CAREONE AT LAWRENCE - LANDSCAPING COMPLIANCE TABLE

LANDSCAPING DESCRIPTION	AREA/LENGTH	ORDINANCE REQUIREMENT DESCRIPTION	REQUIRED	EXISTING	PROPOSED
§525.C.2 STREET TREES	PROVINCE LINE ROAD (310 LF)	LARGE TREES - 1 TREE SPACED AT 40'	8	7	15
	LAWRENCEVILLE ROAD - U.S. ROUTE 206 (939 LF)	LARGE TREES - 1 TREE SPACED AT 40'	24	11	56
§525.H.3 REQUIRED MINIMUM BUFFER WIDTH					
• TABLE 5.10 - INSTITUTIONAL TO RESIDENTIAL TYPE A - 50 FT BUFFER REQUIRED					
• TABLE 5.11 - MINIMUM PLANT DENSITY FOR BUFFERS	BUFFER LENGTH BETWEEN LOT 2.01 AND LOT 2.02 = 200 LINEAL FT	• 8 LARGE OR MEDIUM TREES PER 100 LINEAL FT	16 TREES (200FT/100FT= 2 *8 = 16)	9	16
		• 12 ORNAMENTAL TREES PER 100 LINEAL FT	24 TREES (200FT/100FT= 2 *12 = 24)	0	24
		• 24 EVERGREEN TREES PER 100 LINEAL FT	48 TREES (200FT/100FT = 2 *24 = 48)	0	48
		• 48 SHRUBS PER 100 LINEAL FT	96 SHRUBS (200FT/100FT = 2 *48 = 96)	0	96
§525.J STORMWATER FACILITIES	*DESIGNED PER NJDEP BMP MANUAL CHAPTER 7 LANDSCAPING GUIDELINES FOR SMALL SCALE BIORETENTION SYSTEM*				
§525.L.2 PARKING AND LOADING AREA LANDSCAPING	TOTAL PARKING ISLAND LENGTH = 382 LINEAL FT	• 6 LARGE OR MEDIUM TREES PER 100 LINEAL FT	23 TREES (382FT/100FT= 3.82 *6 = 23)	N/A	23
		• 4 ORNAMENTAL TREES PER 100 LINEAL FT	16 TREES (382FT/100FT= 3.82 *4 = 23)	N/A	16
		• 60 SHRUBS PER 100 LINEAL FT	230 SHRUBS (382FT/100FT= 3.82 *60 = 23)	N/A	230

Prepared by T&M Associates
Date: 12/23/22

CAREONE AT LAWRENCE - TREE DENSITY CALCULATIONS - §541.H

ORDINANCE REQUIREMENT	TOTAL	
SINGLE FAMILY DETACHED RESIDENTIAL		
PROPOSED LOT 2.01	1.000	GROSS TRACT AREA (ACRES)
§541.I.1 - GROSS TRACT AREA x 15	15	REQUIRED TREE DENSITY
§541.I.3 - TABLE 5.19 CONVERSION OF CALIPER TO TREE DENSITY UNITS FOR EXISTING TREES	99.6	EXISTING TREE DENSITY - 41 EXISTING TREES VARYING FROM 8" TO 41" CALIPER
§541.I.4 - TABLE 5.20 CONVERSION FROM CALIPER TO TREE DENSITY UNITS FOR DECIDUOUS REPLACEMENT TREES	12.0	PROPOSED TREE DENSITY - NEW DECIDUOUS TREES - 20 TREES X 0.6 (3 INCH CALIPER)
§541.I.4 - TABLE 5.21 CONVERSION FROM CALIPER TO TREE DENSITY UNITS FOR CONIFEROUS REPLACEMENT TREES	28.8	PROPOSED TREE DENSITY - NEW CONIFEROUS TREES - 36 TREES X 0.8 (5-6 FT HEIGHT)
	67.0	27 EXISTING TREES TO REMAIN VARYING FROM 8" TO 38" CALIPER
	107.8	**TOTAL PROPOSED TREE DENSITY**
ASSISTED LIVING/SKILLED NURSING		
PROPOSED LOT 2.02	5.449	GROSS TRACT AREA (ACRES)
§541.I.1 - GROSS TRACT AREA x 15	81.7	REQUIRED TREE DENSITY
§541.I.3 - TABLE 5.19 CONVERSION OF CALIPER TO TREE DENSITY UNITS FOR EXISTING TREES	311.2	EXISTING TREE DENSITY - 144 EXISTING TREES VARYING FROM 8" TO 40" CALIPER
§541.I.4 - TABLE 5.20 CONVERSION FROM CALIPER TO TREE DENSITY UNITS FOR DECIDUOUS REPLACEMENT TREES	123.0	PROPOSED TREE DENSITY - NEW DECIDUOUS TREES - 205 TREES X 0.6 (3 INCH CALIPER)
§541.I.4 - TABLE 5.21 CONVERSION FROM CALIPER TO TREE DENSITY UNITS FOR CONIFEROUS REPLACEMENT TREES	149.6	PROPOSED TREE DENSITY - NEW CONIFEROUS TREES - 187 TREES X 0.8 (5-6 FT HEIGHT)
	86.0	39 EXISTING TREES TO REMAIN VARYING FROM 8" TO 40" CALIPER
	358.6	**TOTAL PROPOSED TREE DENSITY**

