Iowa Storm Water Management Manual

Design Standards Chapter 7- Detention Practices

A. Introduction

This section provides design guidelines for a group of stormwater management BMPs broadly referred to as detention basins or ponds. Guidance is provided for stormwater runoff storage for meeting stormwater management control requirements (i.e., water quality treatment, downstream channel protection, overbank flood protection, and extreme flood protection). Storage of stormwater runoff within a stormwater management system is essential to providing the extended detention of flows for water quality treatment and downstream channel protection, as well as for peak flow attenuation of larger flows for overbank and extreme flood protection. Traditional systems consist of detention basins for attenuation of peak runoff rates from storm exceeding the 5-year design storm. For water quality control and downstream channel protection, the detention storage volume is often based on the smaller, more frequent events (≤1-year storm event). For these smaller design storms, and for smaller drainage areas (≤5-10 acres), smaller volumes of runoff storage can be provided within onsite systems as integrated components of infiltration practice structural controls, and non- structural features and landscaped areas (infiltration basins, bioretention areas, and porous pavement systems).
Figure C7-S1- 1 illustrates various storage facilities that can be considered for a development site.

Engineers have designed small and large ponds for many years for a wide range of applications, including farm ponds, recreational ponds, water supply reservoirs, managing the increased runoff rate from urban development, flood control reservoirs, and multiple uses reservoirs. The collective knowledge of ponds, their design, construction, operation, and maintenance is extensive. However, their use for environmental protection purposes including stream channel protection, water quality treatment, and protection of receiving waters is a recent development, and in many instances requires re-assessing the traditional applications of pond design techniques to meet these new objectives.

There is also some concern regarding the effectiveness of detention practices for providing downstream flood control. The design of detention facilities is often confined to the limits of the property for which the facility is being designed, without much regard for potential downstream impacts. The issue of super-positioning of hydrograph peaks is often overlooked, and yet can result in simply transferring the flood or channel erosion problem to unsuspecting downstream property owners. The use of detention to control stormwater quality was first used in the early 1980s. By the late 1980s, sufficient empirical data was available to design extended detention basins for water quality purposes with reasonable confidence in their performance. Extended detention basins are best at removing suspended constituents, but they are not particularly effective in removing soluble contaminants. Removal rates of solids by wet detention basins tend to outperform dry detention basins. A comparison of constituent removal efficiencies of extended detention basins and detention ponds is presented in Table C7-S1- 1.

Table C7-S1- 1: Comparison of pollutant removal percentages by water quality BMP

Type of Pond	TSS	Nitrogen	Phosphorous	Lead	Zinc	BOD
Dry, extended detention	50-80	0 (dissolved) 10-30 (total)	0 (dissolved) 10-50 (total)	35-80	35-70	20-40
Wet detention	70-85	50-70 (dissolved) 30-40 (total)	50-70 (dissolved) 50-65 (total)	25-85	25-85	20-40
Infiltration basin	60-98	60-98 (total)	60-98 (total)	60-98	60-98	N/A

Source: USEPA (1983), Stahre and Urbonas (1990), ASCE (2001)

1. **Dry detention basins.** A dry detention basin is used to reduce peak discharge and detain runoff for a specified short period of time. Detention volumes are designed to completely drain after the design storm has passed. Detention is used to meet overbank flood protection criteria, and extreme flood criteria where required. While many jurisdictions initially applied this approach to control the 10-year, 25-year, 50-year, or 100-year storm flow rates, the normal application in Iowa jurisdictions has been to control the 5-year storm runoff rate. (Note: this is often a function of the downstream stormwater conveyance capacity, i.e., storm sewer). A small number of jurisdictions have also adopted control for the 2-year peak flow rate as an attempt to control downstream bank erosion.
2. Figure C7-S1- 1 shows a typical dry detention basin.

Chapter 7, section 2 provides criteria for designing dry detention and extended dry detention BMPs. Criteria are provided for sizing the required pond volume, basin configuration, outlet protection, vegetative cover, and other elements.

Figure C7-S1- 1: Dry detention basin

3. **Extended dry detention.** Extended dry detention (ED) is used to drain a runoff volume over a specified period of time, typically 24 hours, and is used to meet channel protection criteria (Cpv). Some structural control designs (wet ED pond and micro-pool ED pond) also include extended detention storage of a portion of the water quality volume.

   Extended detention for stormwater quality was first used for new installations of extended detention ponds, or as retrofits of old dry ponds. Extended detention refers to a basin designed to extend detention beyond that required for stormwater peak rate control to provide some water quality affect.

   Extended detention basins are viable and effective treatment facilities. When properly designed, significant reductions are possible in the total suspended sediment load and of constituents associated with these sediments. Typically these basins are less effective in removing soluble solids. The elements of a typical extended detention basin are illustrated in
   Figure C7-S1- 2. The amount of reduction depends on a wide variety of factors, including:
   - Surface area of the basin
   - Peak outflow rate
   - Size distribution of the particles
   - Specific gravity of particles
   - Fraction of the sediment that is active clay
   - Type of associated pollutant concentrations
   - Fraction of influent solids that are colloidal, dissolved, and non-settleable

Extended detention basins will sometimes have a small permanent pool below the invert of the low flow outlet. This is normally so small that it does not materially impact trapping of sediment and chemicals, and is typically included for aesthetics or to cover deposited sediments.

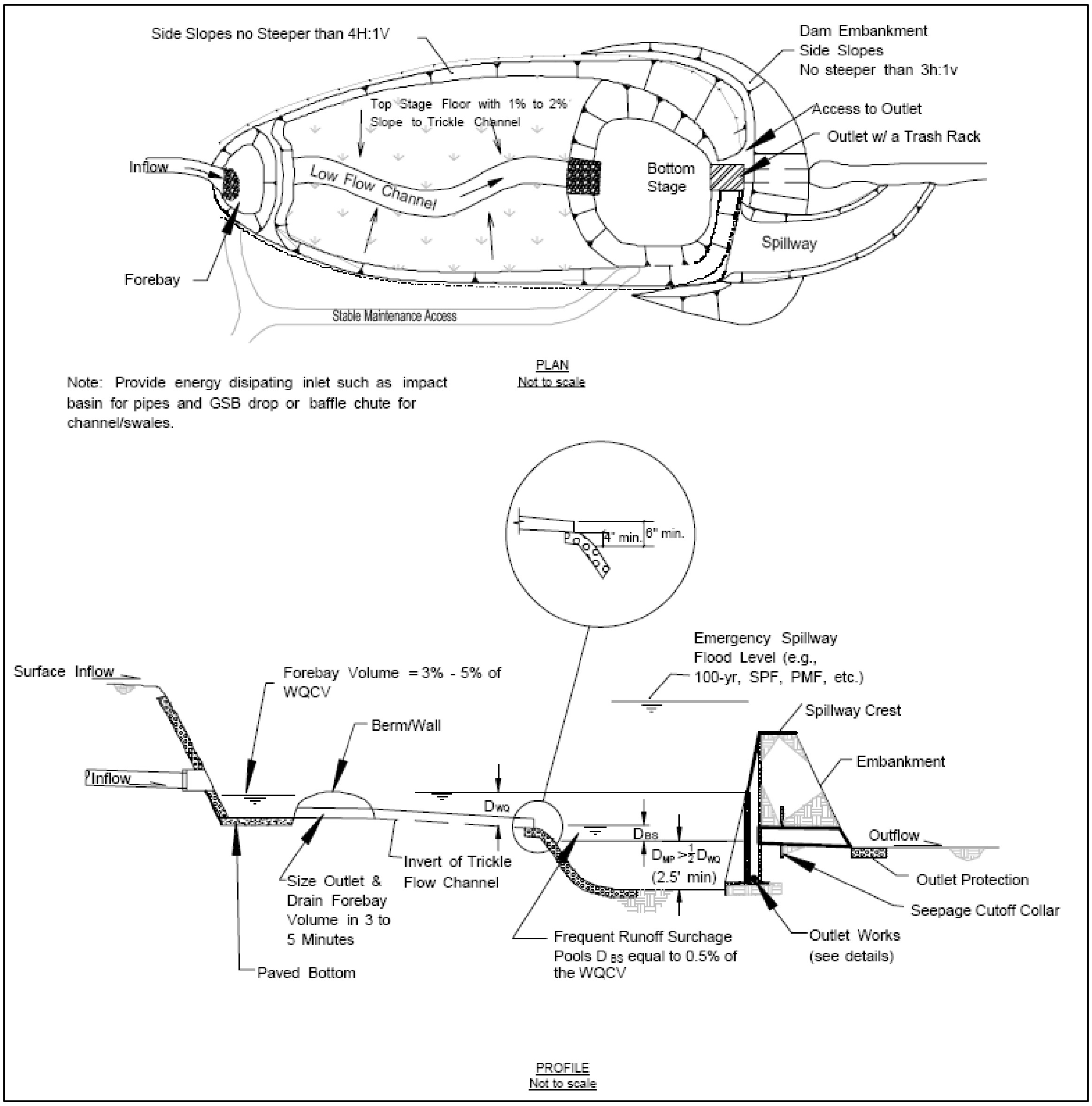

Figure C7-S1- 2: Extended dry detention basin
Source: UDFCD, 2005

4. **Wet detention basins.** Wet detention basin facilities (i.e., wet ponds, retention basins) are designed to contain a permanent pool of water with emergent wetland vegetation around the perimeter, designed to remove pollutants from stormwater. These are often called stormwater ponds or stormwater wetlands, and are constructed to provide water quality treatment. Removal rates of solids by wet detention basins tend to outperform dry detention basins. The larger permanent pool of wet detention basins allows water to reside in the interval between storms, when further treatment occurs. A wet detention basin can be sized to remove nutrients and dissolved constituents, while any temporary pool that may be associated with an extended dry detention basin is smaller and is provided for aesthetics, as discussed under the extended detention discussion above.
5. Figure C7-S1- 3 illustrates the elements of a wet detention basin.

   Chapter 7, section 3 provides criteria for the design of wet detention ponds. Guidance is provided for the following design parameters: pool volume, pool depth, surface area of permanent pool, minimum drainage area and pond volume, side slopes, pond configuration, outlets, and other elements. Criteria are also provided for the design of wetland ponds. These criteria include: general feasibility, conveyance, pre-treatment, treatment, and maintenance.

