbidity Reduction

Practice Description

Chemicals such as anionic polymers (polyacrylamide, or PAM) and formulated chitosan products can be mixed with on-site storm water to increase the settling rate of sediment particles. These water clarifying compounds, or water clarifying compounds, cause very small clay soil particles to bind together to form floccules (often referred to as flocs) that clump together and settle out. Small particles can otherwise take many days (if ever) to settle out of the collected storm water.

It is important to protect the receiving waters from aquatic toxicity. If a decision is made to use water clarifying compounds, it is vital they be formulated, selected and mixed properly into the collected storm water. Any material can be toxic if used incorrectly, whether it is naturally occurring or synthetic. Manufacturer's specifications should be followed, and responsible parties should be trained to administer the products properly.

Consideration should be given first to erosion control and then appropriate sediment catchments as the main treatment for turbidity and suspended solid particles. It is also recommended land disturbance be phased in a way to keep disturbance areas as small as possible, as a way to protect water quality and to meet storm water regulations (see Chapter 1.) This proposed staging and dispersement of smaller sediment catchments is compatible with today's placement of permanent storm water control measures.

Note: Large detention basins are no longer the sole preference for permanently managing storm water, because management has evolved to include dispersed practices as a way to meet storm water quality regulations. (see Post-Construction Section).

If that approach is not feasible or fails to produce successful results, the permittee may utilize water clarifying compounds specified by the design engineer with appropriate instruction and application training. If the decision is made to use water clarifying compounds:

- Use water clarifying compounds in conjunction with a best management practice that allows the flocs to settle out and maintain storm water control regularly to ensure the settled flocs are collected and removed from the system to prevent them from unintentionally entering nearby waterbodies.
- Determine if water clarifying compounds are best applied in conjunction with particle curtains, dispersion fields, baffles, a sand filtration system or other practice, and such system should be designed by a licensed engineer, with appropriate consideration of:
  - The nature of the receiving water.
  - System sizing.
  - Pond sizing.
  - Flow requirements.
  - Method of dosing.
  - Proper pH range and pH protection.
  - The system must be designed to capture sediment on-site.

- The operator must be properly trained to use the system and should have direct access to written specifications and operation procedures.
- Site-specific soil bench testing (e.g., jar testing) should be done in advance to determine proper application rates and methods per manufacturer's specifications. This will help to meet state and federal water quality standards for nephelometric turbidity units and to assure the chemical is performing to the best of its ability.
- The water clarifying compounds must be mixed into the water at a specified flow rate to ensure proper dispersion and ion exchange.
- Effluent should be monitored for residual chemical products or aquatic toxicity.
- Keep records for chemical use, effluent testing and corrective measures taken.
- Chemicals must be handled and stored according to applicable material safety data sheets.
- All construction land disturbance (state and local) permit requirements must be met.
- Local regulations may also govern the use of water clarifying compounds.
- Your local or state permitting authority may require prior review and approval of any use of chemicals to control erosion or turbidity, and if approved, include details in the storm water pollution prevention plan.
- Any product, including anionic water clarifying compounds, can be toxic to aquatic life if applied inappropriately.
- Use only products that have undergone whole product testing in an EPA approved laboratory using EPA protocol for acute and chronic toxicity.
- Do not use cationic "PAM", unformulated chitosan, alum or ferric iron compounds as they can be toxic to fish at very low levels. Such material binds to fish gills or depletes available oxygen, hindering oxygen uptake.
- Do not apply directly to or in close proximity to waterbodies.
- Do not use in areas with a shallow groundwater table or highly permeable soils.

Note: The terms flocculant and polymer are commonly used in the storm water industry. Technically, coagulants are often positively charged chemicals used to bind with negatively-charged particles to form flocs. Flocculants are settling aids that increase the rate of this binding process by bridging flocs into larger clumps. The important thing to remember is chemical additives bind to pollutants through negative and positive ion attractions, and in order to protect water quality, strict attention should be paid to proper selection and application.

Dry Pond (Detention)

Figure 6.118 Dry Pond. Source: ABC's of BMP's, LLC

Practice Description

A dry pond is a surface storage basin or facility designed to provide water quantity control and limited water quality benefits through stormwater detention or extended detention. Dry ponds, also known as dry detention basins or dry detention ponds, are ponds designed to store and then release stormwater runoff from a specified design rainfall event. Unlike wet ponds, dry ponds do not have a permanent pool.

The historical purpose of a dry pond is to reduce the peak flow rate of stormwater runoff– essentially providing flood control. These types of dry ponds seldom meet the overall quantity and quality objectives as a stand alone practice. Flood detention ponds were not designed to detain stormwater from small flow events.

Variations of dry ponds include:

- Dry pond for peak flow rate (flood) control only (Figure 6:118).
- Extended detention dry pond for limited water quality control and for channel protection .
- Combination dry pond – combining flood control with extended detention.

Sometimes a dry pond is an acceptable option for achieving flood detention. However, volume reducing (i.e., retention) practices are preferred over flood detention practices as a method of flood control in the lower portion of a major watershed or drainage basin. A dry pond should also be a last resort option in the upper portion of the watershed, because many alternative practices are available to simultaneously reduce volume, protect against flooding and achieve water quality. As an example, Figure 6:119 illustrates a similar 100-year flood detention benefit is achieved by retaining 1.1-inches of rainfall retention in multiple mircoscale practices across a residential development.

Given adequate space in the urban environment, dry ponds can be used to retrofit a drainage area to provide flood control, channel protection and in some cases temperature control. As noted above, it is also important to note where in the major watershed the detention basin is located. As a rule of thumb, detention basins are most effective when placed in the upper 1/3 of a major watershed. Otherwise, detention basins provided in the lower portion of the watershed will likely release water at the same time flow from the upper portion of the watershed reaches the same point. This can make downstream flooding and erosion problems worse by forcing even larger volumes of water into the downstream channel.

Dry ponds are sometimes converted from construction site sediment basins through the removal of sediment, addition of vegetation and modification of the basin outlet structure. Dry ponds are permanent “post construction” ponds as opposed to a sediment basin, and therefore should not be designed or used to store construction site sediment.

