Constructed Wetland Pond T-8

Description

Photograph CWP-1. This constructed wetland pond, located downstream of an extended detention basin, is part of a BMP "treatment train."

A constructed wetlands pond is a shallow retention pond designed to permit the growth of wetland plants such as rushes, willows, and cattails. Constructed wetlands slow runoff and allow time for sedimentation, filtering, and biological uptake.

Constructed wetlands ponds differ from "natural" wetlands, as they are artificial and are built to enhance stormwater quality. Do not use existing or natural wetlands to treat stormwater runoff. Stormwater should be treated prior to entering natural or existing wetlands and other environmentally sensitive areas. Allowing untreated stormwater to flow into existing wetlands will overload and degrade the quality of the wetland. Sometimes, small wetlands that exist along ephemeral drainageways on Colorado's high plains can be enlarged and incorporated into the constructed wetland system. Such actions, however, require the approval of federal and state regulators.

Regulations intended to protect natural wetlands recognize a separate classification of wetlands, constructed for water quality treatment. Such wetlands generally are not allowed to be used to mitigate the loss of natural wetlands but are allowed to be disturbed by maintenance activities. Therefore, the legal and regulatory status of maintaining a wetland constructed for the primary purpose of water quality enhancement is separate from the disturbance of a natural wetland. Nevertheless, any activity that disturbs a constructed wetland should be cleared through the U.S. Army Corps of Engineers to ensure it is covered by some form of an individual, general, or nationwide 404 permit.

Constructed Wetland Basin	
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	Good
Bacteria	Poor
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

A constructed wetland pond requires a positive net influx of water to maintain vegetation and microorganisms. This can be supplied by groundwater or a perennial stream. An ephemeral stream will not provide adequate water to support this BMP.

A constructed wetland pond is best used as a follow-up BMP in a watershed, although it can serve as a stand-alone facility. Algae blooms may be reduced when BMPs that are effective in removing nutrients are placed upstream. Constructed wetland ponds can also be designed for flood control in addition to capture and treatment of the water quality capture volume (WQCV).

Although this BMP can provide an aesthetic onsite amenity, constructed wetland ponds designed to treat stormwater can also become large algae producers. The owner should maintain realistic expectations.

Benefits

- Creates wildlife and aquatic habitat.
- Provides open space opportunities.
- Cost effective BMP for larger tributary watersheds.

Limitations

- Requires both physical supply of water and a legal availability (in Colorado) to impound water.
- Ponding depth can pose safety concerns requiring additional considerations for public safety during design and construction.
- Sediment, floating litter, and algae blooms can be difficult to remove or control.
- Ponds can attract water fowl which can add to the nutrients leaving the pond.

Designing for Maintenance

Recommended ongoing maintenance practices for all BMPs are provided in Chapter 6 of this manual. During design consider the sediment removal process, including access and equipment for the pond. As sedimentation occurs and depth becomes limited, removal of sediment from the pond bottom will be required to support beneficial habitat.

Be aware, nutrient rich inflow will produce algae blooms in this BMP. Source control BMPs, such as reduced fertilizer use, should be implemented to reduce regular maintenance.

Design Procedure and Criteria

The following steps outline the design procedure for a constructed wetland pond:

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 constructed wetland 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 storage volume based on a 24-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/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 of the USDCM (for EURV).

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

  For WQCV:

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

  For EURV:

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

  Where:

  V = design volume (acre ft)

  A = watershed tributary to the constructed wetland pond (acre)

3. **Depth of Surcharge WQCV***:* In order to maintain healthy wetland growth, the surcharge depth for WQCV above the permanent water surface should not exceed 2 feet.

4. **Basin Shape**: Always maximize the distance between the inlet and the outlet. Shape the pond with a gradual expansion from the inlet and a gradual contraction to the outlet to limit short-circuiting. Try to achieve a basin length to width ratio between 2:1 to 4:1. It may be necessary to modify the inlet and outlet point through the use of pipes, swales, or channels to accomplish this.

