



## Design Considerations

- Area Required
- Slope
- Water Availability
- Aesthetics
- Environmental Side-effects

Targeted Constituents	Removal
-----------------------	---------

Sediment	High
Nutrients	Med
Trash	High
Metals	Med
Bacteria	High
Oil and Grease	High
Organics	High
Flow Control	High

## Description

Wet ponds (stormwater ponds, retention ponds, wet extended detention ponds) are constructed basins that have a permanent pool of water throughout the year (or at least throughout the wet season) and differ from constructed wetlands primarily in having a greater average depth. The primary removal mechanism is settling as stormwater runoff resides in this pool, but limited pollutant uptake, particularly of nutrients, also occurs to some degree through biological activity in the pond.



## California Experience

Caltrans constructed a wet pond in northern San Diego County (I-5 and La Costa Blvd.). The most significant issues at this site were related to vector control, vegetation management, and concern that endangered species would become resident and hinder maintenance activities.

Some reduction of many of the pollutants regulated by the State and Regional Water Boards is possible in wet ponds.

## Advantages

- Provides stormwater treatment and can be designed to meet hydromodification management requirements.
- Can provide substantial aesthetic, recreational value and wildlife habitat.
- When incorporated, a permanent wet pool can provide water quality improvement across a relatively broad spectrum of constituents including dissolved nutrients.
- Offers significant channel protection by preventing the discharge of damaging peaks and volume from impervious area.

## Limitations

- Mosquito and midge breeding is likely to occur in ponds.
- A large footprint is often required; depending on volume and depth, pond designs may require approval from the State Division of Safety of Dams.
- Pose a risk to cold water systems because of their potential for stream warming.

## Performance

The observed pollutant removal of a wet pond is highly dependent on two factors: the volume of the permanent pool relative to the amount of runoff from the typical event in the area and the quality of the base flow that sustains the permanent pool. A Caltrans study indicated that when the permanent pool is much larger than the volume of runoff from an average event, then displacement of the permanent pool by the wet weather flow is the primary process. A statistical comparison of the wet pond discharge quality during dry and wet weather shows that they are not significantly different. Consequently, there is a relatively constant discharge quality during storms that is the same as the concentrations observed in the pond during dry weather conditions. Table 1 below details expected effluent concentrations and removal processes for each pollutant.

Table 1. Typical pollutant removal for constituents and removal processes

Pollutant	Typical Removal	Median effluent concentration <sup>1</sup>	Removal processes	References
<b>Sediment</b>	High (75-95%)	<u>11.5 mg/L</u>	Settling, and sorption	Geosyntec Consultants and Wright Water Engineering 2012; Barrett 2008; Scholes 2007; Pettersson et al. 1999
<b>Metals</b>	Medium	<u>TAs: 0.89 µg/L,</u> <u>TCd: 0.20 µg/L,</u> <u>TCr: 1.37 µg/L,</u> <u>TCu: 4.39 µg/L,</u> <u>TFe: 265 µg/L,</u> <u>TPb: 2.87 µg/L,</u> <u>TNi: 2.23 µg/L,</u> <u>TZn: 21.67 µg/L</u>	Removal with sediment, sorption	Geosyntec Consultants and Wright Water Engineering 2012; Fassman 2012; Scholes 2007
<b>Total phosphorus</b>	Medium (-55-100%)	<u>0.091 mg/L</u>	Sorption, and settling. Can be a net source or sink via breakdown or uptake of plant material	Geosyntec Consultants and Wright Water Engineering 2012; Dietz and Claussen 2005, 2006; Wu et al. 1996; Barrett 2008; Burton 2002
<b>Total nitrogen</b>	Medium (50-75%)	<u>TN: 1.20 mg/L,</u> <u>TKN: 1.01 mg/L,</u> <u>NO<sub>2,3</sub>-N: 0.13 mg/L</u>	Plant uptake if sufficient vegetation, denitrification	Geosyntec Consultants and Wright Water Engineering 2012; Barrett 2008; Collins 2010

Pollutant	Typical Removal	Median effluent concentration <sup>1</sup>	Removal processes	References
Bacteria	High	<u>E. coli - 100 (MPN/100 mL)</u> <u>Fecal Coliform - 581 (MPN/100 mL)</u>	Microbial degradation, photolysis, sorption, settling	Geosyntec Consultants and Wright Water Engineering 2012; Scholes 2007; Struck 2006
Trash	High	<i>N/A</i>	Filtration (Media treatment depth of 1.5 feet) and/or screened outlet	Barrett et al. 2013

<sup>1</sup>Underlined effluent concentrations were (statistically) significantly lower than influent concentrations, as determined by statistical hypothesis testing on the available sampled data. Effluent concentrations displayed in *italics* were (statistically) significantly higher than influent concentrations.

