WDB

Wet Detention Basin

Description

Wet ponds are constructed basins that have a permanent pool of water throughout the year (or at least throughout the wet season). A wet detention basin is a very desirable method to satisfy both stormwater detention and stormwater quality requirements. It is applicable to most locations for which the contributing drainage area can support a permanent pool of water. A wet detention basin can be enhanced with other stormwater treatment BMPs such as a pretreatment sediment forebay, baffle box, or stormwater quality inlet.

This practice will provide a significant reduction in sediment and most types of pollutants. A wet detention basin is generally more effective than a dry detention basin at allowing sediments and other pollutants to settle out.

Selection Criteria

One primary objective is to reduce the incoming peak flow discharge and slow the stormwater runoff response for a particular property or development, thus reducing flooding downstream. Peak flow runoff after development should not be greater than it was prior to development. Procedures for preparing calculations are outlined in Section 3.4 Peak Flow Calculations, including the correct use of NRCS Technical Release 55 for determining the required detention storage.

The second primary objective is to remove suspended sediments, trash and debris, oil, grease and other pollutants to protect the water quality of local streams and channels. Wet detention basins not only allow physical settling of sediments and pollutants, but will also permit a limited amount of chemical mixing and interaction of dissolved nutrients and metals. Biological uptake will also occur to some degree within a wet detention basin. Dissolved contaminants are removed by a combination of physical adsorption to bottom sediments and suspended fine sediments, natural chemical flocculation, and uptake by aquatic plants.

Wet detention basins are ideal for large regional detention facilities; larger drainage areas are likely to have a minimum baseflow entering the system. Wet detention basins should be used if it is imperative to achieve high levels of particulate and dissolved contaminant removal. Wet ponds are among the most effective storm water management practices at removing storm water pollutants. A wide range of research is available to estimate the effectiveness of wet ponds.

Table 1: Typical Removal Rates:	
Pollutant	**Removal Rate**
Total Suspended Solids	67%
Total Phosphorous	48%
Total Nitrogen	31%
Nitrate Nitrogen	24%
Metals	24–73%
Bacteria	65%

Schueler (1987)

There is considerable variability in the effectiveness of ponds, and it is believed that properly designed and maintained ponds may help improve their performance. The International Stormwater Best Management Practice (BMP) database is a compilation of storm water practices which includes both design information and performance data for various practices. More updated efficiencies and information on this database is available from the BMP database web page at *www.bmpdatabase.org*.

Design Considerations

A permanent detention basin design must be stamped by a professional engineer licensed in the state of Tennessee. The professional engineer must be qualified by education and experience to perform the necessary hydrologic and hydraulic calculations. A wet detention basin must be located and designed so that failure of the structure will not result in danger to human life, damage to personal property, inundation of public streets or highways, interruption of public services or utilities, or inconvenience to the general public.

- Wet detention basins must be designed to have adequate detention storage and outlet structures. Multi-stage detention is required for the 1-year, 2-year, 5-year, 10-year, and 25-year in all watersheds. Additional stages (i.e., 50-year and 100-year) may be required.

- The outlet structure must be made from durable concrete or masonry construction, and typically, the outlet structure has multiple weirs and/or orifices to release the multiple design storms at predevelopment rates.

- Water quality is obtained through treatment of the first flush volume. The first flush volume is the initial ¾ inch of stormwater runoff. The initial wave of stormwater runoff is more likely to contain aerially-deposited sediments, particulates from vehicles (such as incomplete combustion, dust from brake linings, tire particles), leaves, trash, cigarette butts, etc. The first flush volume must be captured, then detained or slowly released over a 72-hour period. See Section 3.3 (First Flush/ Water Quality Requirement)

- The permanent pool storage volume should be designed with vegetation around the water surface, with riprap or non-erosive materials near inlet and outlet structures. Sediments and particulates continue to settle in the permanent pool storage volume for a few days after a rainfall event.

- Additional measures may be required to improve stormwater quality, depending upon the nature of the land use and expected pollutants. Pretreatment of stormwater runoff with a media filtration inlet or oil/water separator may be necessary. A trash rack for capturing floating debris and a floatables skimmer are generally considered to be standard equipment for a stormwater treatment BMP prior to the pond.

