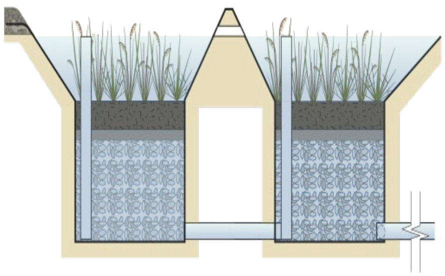
11.5 SUBSURFACE GRAVEL WETLANDS



Subsurface gravel wetlands are a stormwater management system designed to maximize the removal of pollutants from stormwater runoff; the system is a combination of a surface marsh and a subsurface gravel bed. Pollutants are treated through settling, by both uptake and filtration by vegetation and by chemical transformation in the subsurface bed, specifically denitrification. Both the total suspended solids (TSS) removal rate and the nitrogen removal rate are 90%. However, subsurface gravel wetlands can only be used to address stormwater runoff water quality when a waiver or variance from N.J.A.C. 7:8-5.3 is granted as they are not considered to be green infrastructure.

N.J.A.C. 7:8 Stormwater Management Rules – Applicable Design and Performance Standards		
	Green Infrastructure	Not Allowed
	Stormwater Runoff Quantity	Not Allowed
GR	Groundwater Recharge	Not Allowed
%	Stormwater Runoff Quality	Only with a waiver or variance from N.J.A.C. 7:8-5.3, 90% TSS

Stormwater Runoff Quality Mechanisms and Corresponding Criteria	
Settling	
Pretreatment	Required
Presence of Surface Wetlands	Required
Vegetative Uptake and Filtration	
Minimum Density of Vegetation	85%
Appropriate Species Selection	See *Chapter 7: Landscaping*
Denitrification	
Submerged Gravel Cells	Required

Introduction

Subsurface gravel wetlands are stormwater management systems used to address the stormwater runoff quality impacts of land development. This type of stormwater facility is a combination of a surface marsh and a subsurface gravel bed. In the surface marsh, pollutants in runoff are treated through filtration and biological uptake by the marsh vegetation and through settling. Stormwater runoff flows vertically from the surface marsh through a perforated pipe into the saturated gravel bed, located directly below the surface marsh. Runoff then moves horizontally through the gravel where pollutants are treated by chemical transformation, specifically denitrification. Denitrification is a microbially-facilitated, multi-step process whereby nitrogen compounds in stormwater runoff are transformed to nitrogen gas. The nitrogen gas is then permanently removed from the system via the soil into the atmosphere.

In addition to pollutant removal, these systems can also provide wildlife habitat and enhance the aesthetics of a site. However, these systems are designed primarily for the treatment of stormwater runoff, so they should not be sited within natural wetland areas because they will not have the full range of ecological functions.

Only with a waiver or variance from N.J.A.C. 7:8-5.3 may a subsurface gravel wetland, designed in accordance with this chapter, be used to satisfy the standards for stormwater quality, since this BMP does not meet the definition of green infrastructure.

Subsurface gravel wetlands must have a maintenance plan and must be reflected in a deed notice recorded in the county clerk's office to prevent alteration or removal.

Applications

Only if a waiver or variance from the green infrastructure requirements of N.J.A.C. 7:8-5.3 is obtained may subsurface gravel wetlands be awarded a TSS removal rate of 90%. To merit the approved TSS removal rate of 90%, subsurface gravel wetlands must also treat the stormwater runoff volume generated by the Water Quality Design Storm (WQDS) and be designed in accordance with all of the design criteria below.

Design Criteria

Basic Requirements

The following design criteria must all be met in order to merit the 90% TSS removal rate approved for this BMP. It is critical that all subsurface gravel wetlands are designed in accordance with these criteria in order to ensure proper operation, to maximize the functional life of the system and to ensure public safety.

Pretreatment

- Pretreatment is required in all subsurface gravel wetlands. Pretreatment reduces the velocity of incoming flows and captures coarser sediments and debris.

- Any roof runoff may be pretreated by leaf screens, first flush diverters or roof washers. For details of these pretreatment measures, see Pages 5 and 6 of *Chapter 9.1: Cisterns.*

    - This pretreatment requirement for roof runoff can be waived by the review agency if the building in question has no potential for debris and other vegetative material to be present in the roof runoff. For example, a building that is significantly taller than any surrounding trees and does not have vegetative roof should not need the pretreatment. However, in making this determination, the review agency must consider the mature height of any surrounding trees.

- Pretreatment may consist of a forebay or any BMPs found in *Chapters 9 or 11.*

- There is no adopted TSS removal rate associated with forebays; therefore, their inclusion in any design should be solely for the purpose of facilitating maintenance. Forebays can be constructed of earthen materials, riprap or concrete and, in each case, must comply with the following requirements:

    - The forebay must be designed to prevent scour of the receiving basin by outflow from the forebay.
    - The forebay should provide a minimum storage volume of 10% of the Water Quality Design Storm (WQDS) and be sized to hold the sediment volume expected between clean-outs.
    - It should fully drain within nine hours in order to facilitate maintenance and to prevent mosquito issues. Under no circumstances should there be any standing water in the forebay 72 hours after a precipitation event.
    - Surface forebays must meet or exceed the sizing for preformed scour holes in the *Standard for Conduit Outlet Protection* in the *Standards for Soil Erosion and Sediment Control in New Jersey* for a surface forebay.

- If a concrete forebay is utilized, it must have at least two weep holes to facilitate low level drainage.

- When using a structural BMP for pretreatment, it must be designed in accordance with the design requirements outlined in the respective chapter. For additional information on the design requirements of each structural BMP, refer to the appropriate chapter in this manual.

Inflow Erosion Control

- The discharge from the inflow pipes must be designed to prevent erosion in any portion of the gravel wetland system, particularly where stormwater runoff generated by storms larger than the WQDS bypass the system. The bypass must be designed to prevent erosion at the weir structures that could occur due to frequent inundation and high flow velocities.

Vegetation

- The character, diversity and hardiness of the wetland vegetation must be sufficient to provide adequate pollutant removal.
- The minimum density of vegetation in the surface wetland cells is 85%.

