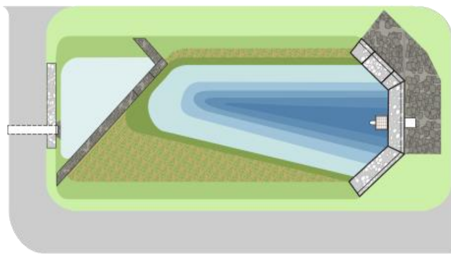
9.11 WET PONDS



Wet ponds, also known as retention basins, are used to address the stormwater quantity and quality impacts of land development. This type of stormwater facility has an elevated outlet structure that creates a permanent pool where stormwater runoff is detained and attenuated. Wet ponds can be designed as multi-stage, multi-function systems; extended detention in the permanent pool provides pollutant treatment for runoff from the Water Quality Design Storm through sedimentation and biological processing; detention and attenuation are also provided for larger storm event through the higher elevation outlets. When designed in accordance with this chapter, the total suspended solids (TSS) removal rate is 50 - 90%, depending upon the storage volume in the permanent pool and the duration of detention time, if extended detention is provided.

N.J.A.C. 7:8 Stormwater Management Rules - Design and Performance Standards		
	Nonstructural	Not Allowed
	Water Quantity	Yes, when designed as an on-line system
GR	Groundwater Recharge	Not Allowed
%	Water Quality	50% TSS removal with 1:1 pool volume ratio; up to 90% TSS removal if extended detention is also provided

Water Quality Mechanisms and Corresponding Criteria	
Settling	
Minimum Ratio of Permanent Pool Volume to WQ Design Storm Runoff	1:1
12 to 24-Hour Extended Detention	Optional
Recommended Minimum Pool Length to Width Ratio	3:1
Presence of a Permanent Pool	Required
Surface Area of Permanent Pool	Minimum of 0.25 acre

Introduction

Wet ponds, also known as retention basins, are used to address the stormwater quantity and quality impacts of land development. This type of stormwater facility has an elevated outlet structure that creates a permanent pool where stormwater runoff is detained and attenuated. Wet ponds can be designed as multi-stage, multi-function systems; extended detention in the permanent pool provides pollutant treatment for runoff from the Water Quality Design Storm through sedimentation and biological processing; detention and attenuation is also provided for larger storm event through the higher elevation outlets.

Wet ponds can also be used to provide wildlife habitat, recreational benefits and water supply for fire protection; they can also be used to enhance the aesthetics of a site. However, these systems are designed primarily for stormwater treatment, so they should not be located within natural areas because they will not have the same range of ecological function.

Wet ponds must have a maintenance plan and should be protected by easement, deed restriction, ordinance or other legal measures that prevent its neglect, adverse alteration, or removal.

Applications

Wet ponds may be designed to reduce peak runoff rates when designed as an on-line system which provides storage volume to accommodate runoff from larger design storms. Regardless of the design storm chosen, wet ponds must be designed for stability in accordance with the *Standards for Soil Erosion and Sediment Control in New Jersey,* as required by N.J.A.C. 7:8.

To receive credit for a TSS removal rate of 50%, wet ponds must be designed to treat the runoff generated by the Water Quality Design Storm and in accordance with all of the criteria below. The removal rate can be increased by providing 12 to 24 hours of extended detention or increasing the volume ratio of the permanent pool to Water Quality Design Storm.

Design Criteria

Basic Requirements

The following design criteria apply to all wet ponds and must be met in order to receive the 50 - 90% TSS removal rate for this BMP. It is critical that all wet ponds are designed in accordance with these criteria in order to ensure proper operation, to maximize the functional life of the system, and to ensure public safety. Additional considerations are presented in the section beginning on page 9.