As a warning to those who design detention basins, it should be realized that future stormwater regulations are likely to be more stringent than the current regulations. This is mostly driven by national and state laws and regulations, which will require municipalities and county governments to accomplish additional pollution reduction with a proportional effort for water quality monitoring and enforcement.

Design Approach

The major features of a wet detention basin are shown in Figure 1 and 2. It is essentially a small pond or lake with rooted wetland vegetation along the perimeter.

The storage volume can be divided into two portions: 1) live detention storage and 2) permanent pool storage. The 'live' detention storage can be thought of as that portion of the detention storage, which is intended to be changing as water surface elevation varies.

The live detention storage (above the lowest opening in the outlet structure) provides peak flood control, erosion control and additional treatment benefits. The recommended design includes a sediment forebay (or even multiple forebays) wherever the stormwater runoff enters the wet detention basin. Live detention storage can also include areas which are not frequently inundated; these areas may have multiple recreational uses. The storage volumes necessary to limit peak flow discharges from a wet detention basin to predevelopment peak flows could be computed using TR-55. Live detention storage volume is computed using the same methods for both dry detention basins and wet detention basins.

The permanent pool storage volume (below the lowest opening in the outlet structure) provides a quiescent volume for settling of particulate contaminants and the uptake of dissolved contaminants by aquatic plants between storms. Wetland vegetation (in the littoral zone) will improve removal of dissolved contaminants, reduce the formation of algae, stabilize the shoreline and reduce waves, provide dissolved oxygen and habitats for aquatic organisms, and create attractive landscaping. The permanent pool storage volume is computed to determine a minimum residence hydraulic time, which is the average time that a drop of water is expected to remain in the wet detention basin.

Basic elements of a wet detention basin are illustrated in Figure 1 and 2. It is recommended that designs include a sediment forebay or other stormwater treatment BMPs to reduce sediment and pollutant loading. Principal elements in assessing the potential for a wet detention basin are the existing and proposed site conditions for soils, topography, vegetation, and the amount of available base flow.

Design flow paths to minimize potential short-circuiting by locating the inlets as far away from the outlet structure as possible. The length-to-width ratio of a basin should be at least 2:1 (and preferably 3:1). If topography or aesthetics require the basin to have an irregular shape, increase the basin area and volume to compensate for dead spaces. Reduce velocity of incoming stormwater with riprap or energy dissipaters.

Bedrock and topography must be considered when grading in Hamilton County area. Karst topography may indicate fractured bedrock or dissolved limestone passages, for which a detention basin would be highly detrimental. The additional water volume that is introduced to the underground limestone passages, or even the additional weight of ponded water, could intensify karst activity.

Interaction with site utilities must be considered during preliminary design. Typical utilities include electrical, telephone, cable TV, water, sewer, natural gas, petroleum, etc. These utilities may or may not be in a dedicated utility easement, so it is always necessary to conduct a careful site survey. Detention basins (including embankments) are not allowed over utility lines.

Detention basin access must be considered during preliminary design, in order to allow for construction and maintenance. Detention basins that are not frequently inspected and maintained often become more of a nuisance than a beneficial part of a stormwater management program. In particular, provide access for inspection and maintenance to the sediment forebay and to the outlet control structure. It may also be desirable to encourage or discourage public access to the detention basin (by using site grading, signs, fences or gates). Additional safety elements include trash racks, grating over pipes and culverts, gentle side slopes whenever possible, increased visibility and/or lighting in residential areas, etc.

Volume and Size

The volume of a wet detention basin consists of two elements: the live detention storage (the upper portion of the basin representing detention capability) and the permanent pool storage volume (the lower portion of the basin representing stormwater quality treatment. Detention computations should generally be checked and verified by performing routing computations.

The minimum permanent pool storage volume should have a hydraulic residence time of 14 days, based on average rainfall during the wettest month of the year. In general, a longer hydraulic residence time is desirable as it allows biological and chemical assimilation of nutrients and pollutants to continue for a longer time. In addition, since sediment removal and maintenance of a wet detention basin is very difficult and costly, additional sediment storage should be designed as part of the permanent pool volume.

Size the permanent pool volume of a wet detention basin using the following formula:

$$V_{pp} = A_T \ R$$

V_{pp} = permanent pool volume (acre-ft)

A_T = total tributary area (acres)

R = average 14-day rainfall (feet)

The average 14-day rainfall is computed using March as the wettest month of the year.