Dry ponds should not be put into use until after all construction is complete and the site is completely stabilized. These ponds detain the stormwater flow from rain events but do not hold it for long periods of time. These are designed to be fully vegetated on bottom and side slopes. The outlet structure is designed and built at the lowest point in the basin, allowing the basin to fully drain. Dry ponds should be constructed so all stormwater is detained, not retained as in a retention or “wet” pond.

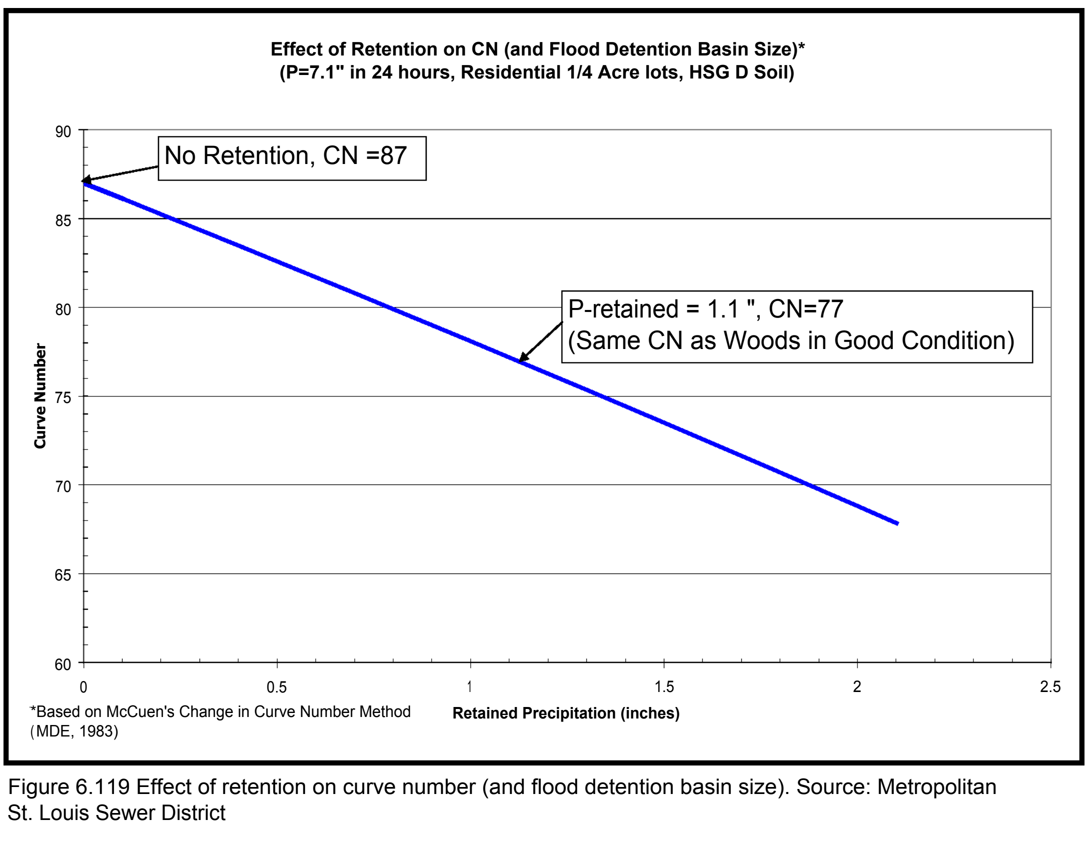

Figure 6.119 Effect of retention on curve number (and flood detention basin size). Source: Metropolitan St. Louis Sewer District

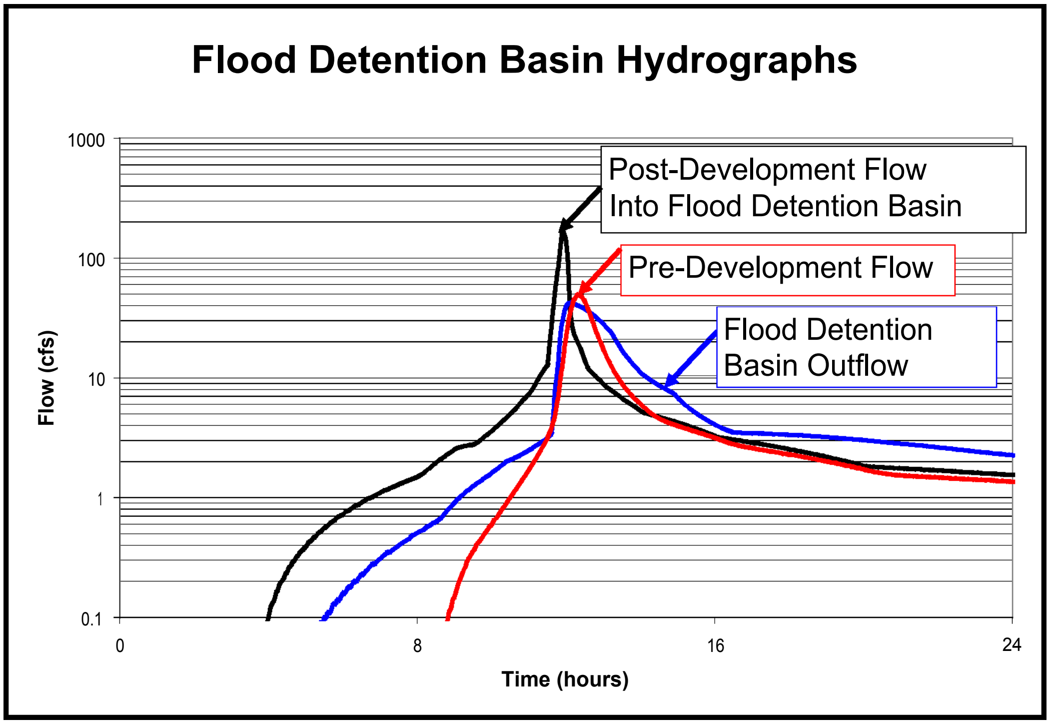

Figure 6:120 Dry pond for peak flow rate control only. Source: Metropolitan St. Louis Sewer District

