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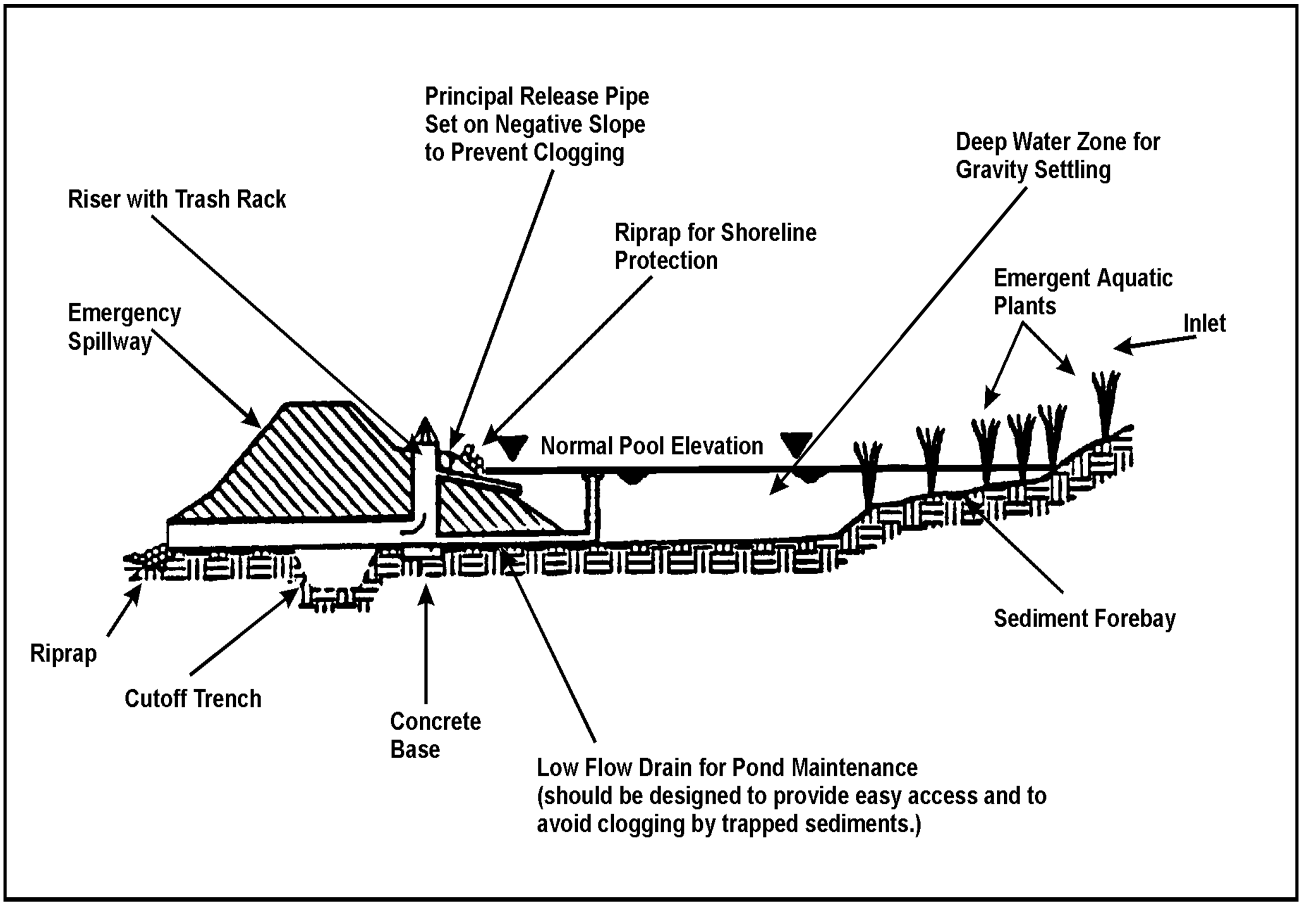
Storm Water Technology Fact Sheet
Wet Detention Ponds

DESCRIPTION

Wet detention ponds are storm water control structures providing both retention and treatment of contaminated storm water runoff. A typical wet detention pond design is shown in Figure 1. The pond consists of a permanent pool of water into which storm water runoff is directed. Runoff from each rain event is detained and treated in the pond until it is displaced by runoff from the next storm. By capturing and retaining runoff during storm events, wet detention ponds control both storm water quantity and quality. The pond's natural physical, biological, and chemical processes then work to remove pollutants. Sedimentation processes remove particulates, organic matter, and metals, while dissolved metals and nutrients are removed through biological uptake. In general, a higher level of nutrient removal and better storm water quantity control can be achieved in wet



Source: Maryland Department of the Environment, 1986.