Grading

The maximum slope above the permanent pool storage volume shall generally be 4H:1V or flatter. This encourages a strong growth of vegetation on the side slopes and helps to prevent soil erosion. Steep slopes, particularly on embankments or other fill soils, contribute to soil erosion, and thereby reduce or negate the effectiveness of a wet detention basin with respect to water quality. Vegetation should be established on the side slopes and basin bottom to the maximum extent practical. If side erosion is particularly severe, consider the use of soil stabilization or armoring techniques. Do not locate detention basins immediately above or below a steep slope or grade, because impounded water may create slope stability problems.

The littoral zone is an area of the detention basin which supports rooted wetland vegetation. The littoral zone should be 1 to 2 feet below the normal water level, with a gentle slope of 6:1 (H:V) or flatter. Typically, the littoral zone is 10 feet wide. The remainder of the permanent pool storage volume may have slopes as steep as 2:1 (H:V); this portion of the wet detention basin is generally protected against rainfall, water velocities and wave action so that erosion does not occur.

The minimum width for top of embankment is 5 feet. Allow for 10% settlement of embankment, unless the embankment is thoroughly compacted with vibratory equipment or sheepsfoot rollers. The top of embankment (after expected settlement) shall generally be at least 2 feet above the top of outlet structure and at least 1 foot above the peak 100-year water surface elevation. Compaction in the immediate area of the emergency spillway can be difficult, but is necessary.

Retaining walls may be used on one or more sides of a detention basin if properly designed. Analysis of a retaining wall should include effects of saturated soil behind the retaining wall, in addition to the usual design considerations of vehicle and structural loadings above the retaining wall. In general, concrete retaining walls should not face southward in order to reduce the potential for heating on hot summer days. Using a backslope drain can increase the flow path lengths to prevent short-circuiting of the detention basin.

Outlet Structure

Detention basin outlet structures must be constructed of durable materials, such as concrete or masonry block. Corrugated metal pipe (CMP) and plastic (HDPE) risers and drain pipes are popular in engineering design, but are susceptible to crushing and flotation in detention basins. A concrete outlet structure is preferable to a masonry block structure because it is sturdier and more durable. Provisions should be made for sufficient reinforcement and anchoring.

The specific flow-controlling elements of an outlet structure may include one or more of the following: a circular orifice, a noncircular orifice, a rectangular weir, a trapezoidal weir, a triangular weir, a V-notch weir, culvert entrance control or a riser overflow opening. The V-notch weir is an efficient combination of low maintenance requirements and a wide range of flow discharges. These types of controls for outlet structures are described at length in Detention Computations BMP.

The first flush volume is typically drained during a minimum time of 24 hours by using an orifice or orifices with a designed size. Maximum drain time should be less than 72 hours to allow for sufficient volume recovery prior to the next period of rainfall.

An antivortex device for the outlet structure may be potentially needed for very large detention basins in areas where public access is not limited. The antivortex device may be a combination of vanes above the outlet structure or guide walls around the outlet structure that lessen the chance of humans drowning or reduce the potential for erosion and structural undercutting.

Emergency Spillway

An emergency spillway should be included in addition to the primary outlet structure on a retention pond. The purpose of this spillway is to pass storm events that exceed the design capacity of the pond, in order to prevent overtopping the embankment. The emergency spillway should be located over an undisturbed abutment area and not over the embankment fill for stability reasons. The emergency spillway capacity should be designed to prevent overtopping the embankment structure or dam during a storm event commensurate with the impoundment volume, dam size, and downstream flood hazard potential in event of dam failure. The minimum spillway capacity should be capable of handling a 100-year storm event. The designer is referred to the requirements set forth in the Tennessee Safe Dams Act and Regulations at: www.state.tn.us/environment/permits/safedam.htm. The Emergency Spillway should be constructed of durable materials.

Other Design Elements

A sediment forebay – to facilitate the cleanout of sediment, trash, debris, leaves, etc. The sediment forebay typically contains 5% to 10% of the total volume for a wet detention basin. It should be located at a point where velocities have dissipated, to allow large sediments and debris to settle out. A forebay can be separated from the remainder of a detention basin by several means: a lateral sill with rooted wetland vegetation, rock-filled gabion, rock retaining wall, or rock check dam placed laterally across the basin. The sediment forebay should be easily accessible so that it can be inspected and maintained.