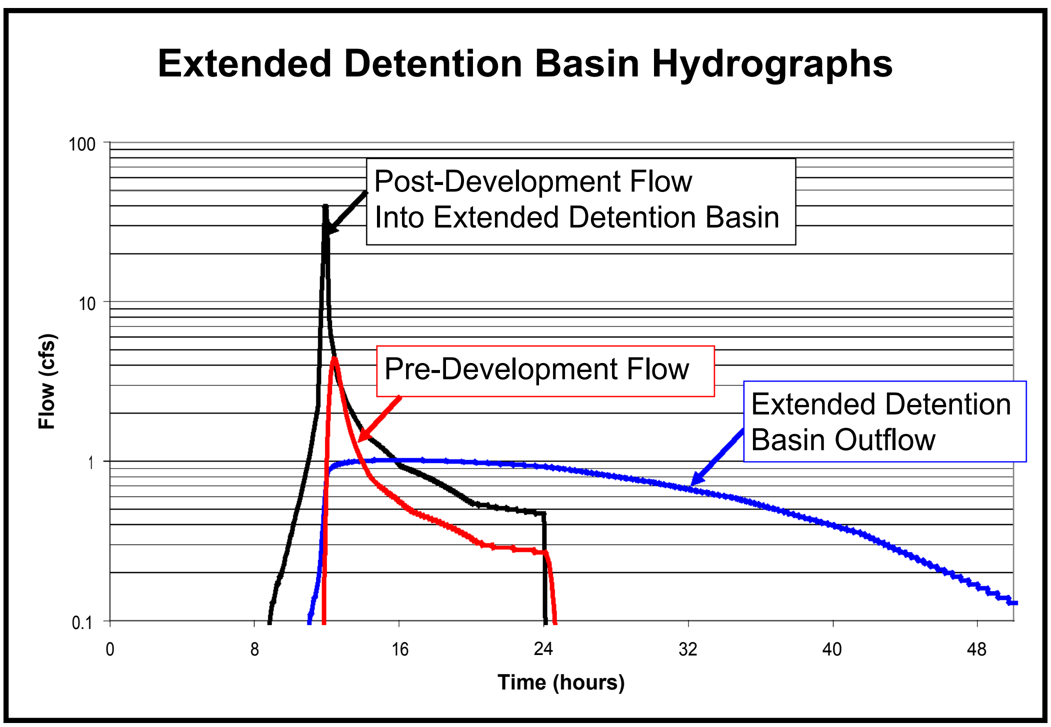

Figure 6.121 Extended detention dry pond for limited water quality control and for channel protection.
Source: Metropolitan St. Louis Sewer District

Pollutant Removal

As noted previously, the historical purpose of a dry pond is to reduce the peak flow rate of stormwater runoff – essentially providing flood control. The dry pond is often used to reduce the peak flow rate from stormwater events and may temporarily minimize flooding downstream. Dry ponds designed to provide extended detention can benefit downstream water quality by protecting downstream channels from the frequent storm events that cause streambank erosion. However, when used to remove settleable pollutants, studies show some of the sediment and other pollutants are re-suspended and then discharged in recurring storm events

See Appendix C for the reference publication *Stormwater BMPs: Selection, Maintenance and Monitoring.* Additionally, dry ponds are not effective removers of soluble pollutants. As such, this practice seldom meets the overall quantity and quality objectives as a standalone practice.

If water quality treatment is a goal of dry detention basin design and construction, a wet or extended stormwater pond design should be incorporated. Dry ponds should be used in conjunction with other practices, as part of an overall treatment series; they should include enhancements such as a sediment forebay, extended storage, a micropool at the outlet, a long shape to minimize short-circuiting or a combination of these features. Effectiveness of dry ponds varies significantly depending on design, incorporation of companion water quality practices and maintenance.

Dry ponds with concrete conveyance channels or pilot swales should not be used, because they convey polluted stormwater directly to stream resources. See Figure 6:122.

Sediment clean-out should be tested for toxicants in compliance with current disposal requirements if commercial or industrial land uses contribute to the catchment, or if visual or olfactory indications of pollution are noticed

Figure 6.122 Detention basin with concrete conveyance channel. Source: Metropolitan St. Louis Sewer District

Costs Considerations

According to the Stormwater Manager's Resource Center, construction costs vary considerably, but the estimated costs of a typical extended dry detention basin may range from $41,600 per one acre-foot pond to $1,380,000 for a 100 acre-foot pond.

Costs associated with required space should be considered, especially when other practices such as bioswales and rain gardens can be worked into the natural landscape and meet water quality requirements.

Consideration should be given also to the economic impacts to neighboring properties. According to Emmerling-Dinovo, a 1995 study found that dry ponds can actually detract from the perceived value of homes adjacent to a dry pond by between three and 10 percent. See the **Appendix C** reference for *Stormwater Detention Basins and Residential Locational Decisions* (1995.)

The estimated cost of maintenance is typically estimated at about three to five percent of the construction cost.

Recommended Minimum Requirements

Key considerations for constructing a dry pond is how big the pond should be, how the land should be graded, the location and size of the outlet structure and the elevation of drainage outlets. Typically, detention basins are designed through modeling to demonstrate specific design storm requirements that will be met. Deviation from the design can result in basin inefficiency at best, and intesifying of downstream flooding and erosion problems at worst.

Design should be in accordance with state-of-the-practice specifications aimed at achieving water quality criteria. When designed in conjunction with other appropriate runoff volume-reducing SCMs, detention basins may be reduced in size. Forebays may be provided at all major inflow points to capture coarse sediment, prevent excessive sediment accumulation in the main basin and minimize erosion by inflow. The basin may also be planted with dense, low-growing native or adaptive vegetation that can withstand periods of inundation and drought, require no mowing and provide aesthetic and wildlife benefits.

For a list of suitable plant species, refer to Appendix C for the *Landscape Guide for Stormwater Best Management Practice Design* , St. Louis, Missouri. Also, see Grow Native! at www.grownative.org for photos and narrative description of plant species native to Missouri and the Midwest region. See additional plant information resources in Appendix C.

