# Appendix F. BMP Information Sheets

## F.1 Biofilters / Bioretention

### Description

Biofilters / Bioretention Basins use herbaceous plants and grasses planted within channels, swales or cells using soil or engineered media, with or without underdrains. (WERF 2005)

#### Pollutants of Concern Treated by Biofilter/Bioretention Cells

| Biofilters and Bioretention | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Solids** | **Solid Metals** | **Dissolved Metals** | **Hydrocarbons** | **Nutrients** | **Ammonia** | **pH** | **Bacteria Pathogens** | **Organics** | **Trash** | **Pesticides Herbicides** |
| TSS | Cu | Zn | O/G | Total N | | | X | PCB | | |
| SSC | Zn | | TPH | | | | | PAH | | |
| Turbidity | Pb | Cr | | | | | | | | |
| Total Solids | Cr | | | | | | | | | |

#### International Stormwater BMP Database 2016 Summary Statistics Table – Bioretention International Stormwater BMP Database

Prepared for City and County of Denver and Urban Drainage and Flood Control District, February 2017. Prepared by Wright Water Engineers and Geosyntec Consultants. (Wright Water Engineers and Geosyntec (Consultants 2016)

| | BMPs[1] | | EMCs[2] | | 25th | | Median Concentration[3] | | | 75th | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **In** | **Out** | **In** | **Out** | **In** | **Out** | **In** | **Out** | **Difference[4]** | **In** | **Out** |
| Enterococcus (MPN/100 mL) | 3 | 3 | 48 | 49 | 180 | 32 | 590 (220, 920) | 220 (58, 440) | ◇◆◆ | 2,400 | 2,200 |
| E. coli (MPN/100 mL) | 7 | 7 | 97 | 96 | 110 | 18 | 1,200 (200, 2,100) | 240 (77, 280) | ◇◆◆ | 5,900 | 1,100 |
| Kjeldahl nitrogen (TKN) (mg/L) | 23 | 23 | 451 | 390 | 0.62 | 0.64 | 1.10 (1.07, 1.24) | 1.39 (1.14, 1.40) | ◇◇◇ | 2.20 | 2.39 |
| Nitrogen, $NO_x$ as N (mg/L) | 26 | 26 | 508 | 434 | 0.21 | 0.18 | 0.35 (0.32, 0.38) | 0.43 (0.38, 0.50) | ◇◆◆ | 0.55 | 1.14 |
| Nitrogen, Nitrate ($NO_3$) as N (mg/L) | 4 | 4 | 45 | 40 | 0.19 | 0.27 | 0.35 (0.24, 0.41) | 0.48 (0.29, 0.56) | ◇◆◆ | 0.48 | 0.88 |
| Nitrogen, Nitrite ($NO_2$) + Nitrate ($NO_3$) as N (mg/L) | 23 | 23 | 462 | 394 | 0.21 | 0.17 | 0.35 (0.31, 0.38) | 0.42 (0.35, 0.51) | ◇◆◆ | 0.56 | 1.24 |

| | BMPs[1] | | EMCs[2] | | 25th | | Median Concentration[3] | | | 75th | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | In | Out | In | Out | In | Out | In | Out | Difference[4] | In | Out |
| Nitrogen, Total (mg/L) | 17 | 17 | 289 | 238 | 0.77 | 0.65 | 1.24 (1.06, 1.35) | 1.04 (0.88, 1.14) | ◇◇◆ | 2.25 | 2.08 |
| Phosphorus as P, Dissolved (mg/L) | 4 | 4 | 66 | 62 | 0.07 | 0.25 | 0.11 (0.08, 0.12) | 0.40 (0.33, 0.50) | ◆◆◆ | 0.23 | 0.88 |
| Phosphorus as P, Total (mg/L) | 30 | 30 | 583 | 505 | 0.07 | 0.08 | 0.13 (0.12, 0.15) | 0.24 (0.18, 0.28) | ◆◆◆ | 0.26 | 0.59 |
| Phosphorus, orthophosphate as P (mg/L) | 20 | 19 | 316 | 269 | 0.01 | 0.04 | 0.02 (0.02, 0.03) | 0.27 (0.18, 0.29) | ◆◆◆ | 0.09 | 0.46 |
| Total suspended solids (mg/L) | 25 | 25 | 520 | 463 | 18.0 | 4.0 | 40.6 (36.0, 46.0) | 10.0 (8.0, 10.0) | ◆◆◆ | 99.2 | 18.5 |
| Cadmium, Dissolved (µg/L) | 4 | 4 | 105 | 95 | 0.01 | 0.03 | 0.03 (0.02, 0.04) | 0.10 (0.05, 0.10) | ◆◆◆ | 0.05 | 0.20 |
| Cadmium, Total (µg/L) | 6 | 6 | 144 | 110 | 0.04 | 0.04 | 0.08 (0.05, 0.09) | 0.07 (0.06, 0.10) | ◇◇◇ | 0.18 | 0.16 |
| Chromium, Total (µg/L) | 3 | 3 | 89 | 83 | 1.94 | 1.00 | 3.20 (2.60, 3.75) | 2.50 (2.50, 2.50) | ◆◆◆ | 5.40 | 2.50 |
| Copper, Dissolved (µg/L) | 7 | 7 | 143 | 127 | 3.21 | 3.28 | 5.11 (4.41, 5.80) | 6.50 (4.70, 7.10) | ◇◇◆ | 8.13 | 12.60 |
| Copper, Total (µg/L) | 14 | 14 | 333 | 300 | 4.90 | 3.57 | 9.20 (7.66, 9.97) | 5.70 (5.09, 6.08) | ◆◆◆ | 19.10 | 10.00 |
| Iron, Total (µg/L) | 4 | 4 | 54 | 52 | 272.50 | 500.00 | 556.3 (378.0, 645.0) | 1100.0 (560.0, 1200.0) | ◇◆◆ | 827.50 | 1,740.00 |
| Lead, Dissolved (µg/L) | 5 | 5 | 118 | 108 | 0.03 | 0.02 | 0.07 (0.05, 0.08) | 0.05 (0.03, 0.06) | ◇◆◇ | 0.13 | 0.10 |
| Lead, Total (µg/L) | 8 | 8 | 176 | 162 | 1.20 | 0.11 | 3.16 (2.01, 4.59) | 0.32 (0.21, 0.42) | ◆◆◆ | 8.21 | 1.23 |
| Nickel, Total (µg/L) | 3 | 3 | 82 | 76 | 2.25 | 2.76 | 3.55 (2.88, 4.84) | 3.81 (3.15, 4.50) | ◇◇◇ | 6.75 | 5.94 |
| Zinc, Dissolved (µg/L) | 6 | 6 | 144 | 132 | 11.30 | 3.28 | 19.95 (15.90, 23.60) | 13.90 (10.00, 15.55) | ◆◆◆ | 49.00 | 20.80 |
| Zinc, Total (µg/L) | 15 | 15 | 367 | 334 | 26.00 | 5.31 | 49.80 (43.53, 56.00) | 12.00 (9.00, 12.68) | ◆◆◆ | 111.50 | 26.00 |

## Certifications[5]

## Component Specific Considerations

- Include local aviation authorities if the stormwater BMP is situated within 10,000 feet of an airport operations area.
- Aviation concerns: Depending on proximity to airports, vegetation must not be allowed to develop at the BMP

that attracts wildlife, which can pose a hazard to aviation.
- Filter media typically will leach phosphorus.
- Ponding depths in bioretention practices are limited to protect vegetation.
- Vegetation must be tolerant of wet and dry periods.

## Design Criteria Considerations

- Are unaffected by arid conditions, however water must be provided to sustain the plant growth or if native grasses/vegetation are used
- Media may be covered as long as cover material infiltration is adequate
- Utilize underdrains or liners if there are site constraints, such as site contamination, high water table, soils with slow infiltration, shallow bedrock or karst, or close proximity to drinking water wells.
- Reduce sediment loads to the BMP using pretreatment.
- Ensure adequate maintenance access and incorporate safety features into the design.
- Develop a landscaping plan for establishment of vegetation, including the use of perennial native plants if applicable and plants tolerant of likely conditions within the BMP.
- Ensure inflow points are properly located, stabilized and protected, and has appropriate slope.
- Runoff volumes beyond the design volume should bypass the BMP.
- Limit drainage area to a BMP (e.g., max 5 acres) or consider multiple BMP when areas are larger.
- In cold climates, assess the feasibility of snow storage in the BMP, considering potential salt loads.
- Select filter media that meets infiltration, plant and pollutant attenuation needs.

## Construction Information

***Construction Submittals***

- *Solid pipes*: Pipes sizes, diameter and materials are important to the functionality of a properly functioning drainage system. Drainage volumes, velocities and flow-rates are dependent on these factors. It is important to reference the plans and specifications when determining the acceptability of each of these drainage components.
- *Perforated pipes*: Pipe size, diameter, material and perforations are important when researching these components. The volume and flow rates within the pipe are affected by the size and quantity of perforations. It is also important to note the type of perforations and how they are oriented when installing each pipe.
- *Aggregate*: Size and material is important when selecting this material. Void ratios, which affect the detention volume of the BMP, are specifically affected by these factors. It is also important to note that clean aggregate should always be used when installing these devices.
- *Landscape fabrics*: Landscape fabrics and watertight mats are used in BMP design, which is important to understand if the project is designed to infiltrate. The materials used on and around the landscape fabrics are also important when determining the type and thickness of the material.
- *Drainage structures (inlets, cleanouts and manholes):* Size is an important component of these features. Sizes have been determined based off pipe sizes and what the structures will be housing. If they are used as a junction, they could be sized differently than if they are housing multiple filters. Some structures are precast; others are completely cast in place, while others use a combination of both.
- *BMP-specific soils*: These soils rely heavily on a set infiltration rate. It is important to note the rate and purchase materials that meet the standards set forth in the specifications. It is also important to note the amount and types of organics in these soils since many of them are not only used for filtration, but for plantings as well.

**Timeframe**

- The area for the infiltration facility should be staked during utility (specifically storm drain) installation.
- During excavation, ensure minimal compaction and verify soil conditions and ensure proper erosion control and sediment control practices are in place around the facility locations.
- Piping to and from these features, in addition to the drainage and overflow structures, are usually installed prior to the subgrade compaction phase. Consider protection from erosion, sediment and debris as installation of each feature is completed.
- It is not recommended that any of the filtration mechanisms associated with these features, whether it be a specialized treatment soil or a media filter, is installed until final site stabilization has occurred. Many of these soils and filters are very expensive and sensitive to excessive soil particle accumulation, so it is recommended

that these are not put into place until after the risk of significant soil loss has passed.

**Protection**

- Piping to and from these features, in addition to the drainage and overflow structures, is usually installed prior to the subgrade compaction phase. It is recommended that the structures of these features be protected from erosion, sediment and debris as installation of each feature is completed. It is not recommended that any of the filtration mechanisms associated with these features, whether it be a specialized treatment soil or a media filter, be installed until final site stabilization has occurred. Many of these soils and filters are very expensive and sensitive to excessive soil particle accumulation, so it is recommended that these not be put into place until after the risk of significant soil loss has passed.
- Some systems, such as grade retention systems, are installed in the utilities phase of construction and prior to subgrade compaction. Above grade retention systems are typically not installed until vertical construction has commenced and roof structures have been installed. Once the retention system has been installed, it is recommended that it be protected throughout construction until final site stabilization.
- Consider erosion control blankets and fiber rolls to protect graded slopes and prevent excessive soil loss.
- Consider inlet sediment bags on installed inlets.
- Consider gravel bag check dams in drainage ditches and gutters.
- Consider silt fences and fiber rolls along the perimeter of devices.

## Inspection Checklist

- Inspect all pipes and structures up and downstream of the device as installation occurs to ensure they are clear of dirt and debris.
- Upon completion of excavation and, if appropriate, before filling of the facility with stone or other fill material, inspect and verify size, locations and depth of facilities.
- During construction, all storm drainage features and installed BMPs should be inspected on a regular basis and cleaned of any sediment and debris.
- During construction, and prior to any storm events, these features should also be inspected and cleaned to insure that the systems do not carry or become clogged with sediment.
- All temporary BMP protection should be inspected and cleaned to insure proper erosion prevention and permanent BMP protection such as inlet bags, fiber rolls and check dams before and after storm events. These construction inspections should be documented, recorded and saved on site.

## Operation and Maintenance Considerations

**Monitoring via Inspection**

*During the first year after construction, more frequent inspection is needed to ensure that the plant material becomes established.*

- During the first six months, the facility should be inspected twice following rainfall events that exceed ½ inch.
- Until the turf areas around and upstream of the basin are mature enough to survive, they should be inspected for bare spots and erosion. Problem areas should be seeded and mulched immediately to obtain a stabilizing turf cover.
- In dry conditions, water plants once per week for the first two months then as needed spring through fall.
- As plants develop, verify that they are consistent with the species specified in the planting plan.
- Plants in need of fertilization may be sparingly spot-fertilized one time as they become established.
- Remove and replace dead plants that do not survive the first growing season.

*Inspect the condition of plant and mulch cover monthly.*

- Mulch and plant material should provide over 75% cover over media bed. Additional mulch should be added as needed until plants mature and provide cover.
- Remove invasive species before they reach 10% of the facility’s plant cover.
- Mow turf when it reaches 6-10 inches in height.
- Remove and replace dying plants.
- Check upstream areas for unusual sources of pollution such as oil or gasoline spills that may injure plants. Remove and replace contaminated mulch and dying plants.

- Remove litter and debris that is washed into or deposited in the facility.

*Annual inspections and cleanup operations noted below are best done during the spring season.*

- Check for clear access to inspect and maintain the facility.
- Check the contributing drainage area for erosion, excessive trash or other materials that could affect the performance of the facility. Remove upstream sources of pollution if possible.
- Check for sediment buildup at curb cuts, gravel diaphragms or pavement edges that prevents flow from getting into the bed. Check all inflow points for clogging and for other signs of bypassing.
- Check for presence of accumulated sand, sediment and trash in the pre-treatment cell or filter beds and remove it.
- Inspect side slopes and embankments for evidence of sloughing, animal burrows, boggy areas, woody growth, sparse vegetative cover or slumping.
- Inspect side slopes, filter strips and other turf areas upstream of the facility for erosion. Repair and stabilize eroding areas.
- Check that filter bed is level to ensure an even spread of water over the surface and prevent ponding or concentrated flows. Remove any accumulated sediment. Level as necessary.
- Check for standing water, compacted areas or evidence of slow draining media. Loosen compacted media and supplement or replace with proper bioretention media as necessary to restore free drainage.
- Check for evidence that the facility is not dewatering. Observe drawdown after a runoff producing rain to verify the facility dewaters within 48 hours. Inspect media for sinking that may indicate failure of underdrain. Inspect observation wells and repair underdrain and other components of internal plumbing if required to restore facility dewatering.
- Inspect mulch for thin or crusted areas and for mulch that is floating. Remove spent mulch and rake surface to break up crusted top layer. Add additional fresh mulch as needed to provide adequate depth and ground cover.
- Check for plants that were winter or salt-killed. Replace with hardier species.
- Inspect for presence of invasive species and remove.
- Check overflow outlet for clogging or sediment deposits. Clear and remove accumulated debris and sediment to restore free flow path to outlet.

**Maintenance**

- Inspect all pipes and structures up and downstream of the device, as installation occurs to ensure they are clear of dirt and debris.
- Upon completion of excavation and, if appropriate, before filling of the facility with stone or other fill material, inspect and verify size, locations and depth of facilities.
- During construction, all storm drainage features and installed BMPs should be inspected on a regular basis and cleaned of any sediment and debris.
- During construction and prior to any storm events, these features should also be inspected and cleaned to insure that the systems do not carry or become clogged with sediment.
- All temporary BMP protections should be inspected and cleaned to insure proper erosion prevention and permanent BMP protection such as inlet bags, fiber rolls and check dams before and after storm events. These construction inspections should be documented and saved on site.
- Upon completion of each facility, including complete establishment of vegetation, if appropriate, perform final inspection to verify the correct size materials and plants have been used per the construction specifications. Also verify the facility is working properly.

**Example Maintenance Agreements**

- Chesapeake Stormwater Network Technical Bulletin No. 10: Bioretention Illustrated: A Visual Guide for Constructing, Inspecting, Maintaining and Verifying the Bioretention Practice, Version 2.0 (Network 2013b)
- Minnesota Pollution Control Agency Stormwater Manual: Bioretention (MPCA 2016)
- North Carolina Department of Environmental Quality Stormwater Design Manual, Minimum Design Criteria and Recommendations for Stormwater Control Measures C-2: Bioretention Cell (NCDEQ 2017)
- Chesapeake Stormwater Network; Design Specification No 9: Bioretention, Version 2.0 (Network 2013a) (VADCR 2013) (Houng 2009)
- West Virginia Department of Environmental Protection Stormwater Management and Design Guidance Manual,

Chapter 4.2.3: Bioretention (WVDEP 2012)

# F.2 Chemical Treatment

**December 2018**

## Description

Chemical treatment involves the addition of chemicals to facilitate pH adjustment, sorption, coagulation/flocculation and precipitation of pollutants. The process typically includes chemical injection followed by filtration.

### Pollutants of Concern Treated by Chemical Treatment

| Chemical Treatment | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Solids** | **Solid Metals** | **Dissolved Metals** | **Hydrocarbons** | **Nutrients** | **Ammonia** | **pH** | **Bacteria Pathogens** | **Organics** | **Trash** | **Pesticides Herbicides** |
| TSS | Cu | Cu | | Phosphorus | X | X | X | PCB | | Pest |
| SSC | Zn | Zn | | Ortho-phosphorus | | | | PAH | | Herb |
| Turbidity | Pb | Pb | | Total Nitrogen | | | | | | |
| Total Solids | Cd | Cd | | Kjeldahl Nitrogen | | | | | | |
| | Cr | Cr | | Nitrate / Nitrite | | | | | | |
| | Ni | Ni | | | | | | | | |
| | As | As | | | | | | | | |
| | Radionuclides | Radionuclides | | | | | | | | |

### Data Available in International Stormwater BMP Database: ☒ Yes ☐ No

## Certifications[6]

### Washington State Technology Assessment Protocol – Ecology

| | TSS | Enhanced (Dissolved Metals) | Total Phosphorus | Oil/Grease |
|---|---|---|---|---|
| **General Use Level Designation** | | | | |
| Chitosan-Enhanced Sand Filtration | ☒ | ☐ | ☐ | ☐ |

## Design Criteria Considerations

- Chemical treatment usually requires storage or flow control measuring equipment upstream of chemical treatment site (e.g., flow restricting valves, tank, water retention basin) in order to provide a controlled flow rate for effective chemical dosing.
- Chemical treatment is usually followed by additional treatment BMPs to remove chemicals/contaminants before discharge (e.g., filtration or settling ponds).
- Chemicals may be hazardous and require secondary containment, fire prevention, or ventilation measures for safe operation. Local emergency management and hazardous chemical storage requirements should be reviewed.
- Chemical compatibility for components at, and downstream of, the chemical treatment site should be reviewed.

## Construction Information

**<u>Construction Submittals</u>**

- Considerable earthwork may be required to install retention basins upstream of chemical treatment area.
- Chemicals for consideration need to be vetted for proper use and placement and for incompatibilities. Chemicals may include chemical adhesives (e.g., polyacrylamide (PAM)).

**Timeframe**

- Hold a pre-construction meeting.
- Assemble materials on site and ensure they meet design specifications.
- Install erosion and sediment controls.
- Till area to specified depth.
- Spread chemical treatment as per specifications.
- Level and seed the site per local / regional specifications.
- Follow erosion control measures as per site plan (e.g., silt fence).
- Stabilize exposed soils.

## Operation and Maintenance Considerations

**Monitoring**

- Ensure equipment or materials housed in shelter or shed are secure.
- Following construction, quarterly inspection of the BMP or device may be necessary to ensure that it is operating within design parameters. Check with the permitting agency or local regulator for specific requirements and demonstrations of the effectiveness of the BMP.
- Inspect system for degraded components, cracks or leaks.
- Periodically observe wildlife or vegetation to ensure that the system is operating within the design parameters.
- Routine monitoring may also include periodic chemical, water or soil sampling to ensure that operating parameters are met. Operators should follow permits or guidance from local regulatory agencies. For ongoing processes, periodic (daily or quarterly) visual inspections and sampling may be necessary. Automated sampling devices or cameras could help reduce maintenance costs for ongoing chemical treatment as well as produce more defensible evidence of performance.
- Routine monitoring may also include the review of analytical data from downstream locations, which are already being periodically monitored by third-party observers.

**Maintenance**

- Post signage to identify hazardous chemicals or materials and health and environmental hazards using Global Harmonization Standards. Ensure Safety Data Sheets are up-to-date and accessible on site.
- Perform periodic disassembly and cleaning of component (i.e., hoses, meters, floats, booster pumps). Remove sludge or debris from tanks and scrapers in accordance with manufacturer's recommendation. Dispose of debris or material in accordance with permit conditions or local regulatory compliance standards.
- Plan periodic reviews of monitoring information annually for BMPs in unstable site conditions, or less frequently under very stable conditions, and adjust as site conditions change.
- Ensure calibration and monitoring equipment is tested in accordance with the manufacturer's recommendations. Check with permitting agency or local regulator for specific requirements and demonstrations of the effectiveness of the BMP.

**Example Inspection Elements**

- Are secondary containment, fire prevention or ventilation measures consistent with local regulations?
- Does the system's storage area for equipment and materials appear to be secure?
- Are warning signs and safety data sheets accessible?
- Does the system appear to be functioning within the design parameters?
- Is there any evidence of damage to the system such as leaks or cracks?
- Describe site conditions, including water, soil, vegetation and wildlife.
- Collect samples based on permit or regulatory agency guidance for the specific BMP.

## References and Links


- NRCS Conservation Practice Standard Field Border Code 386-1
- Texas Commission on Environmental Quality: Complying with the Edwards Aquifer Rules: Technical Guidance on Best Management Practices
- State of Washington Department of Ecology Stormwater Management Manual for Western Washington – Vol. II

# F.3 Constructed Wetlands

**December 2018**

## Description

Basins with open water surfaces, using a blend of shallow and deep zones, to take advantage of natural treatment processes.

