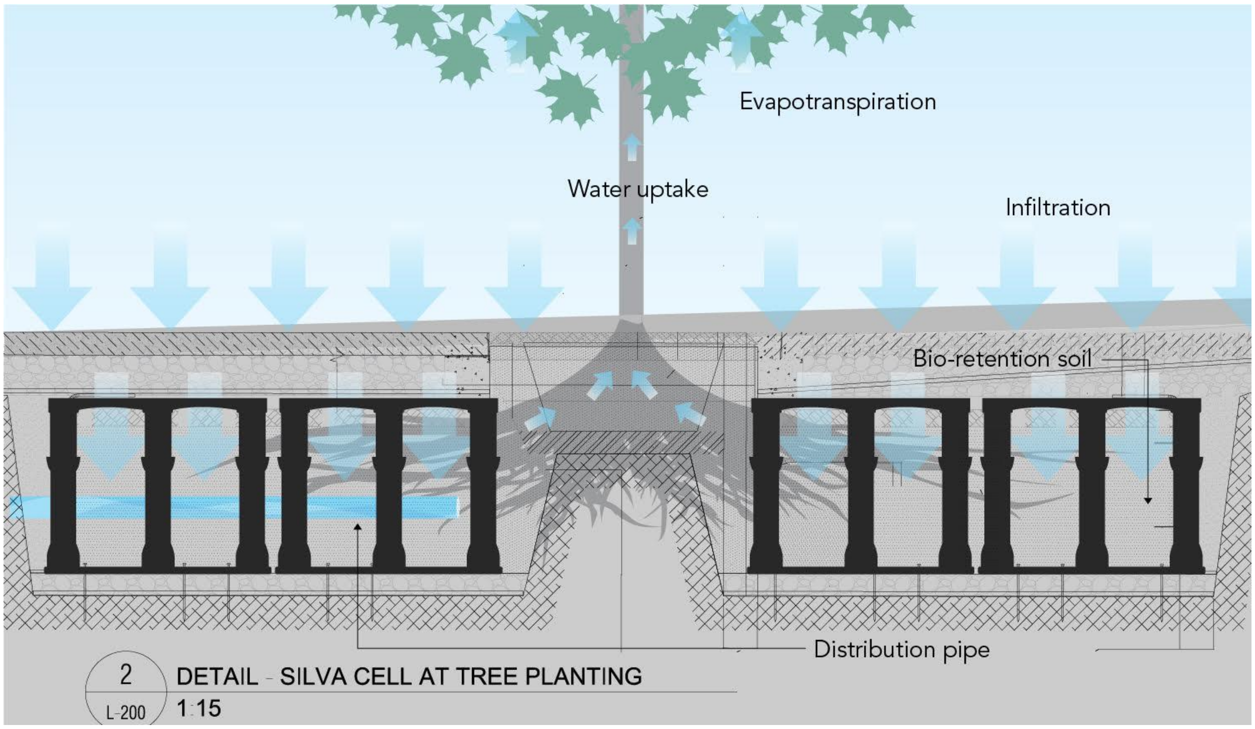
4.13.2 Silva Cell Suspended Pavement with Bioretention by DeepRoot Green Infrastructure SCM

The following chapter from the NCDEQ Stormwater Design manual (Part D-2, last updated 8/7/2017) is accepted in the Charlotte-Mecklenburg SCM Design Manual with the following additional requirements.

