DDB

Dry Detention Basin

Description

A detention basin (also known as a detention pond) is the most common method to satisfy both stormwater detention and stormwater quality requirements. It is applicable to small and large developments, can be easily designed and constructed, and is long lasting and durable while reducing peak flows (with adequate inspection and maintenance). This practice will also provide a significant reduction in sediment, toxic materials, heavy metals, floatable materials, oxygen demanding substances, and oil and grease.

A dry detention basin is intended to drain dry between storm events, but sometimes may not have a chance to drain completely between closely occurring storm events. The detention basin begins to fill as stormwater runoff enters the facility. The first flush volume is captured, detained, and drawn down over the next 96-hours in order to ensure water quality (see Section 3.3 First Flush/Water Quality Requirements). One or more outlet structures then release the stormwater runoff slowly to reduce peak discharge rates and to provide time for sediments to settle. (Proper maintenance should be followed in removing solids and pollutants.) Some soluble pollutants are captured by a combination of vegetation and soils.

Selection Criteria

The primary objective is to reduce the incoming peak flow discharge and slow the stormwater runoff response from a particular property or development, thus reducing flooding downstream. Peak flow runoff after development should not be greater than it was prior to development.

The secondary objective is to remove suspended sediments, trash and debris, oil, grease and other pollutants to protect the water quality of local streams and channels. Although dry detention basins are usually not as effective at removing soluble pollutants as wet detention basins and wetlands, dry detention basins are usually easier and less expensive to construct, inspect and maintain. Dry detention basins can be used wherever a lack of sufficient supply water would prevent the use of wet detention basins or wetlands. Portions of a dry detention basin that are not wetted frequently can be attractively landscaped or used for other purposes.

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.

As the primary objective, dry 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 design storm events in all watersheds. Additional stages (i.e. 50-year and 100-year) may be required.

As the secondary objective, water quality is obtained through the use of the first flush treatment volume (See Section 3.3 First Flush/Water Quality Requirement). The 'first flush' 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 retained or slowly released over a 96-hour period. The overall goal for stormwater treatment is based on 80% removal of total suspended sediments for first flush volume.

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 is generally considered to be standard equipment for a stormwater treatment BMP.

Stormwater runoff that falls onto pavement and rooftops should be detained and treated in a manner that will reduce thermal impacts to streams. This may include locating a detention basin away from sunlight by using shade.

Location and Layout

Basic elements of a dry detention basin are illustrated in Figure 1. The recommended design includes the use of a sediment forebay to reduce sediment loading, particularly if the post-construction detention basin is a modification from a temporary sediment basin during the construction phase. The use of an upper stage (for storage of infrequent storms) is optional; there are both benefits and drawbacks. A shallow detention basin with a large surface area will usually perform better than a deeper detention basin with the same volume. However, shallow storage areas increase the overall surface area needed for detention.

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). Baffles or back- slope drains may be used to prevent short-circuiting. If topography or aesthetics require the pond to have an irregular shape, increase pond area and volume to compensate for dead spaces. It is important to reduce the velocity of incoming stormwater using riprap or other energy dissipaters.

Although dry detention basins are generally less expensive to construct and maintain than wet detention basins, they provide lower water quality benefits. The primary disadvantage of a dry detention basin is the amount of surface area required, which can be reduced somewhat by using concrete retaining walls on one or more sides and/or using green infrastructure such as porous pavement or other Low Impact Designs (LIDs). In general, concrete retaining walls should not face southward in order to reduce the potential for heating on hot summer days.

Bedrock and topography must be considered when grading in some areas of the state. Karst topography may indicate fractured bedrock, dissolved limestone passages, or sinkholes, 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 and eventually collapse the bed of the detention pond.

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) should not be allowed over utility lines. Conversely, utility trenches should not be constructed on existing detention basin structures.

Detention basin easements and access must be considered during preliminary design, in order to allow for the construction easement 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.

Small detention basins serving individual properties do not offer as much recreational benefits as community or regional detention basins would. Regional facilities can often be landscaped to offer recreational and aesthetic benefits. Benefits to can also be provided in the form of islands, buffer areas, or preservation zones. It is important to maintain such areas. However, because their primary purpose is for stormwater management, under no circumstances should debris be allowed to accumulate near the outlet.

