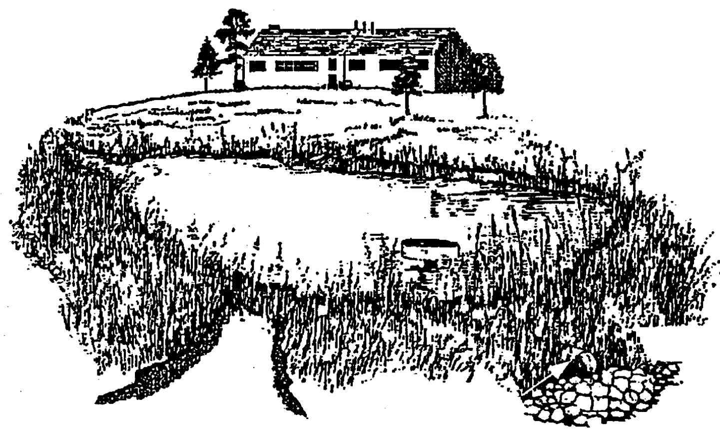
Wet Ponds



Description

A wet pond, also known as a wetpool, a retention basin, or a "NURP" pond (if the pond incorporates specific design parameters), is a constructed stormwater pond that retains a permanent pool of water. Wet ponds are generally on-line, end-of-pipe BMPs. The primary pollutant removal mechanism in a wet pond is sedimentation. Significant loads of suspended pollutants, such as metals, nutrients, sediments, and organics, can be removed by sedimentation. Dissolved contaminants are removed by a combination of processes: physical adsorption to bottom sediments and suspended fine sediments, natural chemical flocculation, bacterial decomposition, and uptake by aquatic plants and algae. Wet ponds have a moderate to high capacity for removing most urban pollutants, depending on how large the volume of the permanent pool is in relation to the runoff from the surrounding watershed. Figure 1 shows a schematic of a typical wet pond.

Generally, large contributing watersheds are required to maintain pool elevations. Minimum contributing watersheds should be at least 10 acres, but not more than one square mile. Sites with less than 10 acres of contributing watershed may be suitable if sufficient ground-water flow is available.

Wet ponds can be used at residential, commercial and industrial sites. Since wet ponds have the capability of removing soluble pollutants, they are suitable for sites where nutrient loadings are expected to be high.

Wet ponds may be single-purpose facilities, providing only runoff treatment, or they may be incorporated into an extended storage or a detention pond design to also provide flow control. Wet ponds themselves are generally ineffective in decreasing runoff volumes,

Purpose

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

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

* Only if a skimmer is incorporated

Wet Ponds

Description (continued)

although some infiltration can occur (depending on groundwater depth and soil type), as well as evaporation in summer months.

Wet ponds work best when the water already in the pond is moved out en masse by incoming flows, a phenomena called "plug flow." Because treatment works on this displacement principle, the permanent pool of wet ponds may be provided below the groundwater level without interfering unduly with treatment effectiveness. Local authorities' regulations concerning groundwater should be consulted before constructing such a wet pond, however.

Removal efficiency is primarily dependent on the length of time that runoff remains in the pond, which is known as the pond's Hydraulic Residence Time (HRT). As discussed above, wet ponds can remove pollutants not only through sedimentation but also through biological uptake processes, whose removal of pollutants is proportional to the length of time runoff remains in the pond.

Studies have shown that more than 90 percent of the pollutant removal occurs during the quiescent period (the period between the rainfall events) (MD DEQ, 1986). However, some removal occurs during the dynamic period (when the runoff enters the pond). Modeling results have indicated that two-thirds of the sediment, nutrients and trace metal loads are removed by sedimentation within 24 hours. These projections are supported by the results of the EPA's 1993 Nationwide Urban Runoff Program (NURP) studies. However, other studies indicate that an HRT of two weeks is required to achieve significant phosphorus removal (MD DEQ, 1986). Researchers have developed design guidelines (discussed below) that are based in part on the influence of the HRT on a wet pond's treatment efficiency.

When properly designed and maintained, a wet pond can add recreation, open space, fire protection and aesthetic values to a project area.

Enhancement Options

Following the recommendations of this BMP section, by providing deep inlet and outlet zones or multiple pools, will usually result in designs that are robust enough to handle the winter and spring conditions without special considerations. However, runoff volume from spring snowmelt events can be very large, often the largest-volume event of the year. Ponds designed to function effectively in summer are often disrupted by winter and spring events. Inspection and maintenance during spring runoff should be a consistent feature of stormwater treatment systems in cold climates.

There are several common modifications that can be made to a wet pond to increase its pollutant removal effectiveness. These options are described below.

Varied Depths Throughout the Permanent Pool

Intermittent benches around the perimeter of the pond are recommended for safety and to promote vegetation. The safety bench should be designed to be at least 10 feet wide and located above normal pool elevations. The aquatic bench should be a minimum of ten feet wide and depths of 6-18 inches should be maintained at normal elevations to support aquatic vegetation. Deeper depths near the outlet will yield cooler bottom water discharges that may mitigate downstream thermal effects during the summer. Figure 2 shows a wet pond with both safety and aquatic benches.