## Suitability and Design

Wet ponds are best suited to drainage areas greater than approximately 10 acres and where base flow rates or other channel flow sources are relatively consistent year-round. Several different versions of the wet pond design exist, the most common (and recommended) variant is the extended detention wet pond, where storage is provided above the permanent pool in order to detain stormwater runoff and promote settling. The constraints of each site dictate the appropriate siting and footprint. Fundamental wet pond design components are as follows:

- Capture volume determined by local requirements or 85 percent of the annual runoff volume.
- Include energy dissipation in inlet design and a sediment forebay to reduce resuspension of accumulated sediment and facilitate maintenance (typically 10 percent of the permanent pool).
- If applicable, permanent pool volume equal to twice the water quality volume.
- The outlet structure should be designed to drain the water quality volume over 72 hours.

In addition, Table 2 details a number of core construction components and corresponding design considerations.

Table 2. Cost of design components and associated considerations

Component/Activity	Cost	Design Consideration
<b>Excavation</b>	\$5.00–\$15.00/ft <sup>2</sup>	Water depth not to exceed 8 ft. Side slopes of the basin should be 3:1 or flatter for grass stabilized slopes. Slopes steeper than 3:1 should be stabilized with an appropriate slope stabilization practice
<b>Soil Media</b> Topsoil	\$1.35/ft <sup>2</sup>	Apply 1 to 4 inches to support plant growth. Depth depends on specified plantings and underlying soil characteristics. Natural, friable soil representative of productive, well-drained soils in the area. Low phosphorus (TP < 15 ppm) with pH 5.5–7.
<b>Hydraulic Restriction Layer</b> Filter fabric Clay 30-mil liner Concrete barrier	\$0.45/ft <sup>2</sup> \$0.65/ft <sup>2</sup> \$0.35/ft <sup>2</sup> \$12.00/ft <sup>2</sup>	If inter-storm rate of water loss exceeds supply from groundwater, baseflow, or runoff ensure water is maintained in permanent pool by use of hydraulic restriction layer
<b>Vegetation</b>	\$1.25–\$3.50/ft <sup>2</sup>	Primarily annual and perennial wetland plants specific to the water depth they would experience. Vegetation occupying no more than 25% of surface area

Wet ponds can be designed as either on- or off-line facilities. For on-line facilities, the principal and emergency spillways must be sized to provide 1.0 foot of freeboard during the 25-year event and to safely pass the 100-year flood. The embankment should be designed in accordance with all relevant specifications for small dams. When the pond is designed as an off-line facility, a splitter structure is used to isolate the water quality volume. The splitter box, or other flow diverting approach, should be designed to convey the 25-year event while providing at least 1 foot of freeboard along pond side slope.

A non-clogging outlet (e.g., reverse-slope pipe) or weir outlet with a trash rack is recommended to minimize the occurrence of clogging. Outlet structures and piping should also be installed with collars to prevent water from seeping through the fill and causing structural failure. Additionally, a separate drain pipe with a manual valve that can completely or partially drain the pond for maintenance purposes.

Road access should be provided along at least one side of BMPs that are seven meters or less in width. Those BMPs that have shoreline-to-shoreline distances in excess of seven meters should have perimeter road access on both sides or be designed such that no parcel of water is greater than seven meters from the road.

## ***Pond Configuration***

Some design features do not increase the volume of a pond, but can increase the amount of time stormwater remains in the device and eliminate short-circuiting. Ponds should always be designed with a length-to-width ratio of at least 1.5:1, where feasible. The wet basin should be configured as a two stage facility with a sediment forebay and a main pool. The basins should be wedge-shaped, narrowest at the inlet and widest at the outlet. In addition, the design should incorporate features to lengthen the flow path through the pond, such as underwater berms designed to create a longer route through the pond. Combining these two measures helps ensure that the entire pond volume is used to treat stormwater. After the first large storm verify desired residence time has been met.