Volume and Size

The volume of a dry detention basin consists of two elements: the live pool (the upper portion of the basin representing detention capability) and the first flush volume (the lower portion of the basin representing stormwater quality treatment).

Since the post-development peak runoff may not exceed the pre-development peak flow rate, the upper section’s volume should be greater than or equal to this difference in volume.

The first flush volume should be sized to capture and slowly release the “first flush” of stormwater runoff, or the volume most likely to contain contaminants and particulate matter. Common practices include slow release of the first ¾ inch of runoff over a 96-hour period ¾ of an inch.

Grading

Side slopes of detention basins and embankment dams shall generally be 3H:1V or flatter. This encourages a strong growth of vegetation on the side slopes, helps to prevent soil erosion, and allows for safer mowing. Steep slopes, particularly on embankments or other fill soils, will contribute to soil erosion if not properly vegetated or stabilized, and thereby reduce or negate the effectiveness of a dry detention basin with respect to water quality. Vegetate the side slopes and basin bottom to the maximum extent practical. If significant side erosion is expected, consider the use of soil stabilization or armoring techniques. Detention basins should not be located immediately above or below a steep slope or grade, because impounded water may create slope stability problems.

Minimum width for top of embankment is 5 feet. The embankment height should allow for up to 10% settlement of embankment, unless the embankment is thoroughly compacted (recommended 95%) 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.

In instances where stormwater runoff does not flow directly down a slope, the side slope of a detention basin can be as steep as 2:1 (H:V) with proper erosion controls, geotextiles, and quick establishment of vegetation. 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.

The use of a backslope drain can be very beneficial in preventing erosion at detention basins. See Figure 5 for a typical detail. The backslope drain is also useful for increasing lengths of flow paths to prevent short-circuiting of the detention basin. Intercepted stormwater can be routed around the detention basin to enter at the most hydraulically distant point from the outlet structure.

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 generally 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.

Figures 2, 3, and 4 illustrate possible designs for the outlet structure. These details are only two possible ways to accomplish stormwater detention and stormwater quality control. The first flush volume can be filtered by an aboveground filter box with sand or aggregate (shown in Figure 2). Figure 3 shows an alternative outlet structure with a water quality manhole. Provide an emergency spillway in order to route large storms through the facility without overtopping.

An anti-vortex device for the outlet structure may be potentially needed for very large detention basins in areas where public access is not controlled. The anti-vortex device may be a combination of vanes above the outlet structure or guide walls around the outlet structure, that increases the inlet flow efficiency and might 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

Sediment forebay – to facilitate the cleanout of sediment, trash, debris, leaves, etc. The sediment forebay typically contains 5% to 10% of the total volume. 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. Operating detention basins often attract neighborhood children. Avoid steep slopes and dropoffs; consider routes for escaping the detention basin if a person accidentally falls in. Avoid depths over 4 feet when possible; provide fencing and signs in areas where children may potentially play, and where steep slopes are used in the detention area.

A low-flow channel (or concrete trickle ditch) can assist in completely draining detention basins with flat slopes. It also assists with the observation and removal of accumulated sediment. A typical design for example is a triangular ditch, 4’ wide and 3” deep with a slope of 0.5 to 1.0 percent.

Depending on the embankment soil, height of dam, and amount of compaction for the embankment, an anti-seep collar or a cutoff layer of compacted clay may be needed around the outlet pipe to prevent internal piping and erosion. An anti-seep collar should extend at least one pipe diameter from the culvert in all directions, with compacted clay backfill using small mechanical tampers. In areas of abundant clay soils, an anti-seep collar is not required for a dry detention basin.

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 tend to force debris up and away from the outlet opening and are somewhat less vulnerable to clogging. These racks should be regularly cleaned and maintained.

Provide means for vehicle access to the detention basin. Detention basins must be located in a maintenance easement so that authorities have the right to inspect the facility. Maintenance easements that are not adjacent to a municipality's right-of-way must also have an access easement, which allows for maintenance vehicle access. This easement should be free of large trees and excessive vehicle grades.

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

Construction and Inspection Considerations

Inadequate storage is the most frequent problem that occurs in the design review before construction, and also for the as-built review after construction

It is highly recommended that the design engineer is involved in the construction and inspection of the detention basin. Special attention should be given to the detention basin volume, elevations of each outlet, embankment crest and emergency spillway crest; side slopes, size and shape of various weirs or orifices, and installation of cutoff collars in embankments.