Construction

Prior to excavation activities of any type, call 1-800-DIG-RITE (344-7483) to obtain utility locations.

Follow all federal, state and local requirements for impoundment sites. See Chapter 1 for information about regulations and permit requirements.

Prior to start of construction, detention basins should be designed by a registered design engineer. Plans and specifications should be reviewed by the site superintendent and field personnel throughout the construction process. The detention basin should be built according to the planned grades and dimensions.

An example construction sequence follows:

- Construction should begin only when the erosion and sediment control measures are in place.
- The site should be prepared for excavation or construction of the embankment. Site preparation includes the removal of existing vegetation within the construction limits, as necessary for construction. Tree roots, rocks or boulders should be removed from the excavated area and disposed of in designated disposal areas.
- Embankments should be constructed. Inlet and outlet structures should be installed, per the construction plans.
- The final grading should include placement of planting soil.
- Seeding, planting and mulching should be completed as specified in the plans. The contractor should install geo-textiles and erosion control measures specified in the plans.
- After all tributary areas are sufficiently stabilized, remove temporary erosion and sediment controls. It is important for the swale to be stabilized before receiving upland flow.

Consult with the registered design engineer if any of the following occur:

- Seepage is encountered during construction.
- Variations in topography on-site indicate detention pond will not capture the drainage area intended.
- Design specifications for fill, pipe, seed/plant variety or seeding/planting dates cannot be met.
- Depression holds water long after the rain event, which does not allow vegetation to survive.
- Substitutions are required. Unapproved substitutions could lead to failure.

construction Verification

Check the finished grades and configuration for all elements. Check elevations and dimensions of all pipes and structures. If at final grade the basin storage volume is less than indicated on the plan (e.g., 10 percent less), orifice invert elevations vary more than 0.1' from plan, or if orifice size if different from plan, then the engineer should be consulted to determine if basin performance has been negatively impacted and if adjustments are needed.

Maintenance and Inspection

A specific operations and maintenance plan should be provided by the design engineer and transferred to the person responsible for long-term operations and maintenance. Adequate training should be provided as well. Typical maintenance requirements include the following:

- Inspect the detention basin after each storm event greater than 1-inch in 24 hours. Remove trash and other debris from the basin. Collected sediment should be removed when 10 percent of the basin design volume has been filled, or 50 percent of the sediment forebay is filled.
- Periodically (e.g., annually) check the embankment, emergency spillway and outlet for erosion damage, piping, settling, seepage or slumping along the toe or around the barrel and repair upon discovery.
- Remove nuisance vegetation on the embankment as needed during the growing season (e.g., April to October).
- Remove rodents that burrow into the dam.

Common Problems and Solutions

Problem	Solution
Piping failure along conduit; caused by improper compaction, omission of anti-seep collar, leaking pipe joints or use of unsuitable soil.	Repair damage, check pipe joints and seal leak if necessary. Use suitable soil for backfill. Consider installing anti-seep collar or pressure-injecting grout around the pipe.
Erosion of spillway or embankment slopes; caused by inadequate vegetation or improper grading and sloping.	Repair damage and establish suitable grade or vegetation. Perform a soil test and amend the embankment as needed to establish vegetation.
Slumping or settling of embankment; caused by inadequate compaction or use of unsuitable soil.	Excavate failed material and replace with properly compacted suitable soil.
Slumping; caused by steep slopes.	Excavate dislocated material and replace with properly compacted suitable soil. Consider flattening slope.
Erosion and caving below principal spillway; caused by inadequate outlet protection.	Repair damaged area and install properoutlet protection.
Basin not located properly for access; results in difficult and costly maintenance.	Improve access to site.
Ponding stormwater for long periods of time and dead vegetation caused by principal discharge area not at lowest elevation.	Check with the engineer to determine if the discharge can be lowered or if the basin can be filled. Re-vegetate damaged areas.
Frequent operation of emergency spillway, long-term ponding and increased erosion potential caused by principal discharge point too small.	Consider increasing capacity of principal discharge, install supplemental discharge or install suitable erosion protection in emergency spillway.
Stormwater released from pond or basin too rapidly; caused by discharge.	Consider resizing discharge and add additional energy dissipation at discharge location.
Unsuccessful vegetation establishment.	Consider selecting plants that are native species tolerant of both wet and dry cycles and appropriate for the plant zone. Deep rooted perennials are encouraged to increase the rate of infiltration. Inspect plans to ensure they are properly planted and have correct soil conditions. Properlywater them through establishment. Maintain plantings to make sure they are not taken over by noxious plants or weeds.

stormwater Wetlands (Constructed Wetlands)

Practice Description

Stormwater wetlands are constructed wetland systems that temporarily store stormwater runoff in shallow pools supportive of wetland plants. They are constructed primarily for the purposes of water quality treatment and flood control; primarily flow attenuation and some runoff volume reduction. Stormwater wetlands are constructed for maximum removal of stormwater pollutants through microbial breakdown of pollutants, pollutant uptake by plants, settling and absorption. Stormwater wetlands typically have less biodiversity than natural wetlands in terms of plant and animal life. Natural wetlands are to be protected and should never be used for stormwater management, because their function is critical to watershed health. See Chapter 1 for regulations and permit requirements.

Constructed wetlands are a widely applicable stormwater management practice in areas where sufficient land is available. There should be significant separation from groundwater if constructed wetlands accept runoff from stormwater hot spots. If the areas are designed to encourage wildlife use, the design must ensure pollutants in stormwater runoff do not affect organisms living in or near the wetland. When retrofitting a watershed with SCMs, stormwater wetlands can provide both educational and habitat value.

For a list of suitable plant species, refer to Appendix C for the *Landscape Guide for Stormwater Best Management Practice Design* , St. Louis, Missouri. Also, see Grow Native! at www.grownative.org for photos and narrative descriptions of plant species native to Missouri and the Midwest region.