### Pollutants of Concern Treated by Constructed Wetlands

| Constructed Wetlands | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Solids** | **Solid Metals** | **Dissolved Metals** | **Hydrocarbons** | **Nutrients** | **Ammonia** | **pH** | **Bacteria Pathogens** | **Organics** | **Trash** | **Pesticides Herbicides** |
| TSS | Cu | Cu | O/G | Phosphorus | | | X | PCB | X | |
| SSC | Zn | Zn | TPH | Ortho-phosphorus | | | | PAH | | |
| Turbidity | Pb | Pb | | Total Nitrogen | | | | | | |
| Total Solids | Cd | Cd | | Kjeldahl Nitrogen | | | | | | |
| | Cr | Cr | | Nitrate / Nitrite | | | | | | |
| | Ni | | | | | | | | | |
| | As | | | | | | | | | |

### a. International Stormwater BMP Database Performance Summary, 2016 – Wetland Channel

| | BMPs[7] | | EMCs[8] | | 25th | | Median Concentration[9] | | | 75th[10] | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **In** | **Out** | **In** | **Out** | **In** | **Out** | **In** | **Out** | **Difference** | **In** | **Out** |
| Fecal Coliform (MPN/100 mL) | 3 | 3 | 21 | 20 | 3,500 | 1,700 | 6,000 (2,300, 7,500) | 4,000 (1,600, 11,000) | ◇◇◇ | 12,000 | 12,000 |
| Kjeldahl nitrogen (TKN) (mg/L) | 9 | 9 | 141 | 129 | 0.97 | 0.85 | 1.50 (1.30, 1.60) | 1.25 (1.10, 1.30) | ◇◆◆ | 2.10 | 1.60 |
| Nitrogen, NOx as N (mg/L) | 11 | 11 | 166 | 149 | 0.19 | 0.10 | 0.37 (0.29, 0.44) | 0.21 (0.17, 0.30) | ◇◆◆ | 0.75 | 0.72 |
| Nitrogen, Nitrate ($NO_3$) as N (mg/L) | 4 | 4 | 82 | 70 | 0.12 | 0.10 | 0.21 (0.16, 0.23) | 0.16 (0.10, 0.20) | ◇◇◆ | 0.31 | 0.30 |
| Nitrogen, Nitrite ($NO_2$) + Nitrate ($NO_3$) as N (mg/L) | 7 | 7 | 84 | 79 | 0.41 | 0.13 | 0.71 (0.52, 0.90) | 0.41 (0.21, 0.72) | ◇◆◆ | 2.51 | 1.12 |
| Nitrogen, Total (mg/L) | 9 | 9 | 107 | 103 | 1.28 | 0.94 | 1.70 (1.50, 1.96) | 1.43 (1.05, 1.55) | ◇◆◆ | 2.69 | 1.87 |
| Phosphorus as P, Dissolved (mg/L) | 5 | 5 | 92 | 89 | 0.05 | 0.06 | 0.08 (0.07, 0.10) | 0.09 (0.07, 0.10) | ◇◇◇ | 0.15 | 0.14 |
| Phosphorus as P, Total (mg/L) | 12 | 12 | 193 | 172 | 0.11 | 0.10 | 0.17 (0.15, 0.19) | 0.15 (0.13, 0.17) | ◇◇◆ | 0.28 | 0.24 |
| Phosphorus, orthophosphate as P (mg/L) | 3 | 3 | 84 | 63 | 0.01 | 0.04 | 0.03 (0.02, 0.04) | 0.06 (0.04, 0.06) | ◆◆◆ | 0.06 | 0.08 |
| Total suspended solids (mg/L) | 12 | 12 | 199 | 178 | 13.0 | 8.0 | 22.0 (18.0, 24.0) | 17.0 (13.0, 19.0) | ◇◆◆ | 98.4 | 40.5 |

| | BMPs[7] | | EMCs[8] | | 25th | | Median Concentration[9] | | | 75th[10] | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | In | Out | In | Out | In | Out | In | Out | Difference | In | Out |
| Cadmium, Total (µg/L) | 6 | 6 | 63 | 49 | 0.08 | 0.09 | 0.50 (0.11, 0.50) | 0.20 (0.12, 0.50) | ◇◇◇ | 0.50 | 0.50 |
| Chromium, Total (µg/L) | 3 | 3 | 70 | 55 | 1.00 | 0.50 | 1.67 (1.20, 2.19) | 1.30 (0.59, 1.93) | ◇◇◆ | 3.23 | 4.00 |
| Copper, Total (µg/L) | 6 | 6 | 97 | 80 | 3.40 | 3.55 | 7.00 (4.50, 10.00) | 6.18 (4.42, 8.10) | ◇◇◆ | 13.16 | 10.03 |
| Lead, Total (µg/L) | 9 | 9 | 119 | 105 | 1.50 | 1.10 | 8.30 (3.01, 10.90) | 3.00 (1.67, 4.00) | ◇◆◆ | 20.24 | 7.55 |
| Nickel, Total (µg/L) | 3 | 3 | 68 | 53 | 2.00 | 2.00 | 2.91 (2.13, 3.00) | 2.20 (2.00, 2.45) | ◇◇◇ | 3.73 | 3.00 |
| Zinc, Dissolved (µg/L) | 3 | 3 | 64 | 56 | 4.61 | 3.04 | 10.09 (6.04, 16.90) | 10.00 (3.04, 10.00) | ◇◇◇ | 20.00 | 20.00 |
| Zinc, Total (µg/L) | 8 | 8 | 135 | 113 | 14.70 | 10.00 | 30.00 (24.00, 40.00) | 20.00 (16.00, 30.00) | ◇◆◆ | 80.73 | 40.00 |

Prepared for City and County of Denver and Urban Drainage and Flood Control District, February 2017. Prepared by Wright Water Engineers and Geosyntec Consultants. (Wright Water Engineers and Geosyntec (Consultants 2016))

## Certifications[11]

## Component Specific Considerations

- Drainage area: Relatively large drainage areas (e.g., 25 acres or more) are recommended to maintain a permanent pool in the wetland.
- Space restrictions: Two to 4 percent of contributing drainage area is required.
- Aviation concerns: Depending on proximity to airports, vegetation must not be allowed to develop at the BMP that attracts wildlife, which can pose a hazard to aviation.
    - If the stormwater BMP is close to an airport operations area, standing water should drain within 48 hours.
- Soil type: Low infiltration rate soil or lined with low permeability material is required.
- Vegetation: Wetland plants.
- Topography: Slopes adjacent to wetlands should promote flow toward the wetland.
- Temperature issues: Temperature increases overall heat inputs compared to untreated surface runoff, but reduces peak heat loading rates.
- Pollutant concentration concerns: Limited removal of dissolved pollutants may export dissolved pollutants if not properly maintained.
- Construction costs: Low.
- Maintenance costs: Low.
- Groundwater: Maintain separation from groundwater used for drinking supply in accordance with local requirements.
- Constructed wetlands are preferred over constructed ponds in karst areas.

## Design Criteria Considerations

Design criteria vary widely depending on site conditions, geographic locations and local or state requirements. When designing constructed wetlands, ensure the design is consistent with local or state requirements. Below are general design considerations.

- Ensure underlying soils are adequate and the constructed wetland is properly sized to maintain a permanent pool. If underlying soils have high infiltration rates, a liner may be required. A liner is required if the underlying aquifer is sensitive to contamination.

## Preconstruction Meeting

- Include local aviation authorities if the stormwater BMP is situated within 10,000 feet of an airport operations area.
- If constructed wetlands discharge to cold water fisheries, consider suitable vegetation canopy to create shading or consider another BMP.
- The drainage area contributing to a constructed wetland should be sufficient to maintain a permanent pool in the wetland.
- Pretreatment, typically with forebays, is recommended to reduce sediment loads to the constructed wetland. Ensure forebays are properly located and sized.
- Constructed wetlands must have proper grading and site layout, considering factors such as permanent pool slopes, variable pool depths, size and shape of wetland benches, and shape and length of flow paths.
- Ensure adequate maintenance access and incorporate safety features into design.
- Develop a landscaping plan for establishment of vegetation.
- Establish a buffer around the wetland and vegetate with water-tolerant plants and trees.
- Ensure inflow points, outflow points, conveyance system and associated structures are properly located, stabilized and protected, and have appropriate slopes.
- Establish appropriate or required setbacks (e.g., from buildings, utilities, property lines).

## Links to design information, representing different regions in the U.S. are included below.

- California Stormwater Quality Association: New Development and Redevelopment BMP Handbook, Section 4. TC-21 Constructed Wetland
- Georgia Stormwater Management Manual – Volume 2: Technical Handbook (Section 3.2.2)
- Minnesota Stormwater Manual – Design Criteria for Stormwater Wetlands
- North Carolina Department of Environmental Quality Stormwater Design Manual: C-3. Wet Pond
- Pennsylvania Stormwater Best Management Practices Manual, BMP 6.6.1: Constructed Wetland
- Virginia Stormwater Design Specification No. 13, Constructed Wetlands, Version 2.0
- (Ecology 2019 (draft)) Stormwater Management Manual for Western Washington, BMP T10.30 Stormwater Treatment Wetlands

## Construction Information

### *Sequence*

- Verify that all pre-construction documents agree, which may include design plans, site survey, specifications, etc.
- Stake out footprint of constructed wetland area.
- Clear and grub vegetation within the project area.
- Excavate wetland area. Dewatering may be necessary if water is encountered.
- Compact and grade bottom surface of BMP. Verify slope is within acceptable tolerances dependent on the wetland size. Flow into wetland should distribute evenly. Avoid ruts and low areas.
- Place influent and effluent pipes and structures during construction. Placement of some structures may occur after lining installation.
- Place manufactured lining and/or constructed clay lining. Verify lining is watertight to facilitate a permanent pool.
- Place bed materials (i.e., sand, gravel, concrete aggregate, crushed stone).
- Plant vegetation. Spacing should be between 1-3 feet on center.
- Flood the wetland to determine proper flow and function. Address any areas that may have eroded during the flood.

### *Component Specific Considerations*

- Construction location should be in an upland area.

- Construction location should not impede natural wetland systems, habitats, or other water bodies.
- A porous soil underneath the wetland is not conducive to maintaining a permanent pool. A manufactured lining, constructed clay lining or a combination of these methods may be necessary.
- Vegetation may take some time to become fully established. Allow at least two seasons for growth, expansion of plant species before changing.

## Operation and Maintenance Considerations

**Monitoring**

- Inspect pretreatment practices to ensure they are functioning properly.
- Inspect maintenance access to ensure it is free of woody vegetation and check to see whether valves, manholes and locks can be opened or operated.
- Inspect water levels to ensure a permanent pool of water is maintained.
- Check the permanent pool or dry wetland area for floating debris or undesirable vegetation.
- Inspect the condition of stormwater inlets, flow orifices and other pipes for clogging, material damage, erosion or undercutting.
- Inspect the condition of the principal emergency spillways and riser for evidence of spalling, joint failure, leakage, corrosion, clogging, erosion, undercutting, rip-rap displacement, woody growth, etc.
- Inspect the condition of all trash racks, reverse-sloped pipes, and flashboard risers for evidence of clogging, leakage, debris accumulation, etc.
- Inspect upstream and downstream banks for evidence the integrity of the embankment has been compromised.
- Inspect side slopes and embankments for evidence of sloughing, animal burrows, boggy areas, woody growth, gully erosion, sparse vegetative cover, erosion, or slumping, and make needed repairs immediately.
- Inspect weirs and high-flow bypasses to ensure they are not damaged and are free from blockage.
- Look for broken signs, locks and other dangerous items.
- Inspect during winter freeze periods to look for signs of improper operation.
- In areas where road sand is used, schedule an inspection of the forebay and stormwater wetland after the spring melt to determine if clean out is necessary.
- Monitor sediment accumulation levels in channels, forebays, micro-pools and main pools.
- Monitor the growth and survival of vegetation. Record the species and approximate coverage. Look for signs of disease, pest infection and stunted growth. Determine if vegetation needs maintenance (e.g., mowing, weeding).
- Monitor for invasive weed species.
- Determine if there is evidence of illicit discharges to the wetland (e.g., presence of a surface sheen (oil or gasoline), murky color (suspended sediment), green color (algae or other biological activity), odors (gasoline or oil), or flows into the wetland during dry weather conditions.

## Maintenance

**First or second year activities**

- Initial fertilization of vegetation may be needed. Do not fertilize after the initial fertilization. Note that local regulations may affect fertilization practices, including prohibiting fertilization in some situations.
- Water plants as needed. In general, consider watering every three days for first month, and then weekly during the first growing season, depending on rainfall. Note that local regulations may affect the amount and timing of watering.
- Replant wetland vegetation if needed.
- Immediately stabilize bare or eroding areas in the contributing drainage area or around the wetland buffer.

**Monthly to quarterly, after major storms, or as needed**

- Remove sediment and oil/grease from pretreatment devices, as well as from overflow structures.
- Remove trash, leaves, brush, sediment and other debris from inlets and outlets.
- Repair undercut, eroded and bare soil areas.
- Mowing done per operations, monitoring and maintenance (OM&M) plan and remove clippings.

**Semi-annually to annually, or as needed**

- Ensure there are no obstacles preventing maintenance personnel and/or equipment access to the constructed wetland.
- Repair eroded or failing embankment.
- Remove burrowing animals if present.
- Remove invasive plants, weeds, and flowering plants before they can set seed and dispose vegetative matter at a waste disposal facility. WARNING: Do not use herbicide unless they are registered for use near waterways.
- Prune according to best professional practices.
- Harvest wetland plants for nutrient control (if applicable).
- Replant wetland vegetation as needed using the original planting schedules for the site to guide species selection and planting densities.
- Repair broken mechanical components when necessary.

## Non-routine maintenance

- Remove sediment in the forebay every 2 to 7 years or after 50 percent of total forebay capacity has been lost.
- Remove sediment in the primary pool approximately every 25 years or after 50 to 75 percent of the pool capacity has been reached. Sediments excavated from stormwater wetlands that do not receive runoff from designated hotspots are not considered toxic or hazardous material and can be safely disposed by either land application or land filling. Sediment testing may be required prior to sediment disposal when a hotspot land use is present. Sediment removed from constructed wetlands should be disposed of according to an approved erosion and sediment control plan.
- BMP components should be replaced if showing signs of wear, which typically occurs at times ranging from 5 to 25 years.
- Repair of structural components (pipe and riser) is required immediately if they impair the functionality of the wetland.
- Thinning or harvesting excess forest growth may be periodically needed to guide the forested wetland into a more mature state. Vegetation may need to be harvested periodically if the constructed wetland becomes overgrown. Thinning or harvesting operations should be scheduled to occur approximately 5 and 10 years after the initial wetland construction.
- Consult a professional if algal growth becomes problematic.

**Example inspection checklists**

- Chagrin River Watershed Partners – Constructed Wetland Inspection and Maintenance Checklist
- Minnesota Pollution Control Agency – Stormwater pond/wetland – operation and maintenance checklist
- Virginia DEQ Operations and Maintenance Constructed Wetlands Checklist
- Oregon State University Extension – Pond/Wetland Maintenance Inspection Form
- Metropolitan Nashville – Davidson County, Stormwater Management Manual, Volume 1, Stormwater Structural BMP Inspection Checklist Templates
- The Ohio State University – Stormwater Management Program Post-Construction BMP Operations and Maintenance Guidance Manual, Appendix B-3 and B-4
- San Francisco Water Power Sewer – Wet Pond & Constructed Wetland Annual Self-Certification Checklist
- University of Minnesota – Stormwater Treatment: Assessment and Maintenance Visual Inspection Checklist

## References and links


- Virginia Stormwater Design Specification Version 2, No. 13 – Constructed Wetlands
- North Carolina DEQ Stormwater BMP Manual
- Minnesota Stormwater Manual
- Pennsylvania Stormwater Best Management Practices Constructed Wetland
- Stormwater Management Manual for Western Washington, BMP T10.30 Stormwater Treatment Wetlands
- Constructed Wetlands Design Manual, Melbourne Water
- EPA Constructed Wetlands Treatment of Municipal Wastewaters Manual
- California Stormwater Quality Association Stormwater Best Management Practice Handbook: New Development and Redevelopment
- A Handbook of Constructed Wetlands

- Consultants, Wright Water Engineers and Geosyntec. 2016. “International Stormwater BMP Database 2016 Summary Statistics Table.”

# F.4 Disinfection Systems

**December 2018**

## Description

Disinfection systems are used to destroy or inactivate pathogens. The primary types of disinfection devices for managing pathogens in stormwater use chlorination, ozone, ultraviolet (UV) light, or antimicrobial filter media.

### Pollutants of Concern Treated by Disinfection Systems

### Data Available in International Stormwater BMP Database: ☒ Yes ☐ No

| Disinfection Systems | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Solids** | **Solid Metals** | **Dissolved Metals** | **Hydrocarbons** | **Nutrients** | **Ammonia** | **pH** | **Bacteria Pathogens** | **Organics** | **Trash** | **Pesticides Herbicides** |
| | | | | | | | X | | | X |

## Certifications[12]

## Design Criteria Considerations

- Ensure availability of electrical utility service with appropriate service type.
- Size unit to provide adequate dose and contact time to ensure disinfection occurs.
- Analyze stormwater to identify contaminants that may impede disinfection. For example, turbidity/suspended solids as well as other chemical constituents adversely affect UV disinfection.
- For ozone disinfection systems, ensure material compatibility to prevent degradation of system components (plastics, seals, etc.).
- Consider protection from vandalism, particularly if used in remote locations.
- Consider additional chemicals in water, incompatibles and potential degradation products. For example, chlorination is not compatible with ammonia contaminated waters.
- Consider organics or oil content in water as it may limit performance and contact holding times with material.

## Construction Information

**Construction Submittals**

- For ozone disinfection systems, verify ozone generator style.
- For UV disinfection systems, verify type and intensity of lamps.
- For chlorination disinfection systems, verify water constituents are compatible with chlorine.
- Verify materials’ compatibility with ozone/UV radiation, as appropriate.
- Antimicrobial filter media should comply with local pesticide regulations.

**Timeframe**

- Generally installed as a pre-manufactured system within a short timeframe.
- Installation time may be lengthened if electrical service must be installed at the site.
- Generally antimicrobial filter media is installed as a post-construction device.

**Protection**

- Divert stormwater away from BMP during construction.
- Protect delicate treatment systems from heavy equipment during construction.
- Antimicrobial filter media and UV may benefit from pre-treatment to remove coagulants or oil residues to prevent clogging.

**Inspection Checklist**

- Are all components of the treatment system functioning properly (e.g., switches, lamps/ozone generators, pumps, etc.)?
- Are there any leaks?
- Is the discharge meeting performance criteria (e.g., flow rate, efficacy)?
- Does the site continue to meet expected environmental impact criteria?

## Operation and Maintenance Considerations

**Monitoring**

**For Chlorination**

- Ensure equipment that is housed in shelter or shed is secure.
- Post signage to identify chlorination materials and health and environmental hazards using Global Harmonization Standards.
- Ensure Material Safety Data Sheets are updated and accessible on site.
- Ensure storage room is well ventilated prior to entry.
- Perform periodic disassembly and cleaning of components (e.g., hoses, meters, floats, booster pumps).
- Remove sludge or debris from tanks and scrapers.
- Ensure calibration and monitoring equipment is tested in accordance with the manufacturer’s recommendations.
- Check with permitting agency or local regulator for specific requirements and demonstrations of the effectiveness of the BMP.
- Inspect chlorine containers for bulging, cracks and leaks. Ensure containers are located on secondary containment pallets. Ensure any gas cylinders are securely fastened to the wall.
- Routine monitoring may also include periodic chemical and biological sampling to ensure that operating parameters are being met. Follow permits or guidance from local regulatory agencies.

**For Ozone**

- Ensure equipment housed in shelter or shed is secure.
- Ensure calibration of monitoring equipment is tested in accordance with the manufacturer’s recommendations.
- Inspect system for degraded components, cracks or leaks.
- Ensure air quality is within applicable U.S Environmental Protection Agency (USEPA), state and municipal parameters for ozone.
- Inspect ozone distribution system, air supply and dielectric assemblies for cracks, rust, sludge or biofilm.
- Routine monitoring may also include periodic chemical and biological sampling to ensure that operating parameters follow permits or guidance from local regulatory agencies.

**Ultra Violet (UV)**

- Ensure equipment housed in shelter or shed is secure.
- Check for the buildup of biofilm on surfaces and for any issues with the automated cleaning system.
- Regularly clean UV lamps and channels in accordance with manufacturer’s instructions and with approved cleaning agents (such as hypochlorite or paracetic acid).
- Check with permitting agency or local regulator for specific requirements and demonstrations of the effectiveness of the BMP.
- Routine monitoring may also include periodic chemical and biological sampling to ensure that operating parameters follow permits or guidance from local regulatory agencies.

**Antimicrobial Filter Media**

- Periodic performance sampling and monitoring downstream for flow rate monitoring.
- Periodic visual inspection.
- Planned periodic filter replacement (e.g., annually).

## Maintenance

**Example inspection checklists**

- Are all components of the treatment system functioning properly (e.g., switches, lamps/ozone generators, pumps, etc.)?
- Are there any leaks?

### References and Links

- Minnesota Pollution Control Agency, Disinfection System – Review Checklist
- (WERF 2005) Chapter 5.5.4.5 page 5-72
- S. EPA, What are Antimicrobial Pesticides?

## F.5 Hydrodynamic Separators

**December 2018**

### Description

Hydrodynamic Separator (HDS) systems use the physics of flowing water to remove a variety of pollutants. The internal structure of the device either creates a swirling vortex or plunges the water into the main sump. Along with supplemental features to reduce velocity, the design of an HDS system separates floatables (e.g., trash, debris and oil) and settleable particles, like sediment, from stormwater. HDS systems are not effective for the removal of very fine solids or dissolved pollutants. The systems are also subject to scour and sediment washout during large storm events.

#### Pollutants of Concern Treated by Hydrodynamic Separators

| Hydrodynamic Devices | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Solids | Solid Metals | Dissolved Metals | Hydrocarbons | Nutrients | Ammonia | pH | Bacteria Pathogens | Organics | Trash | Pesticides Herbicides |
| TSS | | | O/G | | | | | | X | |
| SSC | | | TPH | | | | | | | |

#### Data Available in International Stormwater Database ☒ Yes ☐ No

- Manufactured Devices Performance Summary – July 2012

### Certifications[13], [14]

#### Washington State Technology Assessment Protocol – Ecology

| | Pre-treatment | TSS | Enhanced (Dissolved Metals) | Total Phosphorus | Oil/Grease |
|---|---|---|---|---|---|
| **General Use Level Designation** | | | | | |
| AquaShield, Aqua-Swirl AquaShield™, Inc's Aqua-Swirl™ Concentrator | ☒ | ☐ | ☐ | ☐ | ☐ |
| CONTECH Engineered Solutions Inc. CDS System | ☒ | ☐ | ☐ | ☐ | ☐ |
| http://www.ecy.wa.gov/programs/wq/stormwater/newtech/use_designations/VORTECHScontechGULD.pdfCONTECH Engineered Solutions Inc. Vortechs System | ☒ | ☐ | ☐ | ☐ | ☐ |
| hydro International's Downstream Defender® | ☒ | ☐ | ☐ | ☐ | ☐ |
| Imbrium Systems Corporatioin Stormceptor System | ☒ | ☐ | ☐ | ☐ | ☐ |
| Royal Environmental Systems, Inc. ecoStorm/ecoStorm Plus Treatment Train | ☐ | ☒ | ☐ | ☐ | ☐ |
| **Conditional Use Level Designation** | | | | | |
| BaySaver Technologies™ Bay Separator | ☒ | ☐ | ☐ | ☐ | ☐ |
| CONTECH Engineered Solutions CDS® System | ☐ | ☐ | ☐ | ☐ | ☒ |
| Suntree Technkologies, Inc's nutrient Separating Baffle Box | ☒ | ☐ | ☐ | ☐ | ☐ |

| | Pre-treatment | TSS | Enhanced (Dissolved Metals) | Total Phosphorus | Oil/Grease |
|---|---|---|---|---|---|
| **Pilot Use Level Designation** | | | | | |
| StormPro® Environment 21, LLC | ☒ | ☒ | ☐ | ☐ | ☐ |

### New Jersey Cat/DEP Verification and Certification:

| | NJCAT Lab Verified | NJCAT Field Verified | NJDEP Certified |
|---|---|---|---|
| AquaShield, Aqua-Swirl Stormwater Treatment System | ☒ | ☒ | ☒ |
| BaySaver Technologies, BaySeparator | ☒ | ☐ | ☐ |
| Contech, CDS System | ☒ | ☒ | ☒ |
| Contech, StormVault | ☐ | ☒ | ☐ |
| Contech, Vortechs | ☐ | ☒ | ☐ |
| Contech, VortSentry | ☒ | ☐ | ☐ |
| Environment 21, StormPro | ☒ | ☐ | ☒ |
| Environment 21, V2B1 | ☒ | ☐ | ☐ |
| Fresh Creek, SiteSaver | ☒ | ☐ | ☒ |
| Hydro International First Defense HC | ☒ | ☐ | ☒ |
| Hydro International Downstream Defender | ☒ | ☐ | ☒ |
| Hydroworks, Hydroguard | ☒ | ☐ | ☐ |
| Imbrium Systems, Stormceptor | ☒ | ☐ | ☐ |
| Kristar Enterprises, FloGard Dual-Vortex | ☒ | ☐ | ☐ |
| Oldcastle, Dual Vortex Separator | ☒ | ☐ | ☒ |
| Suntree Technologies, Nutrient Separating Baffle Box | ☒ | ☐ | ☒ |
| Terre Hill, Terre Kleen Hydrodynamic Separator | ☒ | ☐ | ☒ |

**<u>Other</u>**

- Maine Department of Environmental Protection, Maine Stormwater BMP Manual, Appendix B: Proprietary Systems
- Minnesota Stormwater Manual – Flow-Through Structures for Pre-treatment

## Component Specific Considerations

- Space restrictions are limited because BMPs are typically located in underground vaults.
- High and low temperatures have minimal impact on operation.
- Can operate successfully under long dry or wet periods.
- Maintenance costs are similar to cleaning catch basins.
- Limited removal of dissolved pollutants.
- Increases removal capabilities and longevity of filter media when installed upstream of the filters.

