6. Landscape and Soil Composition Specifications

6.1. Importance of Plants and Soil Composition in BMPs

The proper selection of plants and soil composition specifications is a critical aspect to the function and success of many stormwater BMPs. Plants increase pollutant removal by providing resistance to the flow of stormwater and subsequently reducing runoff velocity. Slower runoff velocities translate into more time for the functioning of pollutant removal pathways such as settling, filtering, infiltration, and adsorption (Schueler, 1996). Additional benefits from BMP plants and soils include:

- Treatment benefits such as organic carbon needed for microbial transformation processes.
- Moderation of environmental factors such as water temperature and oxygen concentrations in sediment.
- Plant roots stabilize the soil, including aggraded sediments, and remove pollutants that adhere to the sediment particles from runoff.
- Increased pollutant removal by up-take, called phytoextraction.
- Amelioration of the heat island effect.

The soil composition of many stormwater BMPs also is vital to their relative success or failure in achieving their intended purpose. Soil specifications can vary according to the design objectives (e.g., nutrient removal), as well as *in situ* topsoil composition. Properly designed soil media aids in infiltration and natural detention as well as plant health. .

6.2. Hydrologic Zones and Plant Selection for Stormwater Wetlands and Wet Detention Basins

The interplay between plants, hydrology, and soil composition are vital to the function of stormwater wetlands and wet detention basins. Therefore, it is essential that selected plant materials are appropriate for the anticipated conditions. Hydrologic zones describe the degree to which an area is inundated by water. Plant selection should be consistent with anticipated hydrology. These tolerance levels have been divided into four zones:

- Deep Pool
- Shallow Water
- Shallow Land
- Upland
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The descriptions of these zones in this chapter are meant to depict them in only the broadest terms. For specific design guidance, please see the Stormwater Wetland and Wet Detention Basin chapters of this manual.

6.2.1. Deep Pool

Open water and permanent deep pools ranges are best colonized by submergent plants. The function of vegetated deep pools areas is to trap sediment in forebays, and in deep pools to absorb nutrients in the water column, improve oxidation and create habitat for frogs and fish during dry times.

6.2.2. Shallow Water

Shallow Water includes all areas that are inundated by the normal pool to a depth of 6 inches. This zone does, however, become drier during periods of drought. Shallow water zones should be heavily vegetated and provide some of the best treatment zones in the wetland.

6.2.3. Shallow Land

The shallow land zone is the temporary storage volume portion of a Wet Pond or Stormwater Wetland. The primary landscaping objectives for this zone are to stabilize the slopes characteristic of this zone and optimize pollutant removal.

6.2.4. Upland

This zone extends above the maximum design water surface elevation (never inundated) and often includes the outermost buffer of a pond or wetland. Plant selections should be made based on soil condition, light, and function within the landscape because little or no water inundation will occur.

6.3. Plant selections for Bioretention Cells (Rain Gardens)

Unlike some of the plant selections for stormwater wetlands and wet detention ponds, plants used in bioretention cells have to be able to withstand widely varying soil moisture conditions. Conditions in bioretention can be very dry for long time periods, punctuated with periods of temporary submergence. Although some plant species used in stormwater wetlands and wet detention ponds can be used in bioretention cells, they are often not suitable for all areas in these BMPs. Additionally, bioretention cells can have an alternate planting option where the entire surface of the cell is grassed. Sod must be installed when grass is used for bioretention cells, seeding is not a viable option. **For specific design guidance, please see the Bioretention chapter of this manual.**

6.4. Landscape Plans

Healthy, thriving vegetation plays a key role in the performance of many stormwater BMP facilities. Facility-specific planting requirements are given in their respective chapters. These requirements are based on the collective experiences of NC DENR and North Carolina State University Biological and Agricultural Engineering faculty and staff as well as standard landscape industry methods for design and construction.

The landscape planting design must include elements that ensure plant survival and overall stormwater BMP facility functional success. Plant selection is a complex task, involving matching the plant's physiological characteristics with a site's particular environmental conditions. The following factors should be considered:

- Site conditions (e.g., wind direction and intensity, street lighting, type and quantity of pollutants contained within stormwater runoff, etc.).
- Soil moisture and drought tolerance.
- Sediment and organic matter build-up.
- Potential for outlet structure clogging (e.g., root structure).
- Maintenance.
- Wildlife use (including mosquitoes).
- Aesthetics/ability to meet both landscape and stormwater BMP requirements.