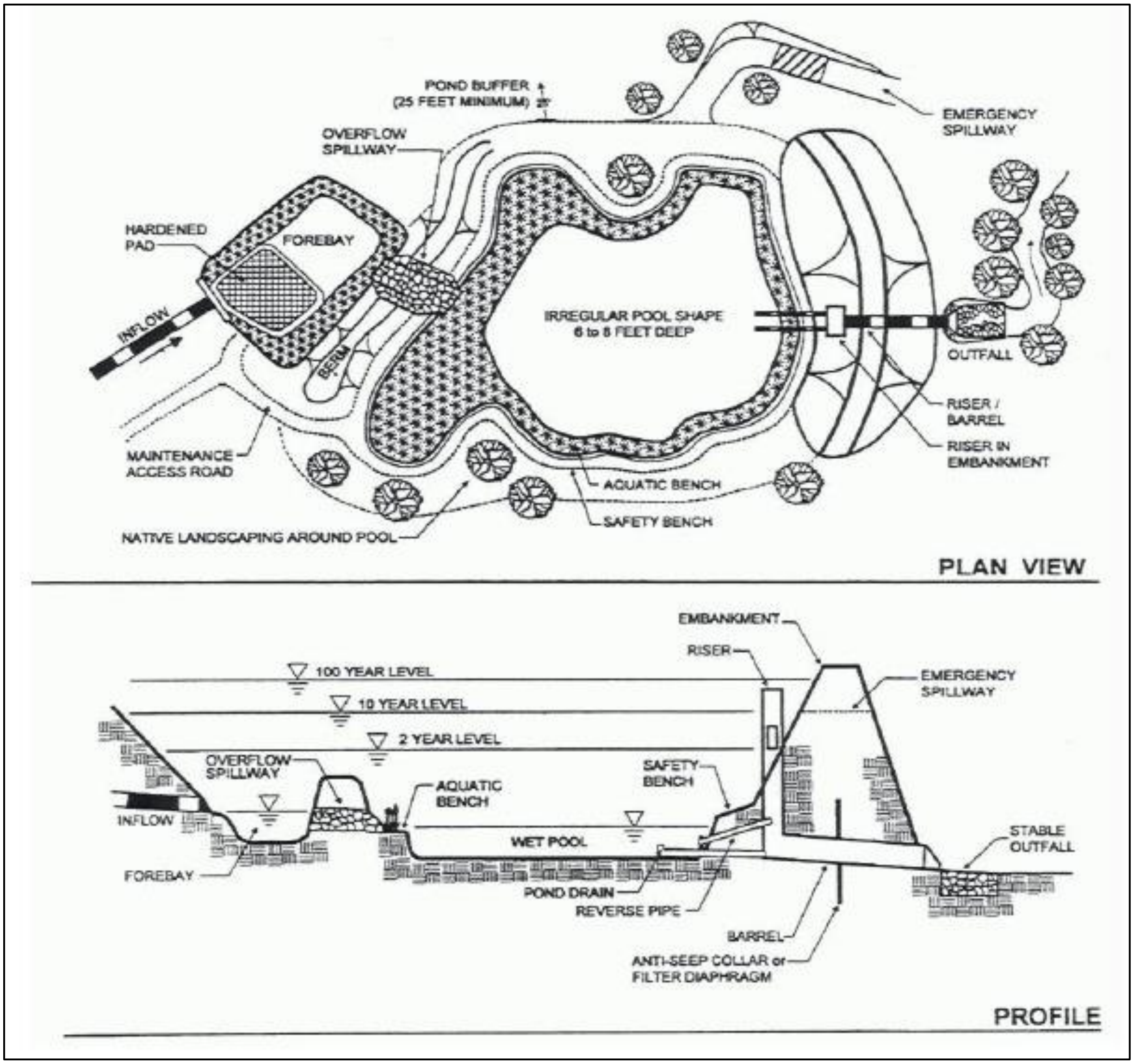

Figure C7-S1- 3: Wet detention basin
Source: Maryland, 2000

6. **Infiltration basins.** Infiltration basins are a special type of detention facility, and are described under infiltration practices. The design of infiltration basins is covered in Chapter 5, section 3. Design criteria are provided for the following elements: general feasibility, conveyance, pre-treatment, treatment, and maintenance. In addition design procedures address the following elements: soil texture, hydrologic design methods, and sizing.

B. Storage facilities

Storage facilities are often classified on the basis of their location and size.

- Onsite storage is constructed on individual development sites.
- Regional storage facilities are constructed at the lower end of a sub-watershed, and are designed to manage stormwater runoff from multiple projects and/or properties. A discussion of regional stormwater controls is found in Chapter 4, section 3. Regional facilities often offer economies of scale and greater reliability in capturing stormwater, while onsite facilities offer institutional and fiscal advantages of implementation as the land is urbanized.

Because of the poorly-documented stormwater pollutant control effectiveness of detention basins designed for flood control, these basins cannot themselves be recommended as viable water quality control measures. However, detention basins can be effective when used in conjunction with other upstream stormwater control practices such as vegetated swales, filter strips, and bioretention area BMPs.

Storage can also be categorized as on-line or off-line.

- Online storage uses a structural control facility that intercepts flows directly within a conveyance system or stream.
- Off-line storage is a separate storage facility to which flow is diverted from the conveyance system.

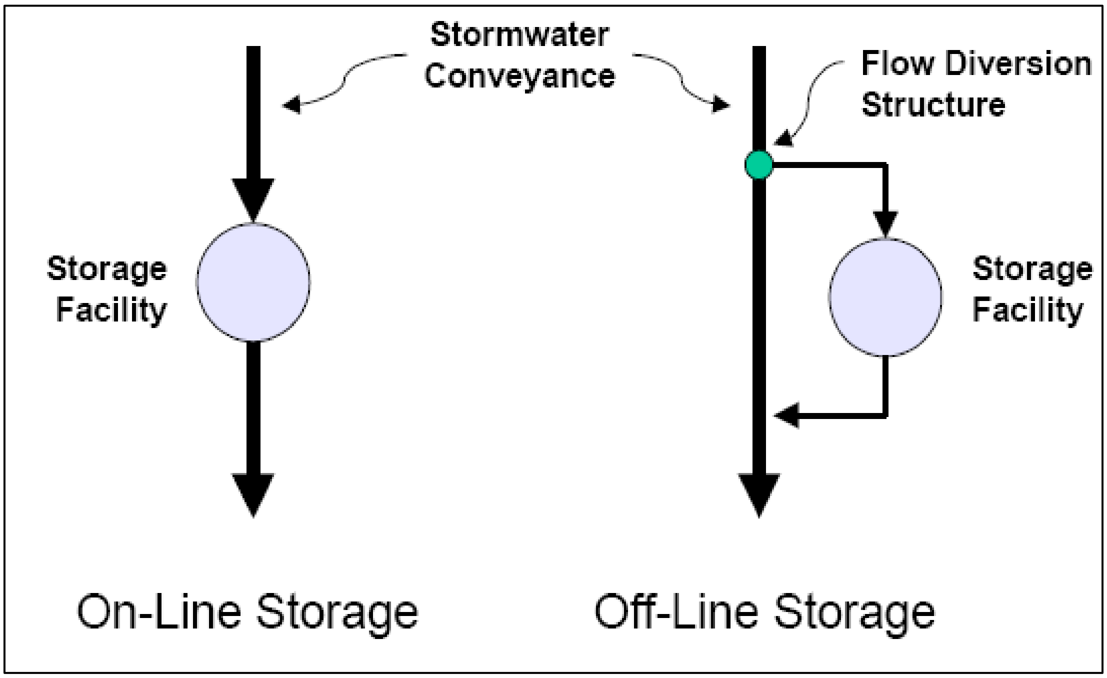

Figure C7-S1- 4: Online vs. Offline storage

Source: Georgia Stormwater Manual, 2002

POLLUTANT REMOVAL Low = <30% Medium = 30-65% High = 65-100%			
	Low	Med	High
Suspended Solids	✓	✓	
Nitrogen	✓		
Phosphorous	✓	✓	
Metals		✓	
Bacteriological	✓		
Hydrocarbons	✓		

Description: A dry detention or extended dry detention basin is a surface storage basin or facility designed to provide water quantity control through detention and/or extended detention of stormwater runoff.

Typical uses: Residential subdivision, high-density residential, ultra-urban areas, and parking lots. Also used for regional detention facilities.

Advantages:
- Applicable for drainage areas up to 75 acres.
- Typically less costly than stormwater (wet) ponds for equivalent flood storage, as less excavation is required.
- Used in conjunction with water quality structural control.
- Recreational and other open space opportunities between storm runoff events.

Limitations:
- Controls for stormwater quantity only – not intended to provide water quality treatment.

Maintenance requirements:
- Remove sediment accumulation to ensure proper functioning.
- Inspect for clogging – install an integrated observation well/peizometer to check water level.
- Remove sediment from pre-treatment areas.

A. Description

Dry detention and dry extended detention (ED) basins are surface facilities intended to provide for the temporary storage of stormwater runoff to reduce downstream water quantity impacts. These facilities temporarily detain stormwater runoff, releasing the flow over a period of time. They are designed to completely drain following a storm event and are normally dry between rain events.

Dry detention basins are intended to provide overbank flood protection (peak flow reduction of the 5-year (Q_{p5}) through 25-year storm (Q_{p25}), and can be designed to control the extreme flood (100-year, Q_f) storm event.

Dry ED basins provide downstream channel protection through extended detention of the channel protection volume (Cpv), and can also provide Q_{p25} and Q_f control. Both dry detention and dry ED basins provide limited pollutant removal benefits, and are not intended for water quality treatment. Detention-only facilities must be used in a treatment train approach with other structural controls that provide treatment of the WQv. Compatible multi-objective use of dry detention facilities is strongly encouraged.

B. Design criteria and physical specifications

1. **Location:**
   a. Dry detention and dry ED basins are to be located downstream of other structural stormwater controls

providing treatment of the water quality volume.

b. The maximum contributing drainage area to be served by a single dry detention or dry ED basin is 75 acres.

2. **General design:**
   a. Dry detention basins are sized to temporarily store the volume of runoff required to provide overbank flood (Q_{p5}-Q_{p25}) protection (i.e., reduce the post-development peak flow of the 25-year storm event to the pre-development rate), and control the 100-year storm (Q_f) if required.
   b. Dry ED basins are sized to provide extended detention of the channel protection volume over 24 hours and can also provide additional storage volume for normal detention (peak flow reduction) of Q_{p25} and Q_f.
   c. Routing calculations must be used to demonstrate that the storage volume is adequate. See Chapter 3, section 11 for procedures on the design of detention storage.
   d. Storage volumes greater than 100 acre-feet are subject to the requirements of the Iowa dams and impoundment regulations (IAC 567-Chapters 70-73) and Iowa DNR Technical Bulletin No. 16 (December 1990).
   e. Vegetated embankments should be less than 20 feet in height and have side slopes no steeper than 3:1 (horizontal to vertical), although 4:1 is preferred. Riprap-protected embankments should be no steeper than 3:1. Geotechnical slope stability analysis is recommended for embankments greater than 10 feet in height and is mandatory for embankment slopes steeper than those given above. All embankments must be designed to State of Iowa guidelines for dam safety Iowa DNR Tech Bulletin #16.
   f. The maximum depth of the basin should not exceed 10 feet.
   g. Areas above the normal high water elevations of the detention facility should be sloped toward the basin to allow drainage and to prevent standing water. Careful finish grading is required to avoid creation of upland surface depressions that may retain runoff. The bottom area of storage facilities should be graded toward the outlet to prevent standing water conditions.
   h. A low-flow or pilot channel across the facility bottom from the inlet to the outlet (often constructed with riprap) is recommended to convey low flows and prevent standing water conditions.
   i. Adequate maintenance access must be provided for all dry detention and dry ED basins.

3. **Inlet and outlet structures:**
   a. Inflow channels are to be stabilized with flared riprap aprons, or the equivalent. A sediment forebay sized to 0.1 inches per impervious acre of contributing drainage should be provided for dry detention and dry ED basins that are in a treatment train with off-line water quality treatment structural controls.
   b. For a dry detention basin, the outlet structure is sized for control of the Q_{p5}-Q_{p25} (based upon hydrologic routing calculations) and can consist of a weir, orifice, outlet pipe, combination outlet, or other acceptable control structure. Small outlets that will be subject to clogging or are difficult to maintain are not acceptable.
   c. For a dry ED basin, a low-flow orifice capable of releasing the channel protection volume over 24 hours must be provided. The channel protection orifice should have a minimum diameter of 3 inches and should be adequately protected from clogging by an acceptable external trash rack. The orifice diameter may be reduced to 1 inch if internal orifice protection is used (e.g., an over-perforated vertical stand pipe with 0.5-inch orifices or slots that are protected by wire cloth and a stone filtering jacket). Adjustable gate valves can also be used to achieve this equivalent diameter. See Chapter 3, section 13 for more information on the design of outlet works.
   d. Seepage control or anti-seep collars should be provided for all outlet pipes.
   e. Riprap, plunge pools or pads, or other energy dissipators are to be placed at the end of the outlet to prevent scouring and erosion. If the basin discharges to a channel with dry weather flow, care should be taken to minimize tree clearing along the downstream channel, and to reestablish a forested riparian zone in the shortest possible distance. See Chapter 14, section 2 for more guidance on energy dissipation design.
   f. A secondary (emergency) spillway is to be included in the stormwater pond design to safely pass the extreme flood flow. The spillway prevents pond water levels from overtopping the embankment and causing structural damage. The secondary spillway must be designed to Iowa DNR standards, and must be located so that downstream structures will not be impacted by spillway discharges.
   g. A minimum of 1 foot of freeboard must be provided, measured from the top of the water surface elevation for the extreme flood, to the lowest point of the dam embankment not counting the secondary spillway.
   h. For structures without a secondary spillway, the top of dam (embankment) elevation should be 2 feet higher than the peak flood elevation expected during the freeboard design flood.