## Design Criteria Considerations

- Each manufactured device has its own generic design flow rate (e.g., gpm/ft$^2$).
- Develop design storm flow rate at the location of the device and select device that can treat that flow. However, it should also provide for overflow so as to not create upstream flooding issues when the design flow is exceeded.

Devices typically have maximum flow rate to mitigate against resuspension of previously settled particles. Selection should also include an evaluation of the maximum anticipated flow. It might be necessary to oversize the device to eliminate the potential for resuspension, or designers could use a flow splitter to limit flow rate into the hydrodynamic separator.

### Construction Information

- This is a Manufactured Treatment Device with specific construction requirements provided by the manufacturer.
- Device is subject to potential resuspension of previously settled solids. Use of a bypass vault upstream of the separator may be appropriate when the technology does not include an internal bypass for peak flows.

### Operation and Maintenance Considerations

- This is a Manufactured Treatment Device with specific Operation and Maintenance requirements provided by the manufacturer.
- Inspect inflow and outflow points, including any diversion structure, to make sure nothing is clogging or otherwise impacting the intended hydraulic performance.
- Need to remove sediment, trash and debris, and oil and grease using a vactor truck on a regular basis to avoid resuspension of sediments.
- Dispose of vactored water and solids in accordance with state or appropriate regulatory requirements.
- Test material for toxins prior to disposal.

## F.6 Infiltration Devices

**December 2018**

### Description

Infiltration devices capture and direct runoff into the ground to reduce water volume and pollutant load from surface waters. Examples include: Drywells, infiltration basins, infiltration trenches, leaching catch basins and subsurface structures.

### Pollutants of Concern Treated by Infiltration Devices

Infiltration devices obtain pollutant removal through a decrease in water volume from surface discharge. Treatment of infiltrating water likely occurs through filtration as water moves through the soil layer along with sedimentation in the basins/structures.

**Data Available in International Stormwater BMP Database: ☒ Yes ☐ No**

### Certifications: None Available[15]

### Component Specific Considerations

- Include local aviation authorities if the stormwater BMP is situated within 10,000 feet of an airport operations area.

### Design Criteria Considerations

- Aviation concerns*:* Depending on proximity to airports, vegetation must not be allowed to develop at the BMP that attracts wildlife, which can pose a hazard to aviation.
- If the stormwater BMP is close to an airport operations area, standing water should drain within 48 hours.
- Infiltration practices should not be used in areas with shallow bedrock, high-water tables, soils with low infiltration rates (D soils), contaminated soils or groundwater beneath the device, or other constraints.
- Maintain appropriate separation distances from wells, basements, septic drainfields, steep slopes that contribute runoff to the practice, or other features.
- Underlying soils should readily allow infiltration of water captured by the device (typically A, B, or C soils).
- Ensure that runoff, in excess of the water quality volume, bypasses the device unless the device is sized to accommodate larger volumes.
- Perforated, raised underdrains may be utilized for situations where the infiltration device loses functionality.
- Pretreatment is recommended to reduce sediment loads to the device.
- Infiltration devices should be designed to draw down captured water within a specified period of time (e.g., 48

hours). Water in excess of this volume (bounce) should be drained from the device through an overflow pipe.
- Bottoms of infiltration devices should be flat to ensure even distribution of infiltration water.
- Consider landscaping in the design to improve aesthetics and provide multi-functionality of the practice.
- Determine if the device will be used for snow storage.

## Construction Information

### Construction Submittals

- Solid pipes: Pipes sizes, diameter and materials are important to the functionality of a properly functioning drainage system. Drainage volumes, velocities and flow-rates are dependent on these factors. It is important to reference the plans and specifications when determining the acceptability of each of these drainage components.
- Aggregate: Size and material is important when selecting this material. Void ratios, which affect the detention volume of the BMP, are specifically affected by these factors. It is also important to note that clean aggregate should always be used when installing these devices.
- Landscape fabrics: Landscape fabrics and watertight mats are used in BMP design. It is important to understand if the project is designed to infiltrate. The materials used on and around the landscape fabrics are also important when determining the type and thickness of the material.
- Drainage structures (inlets, cleanouts and manholes): Size is an important component of these features. Sizes have been determined based off of pipe sizes and what the structures will be housing. If they are used as a junction, then they could be sized differently than if they are housing multiple filters. Some structures are precast; others are completely cast in place, while others use a combination of both.

### Timeframe

- The area to be used for the infiltration facility should be staked during utility installation (specifically storm drain), and excavation to ensure minimal compaction, verify soil conditions and ensure proper erosion control and sediment control practices are in place around the facility locations.
- Piping to and from these features, in addition to the drainage and overflow structures, are usually installed prior to the subgrade compaction phase. It is recommended that the structures of these features be protected from erosion, sediment and debris as installation of each feature is completed.
- These systems, such as underground infiltration devices, are installed in the utilities phase of construction and prior to subgrade compaction. Once the infiltration device has been installed, it is recommended that it be protected throughout construction until final site stabilization.
- If the infiltration system is being installed, as a during construction sediment basin, all sediment should be removed during the final site stabilization phase and again prior to the contractor’s “move out” to ensure all construction sedimentation deposits have been removed.

### Protection

- Piping to and from these features, in addition to the drainage and overflow structures, is usually installed prior to the subgrade compaction phase. It is recommended that the structures of these features be protected from erosion, sediment and debris as installation of each feature is completed.
- Use erosion control blankets and fiber rolls to protect graded slopes and prevent excessive soil loss.
- Use inlet sediment bags on installed inlets.
- Add gravel bags on check dams in drainage ditches and in gutters.
- Apply silt fences and fiber rolls along the perimeter of devices.

### Inspection Checklist

- Inspect all pipes and structures up and downstream of the device, as installation occurs, to ensure they are clear of dirt and debris.
- Upon completion of excavation and, if appropriate, before covering the facility (if required), inspect and verify size, locations and depth of facilities.
- During construction, all storm drainage features and installed BMPs should be inspected on a regular basis and cleaned of any sediment and debris. During construction and prior to any storm events, these features should also be inspected and cleaned to insure that the systems do not carry, or become clogged, with sediment.
- All temporary BMP protection should be inspected and cleaned to insure proper erosion prevention and

permanent BMP protection (e.g., inlet bags, fiber rolls and check dams) before and after storm events. These construction inspections should be documented, recorded and saved on site.
- Upon completion of each facility, perform a final inspection to verify the correct size and materials have been used per the construction specifications. Also verify the facility is working properly.

## Operation and Maintenance Considerations

**Monitoring**

Note that monitoring practices vary with the BMP design. For example, some infiltration practices are vegetated while others are not; some practices are aboveground and others are belowground. For information on bioinfiltration and permeable pavement practices designed for infiltration, see those BMPs. Inspection frequency should be greater in the first year of operation.

- Generally inspect the upland contributing drainage area for any controllable sources of sediment or erosion.
- Inspect maintenance access to ensure it is free of woody vegetation, and check to see whether valves, manholes and/or locks can be opened and operated.
- Measure the drawdown rate at the observation well following rainfall events of a specific size (e.g., ½ inch). Typical observation times are 48 to 72 hours. Clogging is evident if standing water is still observed in the well after this period of time.
- Inspect the condition of the observation well and make sure it is capped.
- Inspect all structural components, including inlets, outlets, pretreatment cells/devices, and flow diversion structures, at least once annually, for cracking, subsidence, spalling, erosion, and sediment or trash buildup. Note if any sediment needs to be removed.
- Determine if erosion or other signs of damage have occurred in the swale (if applicable).
- Inspect internal and external infiltration side slopes and buffers for evidence of sparse vegetative cover, poor quality of vegetative cover, erosion or slumping.
- Check that no vegetation forms an overhead canopy that may drop leaf litter, fruits and other vegetative materials that could clog the infiltration device.
- Look for weedy growth on the stone surface that might indicate sediment deposition or clogging.
- Inspect for grass or other plants growing on the surface of the practice.
- Inspect for compaction caused by vehicular traffic.
- Inspect to ensure the BMP is not used for stockpiling of plowed snow and ice, compost, or any other material.
- Inspect for evidence of water contamination or spills.
- Inspect practices with filter fabric for sediment deposits by removing a small section of the top layer.
- In cold climates, inspect inflow points and infiltration surface for buildup of road sand associated with the spring melt period.

## Maintenance

Note that maintenance practices vary with the BMP design. For example, some infiltration practices are vegetated while others are not. For information on biofiltration and permeable pavement practices designed for infiltration, see those BMPs.

**First or second year activities**

- Water vegetation as needed until plants mature.
- Initial fertilization of vegetation may be needed. Do not fertilize after the initial fertilization.

**Monthly to quarterly, after major storms, or as needed**

- Ensure that the contributing drainage area is stabilized.
- Remove sediment and oil/grease from pretreatment devices, as well as from overflow structures.
- Replace pea gravel/topsoil and top surface filter fabric (when clogged).
- Ensure that the contributing drainage area, inlets and facility surface are clear of debris.
- Repair and correct undercut and eroded areas at inflow and outflow structures.
- Remove trash, debris, grass clippings, trees and other large vegetation and dispose of properly.
- Stabilize or replace mulch when erosion or decomposition is evident.
- Prune and weed as needed and maintain vegetation in and around the practice at desired height (e.g., six inches).

- Mow vegetated filter strips as necessary and remove the clippings.
- Replace vegetation whenever percent cover falls below acceptable levels (e.g., 90 percent) or project specific performance requirements are not met.

**Semi-annually to annually, or as needed**

- Remove any sediment and debris buildup in pretreatment areas.
- Clean out sediment traps, forebays, inlet/outlet structures, overflow spillway, and basin/trench if necessary. Sediment removal should take place when all runoff has drained from the planting bed and the basin is dry.
- Sod the filter strip/grass channel as necessary.
- Replant areas impacted by sand/salt build up.
- Cut back and remove previous year's plant material and remove accumulated leaves if needed (or controlled burn where appropriate).
- Remove any dead or severely diseased vegetation.
- Remove trees that start to grow in the vicinity of the infiltration facility.
- Annual tilling of the sand layer, using lightweight equipment, may assist in maintaining the infiltration capacity of a surface type system by breaking up clogged surfaces.
- Disposal of debris, trash, sediment and other waste material must be done at suitable disposal/recycling sites and in compliance with all applicable local, state and federal waste regulations.

**Non-routine maintenance**

- Repair emergency overflow berm, pipes and other structural components as needed or replace if beyond repair.
- Take appropriate corrective action if the infiltration basin fails to drain the design storm within a specified time.
- If original infiltration rate is significantly decreased (e.g., by 50%), scrape bottom, remove sediment and restore original cross-section and infiltration rate.
- If needed:
    - seed or sod to restore ground cover, disc or otherwise aerate bottom and dethatch basin bottom

**Example inspection checklists**

- California Stormwater BMP Handbook
    - Infiltration trench
    - Infiltration basin
- Minnesota Stormwater Manual – Typical Maintenance Problems and Activities for Infiltration Practices
- Virginia Department of Transportation BMP Maintenance Manual, 2016
- Virginia DEQ Constructed Wetlands: O & M Checklist
- Oregon State University Extension – Operation, Maintenance & Management Checklist
- Metropolitan Nashville – Davidson County Stormwater Management Manual – Stormwater Structural BMP Inspection Checklist Templates
- Ohio State University Stormwater Management Program Post Construction BMP Operations and Maintenance Guidance Manual 12/1/09. App B-7 & B-8
- San Francisco Water Power Sewer – Annual Self-Certification Checklist
- University of Minnesota – Stormwater Treatment: Assessment and Maintenance
- North Carolina Stormwater BMP Manual, C-1 Infiltration Practices, 2017

## References and Links


- Virginia DCR Stormwater Design Specifications No 8 Infiltration Practices
- https://www.ncsu.edu/ehs/environ/DWQ_StormwaterBMPmanual_001%5b1%5d.pdf
- North Carolina Environmental Quality Stormwater Design Manual
- Minnesota Stormwater Manual – Operation and Maintenance of Stormwater Infiltration Practices
- Pennsylvania Stormwater Best Management Practices Manual
    - Infiltration basin section 6-2
    - Subsurface infiltration bed 6.3
- New Jersey Stormwater Best Management Practices Manual
- Maine Stormwater Best Management Practices Manual
- California Stormwater BMP Handbook

    - Infiltration Trench
    - Infiltration Basin
- Philadelphia Water Department – Stormwater Management Practice Guidance (see Chapter 4.4. Subsurface Infiltration)

## F.7 Initial Settling Basins

**December 2018**

### Description

An initial settling basin is used to remove settleable solids prior to treatment by other treatment BMPs. An example is a sediment forebay.

#### Pollutants of Concern Treated by Initial Settling Basins

| Initial Settling Basins | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Solids** | **Solid Metals** | **Dissolved Metals** | **Hydrocarbons** | **Nutrients** | **Ammonia** | **pH** | **Bacteria Pathogens** | **Organics** | **Trash** | **Pesticides Herbicides** |
| TSS | Cu | | O/G | | | | | | X | |
| SSC | Zn | | TPH | | | | | | | |
| Turbidity | Pb | | | | | | | | | |
| Total Solids | Cd | | | | | | | | | |
| | Cr | | | | | | | | | |
| | Ni | | | | | | | | | |
| | As | | | | | | | | | |

**Data Available in International Stormwater BMP Database:** ☒ **Yes** ☐ **No**

### Certifications[16]

### Component Specific Considerations

- Aviation concerns: Depending on proximity to airports, vegetation must not be allowed to develop at the BMP that attracts wildlife, which can pose a hazard to aviation.
- If the BMP is close to an airport operations area, standing water should drain within 48 hours to avoid creating a bird habitat.
- Soil type: Low infiltration rate or lined with low permeability material.
- Topography: Slopes adjacent to ponds should promote flow toward the initial settling basin.
- Temperature issues: Increase overall heat inputs compared to untreated surface runoff, but reduce peak heat loading rates.
- Long dry periods: Permanent pool must be maintained unless there are extended dry periods where BMP function is unnecessary.
- Construction costs: Low to moderate.
- Maintenance costs: Moderate.
- Mosquitoes: If water does not drain properly, infiltration basins can become mosquito breeding grounds.
- Groundwater: In accordance with local requirements, maintain separation from groundwater used for drinking supply.

### Design Criteria Considerations

Initial settling basins provide pretreatment for the purpose of preserving and lengthening the life of other treatment units which are next in line and receiving the discharge from the initial settling basin. Their purpose is to capture the heavier sediment, which normally settles out soon after an influent arrives into a treatment unit.

**Preconstruction meeting**

- Include local aviation authorities if the stormwater BMP is situated within 10,000 feet of an airport operations area.

**Features that should be designed into an initial settling basin:**

- Initial settling basins should be designed for equipment entering the basin to remove the settled sediment.
- Water flowing from the initial settling basin entering the BMP should be designed for non-erosive outlet conditions.
- Water volume in the initial settling basin should be 10% of the BMP’s treatment volume, 4 to 6 feet deep, and the volume of the initial settling basin counts towards the design of the BMP.
- The initial settling basin should be designed with a surface area equivalent to 10 percent of a permanent pool surface area or equivalent to 0.1 percent of the drainage area.
- A fixed vertical sediment depth marker should be installed in the initial settling basin to measure sediment deposition over time. The marker should be sturdy and placed deep enough into the bottom of the initial settling basin so that ice movement does not affect its position.
- The bottom of the initial settling basin should be hardened using concrete, asphalt or grouted riprap, to make sediment removal easier.

## Construction Information

**Sequence**

- Verify that all pre-construction documents agree, which may include: design plans, site survey, specifications, etc.
- Stake out footprint of initial settling basin.
- Clear and grub the area. Remove any excess material.
- Excavate the sediment basin area.
- Fill, grade and compact embankment and spillway areas.
- Install spillway/weir structure (if applicable).
- Install energy dissipater at the influent location.
- Establish mixed grass vegetation along embankment, basin and spillway area (if applicable).

**Considerations**

- Initial settling basins are typically constructed as a pre-treatment method before another BMP. Connection to, and construction of, a secondary treatment method should be kept in mind during construction of the settling basin.
- Larger debris can be prevented from entering the settling basin by installing rack and screen devices.

## Operation and Maintenance Considerations

- Following construction, quarterly inspection of the basin may be necessary to ensure that it is operating within design parameters. No water should overflow from the basin when in use. Most settling basins typically have a recommended 8- to 24-hour hydraulic retention time. Check with the permitting agency or local regulator for specific requirements and demonstrations of the effectiveness of the BMP.
- Inspect for damage to the structure, such as cracks or loss of material to structure, including inlets and berms.
- Inspect embankments for signs of erosion or damage to stabilizing cover or grass.
- Measure the sediment level in the basin and determine if removal is necessary. This will depend on the hydraulic retention volume of the initial settling basin.
- Routine monitoring may also include periodic turbidity sampling to ensure that operating parameters are met. Operators should follow permits or guidance from local regulatory agencies.
- Routine removal of sediment, algae and debris is required to ensure the initial settling basin is operating properly prior to start of wet season, which is typically spring.
- Dispose of sediment following permit or regulatory requirements. If there is a known or suspected constituent of potential concern, sample prior to removal and confirm an appropriate receiving landfill or location.
- Inspect initial settling basin following large storm events, fires or landslides for damage or removal of materials or objects.

- Check downstream outlets of the system for silt materials, which may indicate issues with the performance of the entire BMP.
- Land use may require maintenance of additional controls such as fencing, signage, mowing, weeding and mosquito/disease vector controls.

### References and Links

- Water Environment & Reuse Foundation Stormwater 2005. Critical Assessment of Stormwater Treatment and Control Selection Issues Section 5.5.4.2 Page 5-17 (Strecker 2005)
- Auburn University and USDA/Natural Resources Conservation Service and Alabama Aquaculture Best Management Practices Practice (BMP) – Settling Basins and Wetlands BMP No. 6
- Brisbane City Draft Water Sensitive Urban Design Engineering Guidelines – Sedimentation Basin Construction Inspection Checklist
- Structural BMP Specifications for the Massachusetts Stormwater Handbook
- Florida Stormwater Erosion and Sedimentation Control Inspector's Manual
- Stormwater Best Management Practice (BMP) Selection and Implementation

## F.8 Media Filter

**December 2018**

### Description

Media filters encompass a variety of both proprietary and non-proprietary filtration systems that deploy a variety of naturally occurring media such as sand, as well as innovative/proprietary filtration media, to remove pollutants from urban runoff. Their effectiveness will be largely governed by the type and gradation of media deployed and their hydraulic loading rate. Most media filters are highly effective for removing particulate. Media filters with reactive media components are also able to target dissolved pollutants such as nutrients and metals.

#### Pollutants of Concern Treated by Media Filters

| Media Filters | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Solids** | **Solid Metals** | **Dissolved Metals** | **Hydrocarbons** | **Nutrients** | **Ammonia** | **pH** | **Bacteria Pathogens** | **Organics** | **Trash** | **Pesticides Herbicides** |
| TSS | Cu | Cu | O/G | Phosphorus | | | X | PCB | X | |
| SSC | Zn | Zn | TPH | Kjeldahl Nitrogen | | | | PAH | | |
| Turbidity | Pb | Pb | | | | | | | | |
| Total Solids | Cd | Cd | | | | | | | | |
| | Cr | Cr | | | | | | | | |
| | Ni | Ni | | | | | | | | |
| | As | As | | | | | | | | |

#### International Stormwater BMP Database Performance Summary, 2016 – Media Filters

Prepared for City and County of Denver and Urban Drainage and Flood Control District, February 2017. Prepared by Wright Water Engineers and Geosyntec Consultants. (Wright Water Engineers and Geosyntec (Consultants 2016))

| | BMPs[17] | | EMCs[18] | | 25th | | Median Concentration[19] | | | 75th | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | In | Out | In | Out | In | Out | In | Out | Difference[20] | In | Out |

| | BMPs[17] | | EMCs[18] | | 25th | | Median Concentration[19] | | | 75th | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | In | Out | In | Out | In | Out | In | Out | Difference[20] | In | Out |
| Fecal Coliform (MPN/100 mL) | 15 | 15 | 184 | 169 | 120 | 33 | 900 (400, 1,500) | 400 (200, 800) | ◇◆◆ | 10,000 | 5,600 |
| Kjeldahl nitrogen (TKN) (mg/L) | 21 | 20 | 323 | 312 | 0.56 | 0.29 | 0.94 (0.83, 1.02) | 0.50 (0.43, 0.55) | ◆◆◆ | 1.78 | 1.00 |
| Nitrogen, $NO_x$ as N (mg/L) | 22 | 21 | 346 | 328 | 0.21 | 0.34 | 0.34 (0.31, 0.37) | 0.57 (0.49, 0.63) | ◆◆◆ | 0.58 | 0.94 |
| Nitrogen, Nitrate ($NO_3$) as N (mg/L) | 12 | 12 | 178 | 174 | 0.20 | 0.30 | 0.32 (0.28, 0.35) | 0.56 (0.46, 0.63) | ◆◆◆ | 0.59 | 0.94 |
| Nitrogen, Nitrite ($NO_2$) + Nitrate ($NO_3$) as N (mg/L) | 10 | 9 | 168 | 154 | 0.24 | 0.38 | 0.35 (0.31, 0.40) | 0.57 (0.48, 0.68) | ◆◆◆ | 0.58 | 0.94 |
| Nitrogen, Total (mg/L) | 10 | 9 | 160 | 151 | 0.79 | 0.73 | 1.22 (1.03, 1.33) | 1.05 (0.90, 1.16) | ◇◇◆ | 2.10 | 1.72 |
| Phosphorus as P, Dissolved (mg/L) | 11 | 10 | 118 | 100 | 0.01 | 0.02 | 0.05 (0.03, 0.06) | 0.04 (0.03, 0.06) | ◇◇◆ | 0.09 | 0.10 |
| Phosphorus as P, Total (mg/L) | 23 | 22 | 372 | 349 | 0.07 | 0.04 | 0.15 (0.13, 0.15) | 0.09 (0.07, 0.10) | ◆◆◆ | 0.28 | 0.16 |
| Phosphorus, orthophosphate as P (mg/L) | 7 | 7 | 116 | 115 | 0.02 | 0.02 | 0.04 (0.03, 0.05) | 0.03 (0.02, 0.04) | ◇◇◆ | 0.09 | 0.07 |
| Total suspended solids (mg/L) | 25 | 25 | 400 | 377 | 22.0 | 3.9 | 56.4 (46.0, 61.9) | 9.0 (6.4, 10.0) | ◆◆◆ | 120.0 | 22.8 |
| Arsenic, Dissolved (µg/L) | 9 | 9 | 104 | 100 | 0.26 | 0.33 | 0.50 (0.48, 0.56) | 0.60 (0.50, 0.66) | ◇◇◆ | 1.13 | 1.00 |
| Arsenic, Total (µg/L) | 9 | 9 | 104 | 100 | 0.50 | 0.48 | 0.91 (0.69, 1.20) | 0.74 (0.58, 0.98) | ◇◇◇ | 1.85 | 1.30 |
| Cadmium, Dissolved (µg/L) | 10 | 10 | 106 | 102 | 0.10 | 0.12 | 0.20 (0.10, 0.20) | 0.15 (0.14, 0.20) | ◇◇◆ | 0.20 | 0.20 |
| Cadmium, Total (µg/L) | 16 | 16 | 194 | 194 | 0.10 | 0.03 | 0.30 (0.20, 0.36) | 0.08 (0.07, 0.12) | ◆◆◆ | 0.60 | 0.20 |
| Chromium, Dissolved (µg/L) | 10 | 10 | 114 | 99 | 0.50 | 0.52 | 1.00 (0.60, 1.00) | 1.00 (1.00, 1.00) | ◇◇◆ | 1.00 | 1.00 |
| Chromium, Total (µg/L) | 10 | 10 | 115 | 109 | 1.20 | 0.82 | 2.00 (1.50, 2.30) | 1.00 (1.00, 1.10) | ◆◆◆ | 3.37 | 1.70 |
| Copper, Dissolved (µg/L) | 11 | 11 | 189 | 176 | 1.63 | 1.50 | 3.75 (2.70, 4.10) | 3.25 (2.53, 3.90) | ◇◇◆ | 7.60 | 6.90 |
| Copper, Total (µg/L) | 20 | 20 | 345 | 330 | 4.97 | 2.46 | 9.98 (8.60, 10.00) | 5.53 (4.58, 6.30) | ◆◆◆ | 16.87 | 10.00 |
| Iron, Total (µg/L) | 8 | 7 | 153 | 132 | 267.76 | 113.23 | 642.3 (452.2, 755.0) | 209.7 (162.8, 256.9) | ◆◆◆ | 1,460.00 | 420.69 |

| | BMPs[17] | | EMCs[18] | | 25th | | Median Concentration[19] | | | 75th | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | In | Out | In | Out | In | Out | In | Out | Difference[20] | In | Out |
| Lead, Dissolved (µg/L) | 10 | 10 | 144 | 140 | 0.32 | 0.41 | 1.00 (1.00, 1.00) | 1.00 (0.49, 1.00) | ◇◇◆ | 1.50 | 1.00 |
| Lead, Total (µg/L) | 20 | 19 | 303 | 289 | 2.66 | 0.71 | 10.00 (8.00, 12.00) | 1.70 (1.20, 2.00) | ◆◆◆ | 22.25 | 3.78 |
| Nickel, Dissolved (µg/L) | 10 | 10 | 113 | 109 | 0.82 | 0.74 | 1.85 (1.00, 2.00) | 1.30 (0.98, 2.00) | ◇◇◇ | 2.10 | 2.00 |
| Nickel, Total (µg/L) | 10 | 10 | 115 | 109 | 2.00 | 1.12 | 3.28 (2.43, 3.60) | 2.00 (2.00, 2.37) | ◆◆◆ | 5.10 | 3.40 |
| Zinc, Dissolved (µg/L) | 11 | 11 | 189 | 174 | 11.20 | 1.81 | 28.20 (21.00, 36.00) | 5.65 (3.37, 8.20) | ◆◆◆ | 84.00 | 21.00 |
| Zinc, Total (µg/L) | 23 | 23 | 387 | 358 | 23.30 | 4.18 | 62.90 (52.40, 70.00) | 14.14 (12.00, 16.44) | ◆◆◆ | 140.97 | 29.97 |