Public safety should be considered, particularly in residential areas. Avoid steep slopes and drop-offs; consider routes for escaping the detention basin if a person had accidentally fallen in. Provide fencing and signs in areas where children may potentially play, or in areas which have deeper water. Limit access to the outlet structure.

Mosquitoes can be reduced by installing a steeper shelf transition at the water surface to reduce areas with water depths less than 12 inches. Small rock walls, gabions or other structures may help to create this shelf transition. Habitats for the introduction of Gambusia (mosquito fish) are also beneficial if the design also includes maintaining water levels for fish survival during the dry season. Water levels also need to be maintained during winter months for fish to survive the cold weather.

Antiseep collars (around the outlet pipe) and cutoff clay layers (within the embankment) are usually necessary to reduce seepage. An antiseep collar should extend at least one pipe diameter from culvert in all directions, with compacted clay backfill using small mechanical tampers.

To prevent the outlet riser from clogging, include trash racks or other debris barriers with a maximum opening size of 2 inches on all outlet structures, except for any emergency spillway structures that are designed for a 25-year storm or greater return period. Trash racks that are placed at an angle to the direction of flow are somewhat less vulnerable to clogging.

Provide means for vehicle access to the wet detention basin. Detention basins must be located in a maintenance easement so that city personnel have the right to inspect the facility. Maintenance easements that are not adjacent to a city right-of-way must also have an access easement, which allows for vehicle access without large trees or excessive vehicle grades.

Include a skimmer, oil/water separator or other type of stormwater runoff pretreatment for detention basins with a potential for oil and grease contamination. In addition to most large parking lots, oil and grease contamination is also likely for vehicle fueling and maintenance facilities.

Provide rooted vegetation at the pond perimeter, which serves several functions. Rooted vegetation enhances the removal of dissolved pollutants and reduces the formation of floating algae. It provides some habitat for insects, aquatic life, and wetland wildlife. The littoral zone for rooted vegetation should be about 10 feet wide with a water depth of 1 to 2 feet. Vegetation in general slows flow velocities and increases settling.

If placement of wetland vegetation along the perimeter is not feasible, consider the use of non-rooted wetland species (i.e. floating plants). Non-rooted vegetation is actually more effective than rooted vegetation in removing dissolved nutrients and metals. Non-rooted vegetation can be placed within floating containers to facilitate periodic removal and cleaning. Another alternative is a rock filter or bed to support non-rooted vegetation (similar to design of wastewater oxidation ponds).

Maintenance

Inspect the wet detention basin regularly (several times a year, see suggested schedules below) and particularly after heavy rainfall events. Record all observations and measurements taken. Perform any maintenance and repairs promptly. Remove debris and trash after storm events. Check outlet structure regularly for clogging.

Remove sediment from forebay regularly to prevent resuspension or movement. The wet detention basin should be dredged or excavated when 10% of permanent pool storage volume has been lost. Sediment removal in a wet detention basin is a major effort requiring dewatering, difficult equipment access, wet soils, and some loss of wildlife and vegetation. Sediment may be permitted to accumulate if the detention basin volume has been overdesigned with adequate controls.

Maintain a thick and healthy stand of vegetation. Mow or trim at regular intervals to encourage thick growth. Remove leaves, grass clippings, or sticks from the wet detention basin to prevent stormwater pollution. Remove trees or nuisance vegetation as necessary in order to protect embankments. Repair banks and eroded areas.

Reduce mosquitoes as necessary. Trim vegetation or alter water surface perimeter to reduce ponded depths that are less than 12 inches. Design of the wet detention basin may include a steeper depth transition to reduce shallow water depths less than 12 inches. Gambusia (mosquito fish) can also be placed in larger ponds if water levels are maintained to insure their survival during the dry season.

A fountain may be desirable to increase the amount of dissolved oxygen in the water. Depths greater than 12 feet may develop anaerobic conditions, which are not desirable.

If both the operational and aesthetic characteristics of a wet detention basin are not properly maintained, then it will become an eyesore and a negative environmental impact. Vegetation needs to be trimmed or harvested. Ensure that repairs are made to walkways, picnic tables, signs and public recreation equipment as needed.