MDC	Charlotte-Mecklenburg Design Standard
MDC 16. MAINTENANCE	In addition to MDC 16 see the Ordinance or Regulations and Administrative manuals of the applicable local jurisdiction for the following requirements: • Access and Maintenance Easements • Inspection and Maintenance Agreements • Inspection and Maintenance Record Keeping Refer to the Best Management Practices (BMP) Maintenance Handbook of the Charlotte Stormwater Website for additional information regarding SCM maintenance: Stormwater Regulations - City of Charlotte (charlottenc.gov)

D-2. Silva Cell Suspended Pavement with Bioretention by DeepRoot Green Infrastructure



Design Objective

A Silva Cell Suspended Pavement System with Bioretention by DeepRoot Green Infrastructure is a sub-surface treatment facility that is filled with a sandy filter media and typically planted with a tree. It is designed to temporarily hold and filter stormwater. The Silva Cell builds on the principles of bioretention, which can be installed in a variety of soil types from clay to sand and in a wide variety of sites. The Silva Cell System was specifically developed for ultra-urban environments with highly impervious contributing drainage areas and limited area above ground for stormwater control and treatment. The Silva Cell system is an effective SCM for removing pollutants, because it uses many different pollutant removal mechanisms, including infiltration, absorption, adsorption, microbial action, tree uptake, and filtration.

Design Volume

The design volume for the Silva Cell System is equivalent to the sum of the void space available above the filter media surface (inside the system) plus the void space available in the washed aggregate layer above the Silva Cell decks up to the invert of the bypass mechanism for the design storm.

Important Links

SCM Credit Document, D-2. Credit for Silva Cell Suspended Pavement with Bioretention

Silva Cell Product Information and Description

Purpose. The Silva Cell product is manufactured by DeepRoot Green Infrastructure. It was originally developed as a tool to promote urban tree growth and vigor by creating high quality uncompacted soil beneath pavements. The modular structure of the Silva Cell unit transfers the active and static loads of the ground surface vertically downward to a compacted aggregated subgrade thereby creating an uncompacted soil volume ideal for root growth and stormwater control. More recently, modifications have been made to pair the Silva Cell with bioretention. Bioretention is an excellent SCM for low-impact development, keeping runoff where it falls so that it can be cleaned, cooled, and recharged. Open bioretention presents challenges in high-density urban areas, where land values and maintenance requirements are high. This is where an underground bioretention system like the Silva Cell are best suited.

Dimensions. The Silva Cell 2 is composed of a base, posts, and a deck. Each unit is 48" long x 24" wide. The assembled units, are available in three heights: 1x (16.7") 2x (30.9"), and 3x (43") (Figures 1 and 2).