## Certifications[21]

### Washington State Technology Assessment Protocol – Ecology

| | TSS | Enhanced (Dissolved Metals) | Total Phosphorus | Oil/Grease |
|---|---|---|---|---|
| **General Use Level Designation** | | | | |
| Baysaver Technologies, LLC Bayfilter™ System Using Bayfilter Cartridge (BFC) | ☒ | ☐ | ☐ | ☐ |
| BaySaver Technologies, BayFilter EMC | ☒ | ☐ | ☒ | ☐ |
| Bio Clean, Modular Wetland Systems | ☒ | ☒ | ☒ | ☐ |
| Contech, Filterra System | ☒ | ☒ | ☒ | ☒ |
| Contech, Media Filtration System | ☒ | ☐ | ☐ | ☐ |
| Contech, StormFilter with PhosphoSorb Media | ☒ | ☐ | ☒ | ☐ |
| Contech, StormFilter with ZPG Media | ☒ | ☐ | ☐ | ☐ |
| Oldcastle, FloGard Perk Filter with ZPC Media | ☒ | ☐ | ☒ | ☐ |
| **Conditional Use Level Designation** | | | | |
| AquaShield Aqua-Filter, Course Perlite Media | ☒ | ☐ | ☒ | ☐ |
| BaySaver Technologies, BayFilter EMC | ☐ | ☒ | ☐ | ☐ |
| Contech, Jellyfish Filter | ☒ | ☐ | ☐ | ☐ |
| Contech, StormFilter with MetalRx Media | ☒ | ☒ | ☐ | ☐ |
| Hydro International, Up-Flo Filter with CPZ Media | ☒ | ☐ | ☐ | ☐ |
| LEAN Environment, Enpurion Metals Treatment | ☒ | ☒ | ☐ | ☐ |
| StormwateRx LLC, Aquip® Enhanced Storm water Filtration System | ☒ | ☒ | ☒ | ☐ |

| | TSS | Enhanced (Dissolved Metals) | Total Phosphorus | Oil/Grease |
|---|---|---|---|---|
| **Pilot Use Level Designation** | | | | |
| AquaShield™, Inc Aqua-Filter™, Aqua-Blend™ C Media | ☒ | ☒ | ☒ | ☒ |
| Bio Clean, The Kraken | ☒ | ☐ | ☐ | ☐ |
| Contech, Jellyfish Filter | ☒ | ☐ | ☒ | ☒ |
| Oldcastle Storm water Solutions, Inc's, The TreePod™ Biofilter with Curb Inlet | ☒ | ☒ | ☒ | ☐ |
| Rotondo Environmental Solutions, LLC's StormGarden Modular Stormwater Bio-Filtration System Standard Box Filter | ☒ | ☐ | ☐ | ☐ |

### New Jersey Cat/DEP TSS Verification and Certification[22]

| | NJCAT Lab Verified | NJCAT/TARP Field Verified | NJDEP Certified |
|---|---|---|---|
| AquaShield Aqua-Filter | ☒ | ☒ | ☐ |
| BaySaver, BayFilter EMC | ☒ | ☐ | ☒ |
| Bio Clean, The Kraken | ☒ | ☐ | ☒ |
| Contech, Filterra | ☒ | ☐ | ☒ |
| Contech, Jellyfish | ☒ | ☒ | ☐ |
| Contech, Media Filtration System | ☐ | ☒ | ☐ |
| Contech, StormFilter with Perlite Media | ☒ | ☒ | ☒ |
| Hydro International, Up-Flo Filter (with Filter Ribbon Media) | ☒ | ☐ | ☒ |

**<u>Other</u>**

- Maine Stormwater Best Management Practices Manual – Proprietary Systems
- Virginia Stormwater BMP Clearinghouse

## Component Specific Considerations

- Space restrictions: Dependent on type of filter. Many proprietary systems can be installed underground minimizing space requirements. Land-based systems such as sand filters require a larger footprint.
- Soil type: Soil type is not typically a concern unless the filter is designed to infiltrate.
- Media type: Per applicable specification and governing verifications/certifications.
- Topography: May not be suitable on steep slopes.
- Temperature issues: Not typically an issue, some underground filters can reduce runoff temperature.
- Pollutant concentration concerns: Limited removal of dissolved pollutants unless reactive media is utilized; may export dissolved pollutants if not properly maintained. High solids concentrations can increase maintenance frequency.
- Longevity: Media filters will all eventually be occluded with particulate and debris. Longevity/mass load capacity of the system should be part of design process, especially if downstream of detention.
- Pretreatment: not all filters require pretreatment, but if provided in the tested configuration it should be included.
- Construction costs: Low to moderate.
- Maintenance costs: Moderate.
- Mosquitoes: Dependent on type of filter. Underground systems may be less prone to breeding.

- Groundwater: In accordance with local requirements, maintain separation from groundwater used for drinking supply.

## Design Criteria Considerations

There is a difference in how most BMP manuals discuss proprietary and non-proprietary media filters. The non-proprietary systems often have a full explanation of how to do the entire system design. Proprietary systems often rely on help from the manufacturer, or just have an approved flow rate per unit of filter area. (Gallons Per Minute/$ft^2$ of media surface area)

**Proprietary Filter Systems**

- New Jersey Stormwater Best Management Practices Manual, Chapter 9.6: Manufactured Treatment Devices
- (Ecology 2019 (draft))) Stormwater Management Manual for Western Washington, BMP T10.30 Stormwater Treatment Wetlands
- 2000 Maryland Stormwater Design Manual Volume I, Section 2.7.1: Urban BMP Groups, BMP Group 4 – Filtering Practices
- Virginia Stormwater Management Handbook, First Edition, Volume 1, Section 3.15: Manufactured BMP Systems

**Non-Proprietary Filter Systems**

- New Jersey Stormwater Best Management Practices Manual, Chapter 9.9: Sand Filters
- 2012 Stormwater Management Manual for Western Washington, As Amended in December 2014 (the 2014 SWMMWW) Volume: Runoff Treatment BMPs, Chapter 8: Filtration Treatment Facilities.
- 2000 Maryland Stormwater Design Manual Volume 1, Section 2.7.1: Urban BMP Groups, BMP Group 4 – Filtering Practices
- California Stormwater Quality Association Municipal BMP Handbook, Section 4.3: BMP Fact Sheets, TC-40: Media Filter. Section 4.3 BMP Fact Sheets, TC-40 Media Filters (non-proprietary)
- Virginia Stormwater Management Handbook, Volume I, Section 3.12: Sand Filters

## Construction Information

**Construction Submittals**

- *Drainage structures (inlets, cleanouts and manholes):* Size is an important component of these features. Sizes have been determined based off of pipe sizes and what the structures will be housing. If they are used as a junction, then they could be sized differently than if they are housing multiple filters. Some structures are precast; others are completely cast in place, while others use a combination of both.
- If the stormwater BMP is close to an airport operations area, standing water should drain within 48 hours.
- *Filters*: Types, size, quantity and pollutant removal ability are important factors when choosing the right media filters. The design engineer will determine the filter manufacturer and type based off features, size and applicability to the current regulations.

**Timeframe**

- Structures related to media filter systems are installed during the utility phase. It is recommended that filters and media filters be installed after final site stabilization.
- Media filters are highly sensitive to sediment and should not be placed until the threat of construction-related sediment deposition has passed.

**Protection**

- Tributary area should be completely stabilized before media is installed to prevent premature clogging.
- No runoff should enter the media filters prior to completion of construction and approval of site stabilization by the responsible inspector.
- Keep effective erosion and sediment control measures in place until construction of the media filter is completed.
- Flush upstream conveyance system to remove accumulated sediment and debris before diverting flow to the Media Filter.
- Do not allow vehicles or traffic on the media filters to minimize rutting and maintenance repairs.

## Inspection Checklist

**Pre-Construction**

- Hold a pre-construction meeting.
- Include local aviation authorities if the stormwater BMP is situated within 10,000 feet of an airport operations area.
- Media filter location should be staked.
- Runoff should be diverted around media filter.
- Temporary erosion and sediment protection should be properly installed.

**Structure/Materials**

- Use materials per specifications.
- Concrete must meet standards.
- Use filter material per specification.
- Use under-drains (e.g., size, materials) per specifications and installed to grade.
- Pre-treatment device should be installed, if needed.

**Final Inspection**

- Media filter should be installed per plans or per manufacturer's recommendations.
- Media filter structure should be free of debris and sediment.
- Upstream conveyance system should be free of debris and sediment.
- Any pre-treatment device must be operational.
- Media filter must be operational.
- Tributary area must be stabilized before flow is diverted to the media filter.

## Operation and Maintenance (O&M) Considerations

- Manufactured treatment device with specific operation and maintenance requirements provided by the manufacturer.

**Visual Inspections**

- Condition of the vault or visible exterior
- Access point
- Interior of vault
- Inlet
- Outlet
- Condition of canisters
- Sediment level
- Debris presence and amount
- Filter surface
- Activities in drainage area to minimize oil and grease
- Surrounding vegetation

**Maintenance**

- Ensure that relevant safety procedures are followed.
- Either remove whole canisters or remove filters/media.
- Remove sediment from vault and forebay using vacuum truck.
- Dispose of removed water and solids in a safe manner. Consult local regulatory authorities to determine appropriate method to dispose of water and solids.
- Test material for toxins and hazardous materials classification to ensure proper disposal.
- Replace media or install new canisters.

## References and Links

- For proprietary systems, see vendor website for O&M guidance as well as applicable verifications/certifications for any additional criteria established.

- Non-proprietary media filters are often detailed in state and local stormwater manuals such as:
    - New Jersey Stormwater Best Management Practices Manual, Chapter 9.9: Sand Filters
    - 2012 Stormwater Management Manual for Western Washington, As amended in December 2014 Volume V
    - 2000 Maryland Stormwater Design Manual Volume 1, Chapter 3 – Performance Criteria for Urban BMP Design

## F.9 Oil Water Separators

**December 2018**

### Description

Oil Water Separators (OWS) are designed to remove petroleum hydrocarbons, grease, sand and grit through settling and floatation/skimming of oils and other floatables.

#### Pollutants of Concern Treated by Oil Water Separators (OWS)

| Oil-Water Separators | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Solids** | **Solid Metals** | **Dissolved Metals** | **Hydrocarbons** | **Nutrients** | **Ammonia** | **pH** | **Bacteria Pathogens** | **Organics** | **Trash** | **Pesticides Herbicides** |
| TSS | | | O/G | | | | | | | |
| SSC | | | TPH | | | | | | | |

#### Data Available in International Stormwater BMP Database: ☒ Yes ☐ No

International Stormwater BMP Database Search Tool

### Certifications[23] None Available

### Other information

- USEPA SPCC Guidance for Regional Inspectors, Chapter 5: Oil/Water Separators
- 2004 Connecticut Stormwater Quality Manual Chapter 11, Section 11-S4: Oil Water Separators
- Catalog of Stormwater Best Management Practices for Idaho Cities and Counties, Volume 4: Permanent Stormwater Controls, Section 3.4: Other Structural Controls, BMP 18: Oil Water Separators Idaho Oil Water Separator Information
- Kentucky Department of Environmental Protection Preventing Groundwater Pollution: Oil Water Separators Oil Water Separator Information
- Michigan Department of Environmental Quality Waste Management Guidance, Oil Water Separators
- Tennessee BMP Manual Stormwater Treatment Activity: Oil Water Separator
- 2012 Stormwater Management Manual for Western Washington, As amened in December 2014 (the @014 SWMMWW), Chapter V-11; Oil Water Separators)
- Knoxville BMP Manual Stormwater Treatment, Activity: Oil Water Separator
- City of Tacoma Stormwater Management Manual 2012 Edition, Volume 5; Water Quality Treatment BMPs, Chapter 11: Oil Water Separators
- King County, WA Fact Sheet: Oil/Water Separator -ow to Select and Maintain an Oil/Water Separator

### Design Criteria Considerations

- Size the OWS according to the drainage area and anticipated flows. Excessive flows will decrease oil removal efficiencies and may re-entrain material previously removed by the OWS.
- Freezing temperatures may decrease the efficiency of OWS.
- Ensure sufficient oil retention capacity to contain the volume of an anticipated release.
- Locate the OWS upstream of any other BMPs.
- Evaluate whether the OWS should be installed in an in-line configuration (to treat all runoff) or an off-line

configuration (to treat a portion of the runoff).
- Segregate stormwater from areas not subject to oil spills to decrease flow rates through the OWS.
- Consider the size and quantity of sediment and trash that may enter the OWS. Some OWS are subject to rapid failure or reduced functionality when subjected to heavy sediment loading so pretreatment may be considered.
- Incorporate removable covers to allow removal of oil, sediment and trash.
- Incorporate design features to enhance oil removal (e.g., baffles to decrease turbulence, plate separators to increase oil removal rates, etc.).
- Evaluate the use of pre-manufactured vs. field-constructed OWS units.
- Determine whether shallow groundwater may affect the OWS unit. Anchors or straps may be required to offset buoyancy forces.
- Evaluate subsurface lithology for conditions (e.g., shallow bedrock) that may prevent subsurface installation of an OWS.

## Construction Information

**Construction Submittals**

- For pre-manufactured OWS units, manufacturer design drawings and specifications.
- Construction materials should withstand long-term subsurface installation.
- Appurtenances (e.g., pipes, grates, manholes, plates, etc.) should match the design specifications.

**Timeframe**

- Pre-manufactured OWS units may be installed within a relatively short timeframe.
- Field constructed OWS units may take an extended period of time to install, based on size and complexity of the design.

**Protection**

- Divert stormwater away from the BMP during construction.
- If shallow groundwater is present, dewatering may be required during installation.

**Inspection Checklist**

- If shallow groundwater is a concern, assure OWS has been properly anchored.
- OWS should be constructed to the correct dimensions.
- Level the OWS.
- All appurtenances (e.g., pipes, baffles, weirs, etc.) should be installed at the correct elevation.
- OWS should hold water with no leaks.
- Each chamber of the OWS should be accessible for inspection/maintenance.

## References for Construction

- California Stormwater Quality Association, Stormwater Best Management Practice Handbook, New Development and Redevelopment (2003)
- (USEPA 1999a)
- Maine Stormwater Best Management Practices Manual, Chapter 9 – Separator BMPs (2016)

### Operation and Maintenance (O&M) Considerations

| Frequency | Inspection Actions |
|---|---|
| Quarterly | • Inspect OWS for structural concerns and oil and debris accumulation.*<br>• Check access points (manholes, ladders, etc.) for ease of ingress and egress. |
| Periodic | • Inspection should be performed periodically.<br>• Records of inspection and maintenance should be maintained, including any manifest for waste removal. |
| Additional Consideration | • Check the specific inspection schedule for a manufactured treatment device. |
| *Only professionals with OSHA confined space certification should enter below ground stormwater systems. | |

### Maintenance

| Frequency | Preventative Maintenance Actions |
|---|---|
| Quarterly | • Based on results of inspection, structural concerns should be addressed.<br>• Repair or replace missing ingress and egress components as required. |
| Periodic | • Remove blockages from outlets and inlets as required.<br>• Remove oil accumulation, as needed, to prevent oil discharge and clean interior of oil water separator. Disposal of waste materials should be in accordance with state and local requirements and may require testing before selecting a disposal location. |
| Additional Consideration | • Check the specific maintenance schedule for a manufactured treatment device as required by the manufacturer. |

## Resources for O&M

- Catalogue of Stormwater Best Management Practices for Idaho Cities and Counties, Volume 4: Permanent Stormwater Controls, Section 3.4; Other Structural Controls, BMP 18: Oil Water Separators
- Northeast Tennessee Water Quality BMP Manual, Chapter 4: Design and Maintenance of Structural BMPs, Section 4.4.7 Oil-Grit (Gravity Separator)
- Goodyear, AZ Oil/water Separator (OWS) Maintenance and Cleaning

# F.10 Permeable Pavement

**December 2018**

## Description

Permeable or porous pavement has a higher than normal percentage of air voids to allow water to pass through it and infiltrate into the subsoil or collect in an underdrain system. Massachusetts Stormwater Handbook and Stormwater Standards

### Pollutants of Concern Treated by Permeable Pavement

| Permeable Pavement | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Solids** | **Solid Metals** | **Dissolved Metals** | **Hydro carbons** | **Nutrients** | **Ammonia** | **pH** | **Bacteria Pathogens** | **Organics** | **Trash** | **Pesticides Herbicides** |
| TSS | Cu | | O/G | Phosphorus | | | | PCB | | |
| SSC | Zn | Zn | TPH | | | | | PAH | | |
| Turbidity | Pb | | | | | | | | | |
| Total Solids | Ni | Ni | | | | | | | | |

International Stormwater BMP Database Performance Summary, 2016 – Porous Pavement International Stormwater BMP Database. Prepared for City and County of Denver and Urban Drainage and Flood Control District, February 2017. Prepared by Wright Water Engineers and Geosyntec Consultants (Consultants 2016)

| | BMPs[24] | | EMCs[25] | | 25th | | Median Concentration[26] | | | 75th | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | In | Out | In | Out | In | Out | In | Out | Difference[27] | In | Out |
| Kjeldahl Nitrogen (TKN) (mg/L) | 6 | 6 | 375 | 206 | 1.40 | 0.70 | 2.20 (1.80, 2.20) | 1.00 (0.90, 1.10) | ◆◆◆ | 3.10 | 1.50 |

| | BMPs[24] | | EMCs[25] | | 25th | | Median Concentration[26] | | | 75th | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | In | Out | In | Out | In | Out | In | Out | Difference[27] | In | Out |
| Nitrogen, $NO_x$ as N (mg/L) | 7 | 7 | 388 | 220 | 0.34 | 0.85 | 0.59 (0.53, 0.62) | 1.36 (1.22, 1.51) | ◆◆◆ | 0.88 | 2.06 |
| Nitrogen, Nitrite ($NO_2$) + Nitrate ($NO_3$) as N (mg/L) | 7 | 7 | 388 | 220 | 0.34 | 0.85 | 0.59 (0.53, 0.62) | 1.36 (1.22, 1.51) | ◆◆◆ | 0.88 | 2.06 |
| Phosphorus as P, Dissolved (mg/L) | 4 | 4 | 244 | 119 | 0.03 | 0.04 | 0.05 (0.04, 0.05) | 0.05 (0.05, 0.07) | ◇◆◆ | 0.08 | 0.10 |
| Phosphorus as P, Total (mg/L) | 8 | 8 | 373 | 219 | 0.12 | 0.07 | 0.19 (0.16, 0.21) | 0.11 (0.10, 0.11) | ◆◆◆ | 0.36 | 0.20 |
| Phosphorus, orthophosphate as P (mg/L) | 6 | 6 | 174 | 114 | 0.03 | 0.03 | 0.05 (0.04, 0.06) | 0.07 (0.05, 0.08) | ◇◆◆ | 0.08 | 0.12 |
| Total suspended solids (mg/L) | 9 | 9 | 404 | 248 | 36.8 | 15.0 | 93.7 (75.0, 126.0) | 26.0 (20.6, 27.0) | ◆◆◆ | 243.0 | 53.2 |
| Arsenic, Total (µg/L) | 4 | 4 | 270 | 128 | 1.76 | 1.65 | 2.50 (2.50, 2.50) | 2.62 (2.23, 2.99) | ◇◆◆ | 2.50 | 4.12 |
| Cadmium, Dissolved (µg/L) | 4 | 4 | 280 | 133 | 0.10 | 0.10 | 0.11 (0.10, 0.12) | 0.11 (0.10, 0.13) | ◇◇◇ | 0.17 | 0.20 |
| Cadmium, Total (µg/L) | 4 | 4 | 270 | 140 | 0.13 | 0.25 | 0.26 (0.22, 0.30) | 0.25 (0.25, 0.25) | ◇◇◆ | 0.59 | 0.43 |
| Chromium, Dissolved (µg/L) | 4 | 4 | 292 | 133 | 0.50 | 1.70 | 0.50 (0.50, 0.50) | 2.70 (2.30, 2.80) | ◆◆◆ | 0.50 | 3.80 |
| Chromium, Total (µg/L) | 4 | 4 | 300 | 143 | 2.04 | 2.50 | 3.62 (3.40, 4.10) | 4.28 (3.51, 5.06) | ◇◇◇ | 6.60 | 7.23 |
| Copper, Dissolved (µg/L) | 7 | 7 | 381 | 216 | 2.80 | 3.00 | 5.00 (4.70, 5.50) | 5.10 (4.40, 5.60) | ◇◇◆ | 7.80 | 7.12 |
| Copper, Total (µg/L) | 11 | 11 | 439 | 262 | 7.50 | 4.00 | 12.00 (10.80, 12.50) | 7.70 (6.70, 8.00) | ◆◆◆ | 23.30 | 13.76 |
| Iron, Dissolved (µg/L) | 4 | 4 | 290 | 139 | 37.33 | 70.00 | 70.0 (60.0, 70.0) | 110.0 (89.7, 120.0) | ◆◆◆ | 120.00 | 205.00 |
| Lead, Dissolved (µg/L) | 4 | 4 | 322 | 154 | 0.50 | 0.50 | 0.50 (0.50, 0.50) | 0.50 (0.50, 0.50) | ◇◇◇ | 0.50 | 0.50 |
| Lead, Total (µg/L) | 8 | 8 | 380 | 199 | 0.61 | 0.11 | 3.05 (1.99, 5.10) | 0.52 (0.32, 0.73) | ◆◆◆ | 10.00 | 2.01 |
| Nickel, Dissolved (µg/L) | 4 | 4 | 280 | 130 | 0.70 | 0.37 | 1.10 (1.00, 1.30) | 0.63 (0.52, 0.71) | ◆◆◆ | 1.73 | 1.00 |
| Nickel, Total (µg/L) | 4 | 4 | 300 | 143 | 2.40 | 1.21 | 3.70 (3.25, 3.80) | 1.76 (1.60, 2.08) | ◆◆◆ | 6.33 | 2.90 |
| Zinc, Dissolved (µg/L) | 7 | 7 | 381 | 216 | 7.10 | 0.46 | 15.00 (12.50, 16.30) | 1.70 (1.07, 2.64) | ◆◆◆ | 26.20 | 10.75 |

| | BMPs[24] | | EMCs[25] | | 25th | | Median Concentration[26] | | | 75th | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | In | Out | In | Out | In | Out | In | Out | Difference[27] | In | Out |
| Zinc, Total (µg/L) | 13 | 13 | 463 | 287 | 22.70 | 2.49 | 50.00 (49.20, 55.80) | 12.20 (9.00, 19.10) | ◆◆◆ | 104.75 | 30.05 |

## Certifications[28]

## Component Specific Considerations

## Design Criteria Considerations

**Structural Design**

- The subgrade is the layer below the paving and the subbase. Where traditional pavement tries to reduce water from entering the subgrade, permeable pavement allows for water to enter the subgrade.
- The subbase is below the paving and provides vertical support, storage capacity and filtering ability.
- Pavement strength (i.e., concrete, paver, asphalt, etc.) is based on the material used and the design specifications for the area.
- Structural thickness can vary based on the local conditions, experience of using permeable pavements, and pavement mixture design.