Wet Ponds

Sediment Forebays

The settling area for incoming sediments can be increased through the addition of a sediment forebay. The use of a sediment forebay, however, is only recommended for wet ponds larger than 4,000 cubic feet. The forebay is an excavated settling basin or a section separated by a low weir at the head of the primary impoundment. Forebays serve to trap sediments before the runoff enters the primary pool, effectively enhancing removal rates and minimizing long term operation and maintenance problems. Periodic sediment removal from the forebay is easier and less costly than removal from the primary wet pond pool. Sediment forebays should be designed for ease of maintenance. Hard bottom forebays make sediment removal easier, and forebays should be accessible by heavy machinery, if necessary. About 10 to 25 percent of the surface area of the wet pond should be devoted to the forebay. The forebay can be distinguished from the remainder of the pond by one of several means: a lateral sill with rooted wetland vegetation, two ponds in series, differential pool depth, rock-filled gabions or retaining wall, or a horizontal rock wall filter placed laterally across the pond. Energy dissipation techniques should be used at the inlet to the sediment forebay to avoid erosion, to promote settling, and to minimize short-circuiting of flows. The length to width ratio of the forebay should be at least 2:1 to minimize short-circuiting. Figures 3a and 3b show a schematic of a wet pond that has a separate sediment forebay.

Pond Shape

To avoid reducing the pollutant removal capability and to maximize travel distance, the inflow points of the wet pond should be as far from the outlet as possible. To maximize stormwater contact and residence time in the pool, a length to width ratio of 3:1 is recommended. A minimum pool surface area of 0.25 acres is recommended. Performance of the wet pond may be enhanced by enlarging the surface area to increase volume, as opposed to deepening the pool.

Multi-Stage Outlets

Wet ponds may be designed with a multi-stage outlet structure to control discharges from different size storms. Usually the pond is designed to control multiple design storms (e.g. 2- and/or 10-year storms) and safely pass the 100-year storm event. However, the design storm may vary depending on local conditions and requirements.

Chemical Treatment

Addition of chemicals to precipitate phosphorus within the permanent pool (e.g. alum) can further enhance the removal of both particulate and dissolved forms of phosphorus entering the wet pond.

Aesthetic Enhancements

Many design features can be incorporated to enhance aesthetics where possible, such as:

- Providing pedestrian access to shallow pool areas enhanced with emergent wetland vegetation. This allows the pond to be more accessible without incurring safety risks.
- Providing side slopes that are sufficiently gentle to avoid the need for fencing (3:1 or flatter).
- Creating flat areas overlooking or adjoining the pond for seating that can be used by residents.
- Incorporating walking or jogging trails into the pond design.
- Including fountains or integrated waterfall features for privately maintained facilities.
- Providing visual enhancement with clusters of trees and shrubs.

Wet Ponds

Description (continued)

Establishing Aquatic Vegetation

Vegetative buffers around the perimeter of the wet pond are recommended for erosion control and additional sediment and nutrient removal. Establishing wetland vegetation on the aquatic bench will enhance removal of soluble nutrients, enhance sediment trapping, prevent sediment resuspension, provide wildlife and waterfowl habitat and conceal trash and debris that may accumulate near the outlet. Shallow depths near the inlet will concentrate sediment deposition in a smaller, more accessible area.

Advantages

- Capable of removing both solid and soluble pollutants.
- Depending on design, wet ponds can be an aesthetically pleasing BMP .
- Wildlife habitat is created when ponds are properly planted and maintained.