Prepared by T&M Associates
Date: 12/23/22

CHAPTER 7

Landscaping

Landscaping is critical to improving both the function and appearance of stormwater best management practices (BMPs). This chapter provides landscaping criteria and plant selection guidance for effective stormwater BMPs. Part 1 describes the natural plant communities of New Jersey based on plant hardiness zones and physiographic regions. Plant selection for stormwater BMPs should match as closely as possible the natural plant communities of that region. Part 2 outlines general guidance that should be considered when landscaping any stormwater BMP. Part 3 presents more specific guidance on landscaping criteria and plant selection for individual BMP designs described in Chapter 9. These include:

- constructed stormwater wetlands;
- infiltration basins and sand filter practices;
- bioretention systems;
- open channels;
- vegetative filters and forested buffers;
- wet ponds; and
- extended detention basins.

Part 4 considers plant acquisition and planting guidelines. Part 5 deals with other plant considerations, such as vegetation maintenance, invasive species, plant availability, and costs.[1]

Native Species

This manual encourages the use of native plants in stormwater management facilities. Native plants are defined as species that evolved naturally to live in this region. Practically speaking, this specifically refers to species that lived in New Jersey before Europeans explored and settled in America. Many introduced species were weeds brought in by accident; others were intentionally introduced and cultivated for use as medicinal herbs, spices, dyes, fiber plants, and ornamentals.

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[1] Parts of this chapter were adopted directly from the 2000 Maryland Stormwater Design Manual (Schueler and Claytor 2000). The chapter also contains material added and adapted to the physiography, plant life, and growing conditions of New Jersey.

Introduced species often escape cultivation and begin reproducing in the wild. This is significant ecologically because many introduced species out-compete or even replace indigenous species in the wild. Some introduced or aggressive species are invasive, have few predators, and can take over naturally occurring species at an alarming rate. These include reed canary grass (Phalaris arundinacea), phragmites (Phragmites communis), kudzu (Pueraria spp.), purple loosetrife (Lythrum salicara), Norway maple (Acer platanoides), autumn olive (Elaeagnus umbellata), Japanese honeysuckle (Lonicera japonica), Japanese rose (Rosa muliflora), garlic mustard (Alliaria officinalis), birdsfoot trefoil (Lotus corniculatus), lesser celandine (Ranunculus ficaria), and cattail (Typha latifolia). By planting non-aggressive, native species in stormwater management facilities, we can protect New Jersey's natural heritage, encourage biodiversity, and provide a legacy for future generations.

Note: Although both phragmites and cattails can be invasive, they also provide water quality and some wildlife benefits. These species should not necessarily be recommended and, if they do appear on site, it is questionable whether a considerable amount of effort or money should be spent controlling or eradicating these species.

Native species have distinct genetic advantages over non-native species for planting in New Jersey. Because they have evolved to live here naturally, indigenous plants are best suited for our local climate. This translates into greater survivorship and less replacement maintenance during the life of a stormwater management facility. Both of these attributes provide cost savings for facility owners.

Finally, people often plant exotic species for their ornamental value. While it is important to plant aesthetic stormwater management facilities for public acceptance and maintenance of property value, it is not necessary to introduce foreign species for this purpose. Many native species can be used as ornamentals. The following species are part of New Jersey's natural heritage and provide high aesthetic value throughout the year: rhododendron (Rhododendron maximum), pink azalea (Rhododendron nudiflorum), red maple (Acer rubrum), pin oak (Quercus palustris), sycamore (Platanus occidentalis), flowering and shrub dogwoods (Cornus spp.), mountain laurel (Kalmia latifolia), willow (Salix spp.), white pine (Pinus strobus), Atlantic white cedar (Chamaecyparis thyoides), American holly (Ilex americana), swamp rose (Rosa palustris), sunflowers (Helianthus spp.), lobelias (Lobelia spp), pickerel weed (Pontederia cordata), swamp rose mallow (Hibiscus moscheutos), and yellow pond lily (Nuphar avena).

When selecting ornamentals for stormwater management facilities, planting preference should be given to native ornamentals. Refer to the plant lists in Part 5 for a list of native species available for stormwater management facility planting.