**Stormwater Management Design**

- Determine permeable pavement type (i.e., porous concrete, pervious pavers, non-pervious interlocking pavers, etc.).
- Consider three specific design features: 1) reduced runoff volume, 2) reduced treatment volume, and 3) reduced impervious area.
- Determine if there is a stormwater treatment option considered and its effectiveness for the design considerations.
- Permeable pavement maintenance can include routine inspection (i.e., operation, clogging, structural integrity, etc.).
- Drainage design should be developed using accepted methods (e.g., Soil Conservation Service curve number) and include parameters such as: absorption, evaporation, rainfall intensity, infiltration rate, and storm duration, while incorporating appropriate compaction to reduce soil density yet maintain structural integrity.
- Permeable pavement properties are highly variable depending on the skill and experience of the installe

## Construction Information

**Construction Submittals**

- Review and accept NRMCA certification documents from contractor or alternatives (i.e., select certified / appropriate permeable pavement installers).
- Verify the execution plan from contractor.
- Verify jointing requirements and details from contractor.
- Review and accept drawings from contractor.
- Considerable earthwork may be required.
- Soil testing should be conducted prior to construction (e.g., soil infiltration rate testing).
- Seasonal earthwork and application may be required and may not be appropriate depending on location.

## Example Submittals Checklist

- American Concrete Institute (ACI) Specification for Pervious Concrete Pavement, ACI 522.1-13

**Timeframe**

- Hold pre-construction meeting and construct test sections to address construction issues.
- Assemble materials on-site and ensure they meet design specifications.
- Follow erosion control measures according to an approved site plan (e.g., silt fence).
- Follow general pervious concrete construction guidelines such as subgrade preparation and layout.
- Place paving material as per site specifications and industry standards:
    - Porous Asphalt – see Jackson (2007)
    - Pervious Concrete – see American Concrete Institute (2008)
    - Interlocking Pavers – see Smith (2006)
- Consolidation
- Jointing
- Curing protection
    - Cold weather protection
    - Hot weather protection
- Protect permeable pavement from adjacent stormwater runoff areas to avoid introduction of sediment

**Example Inspection Checklist**

- Virginia Department of Environmental Quality (DEQ) Design Specification No 7: Permeable Pavers, Version 2.0

## Operation and Maintenance Considerations

- Post signage to identify the porous pavement areas. Avoid typical measures for maintaining standard pavements including application of sand, salt and snow melting chemicals, seal coating and power washing.
- In winter, do not pile plowed snow on pavement to prevent concentrations of grit and nutrients from being deposited on pavement.
- Maintain stabilizing ground cover around pavement to prevent erosion and washing of sediment onto the permeable pavement surface.
- Check pre-treatment devices, flow diverters for structural integrity and for erosion or sediment buildup. Remove sediment, repair eroded areas and restabilize.
- Keep surface clean of leaves, grass clippings, dirt and litter that could clog pavement and prevent infiltration.
- Clean surface yearly in spring with a vacuum sweeper. Do not apply water or spray during cleaning. For unit paver installations, set vacuum power to avoid picking up stones between pavers.
- Check integrity of observation wells and verify that the water storage sump dewaters within 3 days following a runoff producing rain. Repair underdrain and internal plumbing components as necessary.
- Inspect pavement surface for sediment deposition, organic debris, staining or ponding that may indicate surface clogging. Remove with vacuum sweeper, check infiltration in suspect areas with 5-gallon buckets of water.
- Inspect pavement for structural integrity. Check for cracks, buckling, slumping or sinking. Repair and replace components of the system as necessary.

## References and Links


- American Concrete Institute (ACI) Pervious Concrete, ACI 522R-06
- American Concrete Institute (ACI) Report on Pervious Concrete, ACI 522R-10
- American Concrete Institute (ACI) Specification for Pervious Concrete Pavement, ACI 522.1-08
- American Concrete Institute (ACI) Specification for Pervious Concrete Pavement, ACI 522.1-13
- California Department of Transportation – Pervious Pavement Guidance
- Jackson, N. 2007. *Design, Construction and Maintenance Guide for Porous Asphalt Pavements*. National Asphalt Pavement Association. Information Series 131. Lanham, MD. (Jackson 2007)
- Minnesota Pollution Control Agency Stormwater Manual: Permeable Pavement
- New York State Stormwater Management Design Manual
- North Carolina Department of Environmental Quality Stormwater Design Manual Minimum Design Criteria and Recommendations for Stormwater Control Measures C-5: Permeable Pavement
- S. Department of Transportation Federal Highway Administration, Permeable Interlocking Concrete Pavement, TechBrief Publication Number FHWA-HIF-15-007
- Smith, D. 2006. *Permeable Interlocking Concrete Pavement-selection design, construction and maintenance. Third Edition*. Interlocking Concrete Pavement Institute. Herndon, VA. (Smith 2006)
- Structural Design Solutions for Permeable Pavements, John Knapton Consulting Engineers, Ltd.

- Virginia Department of Environmental Quality (DEQ) Design Specification No 7: Permeable Pavement, Version 2.0
- West Virginia Department of Environmental Protection Stormwater Management and Design Guidance Manual, Chapter 4.2.4: Permeable Pavement

# F.11 Racks and Screens

**December 2018**

## Description

Racks and screening devices separate solids, primarily larger than the size openings. The systems deal with the entire water column.

### Pollutants of Concern Treated by Racks and Screens

| Racks and Screen Devices | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Solids | Solid Metals | Dissolved Metals | Hydrocarbons | Nutrients | Ammonia | pH | Bacteria Pathogens | Organics | Trash | Pesticides Herbicides |
| | | | O/G | | | | | | | |
| | | | TPH | | | | | | X | |

### Data Available in International Stormwater BMP Database: ☒ Yes ☐ No

## Certifications[29] None Available

## Design Criteria Considerations

Racks are commonly used in stormwater systems to block larger objects that tend to block flow, and pass smaller objects. Screens may be used in conjunction with racks, blocking smaller objects later in the line. When screens are used, more attention must be given to load and maintenance to prevent blockage of the flow. Automated mechanisms may be mounted on screens, which activate at timed intervals to clear and hold the load that accumulates on a screen.

## Construction Information

**Sequence**

- Installation sequence may vary due to type and size of trash collected in addition to the amount of proprietary rack and screen devices on the market. Please consult the manufacturer’s manual or website for specific installation instructions. Devices may also be designed for the needs of a site. Site-specific devices should be built per the instructions and according to technical information specified by the design engineer.

**Considerations**

- Determine size of solids that will be prevented from entering the storm structure and verify the device selected meets the needs.
- Consider points of entry for the structure. Each entry point may require a rack and screen device.
- Ensure all proper mounting hardware is provided as outlined in the installation instructions.
- Perform an inspection of the structure prior to installation to determine if the device can be properly installed.
- Inspections should be performed after installation to verify the device is secure.

## Operation and Maintenance Considerations

**Monitoring**

| Frequency | Inspection Actions |
|---|---|
| Periodic | • Inspection should be performed following rain events.<br>• Inspection should check for rusted or broken sections. |

**Maintenance**

| Frequency | Preventative Maintenance Actions |
|---|---|
| Periodic | • Trash and debris should be removed as needed. *Disposal should be in accordance with state and local requirements.<br>• Repair rusted or broken sections as needed. |
| *Caution should be exercised if attempting to remove trash and debris during heavy rain events. | |

### References and Links

- BioClean Environmental Services, Inc – Grate Inlet Filter Operation & Maintenance
- Effluent Design & Fabrication – Recommended Periodic Maintenance Schedule & Procedures

## F.12 Sediment Basin

**December 2018**

### Description

Sediment basins are used to remove settleable solids from stormwater runoff, often prior to treatment by other BMPs.

#### Pollutants of Concern Treated by Sediment Basins

| Sedimentation Basins | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Solids** | **Solid Metals** | **Dissolved Metals** | **Hydrocarbons** | **Nutrients** | **Ammonia** | **pH** | **Bacteria Pathogens** | **Organics** | **Trash** | **Pesticides Herbicides** |
| TSS | Cu | | O/G | Phosphorus | | | X | PCB | X | |
| SSC | Zn | | TPH | | | | | PAH | | |
| Turbidity | Pb | | | | | | | | | |
| Total Solids | Cd | | | | | | | | | |
| | Cr | | | | | | | | | |
| | Ni | | | | | | | | | |
| | As | | | | | | | | | |

**International Stormwater BMP Database Performance Summary, 2016 – Retention Pond International Stormwater BMP Database Prepared for City and County of Denver and Urban Drainage and Flood Control District, February 2017. Prepared by Wright Water Engineers and Geosyntec Consultants (Consultants 2016))**

| | BMPs | | EMCs | | 25th | | Median | | | 75th | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | In | Out | In | Out | In | Out | In | Out | Difference | In | Out |
| E. coli (MPN/100 mL) | 4 | 4 | 69 | 65 | 580 | 10 | 2,000 (990, 3,100) | 80 (24, 170) | ◆◆◆ | 5,500 | 700 |
| Fecal Coliform (MPN/100 mL) | 10 | 12 | 121 | 161 | 300 | 50 | 3,400 (1,500, 5,000) | 1,400 (360, 2,300) | ◇◆◆ | 23,000 | 8,500 |
| Kjeldahl nitrogen (TKN) (mg/L) | 36 | 36 | 498 | 493 | 0.76 | 0.70 | 1.24 (1.10, 1.31) | 1.00 (0.91, 1.03) | ◆◆◆ | 2.00 | 1.50 |
| Nitrogen, $NO_x$ as N (mg/L) | 46 | 46 | 707 | 704 | 0.18 | 0.05 | 0.42 (0.38, 0.45) | 0.17 (0.15, 0.19) | ◆◆◆ | 0.81 | 0.43 |

| | BMPs | | EMCs | | 25th | | Median | | | 75th | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | In | Out | In | Out | In | Out | In | Out | Difference | In | Out |
| Nitrogen, Nitrate ($NO_3$) as N (mg/L) | 15 | 15 | 251 | 247 | 0.25 | 0.12 | 0.50 (0.40, 0.54) | 0.25 (0.19, 0.27) | ◆◆◆ | 0.83 | 0.50 |
| Nitrogen, Nitrite ($NO_2$) + Nitrate ($NO_3$) as N (mg/L) | 31 | 31 | 456 | 457 | 0.15 | 0.02 | 0.38 (0.33, 0.41) | 0.12 (0.09, 0.15) | ◆◆◆ | 0.79 | 0.34 |
| Nitrogen, Total (mg/L) | 27 | 27 | 414 | 431 | 0.99 | 0.81 | 1.56 (1.42, 1.74) | 1.20 (1.10, 1.25) | ◆◆◆ | 2.59 | 1.69 |
| Phosphorus as P, Dissolved (mg/L) | 18 | 19 | 373 | 394 | 0.07 | 0.03 | 0.13 (0.11, 0.14) | 0.06 (0.05, 0.07) | ◆◆◆ | 0.21 | 0.14 |
| Phosphorus as P, Total (mg/L) | 55 | 55 | 891 | 873 | 0.09 | 0.04 | 0.20 (0.18, 0.22) | 0.09 (0.08, 0.10) | ◆◆◆ | 0.42 | 0.20 |
| Phosphorus, orthophosphate as P (mg/L) | 33 | 33 | 524 | 508 | 0.02 | 0.01 | 0.06 (0.05, 0.07) | 0.02 (0.02, 0.03) | ◆◆◆ | 0.15 | 0.06 |
| Total suspended solids (mg/L) | 56 | 56 | 923 | 933 | 15.0 | 4.3 | 47.2 (40.0, 54.0) | 11.7 (10.0, 12.3) | ◆◆◆ | 139.8 | 28.0 |
| Arsenic, Total (µg/L) | 4 | 4 | 25 | 23 | 1.00 | 0.52 | 1.20 (1.00, 1.80) | 1.00 (0.55, 1.00) | ◇◇◇ | 2.00 | 1.41 |
| Cadmium, Dissolved (µg/L) | 3 | 3 | 40 | 69 | 0.20 | 0.12 | 0.26 (0.20, 0.33) | 0.12 (0.12, 0.12) | ◆◆◆ | 0.50 | 0.20 |
| Cadmium, Total (µg/L) | 25 | 25 | 383 | 408 | 0.17 | 0.09 | 0.40 (0.29, 0.41) | 0.20 (0.14, 0.20) | ◆◆◆ | 1.00 | 0.44 |
| Chromium, Dissolved (µg/L) | 4 | 4 | 41 | 81 | 1.00 | 0.87 | 1.00 (1.00, 2.00) | 1.00 (1.00, 1.00) | ◇◆◇ | 2.00 | 1.00 |
| Chromium, Total (µg/L) | 13 | 13 | 170 | 168 | 2.43 | 1.00 | 4.18 (3.70, 4.85) | 1.50 (1.00, 2.00) | ◆◆◆ | 8.00 | 4.19 |
| Copper, Dissolved (µg/L) | 16 | 16 | 363 | 364 | 3.08 | 2.30 | 4.90 (4.28, 5.40) | 3.23 (3.00, 3.50) | ◆◆◆ | 7.33 | 4.89 |
| Copper, Total (µg/L) | 41 | 41 | 732 | 723 | 4.40 | 2.69 | 9.00 (7.75, 9.20) | 4.32 (4.00, 4.69) | ◆◆◆ | 16.00 | 6.76 |
| Iron, Dissolved (µg/L) | 5 | 5 | 115 | 125 | 19.62 | 27.17 | 52.0 (31.0, 60.0) | 64.0 (46.0, 72.2) | ◇◇◆ | 120.00 | 120.00 |
| Iron, Total (µg/L) | 16 | 16 | 317 | 312 | 393.42 | 152.87 | 1051.0 (820.0, 1200.0) | 266.4 (222.5, 301.0) | ◆◆◆ | 3,160.00 | 485.00 |
| Lead, Dissolved (µg/L) | 11 | 12 | 163 | 176 | 0.17 | 0.13 | 1.00 (0.66, 2.00) | 1.00 (0.36, 1.00) | ◇◇◇ | 4.00 | 3.38 |
| Lead, Total (µg/L) | 39 | 39 | 618 | 639 | 3.00 | 1.00 | 9.00 (6.70, 9.71) | 3.00 (2.00, 3.00) | ◆◆◆ | 26.04 | 8.62 |
| Nickel, Dissolved (µg/L) | 4 | 4 | 17 | 17 | 1.00 | 1.13 | 1.80 (1.00, 2.00) | 2.30 (1.00, 3.70) | ◇◇◆ | 2.00 | 4.40 |
| Nickel, Total (µg/L) | 10 | 10 | 113 | 109 | 2.50 | 2.00 | 4.39 (3.50, 6.00) | 2.20 (2.00, 2.70) | ◆◆◆ | 9.38 | 5.92 |

| | BMPs | | EMCs | | 25th | | Median | | | 75th | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | In | Out | In | Out | In | Out | In | Out | Difference | In | Out |
| Zinc, Dissolved (µg/L) | 18 | 18 | 360 | 346 | 10.00 | 5.58 | 23.00 (18.99, 24.95) | 15.00 (11.73, 16.20) | ◆◆◆ | 40.00 | 29.75 |
| Zinc, Total (µg/L) | 48 | 48 | 804 | 767 | 28.47 | 11.00 | 49.00 (43.10, 50.00) | 21.37 (20.00, 23.00) | ◆◆◆ | 85.00 | 38.60 |

## Certifications[30]: None Available

## Component Specific Considerations

- As a primary settling practice, sediment basins may not be effective for removal of dissolved pollutants.
- Sediment basins can work well upstream of filters or other practices that require a controlled flow rate.
- Provisions for maintenance (e.g., periodically removing the accumulated sediment) must be provided to maximize the operational life of the system.
- Include local aviation authorities if the stormwater BMP is situated within 10,000 feet of an airport operations area.

## Design Criteria Considerations

- The design goal for a basin is to increase the cross-sectional flow area so that flow velocity is sufficiently reduced to promote settling of sediment within the basin.
- A sediment basin should maintain a permanent pool of water unless this is precluded by site conditions, local laws, or safety concerns. This can help to prevent resuspension of soil that has already settled out, and will provide an immediate reduction in velocity for incoming storm flows.
- Depending on proximity to airports, vegetation must not be allowed to develop at the BMP that attracts wildlife, which can pose a hazard to aviation.
- If the stormwater BMP is close to an airport operations area, standing water should drain within 48 hours.
- A sediment basin must have sufficient capacity, including total volume and volume for sediment storage, to reduce the velocity of expected storm flows and allow for deposition.
- A sediment basin should be designed to store the expected volume of sediment from the contributing drainage area, consistent with the expected maintenance frequency.
- A sediment basin may or may not be lined. Local regulations may require a liner in certain circumstances (e.g., in water supply areas where groundwater contamination is of particular concern).
- The outlet is typically at the surface at the opposite end of the basin from the inlet.
- Basins should typically be half as wide as they are long; however, appropriately placed baffles may provide sufficient velocity reductions where there are restrictions preventing the optimal shape.
- Baffle sheets with holes may be used to spread the flow over the whole cross-section of the basin.
- Design of detention storage should be sized using local design guidance, or as indicated by hydrologic and hydraulic modeling to attain flow through velocities conducive to settling.
- Temporary flood storage should be calculated based on local storm patterns with the goal of maintaining quiescent flow from inlet to outlet, or else should be diverted around the sediment basin to avoid resuspension.
- Basins typically have at least one side made from bermed dirt forming a dam. Above the permanent water line, dam slopes are typically 3:1 (H:V), though retaining walls may be used where space constraints are present.
- Below the permanent water line, slopes can be 2:1 (H:V), although a shallow bench below the water line may be advisable to reduce drowning hazard.
- The principal spillway should be at least a 6-inch vertical pipe opening at the normal high water level, which bends and leaves the basin horizontally at the base of the dam’s outside wall.
- The auxiliary spillway should be 1 foot over the normal high water level where excess water from heavy storms can pass over the crest of the spillway and flow down on a stabilized surface durable enough to withstand heavy and fast water flow damage.
- The top of the dam should have a freeboard depth above the height of the auxiliary spillway, the depth of which

is calculated based on a comparison of water pore pressure, soil pressure and a safety factor.

- Locally appropriate vegetation that can thrive under operational conditions should be incorporated into the design to help stabilize the surface of the banks.
- Basins should be located at least 50 feet from designated floodplains unless local ordinances are more restrictive.
- A basin should not be constructed within a stream or waters of the state.
- Factors affecting the performance of a sediment basin include (1) size and shape of the basin, (2) soil properties, (3) runoff volume and flow, (4) water chemistry, and (5) permanent vs. dry pond design.
- A two-cell design may be used with a berm in between to allow sediment/particulate to settle out prior to flow into the second cell.
- Length to width ratio should be maximized.
- For proper function, a baffle may be placed in cell 2 to maximize sediment removal efficiency and to increase the effective flow rate from the inflow to the riser.
- A means of dewatering the sediment basin (e.g., a riser and barrel) should be provided.
- An emergency spillway should be designed to act as a safety release for a sediment basin by conveying the larger less frequent storms through the basin without overtopping the embankment. It also acts as an emergency outlet if excessive sedimentation or damage to the riser occurs.
- The emergency spillway may consist of a non-erodible open channel constructed adjacent to the embankment.
- Finally a service road is necessary to access general maintenance of the sediment basin without hurting the integrity of the sediment basin construction.

## Construction Information

- Vegetation must be established as soon as possible following construction to help stabilize the surface of the banks.
- The basin must be built within the property boundaries unless special easements are granted.
- Sediment basins may be newly constructed for post-construction purposes, or may be constructed from construction-phase sedimentation basins.
- Conversion of construction-phase sedimentation basins to post-construction sediment basins may require substantial modification including regrading, cleaning out deposited sediment, replacement of inlet and outlet structures, and preparation of soil for planting.
- Sediment basins must be constructed in full accordance with approved design plans and shall comply with all applicable state and local ordinances, permits, rules and regulations.
- The slopes of the bank must be stabilized and the embankment compacted.
- The pipe from the riser to the outfall should be watertight.
- Rip rap, or other effective methods, should be utilized at the outflow to prevent erosion and further disperse the energy from the flow.

A generalized schematic depicts a typical sediment basin.

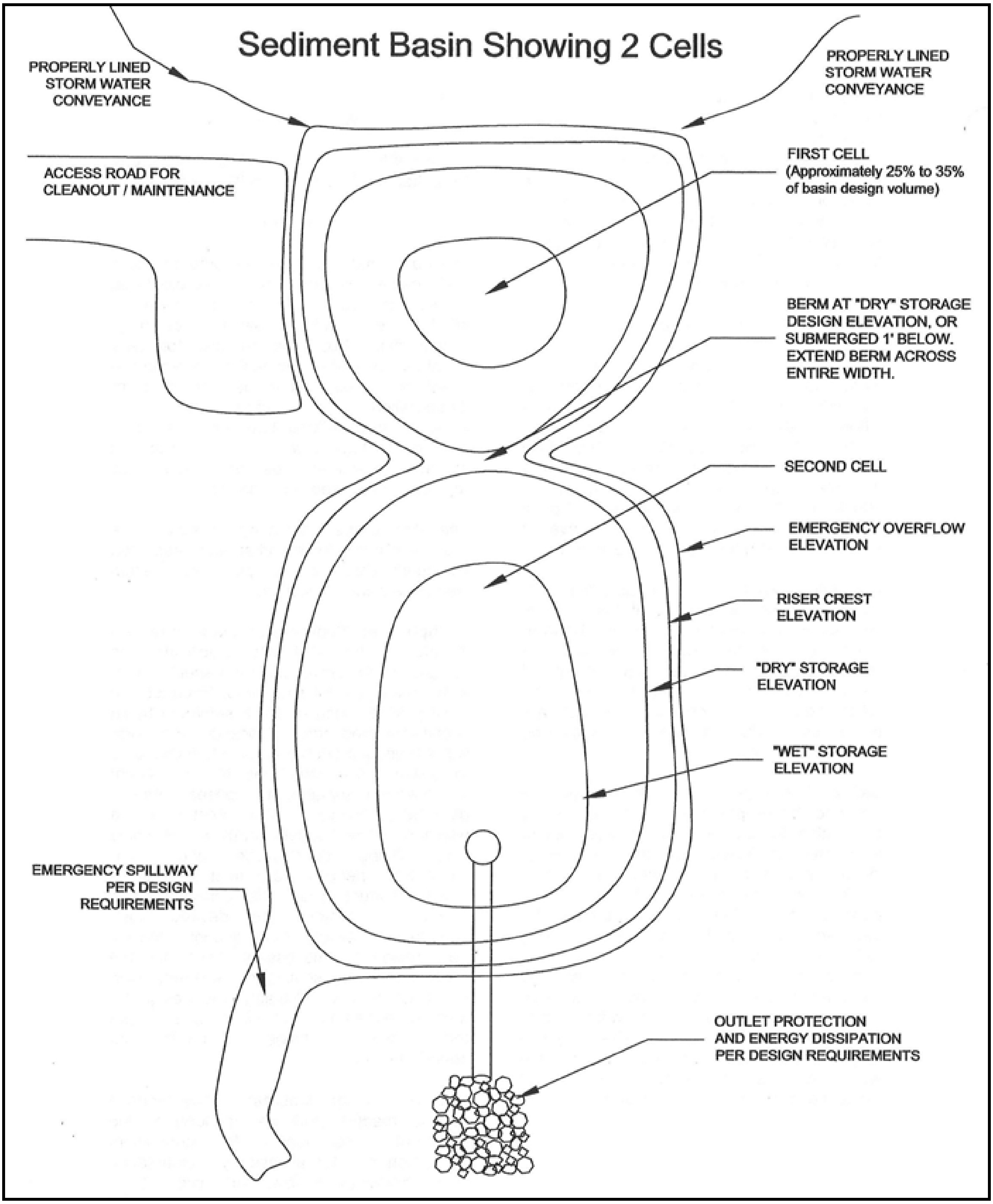


**Figure 1: (TDEC 2002). Erosion & Sediment Control Handbook: A Guide for Protection of State Waters Through the Use of Best Management Practices during Land Disturbing Activities, Second Editions (Tennessee Department of Environmental Protection, March 2002).**

## Operation and Maintenance Considerations

**Monitoring and Inspection**

- The sediment basin should be easily accessible for maintenance and repair.

