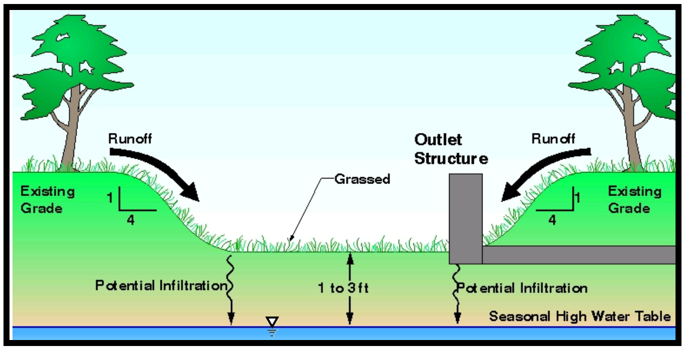
ACTIVITY: Dry Detention Basin	ST – 01



CITY OF KNOXVILLE

Targeted Constituents

● Significant Benefit ◗ Partial Benefit ○ Low or Unknown Benefit

● Sediment	◗ Heavy Metals	◗ Floatable Materials	◗ Oxygen Demanding Substances	
◗ Nutrients	◗ Toxic Materials	◗ Oil & Grease	○ Bacteria & Viruses	○ Construction Wastes

Description

A dry detention basin 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 (with adequate inspection and maintenance). This practice will provide a significant reduction in sediment, as well as a partial reduction in nutrients, toxic materials, heavy metals, floatable materials, oxygen demanding substances, and oil and grease.

A dry detention basin is intended to be dry between storm events, but may not necessarily have a chance to drain completely prior to the next storm event. The detention basin begins to fill as stormwater runoff enters the facility. The first flush volume is captured in order to ensure water quality. One or more outlet structures then release the stormwater runoff slowly to reduce peak discharge rates and to provide time for sediments to settle. Prevent litter and debris from leaving the detention basin (thus protecting Knoxville's streams and lakes). Some soluble pollutants are captured by a combination of vegetation and soils.

Selection Criteria

- The primary objective is to reduce the peak flow discharge and slow the stormwater runoff response for a particular property or development, thus reducing flooding downstream. Procedures for preparing calculations are outlined in ST-10 (Detention Computations) including the correct use of NRCS Technical Release 55 for determining the required detention storage. An example detention problem is worked with complex spreadsheets (ST-11) and HEC-1 / HEC-HMS runs (ST-12).
- The secondary objective is to remove suspended sediments, trash and debris, oil, grease and other pollutants to protect the water quality of Knoxville 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.
- Dry detention basins can also supply multiple benefits for passive recreation during dry periods (recreational trails, ball fields, picnicking). Portions of a dry detention basin that are not wetted frequently can be attractively landscaped or used for other purposes. See Figure ST-09-1 for the typical placement of various stormwater treatment BMPs near streams and natural areas.

Design Approach

- As the primary objective, dry detention basins must be designed to have adequate detention storage and outlet structures. See ST-10 for a discussion of detention design methods and formulas that are acceptable. The City of Knoxville requires detention for the 1-year, 2-year, 5-year, 10-year, 25-year and 100-year NRCS Type II rainfall storm design events. 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 five design storms at predevelopment rates.
- As the secondary objective, water quality is obtained through the use of the first flush treatment volume. The first 0.5 inches of stormwater runoff, over the entire contributing drainage area, is defined as the first flush volume (with a minimum value of 4500 cubic feet which is defined by the city stormwater ordinance). 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 and then slowly released over a minimum 24-hour period (and maximum of 72 hours). The overall goal for stormwater treatment is based on 75% removal of total suspended sediments for first flush volume, as indicated in Figure 4-2 of the Knoxville BMP Manual for a 24-hour detention time.
- 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 trees or buildings as shade.

Location & Layout

Basic elements of a dry detention basin are illustrated in Figure ST-01-1. The recommended design includes the use of a sediment forebay to reduce sediment loading, particularly if the detention basin is modified to also function as 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 backslope 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. 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 the Knoxville 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.

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. Jogging and walking trails, picnic areas, and ball fields are some of the typical uses. For example, portions of a flood control facility can be used for exercise areas, soccer fields, or football fields. Wildlife benefits can also be provided in the form of islands, buffer areas, or preservation zones. Figure ST-09-1 shows an example of a multi-use regional facility.

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). These two elements should be sized according to ST-10, Detention Computations, and also the procedures from NRCS Technical Release 55 (reference 175). Verify that the preliminary estimate volume and size works by routing the stormwater hydrographs.