FIGURE 1 TYPICAL LAYOUT OF A WET DETENTION POND

detention ponds than can be achieved with other Best Management Practices (BMPs), such as dry ponds, infiltration trenches, or sand filters.

There are several common modifications that can be made to the ponds to increase their pollutant removal effectiveness. The first is to increase the settling area for sediments through the addition of a sediment forebay, as shown in Figure 1. Heavier sediments will drop out of suspension as runoff passes through the sediment forebay, while lighter sediments will settle out as the runoff is retained in the permanent pool. A second common modification is the construction of shallow ledges along the edge of the permanent pool. These shallow peripheral ledges can be used to establish aquatic plants that can impede flow and trap pollutants as they enter the pond. The plants also increase biological uptake of nutrients. In addition to their function as aquatic plant habitat, the ledges also have several other functions, which can include including acting as a safety precaution to prevent accidental drowning and providing easy access to the permanent pool to aid in maintenance. Finally, perimeter wetland areas can also be created around the pond to aid in pollutant removal.

APPLICABILITY

Wet detention ponds have been widely used throughout the U.S. for many years. Many of these ponds have been monitored to determine their performance. EPA Region V is currently performing a study on the effectiveness of 50 to 60 wet detention ponds. Other organizations, such as the Washington, D.C., Council of Governments (WMCOG) and the Maryland Department of the Environment, have also conducted extensive evaluations of wet detention pond performance.

ADVANTAGES AND DISADVANTAGES

Wet detention ponds provide both storm water quantity and quality benefits, and provide significant retrofit coverage for existing development. Benefits include decreased potential for downstream flooding and stream bank erosion and improved water quality due to the removal of suspended solids, metals, and dissolved nutrients.

While the positive impacts from a wet detention ponds will generally exceed any negative impacts, wet detention ponds that are improperly designed, sited, or maintained, may have potential adverse affects on water quality, groundwater, cold water fisheries, or wetlands. Improperly designed or maintained ponds may result in stratification and anoxic conditions that can promote the resuspension of solids and the release of nutrients and metals from the trapped sediments. In addition, precautions should be taken to prevent damage to wetland areas during pond construction. Finally, the potential for groundwater contamination should be carefully evaluated. However, studies to date indicate that wet detention ponds do not significantly contribute to groundwater contamination (Schueler, 1992).

The following limitation should also be considered when determining the feasibility of installing a wet detention pond:

1. Wet detention ponds must be able to maintain a permanent pool of water. Therefore, ponds cannot be constructed in areas where there is insufficient precipitation to maintain the pool or in soils that are highly permeable. In wetter regions, a small drainage area may be sufficient to ensure that there is enough water to maintain a permanent pool; whereas in more arid regions, a larger drainage area may be required. In some cases, soils that are highly permeable may be compacted or overlaid with clay blankets to make the bottom less permeable.

2. Land constraints, such as small sites or highly developed areas, may preclude the installation of a pond.

3. 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.

4. The local climate (i.e., temperature) may affect the biological uptake in the pond.

5. Without proper maintenance, the performance of the pond will drop off sharply. Regular cleaning of the forebays is particularly important. Maintaining the permanent pool is also important in preventing the resuspension of trapped sediments. The accumulation of sediments in the pond will reduce the pond's storage capacity and cause a decline in its performance. Therefore, the bottom sediments in the permanent pool should be removed about every 2 to 5 years. 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 (NVPDC, 1992). Some states have allowed sediment disposal on-site, as long as the sediments are deposited away from the shoreline to prevent their re-entry into the pond.

DESIGN CRITERIA

In general, pond designs are unique for each site and application. Criteria for selecting the site for installation of the pond should include the site's ability to support the pond environment, as well as the cost effectiveness of locating a pond at that specific site. In addition, the pond should be located where the topography of the site allows for maximum storage at minimum construction costs (NVPDC, 1992). Site-specific constraints for pond construction may include wetlands impacts, existing utilities (e.g., electric or gas) that would be costly to relocate, and underlying bedrock that would require expensive blasting operations to excavate.

The site must have adequate base-flow from the groundwater or from the drainage area to maintain the permanent pool. Typically, underlying soils with permeabilities of between 10^{-5} and 10^{-6} cm/sec will be adequate to maintain a permanent pool.

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.(Schueler, 1992). 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.

Wet detention 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.

Storm water quality control is achieved through pollutant removal in the permanent pool. 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 detention ponds remove pollutants through both sedimentation and biological uptake processes, both of which increase with the length of time runoff remains in the pond. These processes can be modeled to determine a design HRT using either the solids settling method or the eutrophication method, respectively (Hartigan, 1988).

The calculated HRT will be dependent on the method selected. HRTs calculated by the eutrophication method can be up to three times greater than HRTs calculated by the solids settling method. The longer HRTs associated with the eutrophication method appear to be due to the slower reaction rates associated with the biological removal of dissolved nutrients (Hartigan, 1988).