Sediment Removal

A primary function of stormwater treatment BMPs is to collect and remove sediments. The sediment accumulation rate is dependent on a number of factors including watershed size, facility sizing, and upstream activities. Sediments should be identified before sediment removal and disposal is performed. Special attention or sampling should be given to sediments accumulated from industrial or manufacturing facilities, heavy commercial sites, fueling centers or automotive maintenance areas, parking areas, or other areas where pollutants are suspected. Treat sediment as potentially hazardous soil until proven otherwise.

Some sediment may contain contaminants for which TDEC requires special disposal procedures. Consult TDEC – Division of Water Pollution Control, Chattanooga Field Office, at (423) 634-5704 if there is any uncertainty about what the sediment contains or if it is known to contain contaminants. Clean sediment may be used as fill material, hole filling, or land spreading. It is important that this material not be placed in a way that will promote or allow re-suspension in stormwater runoff. Some demolition or sanitary landfill operators will allow the sediment to be disposed at their facility for use as cover. This generally requires that the sediment be tested to ensure that it is innocuous.

In addition to incorporating features into the pond design to minimize maintenance, some regular maintenance and inspection practices are needed. The table below outlines these practices.

Table 2. Typical maintenance activities for wet ponds

Activity	Schedule
• If wetland components are included, inspect for invasive vegetation.	Semi-annual inspection
• Inspect for damage. • Note signs of hydrocarbon build-up, and deal with appropriately. • Monitor for sediment accumulation in the facility and forebay. • Examine to ensure that inlet and outlet devices are free of debris and operational.	Annual inspection
• Repair undercut or eroded areas.	As needed maintenance
• Clean and remove debris from inlet and outlet structures. • Mow side slopes.	Monthly maintenance
• Manage and harvest wetland plants.	Annual maintenance (if needed)
• Remove sediment from the forebay.	1- to 2-year maintenance
• Monitor sediment accumulations, and remove sediment when the pool volume has become reduced significantly or the pond becomes eutrophic.	2-to 5-year maintenance

Other Considerations

A wet detention basin will require frequent inspection and maintenance. Trash, debris, leaves and other large items should be removed from the detention basin following each rainfall event. If upstream erosion is not properly controlled, wet detention basins can be maintenance-intensive with respect to sediment removal, nuisance odors, insects and mosquitoes, etc.

A wet detention basin may not have sufficient vegetation on the slopes and bottom to prevent erosion and pollutant resuspension. Vegetation must be maintained and cut at adequate intervals

A wet detention basin that impounds more than 30 acre-feet volume (and minimum 6 feet high) or which is higher than 20 feet (and minimum 15 acre-feet of volume) is subject to the Tennessee Safe Dams Act of 1973 and as amended by law. The Safe Dams Act is administered by the TDEC Division of Water Supply; further information on design standards, regulations and permit applications is available at the TDEC website: http://www.state.tn.us/environment/permits/safedam.php

Portions of a wet detention basin that are not wetted frequently can be attractively landscaped or used for other purposes.

Additional Information

Wet detention basins may not be feasible in very dense urban areas. Do not locate detention basins on steep unstable slopes or on shallow fractured bedrock. Impervious soils such as clay are desirable to maintain water levels during the summer or other dry periods