The first flush volume must have a minimum size to meet the City of Knoxville Stormwater and Street Ordinance (Section 22.5-36). Detention basins shall be sized to collect the 0.5 inches of stormwater runoff from the entire contributing area, or the first 4500 cubic feet of stormwater runoff, whichever is greater. The first flush volume must be released at a controlled rate over a minimum 24-hour period (and a maximum time period of 72 hours).

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. Figure 4-2 of the BMP Manual shows the measured pollution removal values for dry detention basins near metropolitan Washington, D.C. It is anticipated that this type of information will become more commonplace and more useful in the near future.

Grading

Side slopes shall generally be 3:1 (H:V) or flatter to allow for traversable access to the bottom of the detention basin. This also 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, will contribute to soil erosion, 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 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.

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.

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 ST-01-5 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

The City of Knoxville requires that a detention basin outlet structure must be constructed from concrete, masonry block, or other durable materials. The City no longer allows metal CMP risers to be used as an outlet structure due to problems with crushing, flotation, and durability. 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: circular orifice, noncircular orifice, rectangular weir, trapezoidal weir, triangular weir, V-notch weir, culvert entrance control or riser overflow opening. These types of controls are described at length in ST-10, Detention Computations.

Figures ST-01-2 and ST-01-3 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 is typically drained during a minimum time of 24 hours by using an orifice 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. The first flush volume can be filtered through sand by using an underdrain system (shown in Figure ST-01-2) or by an aboveground filter box with sand or aggregate (shown in Figure ST-01-3). Figure ST-01-4 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.

Other Design Elements

- A sediment forebay is recommended for larger detention basins – 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. Avoid steep slopes and dropoffs; consider routes for escaping the detention basin if a person had accidentally fallen in. Avoid depths over 4 feet when possible; provide fencing and signs in areas where children may potentially play.
- A low-flow channel (or concrete trickle ditch) can assist detention basins with flat slopes to drain completely. It also assists with the observation and removal of accumulated sediment. A typical design would be a triangular ditch, maybe 4' wide and 3" deep with a slope of 0.5 to 1.0 percent.
- Depending on the amount of compaction for the embankment, an antiseep collar or a cutoff layer of compacted clay may be needed around the outlet pipe. An antiseep collar should extend at least one pipe diameter from culvert in all directions, with compacted clay backfill using small mechanical tampers. In most instances, an antiseep collar is not required for a dry detention basin due to the abundant amount of clay soils in the Knoxville area.
- Include trash racks or other debris barriers with a maximum opening size of 2" (and preferably 1") 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 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 greater than 50 percent impervious surface or which 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.
- 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 arounds the outlet structure, that might lessen the chance of humans drowning or reduce the potential for erosion and structural undercutting.

Common Problems

- Inadequate storage is the most frequent problem that occurs in the design review before construction, and also for the as-built review after construction. This can occur for several reasons:
  - A. The design engineer did not allow enough room to construct the detention basin (most often due to insufficient design detail such as slope transitions, setbacks, parking lot widths, inaccurate contours, utilities not shown).
  - B. The engineer who performs the stormwater computations is not the same person as the design engineer who does site layout and grading. The required detention storage volume and outlet structure details need to be communicated clearly to the design engineer for inclusion on the plans.
  - C. The construction contractor does not excavate deep enough or does not build berms of sufficient height to hold the required detention volume. This may occur due to rock formations encountered or to groundwater.

D. The construction contractor changes the basin configuration during the construction without being aware of the required volume. Approval from the City of Knoxville was not obtained for a design change.

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, 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. The two most common problems for detention basin outlets are:

  A. The discharge capacity of the outlet structures is too great. This causes excessive basin outflows and results in fast drawdown times and inadequate filling of the detention basin volume. Both stormwater detention and stormwater quality will suffer.

  B. The outlet structure clogs because it is not adequately protected against trash and debris. The use of innovative trash racks is recommended. A typical trash rack is often created using welded rebar with 2” openings is sufficient to stop most beverage cans, food containers from restaurants, tree limbs, etc. A trash rack sized with 1” to 1.5” openings is preferable to also catch leaves and small sticks.

Maintenance

- 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 structure 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, look for reduced infiltration or ponded water; sand layer replacement may be needed.
- 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.
- If both the operational and aesthetic characteristics of a dry detention basin are not properly maintained, then it becomes an eyesore and has 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, 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. Treat sediment as potentially hazardous until proven otherwise.