Hydraulics

- Each surface wetland cell in a subsurface gravel wetland system must be sized to contain 50% of stormwater runoff generated by the WQDS without overflow.
- The maximum water depth in the surface wetland cells above the wetland soil is 2 feet.
- All surface standing water must drain within 72 hours. Standing water in any other surface component beyond 72 hours should be avoided where possible; however, in circumstances where this is unavoidable, a physical barrier must be placed over the standing water to prevent mosquito access. The physical barrier may consist of foam, mesh or similar materials. Additional details regarding flow rates through the barriers must be included in the hydraulic analysis to assess the impacts clogging may have on the system. This analysis must include a minimum safety factor of 2 based on the anticipated material that may be loaded on the barrier. Furthermore, the replacement frequency of any physical barrier must be included in the Maintenance Manual.
- The section of the perforated inflow riser pipe that passes through the wetland soil must be solid to prevent runoff from discharging into the surrounding soils.

Geometry of Individual Cell Layers

- The minimum soil depth in the surface wetland cells is 8 inches.
- The minimum depth of the transition layer between the wetland soil and the subsurface gravel cells is 3 inches.
- The gravel cells must be filled with ¾-inch crushed stone at a minimum depth of 2 feet.
- The minimum distance between the inflow and the outflow in each gravel cell is 15 feet.

Permeability

- The bottom of the gravel bed must be lined with impermeable material such that there is no migration of runoff into the adjacent groundwater table and there is no drawdown of existing groundwater. In areas where soils are sufficiently impermeable to prevent the mixing of runoff in the gravel cells with adjacent groundwater, a liner may be omitted provided that the bottom of the gravel cells are, at least, 1 foot above the seasonal high water table (SHWT).

Outlet Structure

- Subsurface gravel wetlands rely on a fully saturated gravel layer for nitrogen treatment. Caution must be taken to ensure that the outlet structure does not act as a siphon; to do this, the outlet for the WQDS must either be vented or designed not to discharge when submerged.

- The design of all hydraulic outlets must consider any significant tailwater effects of downstream waterways or facilities, including instances where the lowest invert in the outlet or overflow structure is below the flood hazard area design flood elevation of a receiving stream. Subsurface gravel wetlands may only be constructed as off-line systems. In off-line systems, most or all of the runoff from storms larger than the WQDS bypass the subsurface gravel wetland through an upstream diversion.

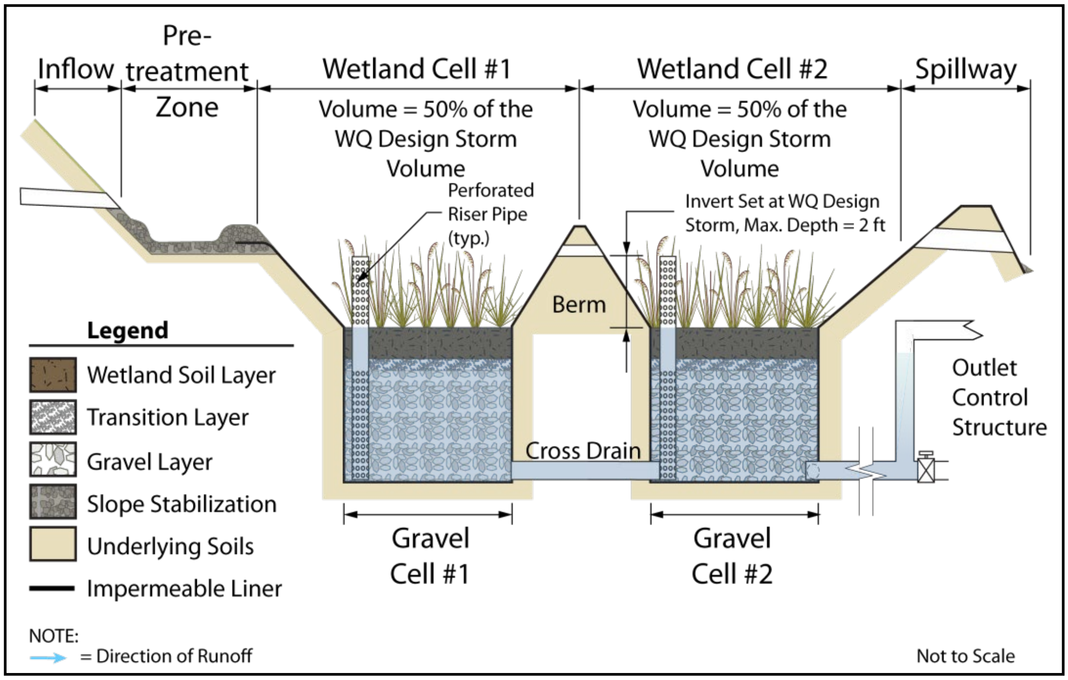
- All subsurface gravel wetlands must be able to convey overflows to downstream drainage systems in a safe and stable manner. The design of the overflow structure must be sufficient to provide safe, stable discharge of stormwater runoff in the event of an overflow. Safe and stable discharge minimizes the possibility of erosion and flooding in down-gradient areas. Therefore, discharge in the event of an overflow must be consistent with the current version of *Standards for Off-Site Stability* found in the *Standards for Soil Erosion and Sediment Control in New Jersey,* as required by N.J.A.C. 7:8 Stormwater Management rules. Subsurface gravel wetlands classified as dams under the NJDEP Dam Safety Standards at N.J.A.C. 7:20 must also meet the overflow requirements of these standards.

- Subsurface gravel wetlands must have drains that allow draindown or backflush when necessary. These drains must be controlled by a lockable valve that is readily accessible from the outlet structure.

Flow Through Subsurface Gravel Wetlands

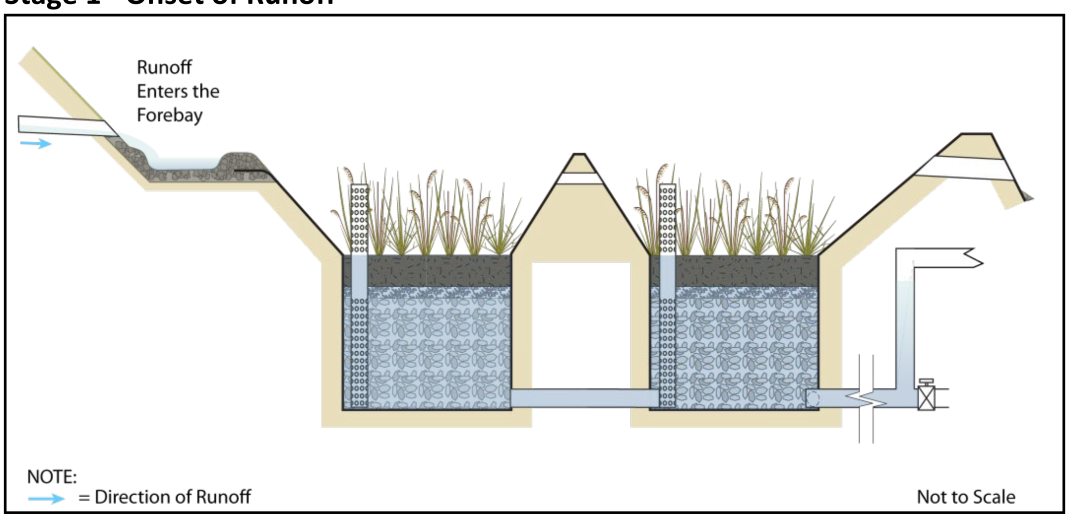
The following illustrations depict the flow of stormwater runoff through the gravel wetland system. For more information on each component, refer to the *Subsurface Gravel Wetland Components* section of this chapter, beginning on Page 10.

