Description

Photograph RP-1. Retention ponds treat stormwater though sedimentation and biological processes including uptake.

A retention pond, sometimes called a "wet pond," has a permanent pool of water with capacity above the permanent pool designed to capture and slowly release the water quality capture volume (WQCV) over 12 hours. The permanent pool is replaced, in part, with stormwater during each runoff event so stormwater runoff mixes with the permanent pool water. This allows for a reduced residence time compared to that of the extended detention basin (EDB). The 12-hour drain time helps to both better replicate pre-development flows for frequent events and reduce the potential for short circuiting treatment in smaller ponds. Retention ponds can be very effective in removing suspended solids, organic matter and metals through sedimentation, as well as removing soluble pollutants like dissolved metals and nutrients through biological processes.

Retention ponds can also be designed to provide Full Spectrum Detention. Widespread use of full spectrum detention is anticipated to reduce impacts on major drainageways by reducing post-development peak discharges to better resemble pre-development peaks.

Retention	
Functions	
LID/Volume Red.	Somewhat
WQCV Capture	Yes
WQCV+Flood Control	Yes
Fact Sheet Includes EURV Guidance	Yes
Typical Effectiveness for Targeted Pollutants[3]	
Sediment/Solids	Very Good
Nutrients	Moderate
Total Metals	Moderate
Bacteria	Moderate
Other Considerations	
Life-cycle Costs[4]	Moderate

[3] Based primarily on data from the International Stormwater BMP Database (www.bmpdatabase.org).

[4] Based primarily on BMP-REALCOST available at www.udfcd.org. Analysis is based on a single installation (not based on the maximum recommended watershed tributary to each BMP).

Site Selection

Retention ponds require groundwater or a dry-weather base flow if the permanent pool elevation is to be maintained year-round. They also require legal and physical use of water. In Colorado, the availability of this BMP can be limited due to water rights issues.

The designer should consider the overall water budget to ensure that the baseflow will exceed evaporation, evapotranspiration, and seepage losses (unless the pond is lined). High exfiltration rates can initially make it difficult to maintain a permanent pool in a new pond, but the bottom can eventually seal with fine sediment and become relatively impermeable over time. However, it is best to seal the bottom and the sides of a permanent pool if the pool is located on permeable soils and to leave the areas above the permanent pool unsealed to promote infiltration of the stormwater detained in the surcharge WQCV.

Studies show that retention ponds can cause an increase in temperature from influent to effluent. Retention ponds are discouraged upstream of receiving waters that are sensitive to increases in temperature (e.g., fish spawning or hatchery areas).

Use caution when placing this BMP in a basin where development will not be completed for an extended period, or where the potential for a chemical spill is higher than typical. When these conditions exists, it is critical to provide adequate containment and/or pretreatment of flows. In developing watersheds, frequent maintenance of the forebay may be necessary.

Benefits

- Creates wildlife and aquatic habitat.
- Provides recreation, aesthetics, and open space opportunities.
- Can increase adjacent property values.
- Cost-effective BMP for larger tributary watersheds.

Limitations

- Safety concerns associated with open water.
- Requires both physical supply of water and a legal availability (in Colorado) to impound water.
- Sediment, floating litter, and algae blooms can be difficult to remove or control.
- Ponds can attract water fowl which can add to the nutrients and bacteria leaving the pond.
- Ponds increase water temperature.

Designing for Maintenance

Recommended ongoing maintenance practices for all BMPs are provided in Chapter 6 of this manual. During design, the following should be considered to ensure ease of maintenance over the long-term.

- Provide pretreatment upstream of the permanent pool.
- Provide maintenance access to the outlet structure as well as the forebay.
- Exceed the minimum criterion for the permanent pool volume. Greater depth will help deter algae growth by reducing temperature and the area of the pond bottom that receives sunlight.

Design Procedure and Criteria

The following steps outline the retention pond design procedure and criteria, and Figure RP-1 shows a typical configuration.