Stormwater wetland designs vary in the relative amount of shallow water, deep water and dry storage above the wetland. The five general design variations include:

- Shallow marsh system.
- Pond/wetland system.
- Extended detention wetland.
- Submerged gravel wetland.
- Pocket Wetland.

Of the wetland types, the extended detention wetland or pond/wetland system may be most common in urban areas with adequate land. Where space is more limited or retrofits are needed, a submerged gravel wetland might be considered. Pocket ponds are only an option where groundwater is available to help charge the pond; not a typical setting in urban environments. The shallow marsh system requires the largest area of all wetland types.

Shallow Marsh System

A shallow marsh system includes a combination of pools (low marsh) and vegetated hummocks (high marsh), plus a micropool at the outlet. Pools wind through the high marsh in meandering pathways to extend the amount of time stormwater is held and treated in the system and to increase contact between stormwater and vegetation. These systems are generally shallow and therefore receive no groundwater inputs, so they typically require large drainage areas (e.g., >25 acres) to contribute the necessary water volume to the system.

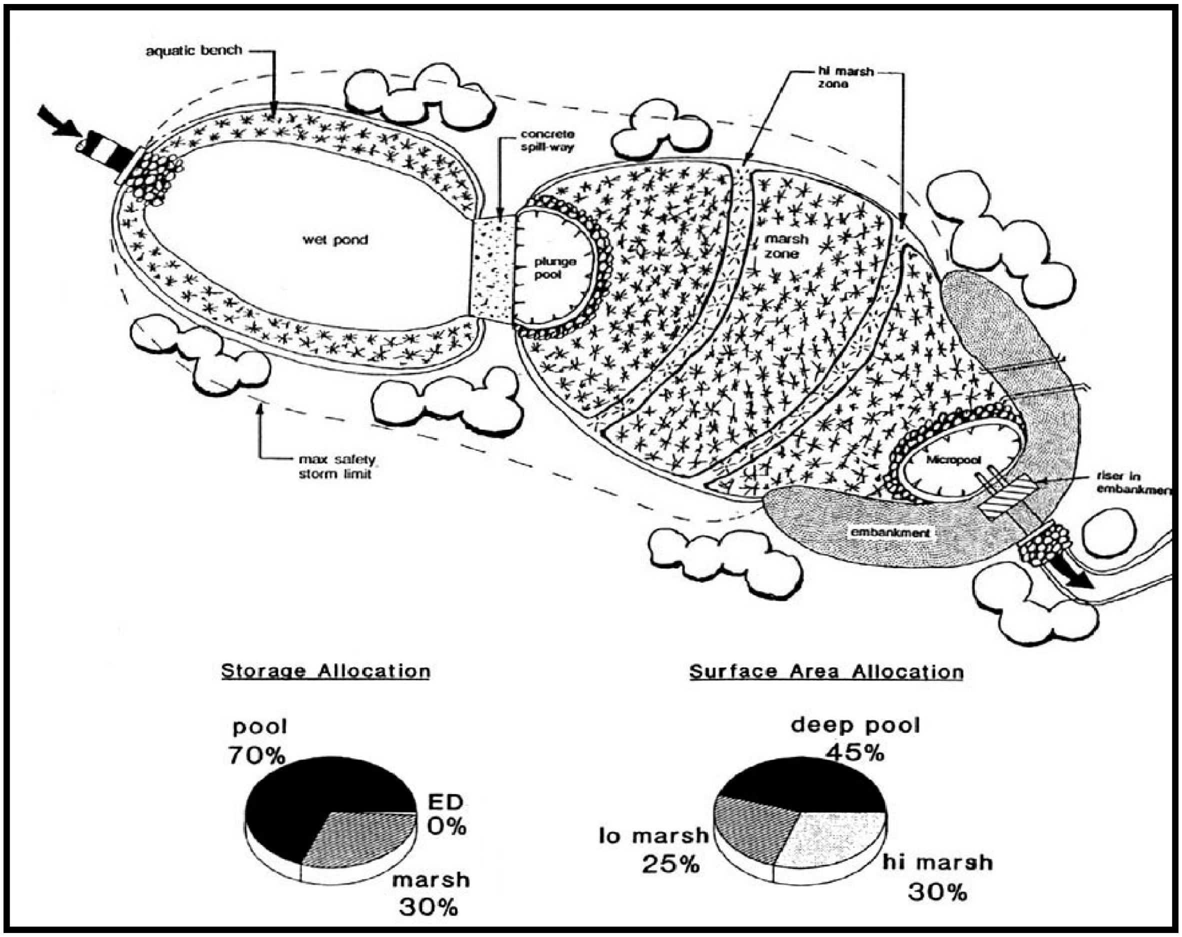

Figure 6.125 Pond/Wetland System Source: Center for Watershed Protection

Extended Detention Wetland

An extended detention wetland is much like a shallow marsh system, but it includes the addition of a forebay and safety bench.

An extended detention wetland includes features to enhance storage, downstream channel protection and pollution reduction. It has sufficient volume to temporarily detain runoff during storm events and hold a permanent pool of fairly shallow depth. Biological and chemical activity in the pond plays an important role in pollutant uptake, particularly of nutrients. Flow through the root systems allows vegetation to remove nutrients and dissolved pollutants from stormwater. When an extended detention wetland is sized, designers need to consider the storage volumes provided. Typically, a significant portion (e.g., 50 percent) of the water quality volume (the volume of rainfall produced by the 90th to 95th percentile storm that occurs in 24 hours) is provided in the micropool(s). The detention volume above the pool is designed to provided extended detention of the remaining portion of the water quality volume, channel protection volume and flood protection volume.

Because the ponding depths are typically shallow to be effective, extended detention wetlands require a large amount of surface area to obtain sufficient volume. Because they function best in larger drainge areas, they may be a good choice to treat runoff from large industrial and commercial project sites that have sufficient space for their construction. These constructed wetlands can also provide aesthetic/recreational value and wildlife habitat.