Initial Equilibrium



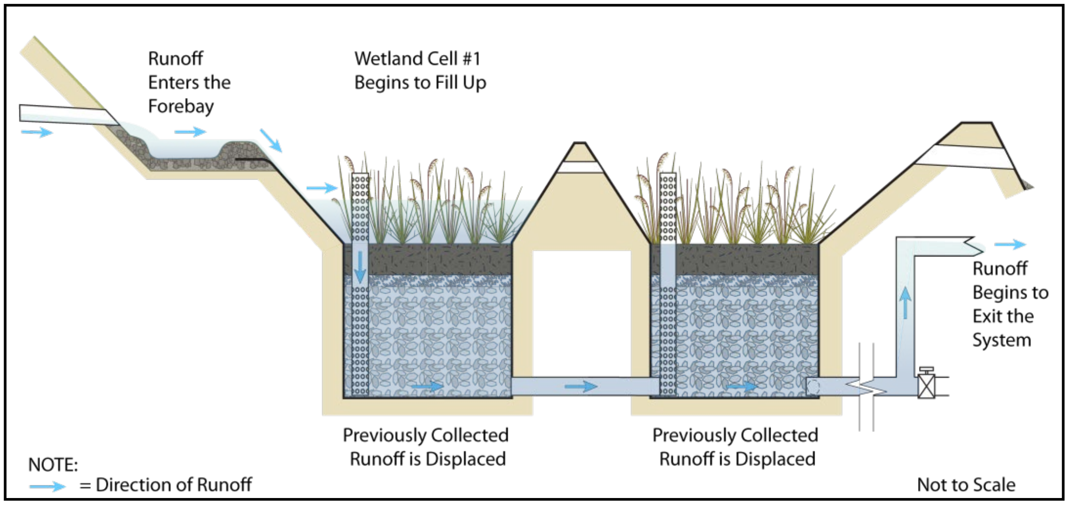
Between storm events, runoff from the previous storm is only detained in the gravel cells; subsurface gravel wetlands are not intended to store stormwater runoff in any surface component for longer than 72 hours after the end of a storm event.

Stage 1 - Onset of Runoff



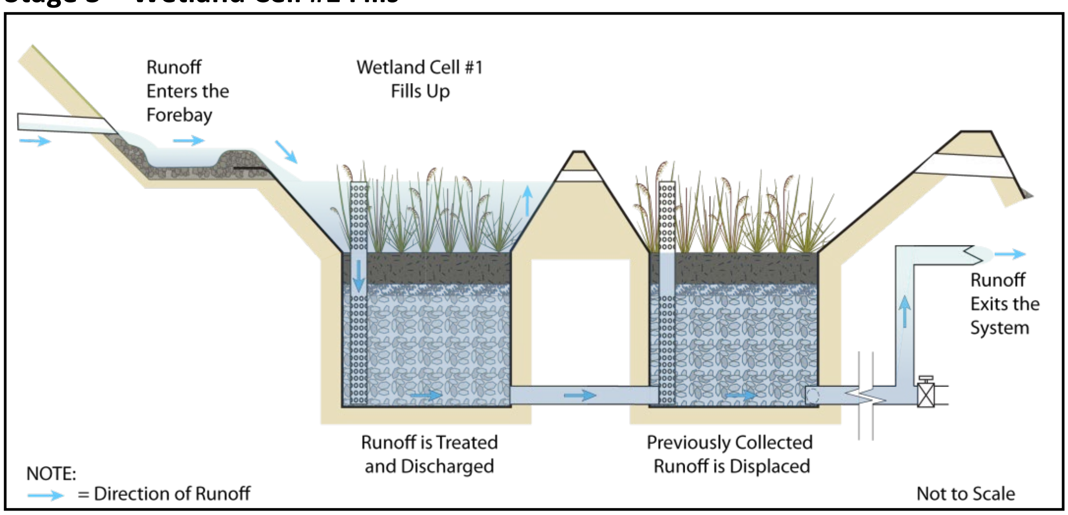
Runoff enters the pretreatment zone, in this case, a forebay.

Stage 2 – Runoff Enters Wetland Cell #1



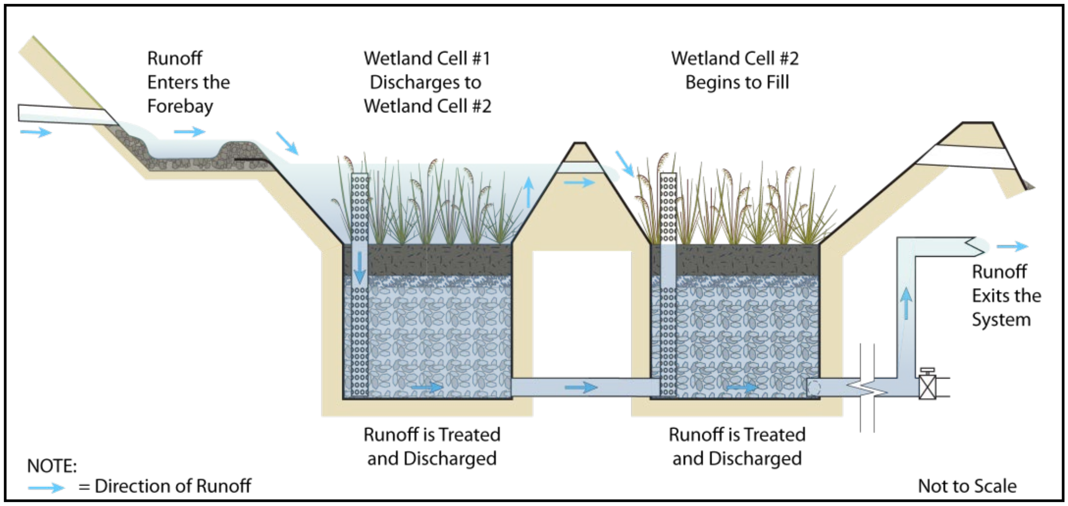
Runoff fills the forebay and begins to flow into Wetland Cell #1. As Wetland Cell #1 fills, runoff is discharged through the perforated riser pipe into Gravel Cell #1. The runoff from the previous storm event only begins to discharge through the outlet structure when it is displaced by the new flow.