C. Inspection and maintenance requirements

Table C7-S1- 2: Typical maintenance activities for dry detention/dry ED basins

Activity	Schedule
• Remove debris from basin surface to minimize outlet clogging and improve aesthetics. • Inspect installed low-flow orifices in ED basins for clogging	Annually and following significant storm events
• Remove sediment buildup • Repair and re-vegetate eroded areas • Perform structural repairs to inlet and outlets	As needed, based on inspection
• Mow to limit unwanted vegetation	Routine

Source: Denver Urban Storm Drainage Manual, 1999

D. Example schematics

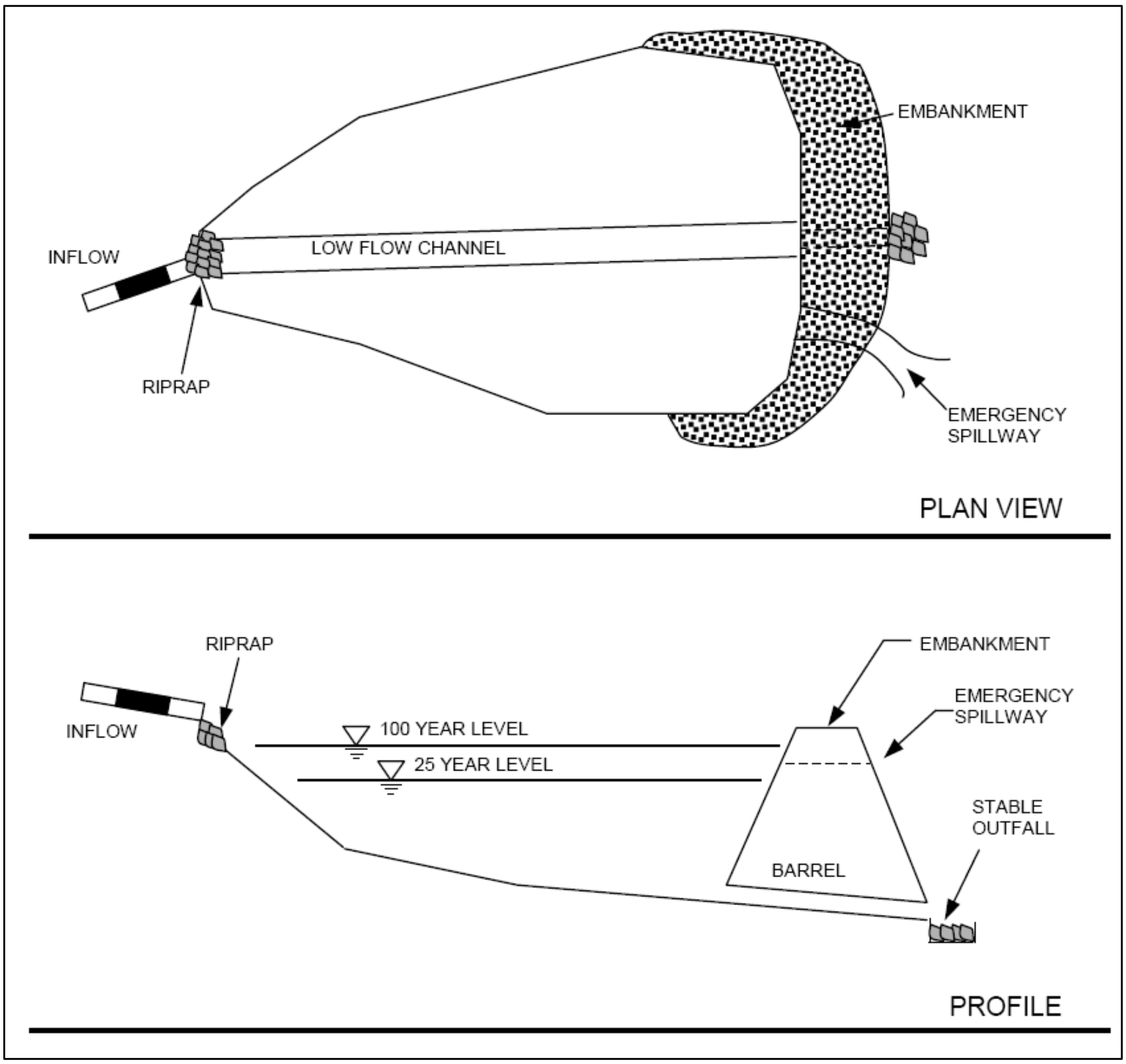

Figure C7-S2- 1: Schematic of dry detention basin

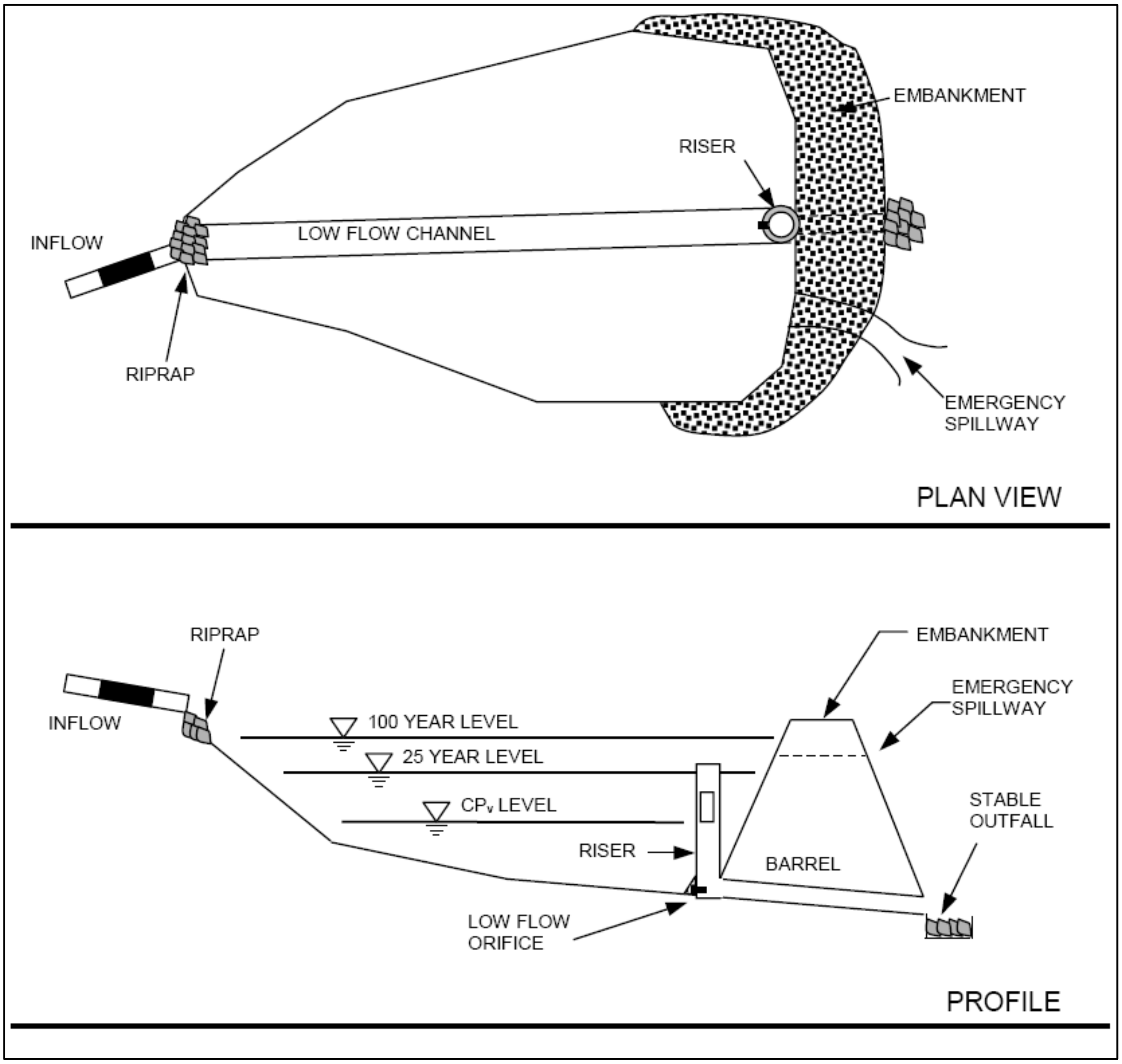

Figure C7-S2- 2: Schematic of extended dry detention basin (Example 1)
Source: Schueler, 1987

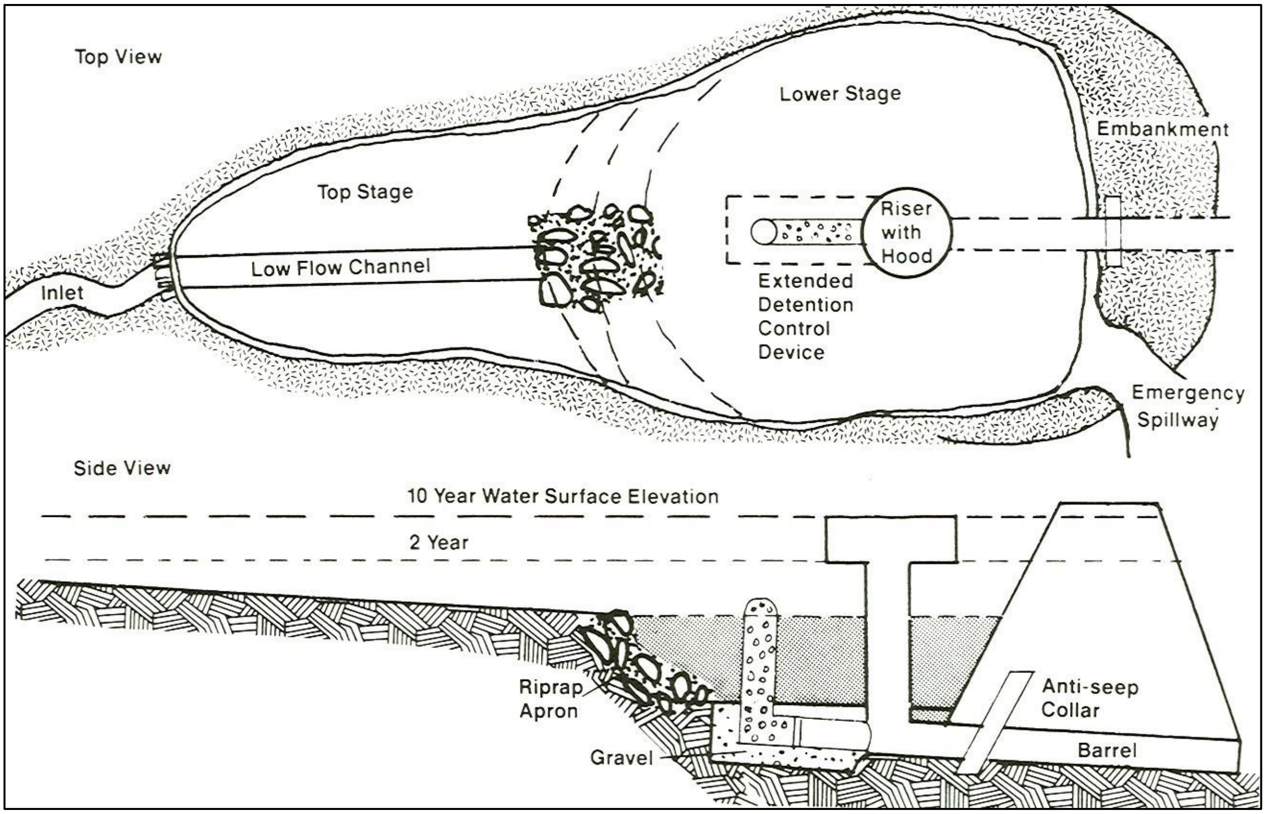

Figure C7-S2- 3: Schematic of extended dry detention basin (Example 2)
Source: Schueler, 1987

Source: Georgia Stormwater Manual, 2001

POLLUTANT REMOVAL Low = <30% Medium = 30-65% High = 65-100%			
	Low	Med	High
Suspended Solids		✓	✓
Nitrogen		✓	
Phosphorous		✓	
Metals		✓	
Bacteriological			✓
Hydrocarbons		✓	

Description: A wet detention basin is a constructed stormwater detention basin that has a permanent pool of water. Runoff from each rain event is detained and treated in the pool primarily through settling and biological uptake mechanisms. Wet ponds are among the most widely used stormwater practices.

