# 4.4.3 Submerged Gravel Wetland

**Limited Application Stormwater BMP**

**Description**: Submerged gravel wetlands are one or more cells filled with crushed rock designed to support wetland plants. Stormwater flows subsurface through the root zone of the constructed wetland where pollutant removal takes place.

## KEY DESIGN CONSIDERATIONS

**DESIGN GUIDELINES:**

- Intended for space-limited applications
- High removal rates for sediment, Biochemical Oxygen Demand, and fecal coliform bacteria
- Max drainage area ≤ 5 acres

**ADVANTAGES / BENEFITS:**

- High TSS removal
- Generally requires low land consumption, and can fit within an area that is typically devoted to landscaping
- High pollutant removal capabilities are expected; however, limited performance data exist
- Can be located in low-permeability soils with a high water table

**DISADVANTAGES / LIMITATIONS:**

- High maintenance burden
- Not recommended for areas with high sediment content in stormwater or clay/silt runoff areas
- Cannot be installed until site construction is complete

**MAINTENANCE REQUIREMENTS:**

- Periodic sediment removal required to prevent clogging of gravel base

## STORMWATER MANAGEMENT SUITABILITY

- [x] **Water Quality**
- [ ] **Channel Protection**
- [ ] **Overbank Flood Protection**
- [ ] **Extreme Flood Protection**

**Accepts Hotspot Runoff:** *Yes (requires impermeable liner)*

## FEASABILITY CONSIDERATIONS

| | |
|---|---|
| L | **Land Requirement** |
| H | **Capital Cost** |
| H | **Maintenance Burden** |

**Residential Subdivision Use:** *No*

**High Density/Ultra-Urban:** *Yes*

**Drainage Area:** *5 acres max.*

**Soils:** *No restrictions*

**L**=Low **M**=Moderate **H**=High

## POLLUTANT REMOVAL

| | |
|---|---|
| H | **Total Suspended Solids** |
| M-L | **Nutrients** - Total Phosphorus / Total Nitrogen |
| M | **Metals** - Cadmium, Copper, Lead, and Zinc |
| M-H | **Pathogens** - Coliform, Streptococci, E.Coli |

## OTHER CONSIDERATIONS:

- Needs to be combined with other controls to provide water quantity control

### 4.4.3.1 General Description

The submerged gravel wetland system consists of one or more treatment cells that are filled with crushed rock or gravel and is designed to allow stormwater to flow subsurface through the root zone of the constructed wetland. The outlet from each cell is set at an elevation to keep the rock or gravel submerged. Wetland plants are rooted in the media, where they can directly take up pollutants. In addition, algae and microbes thrive on the surface area of the rocks. In particular, the anaerobic conditions on the bottom of the filter can foster the denitrification process. Although widely used for wastewater treatment in recent years, only a handful of submerged gravel wetland systems have been designed to treat stormwater. Mimicking the pollutant removal ability of nature, this structural control relies on the pollutant-stripping ability of plants and soils to remove pollutants from runoff.

### 4.4.3.2 Stormwater Management Suitability

Submerged gravel wetlands are designed as off-line systems for treatment of the water quality volume and will need to be used in conjunction with another structural BMP that can provide downstream channel protection, overbank flood protection, and extreme flood protection.

Water Quality (WQv)
In submerged gravel wetlands, stormwater runoff flows through a gravel filter with wetland plants at the surface. Pollutants are removed through biological activity on the surface of the gravel and pollutant uptake by the plants. This practice is fundamentally different from other wetland designs because while most wetland designs behave like wet ponds, with differences in grading and landscaping, gravel wetlands are similar to filtering practices. The filtration process effectively removes suspended solids and particulates, biochemical oxygen demand (BOD), fecal coliform bacteria, and other pollutants.

Channel Protection (CPv)
The WQv is diverted to the submerged gravel wetland, therefore, it requires the use of another structural BMP to provide CPv extended detention.