Stage 3 – Wetland Cell #1 Fills



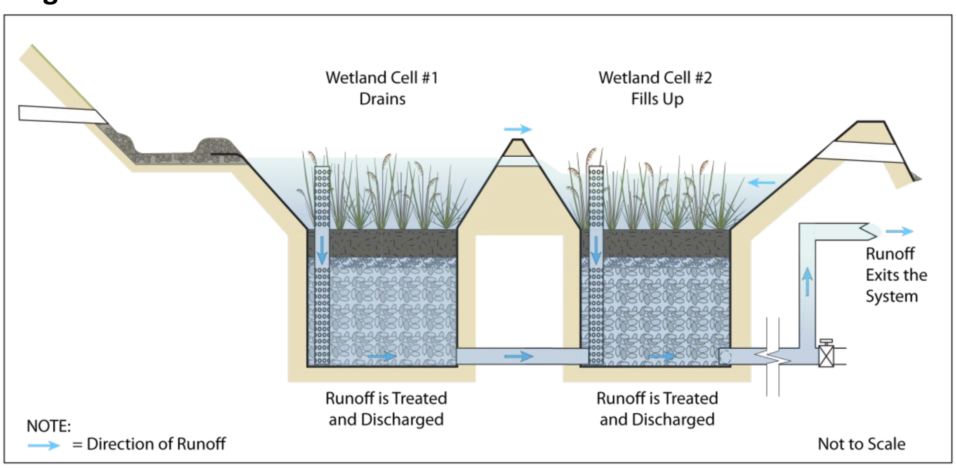
As the rain event continues, Gravel Cell #1 begins to discharge into Gravel Cell #2 through the subsurface cross drain. The continuous inflow of runoff into the system forces the flow from Gravel Cell #2 to discharge through the outlet structure.

Stage 4 - Runoff Enters Wetland Cell #2



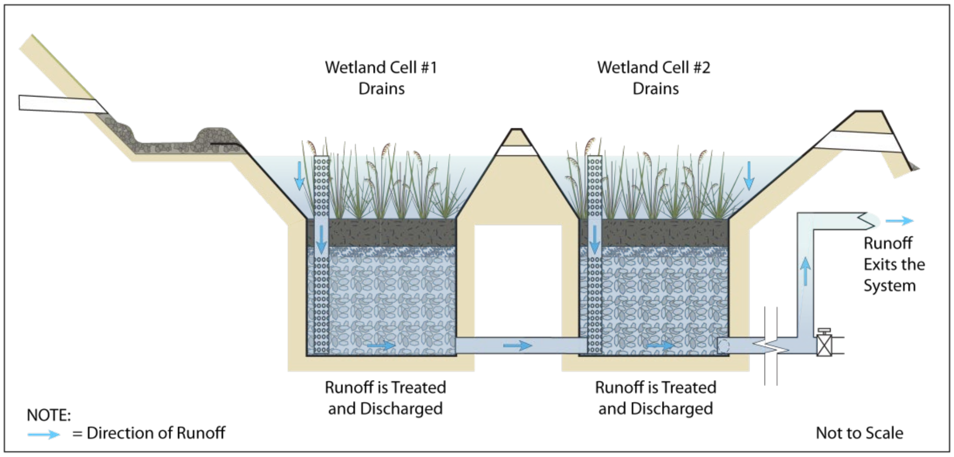
As runoff continues to enter the system, it discharges from Wetland Cell #1 to Wetland Cell #2 through the surface cross drain, and it continues to discharge from Gravel Cell #1 to Gravel Cell #2 through the subsurface cross drain. As Wetland Cell #2 fills, runoff begins to discharge into Gravel Cell #2 through the perforated riser pipe in Wetland Cell #2. This runoff will travel horizontally through the gravel in Gravel Cell #2 prior to being forced out of the system through the outlet structure by runoff from Gravel Cell #1 discharging into Gravel Cell #2.

Stage 5 – Wetland Cell #2 Fills



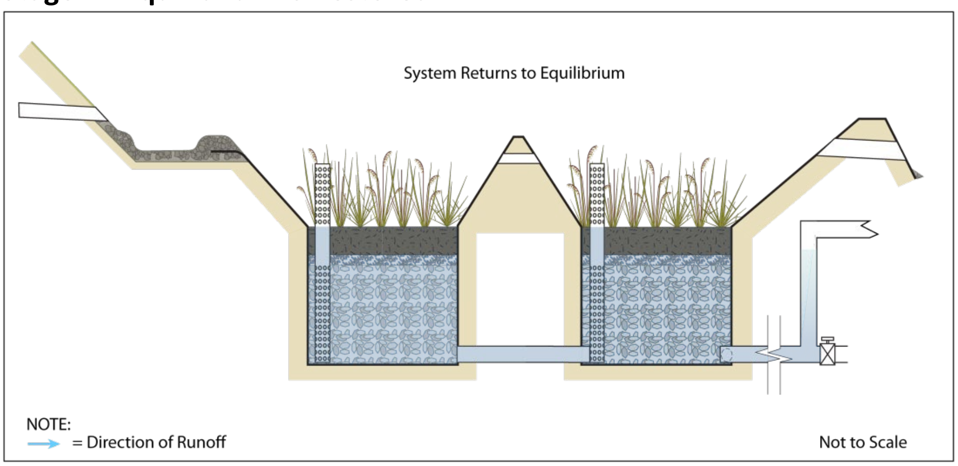
At this stage, which is some time after the end of the rain event, runoff no longer enters the system. Runoff in Wetland Cell #1 discharges to either Gravel Cell #1, through the perforated riser pipe, or to Wetland Cell #2, through the surface cross drain. Runoff in Wetland Cell #2 discharges to Gravel Cell #2 through the perforated riser pipe. Runoff continues to discharge through the outlet structure.