Minimum Inflow Drainage Area

- In order to function properly, wet ponds must have a minimum inflow drainage area of 20 acres. Smaller drainage areas may be permissible if detailed analysis indicates that sufficient base or groundwater flow is available to maintain the permanent pool depth. A water budget must be included in this analysis. A wet pond water budget consists of the calculated analysis of soil inundation or saturation within 1 foot of the ground surface for consecutive days that represent at least 12.5% of the growing season (approximately 30 consecutive days). All of the inputs to and outputs from the wet pond must be considered; this includes runoff, flooding, groundwater inflow, evapotranspiration, and groundwater outflow. For more information on water budgets, see the *Regionalized Water Budget Manual for Compensatory Wetland Mitigation Sites in New Jersey* at http://www.nj.gov/dep/landuse/download/mit_011.pdf.

Minimum Geometry

- The minimum permanent pool surface area is 0.25 acres.

- The minimum required ratio of the permanent pool volume to the Water Quality Design Storm volume is 1:1.

Detention Time

- In systems providing extended detention, the minimum detention time that can be used to calculate the TSS removal rate is 12 hours, and the maximum detention time that can be used to calculate the TSS removal rate is 24 hours.

Permanent Pool

- It is crucial for a wet pond to maintain its permanent pool level; if the soil at the site is not sufficiently impermeable to prevent excessive seepage, construction of an impermeable liner or other soil modifications will be necessary.

Safety

- Safety ledges must be constructed on the slopes of all wet ponds with a permanent pool deeper than 3 feet. Two ledges must be constructed, each 4 to 6 feet in width. The first ledge must be located between 1 and 1.5 feet above the permanent pool level; the second ledge must be constructed approximately 2.5 feet below the permanent pool level.

Outlet Structure

- The minimum diameter of any outlet orifice in a wet pond is 2.5 inches, as required by N.J.A.C. 7:8-5.7(a)4; additional information regarding outlet structures can be found in the Residential Site Improvement Standards at N.J.A.C. 5:21-7.

- Trash racks must be installed at the intake to the outlet structure. They must also be designed to avoid acting as the hydraulic control for the system, and they must meet the following criteria, as required by N.J.A.C. 7:8-5.7(a)2 and 6.2(a):

  - Parallel bars spaced at 1-inch intervals, up to the elevation of the Water Quality Design Storm,
  - Minimum bar spacing: 1 inch, for elevations in excess of the Water Quality Design Storm,
  - Maximum bar spacing: 1/3 the diameter of the orifice or 1/3 the width of weir, with a maximum spacing of 6 inches, for elevations in excess of the Water Quality Design Storm,
  - Maximum average velocity of flow through clean rack: 2.5 feet/second, under full range of stage and discharge, computed on the basis of the net area of opening through rack,
  - Constructed of rigid, durable and corrosion-resistant material, and
  - Designed to withstand a perpendicular live loading of 300 lbs./s.f.

- All wet ponds must be designed to safely convey overflows to downstream drainage systems. The design of the overflow structure must be sufficient to provide safe, stable discharge of stormwater in the event of an overflow. Safe and stable discharge minimizes the possibility of erosion and flooding in down-gradient areas. Therefore, discharge in the event of an overflow must be consistent with the current version of *Standard for Off-Site Stability* found in the *Standards for Soil Erosion and Sediment Control in New Jersey*, as required by N.J.A.C. 7:8. Wet ponds classified as dams under the NJDEP Dam Safety Standards at N.J.A.C. 7:20 must also meet the overflow requirements of these Standards, including safe conveyance of the wet pond's spillway design storm.

Wet Pond Essentials of Pollutant Removal

Pollutants in runoff are treated in wet pond systems by both chemical reactions and the physical processes of dispersion and settling. These processes work most efficiently under ideal plug-flow conditions; under these conditions, a pulse of runoff enters the wet pond and is treated as it moves through the system. In order to simulate these conditions, wet ponds should be designed to maximize the length-to-width ratio.

In addition to plug-flow conditions, pollutant removal is also directly affected by the surface area of the permanent pool; the settling rate of particulate solids increases with increasing surface area. The surface area of the permanent pool is dependent on site topography, minimum and maximum pool depths, and the desired settling rate; however, as previously mentioned, the minimum required permanent pool surface area is 0.25 acres.