Overbank Flood Protection (up to $Qp_{25}$) and Extreme Flood Protection ($Qp_{100}$)
Submerged gravel wetlands are not useful for flood protection. Another structural BMP, such as a conventional detention pond, must be used in conjunction with a submerged gravel wetland to provide flood protection. All submerged gravel wetlands must provide flow diversion to protect the gravel bed.

### 4.4.3.3 Pollutant Removal Capabilities

The pollution removal efficiency of the submerged gravel wetland is similar to a typical wetland. Recent data show a TSS removal rate in excess of the 80% goal. This reflects the settling environment of the gravel media. These systems also exhibit removals of about 60% Total Phosphorous and 20% Total Nitrogen. The growth of algae and microbes among the gravel media has been determined to be the primary removal mechanism of the submerged gravel wetland.

The following design pollutant removal rates are conservative average pollutant reduction percentages for design purposes derived from sampling data, modeling and professional judgment.

- Total Suspended Solids – 80%
- Total Phosphorus – 60%
- Total Nitrogen – 20%
- Heavy Metals – 50%
- Pathogens – 70%

For additional information and data on pollutant removal capabilities for submerged gravel wetlands, see the National Pollutant Removal Performance Database (2nd Edition) available at www.cwp.org and the International Stormwater Best Management Practices (BMP) Database at www.bmpdatabase.org.

#### 4.4.3.4 Application and Site Feasibility Criteria

Submerged gravel wetlands are well-suited for highly impervious areas where land available for structural BMPs is limited. Submerged gravel wetlands should primarily be considered for new construction or retrofit opportunities for commercial, industrial, and institutional areas where the sediment load is relatively low, such as: parking lots, driveways, loading docks, gas stations, garages, airport runways/taxiways, and storage yards.

To avoid clogging, the use of submerged gravel wetlands should be avoided in areas with less than 50% impervious cover, or high sediment yield sites with clay/silt soils.

The following basic criteria should be evaluated to ensure the suitability of a submerged gravel wetland for meeting stormwater management objectives on a site or development.

<u>General Feasibility</u>

- Suitable for use in high density/ultra-urban areas
- Not suitable for use in a residential subdivision
- Not suitable for use as a regional stormwater control. On-site applications are typically most feasible.

<u>Physical Feasibility - Physical Constraints at Project Site</u>

- <u>Drainage Area</u> – 5 acres maximum for a submerged gravel wetland. Submerged gravel wetland systems need sufficient drainage area to maintain vegetation. See subsection 3.1.8 for guidance on performing a water balance calculation.
- <u>Space Required</u> – Function of drainage area and available head at site.
- <u>Minimum Head</u> – The local slope should be relatively flat. While there is no minimum slope requirement, there does need to be enough elevation drop from the inlet to the outlet to ensure that hydraulic conveyance by gravity is feasible (generally about 3 to 5 feet).
- <u>Pretreatment</u> – Submerged gravel wetland designs shall include a sediment forebay or other equivalent pretreatment measures to prevent sediment or debris from entering and clogging the gravel bed.
- <u>Minimum Depth to Water Table</u> – Unless they receive hotspot runoff, submerged gravel wetland systems can be allowed to intersect the groundwater table. If a submerged gravel wetland receives hotspot runoff and has an underlying water supply aquifer, a separation distance of 2 feet is required between the bottom of the gravel and the elevation of the seasonally high water table to prevent groundwater contamination.
- <u>Soils</u> – Not recommended for clay/silt drainage areas that are not stabilized.

<u>Other Constraints / Considerations</u>

- See subsection 4.3.4 (*Stormwater Wetlands*) for additional planning and design guidance.

#### 4.4.3.5 Planning and Design Standards

The following standards shall be considered **minimum** design standards for the design of submerged gravel wetlands. Submerged gravel wetlands that are not designed to these standards will not be approved. The Director of Engineering and Public Works (the Director) shall have the authority to require additional design conditions if deemed necessary.