Part 1: Natural Plant Communities of New Jersey

Plant Hardiness Zones

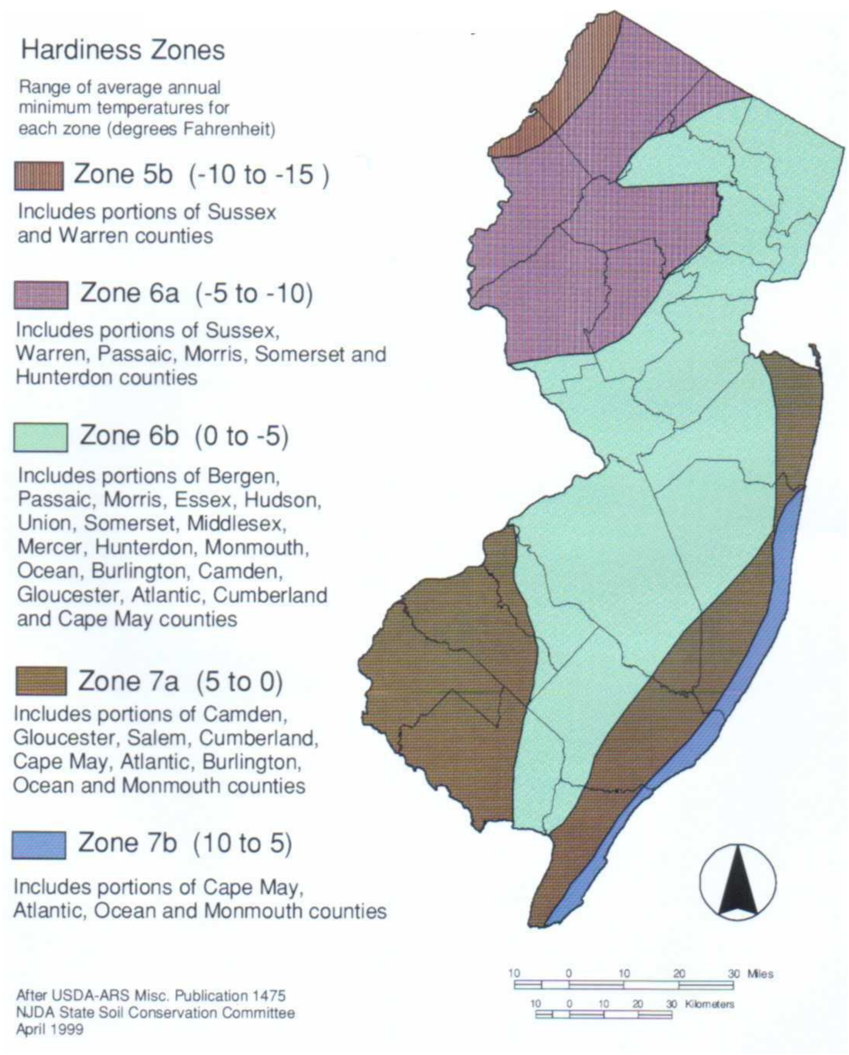
Hardiness zones are based on historical annual minimum temperatures recorded in an area. A BMP's location in relation to plant hardiness zones is important because plants differ in their ability to withstand very cold winters. This does not imply that plants are not affected by summer temperatures; New Jersey summers can be very hot, and heat tolerance should be considered in plant selection as well.

It is best to recommend plants known to thrive in specific hardiness zones. The plant list included at the end of this chapter identifies the hardiness zones for each species listed as a general planting guide. It should be noted, however, that certain site factors can create microclimates or environmental conditions that permit the growth of plants not listed as hardy for that zone. By investigating numerous references and using personal experience, a designer should be able to confidently recommend plants that will survive in microclimates.

Table 7-1: USDA Hardiness Zones for New Jersey

Zone		USDA Minimum Temperature
Temperate Zone 5	a	-20 to -15
	b	-15 to -10
Temperate Zone 6	a	-10 to -5
	b	-5 to 0
Temperate Zone 7	a	0 to 5
	b	5 to 10

Figure 7-1: USDA Plant Hardiness Zones' Average Annual Minimum Temperature (New Jersey)



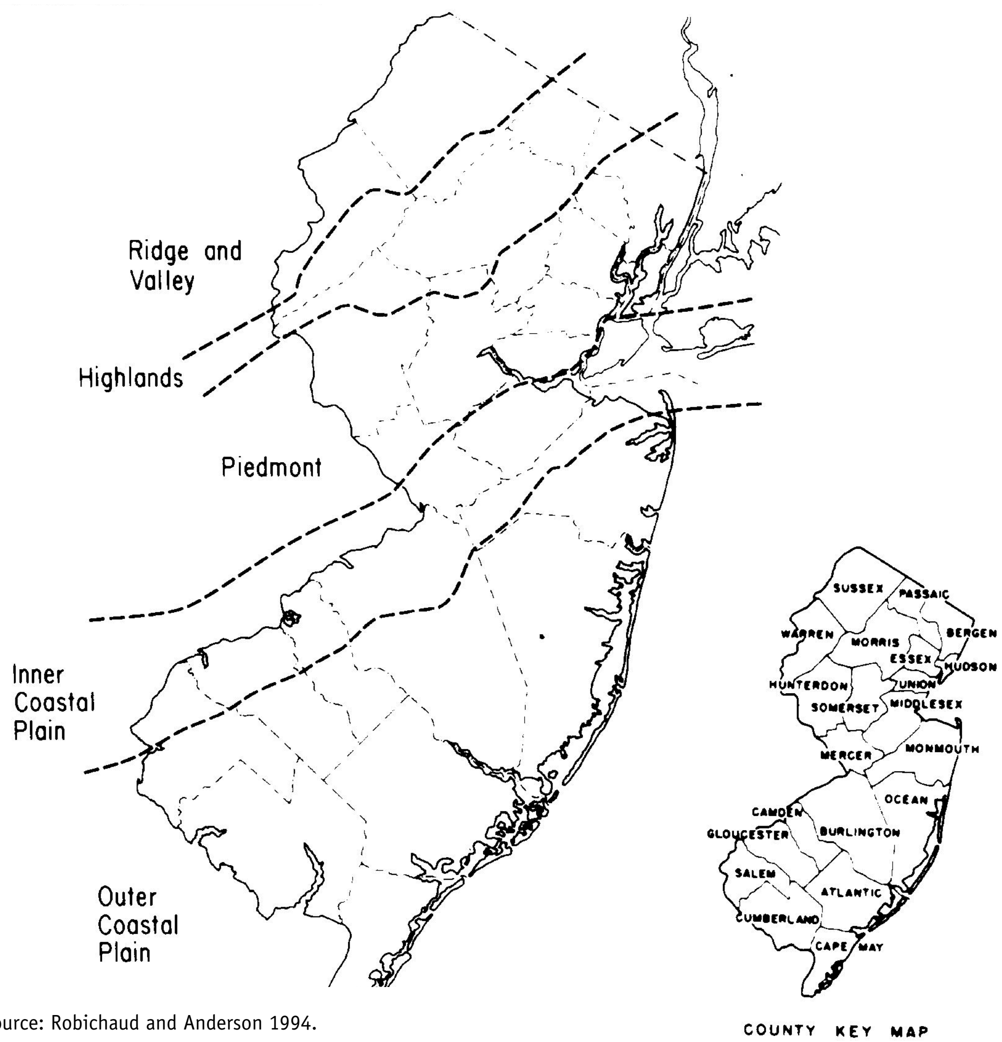
This figure can be viewed in color in the PDF version of this chapter available at http://www.state.nj.us/dep/watershedmgt/bmpmanualfeb2004.htm