1. **Baseflow**: Unless the permanent pool is establish by groundwater, a perennial baseflow that exceeds losses must be physically and legally available. Net influx calculations should be conservative to account for significant annual variations in hydrologic conditions. Low inflow in relation to the pond volume can result in poor water quality. Losses include evaporation, evapotranspiration, and seepage. Evaporation can be estimated from existing local studies or from the National Weather Service (NWS) Climate Prediction website. Data collected from Chatfield Reservoir from 1990 to 1997 show an average annual evaporation of 37 inches, while the NWS shows approximately 40 inches of evaporation per year in the Denver metropolitan area. Potential evapotranspiration (which occurs when water supply to both plant and soil surface is unlimited) is approximately equal to the evaporation from a large, free-water surface such as a lake (Bedient and Huber, 1992). When retention ponds are placed above the groundwater elevation, a pond liner is recommended unless evaluation by a geotechnical engineer determines this to be unnecessary.

2. **Surcharge Volume**: Provide a surcharge volume based on a 12-hour drain time.

   - Determine the imperviousness of the watershed (or effective imperviousness where LID elements are used upstream).

   - Find the required storage volume. Determine the required WQCV or EURV (watershed inches of runoff) using Figure 3-2 located in Chapter 3 of this manual (for WQCV) or equations provided in the *Storage* chapter of Volume 2 (for EURV).

   - Calculate the design volume (surcharge volume above the permanent pool) as follows:

   For WQCV:

   $$V = \left[\frac{\text{WQCV}}{12}\right] A \qquad \text{Equation RP-1}$$

   For EURV:

   $$V = \left[\frac{\text{EURV}}{12}\right] A \qquad \text{Equation RP-2}$$

   Where:

   V = design volume (acre ft)

   A = tributary catchment drainage area (acres)

3. **Basin Shape:** Always maximize the distance between the inlet and the outlet. A basin length to width ratio between 2:1 and 3:1 is recommended to avoid short-circuiting. It may be necessary to modify the inlet and outlet locations through the use of pipes, swales, or channels to accomplish this.

4. **Permanent Pool**: The permanent pool provides stormwater quality enhancement between storm runoff events through biochemical processes and continuing sedimentation.

   - Volume of the permanent pool:

   $$V_p \geq 1.2 \left[\frac{\text{WQCV}}{12}\right] A \qquad \text{Equation RP-3}$$

   Where:

   V_p = permanent pool volume (acre ft)

   A = tributary catchment drainage area (acres)

- Depth Zones: The permanent pool should have two zones:
  - Safety Wetland Bench: This area should be located along the perimeter of the pond, 6 to 12 inches deep and a minimum of 4 feet wide. Aquatic plant growth along the perimeter of the permanent pool can help strain surface flow into the pond, protect the banks by stabilizing the soil at the edge of the pond, and provide biological uptake. The safety wetland bench is also constructed as a safety precaution. It provides a shallow area that allows people or animals who inadvertently enter the open water to gain footing to get out of the pond.
  - Open Water Zone: The remaining pond area should be open, providing a volume to promote sedimentation and nutrient uptake by phytoplankton. To avoid anoxic conditions, the maximum depth in the pool should not exceed 12 feet.

5. **Side Slopes**: Side slopes should be stable and sufficiently gentle to limit rill erosion and to facilitate maintenance. Side slopes above the safety wetland bench should be no steeper than 4:1, preferably flatter. The safety wetland bench should be relatively flat with the depth between 6 to 12 inches. The side slope below this bench should be 3:1 (or flatter when access is required or when the surface could be slippery). The steeper 3:1 slope below the safety wetland bench can be beneficial to deterring algae growth as it will reduce the shallow area of the pond, thus reducing the amount of sunlight that penetrates the pond bottom.

6. **Inlet**: Dissipate energy at the inlet to limit erosion and to diffuse the inflow plume. Inlets should be designed in accordance with the *Hydraulic Structures* chapter of Volume 2. This chapter includes design of impact basins and drop structures.