Proper hydraulic design of the outlet is critical to achieving good performance for both stormwater detention and stormwater quality of the dry detention basin.

Maintenance

Effective and safe operation of a detention basin depends on continuous maintenance of all system components. This means that the owner should have a regular inspection program in place for checking the condition and integrity of the basin, dam, and outlet control system to prevent minor problems from becoming serious safety and operation problems. Detention basin easements and access must be considered during the planning stage in order to allow for proper inspection and maintenance.

As a minimum, an owner should inspect the dry detention basin regularly (several times a year) and particularly after heavy rainfall events. Record all observations and measurements taken. Perform any maintenance and repair erosion promptly. Remove debris and trash after storm events. Check outlet structures regularly for clogging.

Remove sediment when accumulation becomes noticeable (1" to 2" over a wide area) or if resuspension is observed or probable. Sediment may be permitted to accumulate if the detention basin volume has been overdesigned with adequate controls to prevent further sediment movement. If a sand underdrain is used and problems develop such as reduced infiltration or ponded water, replacement of the sand layer may be necessary.

Maintain a thick and healthy stand of vegetation (usually grass). Mow or trim at regular intervals to encourage thick growth. Remove leaves, grass clippings, or sticks from detention basin regularly to prevent stormwater pollution. Remove trees or nuisance vegetation as necessary to ensure structural integrity of the basin.

This is especially true in embankments. Signs should be posted at detention ponds to discourage local homeowners from depositing yard trimmings, waste, and fill materials inside the basin. Appropriate signs and barriers such as fences should also be considered at detention basins where children have easy access to the site.

If both the operational and aesthetic characteristics of a dry detention basin are not properly maintained, recognize that it becomes an eyesore and has a negative environmental impact. Vegetation needs to be trimmed or harvested. Signs should be posted and maintained at detention ponds to warn of hazardous water conditions and to prohibit local homeowners from depositing yard trimmings, waste, and other fill materials inside the basin.

In addition to incorporating features into the pond design to minimize maintenance, some regular maintenance and inspection practices are needed. Table 1 outlines some of these practices.

Table 1. Typical maintenance activities for dry ponds

Activity	**Schedule**
• Note erosion of pond banks or bottom	Semiannual inspection
• Inspect for damage to the embankment • 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 • Mow side slopes • Manage pesticide and nutrients • Remove litter and debris	Standard maintenance
• Seed or sod to restore dead or damaged ground cover	Annual maintenance (as needed)
• Remove sediment from the forebay	5 to 7-year maintenance
• Monitor sediment accumulations, and remove sediment when the pond volume has been reduced by 25 percent	25- to 50-year maintenance