Physiographic Provinces

New Jersey's five physiographic sections describe distinct geographic regions in the state with similar physical and environmental conditions (Figure 7-2). These physiographic provinces include, from west to east, the Ridge and Valley, Highlands, Piedmont, Inner Coastal Plain, and Outer Coastal Plain. Each physiographic region is defined by unique geological strata, soil type, drainage patterns, moisture content, temperature, and degree of slope, which often dictate the predominant vegetation. Because the predominant vegetation has evolved to live in these specific conditions, a successful stormwater management facility planting design can be achieved through mimicking these natural associations.

The five physiographic regions are described below with associated vegetation listed for general planting guidance. [2] For more detailed information and plant listings, please refer to Plant Communities of New Jersey (Robichaud and Anderson 1994).

Figure 7-2: The Five Physiographic Sections of New Jersey



Source: Robichaud and Anderson 1994.

[2] These descriptions were adapted, in part, from Robichaud and Anderson 1994, and Robichaud and Buell 1973.

Ridge and Valley Section

The Ridge and Valley physiographic province in the northwestern corner of New Jersey covers 635 square miles or about 7 per cent of the total land in New Jersey. It occupies a large part of Warren and Sussex counties. Ridges and valleys occur in this section because parent rock formations underlying the ridges and the valleys differ. Softer rocks such as limestone and shale erode faster than the more resistant sandstone and conglomerates. The lowest valley levels occur wherever limestone underlies the surface; the areas of shale, a slightly more resistant rock, are about 200 to 400 feet higher than the limestone, and ridges occur wherever the bedrock material is more resistant to erosion, such as sandstone or conglomerate rock.

Differences in parent rock material not only account for the variation in relief, but also create contrasts in the kind and amount of soil coverage. In general, the soil covering the Kittatinny and other ridges in this section is poor in quality from the standpoint of vegetation. The soil layer is thin on the ridges, with bedrock exposed in many places. Also, the ridge soil tends to be very acidic and of low fertility and, often, very stony.

In contrast, the soils in the valleys, derived from limestone and shale that were covered by glacial till, are for the most part deeper, more fertile, and well drained. Peat or large muck deposits (thick layers of organic material) may occur where shallow glacial lakes once existed. These were later invaded by vegetation, the dead remains of which accumulated as peat or muck.

Highlands Section

The Highlands physiographic province is located southeast of the Ridge and Valley section and covers about 900 square miles or approximately 12 per cent of New Jersey's land area. As shown in Figure 7-2, this section is broader at the north, where it is about 20 miles wide; at its southern end bordering the Delaware River Valley, it is only 10 miles wide. The Highlands region also has parallel ridges and valleys, but these differ from the Ridge and Valley section in the type of parent rock underlying the surface. Also, the ridges are more massive and generally much broader, while the valleys are narrower and have steeper slopes. Frequent rock outcroppings occur. Glacially formed lakes, such as Lake Hopatcong and Green Pond, contrast with adjacent ridges to make the Highlands a very scenic area of New Jersey.

The geologic formations of the Highlands region are estimated to be approximately 1 billion years old. Elevations in the northern part of the basin in the Highlands average approximately 1,000 feet above mean sea level, while the southern part of the Highlands show valley contours reaching a low of 350 feet. Ridges of the Highlands have resisted erosion due to the very hard rock, sandstone, gneiss, granite, marble, quartzite, igneous, and metamorphic material of which they are made. Highland valleys consist of much softer materials of limestone or shale, making them less resistant to erosion. The soils of the Highlands have been weathered from glacial till deposits and eroding bedrock and are generally shallow and stony, with frequent rock outcrops.

Piedmont Section

The Piedmont physiographic province, which occupies about 21 per cent of New Jersey's land area, is composed mostly of shale, sandstone, and argillite formations that are typically red or brownish-red in color. These formations are less resistant to erosion than the adjacent Highland gneissic rock and so, in comparison to the Highlands, the Piedmont is actually a lowland. The Piedmont section slopes gently southeastward from about 400 feet above sea level at its northwestern margin, to an elevation less than 100 feet at its southern margin bordering the Delaware, and to sea level at Newark Bay. Flat in some areas, the Piedmont contour is slightly rolling with mostly gentle slopes; however, in some areas, rivers have cut rather steep-sided valleys.