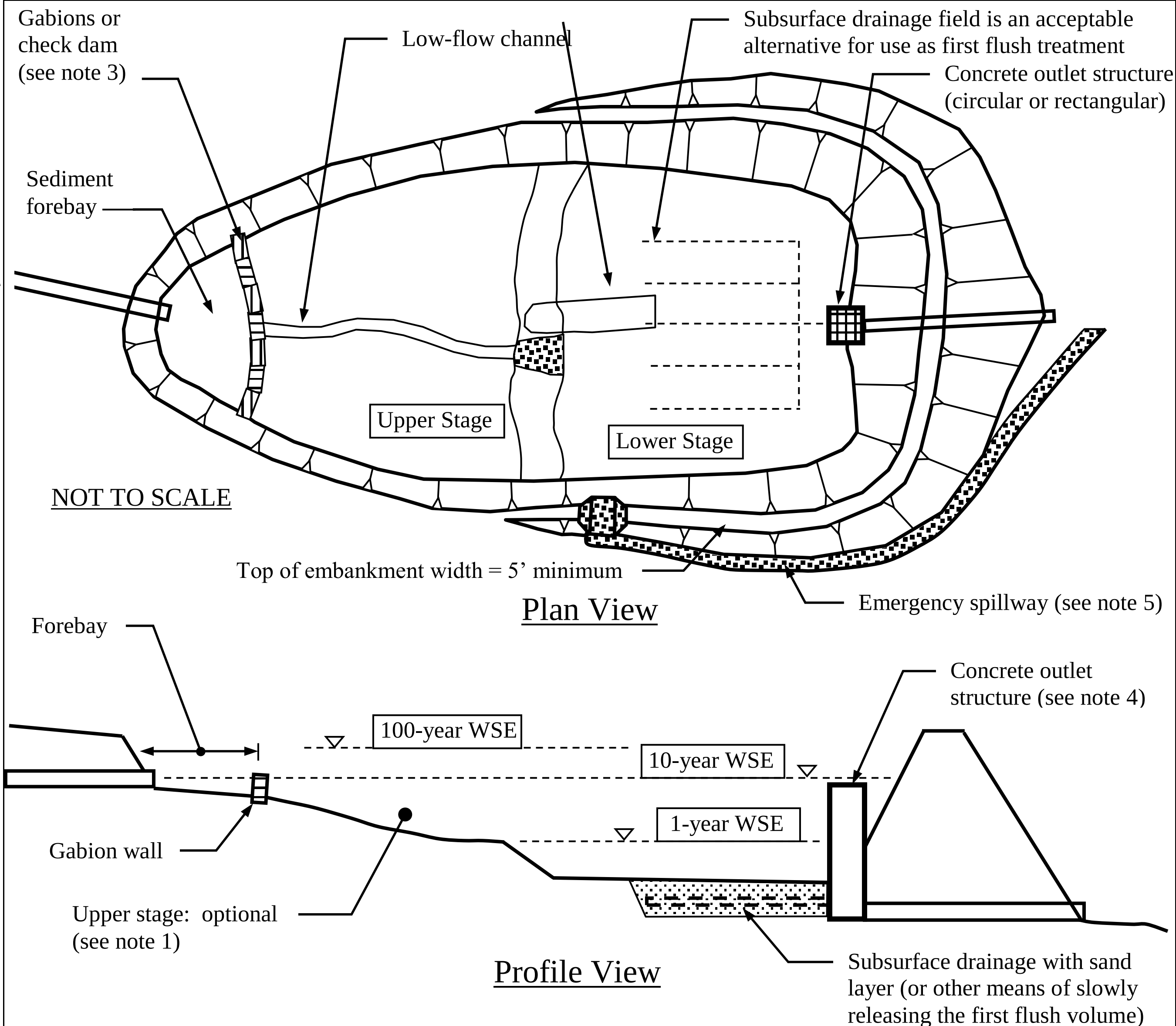
Some sediment may contain contaminants for which TDEC requires special disposal procedures. Consult TDEC – Division of Water Pollution Control (594-6035) if there is any uncertainty about what the sediment contains or if it is known to contain contaminants. Clean sediment may be used as fill material, 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.

Limitations

- A dry 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, dry detention basins can be maintenance-intensive with respect to sediment removal, nuisance odors, insects and mosquitoes, etc.
- A dry 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. Remove grass clippings from detention basin immediately after cutting, using rakes or other hand equipment.
- A dry detention basin that impounds more than 30 acre-feet of 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
- Dry detention basins require a relatively large surface area (1% to 3% of the contributing drainage area) in order to provide sufficient pond volume for detention and water quality. Dry detention basins require a differential elevation between inlets and outlets, for which extremely flat areas may not be suitable.