7. **Forebay**: Forebays provide an opportunity for larger particles to settle out, which will reduce the required frequency of sediment removal in the permanent pool. Install a solid driving surface on the bottom and sides below the permanent water line to facilitate sediment removal. A soil riprap berm should be constructed to contain the forebay opposite of the inlet. This should have a minimum top width of 8 feet and side slopes no steeper than 4:1. The forebay volume within the permanent pool should be sized for anticipated sediment loads from the watershed and should be at least 3% of the WQCV. If the contributing basin is not fully developed, additional measures should be taken to maintain a relatively clean forebay. This includes more frequent maintenance of the forebay and/or providing and maintaining temporary erosion control.

8. **Outlet:** The outlet should be designed to release the WQCV over a 12-hour period. This can be done through an orifice place as detailed in BMP Fact Sheet T-12. Use reservoir routing calculations as discussed in the *Storage* chapter of Volume 2 or use equation RP-4, a simplified orifice sizing equation (see Technical Memorandum dated July 13, 2010 available at www.udfcd.org).

$$A_O = \frac{201V^{\left(0.95/H^{0.085}\right)}}{T_D H^{0.164}}$$ Equation RP-4

Where:

A_O = area per row of orifices spaced on 4-inch centers (in^2)

V = design volume (WQCV or EURV) (acre ft)

T_D = time to drain the prescribed volume (hrs) (i.e., 12 for WQCV or 72 for EURV)

H = depth of surcharge volume (ft)

Refer to BMP Fact Sheet T-12 for schematics pertaining to structure geometry, grates, trash racks, orifice plate, and all other necessary components.

9. **Trash Rack**: Provide a trash rack of sufficient size to prevent clogging of the primary water quality outlet. Similar to the trash rack design for the extended detention basin, extend the water quality trash rack into the permanent pool a minimum of 28 inches. The benefit of this is documented in Fact Sheet T-5. BMP Fact Sheet T-12 provides additional guidance on trash rack design including standard tables for most designs.

10. **Overflow Embankment**: Design the embankment not to fail during the 100-year storm. If the embankment falls under the jurisdiction of the State Engineer's Office, it should be designed to meet the requirements of the State Engineer's Office. Embankment slopes should be no steeper than 4:1, preferably flatter, and planted with turf grasses. Poorly compacted native soils should be excavated and replaced. Embankment soils should be compacted to 95% of maximum dry density for ASTM D698 (Standard Proctor) or 90% for ASTM D1557 (Modified Proctor). Spillway structures and overflows should be designed in accordance with local drainage criteria and should consider the use of stabilizing materials such as buried soil riprap or reinforced turf mats installed per manufacturer's recommendations.

11. **Maintenance Considerations:** The design should include a means of draining the pond to permit drying out of the pond when it has to be "mucked out" to restore volume lost due to sediment deposition. A means to drain the pond or a portion of the pond by gravity is preferred but not always practicable. Some level of pumping is typically required. Past versions of this manual included an underdrain at the perimeter of the pond with a valved connection to the outlet structure for this purpose. This remains an acceptable method for draining the pond. Additional alternatives include providing a drywell with a piped connection to the outlet structure or to a downstream conveyance element or connecting a valved pipe directly to the outlet structure. The pipe should include a valve that will only be opened for maintenance.

12. **Vegetation:** Vegetation provides erosion control and enhances site stability. Berms and side-sloping areas should be planted with native grasses or irrigated turf, depending on the local setting and proposed uses for the pond area. The safety wetland bench should be vegetated with aquatic species. This vegetation around the perimeter of an open water body can discourage frequent use of the pond by geese.

Providing a buffer of tall native grasses around a retention pond provides treatment through filtering (straining) and helps discourage frequent use of the pond by geese.

Photograph RP-2. This retention pond outlet structure is both accessible and functional while not interfering with the natural aesthetic.

13. **Access:** All weather stable access to the bottom, forebay, and outlet works area should be provided for maintenance vehicles. Grades should not exceed 10% for haul road surfaces and should not exceed 20% for skid-loader and backhoe access. Provide a solid driving surface such as gravel, concrete, articulated concrete block, concrete grid pavement, or reinforced grass pavement. The recommended cross slope is 2%.