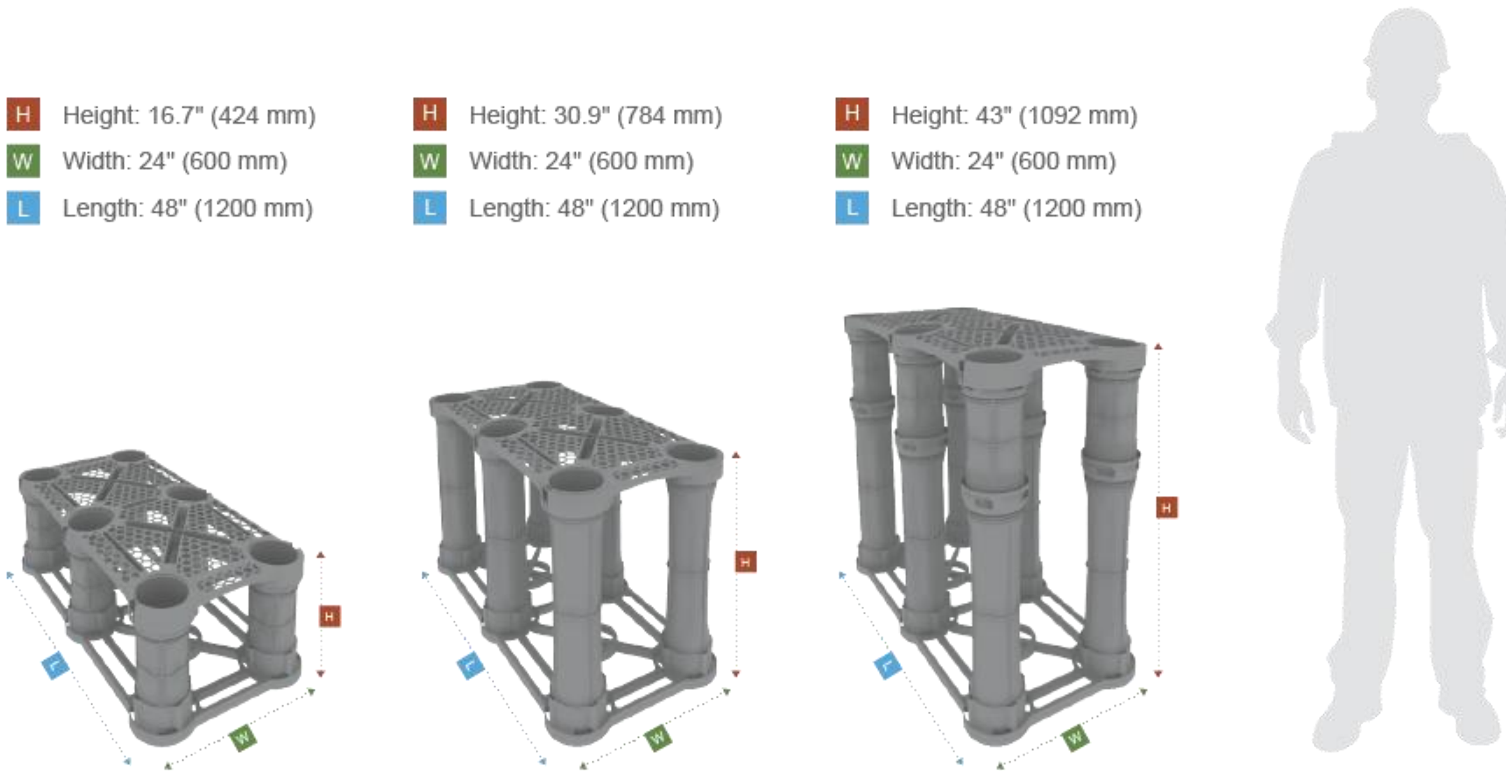
Loading. The Silva Cell Supports vehicle loading equal to 32,000 lbs, which allows use in areas that accommodate 3 - 4 axle vehicles such as those used for emergency, delivery, and maintenance. Meets AASHTO HS-20 (USA) loading standards when used with standard paving profiles. Increased loading capacity can be achieved by adjusting the standard profiles.

Utilities. 14" apertures easily accommodate new or existing utilities underground.

Flexibility. Independent units allow maximum flexibility around existing or planned site considerations.

Figure 1: Silva Cell 2 Product Components

Figure 2: Silva Cell 2 (Left: 1x, Middle: 2x and Right: 3x)



Guidance on the MDC

MDC 1. BUA IN THE CONTRIBUTING DRAINAGE AREA.
The contributing drainage area to the Silva Cell System shall have a BUA fraction of 75% or greater.

Impervious drainage areas contribute less sediment load to the SCM. It is important to limit sediment supply to subsurface SCMs due to maintenance limitations.

MDC 2. SEPARATION FROM THE SHWT.
The lowest point of the Silva Cell System shall be a minimum of two feet above the SHWT. However, the separation may be reduced to no less than one foot if the applicant provides a hydrogeologic evaluation prepared by a licensed professional.

The separation from the seasonal high water table is needed to ensure that the media does not become saturated and unable to function effectively. See Part A-3 for more information about conducting soil tests for SCMs.

MDC 3. PREATREATMENT.
Pretreatment in the form of inlet protection (Trashguard, catch basin insert, grate or linear radial screens) shall be provided to prevent trash, debris and sediment from being conveyed to the soil media contained within the Silva Cells. Pretreatment measures shall be designed for access by typical methods and equipment.