- The sediment basin should be inspected on a weekly basis, within 24 hours of a predicted storm event and at the end of an extended rain event.
- If baffles are installed, they should be checked for holes and breaks.
- Trash racks should be inspected for debris and blockages.
- The emergency spillway should be inspected for structural integrity and obstructions.
- The banks should be inspected to ensure structural integrity and the inlet and outlet should be inspected to ensure that they are at design flow capacity.
- Any perimeter fences and signage should be inspected to ensure that they are not damaged.
- The outer edge of the outlet pipe should be inspected for excessive seepage and the riser pipe should be inspected for vandalism or damage.
- The basin should be inspected for accumulated sediment. It may be helpful to measure or mark the sediment level in the basin to establish a baseline sediment level prior to bringing the basin online.

**Maintenance**

- If the inlet, outlet or banks require repair, these should be completed as soon as possible.
    - Accumulated sediment should be removed when sediment reaches one half of the basin design. Sediment removed from the basin should be disposed of in a proper manner, consistent with local regulations, and placed in a designated disposal area.
    - The permanent pool should be inspected for evidence of pollutants such as oil, grease, odors and discolored water.
- Vector control should be conducted on an as needed basis. Mosquito fish (where permitted), mosquito dunks (where permitted), and aeration are some possible means of enhancing natural mosquito control.
- Excessive vegetation in the permanent pool should be removed on an annual or as needed basis, consistent with original design objectives.

**Example inspection checklists**

- City of Freemont, CA Extended Detention Basin inspection and Maintenance Check list
- City of Franklin TN Stormwater Pond Inspection and Maintenance Check list
- Genesee County Drain Commissioner low Impact Development Manual for Michigan, Appendix F; Maintenance Inspection Checklist

**Example maintenance agreements**

- City of Winston-Salem, NC Wet Detention Basin Operations and Maintenance Manual
- Minnesota Stormwater Manual Example Maintenance Agreement 1
- North Royalton, OH Inspection and Maintenance Agreement for Stormwater Best Management Practices

## References and Links

- California Storm Water Quality Association Stormwater Best Management Practice Handbook Portal: Construction Fact Sheet, SE-2 – Sediment Basin
- Wisconsin Department of Natural Resources Sediment Control Standard 1064: Sediment Basin
- USEPA Stormwater Wet Pond and Wetland Management Guidebook
- Dyersburg, TN Erosion & Sediment Control Handbook – Sediment Basin
- Massachusetts Erosion and Sediment Control Guidelines for Urban and Suburban Areas – Sediment Basin
- Fundamentals of Erosion Prevention & Sediment Control Inspections, Tennessee Department of Environment and Conservation, Buchanan, John R, Ph.D., P.E., 2014 (Buchanan 2014b)
- Tennessee Department of Environment and Conservation Erosion and Sediment Control Handbook, Fourth Edition
- Michigan DEQ NPS BMP Manual, SB-1 – Sediment Basin

# F.13 Skimmers and Booms

**December 2018**

## Description

Removes floatable gross solids, floatable liquids, and particles brought to the surface via floatation mechanisms.

### Pollutants of Concern Treated by Skimmers and Booms

| Skimmers and Booms | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Solids** | **Solid Metals** | **Dissolved Metals** | **Hydrocarbons** | **Nutrients** | **Ammonia** | **pH** | **Bacteria Pathogens** | **Organics** | **Trash** | **Pesticides Herbicides** |
| | | | O/G | | | | | | X | |
| | | | TPH | | | | | | | |

### Data Available in International Stormwater BMP Database: ☒ Yes ☐ No

## Certifications[31] None Available

## Design Criteria Considerations

The basis for the use of skimmers and booms is the natural separation process of substances with a lower specific gravity than water, which causes them to rise to the surface, or float. The design principle is to interrupt the path on the surface of a quiescent pool of water flowing gently from an inlet to an outlet. Floating substances will be stopped at the surface interruption as the water flows under it, and the floating scum, oil, twigs, trash, or whatever can be removed.

The skimmer or boom must interrupt all possible paths between the inlet and the outlet. This is usually done by placing a skimmer or boom from side to side across the basin between the inlet and the outlet, by circling or surrounding the outlet with a skimmer, or by discharging from the outlet just under the surface.

## Construction Information

The purpose of a skimmer or boom is to slow the spread, or contain undesirable floating liquids or particulates. Booms are placed across narrow entrances such as stream outlets or a small inlet to hinder the passage of floatable liquids or particulate into marshland or a sensitive habitat. A boom can be placed around a sensitive area to prevent materials such as oils from reaching it. A hard boom is used to deflect or contain a plume. A sorbent boom looks like a sausage and is made of material to absorb oils. Skimmers are devices that can remove oil from the water surface before it reaches sensitive areas.

The success of booming operations can be limited by the rapid spread of floating contaminant and the effects of currents, wind or waves. Booms should be sufficiently flexible to follow wave motion, yet sufficiently rigid to retain as much floating material as possible. As a general rule, the minimum height of a freeboard to prevent oil splash over should be selected. Too high a freeboard may cause containment problems due to wind. Booms should be anchored or moored to prevent driftage. Available boom designs should be evaluated to meet the needs of the current problem. Appreciate the limitations of the booms and be prepared to improvise or react accordingly to the situation at hand. Most conventional booms are not capable of contaminant containment in water velocities in excess of 1 knot.

There are a variety of skimmers; however, focus will be placed on those types deployed manually in a port or shoreline. Skimmers should be deployed in the highest concentration of oil. The goal is to extract the greatest amount of product from the water. Skimmers are often combined with pumping elements. Skimmers are designed to recover oil in preference to water. Important factors in selecting a skimmer are its viscosity and adhesive properties. The recovery element of a skimmer diverts the oil from the water surface to the inlet side where it is pumped to a receiving container for disposal. Oleophilic skimmers have an affinity for oils. The contaminant is scraped off the skimmer and removed. Non-oleophilic skimmers rely on vacuuming/pumping the oil or plume to a storage container. Skimmers should be monitored to ensure optimum oil to water ratio is obtained. Often skimmers can be used in combination with booms to help centralize the plume.

**Figure 2: Placement of booms to prevent an oil sheen from spreading in the Columbia River.**
*Source: The Seattle Times, Mike Carter, March 19, 2017.*

## Operation and Maintenance (O&M) Considerations

**Monitoring**

| Frequency | Inspection Actions |
|---|---|
| Periodic | • Inspection should be performed following rain events.<br>• Inspection should check for rusted or broken sections to be repaired as needed. |
| Additional Consideration | • Check the specific inspection schedule for a manufactured treatment device. |

**Maintenance**

| Frequency | Preventative Maintenance Actions |
|---|---|
| Periodic | • Trash and debris should be removed as needed and may be removed by hand or by vacuum truck. Disposal should be in accordance with state and local requirements.<br>• Replace media as required based on loading rates. |
| Additional Consideration | • Check the specific maintenance schedule for a manufactured treatment device as required by the manufacturer. |

## Resources for O&M

- Contech Engineered Solutions CDS Inspection and Maintenance Guide
- Bio Clean Environmental Services, Inc. Maintenance and Cleaning Manual
- Floatable Skimmers, Hamilton County, TN Best Management Practices Manual, Section 8.1 – Floatables Skimmer

## References and Links

- International Tank Owners Pollution Federation Limited (ITOPF) Handbook Pgs 21 – 22

## F.14 Soil Management and Soil Amendments

**December 2018**

### Description

Soils in terrestrial environments can have multiple pollutant removal functions including sorption and precipitation of metals, phosphorus, and organics, as well as hosting conditions amendable to biological transformations (e.g., denitrification). Proper soil management during construction phase can help preserve these functions during the post-construction phase. Application of soil amendments (i.e., substances added to soils as specific compositional design enhancements) can improve the pollutant removal functions of soil.

#### Pollutants of Concern Treated by Soil Management and Soil Amendments

| Soil and Soil Amendments | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Solids** | **Solid Metals** | **Dissolved Metals** | **Hydrocarbons** | **Nutrients** | **Ammonia** | **pH** | **Bacteria Pathogens** | **Organics** | **Trash** | **Pesticides Herbicides** |
| TSS | Cu | Cu | O/G | Phosphorus | $NH_3$ | X | X | PCB | | X |
| SSC | Zn | Zn | TPH | Ortho-Phosphorus | | | | PAH | | |
| Turbidity | Pb | Pb | | Total Nitrogen | | | | | | |
| Total Solids | Cd | Cd | | Kjeldahl Nitrogen | | | | | | |
| Total Dissolved Solids | Cr | Cr | | Nitrate / Nitrite | | | | | | |
| | Ni | Ni | | | | | | | | |
| | As | As | | | | | | | | |

**Data Available in International Stormwater BMP Database: ☒ Yes ☐ No**

### Certifications[32] None Available

### Component Specific Considerations

- Space Restrictions: not applicable. Any area on site where soils are present can be a soil preservation or soil amendment candidate area.
- Soil type: In general, “poorer” soils may realize greater benefit from amendments.
- Both soil preservation and soil amendment should seek to match topsoil similar to that existing in undeveloped sites. Areas can be improved in tilth and organic matter to help maintain a soil appropriate for vegetation.
- Vegetation: A preferred option is a perennial variety that is appropriate for the climate and soil type. No to low maintenance types are preferable.
- Aviation concerns: Depending on proximity to airports, vegetation must not be allowed to develop at the BMP that attracts wildlife, which can pose a hazard to aviation, especially ducks and geese. If the stormwater BMP is close to an airport operations area, standing water should drain within 48 hours.
- Topography: Steep slopes may be unsuitable or need additional mechanical stabilization.
- Temperature issues: Replacing impervious surfaces with soils can greatly reduce peak temperatures from the resulting runoff.
- Long dry periods: Topsoil of suitable tilth and organic matter is able to maintain vegetation with less watering longer than when no topsoil is present.
- Pollutant concentration concerns: Soil testing and proper application of amendments are key to ensuring amendments are retained on site. Excessive compost application or poorly timed surface application of amendments can lead to greater export, and a greater need to reapply.
- Volume reduction: Reducing the water flow volume significantly reduces both total runoff volume and peak flows. Much of the storm water never leaves the site as the water is captured and evaporates or is utilized by vegetation. Peak runoff rates are lowered as the time of concentration (delay from precipitation to runoff) is

increased since more time is necessary to saturate the ground prior to runoff.
- Construction costs: Plan ahead during the construction process to stockpile and respread topsoil prior to final stabilization. Developers often respread prior to house building necessitating removal and respread after houses are built. Developers can also leave one topsoil stockpile on each individual house lot or one large stockpile in the development for builders to spread on their lots. Subsoil that has been compacted by heavy machinery may need decompaction for best results.
- Amendments: Sites on heavily worked areas may need additional organic matter to improve or even create artificial topsoil. This can be done with compost, other organic sources and in situ soil. This can help sustain a vegetative layer of sufficient density.
- Existing sites: Soil can be improved on existing sites by the addition of offsite topsoil, compost, other organic materials, or sand, as appropriate. These can be applied either as a thin layer that naturally incorporates itself over time or mechanically incorporated into the existing soil.
- Maintenance costs: There are very few things beyond vegetation management (e.g., cutting and watering) that would be required at any vegetated site.
- Limitations: Areas that have little organic matter in the topsoil, and little to no compost or other organic matter, may have limited potential for amendment.

## Design Criteria Considerations

- Include local aviation authorities if the stormwater BMP is situated within 10,000 feet of an airport operations area.
- Soil testing should be conducted prior to design and construction to determine the type of soil management or amendment.
- Management may include tilling to restore soil porosity.
- Amendments for consideration may include:
    - Compost, to add nutrients and organic matter, and to increase water retention capacity
    - Chemical treatment such as lime to raise pH
    - Polymers to increase water retentions (i.e., biopolymers, petroleum-based, etc.)
        - Exercise caution when choosing polymers. Clearly identify what is expected to be accomplished and evaluate whether the polymer will accomplish the goals.

## Links and References to Design of Soil BMPs

- University of California, Agriculture and Natural Resources “A Greenhouse Experiment finds Water-sorbing Polymers do not Conserve Water.
- Iowa Storm Water Management Manual – Chapter 5 – Section 6: Soil Quality Management and Restoration
- Washington State’s Soil BMPs for New Construction: How-to Guide, Specs, and Low Impact Development
- Michigan DEQ NPS BMP Manual – Soil Management Chapter
- Pennsylvania Stormwater BMP Manual – Section 6.7 – BMP 6.7.3 Soil Amendment and Restoration
- Virginia DEQ Stormwater Design Specification No. 4 – Soil Compost Amendment
- Tennessee Permanent Stormwater Management and Design Guidance Manual – Appendix C – Soil Amendments
- USDA NRCS Soil Quality Technical Notes

## Construction Information

- Earthwork may be required.
- Amendments need to be vetted for proper use and placement.
- Seasonal earthwork and application may be required or may not be appropriate depending on location.

**Timeframe**

- Hold a pre-construction meeting.
    - Include local aviation authorities if the stormwater BMP is situated within 10,000 feet of an airport operations area.
- Assemble materials on site and ensure all material meets design specifications.
- Install erosion and sediment controls.
- Area to be amended/treated should be tilled to a specified depth.
- Spread and mix amendment as per specifications.

- Level and seed the site per local / regional specifications.
- Follow erosion control measures as per site plan (e.g., silt fence).
- Stabilize exposed soils.

**Protection**

- Use of soil amendments will require review of product safety data sheets and proper use of personnel protective equipment (PPE).
- Soil testing should be conducted within one to several weeks of post construction to ensure the amendment has been properly incorporated into the soil.

## Operation and Maintenance Considerations

**Monitoring**

A visual inspection should occur periodically and whenever an above average rain event occurs to evaluate excessive runoff, flooding, other non-infiltration, dead vegetation, and compaction.

**Maintenance**

- Depending on the amendment type used, there may be a need for reapplication.
- All bare or dead spots should be seeded or have vegetation added.
- Additional fertilizing may be required.
- If excessive compaction occurs, the soil may need to be tilled, ripped or thatched depending on the site-specific requirements.

**Inspection Checklist**

- Log locations using GPS coordinates for ongoing site inspections and management.
- Dig test pit to verify depth of soils and soil amendment.
- A rod penetrometer should be used to establish uncompacted soil depth.

## References and Links


- New York State Stormwater Management Design Manual – Chapter 6: Ponds
- Virginia DEQ Stormwater Design Specification No 4: Soil Compost Amendment
- (Larson, 2 et. al., 2016) Larson, S., W.A. Martin, R. Wade, R. Hudson, C. Nestler. 2016. “Technology Transfer of Biopolymer Soil Amendments for Rapid Revegetation and Erosioin Control at Fort A.P. Hill, Virginia.” *S. Army Corp of Engineers* ERDC/EL TN-16-2.


# F.15 Tanks and Vaults

**December 2018**

## Description

Typically, tanks and vaults are underground structures that are used to store and either slowly release or reuse surface water. Detention tanks are underground storage facilities typically constructed with large diameter corrugated metal pipe. Detention vaults are box shaped underground storage facilities typically constructed with reinforced concrete. For runoff treatment, see the Information Sheet for Wet Ponds.

### Pollutants of Concern Treated by Tanks and Vaults

| Tanks and Vaults | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Solids** | **Solid Metals** | **Dissolved Metals** | **Hydrocarbons** | **Nutrients** | **Ammonia** | **pH** | **Bacteria Pathogens** | **Organics** | **Trash** | **Pesticides Herbicides** |
| TSS | Cu | | O/G | Phosphorus | | | X | PCB | X | |
| SSC | Zn | | TPH | | | | | PAH | | |
| Turbidity | Pb | | | | | | | | | |

| Tanks and Vaults | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Solids** | **Solid Metals** | **Dissolved Metals** | **Hydrocarbons** | **Nutrients** | **Ammonia** | **pH** | **Bacteria Pathogens** | **Organics** | **Trash** | **Pesticides Herbicides** |
| Total Solids | Cd | | | | | | | | | |
| | Cr | | | | | | | | | |
| | Ni | | | | | | | | | |
| | As | | | | | | | | | |

**Data Available in International Stormwater BMP Database: ☒ Yes ☐ No**

## Certifications[33] None Available

## Component Specific Considerations

- Space restrictions: Typically buried so there are land requirements for cover. BMP can be placed beneath pavement for roadways or parking.
- Soil type: Soils must provide structural stability for foundation of tank or pipe.
- Vegetation: No vegetation is used in vaults or tanks.
- Continuous rainfall limits ability to empty vault and reduces available storage for detention. Larger facilities are needed in wetter locations.
- Pollutant concentration concerns: Provide limited removal of pollutants and may export pollutants if not properly maintained. High flows may re-suspend solids on bottom of tank.
- Construction costs: Moderate to high, but do not eliminate use of land above the tank.
- Maintenance costs: Moderate.
- Mosquitoes: If water does not drain properly, then vaults can become mosquito breeding grounds.
- Groundwater: Maintain separation from groundwater in accordance with local requirements. High groundwater may cause the tank to float when empty.

## Design Criteria Considerations

- Washington DC Department of Energy and Environment: Stormwater Best Management Practices Chapter 3, Stormwater Storage Practices
- Fayetteville, AR Drainage Criteria Manual – Appendix E – Detention Structural Controls
- Oregon Department of Transportation Highway Division Hydraulics Design Manual – Chapter 12: Storage Facilities

## Construction Information

The purpose of a vault is to manage and control the volume, and discharge timing, of stormwater runoff and mitigate erosion and flooding. This type of BMP may be selected when space is not available for a sediment or retention basin. Often this can be a preferred option in a basement or garage or to keep waterfowl away, which might be attracted by a pond. Materials for a vault include corrugated metal pipe, aluminum steel, concrete, fiberglass or plastic. Consideration must be made for the potential use of vehicles above the structure after installation. These structures do very little for water treatment but can control peak flow.

Filters should be placed on the inlet to prevent soil and sediment intrusion. After installation there should be adequate ports to inspect and maintain the storage and outfall points of the system. Sediment and debris extraction will be necessary periodically. Above access via a ladder may be necessary and inspected routinely. In addition piping, valves, vents or baffles need to be inspected.

**Figure 3: The Government of Nashville and Davidson County elected to remove an above-ground detention pond and construct an underground stormwater detention vault.**
*Photo Credit: Oldcastle Solutions.*

### Operation and Maintenance (O&M) Considerations

| Frequency | Inspection Actions |
|---|---|
| Annual | • Inspect tanks and vaults for structural concerns and sediment accumulation.*<br>• Check access points (e.g., manholes, ladders, etc.) for ease of ingress and egress. |
| Periodic | • Inspection should be performed following rain events to check for proper drawdown times. |
| Additional Consideration | • Check the specific inspection schedule for a manufactured treatment device. |
| *Only professionals with OSHA-confined space certifications should enter below-ground stormwater systems. | |

| Frequency | Preventative Maintenance Actions |
|---|---|
| Annual | • Based on results of inspection, structural concerns should be addressed.<br>• Repair/replace missing ingress and egress components as required. |
| Periodic | • Remove blockages from outlets and inlets as required.<br>• Remove sediment and debris when accumulation exceeds a specified percent. Disposal should be in accordance with state and local requirements.<br>• Repair any openings or voids that may allow soil or groundwater intrusion. |
| Additional Consideration | • Check the specific maintenance schedule for a manufactured treatment device as required by the manufacturer. |

**Resources for O&M**

- City of Battle Ground, WA Stormwater Facility Maintenance Manual BG02.01
- Portland Stormwater Management Manual Chapter 3, Operations and Maintenance, January 2014
- NYC Department of Environmental Protection Guidelines for the Design and Construction of Stormwater

Management Systems

## References and Links


- Tennessee Erosion & Sediment Control Handbook, Tennessee Department of Environment and Conservation – Water Pollution Control, March 2002 (TCEQ 2002)
- Fundamentals of Erosion Prevention & Sediment Control Inspections, Tennessee Department of Environment and Conservation, Buchanan, John R, Ph.D., P.E., 2014 (Buchanan 2014a)
- Stormwater Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring, Detention Tanks and Vaults (Fact Sheet), Washington D.C., United States Department of Transportation, Federal Highway Administration (USDOT 2000)


# F.16 Vegetated Systems, Swales and Strips

**December 2018**

## Description

Vegetation can be used to uptake organic and inorganic pollutants from water and soil solutions. Water filters through the vegetation and root systems.