<u>A. LOCATION AND SITING</u>

- Submerged gravel wetlands shall have a contributing drainage area of 5 acres or less.
- Submerged gravel wetlands are generally applied to land uses with a high percentage of impervious surfaces and should not be utilized for sites that have less than 50% impervious cover. Any disturbed or denuded areas located within the area draining to and treated by the submerged gravel wetland shall be stabilized prior to construction and use of the submerged gravel wetland.

*Manufactured (i.e., Proprietary) Submerged Gravel Wetlands:*

- A manufacturer of a treatment system utilizing a submerged gravel wetland is identified below. Manufactured submerged gravel wetlands should be selected on the basis of good design, suitability for the desired pollution control goals, durabilty, ease of installation, ease of maintenance, and reliability. The product listed below is not the only product available, nor should its presence in this manual be construed as an endorsement of this product. It is merely shown as a manufactured submerged gravel wetland that is known to operate in the southeast.

| | |
|---|---|
| StormTreat | www.stormtreat.com |

B. PRETREATMENT / INLETS

- Sediment regulation and removal is critical to sustain submerged gravel wetlands. A gravel wetland facility shall have a sediment forebay or equivalent upstream pretreatment.
- A sediment forebay is designed to remove incoming sediment from the stormwater flow prior to dispersal into the wetland. The forebay shall consist of a separate cell, formed by an acceptable barrier. A forebay shall be provided at each inlet, unless the inlet provides less than 10% of the total design storm inflow to the gravel wetland facility.
- The forebay shall be sized to contain 0.1 inches per impervious acre (363 $ft^3$) of contributing drainage and shall be no more than 4 to 6 feet deep. The pretreatment storage volume is part of the total WQv design requirement and may be subtracted from the WQv for wetland storage sizing.
- Inflow channels shall be stabilized with flared riprap aprons, or the equivalent. Exit velocities from the forebay to the wetland shall be non-erosive.

C. OUTLET STRUCTURES

- An outlet pipe shall be provided from the submerged gravel wetland to the facility discharge. The design shall ensure that the discharges occur in a non-erosive manner.

D. MAINTENANCE ACCESS

- A minimum 20' wide maintenance right-of-way or drainage easement shall be provided to a submerged gravel wetland from a driveway, public or private road. The maintenance access easement shall have a maximum slope of no more than 15% and shall have a minimum unobstructed drive path having a width of 12 feet, appropriately stabilized to withstand maintenance equipment and vehicles.

E. LANDSCAPING

- A landscaping plan shall be developed that indicates the methods used to establish and maintain wetland coverage. Minimum considerations of the plan include: selection of plant species, planting plan and sources of plant material. More information on wetland plants can be found at the following websites:
  - http://wetlands.fws.gov/
  - http://www.npwrc.usgs.gov/resource/plants/floraso/species.htm
  - http://www.tva.gov/river/landandshore/stabilization/plantsearch.htm

### 4.4.3.6 Design Procedures

Step 1. Compute runoff control volumes

Calculate WQv, CPv in accordance with the guidance presented in Volume 2, Chapter 2.

Step 2. Determine if the development site and conditions are appropriate for the use of a stormwater wetland

Consider the Application and Site Feasibility Criteria in subsections 4.4.3.4 and 4.4.3.5-A (Location and Siting).

Step 3. Confirm design criteria and applicability

Check with Knox County, TDEC, or other agencies to determine if there are any additional restrictions and/or surface water or watershed requirements that may apply.

Step 4. Compute WQv peak discharge ($Q_{wq}$)

The peak rate of discharge for the water quality design storm is needed for sizing the off-line diversion structures (see Volume 2, Chapter 3 for more information on this calculation).

(a) Using WQv, compute CN

(b) Compute time of concentration using TR-55 method

(c) Determine appropriate unit peak discharge from time of concentration

(d) Compute $Q_{wq}$ in inches from unit peak discharge, drainage area, and WQv.