References

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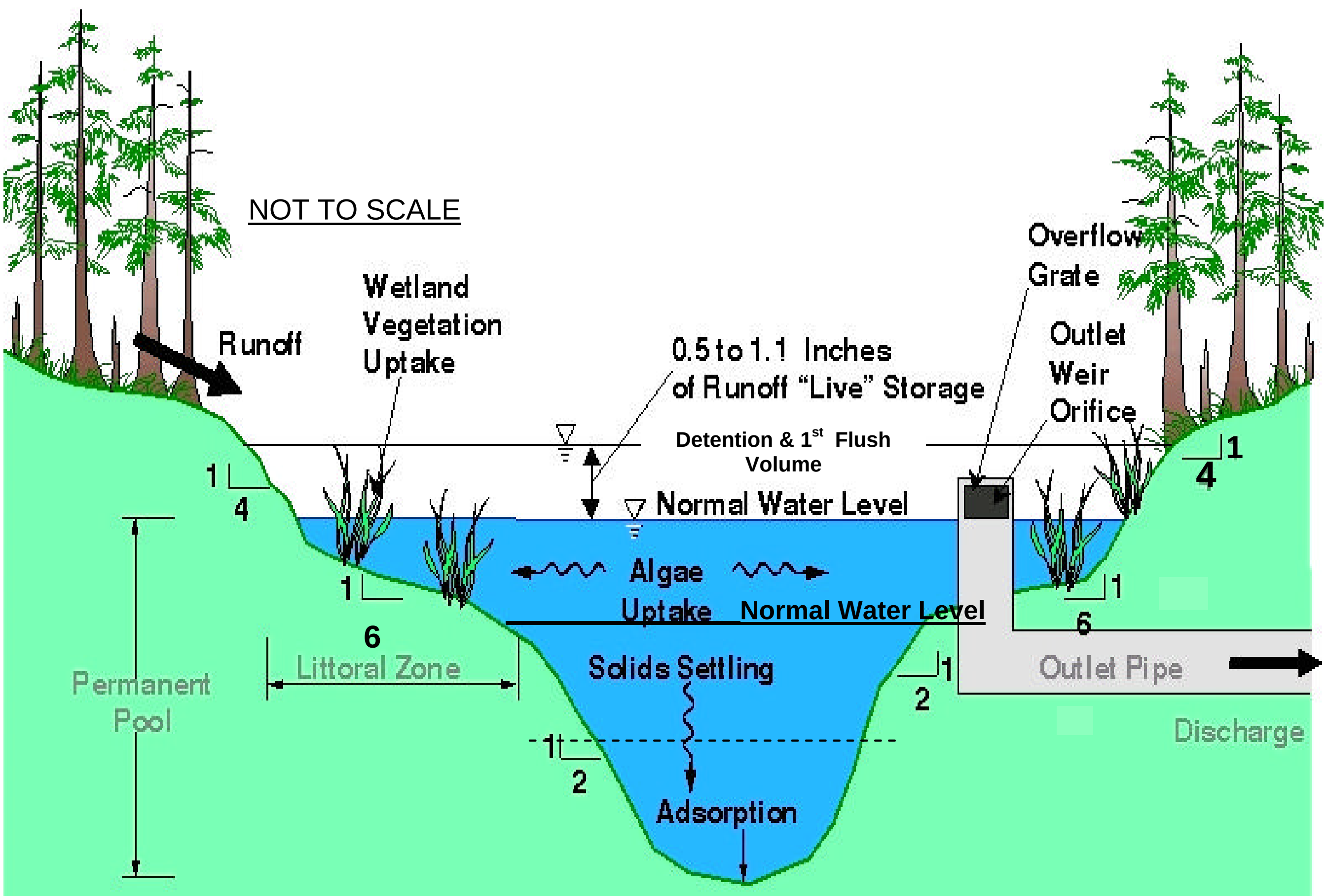