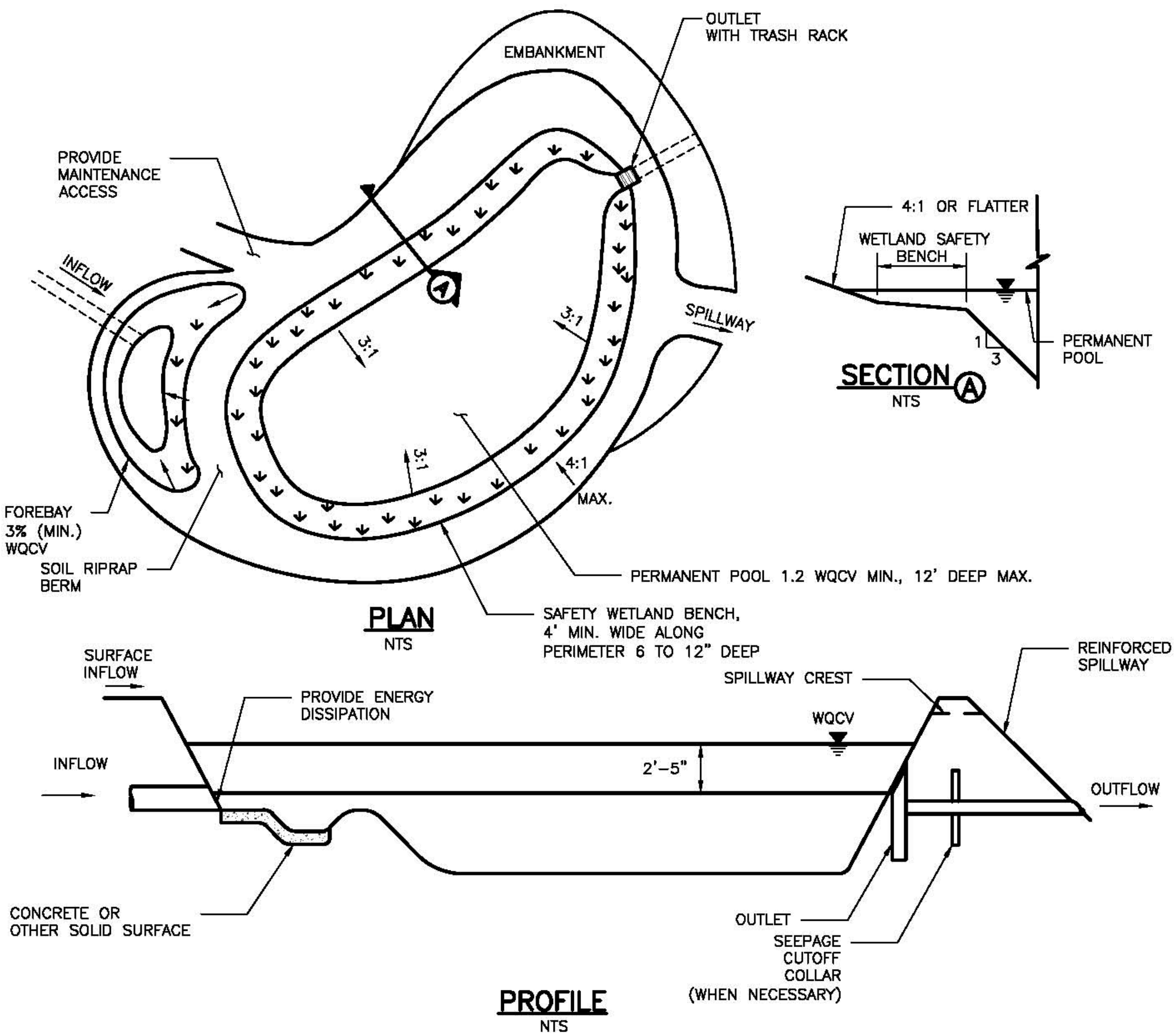


Figure RP-1. Retention Pond Plan and Sections

Aesthetic Design

Since all land owners and managers wish to use land in the most efficient manner possible, it is important that retention basins become part of a multi-use system. This encourages the design of retention ponds as an aesthetic part of a naturalized environment or to be expanded to include passive and/or active open space. Within each scenario, the retention basin can begin to define itself as more than just a drainage facility. When this happens, the basin becomes a public amenity. This combination of public amenity and drainage facility is of much greater value to a landowner. Softened and varied slopes, interspersed irrigated fields, planting areas and wetlands can all be part of a retention pond.