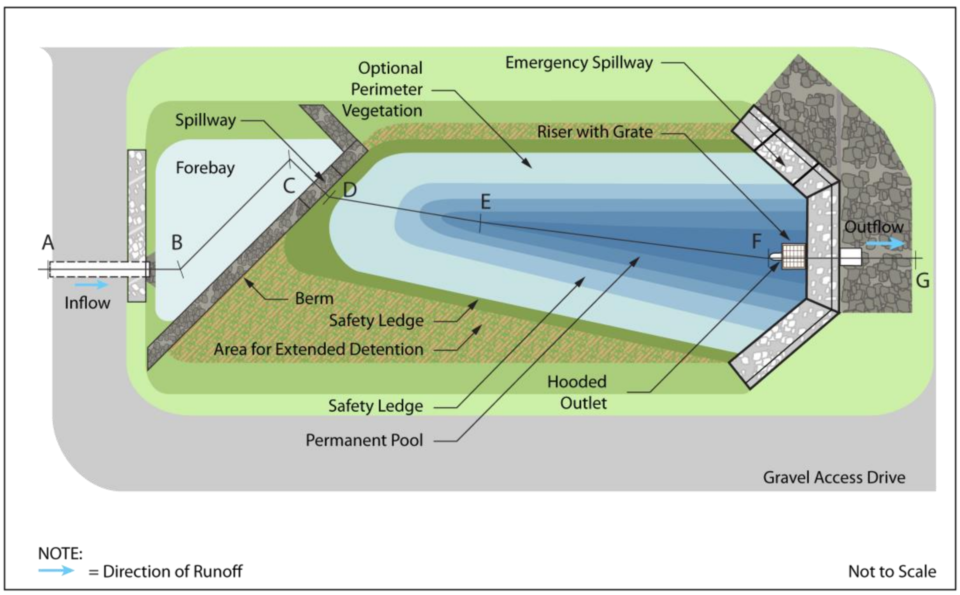
The depth of the permanent pool is another important design parameter. The permanent pool should be shallow enough to avoid thermal stratification, which can cause short-circuiting and anaerobic conditions in bottom waters; however, it must also be deep enough to minimize algal blooms and resuspension of previously deposited materials by subsequent storms and strong winds. The mean depth of the permanent pool is calculated by dividing the storage volume of the permanent pool by the pool surface area. A mean depth of 3 to 6 feet is normally sufficient to maintain a healthy environment within the permanent pool.

The outlet structure or riser should be located in a deep area of the permanent pool to facilitate withdrawal of cold bottom water; this will help mitigate any downstream thermal impacts. Additional information regarding outlet structures can be found in the *Standards for Soil Erosion and Sediment Control in New Jersey.*

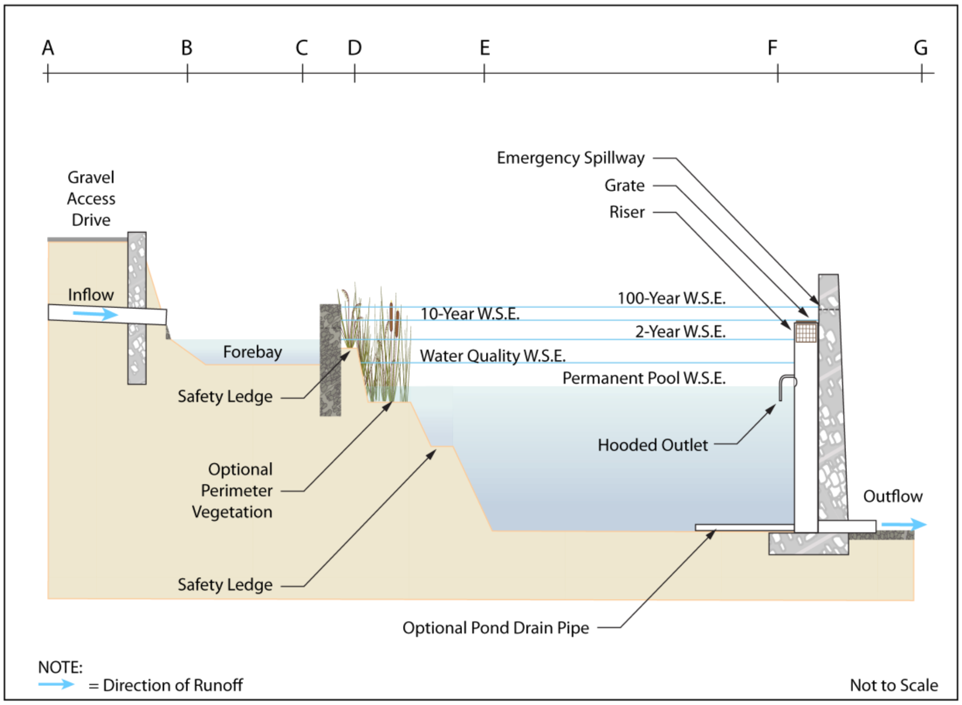
The hydraulic design of the outlet structure, outlet pipe, and emergency spillway in a wet pond must consider any significant tailwater effects of downstream waterways or facilities, including instances where the permanent pool level is below the flood hazard area design flood elevation of the receiving stream.