Interestingly, in the Piedmont, several ridge formations tower over the adjacent lowlands – the three Watchung Mountains (850, 650, and 350 feet high), Cushetunk Mountain, the Sourlands, and the Palisades. These ridges are made of intrusive or extrusive lava material known as diabase and basaltic rocks, both of which are much harder than the shale and sandstone of the Piedmont. While the diabase and basalt have resisted erosion, the less resistant shale and sandstone have been worn down, resulting in the lower elevations.

Differences in rock formations, combined with the fact that glacial deposits of varying age covered only part of the Piedmont, have resulted in a variety of soil types within the area. These variations appear to be less important to vegetation than the variation of soil water drainage.

Exposed rock and soil at the surface of the Piedmont is the product of intense weathering of local bedrock and the influence that glacial ice sheets had on the landscape. Continuous cycles of freezing and thawing in the rocks and soils produced landform characteristics consisting of subsurface depressions and uneven ground. Boulder fields, like those found on the Rocky Hill Ridge, were heaved to the surface by the expanding and contracting of the permafrost during glacial periods. During the interglacial periods when the ice sheets retreated, massive loads of sediment were deposited in meltwater streams. Remnants of these outwash sediments formed thin, patchy deposits known as till on the surface of the Piedmont uplands. Riverbeds, stream valleys, and other lowlands were filled with glacial sediments, forming river terraces and wide outwash plains. Silt, clay, and fine sand deposits filled the bottoms of glacially formed lakes and ponds, which have since become swamps and meadows layered with peat and muck. Subsequent weathering and erosion have continued to shape and reshape the surface and produce the modern soil profile of the Piedmont.

Common Species of Ridge and Valley, Highlands, and Piedmont Sections

Tree Species	Understory
• Hickory • Chestnut oak • Scarlet oak • Scrub oak • White oak • Red oak • Black oak • Scrub pine • Pitch pine • Short leaf pine • White pine • Hemlocks • Beech • Black jack oak • Sugar maple	• Sweet fern • Flowering dogwood • Black haw • Chinquapin • Sassafras • Redbud • Mountain laurel • Blueberry • Fringe tree • Pink azalea • Spicebush • Maple-leaved arrowwood

Inner and Outer Coastal Plain Sections

The Inner and Outer Coastal Plain provinces are recognized by flat or gently rolling topography and elevations rising from sea level to a height of 373 feet. Coastal Plain marshes and swampy tidal flats occur throughout the New Jersey Coastal Zone. Sands, sandy loams, and silt loams resulting from sea deposits make up the soils of the Coastal Plain. The climate is mild and sometimes rainy, similar to that found further south. Because of low topographic relief and proximity to sea level, extensive swamp areas are common to the Coastal Plain province. Most notable are the Atlantic White Cedar swamps found in the Pinelands.

Common Species of the Inner and Outer Coaster Plain Sections

Tree Species	Understory
• Loblolly pine • Virginia pine • Pitch pine • Pond pine • Sweet gum • Willow oak • Water oak • Basket oak • Pin oak • Post oak • Spanish oak • Black cottonwood • Pale hickory • Bitternut hickory • Sweet bay • American holly • Beech • Tulip tree • River birch	• Blueberry • Huckleberry • Greenbrier • Sand blackberry • Beach plum • Beach heather • Bay berry • Sweet pepper bush • Azalea • Maleberry • Stagger bush • Fetter bush • Inkberry • Alder buckhorn

Floodplain Regions

Floodplains occur across New Jersey's physiographic provinces as low-lying areas adjacent to streams and rivers. Floodplain plant communities are similar across most of the state because of common soil characteristics governed by occasional flooding and high groundwater. Stormwater management facilities are often located in floodplains, and plant associations in these areas can provide valuable information for successful BMP plantings.

Common Species of Floodplain Regions

Tree Species	Understory
• River birch • Willows • Silver maple • Sweet gum • Sycamore • Box elder • Green ash • American elm • Swamp white oak • Basswood • Hackberry	• Shrub willows • Ninebark • Silky and redosier dogwoods • Sweet pepperbush • Buttonbush • Spicebush • Winterberry and inkberry holly • Elderberry • Alders

Three Hydrologic Zones

Before planting within a stormwater management facility, it is necessary to determine which hydrologic zones will be created. Hydrologic zones describe the degree to which an area is inundated by water. Plants have differing tolerances to inundation; as an aid to landscape designers, these tolerance levels have been divided into six zones for which corresponding plant species have been identified.

Part 4 includes a native plant list with appropriate hydrologic zones designated for each species. The hydrologic zones that are bracketed "[ ]" are where the plants tend to occur. There may be other zones listed outside of these brackets. These plants may occur in these zones, but are not typically found in them. On occasion, plants may be found outside of their hardiness and hydrologic zone. Plants tend to grow anywhere they can compete and survive. Additionally, hydrologic conditions in a stormwater management facility may fluctuate in unpredictable ways; thus, the use of plants capable of tolerating wide varieties of hydrologic conditions greatly increases a successful planting. Conversely, plants suited for specific hydrologic conditions may perish when hydrologic conditions fluctuate, expose the soil, and increase the chance for erosion.