Typical uses: Residential subdivision, low-density commercial; not recommended for high-density residential, ultra-urban areas.

Advantages:

- Moderate to high removal of urban pollutants. The permanent wet pool can provide significant water quality improvement across a relatively broad spectrum of constituents, including dissolved nutrients.
- High community acceptance. Wet basins can provide substantial aesthetic/recreational value and wildlife and wetlands habitat. Ponds are often viewed as a public amenity when integrated into a park setting.
- Widespread application with sufficient capture volume can provide additional control of channel erosion and enlargement.

Limitations:

- Minimum contributing drainage area of 25 acres; 10 acres for a micro-pool ED pond. Need for base flow or supplemental water if water level is to be maintained.
- Mosquito and midge breeding is likely to occur in ponds.
- Cannot be placed on steep unstable slopes.
- Potential for thermal impacts in downstream reach from warmer discharge.
- Depending on volume and embankment height, pond designs may require approval from the Iowa Department of Natural Resources (Re: Iowa Technical Bulletin 16).

Maintenance requirements:

- Monitor sediment accumulation and remove periodically.
- Remove debris from inlet and outlet structures.
- Maintain side slopes and shoreline vegetation.

A. Description

Stormwater ponds (also referred to as wet ponds, retention ponds, or wet extended duration [ED] ponds) are constructed stormwater retention basins that have a permanent pool of water throughout the year. They can be created by excavating an already existing natural depression, or through the construction of embankments.

In a stormwater pond, runoff from each rain event is detained and treated in the pool through gravitational settling and biological uptake until it is displaced by runoff from the next storm. The permanent pool also serves to protect deposited sediments from re-suspension. Above the permanent pool level, additional temporary storage (live storage) is provided for runoff quantity control. The upper stages of a stormwater pond are designed to provide extended detention of the 2-year

storm for downstream channel protection, as well as normal detention of larger storm events (25-year and, optionally, the 100-year storm event). A general schematic of a wet detention basin is shown in
Figure C7-S3- 1.

Stormwater ponds are among the most cost-effective and widely-used stormwater practices. A well- designed and landscaped pond can be an aesthetic feature on a development site when planned and located properly.

There are several different variants of stormwater pond design, the most common of which include the wet pond, the wet extended detention pond, and the micro-pool extended detention pond. In addition, multiple stormwater ponds can be placed in series or parallel to increase performance or meet site design constraints. Below are descriptions of each design variant:

1. **Wet pond.** A wet pond is a stormwater basin constructed with a permanent (dead storage) pool of water equal to the water quality volume. Stormwater runoff displaces the water already present in the pool. Temporary storage (live storage) can be provided above the permanent pool elevation for larger flows.

2. **Wet extended detention (ED) pond.** A wet extended detention pond is a wet pond where the water quality volume is split evenly between the permanent pool and extended detention (ED) storage provided above the permanent pool. During storm events, water is detained above the permanent pool and released over 24 hours. This design has similar pollutant removal to a traditional wet pond, but consumes less space.

3. **Micro-pool extended detention (ED) pond.** The micro-pool extended detention pond is a variation of the wet ED pond where only a small "micro-pool" is maintained at the outlet to the pond. The outlet structure is sized to detain the water quality volume for 24 hours. The micro- pool prevents re-suspension of previously-settled sediments, and also prevents clogging of the low flow orifice.

4. **Multiple pond systems.** Multiple pond systems consist of constructed facilities that provide water quality and quantity volume storage in two or more cells. The additional cells can create longer pollutant removal pathways and improved downstream protection.

Figure C7-S3- 2 shows a number of examples of stormwater pond variants.
Figure C7-S3- 6,
Figure C7-S3- 7, and
Figure C7-S3- 8 provide plan view and profile schematics for the design of a wet pond, wet extended detention pond, micro-pool extended detention pond, and multiple pond system.

B. Stormwater management suitability

Stormwater ponds are designed to control both stormwater quantity and quality. Thus, a stormwater pond can be used to address all of the unified stormwater sizing criteria for a given drainage area.

1. **Water quality.** Ponds treat incoming stormwater runoff by physical, biological, and chemical processes. The primary removal mechanism is gravitational settling of particulates, organic matter, metals, bacteria, and organics as stormwater runoff resides in the pond. Another mechanism for pollutant removal is uptake by algae and wetland plants in the permanent pool, particularly of nutrients. Volatilization and chemical activity also work to break down and eliminate a number of other stormwater contaminants, such as hydrocarbons.

2. **Channel protection.** A portion of the storage volume above the permanent pool in a stormwater pond can be used to provide control of the channel protection volume (Cpv). This is accomplished by releasing the 1-year, 24-hour storm runoff volume over a 24-hour period (extended detention).

3. **Overbank flood protection.** A stormwater pond can also provide storage above the permanent pool to reduce the post-development peak flows of the 5-yr (Q_{p5}) through the 25-year storm (Q_{p25}) to pre-development levels (detention).

4. **Extreme flood protection.** In situations where it is required, stormwater ponds can also be used to provide detention to control the 100-year storm peak flow (Q_f). Where this is not required, the pond structure is designed to safely pass extreme storm flows.

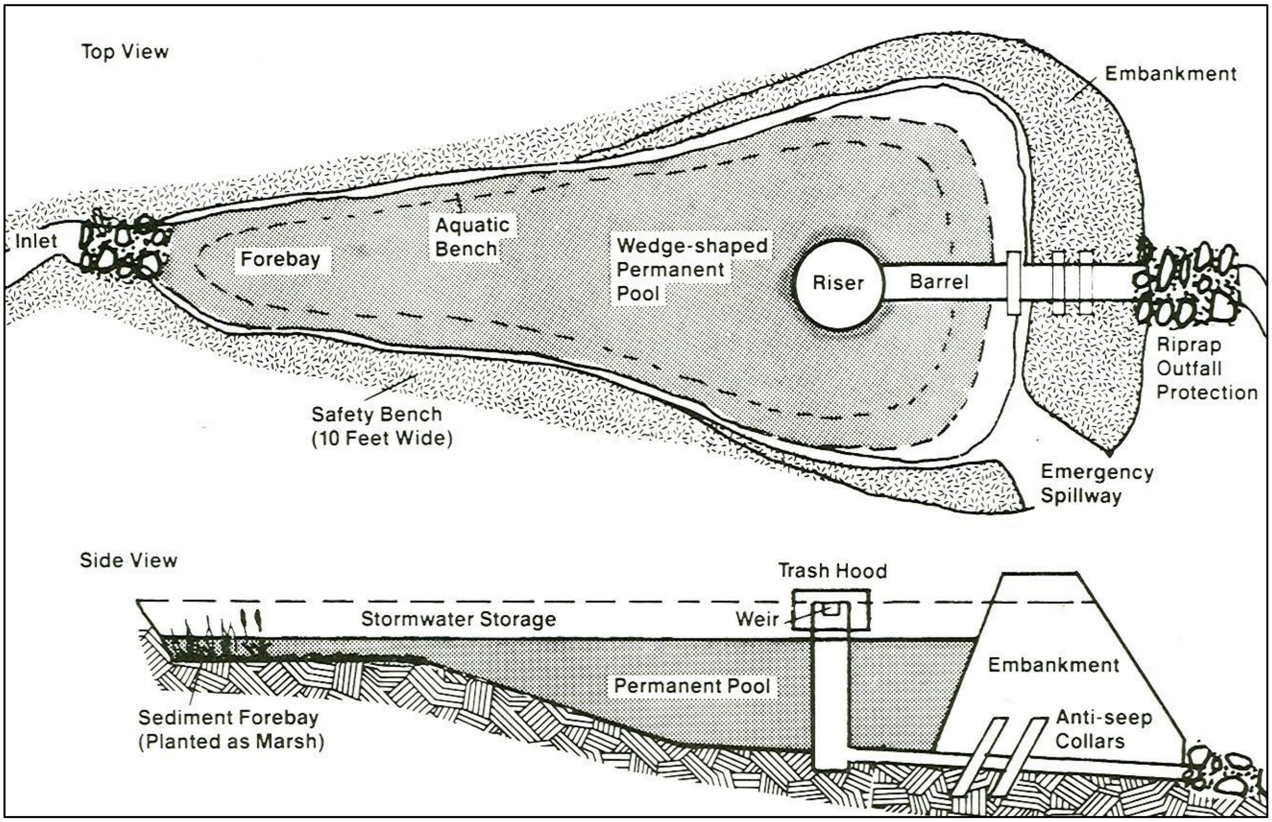

Figure C7-S3- 1: Schematic of wet detention basin (wet pond)
Source: Schueler, 1987

Wet Pond

Wet ED Pond

Micropool ED Pond

Wet ED Pond

Figure C7-S3- 2: Examples of design variants of wet detention basins
Source: Georgia Stormwater Manual, 2001

C. Pollutant removal capabilities

All of the stormwater pond design variants are presumed to be able to remove 80% of the total suspended solids load in typical urban post-development runoff when sized, designed, constructed, and maintained in accordance with the recommended specifications. Undersized or poorly-designed ponds can reduce TSS removal performance.

The following design pollutant removal rates are conservative average pollutant reduction percentages for design purposes derived from sampling data, modeling, and professional judgment. In a situation where a removal rate is not deemed sufficient, additional controls may be put in place at the given site in a series or treatment train approach.

- Total suspended solids – 85%
- Total phosphorus – 50%
- Total nitrogen – 30%
- Fecal coliform – 70% (if no resident waterfowl population present)
- Heavy metals – 50%

For additional information and data on pollutant removal capabilities for stormwater ponds, see the National Pollutant Removal Performance Database (2nd Edition) available at http://www.cwp.org/ and the National Stormwater Best Management Practices (BMP) Database at http://www.bmpdatabase.org/.

D. Application and feasibility

Stormwater ponds are generally applicable to most types of new development and redevelopment, and can be used in both residential and nonresidential areas. Ponds can also be used in retrofit situations. The following criteria should be evaluated to ensure the suitability of a stormwater pond for meeting stormwater management objectives on a site or development.