Individual plants often have physiological characteristics difficult to convey in a general list. It is necessary to investigate specific information to ensure successful plant selection. There are many resources available to guide designers in the selection of plant material for stormwater BMP facilities. Knowledgeable landscape architects, wetland scientists, urban foresters, and nursery suppliers provide valuable information for considering specific conditions for successful plant establishment and accounting for the variable nature of stormwater hydrology.

6.4.1. Required Items in a Landscape Plan

Landscape plans must be prepared by a qualified design professional. They must include the following items, at a minimum:

1. Landscape plan sheet
   - A scaled construction drawing (typically at 1″ = 20′) to accurately locate and represent the plant material used within the BMP facility. Representation of plant material should be to scale and depicted at the mature width or spread.
   - A key that identifies all plant material used in the planting plan. The symbols used to identify the plants will correlate with the plant schedule. Plant groupings on the drawing are usually shown by an identifying symbol and the number of plants in that particular group.
   - A list any other necessary information to communicate special construction requirements, materials, or methods such as specific plants that must be field located or approved by the designer and size or form matching of an important plant grouping.

2. Plant list/table
   - This must include scientific name, common name, quantity, nursery container size, quantity, container type (e.g., bare root,

b&b, plug, container, etc.), appropriate planting season, and other information in accordance with the BMP facility-specific planting section and landscape industry standards.
- Source of the plant materials must be indicated in the plant schedule. Plant material should be purchased from a similar provenance[1] or local source to ensure survivability.

3. Soil media specifications. If topsoil is specified, indicate the topsoil stockpile location, including source of the topsoil if imported to the site.

4. Construction notes with sequencing, soil and plant installation instructions, and initial maintenance requirements.

5. A description of the landscape contractor's responsibilities.

6. A minimum two-year warranty period stipulating requirements for plant survival/replacement.

At the end of the first year and again at the end of the two-year warranty period, all plants that do not survive must be replaced. Establishment procedures, such as control of invasive weeds, animal and vandal damage, mulching, re-staking, watering, and mesh or tube protection replacement, shall be implemented to the extent needed to ensure plant survival. Staking must be removed after establishment (approximately 12 months), to prevent girdling (strangling) of all woody plants.

The design for plantings shall minimize the need for herbicides, fertilizers, pesticides, or soil amendments at any time before, during, and after construction and on a long-term basis. Furthermore, plantings shall be designed to minimize the need for mowing, pruning, and irrigation.

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[1] Provenance means "place of origin." Plant provenance refers to the place where a plant evolved and had its genetic makeup determined. Trees and shrubs may be native to many areas of the country or world, but you can have a case where the seeds or cuttings taken from the same tree or shrub in Illinois or Pennsylvania would have a different genetic makeup than one taken from the same species in North Carolina.

Plants evolve and adapt over the years - these changes are mapped into the genetic material. This mapping can have a profound effect on cold hardiness, resistance to heat, or drought tolerance.

Keep this in mind this spring when you purchase a shrub or tree for your stormwater BMP. Check if it is native to your area, but also find out where that particular tree or shrub was actually grown. A good nursery or greenhouse should have already considered that when they placed the plant for sale - but you should still keep it in mind when you purchase.

Grass or wildflower seed must be applied at the rates specified by the suppliers. If plant establishment cannot be achieved with seeding by the time of substantial completion of the stormwater facility portion of the project, then the contractor shall plant the area with wildflower sod, plugs, container plants, or other means to complete the specified plantings and protect against erosion before water is allowed to enter the stormwater BMP facility.

6.4.2. Guidelines for Plant Placement

The guidelines listed below should be followed:

- No trees or shrubs should be planted within 10 feet of inlet or outlet pipes, or manmade drainage structures such as spillways or flow spreaders. Species with roots that seek water (e.g., willow and poplar), should be avoided within 50 feet of pipes or manmade structures.