Stage 6 – Runoff Exits the System as the Wetland Cells Drain



Discharge of treated runoff through the outlet structure continues as the runoff that is stored in both of the wetland cells discharges into the gravel cells.

Stage 7 - Equilibrium is Restored

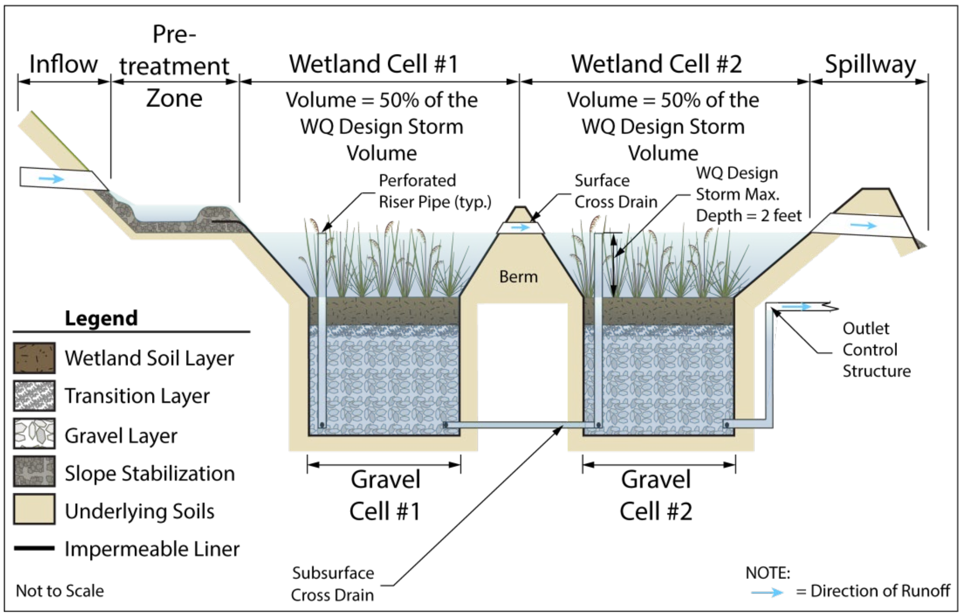


After all of stored runoff in the wetland cells is discharged to the gravel cells, outflow from the outlet structure ceases in the absence of displacement from new runoff. The system returns to equilibrium.

Subsurface Gravel Wetlands Components

The illustration below shows the basic components of a subsurface gravel wetland system: a pretreatment zone, two surface wetland cells connected by a cross drain, a transition layer located below each surface wetland cell, two subsurface gravel cells connected by a subsurface cross drain, two perforated riser pipes connecting each of the wetland cells to the gravel cells below them and an outlet structure.

Profile View – General Components



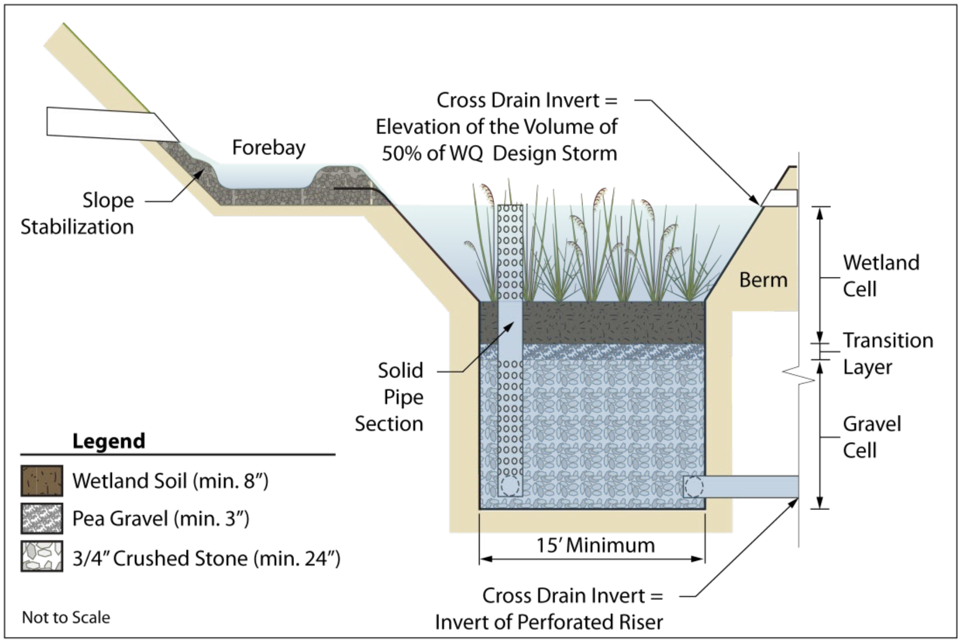
Each surface wetland cell must be connected by a cross drain and sized to store 50% of the WQDS volume. The strategy (forebay, vegetative filter strip or MTD) selected for use in the pretreatment zone must be sized separately from the gravel wetland system.

The transition layer between the wetland soil and the gravel cells is required to prevent the finer portion of the wetland soil from migrating into the gravel cells. The transition layer may be composed of either pea gravel or a combination of sand and pea gravel. Filter fabric may not be used in place of the transition zone because the fine components of the wetland soil may clog the filter fabric; additionally, filter fabric may restrict the root growth of the wetland vegetation.

The subsurface gravel cells must always be completely filled with stormwater runoff in order to provide the anoxic environment necessary for denitrification to occur. The minimum distance of 15 feet between the inflow and the outflow in each subsurface gravel cell is necessary to ensure that the runoff has sufficient time in the anoxic environment for denitrification to occur.