Wet ponds with greater amounts of vegetation often have channels through the vegetated areas and contain dead areas where stormwater is restricted from mixing with the entire permanent pool, which can lead to less pollutant removal. Consequently, a pond with open water comprising about 75 percent of the surface area is preferred. The perimeter of all permanent pool areas with depths of 4.0 feet or greater should be surrounded by an aquatic bench. This bench should extend inward 5-10 feet from the perimeter of the permanent pool and should be no more than 18 inches below normal depth. The area of the bench should not exceed about 25% of pond surface. The depth in the center of the basin should be 4–8 feet deep to prevent vegetation from encroaching on the pond open water surface.

A sediment forebay should be used to isolate gross sediments as they enter the facility and to simplify sediment removal. The sediment forebay should consist of a separate cell formed by an earthen berm, gabion, or loose riprap wall. The forebay should be sized to contain 15 to 25% of the permanent pool volume and should be at least 3 feet deep. Exit velocities from the forebay should not be erosive. Direct maintenance access should be provided to the forebay. The bottom of the forebay may be hardened (concrete) to make sediment removal easier. A fixed vertical sediment depth marker should be installed in the forebay to measure sediment accumulation. An emergency spillway should be provided to safely bypass extreme flood flows.

Construction costs associated with wet ponds vary considerably. Much of this variability can be attributed to the degree to which the existing topography will support a wet pond, the complexity and amount of concrete required for the outlet structure, and whether it is installed as part of new construction or implemented as a retrofit of existing storm drain system.

## ***Vegetation***

A plan should be prepared that indicates how aquatic and terrestrial areas will be stabilized with vegetation. Wetland vegetation elements should be placed along the aquatic bench or in the shallow portions of the permanent pool. The optimal elevation for planting of wetland vegetation is within 6 inches vertically of the normal pool elevation. A list of some wetland vegetation native to California is presented in Table 3. Climatic considerations local to the wet pond should indicate which native vegetation is most appropriate.

Table 3. List of wet pond vegetation native to California

Botanical Name	Common Name
<i>Baccharis Salicifolia</i>	Mule Fat
<i>Frankenia Grandifolia</i>	Heath
<i>Salix GoodingII</i>	Black Willow
<i>Salix Lasiolepis</i>	Arroyo Willow
<i>Samucus Mexicanus</i>	Mexican Elderberry
<i>Haplopappus Venetus</i>	Coast Goldenbrush
<i>Distichis Spicata</i>	Salt Grass
<i>Limonium Californicum</i>	Coastal Statice
<i>Atriplex Lentiformis</i>	Coastal Quail Bush
<i>Baccharis Pilularis</i>	Chaparral Broom
<i>Mimulus Longiflorus</i>	Monkey Flower
<i>Scirpus Californicus</i>	Bulrush
<i>Scirpus Robustus</i>	Bulrush
<i>Typha Latifolia</i>	Broadleaf Cattail



Figure 1. Example forebay. Also note other components of the pond: earthen berm and native vegetation