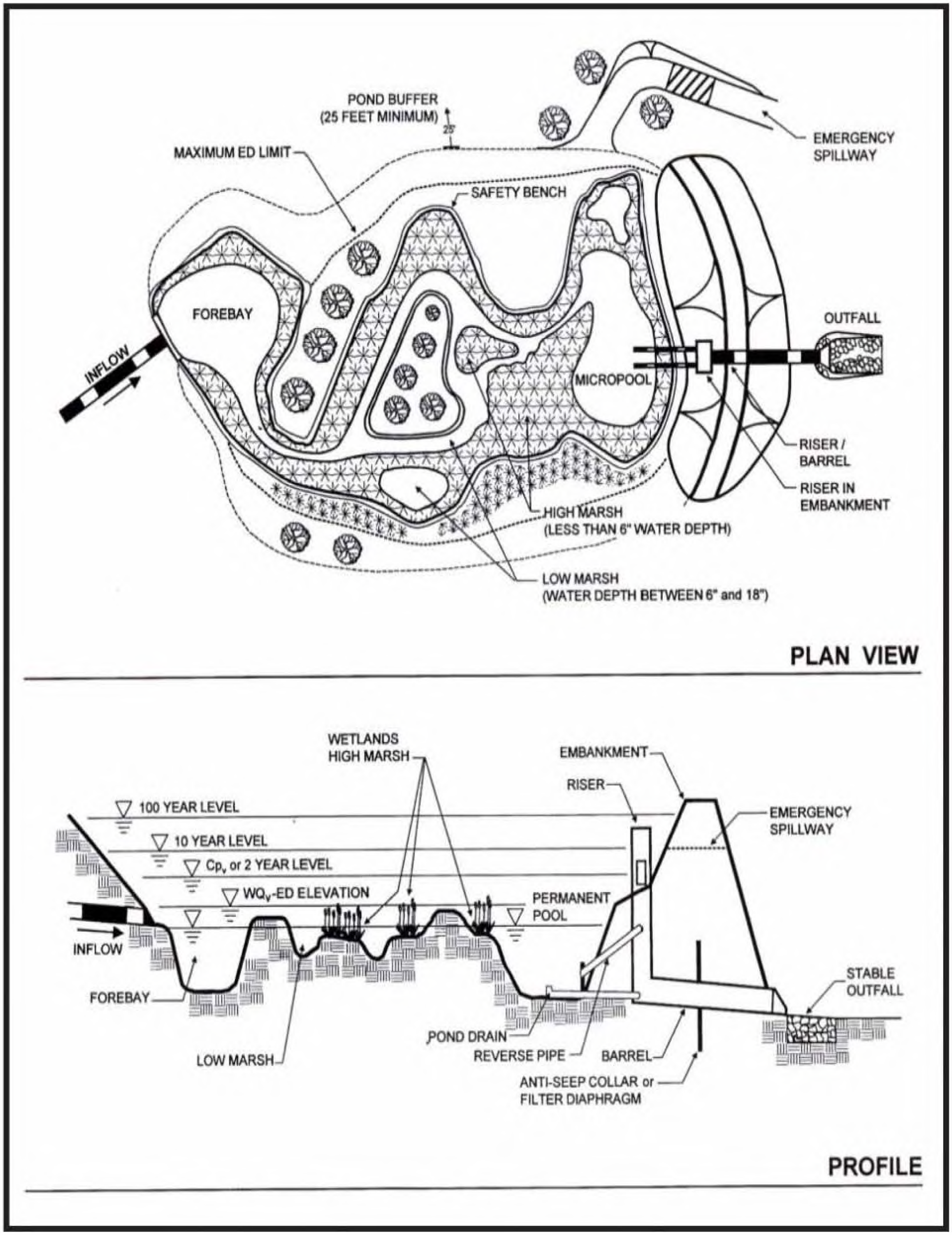

Figure 6.126: Constructed Extended Detention Wetland. Source: Center for Watershed Protection

Figure 6.127: Extended Detention Wetland in a Residential Development. Dover, Delaware. Source: Kevin Magerr, PE, CPESC, CPSWQ.

The successful design, installation and function of constructed wetlands depends on the hydrology, underlying soils, planting soil, size and volume, vegetation, configuration, and maintenance access. Large areas are necessary for application of this SCM; the contributing drainage area should be at least 10 acres. The area for a wetland is generally 3 to 5 percent of its drainage area but it should be sized to treat the water quality volume and if necessary, mitigate the peaks of larger runoff events. A wetland must be able to receive and retain enough rain, runoff and groundwater to maintain vegetation. Even with a large drainage area, a constant source of inflow can improve the biological health of a wetland.

Submerged Gravel Wetland

A submerged gravel wetland is a practice that can be used in retrofit situations draining less than five acres. In the submerged gravel wetland, the system is designed for runoff to flow through a rock filter with wetland plants at the surface. Pollutants are removed through biological activity on the surface of the media (e.g., gravel) and pollutant uptake by the plants. This practice is fundamentally different from other wetland designs because, while most wetland designs behave

Figure 6.128: Submerged Gravel Wetland. Source: Center for Watershed Protection, Copyright 2000.

much like wet ponds (with differences in grading and landscaping), gravel-based wetlands are more similar to filtering systems. Design considerations should be given to potential clogging and odor problems. Submerged gravel wetlands are commonly associated with wastewater treatment applications, but have been adapted to stormwater treatment application.