The following two illustrations depict the various components comprising a wet pond in both plan and profile view. The lettered path shown in the plan view represents the alignment along which an imaginary slice was made to prepare the corresponding profile view.

Wet Pond - Plan View



Wet Pond - Profile View



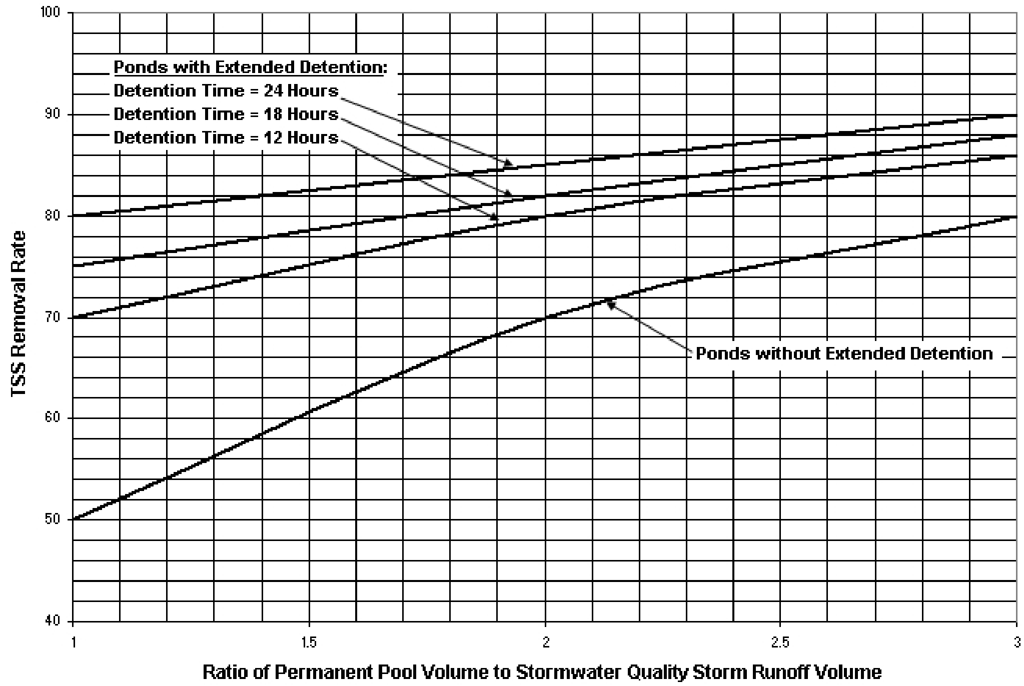
TSS Removal Rates for Wet Ponds

Wet ponds should be designed to treat the volume generated by the Water Quality Design Storm. Techniques to compute this volume are discussed in *Chapter 2: Computing Stormwater Runoff Rates and Volumes*. The TSS removal rate for a wet pond is determined by the ratio of its permanent pool volume to the Water Quality Design Storm volume. The minimum required ratio is 1:1; at this minimum ratio, the wet pond would have a TSS removal rate of 50%. TSS removal rates will increase as the ratio of the permanent pool volume to the Water Quality Design Storm volume increases; the maximum TSS removal rate for a wet pond designed without extended detention is 80% at a 3:1 ratio.