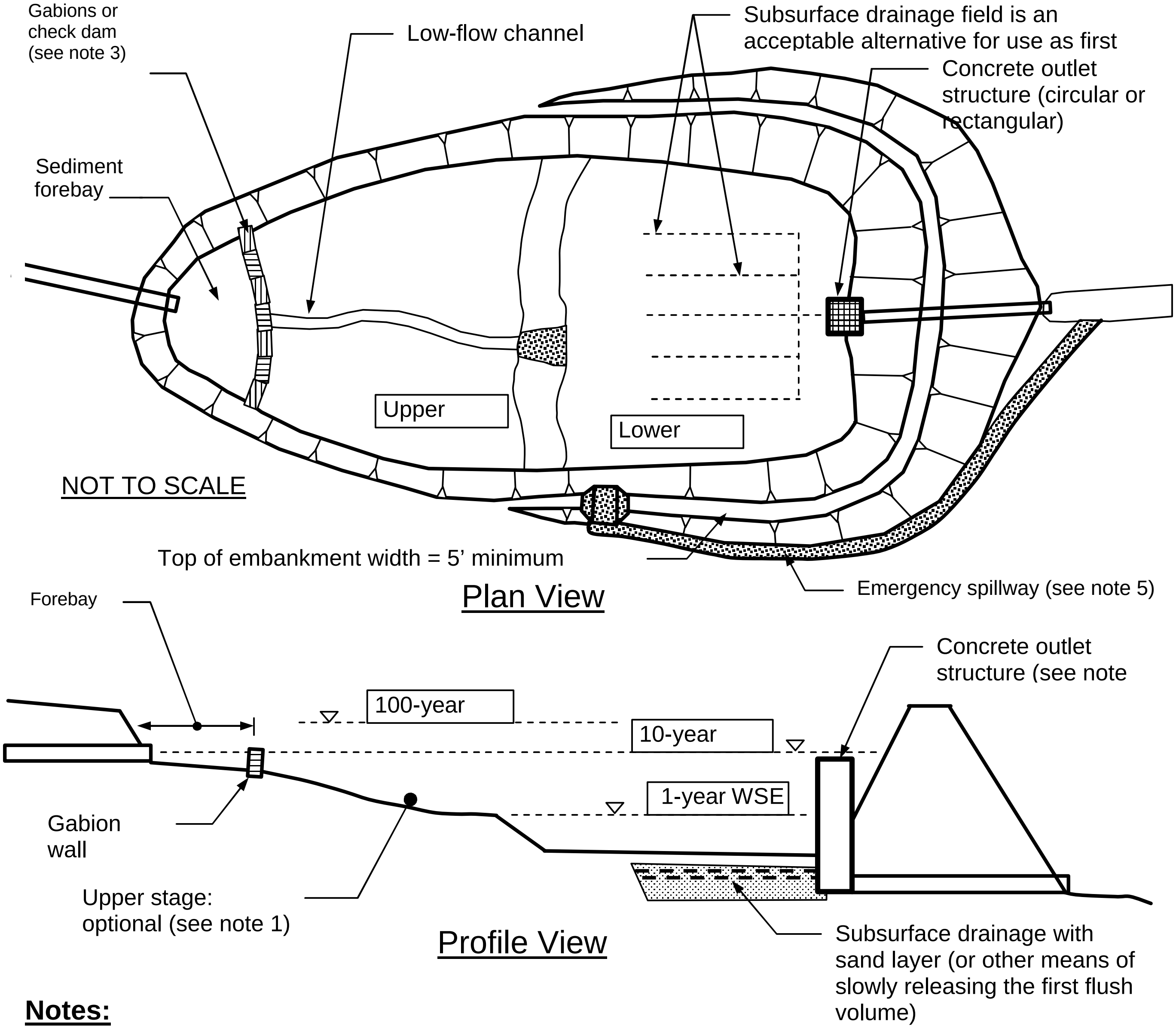
Source: USEPA

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, construction upstream, nearby industrial, or commercial activities, etc.

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. Sediment should be treated as potentially hazardous until proven otherwise.

Some sediment may contain contaminants for which TDEC requires special disposal procedures. Consult TDEC – Division of Water Pollution Control, Chattanooga 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 resuspension 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.



Notes:

1. This example of a typical dry detention basin layout shows an upper stage which is used for stormwater detention on infrequent storms. An upper stage can also be located on the side of a dry detention basin, eliminating the need for a low-flow channel.
2. The lower stage is typically sized to handle the first flush volume or the 1-year design storm, whichever is greater.
3. A forebay can be constructed from gabions, rock check dams, or a separate berm with culvert. A forebay can facilitate the capture and cleanup of coarse sediments, debris and trash.
4. 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.
5. 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 1 Typical Dry Detention Basin Layout