The design should be aesthetic whether it is considered to be an architectural or naturalized basin. Architectural basins incorporate design borrowed or reflective of the surrounding architecture or urban forms. An architectural basin is intended to appear as part of the built environment, rather than hiding the cues that identify it as a stormwater structure. A naturalized basin is designed to appear as though it is a natural part of the landscape. This section provides suggestions for designing a naturalized basin. The built environment, in contrast to the natural environment, does not typically contain the randomness of form inherent in nature. Constructed slopes typically remain consistent, as do slope transitions. Even dissipation structures are usually a hard form and have edges seldom seen in nature. If the retention pond is to appear as though it is a natural part of the landscape, it is important to minimize shapes that provide visual cues indicating the presence of a drainage structure. For example, the pond sides in the area of the surcharge volume should be shaped more naturally and with varying slopes for a naturalized pond. See Figure RP-2 for an example.

Suggested Methods for Creating the Look of a Naturalized Pond:

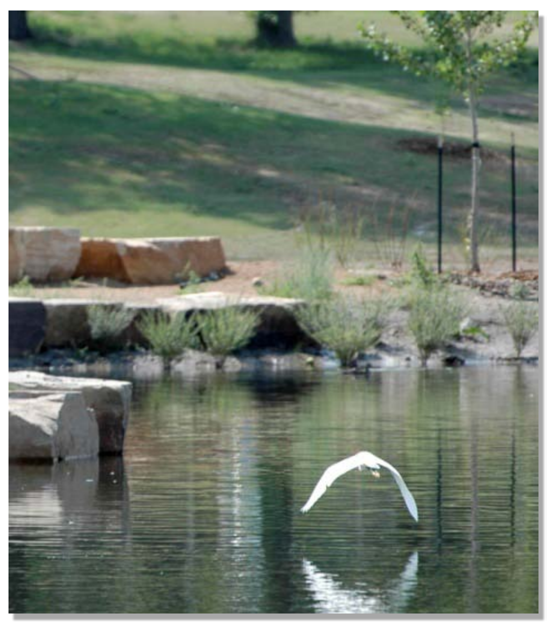
- Create a flowing overall form that looks like it was shaped by water. This includes the banks of the retention pond, which should have an undulating outline rather than a straight line.
- One side of the pond can be higher than the other side. This may require a berm.
- The shape of the permanent pool should vary from the shape of the surcharge volume.
- The slopes on at least three sides of the pond (above the permanent pool) should be varied and gentle. To achieve this, one or more sides of the basin may have to be stabilized by a retaining structure, i.e., stacked boulders and walls.
- Vary slope transitions.

Photograph RP-3. (altered photo) When incorporating rock into a structure, use other matching, functional rock to prevent the structure from looking out of context. Photo courtesy of Design Concepts.

Photograph RP-4. (altered photo) Variations in slope and texture around the pond are brought together by mass groupings of local stone boulders. The boulders are placed intermittently around the pond in groups and interspersed with plantings. Photo courtesy of Design Concepts. Note: A minimum 4-foot vegetated buffer (littoral zone) is recommended to strain surface flow into the pond, protect the banks by stabilizing the soil at the edge of the pond, and provide biological uptake.

- Any use of rock for energy dissipation or for erosion control should graduate away from the area of hard edge into the surrounding landscape. Other functional matching rock should occur in other areas of the pond to prevent the energy dissipation structure from appearing out of context. Photo RP-3 serves as an example of this.
- If concrete is required in the basin, colored concrete matching the rocks or other site features of the surrounding landscape can be used to prevent the structure from appearing out of context. Colored concrete, form liners and veneers for construction walls are preferred for outlet structures.
- Adjust the vegetation to the different uses of the pond surrounding.
- Ground cover should reflect the type of water regime expected for the location within the basin. For example, riparian plants would be placed around the edge of the retention pond, groups of trees and shrubs would be placed in more manicured areas that have no retention or detention function.