In systems that provide extended detention above the permanent pool water surface elevation, TSS removal rates are also determined by detention time. Definitions and details of extended detention are presented in *Chapter 9.4: Extended Detention Basins*.

The following chart shows the TSS removal rate of wet pond systems based on the ratio of the permanent pool volume to the Water Quality Design Storm volume and detention time. The maximum TSS removal rate for a wet pond is 90%; to achieve this TSS removal rate, the system must be designed with 24-hours of extended detention and a 3:1 ratio of permanent pool volume to Water Quality Design Storm runoff volume.

TSS Removal Rate of Wet Pond Systems



The following example illustrates how to use the chart to determine the TSS removal rate provided:

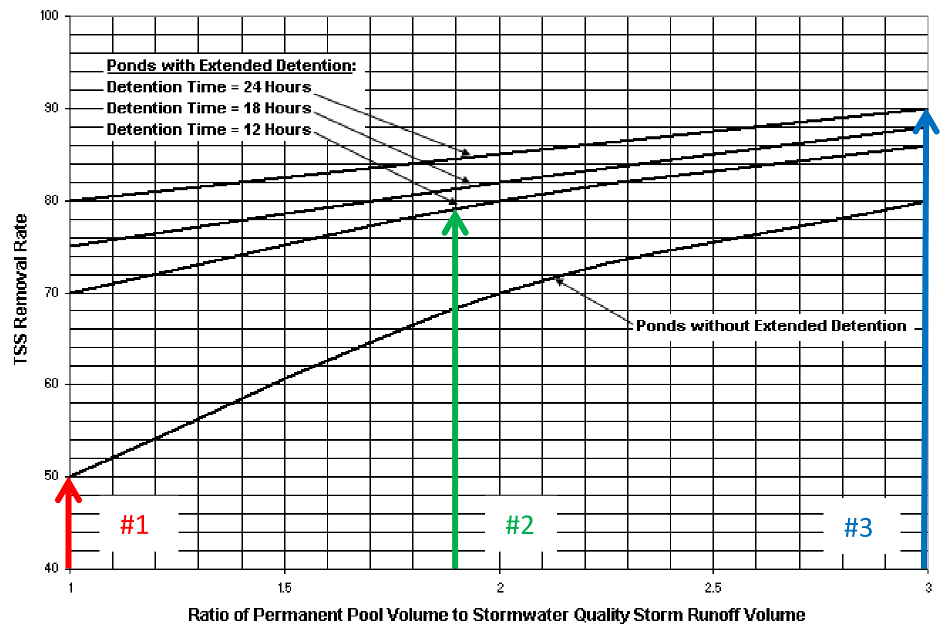
Example: A number of pond designs are to be evaluated for TSS removal rates.

Design Number	Permanent Pool Volume (ac-ft)	WQ Runoff Volume	Extended Detention Period			Ratio of Permanent Pool to WQ Runoff	% TSS Removal
			12 Hr	18 Hr	24 Hr		
1	1.246	1.246	-	-	-		
2	2.764	1.481	X	-	-		
3	0.704	0.058	-	-	X		