5. **Permanent Pool**: The permanent pool provides stormwater quality enhancement between storm runoff events through biochemical processes and sedimentation. This requires a minimum volume as provided in Equation CWP-3.

$$V_p \geq 0.75\left[\frac{\text{WQCV}}{12}\right] A \qquad \text{Equation CWP-3}$$

  Where:

  V_p = permanent pool volume (acre ft)

  A = watershed tributary to the constructed wetland pond (acre)

  Proper distribution of wetland habitat within and surrounding the permanent pool is needed to establish a diverse ecology. Distribute pond area in accordance with Table CWP-1.

Table CWP-1.

Pond Components	Permanent Pool Surface Area	Water Design Depth
Forebay, outlet and open water surface areas	30% to 50%	2 to 4 feet deep
Wetland zones with emergent vegetation	50% to 70%	6 to 12 inches deep[1]
[1] One-third to one-half of this zone should be 6 inches deep.		

6. **Side slopes:** Side slopes should be stable and sufficiently gentle to limit rill erosion and to facilitate maintenance. They should provide a safety wetland bench along the perimeter of the pond. This area should be 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. Side slopes above the safety wetland bench should be no steeper than 4:1, preferably flatter. The safety wetland bench surrounding the perimeter of the pond should be relatively flat with the depth between 6 to 12 inches.

7. **Inlet**: Provide energy dissipation for flows entering the basin to limit sediment resuspension. Inlet designs should correspond to UDFCD drop-structure criteria, impact basin pipe outlet structure standards, or other energy dissipating and flow diffusing structure designs.

8. **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.

9. **Outlet**: The outlet should be designed to release the WQCV over a 24-hour period. This can be done through an orifice plate as detailed in BMP Fact Sheet T-12. Use reservoir routing calculations as discussed in the *Storage* Chapter of Volume 2 or use equation CWP-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 CWP-4

Where:

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

V = volume of stormwater to be drained (WQCV or EURV) (acre ft)

T_D = time to drain the prescribed volume (i.e., 24 for WQCV or 72 for EURV) (hrs)

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.

10. **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 details and standard tables and for most designs.

11. **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 percent of maximum dry density for ASTM D698 (Standard Proctor) or 90 percent 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.

12. **Maintenance Considerations:** The design should include a means of draining the pond to facilitate drying out of the pond when it has to be "mucked out" to restore volume lost due to sediment deposition. 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 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.

13. **Vegetation**: Vegetation provides erosion control and enhances site stability. Berms and side-sloping areas should be planted with native bunch or turf-forming grasses. The safety wetland bench at the perimeter of the pond should be vegetated with aquatic species. Aquatic species should be planted in the wetland bottom. Initial establishment of the wetlands requires control of the water depth. After planting wetland species, the permanent pool should be kept at 3 to 4 inches deep at the plant zones to allow growth and to help establish the plants, after which the pool should be raised to its final operating level.

14. **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%.

Diverse wetlands make healthy wetlands. Create zones with different depths and plant a variety of vegetation.