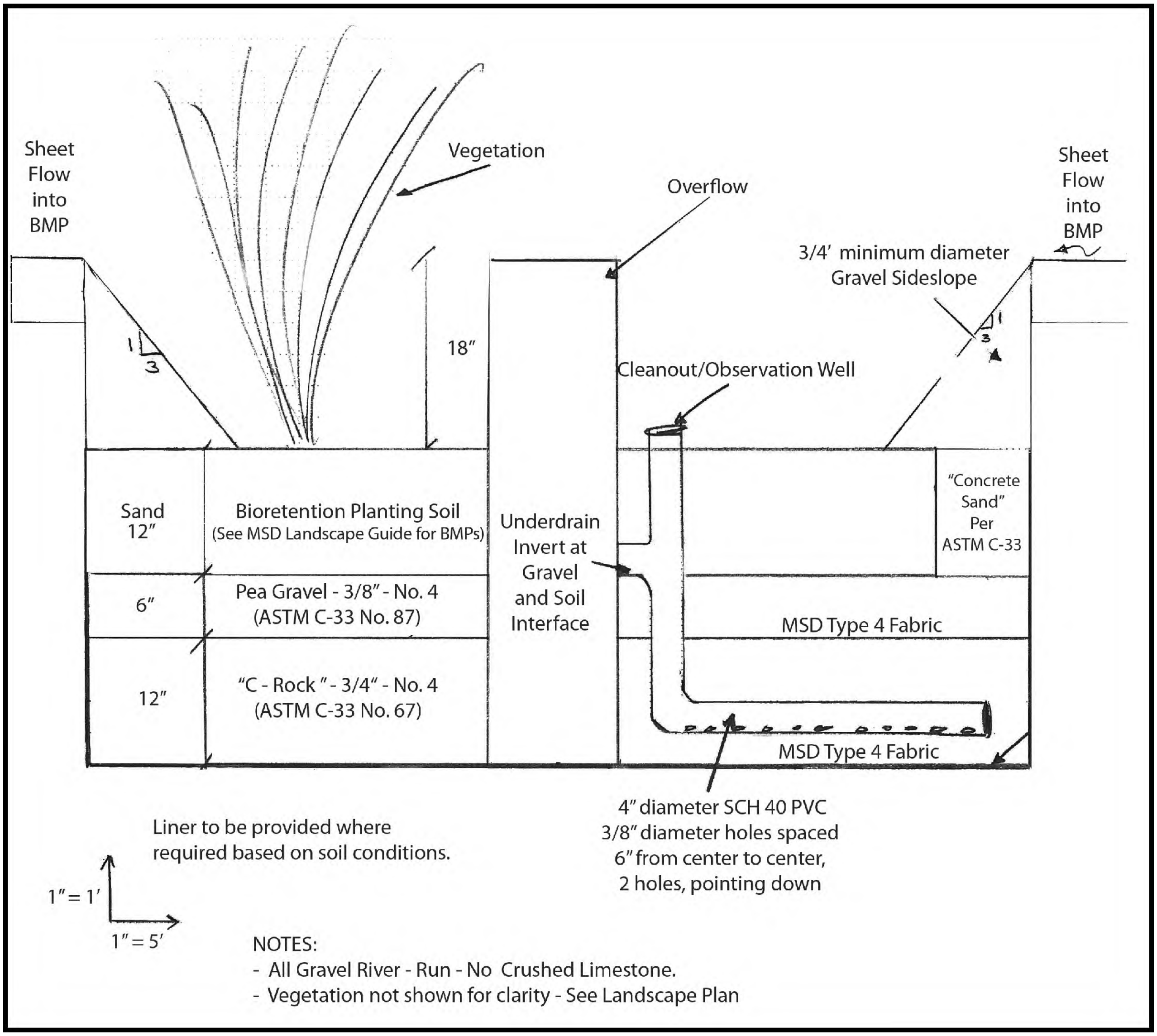

Figure 6.129. Submerged Gravel Wetland. Source: Metropolitan St. Louis Sewer District

Pond/Wetland System

A pond/wetland system consists of multiple cells with at least one wet pond followed by at least one shallow marsh and draining areas less than 25 acres. This practice can save space when compared to a shallow marsh system which requires a greater area of land to address storage.

Pollutant Removal

Wetlands can be designed to primarily remove total suspended solids, oils and greases, fecal coliform and biochemical oxygen demand. They can also be designed to remove some levels of Total phosphorus, nitrogen, heavy metals and floatables.

The following in formation on pollutant removal comes from EPA's *Stormwater Wetland* fact sheet. (See reference in Appendix C.) Wetlands are among the most effective stormwater management practices at removing stormwater pollutants. A wide range of research is available to estimate the effectiveness of wetlands. Wetlands have high pollutant removal rates, and are particularly effective at removing nitrate and bacteria. Table 6.18 provides pollutant removal data derived from the Center for Watershed Protections's National Pollutant Removal Database for Stormwater Treatment Practices (Winer, 2000).

Table 6.18. Typical Pollutant Removal Rates of Wetlands (%) (Winer, 2000.)

Pollutant	Stormwater Treatment Practice Design Variation			
	Shallow Marsh	ED Wetland1	Pond/Wetland System	Submerged Gravel Wetland1
Suspended Solids	83±51	69	71±35	83
Total Phosphorus	43±40	39	56±35	64
Total Nitrogen	26±49	56	19±29	19
Nitrogen Oxide	73±49	35	40±68	81
Metals	36-85	(80)-63	0-57	21-83
Bacteria	761	NA	NA	78

[1] Data based on fewer than five data points

The effectiveness of wetlands varies considerably, but many believe proper design and maintenance help to improve their performance. The siting and design criteria presented in the EPA's *Stormwater Wetland* fact sheet reflect the best current information and experience to improve the performance of wetlands. A joint project of the American Society of Civil Engineers and the EPA Office of Water may help to isolate specific design features that can improve performance. The National Stormwater Best Management Practice database is a compilation of stormwater practices that includes both design information and performance data for various practices. As the database expands, inferences about the extent to which specific design criteria influence pollutant removal may be made. [More information is available at the International BMP Database located at www.bmpdatabase.org .]

Additional Considerations

The following information about wetland limitations is adapted from EPA's *Stormwater Wetland* fact sheet. See reference in Appendix C. Some features of stormwater wetlands that might make a design challenging include the following:

- Each wetland consumes a relatively large amount of space, making it an impractical option on some sites.
- Improperly designed wetlands might become a breeding area for mosquitoes.

- Wetlands require careful design and planning to ensure wetland plants are sustained after the practice is in place.
- It is possible stormwater wetlands may release nutrients during the non-growing season.
- Designers need to ensure wetlands do not negatively impact natural wetlands, forest or groundwater quality.