1. **General feasibility.**
   - Suitable for residential subdivision usage: yes
   - Suitable for high-density/ultra-urban areas: land requirements may preclude use
   - Regional stormwater control: yes

2. **Physical feasibility - physical constraints at project site.**
   a. **Drainage area.** A minimum of 25 acres is needed for wet pond and wet ED pond to maintain a permanent pool; 10 acres minimum for micro-pool ED pond. A smaller drainage area may be acceptable with an adequate water balance and anti-clogging device. In these cases, a water balance may be performed (see Chapter 3, section 10 for details).
   b. **Space required.** Approximately 2-3% of the tributary drainage area.
   c. **Site slope.** There should be more than 15% slope across the pond site.
   d. **Minimum head.** Elevation difference needed at a site from the inflow to the outflow: 6-8 feet.
   e. **Minimum depth to water table.** If used on a site with an underlying water supply aquifer or when treating a

hotspot, a separation distance of 2 feet is required between the bottom of the pond and the elevation of the seasonally high water table.

f. **Soils.** Underlying soils of hydrologic Group C or D should be adequate to maintain a permanent pool. Most Group A soils and some Group B soils will require a pond liner. Evaluation of soils should be based upon an actual subsurface analysis and permeability tests.

g. **Topography.** A stormwater pond should be sited such that the topography allows for maximum runoff storage at minimum excavation or construction costs. Pond siting should also take into account the location and use of other site features such as buffers and undisturbed natural areas, and should attempt to aesthetically fit the facility into the landscape. Bedrock close to the surface may prevent excavation.

h. Minimum setback requirements for stormwater pond facilities (when not specified by local ordinance or criteria):

- From a property line: 10 feet
- From a private well: 100 feet; if well is down-gradient from a hotspot land use, then the minimum setback is 250 feet
- From a septic system tank/leach field: 50 feet
- All utilities should be located outside of the pond/basin site

3. Other constraints/considerations:

a. Consideration should be given to the thermal influence of stormwater pond outflows on downstream coldwater fisheries habitat.

b. Stormwater ponds cannot be located within a stream or any other navigable waters of the US, including wetlands, without obtaining a Section 404 permit under the Clean Water Act, and any other applicable state permit.

E. Design approach

Two alternative approaches are used to establish design criteria for water quality purposes in wet detention ponds. The first approach is based on solids-settling, and assumes that all pollutant removal within the pond occurs primarily due to sedimentation. The second approach treats the wet pond as a lake with controlled levels of eutrophication to account for the biological, physical, and chemical processes that are principal mechanisms for nutrient removal (Hartigan, 1989 and Walker, 1987). Both approaches relate the pollutant removal efficiencies to hydraulic residence time.

The design approach is selected on the basis of the water quality control efforts (TSS vs. nutrient) reduction, as well as site and economic constraints. The controlled eutrophication approach requires longer residence times and larger storage volumes compared to those of the solids-settling approach. However, if the chief concern is to control nutrient levels in waters such as lakes and reservoirs, it is then advantageous to use the controlled eutrophication approach. If the major goal is the removal of a broad spectrum of pollutants, especially those adsorbed onto suspended matter, it may be preferable to base the design criteria on the sedimentation models. Currently, the most common pond water quality practice designs for runoff pollution control rely heavily on the sedimentation process.

1. **Design variations.** Two basic design variations can be used to satisfy particular site-specific conditions or requirements. These are:

   a. A wet pond with a permanent pool of water with a volume (VB) equal to some fraction or multiple of the mean storm runoff volume (VR). The runoff displaces a portion of the pool volume, is treated during the dry period, and in turn is displaced by the next storm. A schematic of this wet pond design is illustrated in

   b. Figure C7-S3- 6.

   c. A multipurpose, multi-stage wet pond designed to provide stormwater management (peak attenuation, etc.) in addition to water quality enhancement.

2. **Design parameters.** The primary removal mechanism for pollutants in wet ponds is by settling of the solid materials. Thus, wet ponds should be designed to maximize sedimentation within the permanent pool. The permanent pool of water is equal to some fraction or multiple of the runoff volume (V_B/V_R). The runoff displaces a portion of the pool volume, is treated during the dry period, and in turn is displaced by the next storm. Schueler and Helfrich (1988) summarized typical design criteria for this approach in

3. Table C7-S3- 1. General hydrologic and hydraulic suggestions for onsite (drainage area 20-100 acres) and regional (drainage area 100-300 acres) wet pond water quality practices for treatment of nutrients and a broader spectrum of pollutants are given in Table C7-S3- 2. Some important design parameters are discussed below:

a. **Pool volume.** The volume of the permanent pool in relation to the drainage area or runoff volume is the most critical parameter in the sizing of the wet pond and its ability to remove pollutants. Various design criteria or rules of thumb are expressed in terms of the V_B/V_R ratio, where V_B is the volume of the permanent pool and V_R is the volume of runoff for an average storm. The starting point for selecting a design is to size the pool for a hydraulic detention time, which is a simple calculation to make, and then check the pollutant removal with the procedures detailed above. The value of detention time T (in years) is given by dividing the permanent pool volume V_B by the product of the total number of runoff events per year, n, namely:

$$T = \frac{V_B}{nV_R}$$

Field studies indicate that an optimum removal of approximately 50% nutrients occurs at T values of 2-3 weeks for pools with mean depths of 3-6 feet (Hartigan et al., 1989). In the eastern US, this optimum range for T values corresponds to V_B/V_R ratios of 4-6. Ponds with values of T greater than 2-3 weeks have a greater risk of thermal stratification and anaerobic bottom waters, resulting in an increased risk of significant export of nutrients from bottom sediments.

The design criteria for the permanent pool storage volume can be quantified in terms of the average hydraulic retention time, T, the ratio V_B/V_R, or minimum total suspended sediment removal rate. For example, the State of Florida (Florida DER, 1988) requires an average hydraulic retention time of 14 days, equivalent to V_B/V_R of 4. The UDFCD's BMP criteria manual in the Denver, Colorado, area (UDFCD, 1992) specifies that the permanent pool storage volume should be 1.0-1.5 times the water quality capture volume, which is equivalent to V_B/V_R on the order of 1.5-2.5.

Another approach is to require detention of a specified runoff volume as surcharge above the permanent pool. Storage in the surcharge zone is released during a specified period through an outlet structure. The surcharge detention requirement is intended to reduce short-circuiting and enhance settling of total suspended sediments. Settling-solids analysis shows that retention ponds sized for nutrient removal with a minimum detention time, T, of 2 weeks and a minimum V_B/V_R of 4 achieve total suspended sediment removal rates of 80 to 90%. Addition of an extended detention zone above the permanent pool is unlikely to produce measurable increases in the removal of total suspended sediments. Still, a surcharge extended detention volume is recommended whenever the V_B/V_R, is less than 2.5. Whenever one is used or required, it is suggested that the maximized event-based volume with a 12-hour drain time be used.

In cases where relatively permeable soils (HSG A and B) are encountered, the risk of drawdown may be minimized by installing a 6-inch clay liner at the bottom of the pond.

b. **Pool depth.** The depth of the permanent pool is an important design parameter since it affects solids-settling. Mean depth of the pool is obtained by dividing the storage volume by the pool surface area. The pool should be shallow enough to ensure aerobic conditions and avoid thermal stratification, yet be deep enough to minimize algal blooms or re-suspension of previously-deposited materials by major storms or wind-generated disturbances. Prevention of thermal stratification will minimize short-circuiting and maintain aerobic bottom waters, thus maximizing pollutant uptake and minimizing the potential release of nutrients to the overlying waters. An average depth of 3-6 feet is sufficient to maintain the environment within the pool. A 10-foot wide and 1-foot deep bench is needed around the perimeter of the pool to promote aquatic vegetation and to reduce the potential safety hazard to the public. Shallow depth near the inlet structure is desirable to concentrate sediment deposition in a smaller and more easily-accessible area. The effluent riser should be located in a deeper area to facilitate withdrawal of cooler bottom water for the mitigation of downstream thermal impacts, if any.

The minimum depth of the open water area should be greater than the depth of sunlight penetration to prevent emergent plant growth in this area, on the order of 6-8 feet. A mean depth of approximately 3-10 feet should produce a pond with sufficient surface area to promote algae photosynthesis, and should maintain an acceptable environment within the permanent pool for the average hydraulic retention times recommended above, although separate analyses should be performed for each locale. If the pond has more than 2 acres of water surface, mean depths of 6.5 feet will protect it against wind-generated re-suspension of sediments. The mean depths of the more effective retention ponds monitored by the NURP study typically fall within this range. A water depth of approximately 6 feet over the major portion of the pond will also increase winter survival of fish (Schueler, 1987).

A maximum depth of 10-13 feet should reduce the risk of thermal stratification (Schueler, 1987). Readily-visible stormwater management facilities receive more and better maintenance than those in less visible, more remote locations. Readily-visible facilities can also be inspected faster and more easily by maintenance and mosquito-control personnel. If maintained at the recommended 3-6 foot depth, the permanent pool can serve as aquatic habitat.

c. **Minimum surface area of permanent pool.** Minimum surface area will be contingent upon local topography, minimum depth, and solids-settling guidelines. For on-site wet pond water quality basins, the typical minimum pool surface area is 0.25 acres.

d. **Minimum drainage area and pond volume.** The minimum drainage area for an onsite wet pond water-quality structure should be large enough to sustain the wet pond during the summer periods. The drainage area should permit sufficient base flow, to prevent excessive retention times or severe drawdowns of the permanent pool during dry seasons. Unless regional experience is available for determining the minimum drainage area required in a particular location, it is recommended that a water balance calculation be performed using local runoff, evapotranspiration, ex-filtration, and base flow data to ensure that the base flow is adequate to keep the pond full during the dry season. Base flow will, of course, vary considerable from watershed to watershed in a region. However, a regionalized analysis would be helpful. Monthly and annual evaporation and precipitation data is available State of Iowa State climatology bureau (http://www.iowaagriculture.gov/climatology.asp) or from the Department of Agronomy at Iowa State University (http://mesonet.agron.iastate.edu/index.phtml).

The maximum tributary catchment area should be set to reduce the exposure of upstream channels to erosive stormwater flows, reduce effects on perennial streams and wetlands, and reduce public safety hazards associated with dam height. Again, regional experience will be useful in providing guidelines. For example, some stormwater master plans have restricted the maximum tributary catchments to 100-300 acres, depending on the amount of imperviousness in the watershed, with highly-impervious catchments restricted to the lower end of this range, and vice versa. As a rule of thumb, a minimum drainage area of 20 acres is required to sustain the desired dry weather inflow. In general, 4 acres of contributing drainage area are needed for each acre-foot of storage. As indicated earlier, however, a local analysis is needed.

e. **Side slopes.** Side slopes along the shoreline of the retention pond should be 4:1 or flatter to facilitate maintenance (such as mowing) and reduce public risk of slipping and falling into the water. In addition, a littoral zone (portion less than 15 feet deep, which is home to most of the aquatic plant life) should be established around the perimeter of the permanent pool to promote the growth of emergent vegetation along the shoreline and deter individuals from wading (see

f. Figure C7-S3- 3). The emergent vegetation around the perimeter serves several other functions: it reduces erosion, enhances the removal of dissolved nutrients in urban stormwater discharges, may reduce the formation of floating algal mats, and provides habitat for aquatic life and wetland wildlife. This bench for emergent wetland vegetation should be at least l0 feet wide with a water depth of 0.5-1.5 feet. The total area of the aquatic bench should be 25-50% of the permanent pool's water surface area. Local agricultural agencies or commercial nurseries should be consulted about guidelines for using wetland vegetation within shallow sections of the permanent pool.