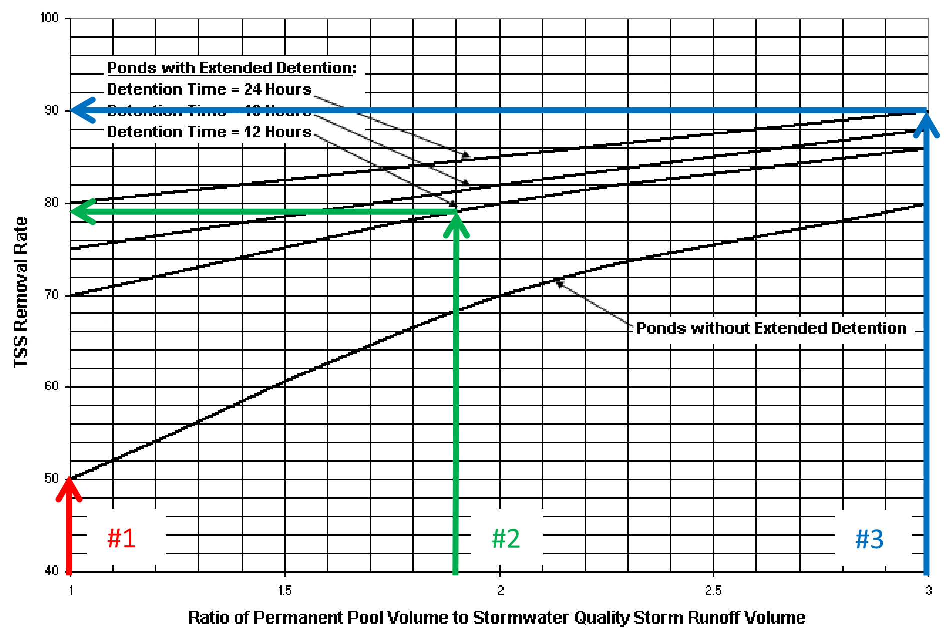
Step #1: For each row, determine the ratio of the Permanent Pool Volume to the Water Quality Design Storm Runoff Volume.

Design Number	Permanent Pool Volume (ac-ft)	WQ Runoff Volume	Extended Detention Period			Ratio of Permanent Pool to WQ Runoff	% TSS Removal
			12 Hr	18 Hr	24 Hr		
1	1.246	1.246	-	-	-	1.0	
2	2.764	1.481	X	-	-	1.9	
3	0.704	0.058	-	-	X	12.1	

Step #2: For each design, find the ratio along the x-axis and project up towards the curves. If the ratio is greater than 3.0, use 3.0. Stop at the curve that matches the period of extended detention the wet pond provides. Design #1 provides no extended detention; therefore, the lowest curve is used to determine the TSS removal rate. Designs #2 and 3 provide extended detention and therefore, use the upper set of curves.



Step #3: For each design, now draw a horizontal line from right to left over to the y-axis to get the TSS removal rate.



The resulting percent TSS Removal Rates appear in the last column of this table.

Design Number	Permanent Pool Volume (ac-ft)	WQ Runoff Volume	Extended Detention Period			Ratio of Permanent Pool to WQ Runoff	% TSS Removal
			12 Hr	18 Hr	24 Hr		
1	1.246	1.246	-	-	-	1.0	50%
2	2.764	1.481	X	-	-	1.9	79%
3	0.704	0.058	-	-	X	12.1	90%

Considerations

A number of factors should be considered when utilizing a wet pond to treat stormwater runoff.

Pretreatment

Pretreatment can extend the functional life of a wet pond by reducing incoming velocities and capturing coarser sediments. Pretreatment can also increase the pollutant removal capability of the system.

- Pretreatment may consist of a forebay or any of the structural BMPs found in *Chapter 9: Structural Stormwater Management Measures*.
- There is no adopted TSS removal rate associated with forebays; therefore, their inclusion in any design should be solely for the purpose of facilitating maintenance. Forebays can be earthen, constructed of riprap, or made of concrete, and must comply with the following requirements:
  - The forebay must be designed to prevent scour of the receiving basin by outflow from the forebay.
  - The forebay should provide a minimum storage volume of 10% of the Water Quality Design Storm and be sized to hold the sediment volume expected between clean-outs.
  - It should fully drain within nine hours in order to facilitate maintenance and to prevent mosquito issues. Under no circumstances should there be any standing water in the forebay 72 hours after a precipitation event.
  - Surface forebays must meet or exceed the sizing for preformed scour holes in the *Standard for Conduit Outlet Protection* in the *Standards for Soil Erosion and Sediment Control in New Jersey* for a surface forebay.
- If a concrete forebay is utilized, it must have at least two weep holes to facilitate low level drainage.
- When using a structural BMP for pretreatment, it must be designed in accordance with the design requirements outlined in the respective chapter. For additional information on the design requirements of each structural BMP, refer to the appropriate chapter in this manual.