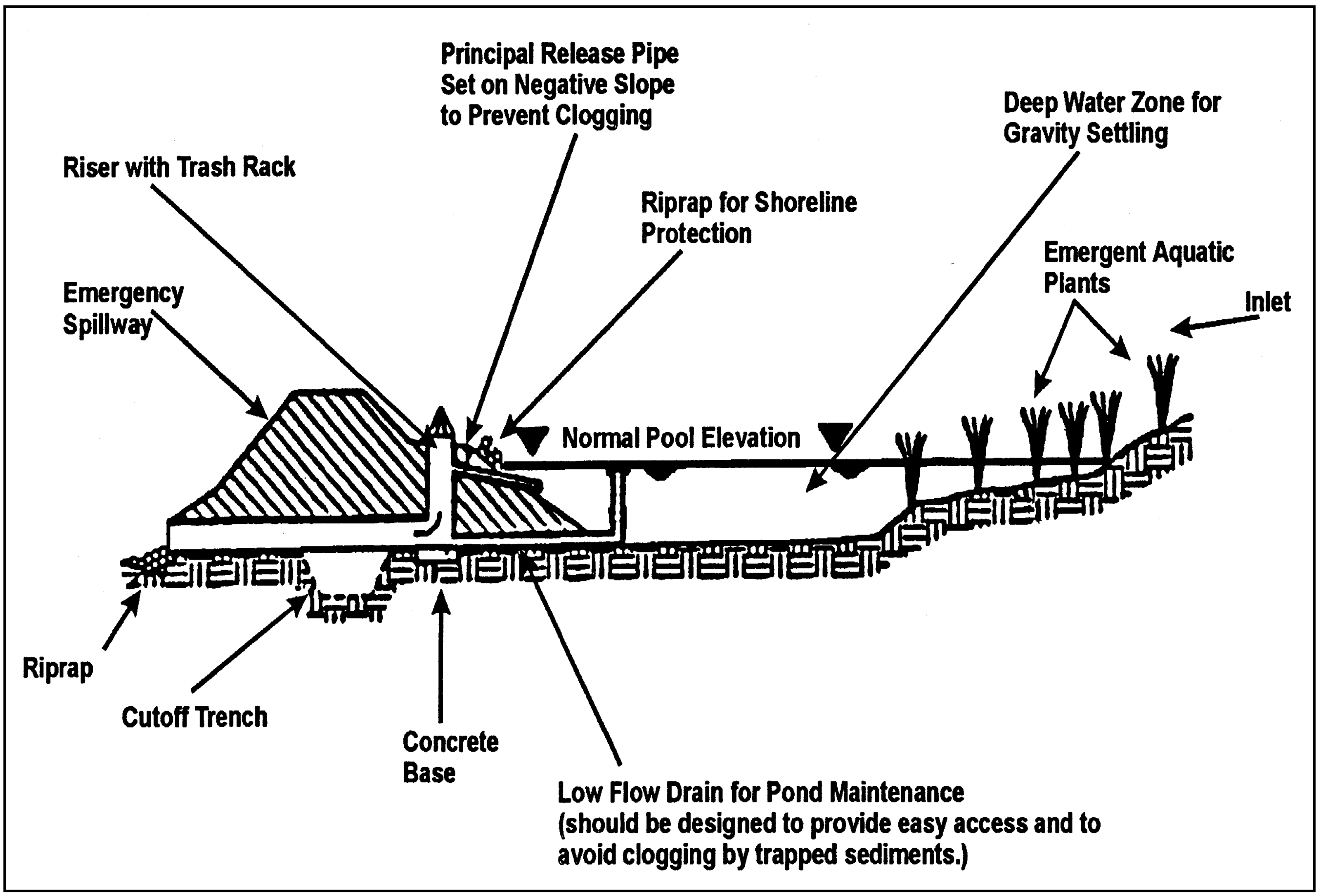


Figure 1: Typical Wet Pond Design
Source: Maryland Department of the Environment, 1986

- Can increase adjacent property values when planned, sited and designed properly.
- Pond sediment removal schedule is generally less frequent than for other BMPs.

Limitations

- Generally not prescribed for drainage areas smaller than 10 acres.
- More costly than extended storage ponds.
- Requires relatively large land area.
- Improperly designed or maintained ponds may result in stratification and anoxic conditions that can promote the release of nutrients and metals from the trapped sediments.
- Discharges from ponds usually consist of warm water, and thus pond use may be limited in areas where warm water discharges from the pond will adversely impact a cold water fishery.