Part 2: General Landscaping Guidance for all Stormwater BMPs

- Plant trees and shrubs at least 15 feet from a dam's toe of slope.
- Do not plant trees or shrubs known to have long taproots within the vicinity of earth dams or subsurface drainage facilities.
- Plant trees and shrubs at least 15 feet from perforated pipes.
- Plant trees and shrubs at least 25 feet from a riser structure.
- Provide 15-foot clearance from a non-clogging, low flow orifice.
- Herbaceous embankment plantings should be limited to 10 inches in height to ensure visibility for inspectors looking for burrowing rodents that may compromise the integrity of the embankment.
- Provide additional stabilization methods for slopes steeper than 2:1, such as turf reinforcement mats or erosion control blankets. Use seed mixes with quick germination rates in this area. Augment temporary seeding measures with container crowns or root mats of more permanent plant material.
- Use erosion control blankets and fabrics in channels that are subject to frequent wash-outs.
- Stabilize all emergency spillways with plant material that can withstand strong flows.
- Root material should be fibrous and substantial, but lack a taproot.
- Place sod in channels that are not stabilized by erosion control blankets.
- Divert flows temporarily from seeded areas until plants are stabilized.
- Check water tolerances of existing plant materials prior to inundating the area.
- Stabilize aquatic and safety benches with emergent wetland plants and wet seed mixes.
- Do not block maintenance access to structures with trees or shrubs.
- To reduce thermal warming, shade inflow and outflow channels as well as the southern exposure of ponds, when possible.
- Avoid plantings that will require routine or intensive chemical applications, i.e., turf areas.
- Have soil tested to determine whether amendments are needed.
- Indigenous plant species should be specified over exotic or foreign species because they are well adapted to local on-site soil conditions and require few or no additional amendments.
- Decrease the areas where turf is used. Use low-maintenance ground cover to absorb run-off.
- Plant riparian buffers with trees, shrubs, and native grasses, where possible, to stabilize banks and provide shade.
- Maintain and frame desirable views. Be careful not to block views at entrances, exits, or difficult road curves. Screen unattractive views into the site. Aesthetics and visual characteristics should be a prime consideration.
- Use plants to prohibit pedestrian access to pools or slopes that may be unsafe.
- Carefully consider the long-term vegetation management strategy for the BMP, keeping in mind the maintenance legacy for future owners. Keep maintenance areas and access free of vegetation to allow vehicle clearance. Provide a planting surface that can withstand compaction from vehicles using maintenance access roads. Make sure the facility maintenance agreement includes requirements that ensure vegetation cover in perpetuity.
- If a BMP is likely to receive excessive amounts of de-icing salt, salt tolerant plants should be used.
- Provide signage for stormwater management areas to help educate the public, and for wildflower areas, when possible, to designate limits of mowing.
- Avoid the overuse of any plant materials, e.g., maples.
- Preserve existing natural vegetation when possible.

Soil Preparation

It is necessary to test the soil in which you are about to plant in order to determine pH, whether acid, neutral, or alkaline; major soil nutrients, nitrogen, phosphorus, and potassium; and minerals such as chelated iron and lime.

Have soil samples analyzed by experienced and qualified individuals such as those at the Rutgers Cooperative Extension, who will explain the results in writing and recommend which soil amendments would be required. Certain soil conditions, such as marine clays (glauconite), 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.

Areas recently involved in construction can become compacted so that plant roots cannot penetrate the soil. Seeds will lie on the surface of compacted soils and are often washed away or eaten by birds. For planting success, soils should be loosened to a 4-inch depth. Hard soils may require discing to a deeper depth. The soil should be loosened regardless of the ground cover to improve seed contact with the soil, increase germination rates, and allow the roots to penetrate the soil. For areas to be sodded, discing is necessary so that roots can penetrate the soil. Good growing conditions can prevent poor vegetative cover, which saves money because vegetation will not need to be replanted.

Whenever possible, topsoil should be spread to a depth of 4 to 6 inches over the entire area to be planted. This provides organic matter and important nutrients for the plant material. The use of topsoil allows vegetation to become established faster and roots to penetrate deeper. This ensures quicker and more complete stabilization, making it less likely that the plants will wash out during a heavy storm.

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

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

Part 3: Specific Landscaping Criteria for BMPs

It is important to recognize that plants typically found in wetlands may be cultivated in non-wetland conditions; hence the importance of obtaining plants cultivated in similar hydrologic and soil conditions as those present in the stormwater management facility. A plant typically found in wetlands, but cultivated in non-wetland conditions, may not survive if installed in wetland conditions.

Ponds and Constructed Wetlands

Before planting within a stormwater management facility, determine which hydrologic zones will be created. Hydrologic zones describe the degree to which an area is inundated by water. Plants have differing tolerances to inundation; the six zones described in this section will dictate which plants will survive where. Every facility does not necessarily exhibit all of these zones.