References

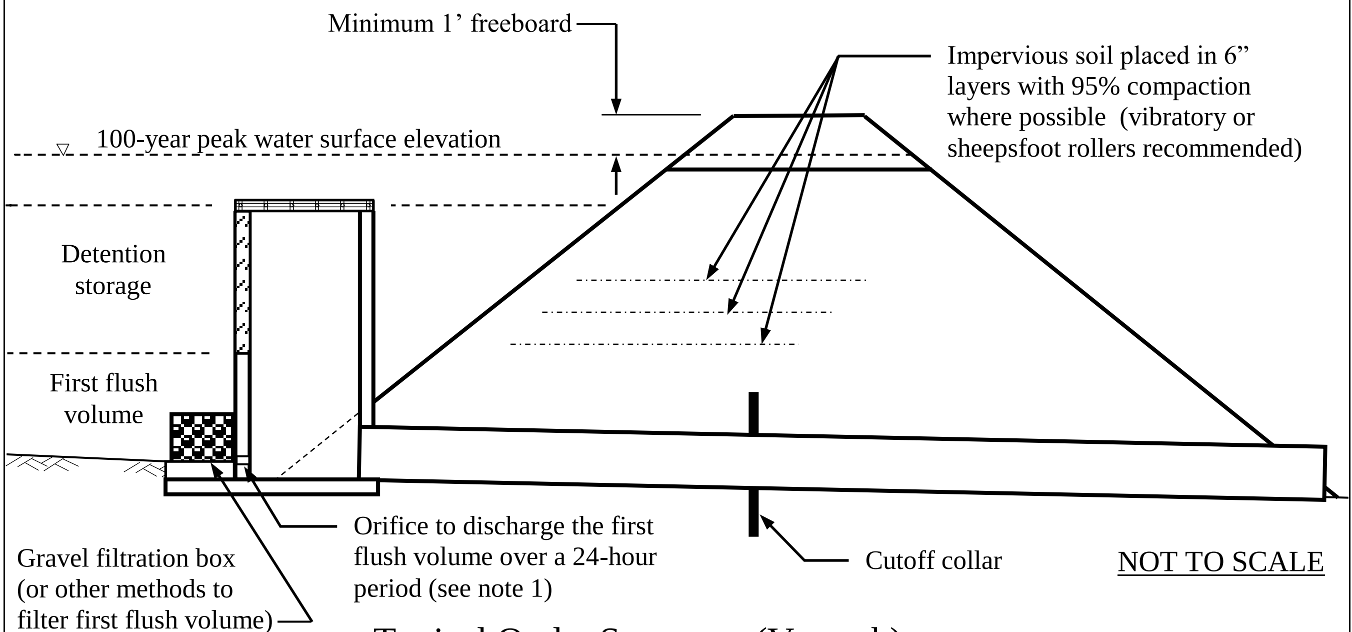
9, 28, 31, 33, 48, 50, 58, 73, 76, 77, 78, 81, 83, 88, 140, 145, 153, 166, 175, 180, 182
(see BMP Manual Chapter 10 for list)



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, 25-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.

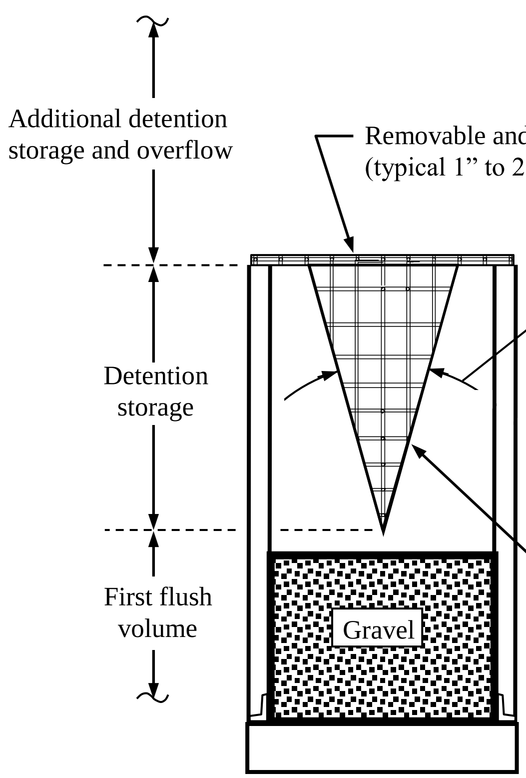
Figure ST-01-1
Typical Dry Detention Basin Layout