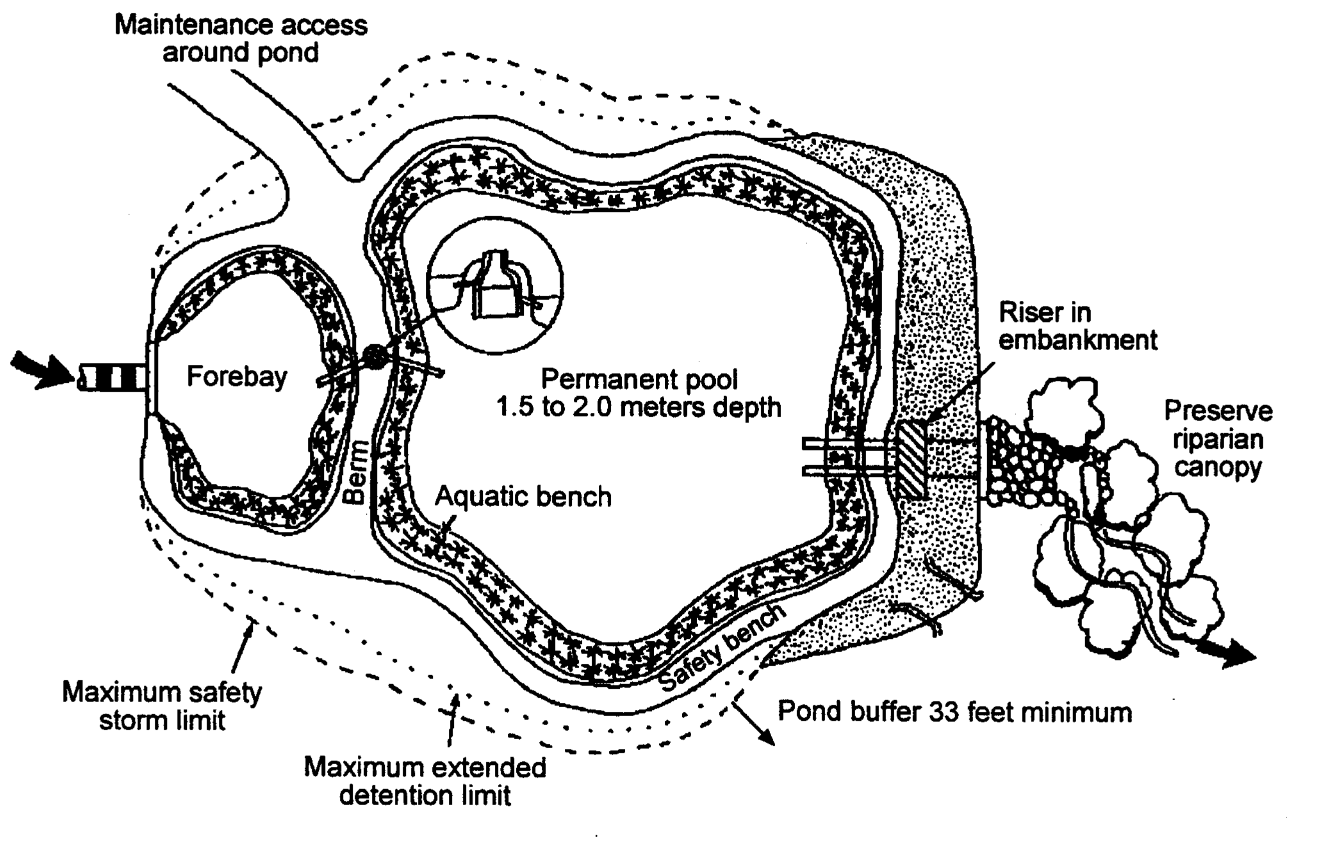


Figure 2: Schematic of a Wet Pond Showing Aquatic and Safety Benches
Source: Schueler, 1987

Wet Ponds

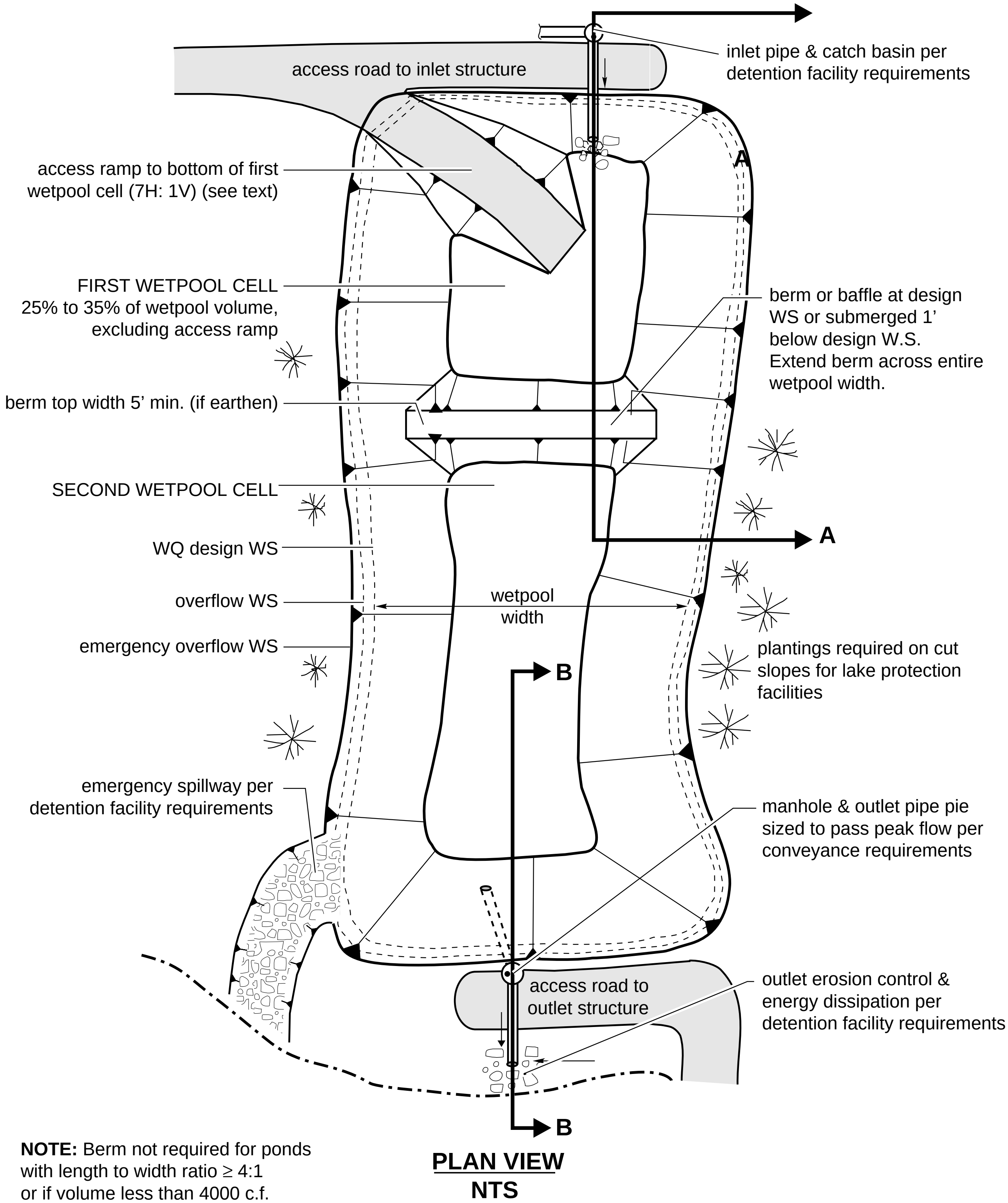
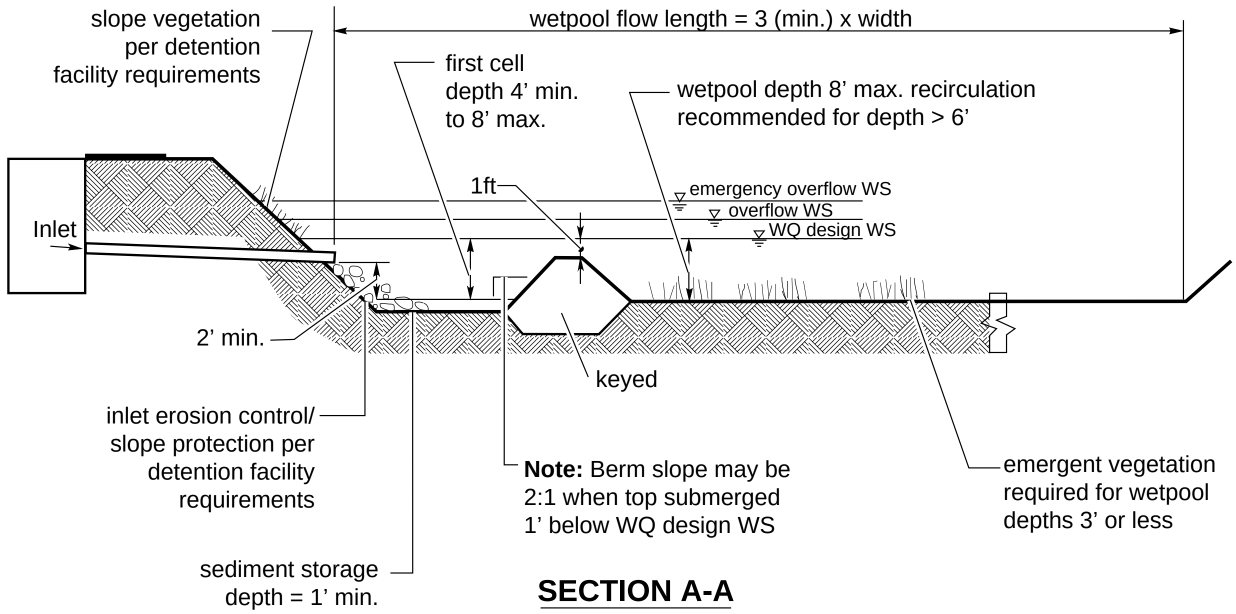