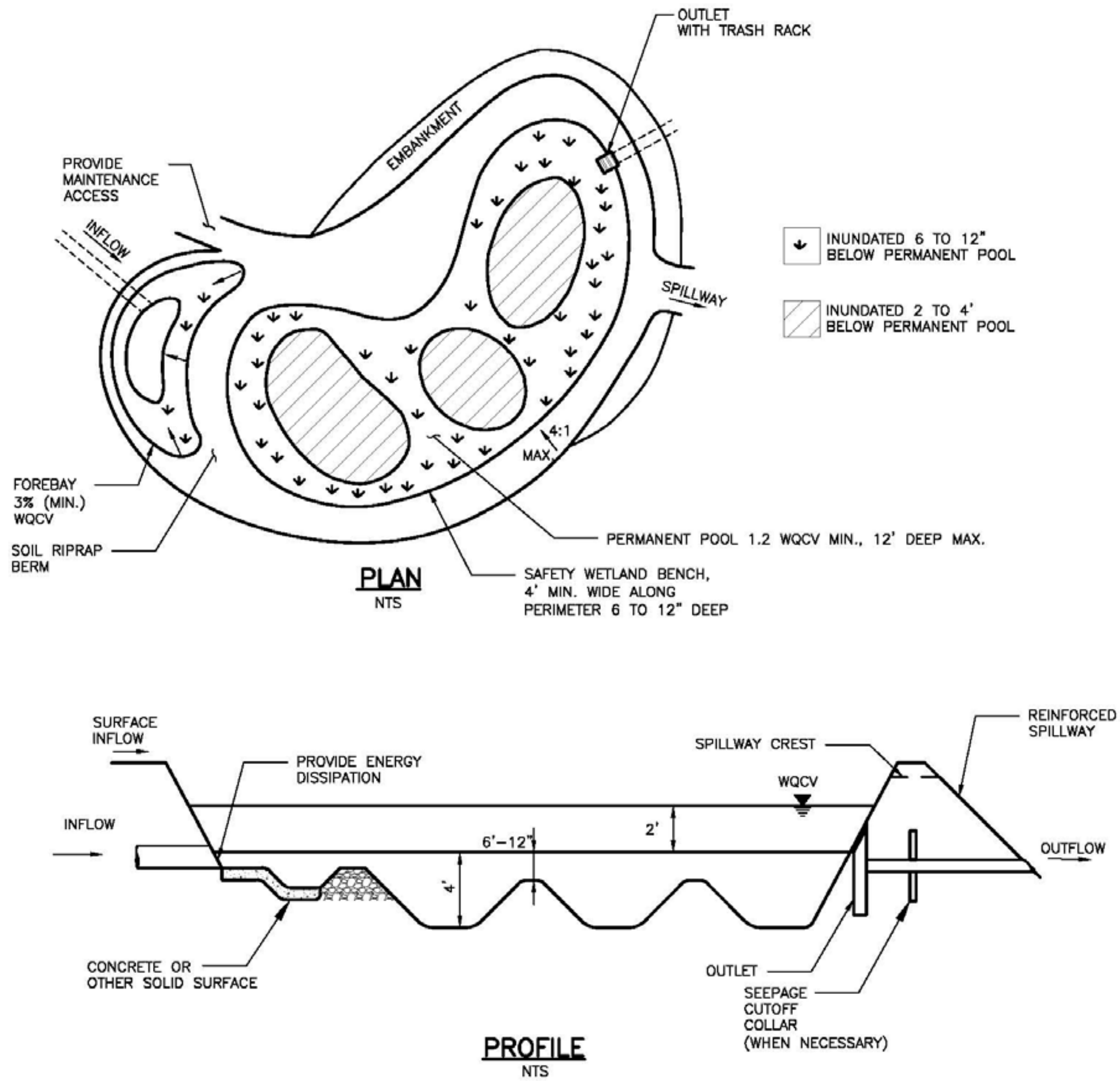

Figure CWP-1 – Constructed Wetland Pond – Plan and Cross-Section

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: Constructed Wetland Pond (CWP)

Sheet 1 of 3

Designer:	N. Calisoff
Company:	BMP Inc.
Date:	November 29, 2010
Project:	Industrial Park
Location:	SW corner of 105th Ave. and 93rd 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 = 60.0 %
B) Tributary Area's Imperviousness Ratio ($i = I_a / 100$)	i = 0.600
C) Contributing Watershed Area	Area = 10.000 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) Design Volume Based on 24-hour Drain Time ($V_{WQCV} = (0.9 * (0.91 * i^3 - 1.19 * i^2 + 0.78 * i) / 12 * Area)$)	V_{WQCV}= 0.177 ac-ft
G) For Watersheds Outside of the Denver Region, Water Quality Capture Volume (WQCV) Design Volume ($V_{WQCV\ OTHER} = (d_6*(V_{WQCV}/0.43))$)	$V_{WQCV\ OTHER}$= ______ ac-ft
H) User Input of Water Quality Capture Volume (WQCV) Design Volume (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 = 0.595 ac-f t
3. Depth of Surcharge WQCV (Should not exceed 2 feet, required even if EURV is chosen)	D_{WQCV} = 2.0 ft
4. Basin Shape (It is recommended to have a basin length to width ratio between 2:1 and 4:1)	L : W = 4.0 : 1
5. Permanent Pool A) Minimum Permanent Pool Volume	V_{POOL} = 0.133 ac-ft
6. Side Slopes A) Maximum Side Slope Above the Safety Wetland Bench (Horiz. dist. per unit vertical, should be no steeper than 4:1)	Z = 4.00 ft / ft
7. Inlet A) Describe means of providing energy dissipation at concentrated inflow locations:	Adequate tailwater during events exceeding the WQCV.