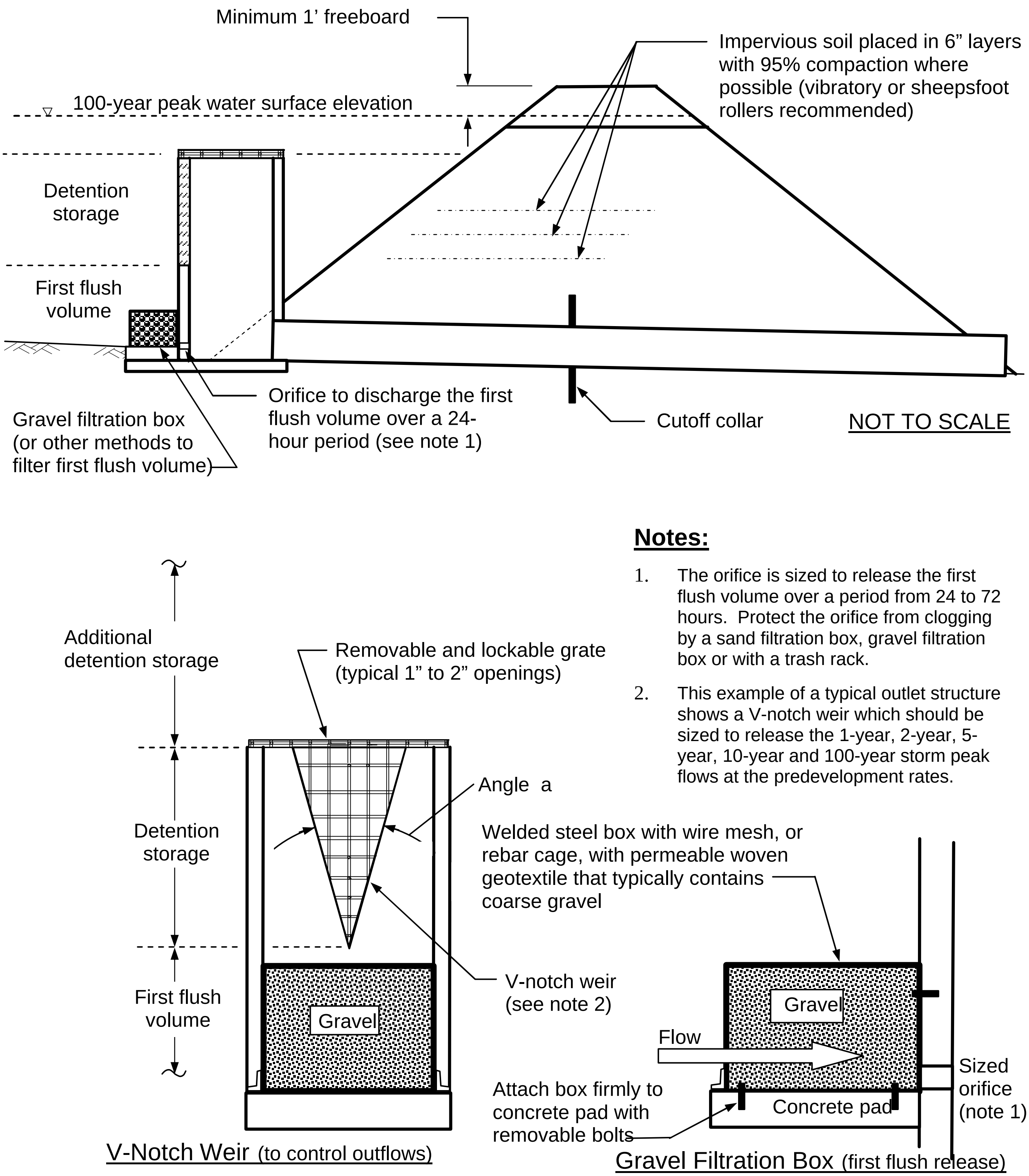
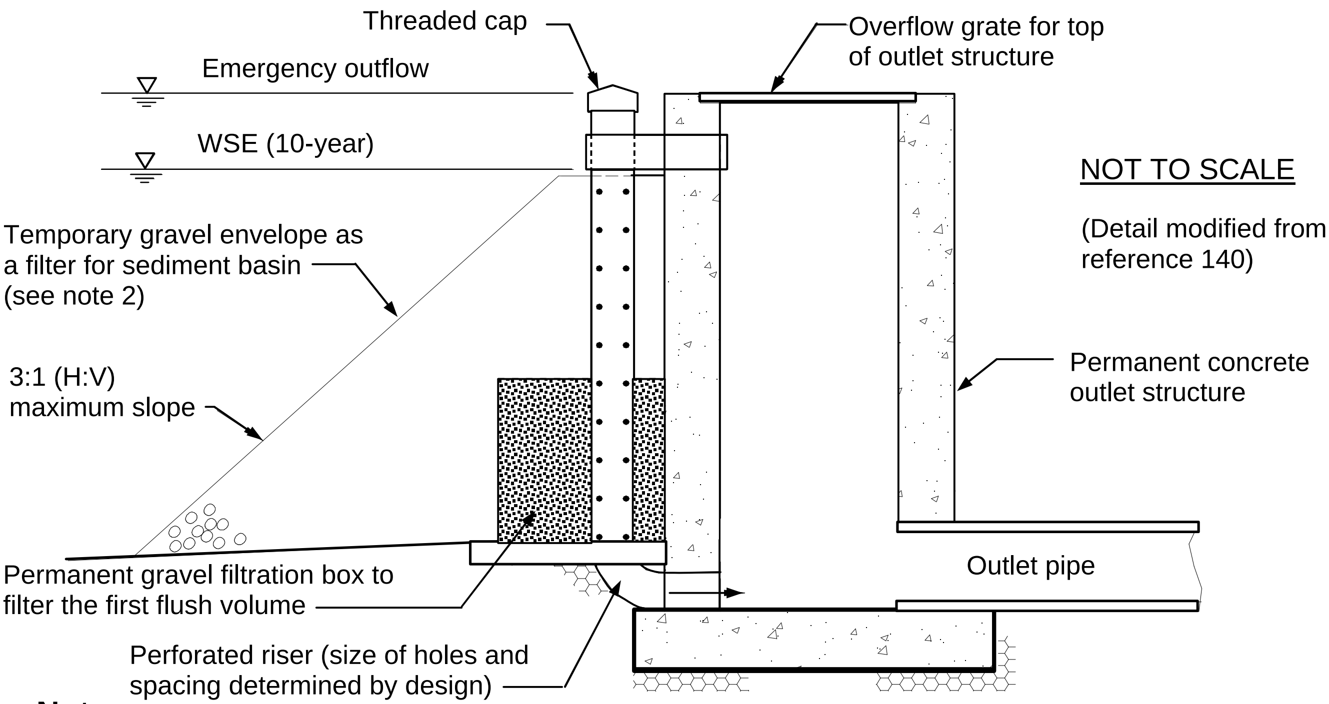