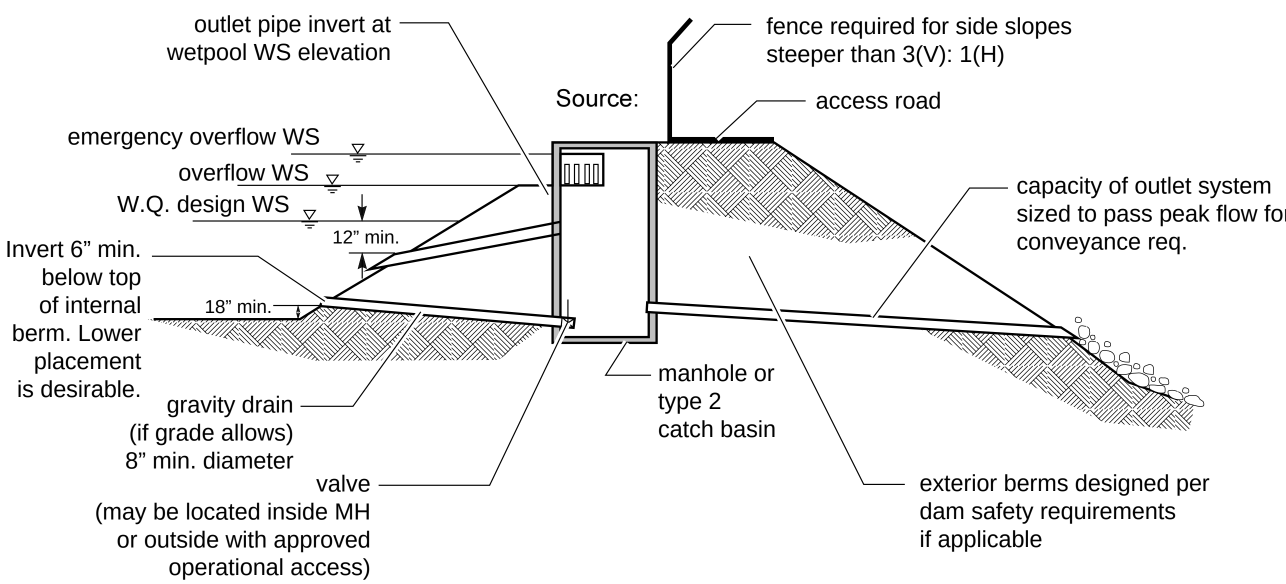
Figure 3a: Wet Pond Design with Separate Sediment Forebay (Plan View)

Source: Stormwater Management in Washington State, 2000

Wet Ponds



Caption



NOTE: See detention facility requirements for location and setback requirements.