Photograph RP-5. A curving stream with vegetated edges provides habitat for wildlife. Photo courtesy of Design Concepts.



Photograph RP-6. Landscape elements such as vegetation and stone highlight the irregularly-shaped pond edge, making it appear more natural. Photo courtesy of Design Concepts.

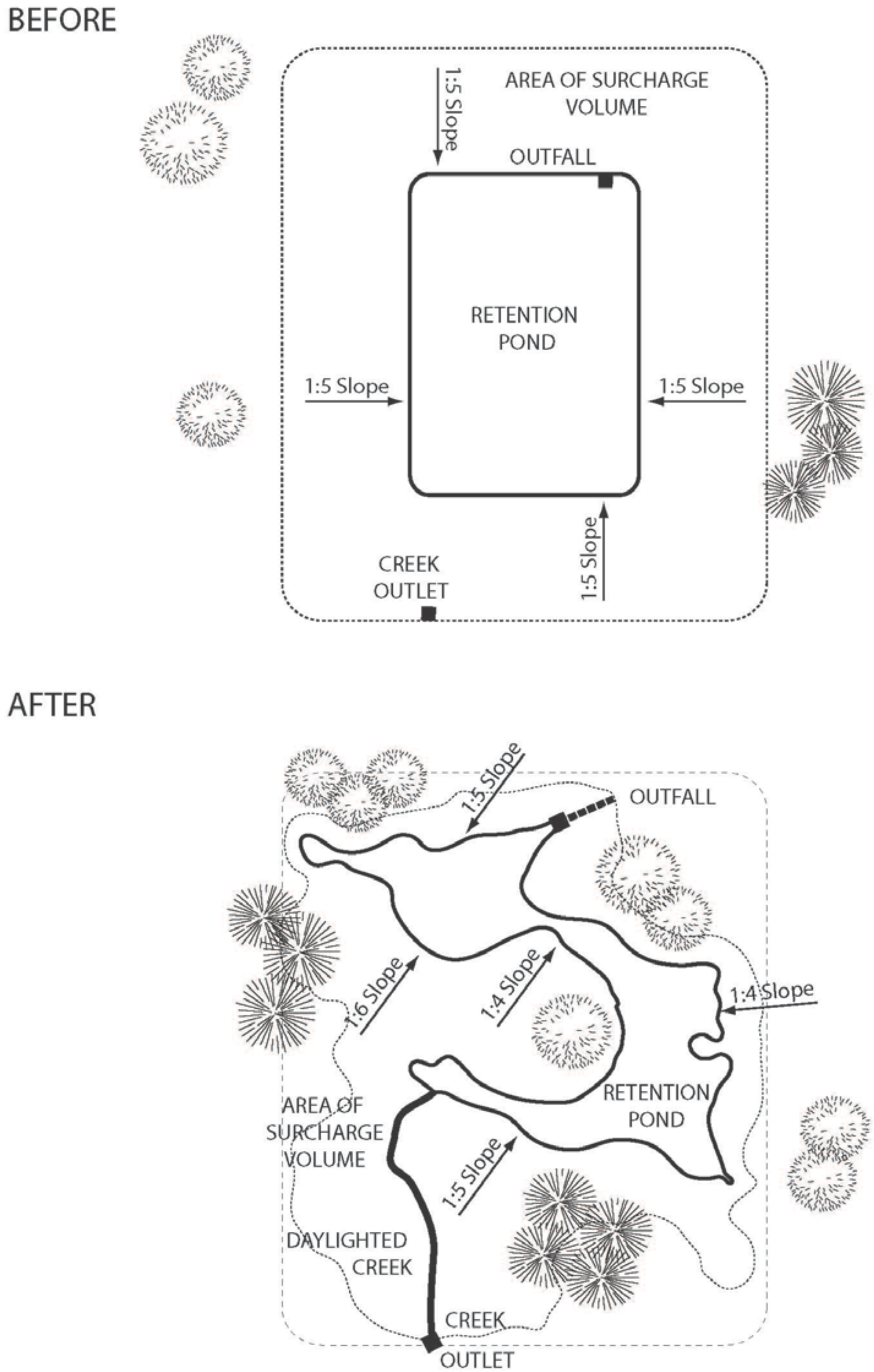


Figure RP-2. Example of a Naturalized Retention Pond

Design Example

The *UD-BMP* workbook, designed as a tool for both designer and reviewing agency is available at www.udfcd.org. This section provides a completed design form from this workbook as an example.