Table 7-2: Hydrologic Zones

Zone	Zone Description	Hydrologic Conditions
Zone 1	Deep water pool	1-6 feet deep permanent pool
Zone 2	Shallow water bench	6 inches to 1 foot deep
Zone 3	Shoreline fringe	Regularly inundated
Zone 4	Riparian fringe	Periodically inundated
Zone 5	Floodplain terrace	Infrequently inundated
Zone 6	Upland slopes	Seldom or never inundated

Zone 1: Deep Water Pool (1 to 6 feet)

Ponds and wetlands both have deep pool areas that comprise Zone 1. These pools range from 1 to 6 feet in depth and are best colonized by submergent plants, if at all. This pondscaping zone has not been routinely planted for several reasons: first, the availability of plant materials that can survive and grow in this zone is limited; and second, it is feared that plants could clog the stormwater facility outlet structure. In many cases, these plants will gradually become established through natural recolonization, i.e., transport of plant fragments from other ponds via the feet and legs of waterfowl. If submerged plant material becomes more commercially available and clogging concerns are addressed, this area can be planted. The function of the planting is to reduce resedimentation and improve oxidation while creating a greater aquatic habitat.

Select plants that can:

- withstand constant inundation of water of 1 foot or greater in depth;
- withstand being submerged partially or entirely;
- enhance pollutant uptake; and
- provide food and cover for waterfowl, desirable insects, and other aquatic life.

Suggested emergent or submergent species include, but are not limited to: spatterdock (Nuphar luteum), water lily (Nymphaea odorata), duckweed (Lemna spp.), duck potato (Saggitaria latifolia), wild celery (Vallisneria americana), sago pondweed (Potamogeton pectinatus), and redhead grass (Potamogeton perfoliatus).

Zone 2: Shallow Water Bench (6 inches to 1 foot)

Zone 2 includes all areas that are inundated below the normal pool to a depth of 1 foot; it is the primary area where emergent plants will grow in stormwater wetlands. Zone 2 also coincides with the aquatic bench found in stormwater ponds. This zone offers ideal conditions for the growth of many emergent wetland species. These areas may be located at the edge of the pond or on low mounds of earth below the surface of the water within the pond. When planted, Zone 2 can be an important habitat for many aquatic and non-aquatic animals, creating a diverse food chain that includes predators that provide natural regulation of mosquito populations, thereby reducing the need for insecticide applications.

Select plants that can:

- withstand constant inundation of water to depths between six inches and 1 foot deep;
- be partially submerged;
- enhance pollutant uptake; and
- provide food and cover for waterfowl, desirable insects, and other aquatic life.

Plants will stabilize the bottom and edge of the pond, absorbing wave impacts and reducing erosion when the water level fluctuates. In addition to slowing water velocities and increasing sediment deposition rates, plants can reduce re-suspension of sediments caused by the wind. Plants can also soften the engineered contours of the pond and conceal drawdowns during dry weather.

Appropriate herbaceous species include: water plantain (Alisma plantago-aquatica), three-sided sedge (Dulchium arundinaceum), managrasses (Glyceria spp.), soft rush (Juncus effusus), arrow arum (Peltandra virginica), smartweeds (Polygonum spp.), pickerelweed (Pontederia cordata), lizard tail (Saururus cernuus), many bulrushes (Scirpus spp.), and giant bur-reed (Sparganium eurycarpum).

Zone 3: Shoreline Fringe (regularly inundated)

Zone 3 encompasses the shoreline of a pond or wetland and extends vertically about 1 foot from the normal pool. This zone may be periodically inundated if storm events are subject to extended detention. This zone occurs in a wet pond or shallow marsh and can be the most difficult to establish since plants must be able to withstand inundation of water during storms, when wind might blow water into the area, or the occasional drought during the summer. To stabilize the soil in this zone, Zone 3 must have a vigorous cover.

Select plants that can:

- stabilize the shoreline to minimize erosion caused by wave and wind action or water fluctuation;
- withstand occasional inundation of water, as plants will be partially submerged at times;
- shade the shoreline, whenever possible, especially the southern exposure, to help reduce water temperature;
- enhance pollutant uptake;
- provide food and cover for waterfowl, songbirds, and wildlife (large plants can be selected and located to control overpopulation of waterfowl);
- be located to reduce human access to potential hazards without blocking maintenance access;
- have very low maintenance requirements because they may be difficult or impossible to reach;

- be resistant to disease and other problems that require chemical applications, since chemical application is not advised in stormwater ponds; and
- be native plants, when possible, because they are low-maintenance and disease-resistant.

Many of the emergent wetlands plants outlined in Table 7-3 also thrive in Zone 3. Some other herbaceous species that do well include: cardinal flower (Lobelia cardinalis), blue flag iris (Iris versicolor), sweet flag (Acorus calamus), Marsh marigold (Caltha palustris), swamp milkweed (Asclepsis incarnata), bentgrass/redtop (Agrostis spp.), switchgrass (Panicum virgatum), Canada bluejoint (Calamagrostis canadensis), many bulrushes (Scirpus spp.), and spike rushes (Eleocharis spp.).

If shading is needed along the shoreline, the following woody species are suggested: river birch (Betula nigra), green ash (Fraxinus pennsylvanica), white ash (Fraxinus americana), pussy willow (Salix discolor), swamp rose (Rosa palustris), buttonbush (Cephalanthus occidentalis), highbush blueberry (Vaccinium spp.), red osier/silky dogwood (Cornus stolonifera/amomum), grey dogwood (Cornus racemosa), arrowood (Viburnum dentatum), spicebush (Lindera Benzoin), sweetbells (Leucothoe racemosa), sweet pepperbush (Clethra alnifolia), winterberry (Ilex verticillata), inkberry holly (Ilex glabra), serviceberry (Amelanchier spp.), black willow (Salix nigra), red maple (Acer rubrum), willow oak (Quercus phellos), swamp white oak (Quercus bicolor), pin oak (Quercus palustris), sweetgum (Liquidambar styraciflua), black gum (Nyssa sylvatica), sweet bay magnolia (Magnolia virginiana), and American sycamore (Platanus occidentalis).