Figure 3b: Wet Pond Design with Separate Sediment Forebay (Profile View)

Source: Stormwater Management in Washington State, 2000

Wet Ponds

Limitations (continued)

- The local climate during winter may affect the biological removal of pollutants in the pond. (Lower temperatures decrease the rate of biological activity). Also, formation of an ice layer may reduce the pond's treatment efficiency.
- Concern for mosquitoes and maintaining oxygen in ponds.
- Cannot be placed on steep unstable slopes.
- Depending on volume and depth, pond designs may require approval from dam safety authorities.

Requirements

Design

Pond Volume and Surface Area

Designing the volume of the permanent pool usually involves defining a rainstorm event called the "water quality event". For wet ponds, the runoff volume generated from the water quality event (called the "water quality volume") is equal to the volume of the wet pond. Local authorities will likely have their own definitions for the water quality event or the runoff volume that it generates. However, two published water quality event recommendations endorsed by the MPCA are the 1-year, 24-hour storm event (roughly 2 to 2.4 inches in Minnesota) and the 2.5-inch, 24-hour storm event (Walker, 1987). If the 1-year, 24-hour storm event is used, an additional volume for sediment storage must be added to the permanent pool design. If Walker's 2.5" storm is used, 25 years of sediment accumulation has already been incorporated into the pond volume.

The volume of runoff from the water quality event is best predicted by a combination of monitoring existing conditions and modeling future conditions. However, local authorities will likely have their own methods for calculating runoff volume from storm events. For design purposes, the water quality volume should be considered an instant flow to the pond, not an inflow-outflow calculation. In other words, this volume should be considered to arrive at the pond all at once, rather than over the course of several hours or days. The assumption of instant runoff is conservative, but it accounts for a great deal of the variability that occurs in both storm events and runoff conditions.

The 25-year sediment volume needed for the pond (if the 1-year, 24-hour storm is used as the water quality event) can be calculated with NRCS sediment storage calculation methods (see Sediment Management, below).

A minimum pool surface area of 0.25 acres is recommended based on the typical drainage area size required to sustain a permanent pool during summer months.

Pond Depth:

Pool depth is an important design factor, especially for sediment deposition. An average pool depth of 3 to 6 feet is recommended. Settling column studies and modeling analyses have shown that shallow ponds have higher solids removal than deeper ones. However, resuspension of settled materials by wind may be a problem in shallow ponds that are less than 2 feet in depth. Depths in excess of 10 feet may result in thermal stratification. Stratified pools tend to become anoxic (low or no oxygen) more often than shallower ponds. For wetpool depths in excess of 10 feet, it is recommended that some form of recirculation be provided in the summer, such as a fountain or aerator, to prevent stagnation and low dissolved oxygen conditions.

Wet Ponds

Varying depths throughout the pond are recommended. Intermittent benches around the perimeter of the pond are recommended to enhance public safety and to promote the growth of aquatic vegetation. Six to eighteen inches of water are needed for optimum wetland vegetation growth. Deeper depths near the riser will yield cooler water bottom discharges, which may mitigate downstream thermal effects.

Avoidance of short-circuiting and the promotion of plug flow:

To prevent short-circuiting, water is forced to flow, to the extent practical, to all potentially available flow routes, avoiding "dead zones" and maximizing the time water stays in the pond during the active part of a storm. Design features that encourage plug flow and avoid dead zones are:

- Providing a broad surface for water exchange across cells rather than a constricted area.
- Maximizing the flowpath between inlet and outlet, including the vertical path, also enhances treatment by increasing residence time. Baffles or islands can be added within the permanent pool to increase the flow path.
- The ratio of flowpath length to width from the inlet to the outlet should be at least 3:1. The flowpath length is defined as the distance from the inlet to the outlet, as measured at mid-depth. The width at mid-depth can be found as follows: width = (average top width + average bottom width)/2.
- All inlets should enter the first cell. If there are multiple inlets, the length-to-width ratio should be based on the average flowpath length for all inlets.
- Using a teardrop shape (as opposed to a rectangular one), as it minimizes dead zones caused by corners.

Pond Slopes:

The side slopes of the permanent pool should be no steeper than 3:1. Flatter slopes help to prevent erosion of the banks during larger storms and make routine bank maintenance tasks, such as mowing, easier. Flat slopes also provide for public safety, and allow easier access. Furthermore, the sides of the pool that extend below the safety and aquatic benches to the bottom of the pool should be at a slope that will remain stable, usually no steeper than 2:1 (horizontal: vertical). Slopes leading to the wet pond should be no steeper than 3:1.

Sediment Management:

A sediment forebay or similar pretreatment device is highly recommended to enhance pollutant removal and to prolong pond effectiveness in larger (>4,000 cubic feet) facilities.

The original design volume of the wet pond should take into account gradual sediment accumulation.

An access for maintenance, minimum width of 10 feet and a maximum slope of 15%, must be provided by public or private right-of-way. This access should never cross the emergency spillway, unless the spillway has been designed for that purpose.

An emergency drain (with a pipe sized to drain the pond in less than 24 hours) should be installed in all ponds to allow access for riser repairs and sediment removal (Schueler, 1987).