Step 5. Size flow diversion structure

A flow regulator should be supplied to divert the WQv to the submerged gravel wetland. Size low flow orifice, weir, or other device to pass $Q_{wq}$.

Step 6. Determine pretreatment volume

A sediment forebay is provided at each inlet, unless the inlet provides less than 10% of the total design storm inflow to the gravel wetland. The forebay shall be sized to contain 0.1 inches per impervious acre (363 $ft^3$) of contributing drainage and shall be 4 to 6 feet deep. The forebay storage volume counts toward the total WQv requirement and may be subtracted from the WQv for subsequent calculations.

Step 7. Design inlets, sediment forebay(s), outlet structures, maintenance access, and safety features.

See subsection 4.4.3.5 for more details.

Step 8. Design landscape plan

A landscape plan for a stormwater wetland shall be prepared to indicate how it will be stabilized and established with vegetation. See subsection 4.4.3.5-E (Landscaping) for more details.

*This page left intentionally blank*

### 4.4.3.7 Inspection and Maintenance Requirements

**Note: Section 4.4.3.7 must be included in the Operations and Maintenance Plan that is recorded with the deed.**

Regular inspection and maintenance is critical to the effective operation of a submerged gravel wetland as designed. It is the responsibility of the property owner to maintain all stormwater BMPs in accordance with the minimum design standards and other guidance provided in this manual. The Director has the authority to impose additional maintenance requirements where deemed necessary.

This page provides guidance on maintenance activities that are typically required for submerged gravel wetlands, along with a suggested frequency for each activity. Individual gravel wetlands may have more, or less, frequent maintenance needs, depending upon a variety of factors including the occurrence of large storm events, overly wet or dry (i.e.., drought) regional hydrologic conditions, and any changes or redevelopment in the upstream land use. Each property owner shall perform the activities identified below at the frequency needed to maintain the gravel wetlands in proper operating condition at all times.

| **Inspection Activities** | **Suggested Schedule** |
|---|---|
| • Ensure that inlets and outlets to each submerged gravel wetland cell are free from debris and not clogged. | Monthly |
| • Check for sediment buildup in gravel bed. | Annually |
| **Maintenance Activities** | **Suggested Schedule** |
| • If sediment buildup is preventing flow through the wetland, remove gravel and sediment from cell. Replace with clean gravel and replant vegetation. | As needed |
| • Ensure that inlets and outlets to each submerged gravel wetland cell are free from debris and not clogged. | Monthly |
| • Check for sediment buildup in gravel bed. | Annually |

Knox County encourages the use of the inspection checklist that is presented on the next page to guide the property owner in the inspection and maintenance of submerged gravel wetlands. The Director can require the use of this checklist or other form(s) of maintenance documentation when and where deemed necessary in order to ensure the long-term proper operation of the submerged gravel wetland. Questions regarding stormwater facility inspection and maintenance should be referred to the Knox County Department of Engineering and Public Works, Stormwater Management Division.

## INSPECTION CHECKLIST AND MAINTENANCE GUIDANCE (continued)
## SUBMERGED GRAVEL WETLAND INSPECTION CHECKLIST

Location: ______________________________________________ Owner Change since last inspection? Y N
Owner Name, Address, Phone: ________________________________________________________
Date: __________ Time: ____________ Site conditions:________________________________________

| Inspection Items | Satisfactory (S) or Unsatisfactory (U) | Comments/Corrective Action |
|---|---|---|
| **Wetland Area** | | |
| Healthy vegetation? | | |
| Animal burrows present? | | |
| Erosion in drainage area feeding wetland? | | |
| Other (describe)? | | |
| **Inlet/Outlet Structures and Channels** | | |
| Clear of debris and functional? | | |
| Trash rack clear of debris and functional? | | |
| Sediment accumulation? | | |
| Condition of concrete/masonry? | | |
| Metal pipes in good condition? | | |
| Control valve operation? | | |
| Drain valve operation? | | |
| Outfall channels function, not eroding? | | |
| Other (describe)? | | |
| **Sediment Forebays** | | |
| Evidence of sediment accumulation? | | |
| **Wetland Vegetation Areas** | | |
| Vegetation adequate? | | |
| Undesirable vegetation growth? | | |
| **Hazards** | | |
| Have there been complaints from residents? | | |
| Public hazards noted? | | |

