5.4.1 Dry Detention

Description: Temporarily ponding runoff in basins to enable particulate pollutants to settle out and reduce the maximum peak discharge to the downstream channel, thereby reducing the effective shear stress on banks of receiving streams. The primary pollutant removal mechanism is gravitational settling. This measure is mainly used for peak flow attenuation and receives little credit for runoff reduction or pollutant removal, therefore, basins should be a part of a greater system of SCMs.

Figure 1: A dry detention basin with a pilot channel.

Site Constraints:
- Minimum contributing area of 10 ac
- Minimum 6-10 ft hydraulic head
- Minimum 3 ft to bedrock

Key Design Criteria:
- Preconstruction geotechnical review
- Size of contributing drainage area
- Permanent and temporary storage volumes
- Design flows/drawdown time
- Pretreatment forebay
- Side slopes
- Internal conveyance flowpath

Maintenance:
- Dredging accumulated sediment
- Vegetation management

Relative Factors:
- Estimated Costs: Moderate
- Runoff reduction: Low
- Pollutant removal: Low
- Risk of Failure: High

Advantages:
- Efficient suspended solids removal
- Reduces stream channel erosion
- Can be a landscape amenity

Disadvantages:
- Can be hard to landscape and maintain due to fluctuating water levels
- Must be benched for safety reasons
- Inefficient at removing dissolved solids
- Can harbor pests
- Relatively large footprint requirement
- Not applicable in high water tables

Design Checklist:
- ❑ Identify management goal(s)
- ❑ Review site constraints
- ❑ Review design criteria
- ❑ Protect site resources
- ❑ Size channel for site conditions
- ❑ Submit plans for review

1. Design

Generally, dry detention basins temporarily store peak flows such that post-construction outflow matches that of pre-construction conditions. While this practice protects receiving channels, it does little for runoff reduction and pollutant removal when used alone. Dry detention may be designed with an outlet structure that allows for detention for some minimum time (usually 24 hours) to provide some runoff reduction and pollutant removal. Temporary ponding enables particulate pollutants to settle out and reduces the maximum peak discharge to the downstream channel, thereby reducing the effective shear stress on banks of the receiving stream. Unlike wet ponds, dry detention basins generally do not have a permanenet pool of water. However, a micropool may be incorporated at the outlet to facilitate pollutant removal.

1.1 Suggested Applications

Dry detention is normally combined with other stormwater treatment options within the stormwater management system (e.g., wet ponds, and constructed wetlands) enhances its performance and appearance. Other design variations are also possible where a portion of the runoff is directed to, for example, a bioretention cell that is within the overall basin footprint but housed in a separate cell, where the ponding depth of the treatment volume and/or flood protection storage is limited by the criteria of that particular practice. This SCM will rarely provide adequate runoff volume reduction and pollutant removal to serve as a stand-alone compliance strategy. Therefore, designers should always maximize the use of upland runoff reduction practices, (e.g., rooftop disconnections, small-scale infiltration, rainwater harvesting, bioretention, grass channels, and water quality swales) that reduce runoff at its source rather than merely treating the runoff at the terminus of the storm drain system. Upland runoff reduction practices will greatly reduce the size, footprint and cost of the downstream basin or pond.

1.2 Site Constraints

Contributing Drainage Area

- Minimum recommended contributing area = 10 ac
- Basin footprint typically 1% to 3% of CDA
- Minimum 6-10 ft hydraulic head
- Depth to bedrock ≥ 3 ft
- Distance from property lines ≥ 10 ft
- Distance from building foundations ≥ 25 ft
- Distance from septic fields ≥ 50 ft
- Distance from private wells ≥ 100 ft

A minimum contributing drainage area of 10 acres is recommended for basins to protect against clogging small orifices that would be required for detention of runoff from smaller contributing areas. Detention may still work with drainage areas less than 10 acres, but designers should be aware that these "pocket" ponds will typically (1) have very small orifices that will be prone to clogging, (2) experience fluctuating water levels, and (3) generate more significant maintenance problems. Water balance calculations should also support a contributing drainage area (CDA) less than 10 acres. A typical basin requires a footprint of 1% to 3% of its contributing drainage area, depending on the depth of the pond (i.e., the deeper the pond, the smaller footprint needed). The depth of a basin is usually determined by the amount of hydraulic head available at the site. The bottom elevation is normally the invert of the existing downstream conveyance system to which the basin discharges. Typically, a minimum of 6 to 10 feet of head is needed for the dry basin to function.