## Maintenance

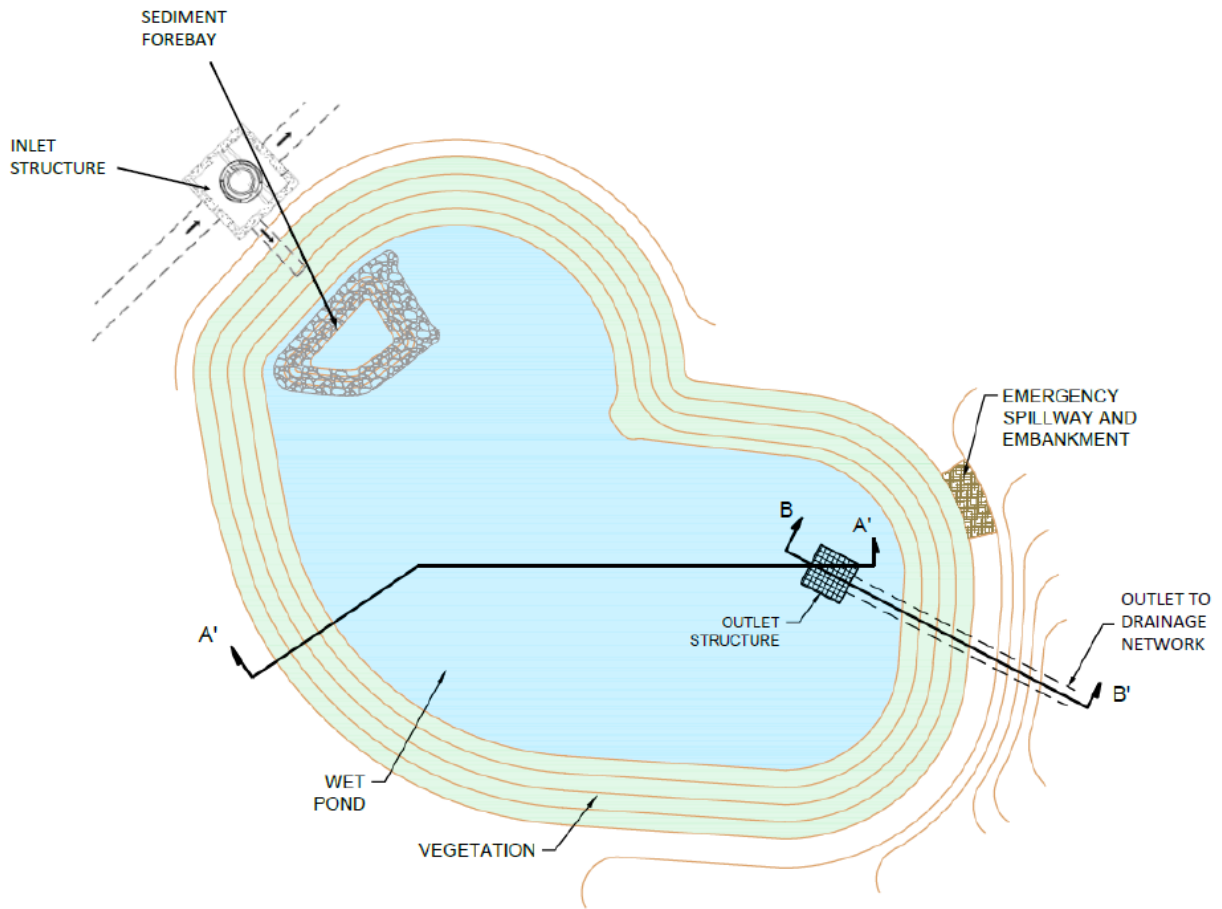
Regular maintenance activity ensures the wet pond functions capacity to remove pollutant load and provides hydrologic benefits is maximized. Typical maintenance involves caring for the pond’s vegetation and removing debris. Table 4 provides recommended frequencies and associated costs.

- Where permitted by the Department of Fish and Game or other agency regulations, stock wet ponds/constructed wetlands regularly with mosquito fish (*Gambusia spp.*) to enhance natural mosquito and midge control.

Table 4. Typical maintenance activities and associated costs and frequency

Frequency	Cost	Activity
<b>Routine Maintenance (required monthly to every 2 years)</b>		Remove excess sediment, trash, and debris across the surface, inlet, and outlet. Check for and stabilize erosion. Pruning and mowing overgrown vegetation that interferes with access, or safety. Removing and replanting dead vegetation
Routine (small)	\$0.44/ft <sup>2</sup>	
Routine (medium)	\$0.34/ft <sup>2</sup>	
Routine (large)	\$0.24/ft <sup>2</sup>	
<b>Intermediate Maintenance (required every 6 to 10 years)</b>		Remove accumulated sediment in the forebay and regrade (when the accumulated sediment volume exceeds 10 percent of the basin volume)
Intermediate (small)	\$1.47/ft <sup>2</sup>	
Intermediate (medium)	\$1.41/ft <sup>2</sup>	
Intermediate (large)	\$1.40/ft <sup>2</sup>	
<b>End of Life Replacement (service life of 20 years)</b>		Excavate to the depth of soil media. Test soil for excessive soil contamination of common stormwater pollutants (e.g. metals, nutrients). Continue to remove underlying soil if pollutants exceed standard for contaminated soil. Replace with clean soil.
Replacement (small)	\$8.19/ft <sup>2</sup>	
Replacement (medium)	\$6.43/ft <sup>2</sup>	
Replacement (large)	\$5.99/ft <sup>2</sup>	
Note: Small System = 500 ft <sup>2</sup> ; Medium System = 2000 ft <sup>2</sup> ; Large System = 4000 ft <sup>2</sup>		