Design (continued)
Requirements

Sediment Storage Design

Sediment volume should be at least the MPCA permit requirement of 250 cubic feet (ft^3) per acre of impervious surface in the tributary watershed. Alternatively, the wet pond can be built with capacity for about 25 years of storage. A detailed analysis of pond sediment storage volume may be helpful to determine cost-effective sediment control plans. Methods such as the NRCS use equations that address many of the sediment storage factors, but they should be evaluated by professionals on a site-specific basis. The basic equation and design considerations are:

$$Vol = A \times Y \times DR \times TE \times E / (217{,}800 \times G)$$

where: Vol = design sediment storage capacity,

E = average rate of erosion in the watershed in tons/acre/year,

A = area of the watershed in acres,

DR = sediment delivery ratio in percent,

G = estimated sediment density in the basin in pounds per cubic foot,

TE = trap efficiency, in percent, and

Y = design storage period in years.

It is important to remember that the Walker design (using a 2.5”, 24-hour water quality event) already incorporates approximately 25 years of sediment storage in its design assumptions.

Pond Inlet/Outlet Structures and Pipes:

The outlet area should be a deeper micropool to provide final settling and prevent resuspension of sediments. The outlet device should be carefully designed, since it is important to the operation of the entire pond system.

Inflow points should be designed with energy dissipaters to reduce inflow velocity.

Several options that are available for pond outlets are discussed in the “Alternative Outlets” fact sheet. Two different outlet designs- one without and one with a riser, are shown in Figures 2 and 3, respectively.

In most cases, emergency spillways should be included in the pond design. Emergency spillways should be sized to safely pass flows that exceed the design storm flows. The spillway prevents pond water levels from overtopping the embankment, which could cause structural damage to the embankment. The emergency spillway should be located so that downstream buildings and structures will not be negatively impacted by spillway discharges. The pond design should include an emergency drain to assist in pond maintenance. The drain pipe should be designed for gravity discharge and should be equipped with an adjustable gate valve. Embankments and spillways should be designed in conformance with the state Dam Safety regulations and criteria.

The design of the wet pond embankment is another key factor to be considered. Proper design and construction of the embankments will prolong the integrity of the pond structure. Subsidence and settling will likely occur after an embankment is constructed. Therefore during construction, the embankment should be overfilled by at least 5 percent (SEWRPC, 1991). Seepage through the embankment can also affect the stability of the structure. Seepage can generally be minimized by adding drains, anti seepage collars, and core trenches. The embankment side slopes can be protected from erosion by using minimum side slopes of 3:1 and by covering the embankment with vegetation or riprap. The embankment should also have a minimum top width of 2 meters (6 feet) to aid in maintenance.

Scour Control:

Scour is the erosion of pond bottom or bank material due to high flow velocities. Scour control is important to maintain the function of the pond and reduce erosion, especially near the inlet. Inlet areas and inlet structures should be designed to control velocities at the inlet whether from large or small storm events.

Flow-diffusion devices, including plunge pools, directional berms or other specially created dissipation structures, are often recommended. For annual events, the velocity leaving the inlet area and entering the main treatment area should be less than 1 foot per second (fps). Decreasing velocity reduces scour and more importantly reduces mixing currents that reduce treatment efficiency.

The MPCA recommends that the following design storms be considered in the pond design (MPCA, 2000). Scour prevention can be achieved if velocities through the main treatment area are limited to the following maximums:

1 foot per second for the 1-yr 2.4” event:

3 feet per second for the 2-yr, 2.8” event:

5 feet per second for the 10-yr, 4.0” event and the 100-yr, 6.0” event

Velocities are calculated as outflow divided by the area of the critical cross-section. All events are considered to be the 24-hour NRCS distribution event.

Water Quantity Control Requirements:

Wet ponds should be designed to meet both storm water quality and quantity control requirements. Storm water quantity requirements are typically met by designing the pond to control post-development peak discharge rates to pre-development levels. Usually the pond is designed to control multiple design storms (e.g. 2- and/or 10-year storms) and safely pass the 100-year storm event. However, the design storm may vary depending on local conditions and requirements.

Design for Winter-Runoff Conditions

During the winter period, the design volume of the wet pond can be less than desired. Ground freezing throughout the tributary watershed effectively increases the watershed’s imperviousness, which increases the fraction of precipitation that reaches the pond. Moreover, the available volume in the permanent pool can be reduced by the formation of ice. Fortunately, winter rainfall and snowmelt events (as opposed to spring) typically produce lower volumes of runoff than summer storms and so most events will continue to be captured entirely (e.g. the volume of runoff will be less than the reduced volume of the wet pond). However, temperature regimes in the northern regions of Minnesota are such that ice cover may persist into the spring period when runoff rates and contaminant washoff rates are higher. In these areas, some authorities recommend that the wet pond volume be increased by an amount equal to the expected volume of the ice cover (Ontario Ministry of the Environment, 1999).

Design Requirements (continued)

The thickness of ice can be estimated using Stefan's equation (Marsalek, 2000):

$$h = a\,(D_f)^{0.5}$$

where: h is the ice thickness in mm

a is a coefficient of ice growth

D_f is the sum of freezing degree-days

The values for the coefficient for ice growth are shown below.