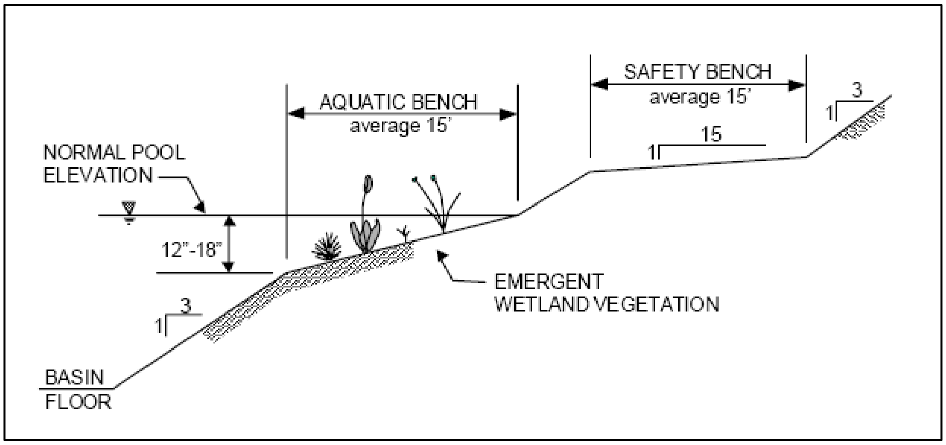

Figure C7-S3- 3: Typical stormwater pond geometry criteria

4. **Pond configuration.** Length to width ratio of the pond should be as large as possible to simulate conditions found in plug flow reaction kinetics. Under the ideal plug flow conditions, a "plug" or "pulse" of runoff enters the basin and moves as a plug through the pond without mixing. Relatively large length-to-width ratios can help reduce short-circuiting, enhance sedimentation, and help prevent vertical stratification within the permanent pool. Griffin et al. (ASCE, 1985) showed that the dead storage for length-to-width ratios less than 2:1 was in the range of 27%, and for length-to-width ratios greater than 2:1, was in the range of 17%. A minimum length-to-width ratio of 2:1 is therefore recommended for the permanent pool. The permanent pool should expand gradually from the basin inlet and contract gradually toward the outlet, maximizing the travel time from the inlet to the outlet. Baffles or islands within the pool can increase the flow path length and reduce short-circuiting.

   To reduce the frequency of major cleanout activities within the pool area, a sediment forebay with a hardened bottom should be constructed near the inlet to trap coarse sediment particles. As with detention basins, a frequently-used value for the forebay storage capacity is approximately 10% of the permanent pool storage. Access for mechanized equipment should be provided to facilitate removal of sediment. The forebay can be separated from the remainder of the permanent pool by one of several means: a lateral sill with wetland vegetation, two ponds in series, differential pool depth, rock-filled gabions, a retaining wall, or a horizontal rock filter placed laterally across the permanent pool.

5. **Pretreatment/inlets:**
   a. Each pond should have a sediment forebay or equivalent upstream pre-treatment. A sediment forebay is designed to remove incoming sediment from the stormwater flow prior to dispersal in a larger permanent pool. The forebay should consist of a separate cell, formed by an acceptable barrier. A forebay is to be provided at each inlet, unless the inlet provides less than 10% of the total design storm inflow to the pond. In some design configurations, the pre-treatment volume may be located within the permanent pool.
   b. The forebay is sized to contain 0.1 inches per impervious acre of contributing drainage, and should be 4-6 feet deep. The pre-treatment storage volume is part of the total WQv requirement, and may be subtracted from WQv for permanent pool sizing.
   c. A fixed vertical sediment depth marker is installed in the forebay to measure sediment deposition over time. The bottom of the forebay may be hardened (e.g., using concrete, paver blocks, etc.) to make sediment removal easier.
   d. Inflow channels are to be stabilized with flared riprap aprons, or an equivalent. Inlet pipes to the pond can be partially-submerged. Exit velocities from the forebay must be non-erosive.

6. **Outlets:**
   a. An outlet for a wet detention basin typically consists of a riser with a hood or trash rack to prevent clogging, and an adequate anti-vortex device for basins serving large drainage areas. Some typical outlet structures and details are provided in Chapter 3, section 13. Anti-seep collars should be installed along outlet conduits passing through or under the dam embankment. If the pond is a part of a larger peak-shaving extended detention basin, the outlet should be designed for the desired flood control performance. Chapter 3, section 13 provides more guidance on outlet design, especially for low flow. Typically, the riser structure should be sized to drain the permanent pool within 48 hours so sediments may be removed mechanically when necessary. The

drain pipe should be controlled by a locking gate valve at the outlet.

b. A number of outlets at varying depths in the riser provide internal flow control for routing of the water quality, channel protection, and overbank flood protection runoff volumes. The number of orifices can vary and is usually a function of the pond design.

   For example, a wet pond riser configuration is typically comprised of a channel protection outlet (usually an orifice) and overbank flood protection outlet (often a slot or weir). The channel protection orifice is sized to release the channel protection storage volume over a 24-hour period (12-hour extended detention may be warranted in some coldwater streams). Since the water quality volume is fully contained in the permanent pool, no orifice sizing is necessary for this volume. As runoff from a water quality event enters the wet pond, it simply displaces that same volume through the channel protection orifice. Thus an off-line wet pond providing only water quality treatment can use a simple overflow weir as the outlet structure.

   In the case of a wet ED pond or micro-pool ED pond, there is generally a need for an additional outlet (usually an orifice) that is sized to pass the extended detention water quality volume that is surcharged on top of the permanent pool. Flow will first pass through this orifice, which is sized to release the water quality ED volume in 24 hours. The preferred design is a reverse slope pipe attached to the riser, with its inlet submerged 1 foot below the elevation of the permanent pool to prevent floatables from clogging the pipe, and to avoid discharging warmer water at the surface of the pond. The next outlet is sized for the release of the channel protection storage volume. The outlet (often an orifice) invert is located at the maximum elevation associated with the extended detention water quality volume, and is sized to release the channel protection storage volume over a 24-hour period (12-hour extended detention may be warranted in some coldwater streams).

   Alternative hydraulic control methods to an orifice can be used, and include the use of a broad-crested rectangular, V-notch, proportional weir, or an outlet pipe protected by a hood that extends at least 12 inches below the normal pool.

c. The water quality outlet (if design is for a wet ED or micro-pool ED pond) and channel protection outlet should be fitted with adjustable gate valves or other mechanism that can be used to adjust detention time.
d. Higher flows (overbank and extreme flood protection) flows pass through openings or slots protected by trash racks further up on the riser.

e. After entering the riser, flow is conveyed through the barrel and is discharged downstream. Anti-seep collars should be installed on the outlet barrel to reduce the potential for pipe failure.
f. Riprap, plunge pools or pads, or other energy dissipators are to be placed at the outlet of the barrel to prevent scouring and erosion. If a pond daylights to a channel with dry weather flow, care should be taken to minimize tree clearing along the downstream channel, and to re- establish a forested riparian zone in the shortest possible distance. Additional guidance on energy dissipation design is included in Chapter 14, section 2.
g. Each pond must have a bottom drain pipe with an adjustable valve that can completely or partially drain the pond within 24 hours.
h. The pond drain should be sized one pipe size greater than the calculated design diameter. The drain valve is typically a hand wheel-activated knife or gate valve. Valve controls shall be located inside of the riser at a point where they will not normally be inundated and can be operated in a safe manner.

See the design procedures Chapter 3, sections 11 and 13 for additional information and specifications on pond routing and outlet works.

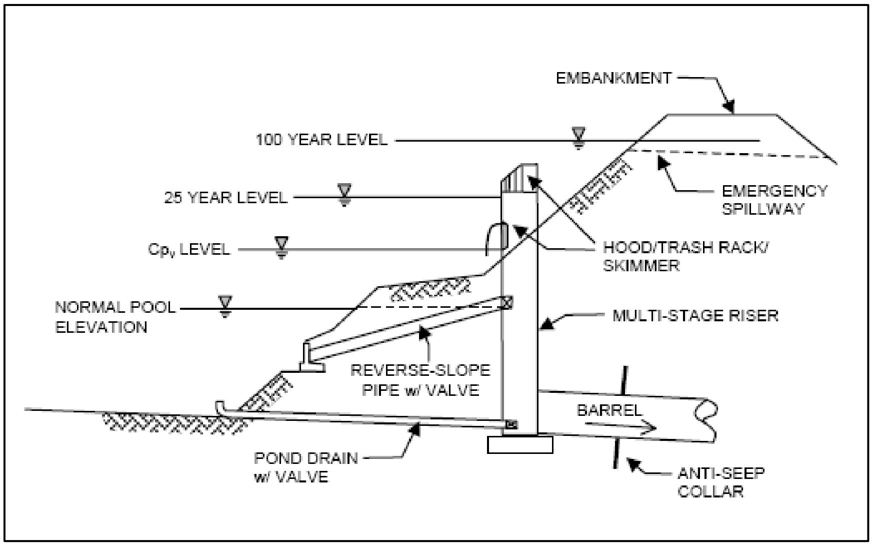

Figure C7-S3- 4: Typical multiple outlet structure for wet detention basin

7. **Secondary (emergency) spillway:**
   a. An emergency spillway is to be included in the stormwater pond design to safely pass the extreme flood flow. The spillway prevents pond water levels from overtopping the embankment and causing structural damage. The emergency spillway must be located so that downstream structures will not be impacted by spillway discharges.
   b. A minimum of 1 foot of freeboard must be provided, measured from the top of the water surface elevation for the extreme flood to the lowest point of the dam embankment, not counting the emergency spillway.

8. **Maintenance access:**
   a. A maintenance right-of-way or easement must be provided to a pond from a public or private road. Maintenance access should be at least 12 feet wide, having a maximum slope of no more than 15%, and be appropriately stabilized to withstand maintenance equipment and vehicles.
   b. The maintenance access must extend to the forebay, safety bench, riser, and outlet and, to the extent feasible, be designed to allow vehicles to turn around.
   c. Access to the riser is to be provided by lockable manhole covers and manhole steps within easy reach of valves and other controls.

9. **Safety features:**
   a. All embankments and spillways must be designed to State of Iowa guidelines for dam safety (see Iowa DNR at http://www.iowadnr.gov/Environmental-Protection/Land-Quality/Dam-Safety), and Iowa Technical Bulletin #16.
   b. Fencing of ponds is not generally desirable, but may be required by the local review authority. A preferred method is to manage the contours of the pond through the inclusion of a safety bench (see above) to eliminate drop-offs and reduce the potential for accidental drowning. In addition, the safety bench may be landscaped to deter access to the pool.
   c. The principal spillway opening should not permit access by small children, and end walls above pipe outfalls greater than 48 inches in diameter should be fenced to prevent access. Warning signs should be posted near the pond to prohibit swimming and fishing in the facility.

10. **Landscaping:**
   a. Aquatic vegetation can play an important role in pollutant removal in a stormwater pond. In addition, vegetation can enhance the appearance of the pond, stabilize side slopes, serve as wildlife habitat, and temporarily conceal unsightly trash and debris. Therefore, wetland plants should be encouraged in a pond design along the aquatic bench (fringe wetlands), safety bench and side slopes (ED ponds), and within shallow areas of the pool itself. The best elevations for establishing wetland plants, either through transplantation or volunteer colonization, are within 6 inches (plus or minus) of the normal pool elevation. Additional information on establishing wetland vegetation and appropriate wetland species for Iowa can be found in the SUDAS Specifications Section 9010.

b. Woody vegetation may not be planted on the embankment, or allowed to grow within 15 feet of the toe of the embankment and 25 feet from the principal spillway structure.
c. A pond buffer should be provided that extends 25 feet outward from the maximum water surface elevation of the pond. The pond buffer should be contiguous with other buffer areas that are required by existing regulations (e.g., stream buffers) or that are part of the overall stormwater management concept plan. No structures should be located within the buffer, and an additional setback to permanent structures may be provided.