Soils, Topography, Water Table and Bedrock

Soil infiltration tests need to be conducted at proposed pond sites to estimate infiltration rates, which can be significant in Hydrologic Soil Group (HSG) A soils and some Group B soils. Infiltration through the bottom of the basin is encouraged unless it will impair the integrity of the embankment. Geotechnical tests should be conducted to determine the infiltration rates and other subsurface properties of the soils underlying the proposed detention basin. If karst features are observed on site, then an alternative practice or combination of practices should be employed at the site where possible. See Appendix B for guidance on stormwater design in karst terrain. The basin should be the option of last resort and, if used in karst, must have an impermeable clay liner or, preferably, a geosynthetic liner to prevent groundwater contamination or sinkhole formation. If less than 3 feet of vertical separation exists between the bottom of the basin and the underlying soil-bedrock interface, basins should not be used unless they have an acceptable liner. Steep sloped areas constrain the use dry detention due to the relatively large and flat footprint that is needed. This SCM should not be used in areas with greater than 15% slopes.

Minimum Setbacks

Local ordinances and design criteria should be consulted to determine minimum setbacks to property lines, structures, and wells. Generally, basins should be set back at least 10 feet from property lines, 25 feet from building foundations, 50 feet from septic system fields, and 100 feet from private wells.

Environmental Considerations

Detention basins should never be constructed within existing natural wetlands, nor should they inundate or otherwise change the hydroperiod of existing wetlands. Designers can expect a great deal of neighborhood opposition if they do not make a concerted effort to save mature trees during design and pond construction. Designers should also be aware that even modest changes in inundation frequency can kill upstream trees (Cappiella *et al.,* 2007).

Safety Risks

Detention basins are generally considered to be safer than other basin options, since they have few deep pools. Steep side-slopes and unfenced headwalls, however, can still create some safety risks. Gentle side slopes should be provided to avoid potentially dangerous drop-offs, especially where detention ponds are located near residential areas. The fluctuating water levels within detention ponds have potential to create conditions that lead to mosquito breeding. Mosquitoes tend to be more prevalent in irregularly flooded ponds than in ponds with a permanent pool (Santana *et al.,* 1994). Designers can minimize the risk by combining ED with a wet pond or wetland.

Aesthetics

Basins tend to accumulate sediment and trash, which residents are likely to perceive as unsightly and creating nuisance conditions. Fluctuating water levels in basins can al.so create a difficult landscaping environment.

1.3 Design criteria

Overall Sizing

In general, the dry basin is sized to detain the volume of water that is equal to the difference in runoff produced from post-construction land cover to that of pre-construction conditions. The outlet discharge is controlled with an outlet device that regulates flow to a rate that protects receiving channels. Sizing detention basins in drainages with green infrastructure controls is different than that with conventional drainage because the use of certain SCMs creates pockets of diffuse storage throughout the drainage. This storage volume up in the contributing area may be accounted for when sizing the volume needed in a dry detention basin, resulting in a smaller volume needed in the basin. Designers may use a site-adjusted curve number that reflects the use of upland runoff reduction practices to compute the remaining treatment and flood protection volumes that must be treated by dry basin. Basins should then be designed to capture and treat the volume as necessary, using volume and discharge requirements set by local MS4 programs.

Treatment volume (cf) = Total treatment volume–volume reduced by upstream SCM(s) as allowed by local programs

Routing elements, such as pipes, channels, and the basin inlet/outlet, should be designed to carry flows calculated using an un-adjusted curve number. While SCMs decrease the total volume of water making it to a detention basin, these measures to little for the larger events, and therefore the routing network should accommodate the full potential runoff flowrate. As for the basin acting as an SCM itself, runoff reduction volume credit may be taken for infiltrated water in basin footprint while water is stored in the basin, assuming no liner. No runoff reduction may be credited for areas with an impermeable liner.

The dry detention basin should be sized to detain this treatment volume for treatment between 24 and 48 hours. After calculating the total treatment volume, the forebay should be designed using guidance in Sec 5.5 and sized to hold at least 10% of the treatment volume. The outlets must then be sized for appropriate storm events. If the pond is additionally going to address peak flow attenuation, the downstream impacts must be considered for the 2-through 100-year events, which are defined by the local MS4 program. The post-construction peak flow must not exceed the pre-construction peak flow as well as meet other channel protection requirements for individual projects as specified by the local MS4 program. Refer to Chapter Section 5.5 for more information on the use of outlet orifices and weirs.