Designing for Pollutant Removal

When designing a wet pond for pollutant removal, there are two different strategies that can be utilized: sedimentation and controlled eutrophication. While both strategies relate pollutant removal efficiencies to hydraulic residence time, the choice of one strategy over the other will largely depend on the target pollutants and both site and economic constraints.

Sedimentation wet ponds treat pollutants entirely through settling; therefore pollutant removal can be maximized by increasing the hydraulic residence time. The recommended minimum length to width ratio of these types of systems is 3:1; in cases where this cannot be achieved, baffles or berms may be added within the pond to increase the travel length and residence time. The design criteria in this chapter are for wet pond systems that rely on the sedimentation strategy; these types of systems are particularly useful where there is a wide range of pollutants adsorbed to suspended solids.

The controlled eutrophication strategy relies on the biological, chemical and physical processes that occur in natural lake systems to treat the pollutants in stormwater runoff. When utilizing this strategy, the designer is creating a wet pond with conditions conducive to eutrophication, specifically longer residence times and larger storage volumes. This type of strategy is particularly useful in cases where nutrients are the concern.

Permanent Pool

There are a number of factors to consider when deciding if a wet pond is suitable for a specific site, particularly the inflow drainage area. As mentioned previously, sufficient dry weather or base flow is necessary to maintain both water quality and dissolved oxygen levels and to control mosquito breeding. An adequate and regular inflow of surface or groundwater will allow for aeration of the permanent pool. In addition to increased dissolved oxygen levels, the regular inflow of water will result in a certain amount of agitation of the water surface; without this agitation, a wet pond can quickly become suitable mosquito breeding habitat. Where sufficient oxygen levels and mixing will be difficult to achieve, a fountain or aerator may be included. If a wet pond is designed for exchange with groundwater, consideration must be given to the types and amount of pollutants expected to be treated by the wet pond; all efforts must be made to ensure that wet ponds designed in this manner do not contribute to groundwater contamination. Finally, consideration must be given to safety around the permanent pool; local safety requirements in excess of those required by this chapter must be addressed in the design of any wet pond.

Thermal Effects

In addition to the above considerations, the selection of a wet pond for a specific site may be limited by the discharge of heated water from the permanent pool during the summer months. Because the permanent pool can act as a heat sink between storm events, runoff discharged from a wet pond may be as much as 10°F warmer than the naturally occurring baseflow in the downstream waterway; additionally, runoff to wet ponds from large impervious surfaces can also significantly raise the temperature of runoff in the system. These elevated temperatures may have adverse impacts, not only on the wildlife utilizing the permanent pool, but also on downstream waterbodies that have temperature-dependent designated uses, such as trout production. Therefore, wet pond designers should pay special attention to the potential of thermal effects on downstream water bodies supporting cold water fisheries. For more information on surface water quality designations, including designated uses, see N.J.A.C. 7:9(A) or http://www.state.nj.us/dep/wms/bwqsa/swqs.htm#1

Thermal impacts of wet ponds may be mitigated in a number of ways. For example, the use of a deep permanent pool with the outlet structure positioned near the lowest elevation allows for discharge of colder bottom water. The planting of shade trees around the perimeter of a wet pond can also help reduce the discharge of heated water by reducing the solar warming of the pool. Finally, designing a wet pond to consist of a series of pools, as opposed to a single pool, can allow cooling to occur prior to discharge into a downstream waterway.