Pretreatment is essential to the long-term success of the Silva Cell System. Pretreatment is not needed for systems that only use direct infiltration through permeable pavement for flow distribution.

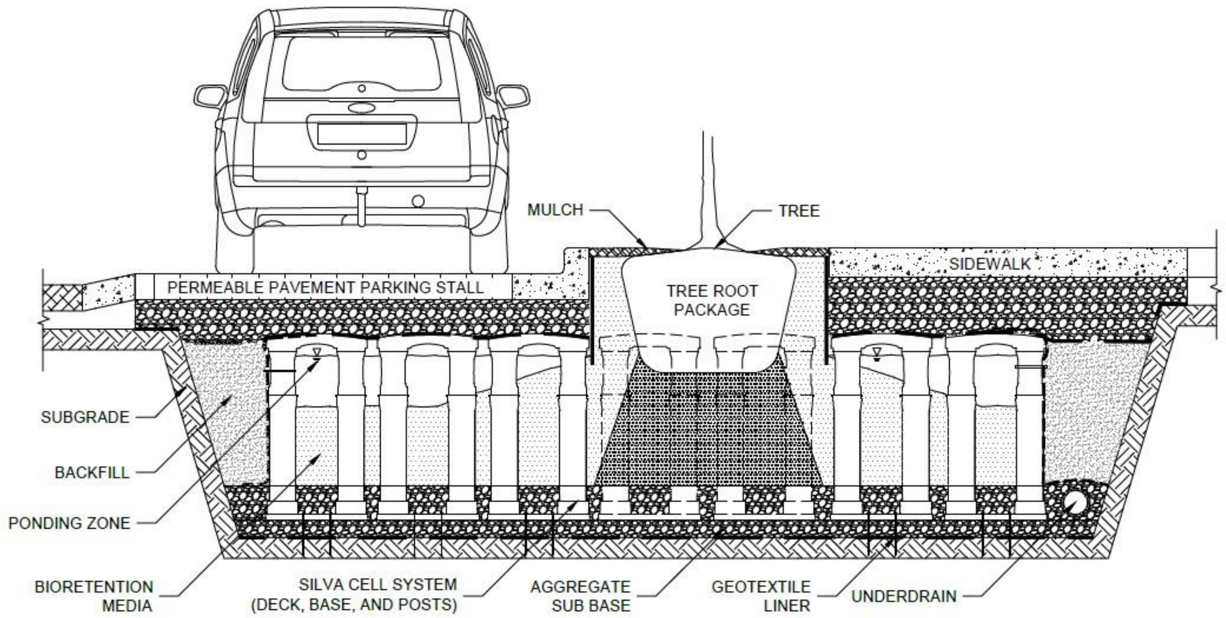
MDC 4. STORAGE OF THE DESIGN VOLUME.
Storage of the design volume shall occur above the filter media surface (up to 6”) and within the aggregate layers above the Silva Cell decks (up to 12”). The maximum total depth of storage above the top of the filter media surface is 18 inches.

The design volume of a Silva Cell System equals the surface storage volume above the filter media plus the storage volume within the aggregate layer. The area above the filter medial should be considered to have a void ratio of 0.92 to account for volume taken up by the Silva Cell posts. The void ratio of the aggregate layer is typically between 0.33 and 0.40, depending on the type of aggregate specified (Figure 3).

Effective storage depth = Depth of the surface storage * 0.92 + Depth of the aggregate layer * the void ratio of the aggregate.

Figure 3: Storage of Runoff within the Silva Cell Suspended Pavement

Note: Upturned elbow with IWS Zone not shown.
See Section Chapter C.2 - Bioretention for IWS configurations



MDC 5. SETTING THE SURFACE AREA.
The surface area of the Silva Cell System that is needed shall be based on dividing the design volume by the effective storage depth.

The design surface area will vary depending on the effective surface storage depth and number of Silva Cell units needed to reach the required surface area and storage volume. There is no set configuration recommended or required by the manufacturer. The Silva Cell units are modular and the plan view configuration is intended to be flexible to work in confined urban environments.