Design Procedure Form: Retention Pond (RP)

Sheet 1 of 3

Designer:	L. Gibson
Company:	BMP, Inc.
Date:	November 29, 2010
Project:	Subdivision B
Location:	NE Corner of 67th Ave. and 88th St.

1. Baseflow A) Is the permanent pool established by groundwater?	Choose One ◉ YES ○ NO
2. Surcharge Volume	
A) Effective Imperviousness of Tributary Area, I_a	I_a = 80.0 %
B) Tributary Area's Imperviousness Ratio ($i = I_a / 100$)	i = 0.800
C) Contributing Watershed Area	Area = 50.000 ac
D) For Watersheds Outside of the Denver Region, Depth of Average Runoff Producing Storm	d_6 = ______ in
E) Design Concept (Select EURV when also designing for flood control)	Choose One ○ Water Quality Capture Volume (WQCV) ◉ Excess Urban Runoff Volume (EURV)
F) Water Quality Capture Volume (WQCV) Based on 12-hour Drain Time ($V_{WQCV} = (0.8 * (0.91 * i^3 - 1.19 * i^2 + 0.78 * i) / 12 * Area)$	V_{WQCV} = 1.094 ac-ft
G) For Watersheds Outside of the Denver Region, Water Quality Capture Volume (WQCV) ($V_{WQCV\ OTHER} = (d_6 * (V_{WQCV}/0.43))$	$V_{WQCV\ OTHER}$ = ______ ac-ft
H) User Input of Water Quality Capture Volume (WQCV) (Only if a different WQCV Design Volume is desired)	$V_{WQCV\ USER}$ = ______ ac-ft
I) Predominant Watershed NRCS Soil Group	Choose One ○ A ○ B ◉ C / D
J) Excess Urban Runoff Volume (EURV) Design Volume For HSG A: $EURV_A = (0.1878i - 0.0104)*Area$ For HSG B: $EURV_B = (0.1178i - 0.0042)*Area$ For HSG C/D: $EURV_{C/D} = (0.1043i - 0.0031)*Area$	EURV = 4.017 ac-f t
3. Basin Shape (It is recommended to have a basin length to width ratio between 2:1 and 3:1)	L : W = 3.0 : 1
4. Permanent Pool	
A) Minimum Permanent Pool Volume	V_{POOL} = 1.313 ac-ft
B) Depth of the Safety Wetland Bench (Recommended to be 6 to 12 inches deep)	D_{LZ} = 6 in
C) Depth of the Open Water Zone (Maximum depth of 12 feet)	D_{OWZ} = 12.0 ft
5. Side Slopes	
A) Maximum Side Slopes Above the Safety Wetland Bench (Horiz. dist. per unit vertical, should be no steeper than 4:1)	Z_{PP} = 5.00 ft / ft
B) Maximum Side Slopes Below the Safety Wetland Bench (Horiz. dist. per unit vertical, should be no steeper than 3:1)	Z_{OWZ} = 3.00 ft / ft
6. Inlet A) Describe means of providing energy dissipation at concentrated inflow locations:	Adequate tailwater during events exceeding the WQCV.

Design Procedure Form: Retention Pond (RP)

Sheet 2 of 3

Designer:	L. Gibson
Company:	BMP, Inc.
Date:	November 29, 2010
Project:	Subdivision B
Location:	NE Corner of 67th Ave. and 88th St.