Table 1 provides specific design criteria. The low flow orifice may be sized using the methods outline in Section 5.4 or locally approved alternative methods. Once the low flow orifice has been sized, design embankments and emergency spillways, investigate potential dam hazard classifications, and finally design inlets, sediment forebays, outlet structures, maintenance access, and safety features per guidelines of the local MS4 program.

Table 1: Dry Detention Design Criteria.

Treatment Volume = (Total Treatment Volume, no SCMs) – (SCM Volume Redution permitted by local program)
Length: Width >= 1.5
Shortest Flowpath Length / Overall Length >= 0.7
Maximum temporary storage depth 10 ft, Maximum micropool depth 4 ft
Includes additional cells or features (micropools, forebay, interlan baffles, etc.)
Contributing drainage area > 10 acres
Runoff reduction volume = Soil-specific infiltration rate*basin area*detention time

Pretreatment Forebay

Sediment forebays are considered to be an integral design feature to maintain the longevity of dry detention basins and to facilitate efficient sediment cleanout. A forebay must be located at each major inlet to trap sediment and preserve the capacity of the main treatment cell. Other forms of pre-treatment for sheet flow and concentrated flow for minor inflow points should be designed consistent with pretreatment criteria found in Chapter 5.4.6. The following criteria apply to forebay design:

- A major inlet is defined as an individual storm drain inlet pipe or open channel serving at least 10% of the ED pond's contributing drainage area.
- The forebay consists of a separate cell, formed by an acceptable barrier (e.g., an earthen berm, concrete weir, or gabion baskets).
- The forebay should be at least 4 feet deep and equipped with a variable width aquatic bench for safety purposes. The aquatic benches should be 4 to 6 feet wide at a depth of 18 inches below the water surface.
- The volume of a forebay should be approximately 10% of the treatment volume. For multiple forebay designs, the total volume of all forebays should be at least 15% of the treatment volume. The relative size of individual forebays should be proportional to the percentage of the total inflow to the pond. Similarly, any outlet protection associated with the end section or end wall should be designed according to state or local design standards.
- The forebay should be designed in such a manner that it acts as a level spreader to distribute runoff evenly across the entire bottom surface area of the main treatment cell.
- The bottom of the forebay may be hardened (e.g., concrete, asphalt, or grouted riprap) in order to make sediment removal easier.

Conveyance and Overflow

Pilot Channels: Consult with local MS4 programs on the use of pilot channels. If there is little risk of soil erosion (eg. soils are colloidal or coure enough to resist the sheet flow shear stress and dense vegetation is established), then basins shall not have a low flow pilot channel, but instead must be constructed in a manner whereby flows are evenly distributed across the pond bottom, to promote the maximum infiltration possible. If there is a high risk of soil erosion due to soil texture, then a shallow pilot channel with a wide cross-section may be used to link the forebay and micropool.

Internal Slope: The maximum longitudinal slope through the basin should be approximately 0.5% to 1% to promote positive flow through the basin.

Primary Spillway: The primary spillway shall be designed with acceptable anti-flotation, anti-vortex, and trash rack devices. The spillway must be accessible from dry land.

Non-Clogging Low Flow Orifice: Basins with drainage areas of 10 acres or less are prone to chronic clogging by organic debris and sediment. Orifices less than 3 inches in diameter may require extra attention during design to minimize the potential for clogging. Designers should always look at upstream conditions to assess the potential for higher sediment and woody debris loads and also consider the detrital load from basin vegetation. The risk of clogging in outlet pipes with small orifices can be reduced by:

- Providing a micropool at the outlet structure:
  - Use a reverse-sloped pipe that extends to a mid-depth of the permanent pool or micropool.
  - Install a downturned elbow or half-round CMP over a riser orifice (circular, rectangular, V-notch, etc.) to pull water from below the micropool surface.
  - The depth of the micropool should be at least 4 feet deep, and the depth may not draw down by more than 2 feet during 30 consecutive days of dry weather in the summer.
- Providing an over-sized forebay to trap sediment, trash and debris before it reaches the ED pond's low-flow orifice.
- Installing a trash rack to screen the low-flow orifice.
- Using a perforated pipe under a gravel blanket with an orifice control at the end in the riser structure to supplement the primary outlet.