Table C7-S3- 1: Hydrologic and hydraulic design criteria for standard extended detention wet pond systems

Permanent Pool Storage	
Design criteria	Treat WQv and/or first flush of runoff
Storage volume	1.25 watershed inch Rv* watershed area
Water surface elevation	Established by invert of extended detention pipe
Pipe sizing (pool drain)	Drain pool volume within 24 hours
Extended Detention Storage	
Design criteria	Provide minimum 24-hour detention for 1-year, 24-hour rainfall event runoff
Storage volume	Cpv (See Chapter 3, section 6)
Water surface elevation	Upper limit set at beginning of 2-year or 5-year design storm storage
Pipe sizing – allowable release rate (Q_R)	Q_R = Cpv – ft3/24-hr/3600
Two-Year Storm Event Peak Discharge Control Storage	
Design criteria	Maintain 2-year pre-development peak discharge for 2-year design; can be replaced with 5-year pre-development discharge IAW local jurisdiction policy.
Storage volume	Obtained from WinTR-55 short cut method of full calculation with WinTR-20, HEC-HMS or other methods.
Water surface elevation	Upper limit: bottom of 100-year storage Lower limit: top of extended detention storage
Safety Storm/Secondary Spillway	
Design criteria	Safety storm: design event depends on hazard classification Secondary (emergency) spillway: must pass the safety storm
Storage volume	Safety storm: obtained from WinTR-55 or WinTR-20 (NRCS, 2005) Secondary spillway: obtained from NRCS spillway charts (NRCS, 1982)

*The Modified Rational method should not be used for storage calculations.

Source: Schueler and Helfrich, 1988

Table C7-S3- 2: Recommended criteria for wet pond design for nutrient removal*

Design Parameter	Recommended Criteria	
	On-site wet pond	Regional
Storage volume (permanent pool)	T = 2 weeks or more V_B/V_R > 4 or higher V_B = 2WQv	Same as onsite wet pond
Mean depth (permanent pool)	3-6 ft	Same as onsite wet pond
Surface area (permanent pool)	>0.25 acres	3-5 acres or more
Drainage area	Minimum of 20-25 acres	100-300 acres, depending on impervious cover
Side slopes	5:1 to 10:1 (H:V)	
Length/width ratio	2:1 or greater	
Soils at site	HSG B, C, or D Compaction may be required on A and B soils	
T = average hydraulic residence time *Projected nutrient removal (P = 65%, Solids 85-90%)		

Source: Hartigan et al, 1989

F. Design procedures

1. **Step 1.** Compute runoff control volumes from the unified stormwater sizing criteria. Calculate the WQv, Cpv, Q_p, and the Q_f. (See Chapter 2, section 1 and Chapter 3, section 6). The ASCE-WEF Maximized Water Quality Volume procedure is recommended for determining the WQv for the basin, using a drawdown time of 48-hours (see Chapter 3, section 6).

2. **Step 2.** Determine if the development site and conditions are appropriate for the use of a stormwater pond. Consider application and feasibility criteria and any location and siting issues.

3. **Step 3.** Confirm local design criteria and applicability. Consider any special site-specific design conditions/criteria (additional site-specific design criteria and issues). Check with local officials and other agencies to determine if there are any additional restrictions and/or surface water or watershed requirements that may apply.

4. **Step 4.** Determine pretreatment volume. A sediment forebay is provided at each inlet, unless the inlet provides less than 10% of the total design storm inflow to the pond. The forebay should be sized to contain 0.1 inches per impervious acre of contributing drainage, and should be 4-6 feet deep. The forebay storage volume counts toward the total WQv requirement, and may be subtracted from the WQv for subsequent calculations.

5. **Step 5.** Determine permanent pool volume (and water quality ED volume).
   a. **Wet pond.** Size permanent pool volume to 1.5 to 2.0*WQv.
   b. **Wet ED pond.** Size permanent pool volume to 1.0WQv. Size extended detention volume to 0.5WQv.
   c. **Micro-pool ED pond.** Size permanent pool volume to 25-30% of WQv. Size extended detention volume to remainder of WQv.

6. **Step 6.** Determine pond location and preliminary geometry. Conduct pond grading and determine storage available for permanent pool (and water quality extended detention if wet ED pond or micro-pool ED pond). This step involves initially grading the pond (establishing contours) and determining the elevation-storage relationship for the pond.
   a. Include safety and aquatic benches.
   b. Set WQv permanent pool elevation (and WQv-ED elevation for wet ED and micro-pool ED pond) based on volumes calculated earlier.

7. **Step 7.** Compute extended detention orifice release rate(s) and size(s), and establish Cpv elevation:
   a. **Wet pond.** The Cpv elevation is determined from the stage-storage relationship, and the orifice is then sized to release the channel protection storage volume over a 24-hour period (12-hour extended detention may be warranted in some coldwater streams). The channel protection orifice should have a minimum diameter of 3 inches, and should be adequately protected from clogging by an acceptable external trash rack. A reverse slope pipe attached to the riser, with its inlet submerged 1 foot below the elevation of the permanent pool, is a recommended design. The orifice diameter may be reduced to 1 inch if internal orifice protection is used (i.e., an over-perforated vertical stand pipe with ½-inch orifices or slots that are protected by wire cloth and a stone filtering jacket). Adjustable gate valves can also be used to achieve this equivalent diameter.

   b. **Wet ED pond and micro-pool ED pond.** Based on the elevations established in Step 6 for the extended detention portion of the water quality volume, the water quality orifice is sized to release this extended detention volume in 24 hours. The water quality orifice should have a minimum diameter of 3 inches, and should be adequately protected from clogging by an acceptable external trash rack. A reverse slope pipe attached to the riser, with its inlet submerged 1 foot below the elevation of the permanent pool, is a recommended design. Adjustable gate valves can also be used to achieve this equivalent diameter. The Cpv elevation is then determined from the stage-storage relationship. The invert of the channel protection orifice is located at the water quality extended detention elevation, and the orifice is sized to release the channel protection storage volume over a 24-hour period (12-hour extended detention may be warranted in some coldwater streams).

8. **Step 8.** Calculate Q_{p25} (25-year storm) release rate and water surface elevation.

a. Set up a stage-storage-discharge relationship for the control structure for the extended detention orifice(s) and the 25-year storm.
b. Complete a final design pond routing using the Modified Puls or Storage-Indication method to check water surface elevation and discharge rate for the Q_5 through Q_{25} storm events.

9. **Step 9.** Design embankment(s) and spillway(s).
   a. Size emergency spillway, calculate 100-year water surface elevation, set top of embankment elevation, and analyze safe passage of the extreme food volume (Q_f).
   b. At final design, provide safe passage for the 100-year event.

10. **Step 10.** Investigate potential pond hazard classification. The design and construction of stormwater management ponds are required to follow the Iowa dam safety guidelines and Iowa DNR Technical Bulletin #16.

11. **Step 11.** Design inlets, sediment forebay(s), outlet structures, maintenance access, and safety features. See Chapter 3, sections 12 and 13 for additional details.

12. **Step 12.** Prepare vegetation and landscaping plan. A landscaping plan for a stormwater pond and its buffer should be prepared to indicate how aquatic and terrestrial areas will be stabilized and established with vegetation.

G. Inspection and maintenance requirements

Table C7-S3- 3: Typical maintenance activities for ponds

Activity	Schedule
• Clean and remove debris from inlet and outlet structures. • Mow side slopes.	Monthly
• If wetland components are included, inspect for invasive vegetation.	Semi-annual inspection
• Inspect for damage, paying particular attention to the control structure. • Check for signs of eutrophic conditions. • Note signs of hydrocarbon build-up, and remove appropriately. • Monitor for sediment accumulation in the facility and forebay. • Examine to ensure that inlet and outlet devices are free of debris and operational. • Check all control gates, valves or other mechanical devices.	Annual inspection
• Repair undercut or eroded areas.	As needed
• Perform wetland plant management and harvesting.	Annually (if needed)
• Remove sediment from the forebay.	5-7 years, or after 50% of the total forebay capacity has been lost
• Monitor sediment accumulations, and remove sediment when the pool volume has become reduced significantly, or the pond becomes eutrophic.	10-20 years, or after 25% of the permanent pool volume has been lost

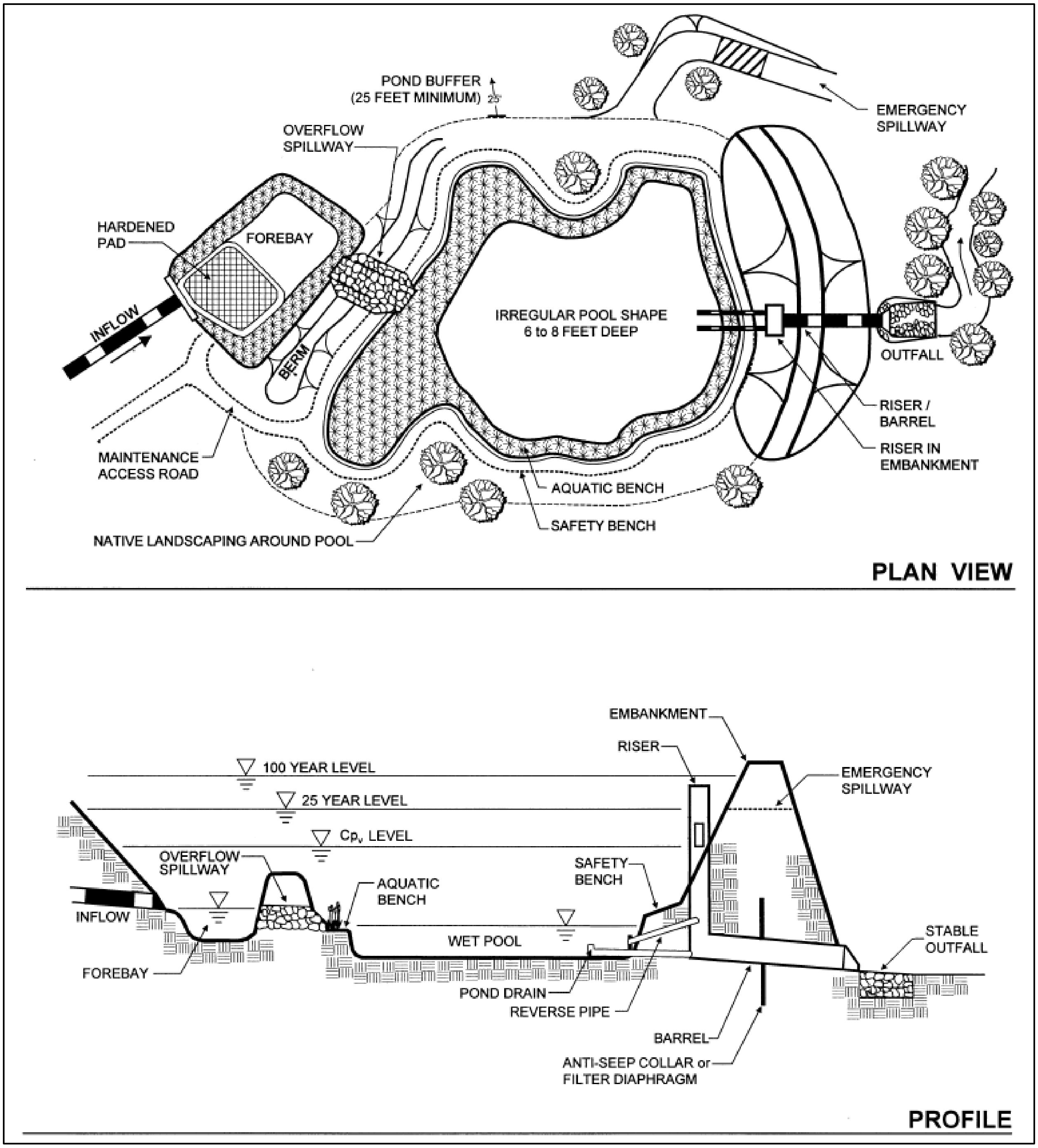

Figure C7-S3- 5: Example schematic of wet detention basin (wet pond)
Source: Center for Watershed Protection