A spreadsheet sizing tool is available from DeepRoot to assist in designing the Silva Cell System. Figure 4 shows a a sample calculation in which the following are specified: a Dv of 584 ft^3 , a 3X Silva Cell configuration and surface storage depth of 6 inches, and a pavement aggregate layer of 12 inches. The effective surface storage depth is then determined followed by the necessary SCM surface area needed to store the treatment volume above the filter media. Silva Cell units needed for the project are also calculated.

Figure 4: Design Storm Sizing Summary and Silva Cell Design Tool Output Summary

Silva Cell Stormwater Design Volume (D_v) Sizing Tool
Only enter data in shaded cells
Outputs for design

Design Parameter	Value	Notes
Drainage Area (ac)	0.16	DA from project plans
Design Volume (ft^3)	548	D_V from stormwater calculations
Silva Cell Configuration	3X	Select one: 2X, 3X
Surface Storage (in)	6	Select one: 3", 4", 5", 6"
Filter Media Depth (in)	37	Determined by SC configuration and surface storage
Aggregate Depth - Layer 1 (in)	6	Min 6", Max. 12"
Aggregate Depth - Layer 2 (in)	12	Min 6", Max. 12"

Void Ratios (V_R)	Value	Notes
Aggregate Storage - Layer 1	0.35	See SC2 Tech Sheet for additional documentation
Aggregate Storage - Layer 2	0.40	See SC2 Tech Sheet for additional documentation
Silva Cell Surface Storage	0.92	See SC2 Tech Sheet for additional documentation

Design Parameter	Value	
Design Storage Depth (in)	12.4	Surface Storage + Aggregate Storage
Design Surface Area (ft^2)	529	T_V / Storage Depth
Number of Silva Cell Units (ea)	66	Each SC unit = 8 ft^2
DA:SA Loading Ratio	13.2	DA / SA, typical BRC is 8:1 to 12:1
Soil Volume (ft^3)	1633	Calculated from Surface Area and Filter Media Depth

MDC 6. FLOW DISTRIBUTION.
Influent stormwater shall be evenly distributed over the surface of the media through the use of distribution pipes from tree wells or catch basins or via direct infiltration through a permeable pavement.

Multiple methods for distribution and conveyance of runoff to the interior of the Silva Cell System are recommended for redundancy and conservative designs. Combinations of tree well flow, catch basins and distribution pipes and infiltration are common.

MDC 7. UNDERDRAIN.
An underdrain with internal water storage (IWS) shall be installed for all Silva Cell Systems. For sites with in-situ soil infiltration rates of two inches per hour or greater immediately prior to the initial placement of the media, IWS zones are recommended. The top of the IWS zone shall be set at a minimum of 18 inches below the subgrade surface.

Underdrain sizing requirements are discussed in Part A-4.a. An internal water storage zone (IWS) is created by adding an upturned elbow in the underdrain piping perpendicular to the horizontal underdrain. Including an IWS enhances the system's ability to attenuate peak flows, infiltrate stormwater, remove TSS and nitrogen, and cool stormwater. In fact, a bioretention system with an IWS will only rarely generate outflows in A and B soils. In Piedmont soils, the IWS remains saturated for a longer time, which creates anaerobic conditions that promote denitrification and increased N removal. In addition to their other benefits, bioretention systems cool stormwater because stormwater is stored and discharged from underground.

MDC 8. TREE SELECTION.
Selection of trees shall consider eco-regional location (mountains, piedmont and coastal plain), hardiness under wet and dry conditions and suitability in the urban environment. A list of recommended tree species is included below.