Figure 2 Typical Outlet Structure with V-notch Weir & Gravel Filtration Box: Profile and Detailed Views



Notes:

1. This type of outlet structure may be used as a permanent outlet structure for a dry detention basin. Maintain the gravel filtration box in unclogged condition within an enclosure in front of outlet structure to protect the perforated riser.

OR

2. This type of outlet structure can be used as a temporary modification to a dry detention basin (so that it may also function as a sediment basin). A temporary plastic riser is securely fastened using bolts, screws or threaded connectors. Use gravel to help protect the temporary riser.

Figure 3 Outlet Structure – Alternative A
Shown as a Temporary Sediment during Construction

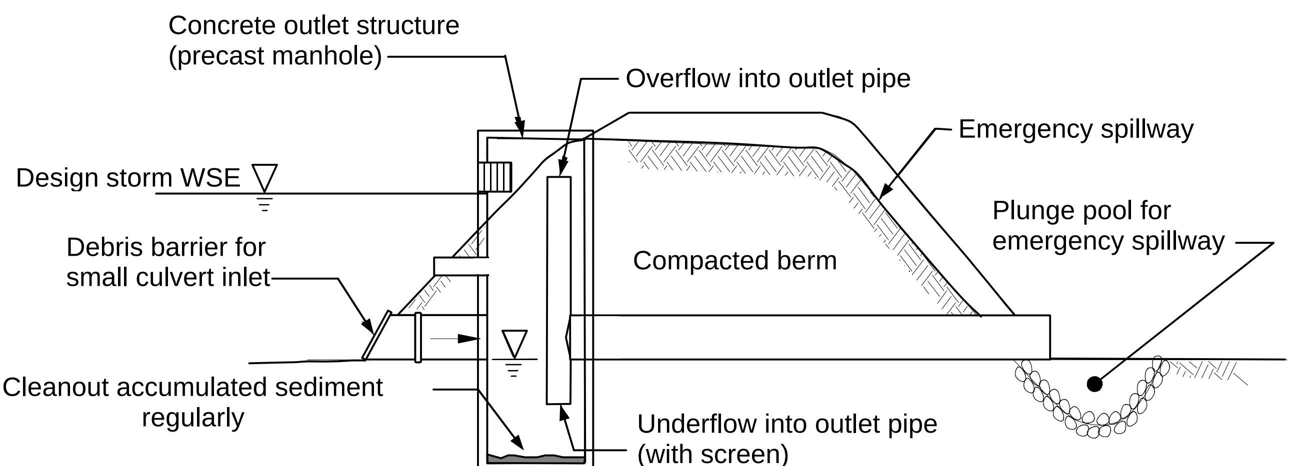


Figure 4 Outlet Structure – Alternative B
Includes Water Quality Manhole and Underflow

A backslope drain has two purposes:

1. Safely convey stormwater to the bottom of a detention basin slope.
2. Increase flow paths by channeling stormwater into the detention basin far away from outlet structure.