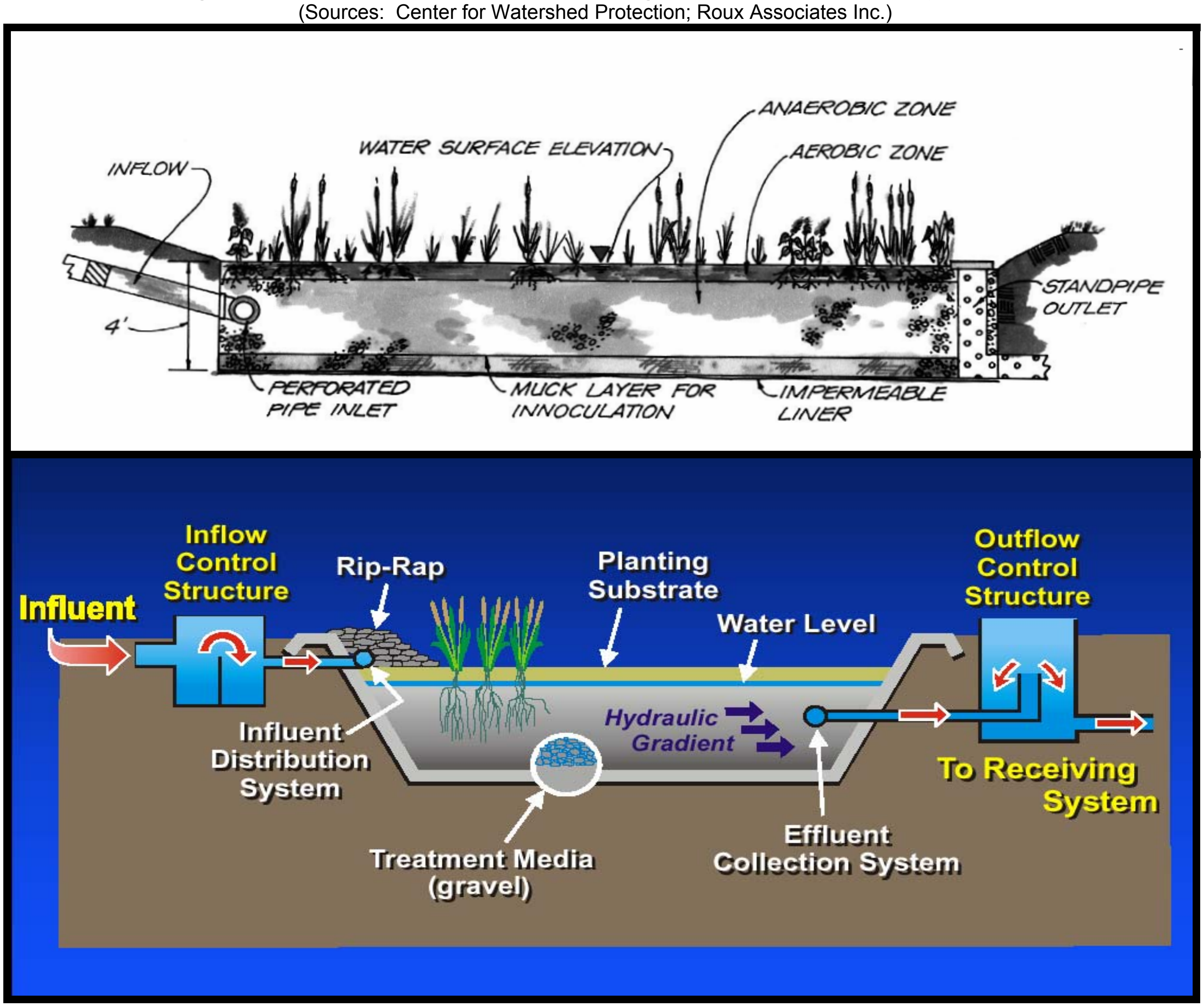
If any of the above inspection items are **UNSATISFACTORY**, list corrective actions and the corresponding completion dates below:

| Corrective Action Needed | Due Date |
|---|---|
| | |
| | |
| | |
| | |
| | |

Inspector Signature:______________________________ Inspector Name (printed)__________________________

#### 4.4.3.8 Example Schematics

**Figure 4-65. Schematics of Submerged Gravel Wetland Systems**
(Sources: Center for Watershed Protection; Roux Associates Inc.)



#### 4.4.3.9 References

Atlanta Regional Council (ARC). *Georgia Stormwater Management Manual Volume 2 Technical Handbook.* 2001.

Center for Watershed Protection (CWP). *Design of Stormwater Filtering Systems.* Prepared for the Chesapeake Research Consortium, Solomons, MD, and U.S. EPA Region 5, Chicago, IL, by the Center for Watershed Protection, Ellicott City, MD, 1996.

Center for Watershed Protection. *Manual Builder.* Stormwater Manager's Resource Center, Accessed July 2005. [www.stormwatercenter.net](www.stormwatercenter.net)

Maryland Department of the Environment (MDE). *Maryland Stormwater Design Manual.* 2000. Available at: http://www.mde.state.md.us/programs/waterprograms/sedimentandstormwater/stormwater_design/index.asp.

New Jersey Department of Environmental Protection. *Stormwater Best Management Practices Manual.* 2004.

Northern Virginia Planning District Commission (NVPDC). Northern Virginia BMP Handbook. Annadale, Virginia: November 1992.

Schueler, T.R. Design of Stormwater Wetland Systems: Guidelines for Creating Diverse and Effective Stormwater Wetland Systems in the Mid-Atlantic Region. Washington, D.C.: Metrolpolitan Washington Council of Governments (MWCOG), October, 1992.

#### 4.4.3.10 Suggested Reading

Adams, L., Dove L.E., D.L. Leedy, and T. Franklin. *Urban Wetlands for Stormwater Control and Wildlife Enhancement – Analysis and Evaluation.* Urban Wildlife Research Center, Columbia, Maryland, 1983.

California Storm Water Quality Task Force. *California Storm Water Best Management Practice Handbooks.* 1993.

City of Austin, TX. *Water Quality Management.* Environmental Criteria Manual, Environmental and Conservation Services, 1988.

City of Sacramento, CA. *Guidance Manual for On-Site Stormwater Quality Control Measures.* Department of Utilities, 2000.

Claytor, R.A., and T.R. Schueler. *Design of Stormwater Filtering Systems.* The Center for Watershed Protection, Silver Spring, MD, 1996.

US EPA. *Storm Water Technology Fact Sheet: Storm Water Wetlands.* EPA 832-F-99-025, Office of Water, 1999.

Faulkner, S. and C. Richardson. *Physical and Chemical Characteristics of Freshwater Wetland Soils.* Constructed Wetlands for Wastewater Treatment, ed. D. Hammer, Lewis Publishers, 831 pp, 1991.

Guntenspergen, G.R., F. Stearns, and J. A. Kadlec. *Wetland Vegetation.* Constructed Wetlands for Wastewater Treatment, ed. D. A. Hammer, Lewis Publishers, 1991.

Metropolitan Washington Council of Governments (MWCOG). A Current Assessment of Urban Best Management Practices: Techniques for Reducing Nonpoint Source Pollution in the Coastal Zone. March, 1992.