- Planting should be restricted on berms that impound water either permanently or temporarily during storm events. This restriction does not apply to cut slopes that form pond banks, only to berms.
    - Trees or shrubs must not be planted on portions of water impounding berms taller than 4 feet high; only grasses may be planted. Grasses allow for unobstructed visibility of berm slopes for detecting potential dam safety problems such as animal burrows, slumping, or fractures in the berm.
    - Trees planted on portions of water-impounding berms less than 4 feet high must be small (less than 20 feet mature height) and have a fibrous root system. These trees reduce the likelihood of blow-down, or the possibility of channeling or piping water through the root system, which may contribute to dam failure on berms that retain water.

    Note: the internal berm within a wet pond is not subject to this planting restriction since the failure of an internal berm would be unlikely to create a safety issue.

- All landscape material, including grass, should be planted in good topsoil. Native underlying soils may be suitable for planting if amended with 4 inches of well-aged compost tilled into the subgrade. Compost used should meet specifications for Grade A compost quality.

- Soil in which trees or shrubs are planted may need additional enrichment or additional compost top-dressing depending on the results of the soil analysis. Consult a nurseryman, landscape professional, or arborist for site-specific recommendations.

- For a naturalistic effect, as well as ease of maintenance, trees or shrubs should be planted in clumps to form '*landscape islands*' rather than evenly spaced.

- The landscaped islands should be a minimum of six feet apart, and if set back from fences or other barriers, the setback distance should also be a minimum of six feet. Where the tree foliage extends low to the ground, the 6-foot setback should be counted from the outer drip line of the trees (estimated at maturity). This setback allows a 6-foot wide mower to pass around and between clumps.

- Evergreen trees and trees which produce relatively little leaf-fall are preferred in areas draining to a detention device.

- Trees should be set back so that branches do not extend over the permanent pool of a detention device (to prevent leaf-drop into the water and clogging issues).

- Drought-tolerant species are recommended.

6.5. Soil Media

Soils are highly complex systems that provide essential environmental benefits including biofiltration of pollutants, nutrients for plant growth, and the storage and slow release of storm flows. The ability of soil to effectively store and slowly release water is dependent on its' properties—texture, structure, organic matter content, and biota—as well as depth. Plant roots, macro fauna, and microbes tunnel, excavate, penetrate, and physically and chemically bond soil particles to form stable aggregates that enhance soil structure and porosity. Soil properties are the principal factor controlling the fate of water in the hydrologic system. Water loss, utilization, contamination, and purification are all affected by the soil (Brady and Weil, 2007).

Organic matter is a critical ingredient in the function of a soil. Mixed into the soil, organic matter absorbs water, physically separates clay and silt particles, and reduces erosion. Microbial populations and vegetation depend on the replenishment of organic matter to retain and slowly release nutrients for growth. Construction activity removes the upper layers of soil, compacts exposed sub-soils low in organic matter, and alters the site's hydrologic characteristics by converting the predominantly subsurface flow regime of the pre-disturbance site to primarily overland flow.

Soil permeability is an important design factor in stormwater BMPs. It is advantageous and sometimes necessary to have high permeability *in-situ* soils for systems where infiltration may be desired (e.g. bioretention, infiltration devices, etc.). It is also advantageous and sometimes necessary to have low permeability *in-situ* soil for systems where permanent ponded water is required (e.g. stormwater wetlands, wet detention basins and liners must be used if *in-situ* permeability is too high). In some BMP systems (e.g. sand filters, bioretention, etc.), high permeability media is required within the BMP, but since relatively small quantities are typically required, suitable soils can be imported to a site if necessary.

The organic content of soils can be an important factor in BMP selection and design for two reasons. First, BMP vegetation thrives best with the proper soil organic content. Organic content requirements for the soil in planted areas can range from 2-10% (Oregon State University Forest Nursery Manual, 1984), but it is a very site and plant specific value, based on an analysis of the topsoil. The organic content of soils can affect pollutant removal rates in BMPs that pass stormwater through soil media. High organic content has been shown to increase removal rates of some metals and some organic compounds.

Finally, another important aspect of soils is their typically high erosivity. Soils need to be quickly stabilized with vegetative cover or they will suffer from wind and water erosion (sometimes severely). Vegetative cover must be properly maintained over the life of the BMP to prevent bare spots from occurring and the subsequent erosion of the exposed soils. Sometimes additional measures (e.g. rock linings, geosynthetics, etc.) must be taken to protect soils from erosion in certain circumstances (i.e., steep slopes, excessive BMP outlet velocities, etc.)