Cost Considerations

The following information comes from EPA's *Stormwater Wetland* fact sheet from their menu of stormwater BMPs. See Appendix C. Wetlands are relatively inexpensive stormwater practices to construct, not counting the cost of land. Construction cost data for wetlands are rare, but one simplifying assumption is that they are typically about 25 percent more expensive than stormwater ponds of an equivalent volume. Using this assumption, an equation developed by Brown and Schueler (1997) to estimate the cost of wet ponds can be modified to estimate the cost of stormwater wetlands using the equation:

C = 30.6V0.705 where: C = Construction, design and permitting cost.
V = Wetland volume needed to control the 10-year storm (ft3).

Using this equation, typical construction costs are the following:

- $57,100 for a 1 acre-foot facility.
- $289,000 for a 10 acre-foot facility.
- $1,470,000 for a 100 acre-foot facility.

Wetlands consume about 3 to 5 percent of the land that drains to them, which is relatively high compared with other stormwater management practices.

For wetlands, the annual cost of routine maintenance is typically estimated at about 3 percent to 5 percent of the construction cost. Alternatively, a community can estimate the cost of the maintenance activities outlined in the maintenance section. Wetlands are long-lived facilities (typically longer than 20 years). Thus, the initial investment into these systems may be spread over a relatively long time period.

Recommended Minimum Requirements

Underlying soils should be identified and tested. Hydrologic soil groups 'C' and 'D' are suitable without modification but'A' and 'B' soils may require the addition of clay or other impermeable material to line the facility. Soil permeability should be tested and calculations should demonstrate the wetland will not dry out. Organic soils should be used to establish vegetation. Vegetation is an integral part of a wetland and plays a role in reducing flow velocities, promoting settling, providing growth surfaces for beneficial microbes, and taking up pollutants. Vegetation types such as emergent, low marsh, high marsh, and buffer plants should be installed in appropriate zones for the various areas in a wetland. To allow maintenance activities, a stable and permanent access should be provided to the forebay, outlet and embankment areas. Also, an understanding of seasonal groundwater levels is critical.

Medium-fine textured soils (such as loams and silt loams) are best to establish vegetation, retain surface water while permitting groundwater recharge and capture pollutants. For a list of suitable plant species, refer to Appendix C for the *Landscape Guide for Stormwater Best Management Practice Design*, St. Louis, Missouri. Also, see Grow Native! at www.grownative.org for photos and narrative description of plant species native to Missouri and the Midwest region.

In karst (e.g., limestone) topography, wetlands should be designed with an impermeable liner to prevent groundwater contamination or sinkhole formation, and to help maintain the permanent pool. The designer should review local requirements for site grading, drainage structures, erosion and sediment control, and potential invasive vegetation.

The wetland should be designed by a registered design engineer as part of the overall site design for long-term water quality. Design considerations include:

- Water quality goals, flood management goals and performance needs (including appropriate variation for new growth, redevelopment or restoration).
- Proximity to karst and groundwater and other limitations.
- Wetland to watershed ratio and other sizing criteria.
- Topography, soils, sediment forebays.
- Buffers to separate wetland from the surrounding area.
- Above ground berms or high marsh wedges placed perpendicular to the flow path to increase dry weather flow paths within the wetland.
- Placement of the outlet with clog-prevention micropool.
- Maintenance access.
- Long-term operation, Inspection and maintenance.
- Construction sequencing.

Construction

Prior to excavation activities of any type, call 1-800-DIG-RITE (344-7483) to obtain utility locations.

Follow all federal, state and local requirements on impoundment sites. See Chapter 1 for information about regulations and permit requirements.

Plans and specifications should be referred to by the site superintendent and field personnel throughout the construction process. The construction sequence may include:

- Separating the wetland area from the contributing drainage area and initiating an appropriate erosion and sediment control plan.
- Clearing the area to be excavated of all existing vegetation. Removing tree roots, rocks and boulders. Filling all stump holes and crevices with impermeable materials.
- Excavating the bottom of the constructed wetland to the desired elevation, as indicated in the plans.
- Grading the embankments.
- Installing inlet and outlet control structures.
- Final grading and compacting of subsoil.
- Applying and grading the planting soils. It is critical the final grading match the design

because aquatic plants are sensitive to the depth of water.

- Installing geotextiles and other permanent erosion control measures.
- Seeding, planting and mulching according to the plans.

Maintenance and Inspection

Routine harvesting of vegetation has been documented to increase nutrient removal capacity of a constructed wetland and prevent the export of these constituents. Typical maintenance includes:

- Inspect the facility semiannually for burrows, sediment accumulation, structural integrity of the outlet and litter accumulation. The banks of the wetland should be inspected and areas of erosion repaired upon discovery. Sediments should be removed if they are within 18 inches of an outlet structure.
- Maintain emergent and perimeter shoreline vegetation. Site and road access are important to facilitate monitoring and maintenance.
- Remove nuisance vegetation or animals, if present.
- Harvest vegetation as prescribed in the specifications. Frequencies will vary. Vegetation is typically not collected during the growing season.
- The side slopes should be maintained at a slope that does not exceed 4:1 (H:V). Slopes showing excessive erosion may require erosion control and safety measures.

Sediments that accumulate in constructed wetlands may require special disposal. If there is any uncertainty about the sediment characteristics, the Missouri Department of Natural Resources should be consulted and department disposal recommendations should be followed.

construction Verification

Check the finished grades and configuration for all earthwork. Check elevations and dimensions of all pipes and structures.

common Problems and solutions

Problem	Solution
Erosion of slopes; caused by inadequate vegetation or improper grading and sloping	Repair damage and establish suitable grade or vegetation.
Slumping or settling of embankment; caused by inadequate compaction or use of unsuitable soil	Excavate failed material and replace with properly compacted suitable soil.
Insufficient vegetation due to improper zones or depths of ponding.	Lower the discharge to release storm flows and re-vegetate damaged areas.
Stormwater released from pond or basin too rapidly; caused by discharge	Consider resizing discharge and add additional energy dissipation at discharge location.
Unsuccessful vegetation establishment.	Plant selection should include native species tolerant of both wet and dry cycles. Deep rooted perennials increase the rate of infiltration.