Design Procedure Form: Constructed Wetland Pond (CWP)

Sheet 2 of 3

Designer:	N. Calisoff
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8. Forebay

A) Minimum Forebay Volume (V_{FMIN} = 3% of the WQCV) — V_{FMIN} = 0.005 ac-ft

B) Actual Forebay Volume — V_F = 0.006 ac-ft

9. 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 = 2.0 feet

C) Volume to Drain Over Prescribed Time — EURV = 0.595 ac-ft

D) Drain Time (Min T_D for WQCV= 24 hours; Max T_D for EURV= 72 hours) — T_D = 72.0 hours

E) Recommended Outlet Area per Row, (A_o) — A_o = 1.56 square inches

F) Orifice Dimensions:
- i) Circular Orifice Diameter or — $D_{orifice}$ = 1 - 3 / 8 inch inches
- ii) Width of 2" High Rectangular Orifices — $W_{orifice}$ = inches

G) Number of Columns — nc = 1 number

H) Actual Design Outlet Area per Row (A_o) — A_o = 3.25 square inches

I) Number of Rows (nr) — nr = 6 number

J) Total Outlet Area (A_{ot}) — A_{ot} = 19.5 square inches

K) Depth of WQCV (H_{WQCV}) (Estimate using actual stage-area-volume relationship and V_{WQCV}) — H_{WQCV} = 2.0 feet

L) Ensure Minimum 24 Hour Drain Time for WQCV — $T_{D\ WQCV}$ = 24.3 hours

10. 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 = 655 square inches

C) For 2", or Smaller, **Circular Opening** (See Fact Sheet T-12):

- i) Depth of Trash Rack below Permanent Pool WS (28 inch min.) — $D_{inundation}$ = 28 inches
- ii) Width of Trash Rack and Concrete Opening ($W_{opening}$) — $W_{opening}$ = 21 inches
- iii) Height of Trash Rack Screen (H_{TR}) — H_{TR} = 52 inches
- iv) Type of Screen

Choose One
- (●) S.S. Well Screen with 60% Open Area*
- ( ) Other (Describe):

Design Procedure Form: Constructed Wetland Pond (CWP)

Sheet 3 of 3

Designer: N. Calisoff
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D) For 2" High Rectangular Opening (See Fact Sheet T-12):	
i) Depth of Trash Rack below Permanent Pool WS (28 inch min.)	$D_{inundation}$ = ______ inches
ii) Width of Rectangular Opening ($W_{orifice}$)	W = ______ inches
iii) Width of Trashrack Opening ($W_{opening}$) from Fact Sheet T-12	$W_{opening}$ = ______ feet
iv) Height of Trash Rack Screen (H_{TR})	H_{TR} = ______ feet
v) Type of Screen (based on depth H) (Describe if "Other")	Choose One ○ Aluminum Amico-Klemp SR Series (or equal) ○ Other (Describe):
vii) Minimum Bearing Bar Size	
11. Overflow Embankment	
A) Describe embankment protection for 100-year and greater overtopping:	buried soil riprap
B) Slope of Overflow Embankment (Horiz. dist. per unit vertical, should not be steeper than 4:1)	Z_E = 5.00 ft / ft
12. Maintenance Considerations	
A) Describe Means of Draining the Pond	pumping
13. Vegetation	Choose One ○ Irrigated ◉ Not Irrigated
14. Access	
A) Describe Sediment Removal Procedures	Gravel trail on north side of pond allows access to forebay. The remainder of the pond will need to be at least partially drained. Layout of the pond is such that excavation can be performed from the maintenance trail.

Notes:

References

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