## Schematic



**A** WET POND - PLAN VIEW  
- NOT TO SCALE

**References and Sources of Additional Information**

- Amalfi, F.A., R. Kadlec, R.L. Knight, G. O'Meara, W.K. Reisen, W.E. Walton, and R. Wass. 1999. A Mosquito Control Strategy For The Tres Rios Demonstration Constructed Wetlands. CH2M Hill, Tempe, AZ, 140 pp.
- Bannerman, R., and R. Dodds. 1992. Unpublished data. Bureau of Water Resources Management, Wisconsin Department of Natural Resources, Madison, WI.
- Barrett, M.E. 2008. Comparison of BMP performance using the International BMP Database. *Journal of Irrigation and Drainage Engineering* 134(5):556–561.
- Borden, R. C., J.L. Dorn, J.B. Stillman, and S.K. Liehr; 1996. *Evaluation of Ponds and Wetlands for Protection of Public Water Supplies*. Draft Report. Water Resources Research Institute of the University of North Carolina, Department of Civil Engineering, North Carolina State University, Raleigh, NC.
- Brown, W., and T. Schueler. 1997. *The Economics of Stormwater BMPs in the Mid-Atlantic Region*. Prepared for the Chesapeake Research Consortium, Edgewater, MD, by the Center for Watershed Protection; Ellicott City, MD.
- Burton, G., R. Pitt. 2002. "Stormwater effects handbook: A toolbox for watershed managers, scientists, and engineers". Lewis Publisher. ISBN 0-87371-924-7. Boca Raton, Florida.
- Caltrans, 2002, *Proposed Final Report: BMP Retrofit Pilot Program*, California Dept. of Transportation Report CTSW-RT-01-050, and Sacramento, CA.
- City of Austin, TX. 1991. *Design Guidelines for Water Quality Control Basins*. Public Works Department, Austin, TX.
- City of Austin, TX. 1996. Evaluation of Non-Point Source Controls: A 319 Grant Project. Draft Water Quality Report Series, Public Works Department, Austin, TX.
- Collins, K. et. al. 2010. Opportunities and challenges for managing nitrogen in urban stormwater: a review and synthesis. *Ecological Engineering* 36: 1507–1519.
- Cullum, M. 1985. Stormwater Runoff Analysis at a Single Family Residential Site. Publication 85-1. University of Central Florida, Orlando, FL. pp. 247–256.
- Dietz, M., Clausen, J. 2005. "A Field Evaluation of Rain Garden Flow and Pollutant Treatment," *Water, Air, & Soil Pollution*, 167, 123-138.
- Dietz, M.E., Clausen, J.C. 2006. "Saturation to Improve Pollutant Retention in a Rain Garden," *Environ. Sci. Technol.*, 40, 1335-1340.
- Dorman, M.E., J. Hartigan, R.F. Steg, and T. Quasebarth. 1989. *Retention, Detention and Overland Flow for Pollutant Removal From Highway Stormwater Runoff*. Vol. 1 Research Report. FHWA/RD 89/202. Federal Highway Administration, Washington, DC.

Dorman, T., M. Frey, J. Wright, B. Wardynski, J. Smith, B. Tucker, J. Riverson, A. Teague, and K. Bishop. 2013. San Antonio River Basin Low Impact Development Technical Design Guidance Manual, v1. San Antonio River Authority. San Antonio, TX.

Dorothy, J.M., and K. Staker. 1990. A preliminary Survey For Mosquito Breeding In Stormwater Retention Ponds In Three Maryland Counties. Mosquito Control, Maryland Department of Agriculture, College Park, MD. 5 pp.

Driscoll, E.D. 1983. *Performance of Detention Basins for Control of Urban Runoff Quality*. Presented at the 1983 International Symposium on Urban Hydrology, Hydraulics and Sedimentation Control, University of Kentucky, Lexington, KY.

Emmerling-Dinovo, C. 1995. Stormwater detention basins and residential locational decisions. *Water Resources Bulletin*, 31(3):515–52.

Fassman, E. 2011. Stormwater BMP treatment performance variability for sediment and heavy metals. *Separation and Purification Technology* 84: 95–103.

Faulkner, S. and Richardson, C., 1991, Physical and chemical characteristics of freshwater wetland soils, in *Constructed Wetlands for Wastewater Treatment*, ed. D. Hammer, Lewis Publishers, 831 pp.