### Pollutants of Concern Treated by Vegetated Systems

| Vegetative Systems: Swales and Strips | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Solids** | **Solid Metals** | **Dissolved Metals** | **Hydrocarbons** | **Nutrients** | **Ammonia** | **pH** | **Bacteria Pathogens** | **Organics** | **Trash** | **Pesticides Herbicides** |
| TSS | Cu | Cu | O/G | | | | X | PCB | X | X |
| SSC | Zn | Zn | TPH | | | | | PAH | | |
| Turbidity | Pb | Pb | | | | | | | | |
| Total Solids | Cd | Cd | | | | | | | | |
| | Cr | | | | | | | | | |
| | Ni | Ni | | | | | | | | |
| | As | | | | | | | | | |

**International Stormwater BMP Database Performance Summary, 2016 – Grass Strips International Stormwater BMP Database Prepared for City and County of Denver and Urban Drainage and Flood Control District, February 2017. Prepared by Wright Water Engineers and Geosyntec Consultants. (Wright Water Engineers and Geosyntec (Consultants 2016)**

| | **BMPs**[34] | | **EMCs**[35] | | **25th** | | **Median Concentration**[36] | | | **75th** | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **In** | **Out** | **In** | **Out** | **In** | **Out** | **In** | **Out** | **Difference**[37] | **In** | **Out** |
| Fecal Coliform (MPN/100 mL) | 15 | 15 | 184 | 169 | 120 | 33 | 900 (400, 1,500) | 400 (200, 800) | ◇◆◆ | 10,000 | 5,600 |
| Kjeldahl nitrogen (TKN) (mg/L) | 21 | 20 | 323 | 312 | 0.56 | 0.29 | 0.94 (0.83, 1.02) | 0.50 (0.43, 0.55) | ◆◆◆ | 1.78 | 1.00 |
| Nitrogen, $NO_x$ as N (mg/L) | 22 | 21 | 346 | 328 | 0.21 | 0.34 | 0.34 (0.31, 0.37) | 0.57 (0.49, 0.63) | ◆◆◆ | 0.58 | 0.94 |
| Nitrogen, Nitrate ($NO_3$) as N (mg/L) | 12 | 12 | 178 | 174 | 0.20 | 0.30 | 0.32 (0.28, 0.35) | 0.56 (0.46, 0.63) | ◆◆◆ | 0.59 | 0.94 |

| | BMPs[34] | | EMCs[35] | | 25th | | Median Concentration[36] | | | 75th | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | In | Out | In | Out | In | Out | In | Out | Difference[37] | In | Out |
| Nitrogen, Nitrite ($NO_2$) + Nitrate ($NO_3$) as N (mg/L) | 10 | 9 | 168 | 154 | 0.24 | 0.38 | 0.35 (0.31, 0.40) | 0.57 (0.48, 0.68) | ◆◆◆ | 0.58 | 0.94 |
| Nitrogen, Total (mg/L) | 10 | 9 | 160 | 151 | 0.79 | 0.73 | 1.22 (1.03, 1.33) | 1.05 (0.90, 1.16) | ◇◇◆ | 2.10 | 1.72 |
| Phosphorus as P, Dissolved (mg/L) | 11 | 10 | 118 | 100 | 0.01 | 0.02 | 0.05 (0.03, 0.06) | 0.04 (0.03, 0.06) | ◇◇◆ | 0.09 | 0.10 |
| Phosphorus as P, Total (mg/L) | 23 | 22 | 372 | 349 | 0.07 | 0.04 | 0.15 (0.13, 0.15) | 0.09 (0.07, 0.10) | ◆◆◆ | 0.28 | 0.16 |
| Phosphorus, orthophosphate as P (mg/L) | 7 | 7 | 116 | 115 | 0.02 | 0.02 | 0.04 (0.03, 0.05) | 0.03 (0.02, 0.04) | ◇◇◆ | 0.09 | 0.07 |
| Total suspended solids (mg/L) | 25 | 25 | 400 | 377 | 22.0 | 3.9 | 56.4 (46.0, 61.9) | 9.0 (6.4, 10.0) | ◆◆◆ | 120.0 | 22.8 |
| Arsenic, Dissolved (µg/L) | 9 | 9 | 104 | 100 | 0.26 | 0.33 | 0.50 (0.48, 0.56) | 0.60 (0.50, 0.66) | ◇◇◆ | 1.13 | 1.00 |
| Arsenic, Total (µg/L) | 9 | 9 | 104 | 100 | 0.50 | 0.48 | 0.91 (0.69, 1.20) | 0.74 (0.58, 0.98) | ◇◇◇ | 1.85 | 1.30 |
| Cadmium, Dissolved (µg/L) | 10 | 10 | 106 | 102 | 0.10 | 0.12 | 0.20 (0.10, 0.20) | 0.15 (0.14, 0.20) | ◇◇◆ | 0.20 | 0.20 |
| Cadmium, Total (µg/L) | 16 | 16 | 194 | 194 | 0.10 | 0.03 | 0.30 (0.20, 0.36) | 0.08 (0.07, 0.12) | ◆◆◆ | 0.60 | 0.20 |
| Chromium, Dissolved (µg/L) | 10 | 10 | 114 | 99 | 0.50 | 0.52 | 1.00 (0.60, 1.00) | 1.00 (1.00, 1.00) | ◇◇◆ | 1.00 | 1.00 |
| Chromium, Total (µg/L) | 10 | 10 | 115 | 109 | 1.20 | 0.82 | 2.00 (1.50, 2.30) | 1.00 (1.00, 1.10) | ◆◆◆ | 3.37 | 1.70 |
| Copper, Dissolved (µg/L) | 11 | 11 | 189 | 176 | 1.63 | 1.50 | 3.75 (2.70, 4.10) | 3.25 (2.53, 3.90) | ◇◇◆ | 7.60 | 6.90 |
| Copper, Total (µg/L) | 20 | 20 | 345 | 330 | 4.97 | 2.46 | 9.98 (8.60, 10.00) | 5.53 (4.58, 6.30) | ◆◆◆ | 16.87 | 10.00 |
| Iron, Total (µg/L) | 8 | 7 | 153 | 132 | 267.76 | 113.23 | 642.3 (452.2, 755.0) | 209.7 (162.8, 256.9) | ◆◆◆ | 1,460.00 | 420.69 |
| Lead, Dissolved (µg/L) | 10 | 10 | 144 | 140 | 0.32 | 0.41 | 1.00 (1.00, 1.00) | 1.00 (0.49, 1.00) | ◇◇◆ | 1.50 | 1.00 |
| Lead, Total (µg/L) | 20 | 19 | 303 | 289 | 2.66 | 0.71 | 10.00 (8.00, 12.00) | 1.70 (1.20, 2.00) | ◆◆◆ | 22.25 | 3.78 |
| Nickel, Dissolved (µg/L) | 10 | 10 | 113 | 109 | 0.82 | 0.74 | 1.85 (1.00, 2.00) | 1.30 (0.98, 2.00) | ◇◇◇ | 2.10 | 2.00 |
| Nickel, Total (µg/L) | 10 | 10 | 115 | 109 | 2.00 | 1.12 | 3.28 (2.43, 3.60) | 2.00 (2.00, 2.37) | ◆◆◆ | 5.10 | 3.40 |

| | BMPs[34] | | EMCs[35] | | 25th | | Median Concentration[36] | | | 75th | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | In | Out | In | Out | In | Out | In | Out | Difference[37] | In | Out |
| Zinc, Dissolved (µg/L) | 11 | 11 | 189 | 174 | 11.20 | 1.81 | 28.20 (21.00, 36.00) | 5.65 (3.37, 8.20) | ◆◆◆ | 84.00 | 21.00 |
| Zinc, Total (µg/L) | 23 | 23 | 387 | 358 | 23.30 | 4.18 | 62.90 (52.40, 70.00) | 14.14 (12.00, 16.44) | ◆◆◆ | 140.97 | 29.97 |

## Certifications[38]

### Washington State Technology Assessment Protocol – Ecology

| | TSS | Enhanced (Dissolved Metals) | Total Phosphorus | Oil/Grease |
|---|---|---|---|---|
| **General Use Level Designation** | | | | |
| Washington State Department of Transportation, Media Filter Drain | ☒ | ☒ | ☒ | ☐ |
| Washington State Department of Transportation, Compost-Amended Biofiltration Swale | ☒ | ☒ | ☐ | ☐ |
| **Conditional Use Level Designation** | | | | |
| Washington State Department of Transportation, Compost-Amended Biofiltration Swale | ☐ | ☐ | ☒ | ☐ |

## Component Specific Considerations

- *Aviation concerns*: Depending on proximity to airports, vegetation must not be allowed to develop at the BMP that attracts wildlife, which can pose a hazard to aviation.

## Design Criteria Considerations

- Include local aviation authorities if the stormwater BMP is situated within 10,000 feet of an airport operations area. If the stormwater BMP is close to an airport operations area, standing water should drain within 48 hours.
- Avoid excessive slopes, to minimize flow velocities, resulting in increased treatment efficiency. Excessive flow velocities may also lead to erosion.
- Ensure sufficient slope to convey water away from pollutant sources and through the vegetated system.
- Ensure sufficient length of the swale or strip to ensure BMP goals are met (e.g., infiltration, deposition, biofiltration, etc.).
- Consider the contributing drainage area and ensure that the BMP is not subjected to excessive flows.
- Check dams may be used to promote sedimentation and infiltration. Use of check dams to promote infiltration will result in nutrient removal similar to other infiltration practices.
- For vegetated filter strips, ensure that stormwater is evenly distributed across the area (e.g., use level spreader).
- For vegetated swales, choose a channel cross-section and side slopes that ensure long-term stability.
- Ensure that vegetated systems are not installed on overly compacted soil. Consider designing the surrounding area to discourage vehicle and foot traffic.
- Pretreatment is recommended for swales.

## Construction Information

### Construction Submittals

- Solid pipes: Pipe sizes, diameter and materials are important to the functionality of a properly functioning drainage system. Drainage volumes, velocities and flow rates are dependent on these factors. It is important to reference the plans and specifications when determining the acceptability of each of these drainage components.
- Aggregate: Size and material is important when selecting aggregate. Void ratios, which affect the detention volume of the BMP, are specifically affected by these factors. It is also important that clean aggregate should always be used when installing these devices.
- Landscape fabrics: Landscape fabrics and watertight mats are used in BMP design. It is important to understand if the project is designed to infiltrate. The materials used on, and around, the landscape fabrics are also important when determining the type and thickness of the material.
- Drainage structures (inlets, cleanouts and manholes): Size is an important component of these features. Sizes have been determined based on pipe sizes and what the structures will be housing. If they are used as a junction, they could be sized differently than if they are housing multiple filters. Structures can be precast, cast-in-place or a combination of both.
- Protection during construction: Site-appropriate erosion and sediment controls should be developed and implemented during the period of active construction through final stabilization.

### Timeframe

- The area to be used for a vegetated system should be survey staked during utility (specifically storm drain) installation.
- During excavation, ensure minimal compaction and verify soil conditions to make sure proper erosion control and sediment control practices are in place around the facility locations.
- Piping to and from drainage features and overflow structures are usually installed prior to the subgrade compaction phase. It is recommended that the structures of these features be protected from erosion, sediment and debris while installation of each feature is completed.
- Vegetated systems, such as swales and strips are installed in the utilities phase of construction and prior to subgrade compaction. Once installed, it is recommended that it be protected throughout construction until final site stabilization.

### Inspection Checklist

- Inspect all pipes and structures up and downstream of the device during installation to ensure they are clear of dirt and debris.
- Upon completion of excavation and, if appropriate, before covering the facility (if required) inspect and verify size, locations and depth of facilities.
- During construction, all storm drainage features and installed BMPs should be inspected on a regular basis and cleaned of any sediment and debris.
- During construction and prior to any storm events, these features should also be inspected and cleaned to insure that the systems do not carry or become clogged with sediment.
- All temporary BMP protection should be inspected and cleaned to insure proper erosion prevention and permanent BMP protection such as inlet bags, fiber rolls and check dams before and after storm events. These construction inspections should be documented, recorded and saved on site.
- Upon completion of each facility, preform final inspection to verify the correct size and materials have been used according to construction specifications. Also verify the facility is working properly.

### References and Links


- California Stormwater Quality Association: Stormwater Best Management Practices Handbook: New Development and Redevelopment (January 2003, See TC-30 and TC-31 (CSQA 2003)
- USEPA Storm Water Technology Fact Sheet: Vegetated Swales (USEPA 1999b)
- Pennsylvania Stormwater Best Management Practice Manual Section 6.4.9 January 2005 (PDEP 2006)

## Operation and Maintenance (O&M) Considerations

**Monitoring**

- Inspect for any active erosion issues (e.g., bare soil, braiding, erosion, excessive ponding, dead grass) in the swale or vegetated filter strip and at outlet/overflow spillway.
- Inspect pretreatment practices to ensure they are functioning properly and not over burdened with sediment or debris.
- Monitor flows through check dam, level spreader or filter strip during a specified rain event (e.g., 0.5 inch, 1 inch, etc.) to ensure short-circuiting is not occurring.
- Inspect upstream and downstream of check dams for evidence of undercutting or erosion.
- Check inflow points for clogging.
- Inspect side slopes and embankments for evidence of sloughing, animal burrows, woody growth, gully erosion, sparse vegetative cover, erosion or slumping.
- Monitor vegetation for invasive weed species and for signs of disease, pest infection, stunted growth and dead plants.
- Determine if vegetation needs maintenance (e.g., mowing, weeding).
- Determine if there is evidence of illicit discharges to the swale or vegetated filter strip (e.g., staining or odor).
- Inspect soil for compaction (qualitative).
- Monitor system to ensure it recovers between storms within a specified time (e.g., 48 or 72 hours).

**Maintenance**

### First or second year activities

- Water plants as needed. In general, consider watering every three days for the first month, and then weekly during the first growing season, depending on rainfall. Note that local regulations may affect the amount and timing of watering.
- Initial fertilization of vegetation may be needed. Do not fertilize after the initial fertilization. Note that local regulations may affect fertilization practices, including prohibiting fertilization in some situations.

### Monthly to quarterly, after major storms, or as needed

- Ensure contributing areas are clear of litter and vegetative debris, and are not eroding sediment into the system.
- Remove sediment and oil/grease from pretreatment devices, as well as from overflow structures.
- Clean sediment and debris from inlets and outlets.
- Mowing should be done per OM&M plan and remove clippings.
- Remove dead or dying vegetation.
- Remove weeds, invasive plants, shrubs and trees.
- Repair eroded areas at inflow and outflow points, on side slopes and at channel base.
- Remove trash, leaves, brush and other debris.
- Re-seed bare patches of grass and water in dry conditions to establish vegetative cover according to local regulations.
- Ensure swales or level spreaders are recovering according to local regulations.

### Semi-annually to annually, or as needed

- Ensure there are no obstacles preventing maintenance personnel and/or equipment access to the swale.
- Remove sediment and other debris from collection sumps, inlets, outlets, overflow spillway and in front of swale blocks.
- Fill erosion channels and holes with approved topsoil or soil mix, and apply correct erosion control practices where appropriate. Consult with erosion control manuals for guidance on erosion control practices (e.g., Florida, Pennsylvania Stormwater Best Management Practice Manual Section 6.4.9 January 2005 Washington State, Iowa)
- Adjust height of swale blocks, check dams or energy dissipators, or remove obstructions, if there is evidence of flow going around them.
- For northern climates, remove winter accumulation of sand each spring.
- Remove leaves and other vegetative debris.
- Remove invasive plants and weeds.
- Prune vegetation, large shrubs or trees that interfere with landscape swale operation.

- Holes in the ground located in and around the swale shall be filled. If necessary, remove burrowing animals first.
- Aerate soil to prevent natural compaction.

## Non-routine maintenance

- Erosion issues shall be corrected as soon as identified.
- Releases of pollutants shall be corrected as soon as identified.
- Repair structures such as inlets, outlets, overflow spillway and underdrains.

**Example inspection checklists**

- Oregon State Extension Field Guide: Maintaining Rain Gardens, Swales and Stormwater Planters
- Minnesota Stormwater Manual, Vegetative Filter System – Operation & Maintenance Checklist
- Stafford County VA Dry Swale O&M checklist
- City of Franklin, TN Stormwater Division Water Quality Swale Inspections and Maintenance Checklist
- Massachusetts Clean Energy Center Operation, Maintenance & Monitoring Plan for Stormwater BMPs and Wetland and Buffer Zone Plantings at the AM Radio Tower Location (see Appendix A)
- San Francisco Water Power Sewer Annual Self-Inspection Checklist – Bioretention Swale
- City of Murfreesboro, TN Operation and Maintenance Checklist – Enhanced Swales, Grass Channels, and Filter Strips
- Florida Stormwater Erosion and Sedimentation Control Inspector's Manual

## References and Links

- Auckland Council Stormwater Forms and Guides
- Oregon State University Extension Field Guide: Maintaining Rain Gardens, Swales and Stormwater Planters
- Maine DEP Stormwater Best Management Practices Manual – Proprietary Systems
- Minnesota Stormwater Manual – Filtration BMPs: Vegetated Filter Strips
- Pennsylvania Stormwater Best Management Practice Manual January 2005
- Virginia DEQ Stormwater Design Specification No. 10 – Dry Swales
- Virginia DEQ Stormwater Design Specification No. 2 – Flow to a Vegetated Filter Strip or Conserved Open Space
- Washington State Department of Ecology – 2-14 Stormwater Management Manual for western Washington; Basic Wet and Continuous Inflow Biofiltration Swales
- Washington State Department of Ecology – 2014 Stormwater Management Manual for Western Washington: BMP T9.40 Basic Filter Strip
- California Stormwater Quality Association – BMP Handbooks
    - California Stormwater Quality Association – BMP Handbook, Vegetated swale
    - California Stormwater Quality Association – BMP Handbook, Vegetated buffer strip
- Florida DEP and Water Management Districts Environmental Resource Permit Stormwater Quality Applicant's Handbook

# F.17 Wet Pond/Wet Basin

**December 2018**

## Description

Also known as a retention pond, a wet pond/wet basin is a surface pond with a permanent pool that enables solids to settle during quiescent times. Water remains in the pond for treatment after the end of a storm event.

### Pollutants of Concern Treated by Wet Pond/Wet Basin

| Wet Ponds/Wet Basins | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Solids | Solid Metals | Dissolved Metals | Hydrocarbons | Nutrients | Ammonia | pH | Bacteria Pathogens | Organics | Trash | Pesticides Herbicides |
| TSS | Cu | Cu | O/G | Phosphorus | | | X | PCB | X | |
| SSC | Zn | Zn | TPH | Nitrogen | | | | PAH | | |

| Wet Ponds/Wet Basins | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Solids** | **Solid Metals** | **Dissolved Metals** | **Hydrocarbons** | **Nutrients** | **Ammonia** | **pH** | **Bacteria Pathogens** | **Organics** | **Trash** | **Pesticides Herbicides** |
| Turbidity | Pb | | | | | | | | | |
| Total Solids | Cd | | | | | | | | | |
| | Cr | | | | | | | | | |
| | Ni | | | | | | | | | |
| | As | | | | | | | | | |

**International Stormwater BMP Database Performance Summary, 2016 – Wetland Basin/Retention Pond International Stormwater BMP Database. Prepared for City and County of Denver and Urban Drainage and Flood Control District, February 2017. Prepared by Wright Water Engineers and Geosyntec Consultants. (Wright Water Engineers and Geosyntec Consultants 2016))**

| | BMPs[39] | | EMCs[40] | | 25th | | Median[41] | | | 75th | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | In | Out | In | Out | In | Out | In | Out | Difference[42] | In | Out |
| **Retention Pond** | | | | | | | | | | | |
| E. coli (MPN/100 mL) | 4 | 4 | 69 | 65 | 580 | 10 | 2,000 (990, 3,100) | 80 (24, 170) | ◆◆◆ | 5,500 | 700 |
| Fecal Coliform (MPN/100 mL) | 10 | 12 | 121 | 161 | 300 | 50 | 3,400 (1,500, 5,000) | 1,400 (360, 2,300) | ◇◆◆ | 23,000 | 8,500 |
| Kjeldahl nitrogen (TKN) (mg/L) | 36 | 36 | 498 | 493 | 0.76 | 0.70 | 1.24 (1.10, 1.31) | 1.00 (0.91, 1.03) | ◆◆◆ | 2.00 | 1.50 |
| Nitrogen, $NO_x$ as N (mg/L) | 46 | 46 | 707 | 704 | 0.18 | 0.05 | 0.42 (0.38, 0.45) | 0.17 (0.15, 0.19) | ◆◆◆ | 0.81 | 0.43 |
| Nitrogen, Nitrate ($NO_3$) as N (mg/L) | 15 | 15 | 251 | 247 | 0.25 | 0.12 | 0.50 (0.40, 0.54) | 0.25 (0.19, 0.27) | ◆◆◆ | 0.83 | 0.50 |
| Nitrogen, Nitrite ($NO_2$) + Nitrate ($NO_3$) as N (mg/L) | 31 | 31 | 456 | 457 | 0.15 | 0.02 | 0.38 (0.33, 0.41) | 0.12 (0.09, 0.15) | ◆◆◆ | 0.79 | 0.34 |
| Nitrogen, Total (mg/L) | 27 | 27 | 414 | 431 | 0.99 | 0.81 | 1.56 (1.42, 1.74) | 1.20 (1.10, 1.25) | ◆◆◆ | 2.59 | 1.69 |
| Phosphorus as P, Dissolved (mg/L) | 18 | 19 | 373 | 394 | 0.07 | 0.03 | 0.13 (0.11, 0.14) | 0.06 (0.05, 0.07) | ◆◆◆ | 0.21 | 0.14 |
| Phosphorus as P, Total (mg/L) | 55 | 55 | 891 | 873 | 0.09 | 0.04 | 0.20 (0.18, 0.22) | 0.09 (0.08, 0.10) | ◆◆◆ | 0.42 | 0.20 |

| | BMPs[39] | | EMCs[40] | | 25th | | Median[41] | | | 75th | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | In | Out | In | Out | In | Out | In | Out | Difference[42] | In | Out |
| Phosphorus, orthophosphate as P (mg/L) | 33 | 33 | 52 4 | 508 | 0.02 | 0.01 | 0.06 (0.05, 0.07) | 0.02 (0.02, 0.03) | ◆◆◆ | 0.15 | 0.06 |
| Total suspended solids (mg/L) | 56 | 56 | 92 3 | 933 | 15.0 | 4.3 | 47.2 (40.0, 54.0) | 11.7 (10.0, 12.3) | ◆◆◆ | 139.8 | 28.0 |
| Arsenic, Total (µg/L) | 4 | 4 | 25 | 23 | 1.00 | 0.52 | 1.20 (1.00, 1.80) | 1.00 (0.55, 1.00) | ◇◇◇ | 2.00 | 1.41 |
| Cadmium, Dissolved (µg/L) | 3 | 3 | 40 | 69 | 0.20 | 0.12 | 0.26 (0.20, 0.33) | 0.12 (0.12, 0.12) | ◆◆◆ | 0.50 | 0.20 |
| Cadmium, Total (µg/L) | 25 | 25 | 383 | 408 | 0.17 | 0.09 | 0.40 (0.29, 0.41) | 0.20 (0.14, 0.20) | ◆◆◆ | 1.00 | 0.44 |
| Chromium, Dissolved (µg/L) | 4 | 4 | 41 | 81 | 1.00 | 0.87 | 1.00 (1.00, 2.00) | 1.00 (1.00, 1.00) | ◇◆◇ | 2.00 | 1.00 |
| Chromium, Total (µg/L) | 13 | 13 | 170 | 168 | 2.43 | 1.00 | 4.18 (3.70, 4.85) | 1.50 (1.00, 2.00) | ◆◆◆ | 8.00 | 4.19 |
| Copper, Dissolved (µg/L) | 16 | 16 | 36 3 | 364 | 3.08 | 2.30 | 4.90 (4.28, 5.40) | 3.23 (3.00, 3.50) | ◆◆◆ | 7.33 | 4.89 |
| Copper, Total (µg/L) | 41 | 41 | 732 | 723 | 4.40 | 2.69 | 9.00 (7.75, 9.20) | 4.32 (4.00, 4.69) | ◆◆◆ | 16.00 | 6.76 |
| Iron, Dissolved (µg/L) | 5 | 5 | 115 | 125 | 19.6 | 27.2 | 52.0 (31.0, 60.0) | 64.0 (46.0, 72.2) | ◇◇◆ | 120.0 | 120.0 |
| Iron, Total (µg/L) | 16 | 16 | 317 | 312 | 393.4 | 152.9 | 1051.0 (820.0, 1200.0) | 266.4 (222.5, 301.0) | ◆◆◆ | 3160.0 | 485.0 |
| Lead, Dissolved (µg/L) | 11 | 12 | 163 | 176 | 0.17 | 0.13 | 1.00 (0.66, 2.00) | 1.00 (0.36, 1.00) | ◇◇◇ | 4.00 | 3.38 |
| Lead, Total (µg/L) | 39 | 39 | 618 | 639 | 3.00 | 1.00 | 9.00 (6.70, 9.71) | 3.00 (2.00, 3.00) | ◆◆◆ | 26.04 | 8.62 |
| Nickel, Dissolved (µg/L) | 4 | 4 | 17 | 17 | 1.00 | 1.13 | 1.80 (1.00, 2.00) | 2.30 (1.00, 3.70) | ◇◇◆ | 2.00 | 4.40 |
| Nickel, Total (µg/L) | 10 | 10 | 113 | 109 | 2.50 | 2.00 | 4.39 (3.50, 6.00) | 2.20 (2.00, 2.70) | ◆◆◆ | 9.38 | 5.92 |

| | BMPs[39] | | EMCs[40] | | 25th | | Median[41] | | | 75th | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | In | Out | In | Out | In | Out | In | Out | Difference[42] | In | Out |
| Zinc, Dissolved (µg/L) | 18 | 18 | 360 | 346 | 10.00 | 5.58 | 23.00 (18.99, 24.95) | 15.00 (11.73, 16.20) | ◆◆◆ | 40.00 | 29.75 |
| Zinc, Total (µg/L) | 48 | 48 | 804 | 767 | 28.47 | 11.00 | 49.00 (43.10, 50.00) | 21.37 (20.00, 23.00) | ◆◆◆ | 85.00 | 38.60 |
| **Wetland Basin/ Retention Pond** | | | | | | | | | | | |
| Enterococcus (MPN/100 mL) | 6 | 6 | 86 | 86 | 210 | 20 | 780 (350, 1,500) | 170 (80, 390) | ◇◆◆ | 4,300 | 1,700 |
| E. coli (MPN/100 mL) | 10 | 10 | 146 | 141 | 580 | 41 | 2,300 (1,400, 3,500) | 450 (200, 700) | ◆◆◆ | 11,000 | 1,600 |
| Fecal Coliform (MPN/100 mL) | 15 | 17 | 163 | 200 | 610 | 79 | 5,000 (2,600, 7,300) | 1,200 (450, 1,800) | ◆◆◆ | 23,000 | 8,500 |
| Kjeldahl nitrogen (TKN) (mg/L) | 44 | 44 | 594 | 584 | 0.73 | 0.67 | 1.17 (1.06, 1.25) | 0.97 (0.92, 1.03) | ◆◆◆ | 1.90 | 1.45 |
| Nitrogen, NOx as N (mg/L) | 61 | 61 | 1,173 | 1,154 | 0.18 | 0.05 | 0.42 (0.39, 0.45) | 0.20 (0.18, 0.24) | ◆◆◆ | 0.76 | 0.51 |
| Nitrogen, Nitrate ($NO_3$) as N (mg/L) | 20 | 20 | 299 | 285 | 0.22 | 0.10 | 0.45 (0.36, 0.48) | 0.22 (0.19, 0.26) | ◆◆◆ | 0.81 | 0.50 |
| Nitrogen, Nitrite ($NO_2$) + Nitrate ($NO_3$) as N (mg/L) | 41 | 41 | 872 | 867 | 0.17 | 0.03 | 0.41 (0.38, 0.44) | 0.20 (0.17, 0.23) | ◆◆◆ | 0.73 | 0.52 |
| Nitrogen, Total (mg/L) | 37 | 37 | 833 | 856 | 1.00 | 0.89 | 1.50 (1.44, 1.57) | 1.31 (1.25, 1.35) | ◆◆◆ | 2.26 | 1.75 |
| Phosphorus as P, Dissolved (mg/L) | 25 | 26 | 684 | 692 | 0.04 | 0.03 | 0.08 (0.08, 0.09) | 0.05 (0.05, 0.06) | ◆◆◆ | 0.17 | 0.11 |
| Phosphorus as P, Total (mg/L) | 75 | 75 | 1,486 | 1,447 | 0.09 | 0.05 | 0.18 (0.17, 0.19) | 0.10 (0.10, 0.11) | ◆◆◆ | 0.36 | 0.21 |
| Phosphorus, orthophosphate as P (mg/L) | 44 | 45 | 976 | 944 | 0.02 | 0.01 | 0.05 (0.04, 0.05) | 0.03 (0.02, 0.03) | ◆◆◆ | 0.11 | 0.07 |
| Arsenic, Total (µg/L) | 4 | 4 | 25 | 23 | 1.00 | 0.52 | 1.20 (1.00, 1.80) | 1.00 (0.50, 1.00) | ◇◇◇ | 2.00 | 1.41 |
| Cadmium, Dissolved (µg/L) | 7 | 7 | 90 | 99 | 0.12 | 0.12 | 0.20 (0.18, 0.24) | 0.12 (0.12, 0.20) | ◇◇◇ | 0.34 | 0.30 |