Perimeter Vegetation

A wet pond may be designed to incorporate a dense growth of wetland vegetation along its perimeter. These vegetation stands are generally 10 to 15-foot wide swaths and are approximately 6 - 12 inches below the permanent pool surface. In addition to enhancing the aesthetics of a wet pond, vegetation also improves the performance of a system in a number of ways. First, vegetation can uptake many soluble pollutants, specifically nutrients; this limits the amount of nutrients available to a pond system, aiding in minimizing algal blooms. The wetland substrate in these stands is also an ideal environment for bacteria, which further aids in pollutant treatment by metabolizing organic matter and nutrients. The location of these stands along the perimeter also helps to stabilize slopes of the wet pond in areas where wave action could otherwise cause erosion. Finally vegetation can help control waterfowl utilization of the wet pond; perimeter plantings obstruct the line of site most waterfowl require to alert them to the presence of predators.

When considering the addition of perimeter vegetation to a wet pond, native species are preferred; however, it is best when choosing plants to consider the prospects of establishing a healthy plant community. Perimeter vegetation should consist of species that are water-tolerant and adapted to similar soil and weather conditions. In addition, species that are tolerant to periodic inundation and increased contact with pollutants tend to fare best in these systems. Adequate depth of topsoil should also be provided; a minimum soil thickness of 6 inches is recommended.

Maintenance

Regular and effective maintenance is crucial to ensure effective wet pond performance; in addition, maintenance plans are required for all stormwater management facilities associated with a major development, pursuant to N.J.A.C. 7:8-5.8. There are a number of required elements in all maintenance plans; these are discussed in more detail in *Chapter 8: Maintenance of Stormwater Management Measures*. Furthermore, maintenance activities are required through various regulations, including the New Jersey Pollutant Discharge Elimination System (NJPDES) Rules, N.J.A.C. 7:14A. Specific maintenance requirements for wet ponds are presented below; these requirements must be included in the wet pond's maintenance plan. In addition, the frequency of a clean out cycle for a wet pond should be considered in the maintenance plan since wet ponds are intended to accumulate sediment. The cleanout cycle for a wet pond in a stabilized watershed can vary, with an average cycle of approximately 10 years.

General Maintenance

- All wet pond components expected to receive and/or trap debris and sediment must be inspected for clogging and excessive accumulation at least twice annually, or as needed; these components may include forebays, bottoms, trash racks, outlet structures, and riprap or gabion aprons.
- The forebay must be cleaned when it accumulates either 6 inches of sediment, there is a 10% loss of forebay volume, or if it remains wet 9 hours after the end of a storm event.
- Disposal of debris, trash, sediment and other waste material must be done at suitable disposal/recycling sites and in compliance with all applicable local, state and federal waste regulations.
- All structural components must be inspected, at least once annually, for cracking, subsidence, spalling, erosion and deterioration.

Vegetated Areas

- When establishing or restoring vegetation, inspections should be performed biweekly.
- Once established, inspections of health, density and diversity should be performed at least twice annually during both the growing and non-growing seasons.
- The vegetative cover must be maintained at 85%; if vegetation has greater than 50% damage, the area must be reestablished in accordance with the original specifications and the inspection requirement above.
- Mowing/trimming of vegetation must be performed on a regular schedule based on specific site conditions; perimeter grass should be mowed at least once a month during growing season.
- Vegetated areas must be inspected at least once annually for erosion, scour and unwanted growth; any unwanted growth should be removed with minimum disruption to the remaining vegetation.

- All use of fertilizers, pesticides, mechanical treatments and other means to ensure optimum vegetation health must not compromise the intended purpose of the sand filter.

Drain Time

- The approximate time it would normally take to completely drain the Water Quality Design Storm volume above the permanent pool must be indicated in the maintenance manual.

- If the actual drain time is significantly different from the design drain time, the components that could provide hydraulic control must be evaluated and appropriate measures taken to return the wet pond to minimum and maximum drain time requirements.

- If the actual drain time is significantly different than the design drain time, the outlet structure and both groundwater and tailwater levels must be evaluated and appropriate measures taken to comply with the maximum drain time requirements.

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