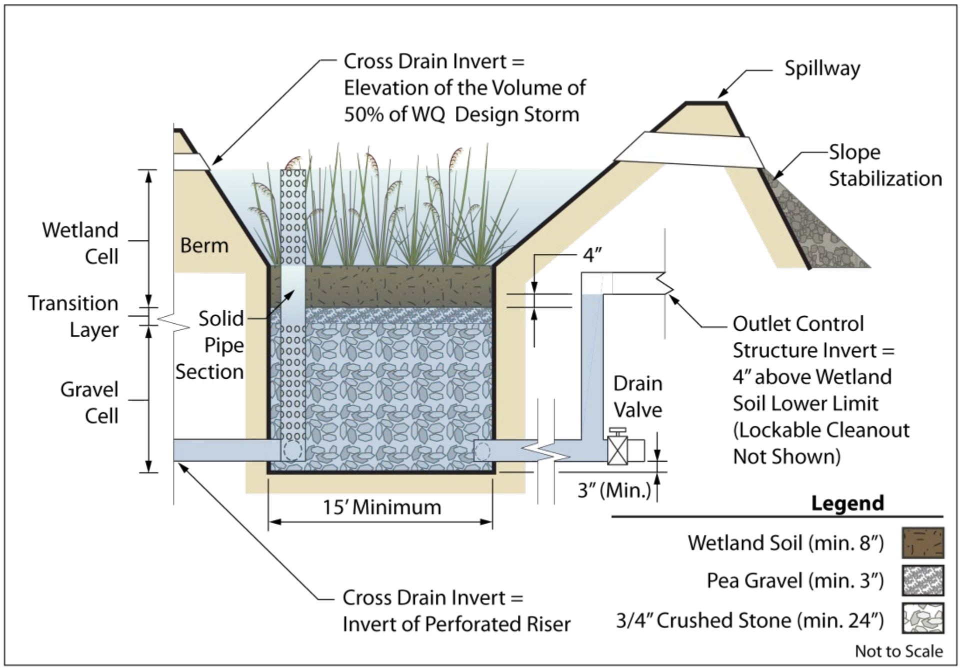
To ensure proper functioning of the system, it is essential that stormwater runoff enters the subsurface gravel cells only from the surface wetland cells and only through the perforated riser pipes; it is also essential that discharges from the gravel cells occur only through the outlet structure. Therefore, the entire system must be lined, which is represented by the thick, black line in the illustrations. In cases where the native soils are sufficiently impermeable, the liner may be omitted provided that the system has the required separation from the SHWT.

Detailed Profile of Wetland Cell #1 and Gravel Cell #1



The illustration above shows a closer view of the first half of the subsurface gravel wetland system. Runoff enters the system through the forebay; from there, it enters Wetland Cell #1. The riser pipe in the wetland cell has perforations up to the elevation of the WQDS. Flows up to this elevation are slowly discharged into Gravel Cell #1; flows in excess of this elevation are temporarily stored in the Wetland Cell #1. The flow that is discharged into Gravel Cell #1 then passes horizontally through 15 feet of gravel where it is captured by the subsurface cross drain.

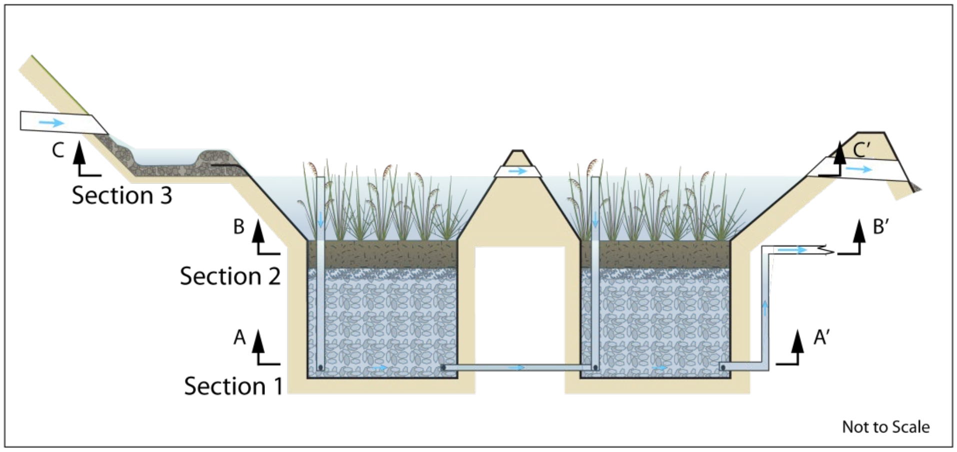
Detailed Profile of Wetland Cell #2 and Gravel Cell #2



This illustration shows a closer view of the second half of the subsurface gravel wetland system. As shown in the previous illustration, runoff up to the elevation of ½ the WQDS volume is temporarily stored in Wetland Cell #1. Flows in excess of this elevation enter Wetland Cell #2 through the cross drain. As with Wetland Cell #1, there is another riser pipe in Wetland Cell #2, which also has perforations up to the elevation of the WQDS; flows up to this elevation are slowly discharged into Gravel Cell #2 through the riser pipe.

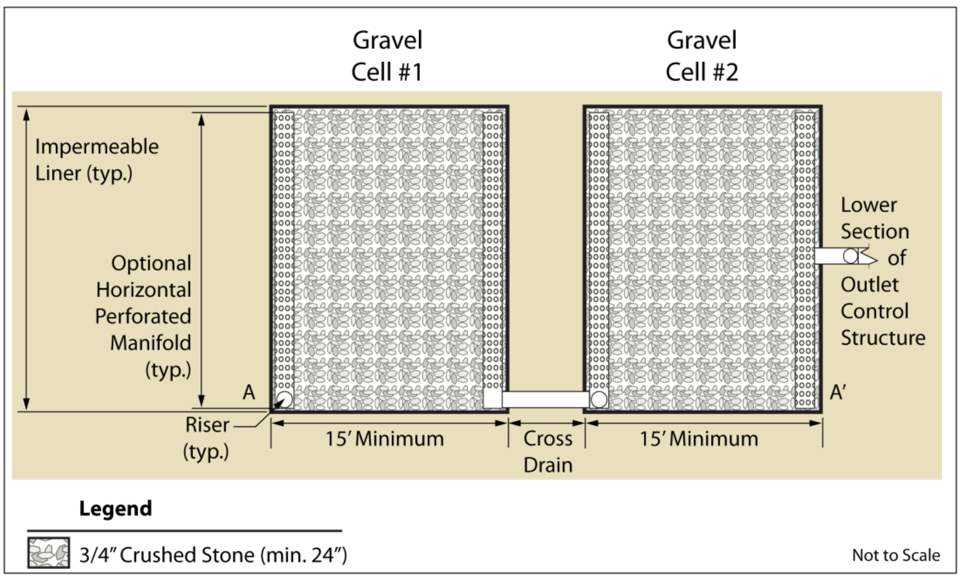
Runoff in Gravel Cell #2 consists of both the flow from Gravel Cell #1 that is discharged into Gravel Cell #2 through the cross drain, and the flow from Wetland Cell #2 that is discharged into Gravel Cell #2 through the perforated riser pipe. All flows in Gravel Cell #2 again flow laterally through 15 feet of gravel before discharging through the outlet structure.