Condition	a ($mm^{\circ}C^{-0.5}d^{-0.5}$)
Theoretical Maximum	34
Windy Lake with No Snow	27
Average Lake with Snow	17-24
Average River with Snow	14-17
Shelter River with Rapid Flow	7-14

Work done a pond in Kingston, Ontario, indicated that a coefficient value of 15 produced results close to measured values. The pond operated with a constant subsurface inflow, which tended to limit the buildup of ice. In general, it is expected that most ponds will be small enough and will receive sufficient inflow to behave more like a river (in terms of ice buildup) than a lake. Where possible however, the designer should consult with the local authorities concerning local knowledge on ice depths (Ontario Ministry of the Environment, 1999).

Snowmelt runoff events in Minnesota may convey high concentrations of urban runoff pollutants to stormwater ponds and other receiving waters. Recommendations to manage this potential influx of contaminated snow and ice melt include: incorporating extended storage (see the Extended Storage Ponds BMP Section) in the pond design, installing grass swales in the drainage system ahead of stormwater ponds, and storing contaminated snow and ice where debris and petroleum products are less likely to be transported to the pond (Oberts, 1991).

Water can flow over the ice in stormwater ponds during spring thaw, and may carry sediment directly out of the pond outlet. If this is a concern for a particular pond design, it is generally a good idea to incorporate extended storage capability of the pond. In this type of design, increasing the volume of the pond above the permanent pool can also enhance winter runoff treatment. One can also increase the depth of the pond below the water quality spillway, thus allowing more room for the ice to collapse into the pond. If the pond is located in an area with a high water table, it may not be feasible to make this design modification.

Standpipe outlets may be destroyed by ice movement in winter. Standpipes are not recommended unless they are designed to withstand ice movement.

In Minnesota's urban areas, snow piles are often created in parking lots, along streets and elsewhere. Store snow where debris oil and other materials cannot readily enter waters of the state. Discharge of such materials directly to waters of the state is prohibited. So, snow-storage areas that minimize surface-water impacts should be planned.

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Following the recommendations of this BMP section, by providing deep inlet and outlet zones or multiple pools, will usually result in designs that are robust enough to handle the winter and spring conditions without special considerations. However, runoff volume from spring snowmelt events can be very large, often the largest-volume event of the year. Ponds designed to function effectively in summer are often disrupted by winter and spring events. Inspection and maintenance during spring runoff should be a consistent feature of stormwater treatment systems in cold climates.

Sequencing

- Wet ponds may be constructed in the early phases of a development project, in order to treat site runoff during construction.
- If the basin is used as a sediment trap during construction, all sediment deposited during construction should be removed before normal operation begins.

Construction

- As with other stormwater BMPs, soils, depth to bedrock, and depth to water table must be investigated before designing a wet pond. At sites where bedrock is close to the surface, high excavation costs may make wet ponds infeasible. If the soils on site are relatively permeable or well drained, it will be difficult to maintain a permanent pool. In this situation, it may be necessary to line the bottom of the wet pond to reduce infiltration.
- All local, state and federal permit requirements should be established prior to initiating the pond design. Depending on the location of the pond, required permits and certifications may include wetland permits, water quality certifications, dam safety permits, sediment and erosion control plans, waterway permits, local grading permits, land use approvals, etc. Since many states and municipalities are still in the process of developing or modifying storm water permit requirements, the applicable requirements should be confirmed with the appropriate regulatory authorities.
- Pond systems can perform well in cold climates because many modification options are available to increase their effectiveness in frigid and snowy conditions. Many of these modifications address the problems associated with pipe freezing (Oberts, 1991 and CWP, 1997).

Maintenance

- Maintenance is required for the proper operation of wet ponds. Plans for wet ponds should identify owners, parties responsible for maintenance, and an inspection and maintenance schedule for wet ponds.
- Once constructed, the wet pond should be inspected after several storm events to confirm drainage system functions, bank stability, and vegetation growth. Problems should be addressed immediately.
- Accumulated trash and debris should be removed from the side slopes, embankment, emergency spillway and weird trash gates as often as needed (at least twice during the growing season). Accumulated sediment in the forebay should be inspected at the same time.
- Wet ponds should be inspected at least twice per year during the growing season to ensure that they are operating as designed. Potential problems that should be checked include: subsidence, erosion, cracking or

Wet Ponds

Maintenance Requirements (continued)

tree growth on the embankment; damage to the emergency spillway; sediment accumulation around the outlet; and erosion within the basin and banks. Any necessary repairs should be made immediately. During inspections, changes to the wet pond or the contributing watershed should be noted, as these may affect basin performance.

- Sediment should be removed from the pond as necessary, and at least once every 5 to 25 years (usually more frequently than once every 25 years). The frequency of sediment removal depends on the years of sediment accumulation that were incorporated into the design volume of the wet pond's permanent pool and forebay and on the occurrence of any high-loading events.
- In most cases, no specific limitations have been placed on disposal of sediments removed from wet detention ponds. Studies to date indicate that pond sediments are likely to meet toxicity limits and can be safely landfilled. On-site sediment disposal is always preferable (if local authorities permit) as long as the sediments are deposited away from the shoreline to prevent their reentry into the pond and away from recreation areas, where they could possibly be ingested by young children.
- Sediments should be tested for toxicants in compliance with current disposal requirements if land uses in the catchment include commercial or industrial zones, or if visual or olfactory indications of pollution are noticed.
- Mosquito control, if necessary.

Wet Ponds

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