Emergency Spillway: Dry detention basins must be constructed with overflow capacity to pass the 100-year design storm event through either the primary spillway or a vegetated or armored emergency spillway.

Adequate Outfall Protection: The design must specify an outfall that will be stable for the 10-year design storm event. The channel immediately below the pond outfall must be modified to prevent erosion and conform to natural dimensions in the shortest possible distance. This is typically done by placing appropriately sized riprap over filter fabric which can reduce flow velocities from the principal spillway to non-erosive levels (3.5 to 5.0 fps depending on the channel lining material). Flared pipe sections that discharge at or near the stream invert or into a step pool arrangement should be used at the spillway outlet.

Inlet Protection: Inlet areas should be stabilized to ensure that non-erosive conditions exist during storm events up to the overbank flood event (i.e., the 10-year storm event). Inlet pipe inverts should generally be located at or slightly below the forebay pool elevation.

In-line basins must be designed to detain the required treatment volume and either manage or be capable of safely passing larger storm events conveyed to the basin (e.g., 10-year flood protection, and/or the 100-year design storm event).

Internal Design Features

Side Slopes: Side slopes leading to the dry basin should generally have a gradient of at least 4:1. Mild slopes promote better establishment and growth of vegetation and provide for easier maintenance and a more natural appearance.

Long Flow Path: Dry detention basins should have an irregular shape and a long flow path from inlet to outlet to increase water residence time, treatment pathways, and pond performance. In terms of flow path geometry, there are two design considerations: (1) the overall flow path through the pond, and (2) the length of the shortest flow path (Hirschman et al., 2009):

- The overall flow path can be represented as the length-to-width ratio OR the flow path. These ratios must be at least 3:1. Internal berms, baffles, or topography can be used to extend flow paths and/or create multiple pond cells.
- The shortest flow path represents the distance from the closest inlet to the outlet. The ratio of the shortest flow to the overall length must be at least 0.7. In some cases – due to site geometry, storm sewer infrastructure, or other factors – some inlets may not be able to meet these ratios. However, the drainage area served by these "closer" inlets should constitute no more than 20% of the total contributing drainage area.

Treatment Volume Storage: The total treatment volume storage should be comprised within the temporarily inundated detention storage and micropool.

Safety Features

- Mild basin side slopes of 3:1 or greater are strongly encouraged.
- The principal spillway opening must be designed and constructed to prevent access by small children.
- End walls above pipe outfalls greater than 48 inches in diameter must be fenced to prevent a hazard.
- An emergency spillway and associated freeboard must be provided in accordance with applicable local or state dam safety requirements. The emergency spillway must be located so that downstream structures will not be damaged by spillway discharges.
- Both the safety bench and the aquatic bench should be landscaped with vegetation that hinders or prevents access to the pool.

Landscaping and Planting Plan

A landscaping plan must be provided that indicates the methods used to establish and maintain vegetative coverage within the ED basin. Minimum elements of a plan include the following:

- Delineation of landscaping zones within the basin
- Selection of corresponding plant species
- Quantity, size, species, root condition, location, and sources of plants.
- The planting plan should allow the vegetation to mature in the right places, but yet kept mowable turf along the embankment and all access areas and preferred no-mow, native grasses and forbs in all other areas.
- Woody vegetation may not be planted or allowed to grow within 15 feet of the toe of the embankment nor within 25 feet from the principal spillway structure.

Avoid species that require full shade, or are prone to wind damage. Extra mulching around the base of trees and shrubs is strongly recommended as a means of conserving moisture and suppressing weeds. For more guidance on planting trees and shrubs in detention ponds, consult Cappiella et al (2006).

Maintenance Reduction Features

Good maintenance access is needed so crews can remove sediments from the forebay, alleviate clogging and make riser repairs. The following maintenance issues can be addressed during design, in order to make ongoing maintenance easier:

- Adequate maintenance access must extend to the forebay, micropool, any safety benches, riser, and outlet structure and must have sufficient area to allow vehicles to turn around.

- The riser should be located within the embankment for maintenance access, safety and aesthetics.
- Access roads must (1) be constructed of load-bearing materials or be built to withstand the expected frequency of use, (2) have a minimum width of 12 feet, and (3) have a profile grade that does not exceed 15%. Steeper grades are allowable if appropriate stabilization techniques are used, such as a gravel road.
- A maintenance right-of-way or easement must extend to the ED basin from a public or private road.