6.5.1. Soil Analysis

In order to reduce costs, *in situ* excavated soil, rather than imported soil can be used for stormwater wetlands (*in situ* soils should never be used for bioretention). Using on-site excavated soil for the amended soil in a stormwater BMP, however, may reduce control over gradation, organic content, and final product performance. In turn, this can significantly increase project costs and complicate construction logistics when attempting to blend soil mix components in restricted space or during winter months.

As a result, if it is determined *in situ* soils will be utilized, then a soil analysis must be conducted. The purpose of the analysis is to determine the viability of soils to assure healthy tree and vegetation growth and to provide adequate infiltration rates through the topsoil, or soil media. The analysis will determine whether on-site soils will ultimately be suitable for the particular BMPs being utilized, what types and quantities of amendments will be required, or if an engineered soil media will be necessary. All soil mixes for stormwater BMPs must be designed to maintain long-term viability and pollutant-processing capability. BMP facilities receiving high quantities of heavy metals will need periodic replacement.

The soil analysis work for a BMP system should be performed by a qualified, licensed professional. Soil analyses should include the following:

- Soil pH (whether acid, neutral, or alkaline).
- Soil texture.
- Soil test NCDA & CS (nutrient content).
- Content (percent clay, organic material, etc.).

Soil samples must be analyzed by experienced and qualified individuals, such as the local Cooperative Extension or NRCS office, who will explain in writing the results,

what they mean, as well as what soil amendments would be required. Certain soil conditions, such as marine clays, can present serious constraints to the growth of plant materials and may require the guidance of qualified professionals. When poor soils cannot be amended, seed mixes and plant material must be selected to establish ground cover as quickly as possible.

A soils report evaluating the above parameters should be included in a stormwater management plan submittal to verify the treatment capability of the soil mix.

Analyzing soils for hydraulic conductivity and infiltration rate is highly recommended.

6.5.2. Soil Amendments

During construction, soils can become very compacted. Additionally, many native soils are of a poor or highly compacted quality.

Compost: If *soils surrounding* BMPs are poor, we recommend that you incorporate an organic amendment in order to protect the investment you have made in plantings, and to increase plant growth. We recommend that if compost is added as an amendment to surrounding soils, it should be incorporated into the soil. Apply at a depth of 1 inch. This should be incorporated into a depth of 3-6 inches by scarifying or core aeration.

We do ***not*** recommend adding compost as an amendment to BMP soil media; nutrient levels are too high and large nutrient losses will result. Additionally, because such a small amount is needed, an even distribution is difficult to achieve on-site.

Pine Bark: A good source of organic matter for Bioretention beds is pine bark fines. Pine bark is readily available and forms the basis for the standard potting soil used by the nursery industry in North Carolina (5 parts bark, 1 part coarse sand). Pine bark is easily mixed and will not add nutrients to the soil mix.

Peat Moss: Peat moss is not recommended as an amendment for *surrounding soils* as it decomposes too quickly in North Carolina (about 3-6 months). Peat moss is, however, recommended *as an amendment to Bioretention* fill media as these organics will be replaced as the cell is used to treat stormwater.

The benefits from adding organic amendments are:

- Reduced erosion through soil stabilization.
- Increased sediment filtration.
- Pollutant adsorption and bioinfiltration (including heavy metals, oil, and grease).
- Improved plant growth, disease resistance, and vigor.
- Increased soil hydrology

6.5.3. Soil Specifications

Soils used within a stormwater BMP must adhere to the following requirements:

- The soil mix must be uniform and free of stones, stumps, roots, or other similar material greater than 2 inches in diameter.

- The pH should be between 4.5 and 7.0. If the pH falls outside of this range, it may be modified with lime to increase the pH or iron sulfate and sulfur to lower the pH. The lime or iron sulfate must be mixed uniformly into the soil prior to use.

- Topsoil stockpile location (if using on-site soils) or source of topsoil if imported to the site. Soil analysis for all topsoil to be used within a BMP facility[2].

6.6. Site Preparation, Grading, and Installation

Vegetation within the footprint of the stormwater BMP facility area should be removed during site preparation with equipment appropriate for the type of material encountered and site conditions. It is recommended that the maximum amount of pre-existing native vegetation be retained and protected. Vegetation protection areas, including wetlands, with intact native soils and vegetation should not be cleared and harvested for use in BMP facilities.