7. Forebay			
A) Minimum Forebay Volume (V_{FMIN} = 3% of the WQCV)	V_{FMIN} =	0.033	ac-ft
B) Actual Forebay Volume	V_F =	0.037	ac-ft
8. Outlet			
A) Outlet Type	Choose One: (●) Orifice Plate ( ) Other (Describe):		
B) Depth of Surcharge Volume (Depth of WQCV or EURV depending on design concept)	H =	3.0	feet
C) Volume to Drain Over Prescribed Time	EURV =	4.017	ac-ft
D) Drain Time (Min T_D for WQCV= 12 hours; Max T_D for EURV= 72 hours)	T_D =	72	hours
E) Recommended Outlet Area per Row, (A_o)	A_o =	7.77	square inches
F) Orifice Dimensions:			
i) Circular Orifice Diameter or	$D_{orifice}$ =		inches
ii) Width of 2" High Rectangular Orifice	$W_{orifice}$ =	3.88	inches
G) Number of Columns	nc =	1	number
H) Actual Design Outlet Area per Row (A_o)	A_o =	7.8	square inches
I) Number of Rows (nr)	nr =	9	number
J) Total Outlet Area (A_{ot})	A_{ot} =	69.8	square inches
K) Depth of WQCV (H_{WQCV}) (Estimate using actual stage-area-volume relationship and V_{WQCV})	H_{WQCV} =		feet
L) Ensure Minimum 12 Hour Drain Time for WQCV	$T_{D\ WQCV}$ =		hours
9. Trash Rack			
A) Type of Outlet Opening	Choose One: ( ) Circular (up to 2" diameter) (●) Rectangular (2" high)		
B) Trash Rack Open Area: $A_t = 0.5 * 77(e^{-0.124D}) * A_{ot}$	A_t =	2,224	square inches
C) For 2", or Smaller, Circular Opening (Reference figure in Fact Sheet T-12):			
i) Depth of Trash Rack below Permanent Pool WS (28 inch min.)	$D_{inundation}$ =		inches
ii) Width of Trash Rack and Concrete Opening ($W_{opening}$)	$W_{opening}$ =		inches
iii) Height of Trash Rack Screen (H_{TR})	H_{TR} =		inches
iv) Type of Screen, Describe if "Other"	Choose One: ( ) S.S. Well Screen with 60% Open Area* ( ) Other (Describe):		

Design Procedure Form: Retention Pond (RP)

Sheet 3 of 3

Designer:	**L. Gibson**
Company:	**BMP, Inc.**
Date:	**November 29, 2010**
Project:	**Subdivision B**
Location:	**NE Corner of 67th Ave. and 88th St.**

D) For 2" High **Rectangular Opening** (See Fact Sheet T-12):

i) Depth of Trash Rack below Permanent Pool WS (28 inch min.) — $D_{inundation}$ = 28.0 inches

ii) Width of Rectangular Opening ($W_{orifice}$) — W = 3.88 inches

iii) Width of Trash Rack Opening ($W_{opening}$) — $W_{opening}$ = 4.1 feet

iv) Height of Trash Rack Screen (H_{TR}) — H_{TR} = 5.3 feet

v) Type of Screen, (Describe if "Other") — Choose One:
- (●) Aluminum Amico-Klemp SR Series (or equal)
- ( ) Other (Describe):

vi) Cross-bar Spacing — **2.00**

vii) Minimum Bearing Bar Size — **1-1/4 in x 3/16 in**

10. Overflow Embankment

A) Describe embankment protection for 100-year and greater overtopping: soil riprap

B) Maximum Embankment Side Slopes (Horiz. dist. per unit vertical, should be no steeper than 4:1) — Z_E = 4.00 ft / ft

11. Maintenance Considerations

A) Describe Means of Draining the Pond — The pond can be partially gravity drained with the valve located in the outlet structure. Remaining water must be pumped.

12. Vegetation — Choose One:
- ( ) Irrigated
- (●) Not Irrigated

13. Access

A) Describe Sediment Removal Procedures — Sediment may be removed from the forebay via the maintenance access located on the maintenance plan.

Notes:

References

Bedient, Philip B. and Wayne C. Huber. 1992. *Hydrology and Floodplain Analysis (Second Edition).* Addison-Wesley Publishing Company.

United States Environmental Protection Agency (EPA). 1999. *Storm Water Technology Fact Sheet: Wet Detention Ponds.*