Material Specifications

Dry detention basins are generally constructed with materials obtained on-site, except for the plant materials, inflow and outflow devices (e.g., piping and riser materials), possibly stone for inlet and outlet stabilization, and filter fabric for lining banks or berms. The basic material specifications for earthen embankments, principal spillways, vegetated emergency spillways and sediment forebays shall be as specified in Tennessee state guidelines.

Dam Safety

The Tennessee Safe Dams Act applies to ponds with storage volumes and embankment heights large enough to fall under the regulation for dam safety, as applicable. Size emergency spillway for any overtopping of a pond in case of a rain event in excess of 100-year storm and for instances of malfunction or clogging of primary outlet structure.

1.4 Typical Details

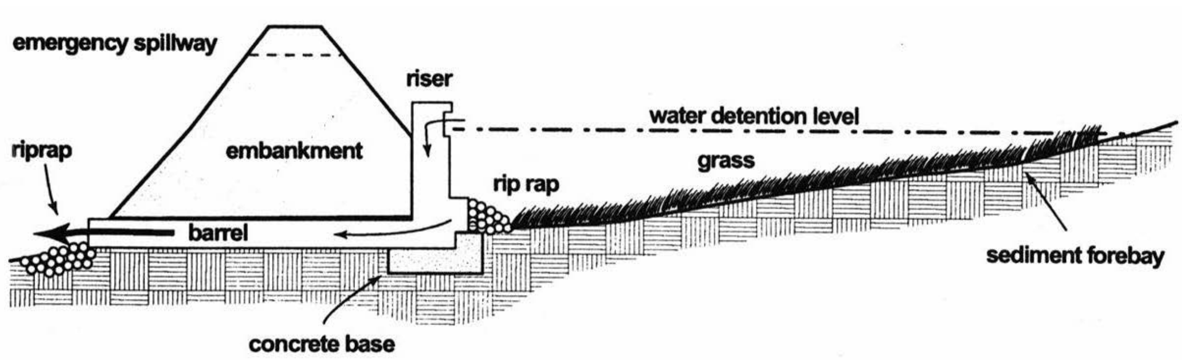

Figure 2: Dry detention pond cross-section (US EPA).

2. Construction

2.1 Pre-Construction

Soil borings should be taken below the proposed embankment, in the vicinity of the proposed outlet area, and in at least two locations within the proposed basin area. Soil boring data is needed to (1) determine the physical characteristics of the excavated material, (2) determine its adequacy for use as structural fill, (3) provide data for structural designs of the outlet works (e.g., bearing capacity and buoyancy), (4) determine compaction/composition needs for the embankment, (5) determine the depth to groundwater and bedrock and (6) evaluate potential infiltration losses and the potential need for a liner if a micropool will be implemented.

2.2 Construction

The following is a typical construction sequence to properly install a dry detention basin. The steps may be modified to reflect different dry basin designs, site conditions, sizes, complexity and configuration of the proposed facility.

Step 1: Converting from a sediment basin. A basin may serve as a sediment basin during project construction. If this is done, the volume should be based on the more stringent sizing rule (erosion and sediment control requirement vs. water quality treatment requirement). Installation of the permanent riser should be initiated during the construction phase, and design elevations should be set with final cleanout of the sediment basin and conversion to the post-construction basin in mind. The bottom elevation of the basin should be lower than the bottom elevation of the temporary sediment basin to allow for sedimentation during construction. Appropriate procedures should be implemented to prevent discharge of turbid waters when the basin is being converted into a basin.

Step 2: Stabilize the Drainage Area. Dry basins should only be constructed after the contributing drainage area to the pond is completely stabilized or if water is routed around them during construction. If the proposed basin site will be used as a sediment trap or basin during the construction phase, the construction notes should clearly indicate that the facility will be dewatered, dredged, and re-graded to design dimensions after the original site construction is complete.

Step 3: Assemble Construction Materials onsite, make sure they meet design specifications, and prepare any staging areas.

Step 4: Clear and Prepare the project area to the desired elevation with desired soil quality (see Section 5.3).

Step 5: Install EPSC Controls prior to construction, including temporary de-watering devices and stormwater diversion practices. All areas surrounding the pond that are graded or denuded during construction must be planted with turf grass, native plantings, or other approved methods of soil stabilization.

Step 6: Excavate the Core Trench and Install the Spillway Pipe.

Step 7: Install the Riser or Outflow Structure and ensure the top invert of the overflow weir is constructed level at the design elevation.