Vegetation is an integral component of Bioretention. The Silva Cell Systems are specifically designed to accommodate trees. Tree roots intercept pollutants, improve soil structure, and increase infiltration rates of the filter media. Tree selection should consider the conditions and aesthetic goals of the site. Visually appealing trees encourage community acceptance. Trees planted in Silva Cell systems used as SCMs can be used to meet local landscaping and urban forestry requirements. Soil moisture conditions within a bioretention system range from saturated (bottom) to relatively dry (top) as well as over time. Bioretention facilities in the piedmont and mountains tend to become wetter over time; coastal bioretention facilities tend to be very dry. The trees used should be facultative species adapted to stresses associated with wet and dry conditions.

Table 1: Tree species suitable for use with the Silva Cell system in NC

Common name	Scientific name	Hardiness zone(s)
American Sweetgum	*Liquidambar styraciflua CV's 'Worplesdon' or 'Cherokee' or 'Corky' or 'Moraine'*	6
Birch, River	*Betula nigra*	4
Birch, White River	*Betula nigra CV 'Heritage'*	4

Buckeye, Yellow	*Aesculus octandra*	5
Cedar, Incense	*Calocedrus decurrens*	6
Cypress, Bald	*Taxodium distichum CV 'Shawnee Brave' or 'Apache Chief' 'Fastigata'*	4
Dogwood, Corelian cherry	*Cornus mas*	5
Dogwood, Flowering	*Cornus forida*	6
Dogwood, Kousa	*Cornus kousa*	5
False Cypress, Atlantic White or Swamp	*Chaemocyparis thyoides*	5
False Cypress, Lawson's	*Chaemocyparis lawsoniana*	6
False Cypress, Nootka	*Chaemocyparis nootkatensis*	6
Hickory, Water	*Carya aquatic*	6
Holly, American	*Ilex opaca*	6
Holly, Blue	*Ilex x meserve*	5
Holly, Dahoon	*Ilex cassine*	8
Holly, English	*Ilex aquifolium*	7
Holly, Possum Haw	*Ilex decidua*	5
Hornbeam, European	*Carpinus betulus*	5
Japanese Cedar	*Cryptomeria japonica*	7
Japanese Stewartia	*Stewartia pseudocammelia*	5
Kentucky Coffee Tree	*Gymnocladus dioica MALE 'Espresso' or 'Stately Manor'*	4
Living Fossil Tree or False Sequioa	*Metasequoia glyptostroboides*	5

Magnolia, Bay	*Magnolia virginiana*	6
Magnolia, Southern	*Magnolia grandiflora*	6
Magnolia, various ornamental	*Magnolia sp. subsp. and CV: M. kobus; M. stellata; M. soulangeana*	5+
Maple, Red	*Acer rubra*	3
Maple, Silver	*Acer saccharinum*	3
Mulberry, Red	*Morus rubra*	5
Oak, Southern Live	*Quercus virginiana*	9
Oak, Swamp	*Quercus bicolor*	4
Oak, Swamp Post	*Quercus lyrata*	6
PawPaw	*Asimina triloba CV 'Davis' or 'Overleese' or 'Sunflower'*	5
Persimmon, American	*Diospyros virginiana MALE*	6
Platanus, London	*Platanus A. x acerifolia CV 'Bloodgood' or 'Columbia'*	5
Tupelo, Black	*Nyssa sylvatica*	4
Tupelo, Swamp	*Nyssa sylvatica var. biflora*	6
Tupelo, Water	*Nyssa aquatic*	7
Willow, Babylon Weeping	*Salix babylonica*	5
Wingnut, Caucasian	*Pterocarya fraxinifolia*	6
Wingnut, Chinese	*Pterocarya stenoptera*	7

MDC 9. MEDIA DEPTH.
The minimum depth of the media shall be 25 inches.

25 inches is the filter media depth when the Silva Cell 2x (31 inch depth) is used with 6 inches of surface storage. However, it is recommended that designers use deeper media depths when targeting nitrogen and temperature reductions.