Guide to Sections in Plan View



The above illustration depicts the same gravel wetland system divided into three horizontal sections, each at different elevations. The following three illustrations each focus on a specific section of the gravel wetland system, as shown above.

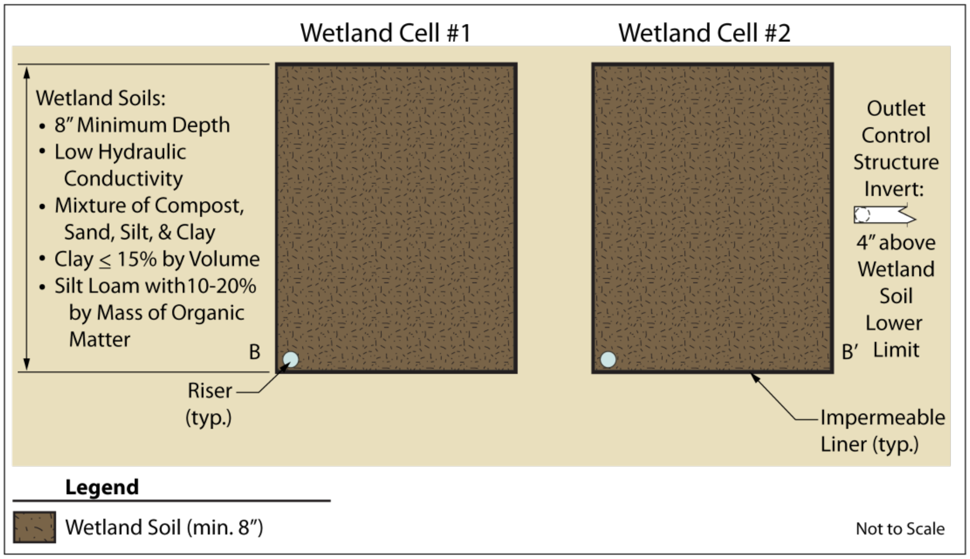
Section 1 Plan View – Gravel Cells #1 and #2



The above illustration depicts a plan view of the gravel cells, which shows an optional horizontal perforated manifold; the manifold is intended to help distribute the flow through the gravel cells in systems where the width of the gravel cells is wide enough to impede dispersal.

The above illustration also shows the required 15-foot minimum length in each of the gravel cells. The benefit of the two-cell system is that it allows the smallest storm events, which generally have the highest pollutant loads, to pass through all 30 feet of gravel. The 30-foot travel path allows the most polluted runoff to remain in the denitrification zone longer, allowing maximum nitrogen treatment. There is no maximum length requirement for the gravel cells; however, if a system is designed to flow through the subsurface gravel cells significantly in excess of the recommended 30 feet, additional analysis must be performed to ensure that any loss of hydraulic head through the gravel cells does not control the drain time of the system. The underdrain pipes must be sized to convey twice the maximum inflow rate; this is necessary to address potential clogging and to ensure that the pipes do not act as a hydraulic control. The system must be designed to drain the WQDS volume between 24 and 48 hours.

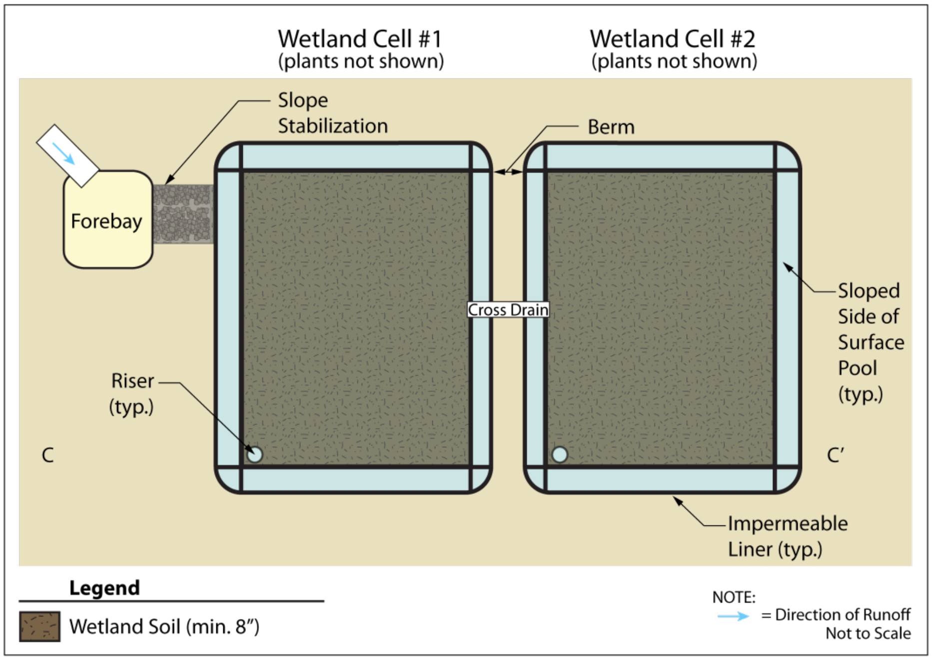
Section 2 Plan View – Wetland Soil Layer in Both Cells



This illustration shows the wetland soil layer at a distance of 4 inches above the transition layer. This elevation is important because it is the elevation at which the invert of the primary outlet must be located. At this elevation, the primary outlet maintains the water level at 4 inches above the bottom of the wetland soil; continuous inundation to this elevation both supports the wetland vegetation and maintains the anoxic state in the gravel cells. It is crucial that the gravel cells remain submerged because the process of denitrification can only occur in the absence of oxygen. Subsurface gravel wetlands do not have a minimum drainage area requirement; however, while a specific water budget is not required, there must be sufficient flow to ensure that the gravel cells remain submerged to the elevation of the invert of the primary outlet.

Because it is essential that runoff enters the gravel cells only through the perforated riser pipe, the wetland soil must have low enough hydraulic conductivity to ensure that runoff does not infiltrate through the soil bed into the gravel cells. This can be accomplished by using the appropriate soil mix. The wetland soil should be mixed using a combination of compost, sand, silt and clay, with the clay component not exceeding 15%, by volume. The soil must be silt loam with 10 to 20% organic content, by mass. The organic matter should consist of leaf compost or peat. Leaf compost should be properly matured and at least a year old. The leaf compost should be made exclusively of fallen deciduous leaves with less than 5% dry weight of woody or green yard debris. The compost should be generally free of trash and other debris. Leaf mulch, composted mixed yard debris, wood chips, biosolids, mushroom compost or composed animal manures are not acceptable sources of organic matter.