Areas that recently have been involved in construction are subject to extreme compaction. Soil compaction can lead to BMP failure where infiltration is a key factor in its function. No material storage or heavy equipment should be allowed within the stormwater BMP facility area after site clearing and grading have been completed, except to excavate and grade as needed to construct the BMP.

Excavation should not be allowed during wet or saturated conditions. Excavation should be performed by machinery operating adjacent to the BMP facility area and no heavy equipment with narrow tracks, narrow tires, or large lugged, high pressure tires should be allowed on the bottom of bioretention or infiltration BMPs. If machinery must operate in a BMP facility for excavation, then use lightweight, low ground-contact pressure equipment and scarify the base at completion to refracture the subsoil as deep as equipment will allow. In other cases where exfiltration is a concern (e.g., stormwater wetlands), it is desirable to compact the soil to form an impermeable barrier between the bottom of the wetland and the surrounding native soils.

[2] This requirement is due to the fact that nitrogen and phosphorous levels in agricultural soils tend to be very high. The purpose of the stormwater BMP is generally to reduce the nutrient load of the runoff into receiving waters as well as peak flow attenuation.

If existing areas surrounding the stormwater BMP facility are disturbed by construction, then the top 6 to 8 inches of soil should be tilled. *No tilling shall occur within the drip line of existing trees*. After tilling is completed, no other construction traffic shall be allowed in the area, except for planting and related work.

All construction and other debris should be removed before topsoil is placed.

Cap the scarified sub-soil with topsoil or the specified soil mix. On-site soil mixing or placement should not be performed if the soil is saturated. The soil mixture should be placed and graded by excavators and/or backhoes operating *adjacent* to the BMP facility. The soil mixture should be placed in horizontal layers not to exceed 12 inches per lift for the entire area of the BMP facility.

Note that if topsoil has been stockpiled in deep mounds for a long period of time, it may be necessary to test the soil for pH as well as microbial activity. If the microbial activity has been destroyed, it is necessary to inoculate the soil after application.

6.6.1 Determining the Final Grade

The soil mixture will settle and proper compaction will be achieved by allowing time for nature compaction and settlement. However, to speed the process, each lift can be watered until just saturated. The water should be applied by spraying or sprinkling.

To achieve the appropriate grade, changes in soil depth from tilling and incorporating soil amendments need to be estimated. The difference in volume of the dense versus the loose soil condition is determined by the 'fluff factor' of the soil. The fluff factor of compacted sub-soils tends to be around 1.3 to 1.4. Tilling typically penetrates the upper 6 to 8 inches. Assuming a 6-inch depth, the depth adjusted for the fluff factor will correspond to 7.8 to 8.4-inch depth of loose soil. If amended at a 2:1 ratio of loose soil to compost, or 4 inches, the final amended soil elevation must account for compost settling into the void spaces of the loose soil and compaction. If the soil and compost are rototilled to mix and then the soil tamped lightly to compress, the resulting increase in elevation for soils amended to a 6-inch depth would be approximately 3 inches.

6.6.2 Planting and After-Care

Soil amendments should be incorporated at the end of the site development process to prevent sediment from entering the BMP facility. The BMP should be planted and mulched immediately after amending the soil to stabilize the site as soon as possible.

Newly installed plant material requires water in order to recover from the shock of being transplanted. Be sure that some source of water is provided, especially during dry periods. This will reduce plant loss and provide the new plant materials with a chance to establish root growth.

In general, fall and winter are optimal for planting in North Carolina. There are some exceptions. Shallow water plants should be installed between April 1 and July 15 in North Carolina. Winter planting is difficult with shallow water plants.

Minimize or eliminate the use of pesticides and fertilizers. A one-time application of fertilized is allowable to help establishment. Landscape management personnel should be trained to adjust chemical inputs accordingly and manage to recognize plant health problems.

September 28, 2007 Changes:

1. 6.2: Corrected the topographic zone depths.

June 17, 2009 Changes:

1. Revised notes for planting zones of Stormwater Wetlands and Wet Detention Ponds.
2. Added planting notes for Bioretention Cells.
3. Modified chapter 6.5.2 (Soil Amendments)