Once the design HRT has been determined, the actual dimensions of the pond must be calculated to achieve the design HRT. The primary factor contributing to a pond's HRT is its volume. Because many wet detention ponds are restricted in area, pond depth can be an important factor in the pond's overall volume. However, the depth of the pool also affects many of the pond's removal processes, and so it must be carefully controlled. It is important to maintain a sufficient permanent pool depth in order to prevent the resuspension of trapped sediments (NVPDC, 1992). Conversely, thermal stratification and anoxic conditions in the bottom layer might develop if permanent pool depths are too great. Stratification and anoxic conditions may decrease biological activity. Anoxic conditions may also increase the potential for the release of phosphorus and heavy metals from the pond sediments (NVPDC, 1992). These factors dictate that the permanent pool depth should not exceed 6 meters (20 feet). The optimal depth ranges between 1 and 3 meters (3 and 9 feet) for most regions, given a 2 week HRT (Hartigan, 1988).

Other key factors to be considered in the pond design are the volume and area ratios. The volume ratio, VB/VR, is the ratio of the permanent pool storage (VB) to the mean storm runoff (VR). Larger VBs and smaller VRs provide for increased retention and treatment between storm events. Low VB/VR ratios result in poor pollutant removal efficiencies.

The area ratio, A/As, is the ratio of the contributing drainage area (A) to the permanent pool surface area (As). The area ratio is also an indicator of pollutant removal efficiency. Data from previous studies indicates that area ratios of less than 100 typically have better pollutant removal efficiencies (MD DEQ, 1986).

The contours of the pond are also important. The pond should be constructed with adequate slopes and lengths. While a length-to-width ratio is usually not used in the design of wet detention ponds for storm water quantity management, a 2:1 length-to-width ratio is commonly used when water quality is of concern. In general, high length-to-width ratios (greater than 2:1) will decrease the possibility of short-circuiting and will enhance sedimentation within the permanent pool. Baffles or islands can also be added within the permanent pool to increase the flow path (Hartigan, 1988). Shoreline slopes between 5:1 and 10:1 are common and allow easy access for maintenance, such as mowing and sediment removal (Hartigan, 1988). In addition, wetland vegetation is difficult to establish and maintain on slopes steeper than 10:1. Ponds should be wedge-shaped so that flow enters the pond and gradually spreads out. This minimizes the potential for zones with little or no flow (Urbonas, 1993).

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 2:1 and by covering the embankment with vegetation or rip-rap. The embankment should also have a minimum top width of 2 meters (6 feet) to aid in maintenance.

Finally, the internal flow control of the pond must be considered. Discharge from the pond is controlled by a riser and an inverted release pipe. Normal flows will be discharged through the wet pond outlet, which consists of a concrete or corrugated metal riser and barrel. The riser is a vertical pipe or inlet structure that is attached to the base with a watertight connection. Risers are typically placed in or adjacent to the embankment rather than in the middle of the pond. This provides easy access for maintenance and prevents the use of the riser as a recreation spot (e.g. diving platform for kids) (Schueler, 1988). The barrel is a horizontal pipe attached to the riser that conveys flow under the embankment.

Typically, flow passes through an inverted pipe attached to the riser, as shown in Figure 1, while higher flows will pass through a trash rack installed on the riser. The inverted pipe should discharge water from below the pond water surface to prevent floatables from clogging the pipe and to avoid discharging the warmer surface water. Clogging of the pipe could result in overtopping of the embankment and damage to the embankment (NVPDC, 1992). Flow is conveyed through the near horizontal barrel and is discharged to the receiving stream. Rip-rap, plunge pools, or other energy dissipators, should be placed at the outlet to prevent scouring and to minimize erosion. Rip-rap also provides a secondary benefit of re-aeration of the pond discharges.

Planners should consider both the design storm and potential construction materials when designing and constructing the riser and barrel. Generally, the riser and barrel are sized to meet the storm water management design criteria (e.g. to pass a 2-year or a 10-year storm event). In many installations, the riser and barrel are designed to convey multiple design storms (Urbonas, 1993). To increase the life of the outlet, the riser and barrel should be constructed of reinforced concrete rather than corrugated metal pipe (Schueler, 1992). The riser, barrel, and base should also provide have sufficient weight to prevent flotation (NVPDC, 1992).

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 a low flow drain, as shown in Figure 1. The drain pipe should be designed for gravity discharge and should be equipped with an adjustable gate valve.

PERFORMANCE

The primary pollutant removal mechanism in a wet detention pond is sedimentation. Significant loads of suspended pollutants, such as metals, nutrients, sediments, and organics, can be removed by sedimentation. Other pollutant removal mechanisms include algal uptake, wetland plant uptake, and bacterial decomposition (Schueler, 1992). Dissolved pollutant removal also occurs as a result of biological and chemical processes (NVPDC, 1992).