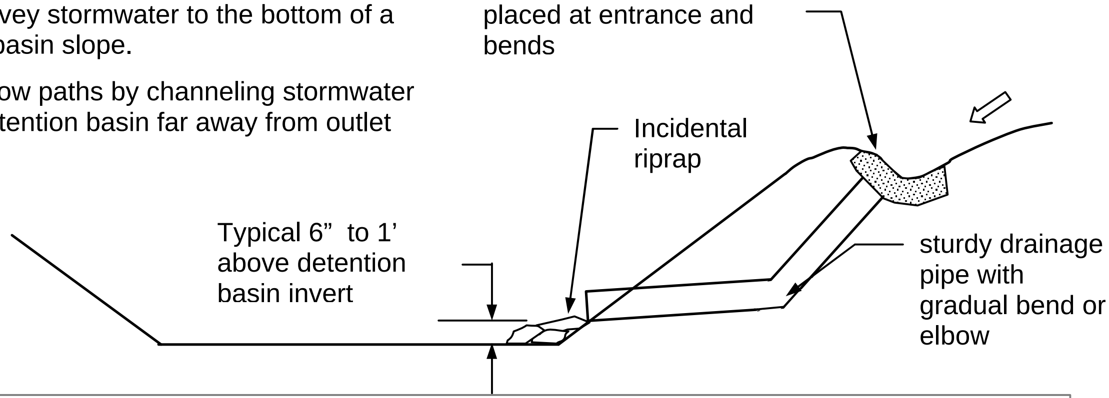


Figure 5 Typical Detail – Backslope Drain

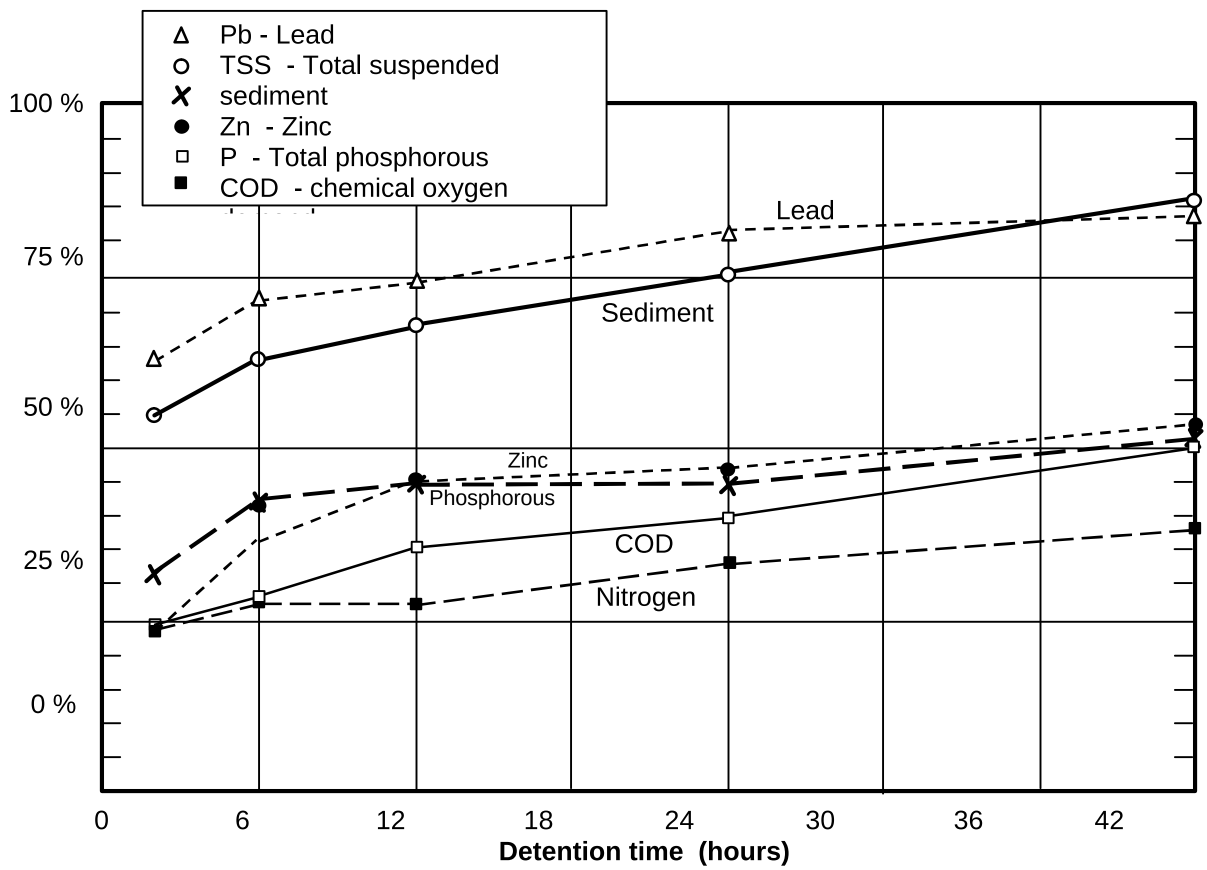


Figure 6 Pollutant Removal for Dry Detention Basins

Required Data for Detention Basin Design:

1. A map showing the predevelopment and postdevelopment tributary areas with computed area in acres.
2. Soil map (with legend and supporting data) to show the Hydrologic Soil Group for soils in drainage areas.
3. Land uses labeled and curve numbers computed for each tributary area.
4. Delineation of the longest flow path and Tc computations for each tributary area.
5. Predevelopment & postdevelopment hydrographs (NRCS Type II distribution for 24-hour storms).
6. Preliminary estimate for needed detention storage volume and for the first flush volume.
7. Storage vs elevation -- curve or rating table. Computed at regular intervals (not just interpolated).
8. Outflow vs elevation -- curve or rating table. Computed at regular intervals (not just interpolated).
9. Routed postdevelopment hydrographs for the 1-year, 2-year, 5-year, 10-year and 100-year storms, showing no increase in peak outflows.
10. First flush orifice is sized to release the first flush volume over a minimum period of 24 hours.

Physical Layout for Detention Basin:

1. Side slopes that are 3:1 (H:V) or flatter, with BMPs to assist in fully establishing vegetation and preventing erosion -- OR -- Side slopes that are not steeper than 2:1 (H:V) with traversable access and additional BMP controls for fully establishing vegetation.
2. Minimum bottom slope of 2% (minimum 1% with paved invert. Not marshy, drains well.
3. Minimum 2:1 length to width ratio for basin. Maximize distance between inlets and the outlet structure.