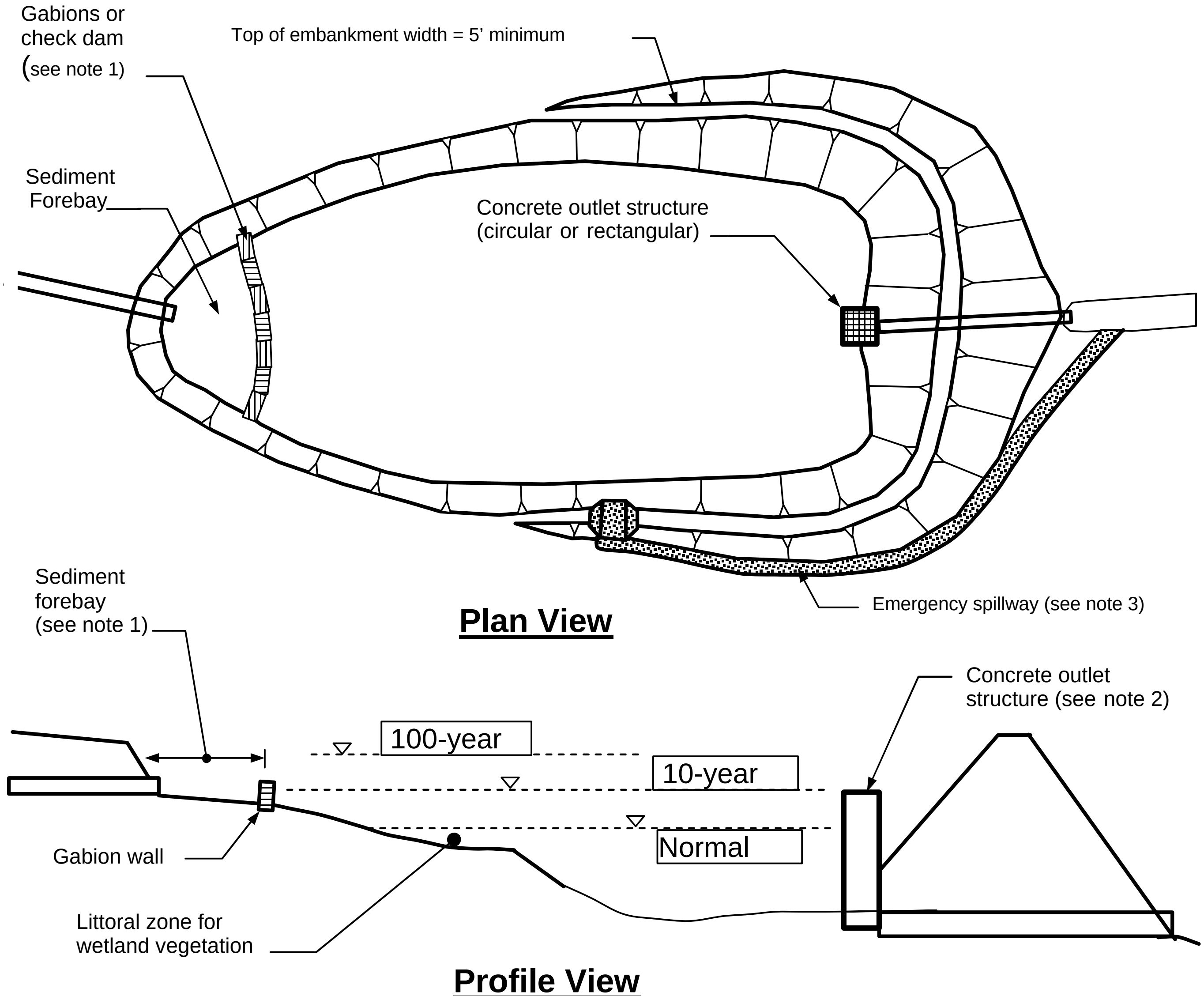
Photo 1 Safety Fence Around Pond