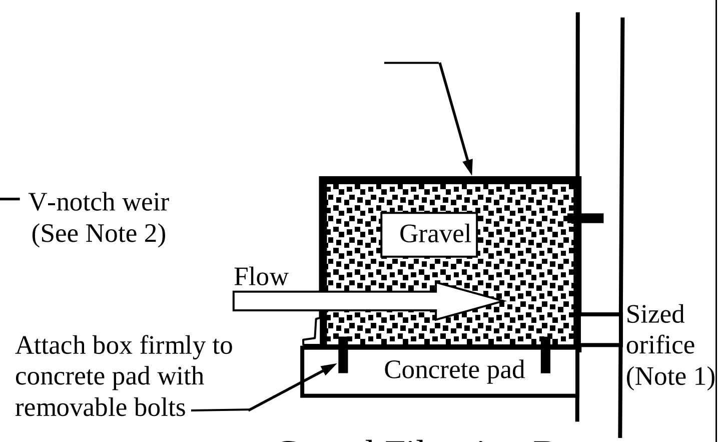
Typical Outlet Structure (V-notch)

Notes:

1. The orifice is sized to release the first flush volume over a period from 24 to 72 hours. Protect the orifice from clogging by a sand filtration box, gravel filtration box or with a trash rack.
2. 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, 25-year and 100-year storm peak flows at the predevelopment rates.

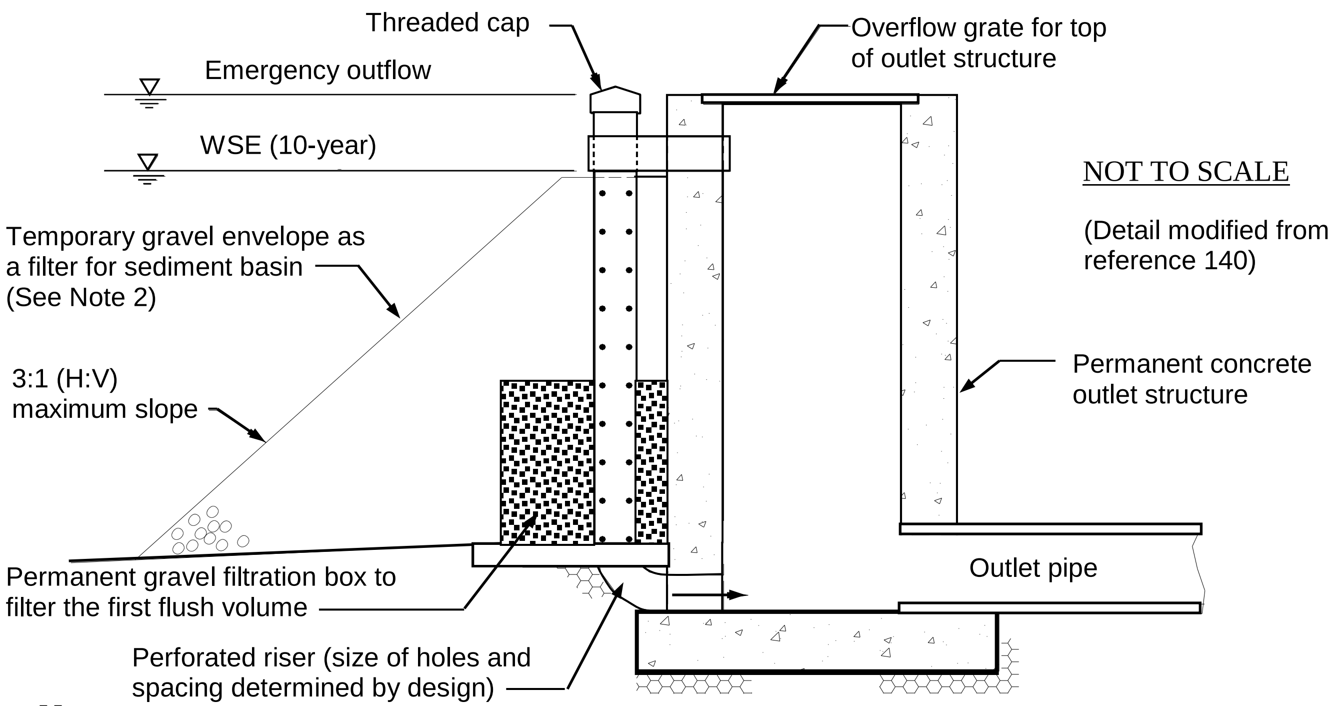


V-Notch Weir
(to control outflows)