MDC 10. MEDIA MIX
The media shall be a homogeneous soil mix with approximate volumes of: 75 to 85 percent medium to coarse washed sand (ASTM C33, AASHTO M 6/M 80, ASTM C330, AASHTO M195, or the equivalent), 10 percent fines (silt and clay), and 5 to 10 percent organic matter (such as pine bark fines).

It is very important to ensure that sand meets the specification above; sand particles that are too fine have caused clogging in several bioretention cells across NC. Higher (12-15 percent) fines should be reserved for areas where TN is the target pollutant. In areas where phosphorus is the target pollutant, lower (8 percent) fines should be used. A 'fine' is defined as passing a #200 sieve.

The filter media mix is designed to maintain long-term fertility and pollutant processing capability. Research on metal attenuation indicates that metal accumulation should not present a toxicity concern for at least 20 years in bioretention facilities (USEPA 2000). If the media in a bioretention cell needs to be replaced, DEQ recommends having it tested for toxicity for proper disposal, although usually a standard landfill can accept it.

MDC 11. MEDIA P-INDEX.
The phosphorus index (P-index) for the media shall not exceed 30 in NSW waters as defined in 15A NCAC 02B .0202 and shall not exceed 50 elsewhere.

Soil media should be sent to an NC Department of Agriculture lab or another reputable lab for analysis of the P-index. The P-Index is a crucial design element. Some of the media in NC and many farm soils contains a high level of phosphorus that can increase the P concentration in stormwater by an order or magnitude or more.

MDC 12. NO MECHANICAL COMPACTION.
The media shall not be mechanically compacted. It is recommended to either water it or walk on it as it is placed.

Inspectors should make allowances for rapid infiltration of water through newly installed media and allow several large storms to infiltrate and consolidate the media before determining infiltration rates in newly installed beds.

MDC 13. PAVEMENT AGGREGATES
Aggregates used above the Silva Cell decks as bedding, base or sub-base layers shall be double washed and free of fine particles and debris at the time of installation.

MDC 14. MONITORING OF MEDIA.
The media contained within the Silva Cell units shall be maintained in a manner that results in a drawdown of at least one inch per hour at the planting surface. At least two inspection ports and monitoring wells shall be installed to measure internal drawdown rates and inspect the soil media for sufficient drawdown and function.

MDC 15. CLEAN-OUT PIPES.
A minimum of one clean-out pipe shall be provided on each underdrain line and distribution line (if included in the design). Clean out pipes shall be capped.

DEQ recommends providing a minimum of one clean-out pipe one per every 1,000 square feet of surface area. Clean out pipes should be in an accessible location for observation and maintenance. Specify PVC pipes with glued clean-out fittings with screw type caps NO flexible pipe allowed.

MDC 16. BYPASS.
A catch basin or overflow inlet shall be used downslope of any inlets in the right-of-way to ensure bypass or overflows will not create flooding.

MDC 16. MAINTENCE.
Maintenance shall be performed per the **Silva Cell Operation and Maintenance Manual**.

Additional Resources

Silva Cell Tech Sheet:
http://www.deeproot.com/silvapdfs/resources/SC2/supporting/SilvaCell-2%20tech-sheet.pdf

Silva Cell Operations and Maintenance Manual:
http://www.deeproot.com/silvapdfs/resources/construction/Silva-Cell-Operations-and-Maintenance-Manual.pdf

Installation Guide:
http://www.deeproot.com/silvapdfs/resources/SC2/construction/SC2-Contractor-Install-Guidelines-web.pdf

Silva Cell Stormwater Sizing Tool:
http://www.deeproot.com/products/silva-cell/landing-page/silva-cell-2/resources

Peer-Reviewed Journal Article in Ecological Engineering:
http://www.sciencedirect.com/science/article/pii/S0925857415001706

Other Silva Cell Technical Resources:
http://www.deeproot.com/products/silva-cell/landing-page/silva-cell-2/resources