Gain, W.S. 1996. *The Effects of Flow Path Modification on Water Quality Constituent Retention in an Urban Stormwater Detention Pond and Wetland System*. Water Resources Investigations Report 95-4297. U.S. Geological Survey, Tallahassee, FL.

Galli, F. 1990. *Thermal Impacts Associated with Urbanization and Stormwater Best Management Practices*. Prepared for the Maryland Department of the Environment, Baltimore, MD, by the Metropolitan Council of Governments, Washington, DC.

Geosyntec Consultants and Wright Water Engineering. 2012. *International Storm Water BMP Database Pollutant Category Summary Statistical Addendum: TSS, Bacteria, Nutrients, and Metals*. 2012. International Storm Water BMP Database. <http://www.bmpdatabase.org/>

Glick, Roger, 2001, personal communication, City of Austin Watershed Protection Dept., Austin, TX.

Holler, J.D. 1989. Water Quality Efficiency Of An Urban Commercial Wet Detention Stormwater Management System At Boynton Beach Mall in South Palm Beach County, FL. *Florida Scientist* 52(1):48–57.

Holler, J.D. 1990. Nonpoint Source Phosphorous Control By A Combination Wet Detention/Filtration Facility In Kissimmee, FL. *Florida Scientist* 53(1):28–37.

Horner, R.R., J. Guedry, and M.H. Kortenhoff. 1990. *Improving the Cost Effectiveness of Highway Construction Site Erosion and Pollution Control*. Final Report. Washington State Transportation Commission, Olympia, WA.

Kantrowitz .I. and W. Woodham 1995. *Efficiency of a Stormwater Detention Pond in Reducing Loads of Chemical and Physical Constituents in Urban Stream flow, Pinellas County, Florida*. Water Resources Investigations Report 94-4217. U.S. Geological Survey, Tallahassee, FL.

Martin, E. 1988. Effectiveness of an urban runoff detention pond/wetland system. *Journal of Environmental Engineering* 114(4):810–827.

Maryland Department of the Environment (MDE). 2000. *Maryland Stormwater Design Manual*. <http://www.mde.state.md.us/environment/wma/stormwatermanual>.

McLean, J. 2000. Mosquitoes In Constructed Wetlands: A Management Bugaboo? In T.R. Schueler and H.K. Holland [eds.], *The Practice of Watershed Protection*. pp. 29-33. Center for Watershed Protection, Ellicott City, MD.

Metzger, M. E., D. F. Messer, C. L. Beitia, C. M. Myers, and V. L. Kramer. 2002. The Dark Side Of Stormwater Runoff Management: Disease Vectors Associated With Structural BMPs. *Stormwater* 3(2): 24-39.

Oberts, G.L. 1994. Performance of stormwater ponds and wetlands in winter. *Watershed Protection Techniques* 1(2):64–68.

Oberts, G.L., P.J. Wotzka, and J.A. Hartsoe. 1989. *The Water Quality Performance of Select Urban Runoff Treatment Systems*. Publication No. 590-89-062a. Prepared for the Legislative Commission on Minnesota Resources, Metropolitan Council, St. Paul, MN.

Oberts, G.L., and L. Wotzka. 1988. The water quality performance of a detention basin wetland treatment system in an urban area. In *Nonpoint Source Pollution: Economy, Policy, Management and Appropriate Technology*. American Water Resources Association, Middleburg, VA.

Occoquan Watershed Monitoring Laboratory. 1983. Metropolitan Washington Urban Runoff Project. Final Report. Prepared for the Metropolitan Washington Council of Governments, Washington, DC, by the Occoquan Watershed Monitoring Laboratory, Manassas, VA.

Ontario Ministry of the Environment. 1991. *Stormwater Quality Best Management Practices*. Marshall Macklin Monaghan Limited, Toronto, Ontario.

Pettersson J.R. (1999). Stormwater ponds for pollution reduction. PhD thesis, Chalmers University of Technology, Göteborg, Sweden.

Protection Agency, Office of Water, Washington, DC, by the Watershed Management Institute, Ingleside, MD.

Santana, F.J., J.R. Wood, R.E. Parsons, and S.K. Chamberlain. 1994. Control Of Mosquito Breeding In Permitted Stormwater Systems. Sarasota County Mosquito Control and Southwest Florida Water Management District, Brooksville, FL., 46 pp.

Saunders, G. and M. Gilroy, 1997. *Treatment of Nonpoint Source Pollution with Wetland/Aquatic Ecosystem Best Management Practices*. Texas Water Development Board, Lower Colorado River Authority, Austin, TX.