| | BMPs[39] | | EMCs[40] | | 25th | | Median[41] | | | 75th | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | In | Out | In | Out | In | Out | In | Out | Difference[42] | In | Out |
| Cadmium, Total (µg/L) | 32 | 32 | 508 | 544 | 0.14 | 0.10 | 0.34 (0.30, 0.40) | 0.20 (0.16, 0.20) | ◆◆◆ | 0.89 | 0.43 |
| Chromium, Dissolved (µg/L) | 4 | 4 | 41 | 81 | 1.00 | 0.87 | 1.00 (1.00, 2.00) | 1.00 (1.00, 1.00) | ◇◆◇ | 2.00 | 1.00 |
| Chromium, Total (µg/L) | 13 | 13 | 170 | 168 | 2.43 | 1.00 | 4.18 (3.70, 4.85) | 1.50 (1.00, 2.00) | ◆◆◆ | 8.00 | 4.19 |
| Copper, Dissolved (µg/L) | 22 | 22 | 469 | 464 | 3.00 | 2.00 | 4.51 (4.17, 4.90) | 3.20 (2.90, 3.33) | ◆◆◆ | 7.00 | 4.82 |
| Copper, Total (µg/L) | 51 | 51 | 975 | 961 | 4.25 | 2.31 | 8.24 (7.69, 9.00) | 4.00 (4.00, 4.33) | ◆◆◆ | 14.20 | 6.58 |
| Iron, Dissolved (µg/L) | 5 | 5 | 115 | 125 | 19.62 | 27.17 | 52.0 (31.0, 60.0) | 64.0 (46.0, 71.5) | ◇◇◆ | 120.00 | 120.00 |
| Iron, Total (µg/L) | 18 | 18 | 404 | 399 | 268.93 | 164.72 | 691.5 (543.5, 825.0) | 278.0 (240.3, 300.0) | ◆◆◆ | 2,089.75 | 480.00 |
| Lead, Dissolved (µg/L) | 15 | 16 | 199 | 206 | 0.19 | 0.15 | 0.98 (0.56, 1.08) | 0.82 (0.45, 1.00) | ◇◇◇ | 3.20 | 3.00 |
| Lead, Total (µg/L) | 47 | 47 | 763 | 780 | 2.00 | 1.00 | 7.07 (6.00, 8.00) | 2.25 (2.00, 2.89) | ◆◆◆ | 20.80 | 7.00 |
| Nickel, Dissolved (µg/L) | 4 | 4 | 17 | 17 | 1.00 | 1.13 | 1.80 (1.00, 2.00) | 2.30 (1.00, 3.70) | ◇◇◆ | 2.00 | 4.40 |
| Nickel, Total (µg/L) | 10 | 10 | 113 | 109 | 2.50 | 2.00 | 4.39 (3.50, 6.00) | 2.20 (2.00, 2.70) | ◆◆◆ | 9.38 | 5.92 |
| Zinc, Dissolved (µg/L) | 24 | 24 | 466 | 446 | 11.00 | 5.15 | 22.60 (19.55, 23.90) | 12.00 (10.00, 14.00) | ◆◆◆ | 37.00 | 24.53 |
| Zinc, Total (µg/L) | 61 | 61 | 1,075 | 1,033 | 29.55 | 11.00 | 49.00 (44.23, 50.00) | 21.00 (19.30, 22.00) | ◆◆◆ | 85.00 | 37.00 |

## Certifications[43]: None Available

## Issues affecting performance or design

- Performance is affected by freezing conditions, arid conditions, limited surface area, and presence of contaminated soils.
- Performance is not affected by high groundwater or high TSS loads.

## Component Specific Considerations

- Space restrictions: The pond footprint is 1 to 3 percent of contributing drainage area.
- Aviation concerns: Depending on proximity to airports, vegetation must not be allowed to develop at the BMP that attracts wildlife, which can pose a hazard to aviation.
- Soil type: A low infiltration rate, or lined with low permeability material, is needed to maintain a permanent pond.
- Vegetation: Wet ponds require wetland plants (in permanent pool) and plants tolerant of wet and dry cycles (on embankment).
- Topography: Slopes adjacent to ponds should promote flow toward the wet pond.
- Temperature issues: Increases overall heat inputs as compared to untreated surface runoff, but reduces peak heat loading rates.
- Pollutant concentration concerns: Limited removal of dissolved pollutants, but may export dissolved pollutants if not properly maintained. Phosphorus-rich sediments may release soluble phosphorus from anoxic pond sediments during spring or fall turnover.
- Long dry periods: A permanent pool must be maintained.
- Construction costs: Low to moderate.
- Maintenance costs: Moderate.
- Mosquitoes: If water does not drain properly, then wet ponds can become mosquito breeding grounds.
- Groundwater: Maintain separation from groundwater used for drinking supply in accordance with local requirements.

## Design Criteria Considerations

Design criteria vary widely depending on site conditions, geographic locations, and local or state requirements. When designing wet ponds, ensure the design is consistent with local or state requirements. Below is a list of general design considerations.

- Ensure underlying soils are adequate and the wet pond is properly sized to maintain a permanent pool. If underlying soils have high infiltration rates, a liner may be required.
- In general, intercepting the groundwater table will help maintain a permanent pool, but a liner is required if the underlying aquifer is sensitive to contamination.
- Maintain appropriate minimum horizontal distances between a water-supply well and the ordinary high-water level of a stormwater retention pond.
- Wet ponds are not recommended in karst areas.
- If wet ponds discharge to cold water fisheries, then change the design for shorter detention times or a smaller permanent pool.
- The drainage area contributing to a wet pond should be sufficient to maintain a permanent pool in the pond.
- Ensure forebays are properly located and sized.
- Pretreatment is recommended to reduce sediment loads to the wet pond.
- Ensure inflow points, outflow points, and the conveyance system are properly located, stabilized and protected, and have appropriate slopes. The conveyance system should include a non-clogging, low-flow orifice, emergency spillway and pond drain.
- Ensure outlets are protected from erosive discharges.
- Wet ponds designed for treatment of specific pollutants may require specific features. For example, a shallow permanent pool prevents stratification and reduces the potential release of phosphorus from sediments.
- Wet ponds must have proper grading and site layout. Consider factors such as pond side slopes, permanent pool slopes, length to width ratio, area of littoral zone, size and shape of pond benches, and shape and length of flow paths.
- Ensure adequate maintenance access and incorporate safety features into design.
- Develop a landscaping plan for the establishment of vegetation.
- If the stormwater BMP is close to an airport operations area, standing water should drain within 48 hours.

Links to design information representing different regions in the U.S. are included below.

- California Stormwater Quality Association: Stormwater Best Management Practice Handbook: New Development and Redevelopment, Section 5.7: BMP Fact Sheets – TC-20: Wet Ponds

- Georgia Stormwater Management Manual, Volume 2: Technical Handbook, Section 4.25 Planning and Design Criteria
- Maine Stormwater Best Practices Manual, Chapter 4 – Wet Ponds
- Minnesota Stormwater Manual – Design criteria for stormwater ponds
- New York State Stormwater Management Design Manual, Chapter 6: Ponds
- North Carolina Department of Environmental Quality Stormwater Design Manual C-3 Wet Pond
- Virginia Department of Conservation and Recreation Stormwater Design Specification No 14: Wet Pond
- 2014 Stormwater Management Manual for Western Washington, BMP T10.10: Wet Ponds – Basic and Large

## Construction Information

**Sequence**

- Pre-construction meeting
- Stabilize the drainage area
- Assemble construction materials on site and ensure they meet design specifications
- Clear and strip the project area to the desired sub-grade
- Install erosion and sediment controls
- Excavate the core trench and install the spillway pipe
- Install the riser or outflow structure
- Construct the embankment and internal berms
- Construct the impoundment area
- Construct the emergency spillway
- Install outlet pipes
- Stabilize exposed soils
- Plant the pond buffer area
- Include references

## Considerations

- Sediment that has accumulated in the pond during construction must be removed after construction or may be used as pond liner material.
- Conduct inspections prior to construction, during initial site preparation, during excavation and grading, during installation of major features, at the time of vegetation establishment, and at the end of the project.

**Example inspection checklists**

- C. Department of Energy and Environment 2013 Stormwater Management Guidebook (See Appendix L)
- Minnesota Stormwater Manual, Stormwater pond/wetland – construction inspection checklist
- New York State Stormwater Management Design Manual, Chapter 6: Ponds
- Tennessee Permanent Stormwater Management and Design Guidance Manual, Section 5.4.2 – Wet Pond

## Operation and Maintenance Considerations

**Monitoring**

- Inspect the condition of stormwater inlets to the pond for material damage, erosion or undercutting.
- Ensure the low-flow orifice is not blocked or clogged.
- Inspect the condition of the principal spillway and riser for evidence of spalling, joint failure, leakage, corrosion, or other deterioration.
- Inspect the pond outfall channel for erosion, undercutting, riprap displacement, and woody growth.
- Inspect the condition of all trash racks, reverse-sloped pipes, or flashboard risers for evidence of clogging, leakage, or debris accumulation.
- Inspect for animal burrows, sinkholes and wet areas along the fill embankments.
- Inspect for gullies, evidence of erosion, slumping, and other disturbances on the bank.
- Inspect internal and external side slopes of the pond for evidence of sparse vegetative cover.
- Inspect the banks of upstream and downstream channels for evidence of sloughing, animal burrows, boggy areas, woody growth, or gully erosion that may undermine embankment integrity.
- Monitor the growth of wetland plants, trees and shrubs. Record the species and their approximate coverage, and

note the presence of any weeds, noxious plants or invasive plant species.
- Determine if vegetation needs maintenance (e.g., mowing, weeding).
- Inspect vegetation to maintain efficacy of mosquito fish (when applicable).
- Measure sediment accumulation levels, particularly in the forebay. In areas where road sand is used, an inspection of the forebay and permanent pool should be scheduled after the spring melt to determine if clean out is necessary.
- Inspect water levels to ensure a permanent pool of water is maintained.
- Inspect annually during winter freeze periods to look for signs of improper operation.
- Inspect maintenance access to ensure it is free of woody vegetation, and check to see whether valves, manholes and locks can be opened and operated.
- Determine if there is evidence of illicit discharges to the pond.
- Inspect the water to determine if there is an oil or gasoline surface sheen or odor, or if the color is murky (suspended sediment) or green (algae or other biological activity).
- Inspect pretreatment practices to ensure they are functioning properly.

**Maintenance**

**First or second year activities**

- Water vegetation as needed, particularly trees.
- Remove and replace any dead or dying plantings.
- Pond buffer and aquatic bench reinforcement plantings should occur in the second year after construction.

**Monthly to quarterly, after major storms, or as needed**

- Remove sediment from the low-flow orifice and the pond inlets and outlets.
- Remove trash from trash rack.
- Keep vegetation at heights that allow inspection for animal burrows, sinkholes or wet areas along the fill embankments. Common mistakes are not mowing important areas because they are too steep or ignoring mowing completely. The amount of maintenance depends on the type of vegetation surrounding the basin. Some grasses need weekly mowing where others can be maintained a couple of times a year.
- Repair undercut, eroded, bare soil areas and gullies in the bank.
- Maintain aquatic vegetation to maintain efficacy of mosquito fish (if applicable).

**Semi-annually to annually, or as needed**

- Conduct shoreline cleanup to remove trash, debris and floatables.
- Open up the riser to access and test the valves.
- Repair broken mechanical components immediately when detected.

**Non-routine maintenance**

- Sediment removal in the forebay should occur every 5 to 7 years or after 50 percent of total forebay capacity has been lost. Sediment removal in the primary pool should occur approximately every 25 years or after 50 percent of the pool capacity has been lost. Sediments excavated from stormwater ponds that do not receive runoff from designated hotspots are not considered toxic or hazardous and can be safely disposed by either land application or land filling. Sediment testing may be required prior to sediment disposal when a hotspot land use is present. Sediment removed from stormwater ponds should be disposed of according to an approved erosion and sediment control plan.
- BMP components should be replaced when showing signs of wear, which typically occurs at times ranging from 5 to 25 years. Components may include:
- Inflow and outflow devices
- Trash racks and anti-vortex devices
- Valves, orifices, and aerators
- Concrete structures
- Pumps and switches
- Earthworks such as embankments and side slopes
- Repair of structural components is required immediately if they impair the functionality of the pond.
- Mow the pond buffer not located along maintenance rights-of-way. The embankment can be managed as a

meadow (mowing every other year), prairie or forest.
- Ponds may be drained in an attempt to improve their functionality or conduct repairs. Ponds should not be drained during the spring, since temperature stratification and high chloride concentrations at the bottom can occur, which could result in negative downstream effects. Care should be exercised while draining the pond to prevent rapid release of sediments or anoxic water. The approving jurisdiction should be notified before draining a pond.

## Example inspection checklists

- Virginia Department of Conservation and Recreation Stormwater Design Specification No 14: Wet Pond
- Kentucky Best Management Practices (BMPs) for Controlling Erosion, Sediment, and Pollutant Runoff from Construction Sites; Chapter 3
- Oregon State University Extension Pond/Wetland Maintenance Inspection Form
- Metropolitan Nashville – Davidson County Stormwater Structural BMP Inspection Checklist Templates
- Tinkers Creek Watershed Partners Maintaining Stormwater Control Measures: Guidance for Private Owners & Operations, Wet Pond or Wet Extended Detention Basin
- Alliance of Rogue Communities Maintaining Your Detention Pond
- Northeast Ohio Storm Water Training Council Maintaining Stormwater Control Measures: Guidance for Private Owners & Operators (see Appendix 2: Inspection & Maintenance Check Lists)
- Clemson University Extension’s Carolina Clear Program Stormwater Pond Semi-Annual Inspection Checklist
- University of Minnesota Stormwater Treatment: Assessment and Maintenance

## Example maintenance agreements

- Wake County, NC Pond and Dam Maintenance Agreement
- City of Winston-Salem, NC Wet Detention Basin Operation and Maintenance Manual
- Apex, NC Wet Pond Operation & Maintenance Agreement
- New York State Stormwater Management Design Manual (Stormwater Ponds)
- Virginia Department of Conservation and Recreation Stormwater Design Specification No 14: Wet Pond
- California Stormwater BMP Handbook (TC-20: Wet Pond)
- Minnesota Stormwater Manual (Operation and Maintenance of Stormwater Ponds)
- Washington State Department of Ecology – 2014 Stormwater Management Manual for Western Washington (BMP T10.10: Wet Ponds – Basic and Large)
- International Stormwater Database

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[1] Number of BMPs included in statistics

[2] Number of Event Mean Concentrations (EMCs), or samples, included in statistics

[3] Median concentration from the EMCs

[4] ◆◇◇ = 95% confidence intervals around influent/effluent medians do not overlap
◇◆◇ = P-value of Mann-Whitney test is less than 0.05
◇◇◆ = P-value of Wilcoxon test is less than 0.05
◆ = Red diamond indicates BMP saw an export of pollutant

[5] Certifications more commonly apply to products, or proprietary BMPs, which generally follow the demonstrative approach and must demonstrate they are effective. Most practices, or public domain BMPs such as Biofilters/Bioretention BMPs, follow the presumptive approach and are presumed to be effective as long as they are built following the design criteria of the regulatory agency. Users should refer to their local regulatory agency for information on approved Biofilter/Bioretention BMPs

[6] Certifications more commonly apply to products, or proprietary BMPs, which generally follow the demonstrative approach and must demonstrate they are effective. Most practices, or public domain BMPs such as chemical treatment, follow the

presumptive approach and are presumed to be effective as long as they are built following the design criteria of the regulatory agency. Users should refer to their local regulatory agency for information on approved chemical treatment BMPs.

[7] Number of BMPs included in statistics

[8] Number of Event Mean Concentrations (EMCs), or samples, included in statistics

[9] Median concentration from the EMCs

[10] ◆◇◇ = 95% confidence intervals around influent/effluent medians do not overlap
◇◆◇ = P-value of Mann-Whitney test is less than 0.05
◇◇◆ = P-value of Wilcoxon test is less than 0.05
◆ = Red diamond indicates BMP saw an export of pollutant

[11] Certifications more commonly apply to products, or proprietary BMPs, which generally follow the demonstrative approach and must demonstrate they are effective. Most practices, or public domain BMPs such as constructed wetlands, follow the presumptive approach and are presumed to be effective as long as they are built following the design criteria of the regulatory agency. Users should refer to their local regulatory agency for information on approved constructed wetland BMPs.

[12] Certifications more commonly apply to products, or proprietary BMPs, which generally follow the demonstrative approach and must demonstrate they are effective. Most practices, or public domain BMPs such as disinfection BMPs, follow the presumptive approach and are presumed to be effective as long as they are built following the design criteria of the regulatory agency. Users should refer to their local regulatory agency for information on approved disinfection BMPs.

[13] Most practices, or public domain BMPs, follow the presumptive approach and are presumed to be effective as long as they are built following the design criteria of the regulatory agency. Products, or proprietary BMPs, generally follow the demonstrative approach and must demonstrate they are effective. Certifications listed within this document are specific to proprietary BMPs.

[14] Certifications reflect those current as of May 2017.

[15] Certifications more commonly apply to products, or proprietary BMPs, which generally follow the demonstrative approach and must demonstrate they are effective. Most practices, or public domain BMPs such as infiltration BMPs, follow the presumptive approach and are presumed to be effective as long as they are built following the design criteria of the regulatory agency. Users should refer to their local regulatory agency for information on approved infiltration BMPs.

[16] Certifications more commonly apply to products, or proprietary BMPs, which generally follow the demonstrative approach and must demonstrate they are effective. Most practices, or public domain BMPs such as initial settling basins, follow the presumptive approach and are presumed to be effective as long as they are built following the design criteria of the regulatory agency. Users should refer to their local regulatory agency for information on approved initial settling basin BMPs.

[17] Number of BMPs included in statistics

[18] Number of Event Mean Concentrations (EMCs), or samples, included in statistics

[19] Median concentration from the EMCs

[20] ◆◇◇ = 95% confidence intervals around influent/effluent medians do not overlap
◇◆◇ = P-value of Mann-Whitney test is less than 0.05
◇◇◆ = P-value of Wilcoxon test is less than 0.05
◆ = Red diamond indicates BMP saw an export of pollutant

[21] Certifications reflect those current as of May 2017.

[22] As of December 2016 all historic NJDEP Certifications were sunset. Data from historic certifications in the NJCAT verification database, but only those certification currently posted on the NJDEP website are active

[23] Certifications more commonly apply to products, or proprietary BMPs, which generally follow the demonstrative approach and must demonstrate they are effective. Most practices, or public domain BMPs such as oil water separator BMPs, follow the presumptive approach and are presumed to be effective as long as they are built following the design criteria of the regulatory agency. Users should refer to their local regulatory agency for information on approved oil water separator BMPs.

[24] Number of BMPs included in statistics

[25] Number of Event Mean Concentrations (EMCs), or samples, included in statistics

[26] Median concentration from the EMCs

[27] ◆◇◇ = 95% confidence intervals around influent/effluent medians do not overlap
◇◆◇ = P-value of Mann-Whitney test is less than 0.05
◇◇◆ = P-value of Wilcoxon test is less than 0.05
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[28] Certifications more commonly apply to products, or proprietary BMPs, which generally follow the demonstrative approach and must demonstrate they are effective. Most practices, or public domain BMPs such as permeable pavement, follow the presumptive approach and are presumed to be effective as long as they are built following the design criteria of the regulatory agency. Users should refer to their local regulatory agency for information on approved permeable pavement BMPs.

[29] Certifications more commonly apply to products, or proprietary BMPs, which generally follow the demonstrative approach and must demonstrate they are effective. Most practices, or public domain BMPs such as racks and screens, follow the presumptive approach and are presumed to be effective as long as they are built following the design criteria of the regulatory agency. Users should refer to their local regulatory agency for information on approved rack and screen BMPs.

[30] Certifications more commonly apply to products, or proprietary BMPs, which generally follow the demonstrative approach and must demonstrate they are effective. Most practices, or public domain BMPs such as sediment basin BMPs, follow the presumptive approach and are presumed to be effective as long as they are built following the design criteria of the regulatory agency. Users should refer to their local regulatory agency for information on approved sediment basin BMPs.

[31] Certifications more commonly apply to products, or proprietary BMPs, which generally follow the demonstrative approach and must demonstrate they are effective. Most practices, or public domain BMPs such as skimmers and booms, follow the presumptive approach and are presumed to be effective as long as they are built following the design criteria of the regulatory agency. Users should refer to their local regulatory agency for information on approved skimmer and boom BMPs.

[32] Certifications more commonly apply to products, or proprietary BMPs, which generally follow the demonstrative approach and must demonstrate they are effective. Most practices, or public domain BMPs such as soil management and soil amendments, follow the presumptive approach and are presumed to be effective as long as they are built following the design criteria of the regulatory agency. Users should refer to their local regulatory agency for information on approved soil management and soil amendment BMPs.

[33] Certifications more commonly apply to products, or proprietary BMPs, which generally follow the demonstrative approach and must demonstrate they are effective. Most practices, or public domain BMPs such as tanks and vaults, follow the presumptive approach and are presumed to be effective as long as they are built following the design criteria of the regulatory agency. Users should refer to their local regulatory agency for information on approved tank and vault BMPs.

[34] Number of BMPs included in statistics

[35] Number of Event Mean Concentrations (EMCs), or samples, included in statistics

[36] Median concentration from the EMCs

[37] ◆◇◇ = 95% confidence intervals around influent/effluent medians do not overlap
◇◆◇ = P-value of Mann-Whitney test is less than 0.05
◇◇◆ = P-value of Wilcoxon test is less than 0.05
◆ = Red diamond indicates BMP saw an export of pollutant

[38] Certification reflect those current as of May 2017

[39] Number of BMPs included in statistics

[40] Number of Event Mean Concentrations (EMCs), or samples, included in statistics

[41] Median concentration from the EMCs

[42] ◆◇◇ = 95% confidence intervals around influent/effluent medians do not overlap
◇◆◇ = P-value of Mann-Whitney test is less than 0.05
◇◇◆ = P-value of Wilcoxon test is less than 0.05
◆ = Red diamond indicates BMP saw an export of pollutant

[43] Certifications more commonly apply to products, or proprietary BMPs, which generally follow the demonstrative approach and must demonstrate they are effective. Most practices, or public domain BMPs such as wet ponds, follow the presumptive approach and are presumed to be effective as long as they are built following the design criteria of the regulatory agency. Users should refer to their local regulatory agency for information on approved wet pond BMPs.