4. Provide minimum freeboard of 12 inches between top of berm and the largest routed storm hydrograph.

Outlet Structure:

1. Concrete, block or precast outlet structure (typical 6” wall thickness), with a concrete outlet pipe.
2. Minimum diameter of outlet structure is 36”, to allow for access within the outlet structure.
3. Orifices and weirs are neatly formed/drilled to correct size. Durable metal weir plates are also acceptable.
4. Provide steps at 18” intervals if outlet structure is more than 3 feet high.
5. Provide lockable grates or other measures to prevent neighborhood children from playing.
6. Provide gravel filtration box (or other durable low-maintenance device) for the first flush orifice.
7. Consider building a trash rack if debris and litter are likely to occur.

References

Knoxville (City of). October 2007. Knoxville Stormwater Engineering Division. City of Knoxville BMP Manual. http://www.ci.knoxville.tn.us/engineering/bmp_manual/

MDE Water Management Administration, Photo of Dry Detention Basin from http://dnrweb.dnr.state.md.us/watersheds/surf/bmp/info/drydetention_hydro.html.

Tennessee Safe Dams Act of 1973. as amended 1991. TCA. Section 69-12-101.

United States Department of Agriculture (USDA). June 1986. Soil Conservation Service (SCS). *Urban Hydrology for Small Watersheds.* Technical Release 55 (TR-55).

USEPA (U.S. Environmental Protection Agency). 1992. Stormwater Management for Construction Activities: Developing Pollution Prevention Plans and Best Management Practices. EPA 832-R-92-005. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

Urban Drainage & Flood Control District, Denver Colorado. September 1999. *Urban Storm Drainage Criteria Manual: Volume 3 – Best Management Practices - Stormwater Quality*.