Figure 1 Schematic of Wet Detention Basin





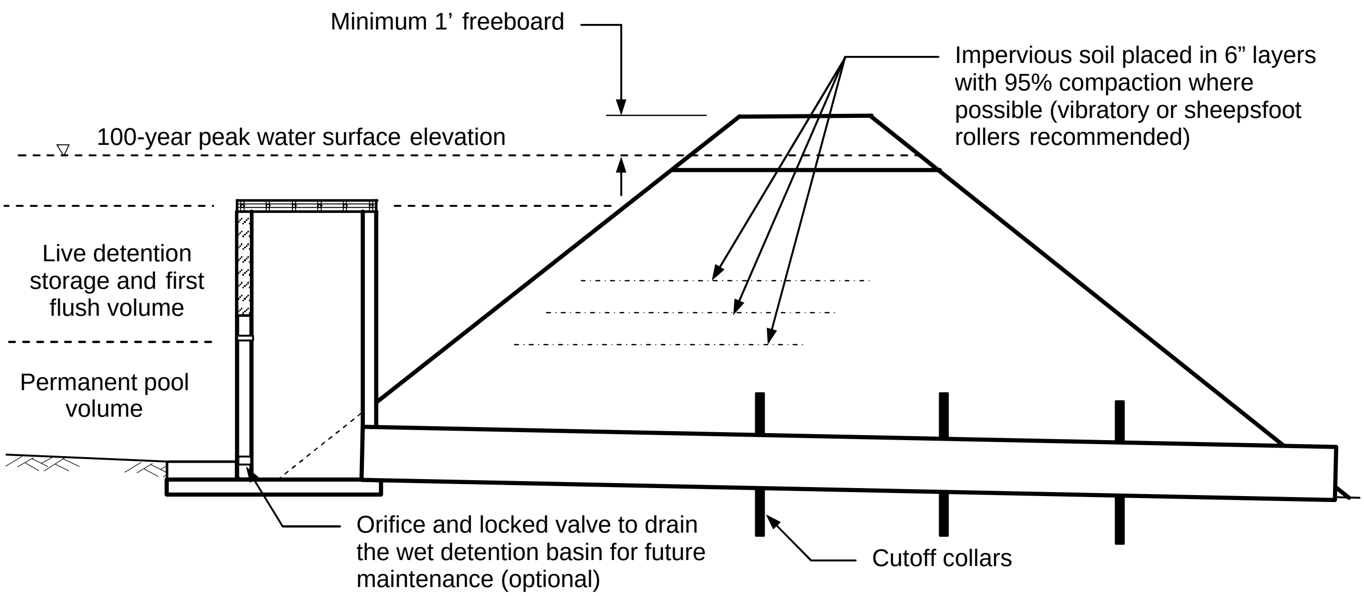
NOT TO SCALE

Notes:

1. A sediment forebay can be constructed from gabions, rock check dams, or a separate berm with culvert. A sediment forebay can facilitate the capture and cleanup of coarse sediments, debris and trash.
2. The outlet structure typically has orifices or weirs at computed elevations that will release the 1-year, 2-year, 5-year, 10-year and 100-year storms at the specified predevelopment peak flow rates.
3. The emergency spillway is generally constructed on natural ground or excavated areas (rather than fill soils) to reduce the potential for erosion and washout.

Figure 2 Typical Wet Detention Basin Layout

Figure 3 Typical Outlet Structure
(shown with a V-notch weir)



Profile View

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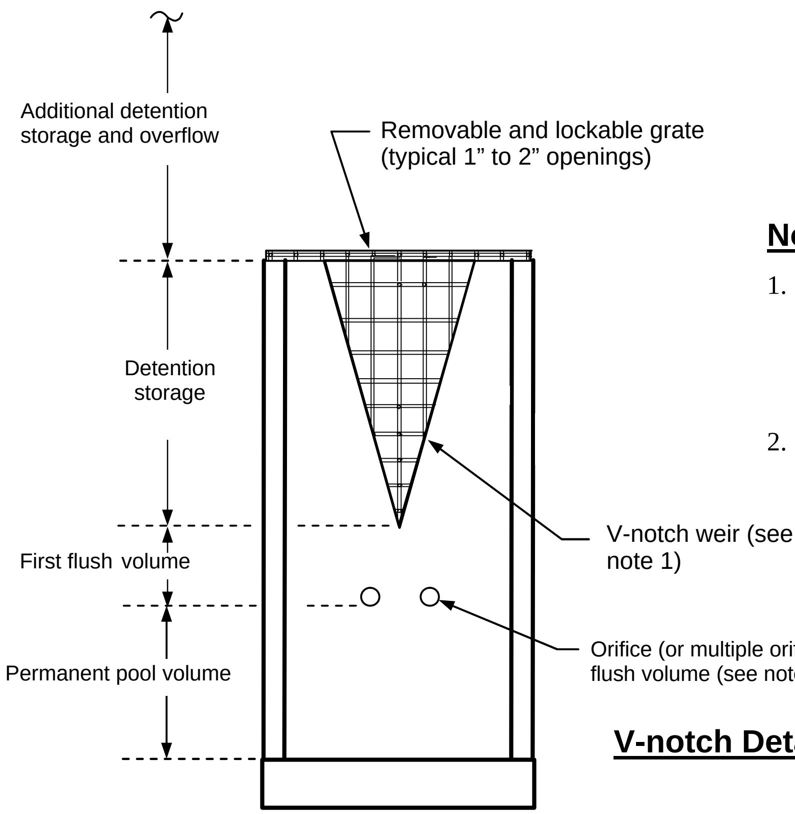

V-notch Detail

Notes:

1. This example of a typical outlet structure shows a V-notch weir which should be sized to release the 1-year, 2-year, 5-year, 10-year and 100-year storm peak flows at the predevelopment rates.
2. The first flush volume orifice or orifices are sized to release the first flush volume over a period from 24 to 72 hours. Protect the orifice from clogging with a trash rack.