Step 8: Construct the Embankment and any Internal Berms in 8 to 12-inch lifts and compact the lifts with appropriate equipment.

Step 9: Excavate/Grade until the appropriate elevation and desired contours are achieved for the bottom and side slopes of the basin.

Step 10: Construct the Emergency Spillway in cut or structurally stabilized soils.

Step 11: Install Outlet Pipes, including downstream rip-rap apron protection and/or channel armor, as necessary.

Step 12: Stabilize Exposed Soils with temporary seed mixtures appropriate for the pond. All areas above the normal pool elevation should be permanently stabilized by hydroseeding or seeding over straw.

Step 13: Plant the Area, following the landscaping plan (see Appendix D).

2.3 Inspections

Inspections are recommended during the following stages of construction:

- Pre-construction meeting
- Initial site preparation (including installation of EPSC controls)
- Excavation/Grading (interim and final elevations)
- Installation of the embankment, the riser/primary spillway, and the outlet structure
- Implementation of the landscaping plan and vegetative stabilization
- Final inspection (develop a punch list for facility acceptance)

If basin has a micropool, then to facilitate maintenance the contractor should measure the actual constructed pond depth at three areas within the micropool (forebay, mid-pond and at the riser), and he/she should mark and geo-reference them on an as-built drawing. This simple data set will enable maintenance inspectors to determine pond sediment deposition rates in order to schedule sediment cleanouts.

3. Maintenance

3.1 Agreements

Examples of the maintenance document are in Appendix F. They include the execution and recording of an Inspection and Maintenance Agreement or a Declaration of Restrictions and Covenants, and the development of a Long Term Maintenance Plan (LTMP) by the design engineer. The LTMP contains a description of the stormwater system components and information on the required inspection and maintenance activities.

3.2 Schedules

Maintenance Inspections

Maintenance of dry detention basins is driven by annual inspections that evaluate the condition and performance of the basin, including the following:

- Measure sediment accumulation levels in forebay.
- Monitor the growth of wetlands, trees and shrubs planted, and note the presence of any invasive plant species.
- Inspect the condition of stormwater inlets to the pond for material damage, erosion or undercutting.
- Inspect the banks of upstream and downstream channels for evidence of sloughing, animal burrows, boggy areas, woody growth, or gully erosion that may undermine embankment integrity.
- Inspect pond outfall channel for erosion, undercutting, rip-rap displacement, woody growth, etc.
- Inspect condition of principal spillway and riser for evidence of spalling, joint failure, leakage, corrosion, etc.
- Inspect condition of all trash racks, reverse sloped pipes or flashboard risers for evidence of clogging, leakage, debris accumulation, etc.
- Inspect maintenance access to ensure it is free of woody vegetation, and check to see whether valves, manholes and locks can be opened and operated.
- Inspect internal and external side slopes of the pond for evidence of sparse vegetative cover, erosion, or slumping, and make needed repairs immediately.

As-Built Inspections

After the basin is constructed, an as-built certification of the basin, performed by a registered Professional Engineer, must be submitted to the local stormwater program. The following are components which should be addressed in the as-built certification:

1. Pretreatment for coarse sediments must be provided.
2. Surrounding drainage areas must be stabilized to prevent sediment from clogging the filter media.
3. Correct ponding depths and infiltration rates must be maintained to prevent killing vegetation.
4. Internal baffling or berms to elongate flowpaths as needed to meet requirements.
5. A mechanism for overflow for large storm events must be provided.

Common Ongoing Maintenance Issues

Dry detention basins are prone to clogging at the outlet orifice. This component of the basin's conveyance should be inspected at least twice a year after initial construction. The constantly changing water levels in the basin makes it difficult to mow or manage vegetative growth. The bottom of basin often becomes soggy, and water-loving trees such as willows may take over. The maintenance plan should clearly outline how vegetation in the pond will be managed or harvested in the future. Any signs of erosion of internal berms or baffles should be addressed with grading, adding armoring, or establishing cover. The maintenance plan should schedule a cleanup at least once a year to remove trash and floatables that tend to accumulate in the forebay, micropool, and on the bottom of the basins. Frequent sediment removal from the forebay is essential to maintain the function and performance of a basin. Maintenance plans should schedule cleanouts every 5 to 7 years, or when inspections indicate that 50% of the forebay capacity has been filled. Excavated sediments are not usually considered toxic or hazardous, and can be safely disposed by either land application or land filling.

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