Scholes, L. M. Revitt, J. Ellis. 2007. A systematic approach for the comparative assessment of stormwater pollutant removal potentials. *Journal of Environmental Management*, 88(2008): 467–478.

Schueler, T. 1997a. Comparative pollutant removal capability of urban BMPs: A reanalysis. *Watershed Protection Techniques* 2(4):515–520.

Schueler, T. 1997b. Influence of groundwater on performance of stormwater ponds in Florida. *Watershed Protection Techniques* 2(4):525–528.

Struck, S.D., M. Borst, and A. Selvakumar. 2006. Performance of Stormwater Retention Ponds and Constructed Wetlands in Reducing Microbial Concentrations. Environmental Protection Agency (EPA) Report 600/R-06/102

Tetra Tech (Tetra Tech, Inc.). 2015. Enhancements to the City of San Diego Green Infrastructure Design Standards City of San Diego Storm Water Division by Tetra Tech, Inc., San Diego, CA.

Tetra Tech (Tetra Tech, Inc.). 2014. Low Impact Development Handbook Stormwater Management Strategies County of San Diego Department of Public Works by Tetra Tech, Inc., San Diego, CA.

Urbonas, B., J. Carlson, and B. Vang. 1994. Joint Pond-Wetland System in Colorado. Denver Urban Drainage and Flood Control District, Denver, CO.

U.S. Environmental Protection Agency (USEPA). 1995. *Economic Benefits of Runoff Controls*. U.S. Environmental Protection Agency, Office of Wetlands, Oceans, and Watersheds, Washington, DC.

Watershed Management Institute (WMI). 1997. *Operation, Maintenance, and Management of Stormwater Management Systems*. Prepared for U.S. Environmental Protection Agency, Office of Water, Washington, DC, by the Watershed Management Institute, Ingleside, MD.

Water Environment Federation and ASCE, 1998, *Urban Runoff Quality Management*, WEF Manual of Practice No. 23 and ASCE Manual and Report on Engineering Practice No. 87.

Wu, J. 1989. Evaluation of Detention Basin Performance in the Piedmont Region of North Carolina. Report No. 89-248. North Carolina Water Resources Research Institute, Raleigh, NC.

Wu, J. S., Holman, R. E., and Dorney, J. R. 1996. “Systematic evaluation of pollutant removal by urban wet detention ponds.” *J. Environ. Eng.*, 122:11, 983–988.

Yousef, Y., M. Wanielist, and H. Harper. 1986. Design and Effectiveness of Urban Retention Basins. In *Urban Runoff Quality—Impact and Quality Enhancement Technology*. B. Urbonas and L.A. Roesner (Eds.). American Society of Civil Engineering, New York, New York. pp. 338–350.

## ***Information Resources***

Center for Watershed Protection (CWP). 1995. *Stormwater Management Pond Design Example for Extended Detention Wet Pond*. Center for Watershed Protection, Ellicott City, MD.

Center for Watershed Protection (CWP). 1997. *Stormwater BMP Design Supplement for Cold Climates*. Prepared for U.S. Environmental Protection Agency, Office of Wetlands, Oceans and Watersheds, Washington, DC, by the Center for Watershed Protection, Ellicott City, MD.

Denver Urban Drainage and Flood Control District. 1992. *Urban Storm Drainage Criteria Manual—Volume 3: Best Management Practices*. Denver Urban Drainage and Flood Control District, Denver, CO.

Galli, J. 1992. *Preliminary Analysis of the Performance and Longevity of Urban BMPs Installed in Prince George's County, Maryland*. Prince George's County, Maryland, Department of Natural Resources, Largo, MD.

MacRae, C. 1996. Experience from Morphological Research on Canadian Streams: Is Control of the Two-Year Frequency Runoff Event the Best Basis for Stream Channel Protection? In *Effects of Watershed Development and Management on Aquatic Ecosystems*. American Society of Civil Engineers, Snowbird, UT. pp. 144–162.

Minnesota Pollution Control Agency. 1989. *Protecting Water Quality in Urban Areas: Best Management Practices*. Minnesota Pollution Control Agency, Minneapolis, MN.

U.S. Environmental Protection Agency (USEPA). 1993. *Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters*. EPA-840-B-92-002. U.S. Environmental Protection Agency, Office of Water, Washington, DC.