The removal rates of conventional wet detention ponds (i.e., without the sediment forebay or peripheral ledges) are well documented and are shown in Table 1. The wide range in the removal rates is a result of varying hydraulic residence times (HRTs), which is further discussed in the Design Criteria section. Increased pollutant removal by biological uptake and sedimentation is correlated with increased HRTs. Proper design and maintenance also effect pond performance.

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

TABLE 1 REMOVAL EFFICIENCIES FROM WET DETENTION PONDS

Parameter	Percent Removal	
	Schueler, 1992	Hartigan, 1988
Total Suspended Solid	50-90	80-90
Total Phosphorus	30-90	
Soluble Nutrients	40-80	50-70
Lead	70-80	
Zinc	40-50	
Biochemical Oxygen Demand or Chemical Oxygen Demand	20-40	

1 hydraulic residence time varies
2 hydraulic residence time of 2 weeks

Source: Schueler, 1992 & MD DEQ, 1986.

hours. These projections are supported by the results of the EPA's 1993 National 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).

The pond's treatment efficiency can be enhanced by extending the detention time in the permanent pool to up to 40 hours. This allows for a more gradual release of collected runoff, resulting in both increased pollutant removal and control of peak flows (Hartigan, 1988).

OPERATION AND MAINTENANCE

Wet detention ponds function more effectively when they are regularly inspected and maintained. Routine maintenance of the pond includes mowing of the embankment and buffer areas and inspection for erosion and nuisance problems (e.g. burrowing animals, weeds, odors) (SEWRPC, 1991). Trash and debris should be removed routinely to maintain an attractive appearance and to prevent the outlet from becoming clogged. In general, wet detention ponds should be inspected after every storm event. The embankment and emergency spillway should also be routinely inspected for structural integrity, especially after major storm events. Embankment failure could result in severe downstream flooding. When any problems are observed during routine inspections, necessary repairs should be made immediately. Failure to correct minor problems may lead to larger and more expensive repairs or even to pond failure. Typically, maintenance includes repairs to the embankment, emergency spillway, inlet, and outlet; removal of sediment; and control of algal growth, insects, and odors (SEWRPC, 1991). Large vegetation or trees that may weaken the embankment should be removed. Periodic maintenance may also include the stabilization of the outfall area (e.g. adding rip-rap) to prevent erosive damage to the embankment and the stream bank. In most cases, sediments removed from wet detention ponds are suitable for landfill disposal. However, where available, on-site use of removed sediments for soil amendment will reduce maintenance costs.

COSTS

Typical costs for wet detention ponds range from \$17.50-\$35.00 per cubic meter (\$0.50-\$1.00 per cubic foot) of storage area (CWP, 1998). The total cost for a pond includes permitting, design and construction, and maintenance costs. Permitting costs may vary depending on state and local regulations. Typically, wet detention ponds are less costly to construct in undeveloped areas than to retrofit into developed areas. This is due to the cost of land and the difficulty in finding suitable sites in developed areas. The cost of relocating pre-existing utilities or structures is also a major concern in developed areas. Several studies have shown the construction cost of retrofitting a wet detention pond into a developed area may be 5 to 10 times the cost of constructing the same size pond in an undeveloped area. Annual maintenance costs can generally be estimated at 3 to 5 percent of the construction costs (Schueler, 1992). Maintenance costs include the costs for regular inspections of the pond embankments, grass mowing, nuisance control, debris and liter removal, inlet and outlet maintenance and inspection, and sediment removal and disposal. Sediment removal cost can be decreased by as much as 50 percent if an on-site disposal areas are available (SEWRPC, 1991).

REFERENCES

1. Center for Watershed Protection, 1998. *Cost and Benefits of Storm Water BMPs*.

2. Hartigan, J.P., 1988 "Basis for Design of Wet Detention Basin BMPs," in *Design of Urban Runoff Quality Control*. American Society of Engineers. 1988.

3. Maryland Department of the Environment, 1986. *Feasibility and Design of Wet Ponds to Achieve Water Quality Control.* Sediment and Storm Water Administration.

4. Northern Virginia Planning District Commission, Engineers and Surveyors Institute, 1992. *Northern Virginia BMP Handbook*.

5. Schueler, T.R., 1992. *A Current Assessment of Urban Best Management Practices*. Metropolitan Washington Council of Governments.

6. Southeastern Wisconsin Regional Planning Commission, 1991. *Costs for Urban Nonpoint Source Water Pollution Control Measures*. Technical Report No. 31.

7. Urbonas, Ben and Peter Stahre, 1993. *Storm Water Best Management Practices and Detention for Water Quality, Drainage and CSO Management*. PTR Prentice Hall, Englewood Cliffs, New Jersey.

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