Gravel Filtration Box
(first flush release)

Figure ST-01-2
Typical Outlet Structure
(Shown with a V-notch weir & gravel filtration box)



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 may be used as a temporary modification to a dry detention basin (so that it may also be 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 ST-01-3
Outlet Structure – Alternative A
(also shown as a temporary sediment basin during construction)

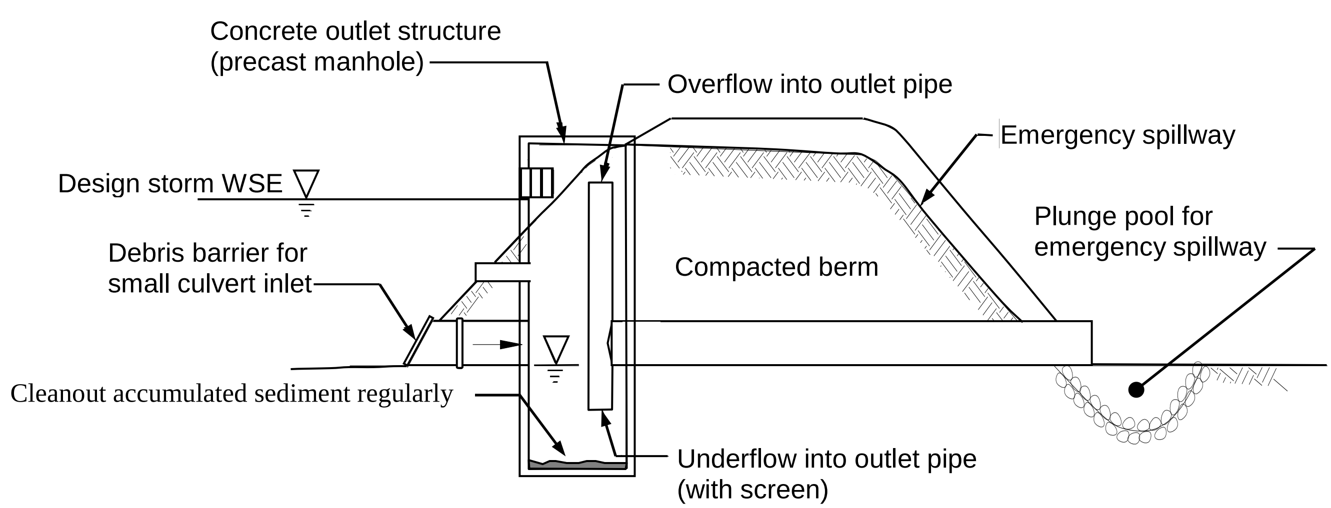


Figure ST-01-4
Outlet Structure – Alternative B
(includes water quality manhole with underflow)

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.

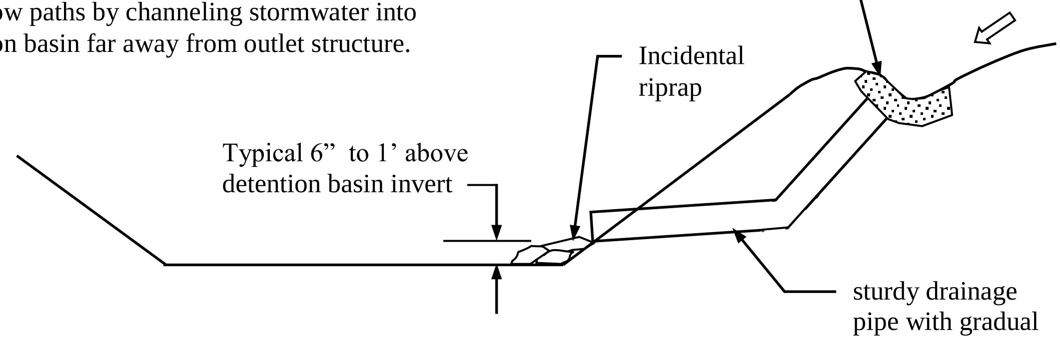


Figure ST-01-5
Typical Detail - Backslope Drain

Required Data for Detention Basin Design: <u>*(see ST-10, Detention Computations)*</u>

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, 25-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.