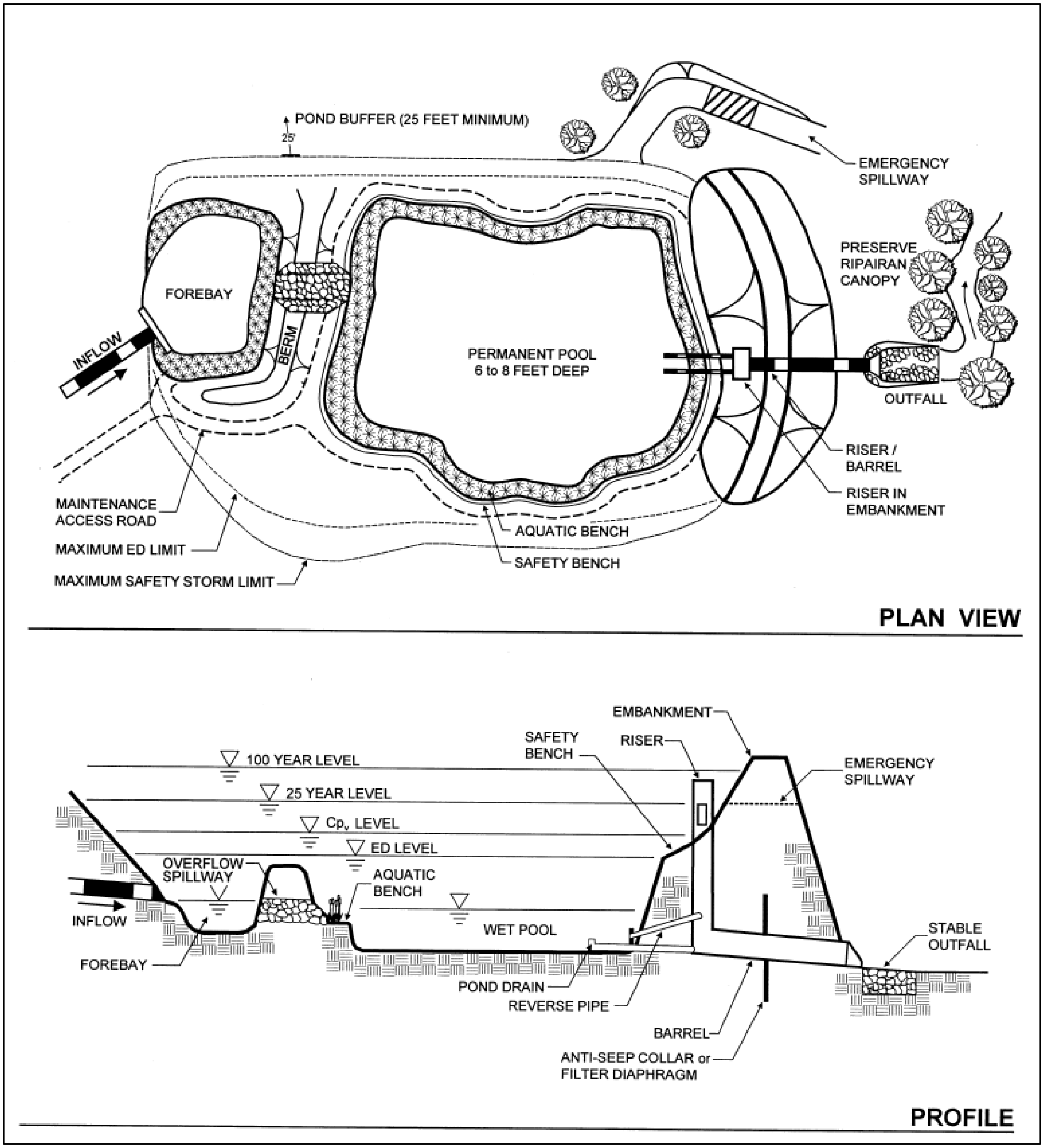

Figure C7-S3- 6: Example schematic of wet extended detention basin (ED wet pond)
Source: Center for Watershed Protection

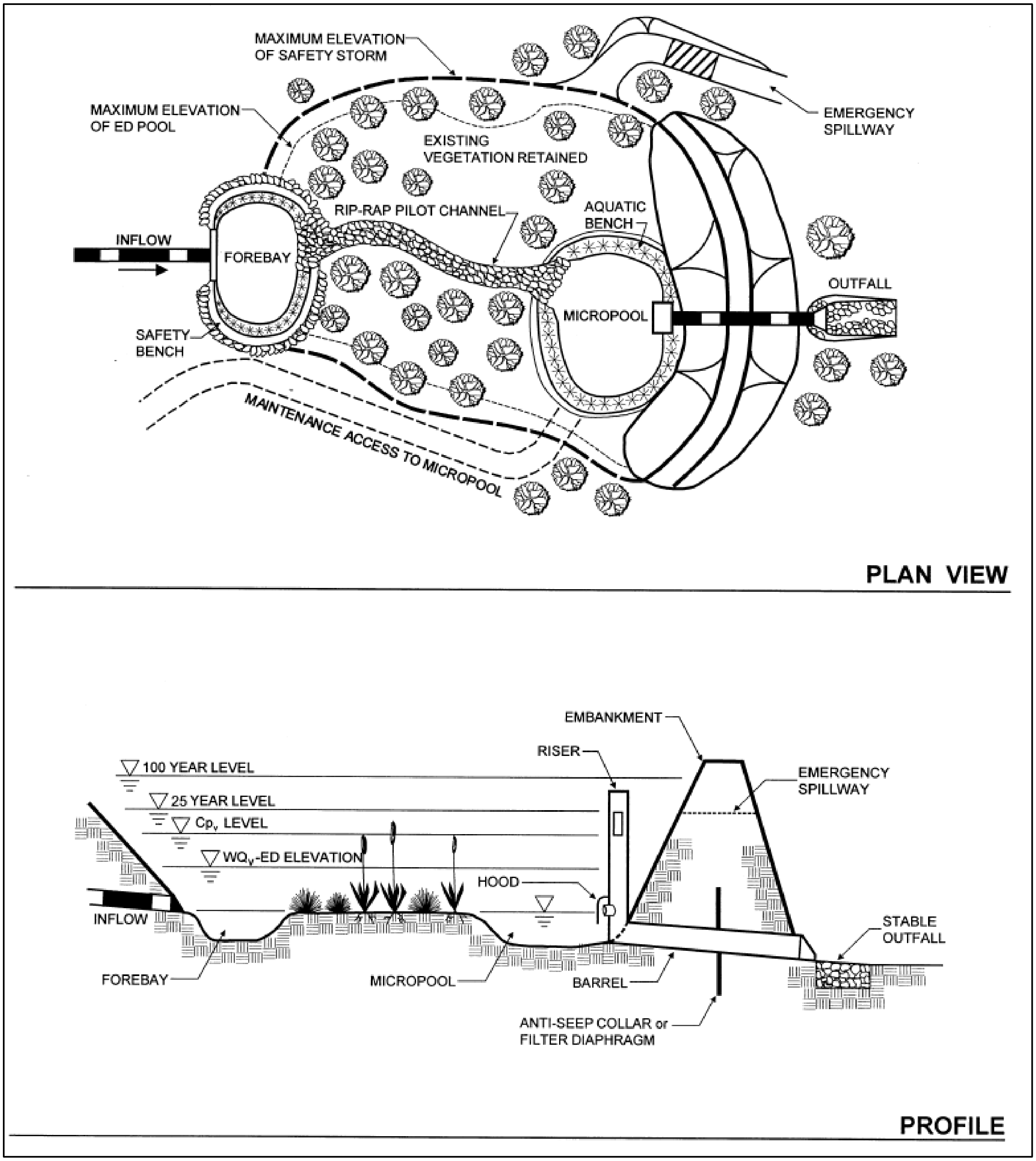

Figure C7-S3- 7: Example schematic of micro-pool extended detention pond
Source: Center for Watershed Protection

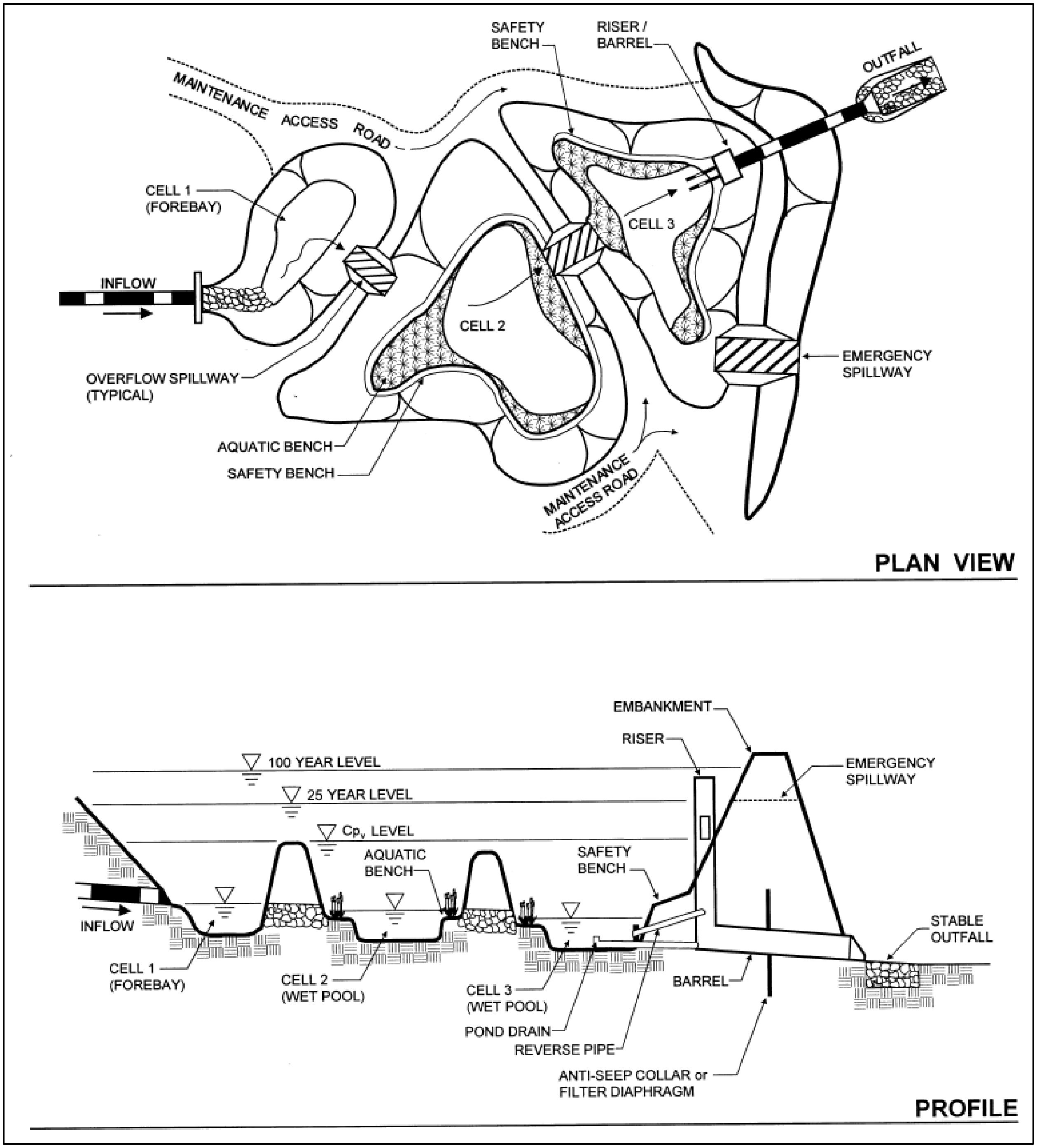

Figure C7-S3- 8: Example schematic of multiple pond system
Source: Center for Watershed Protection