Section 3 Plan View – Wetland Cells at the Surface Cross Drain



This illustration depicts the top of the gravel wetland system looking down through the wetland cells at the elevation of the surface cross drain; the vegetation has been omitted to better show the other components. As previously shown, runoff enters the system through the forebay and then flows into Wetland Cell #1. All flows up to the elevation of the WQDS volume are discharged into Gravel Cell #1 through the perforated riser pipe.

It is essential that the perforated riser pipes are sized with sufficient capacity to ensure that they do not control the drain time of the system. In addition, in order to address potential clogging, they must be sized to convey twice the maximum inflow rate; the recommended minimum diameter of these pipes is 12 inches.

The cross-drain from Wetland Cell #1 to Wetland Cell #2 has no perforations and must be sized to convey, at minimum, the peak inflow from the WQDS. The berm between the wetland cells must be constructed out of material that prevents seepage between cells; flow between wetland cells may only occur through the cross drain. All berms and weirs must be constructed to remain stable through all anticipated flows and velocities.

Considerations

A number of factors should be considered when utilizing a subsurface gravel wetland to treat stormwater runoff.

Site Constraints

Setback requirements for submerged gravel wetlands vary; ensure compliance with any applicable federal, state or local requirement.

Permeability

Consideration should be given to determining whether the subsurface soils are sufficiently impermeable to prevent the migration of groundwater into the subsurface gravel cells. In cases where this is not achievable, an impermeable liner must be used. When designing a subsurface gravel wetland with an impermeable liner, proper installation of these liners is critical to ensure long-term functioning of the system. For more information on the installation of impermeable liners, refer to N.J.A.C. 7:26-2A.7.

Vegetation

- Native species are preferred, but it is best when choosing plants to consider the prospects of establishing a healthy plant community.
- Selected species must be able to adapt to a broad range of conditions, including wide variations in water depth and inundation.
- A variety of plants should be selected; diversity will minimize the risk of loss from pest and disease, both of which are common in monocultures.
- Plant communities develop best through the use of wetland mulch. Wetland mulch is enriched with plant roots and seeds; it enhances the diversity of the plant community and speeds establishment. However, the seed content in wetland mulch is often unpredictable and undesirable species may be introduced. If wetland mulch is used, it should be collected at the end of the growing season and kept moist until installation.
- Wildlife access to the subsurface gravel wetland must be prohibited during the initial planting phase; in addition, precautions, such as deer fencing, muskrat trapping and planting after seasonal bird migrations should be considered.

Bacteria Colonies

In order for denitrification to occur, the proper species of bacteria must be present; these bacteria occur only in anoxic environments. In addition, the process of denitrification requires a carbon source; the carbon source in this type of stormwater facility is the wetland vegetation in the surface cells. Because denitrification requires both, it is recommended that the wetland plants fully establish prior to putting the system into operation. Generally, an entire growing season is sufficient time for both the vegetation to establish and the bacteria to colonize the gravel cells.

Regulatory Issues

A subsurface gravel wetland, once constructed, may be regulated by the Freshwater Wetlands Protection Act and may require additional permits for maintenance or modification. Subsurface gravel wetlands classified as dams under the NJDEP Dam Safety Standards at N.J.A.C. 7:20 must also meet the overflow requirements of these standards.

Maintenance

Regular and effective maintenance is crucial to ensure effective subsurface gravel wetland performance; in addition, maintenance plans are required for all stormwater management facilities associated with a major development. There are a number of required elements in all maintenance plans, pursuant to N.J.A.C. 7:8-5.8; these are discussed in more detail in *Chapter 8: Maintenance and Retrofit of Stormwater Management Measures*. Furthermore, maintenance activities are required through various regulations, including the New Jersey Pollutant Discharge Elimination System (NJPDES) Rules, N.J.A.C. 7:14A. Specific maintenance requirements for subsurface gravel wetland are presented below; these requirements must be included in the subsurface gravel wetland's maintenance plan.

General Maintenance

- Lockable cleanout pipes are required.
- A bottom drainpipe valve is required; it must be located at a minimum elevation of 3 inches above the bottom of the subsurface gravel cell.
- All valves for maintenance must be clearly shown in the Operations and Maintenance Manual; additionally, it must also be conspicuously stated that all valves are to remain closed except when necessary to perform specific activities, such as temporary drawdown or backflush.
- An adjustable outlet is required in order to maintain the water levels necessary for the initial establishment of vegetation; once vegetation is established, the outlet must maintain the water elevation at 4 inches above the bottom of the wetland soil.
- Drains with lockable valves are required to allow the drawdown or backflush of wetland cells; these drains must be readily accessible.
- All structural components must be inspected, at least once annually, for cracking, subsidence, spalling, erosion and deterioration.
- Components expected to receive and/or trap debris and sediment must be inspected for clogging at least twice annually , as well as after every storm exceeding 1 inch of rainfall.
- If a forebay is used in the pretreatment zone, it must be cleaned when it accumulates either 6 inches of sediment, there is a 10% loss of forebay volume, or if it remains wet 9 hours after the end of a storm event.
- 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.

Vegetated Areas

- Bi-weekly inspections are required when establishing/restoring vegetation.
- A minimum of one inspection during the growing season and one inspection during the non-growing season is required to ensure the health, density and diversity of the vegetation.
- Pruning within the wetland cells must be performed on a regular schedule based on specific site conditions; perimeter grass should be mowed at least once a month during growing season.
- Vegetated areas must be inspected at least once annually for erosion, scour and unwanted growth; any unwanted growth should be removed with minimum disruption to the remaining vegetation.
- Vegetative cover must be maintained at 85%; damage must be addressed through replanting in accordance with the original specifications.
- Vegetation in the wetland cells must be harvested at least once every 3 years and no more than once a year to prevent the re-suspension of nitrogen from decaying vegetation.
- All use of fertilizers, pesticides, mechanical treatments and other means to ensure optimum vegetation must not compromise the intended purpose of the gravel wetland system.
- Caution must be taken when using pesticides because subsurface gravel wetlands require a healthy bacteria community to function properly.
- The types and distribution of dominant plants must be assessed during the semi-annual inspections, and an appropriate balance between original and volunteer species must be achieved in accordance with the intent of the original wetland design.

Drain Time

- The approximate drain time for the surface wetland cells must be indicated in the maintenance manual.
- If the actual drain time is significantly different than the design drain time, the components that could provide hydraulic control must be evaluated and appropriate measures taken to return the wetland to the design drain time.

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