Zone 4: Riparian Fringe (periodically inundated)

Zone 4 extends from 1 to 4 feet above the normal pool. Plants in this zone are subject to periodic inundation after storms and may experience saturated or partly saturated soil. Nearly all of the temporary extended detention area is included within this zone.

Select plants that can:

- withstand periodic inundation of water after storms, as well as occasional drought during the warm summer months;
- stabilize the ground from erosion caused by run-off;
- shade the low-flow channel to reduce pool warming whenever possible;
- enhance pollutant uptake;
- be very low maintenance, as they may be difficult or impossible to access;
- provide food and cover for waterfowl, songbirds, and wildlife (plants may also be selected and located to control overpopulation of waterfowl); and
- be located to reduce pedestrian access to the deeper pools.

Native plants are preferred because they are low-maintenance and disease-resistant. Frequently used plant species in Zone 4 include: many asters (Aster spp.) and goldenrods (Solidago spp.), beebalm (Monarda didyma), bergamont (Monarda fistulosa), lobelias (lobelia spp.), coneflower(Rudbeckia spp.), violets (Viola spp.), lilies (Lilium spp.), primrose (Oenothera spp.), milkwort (Polygala spp.), flatsedge (Cyperus spp.), hollies (Ilex spp.), steeplebush (Spirea tomentosa), serviceberry (Amelanchier arborea), nannyberry (Viburnurn lentago), sweet pepperbush (Clethra alnifolia), bayberry (Morella pensylvanica), elderberry (Sambucus canadensis), sweetbay magnolia (Magnolia virginiana), hawthorn (Crategus), shrub dogwoods (Cornus spp.), green ash (Fraxinus pennsylvanica), river birch (Betula nigra), sweetgum (Liquidambar styraciflua), American hornbeam (Carpinus caroliniana), persimmon (Diospyros virginiana), and red maple (Acer rubrum).

Zone 5: Floodplain Terrace (infrequently inundated)

Zone 5 is periodically inundated by floodwaters that quickly recede in a day or less. Operationally, Zone 5 extends from the maximum two-year or Cpv water surface elevation up to the 10 or 100-year maximum water surface elevation. Key landscaping objectives for Zone 5 are to stabilize the steep slopes characteristic of this zone and establish low maintenance natural vegetation.

Select plants that can:

- withstand occasional but brief inundation during storms and, between storms, typical moisture conditions that may be moist, slightly wet, or even swinging entirely to drought conditions during the dry weather period;
- stabilize the basin slopes from erosion;
- be very low maintenance as ground cover since they may be difficult to access on steep slopes or mowing frequency may be limited (a dense tree cover may help reduce maintenance and discourage resident geese); and
- provide food and cover for waterfowl, songbirds, and wildlife.

Placement of plant material in Zone 5 is often critical. Some commonly planted species in Zone 5 include: phlox (Phlox spp.), solomon's seal (Polygonatum biflorum), many fescues (Festuca spp.), many viburnums (Viburnum spp.), Virginia rose (Rosa virginiana), American hornbeam (Carpinus caroliniana), cherries (Prunus spp.), willow oak (Quercus phellos), hickories (Carya spp.), and witch-hazel (Hamamelis virginiana).

Zone 6: Upland Slopes (seldom or never inundated)

This zone extends above the maximum 100-year water surface elevation and often includes the outer buffer of a pond or wetland. Unlike other zones, this upland area may have sidewalks, bike paths, retaining walls, and maintenance access roads. Care should be taken to locate plants so they will not overgrow these routes or create hiding places that might make the area unsafe. Plant selections should be made based on soil condition, light, and function within the landscape because little or no water inundation will occur. Ground covers should require infrequent mowing to reduce the cost of maintaining this landscape.

Placement of plants in Zone 6 is important since they are often used to create a visual focal point, frame a desirable view, screen undesirable views, serve as a buffer, or provide shade to allow a greater variety of plant materials. Particular attention should be paid to seasonal color and texture of these plantings.

Some frequently used plant species in Zone 6 include: fine fescues (Festuca spp.), basswood (Tilia americana), Flowering dogwood (Cornus florida), Sassafras (Sassafras albidum), American beech (Fagus grandifolia), white ash (Fraxinus americana), scarlet oak (Quercus coccinea), white oak (Quercus alba), Black oak (Quercus velutina), and pine species (Pinus spp.).

Infiltration and Filter Systems

Infiltration and filter systems either take advantage of existing permeable soils or create a permeable medium such as sand for groundwater recharge and stormwater quality control. In some instances where permeability is great, these facilities are used for quantity control as well. The most common systems include infiltration trenches, infiltration basins, sand filters, and organic filters.

When properly planted, vegetation will thrive and enhance the functioning of these systems. For example, pre-treatment buffers will trap sediments that often are binded with phosphorous and metals. Vegetation planted in the facility will aid in nutrient uptake and water storage. Additionally, plant roots will provide arteries for stormwater to permeate soil for groundwater recharge. Successful plantings provide aesthetic value and wildlife habitat, making these facilities more desirable to the public.

Figure 7-3: Plan View of Hydrologic Zones Around Stormwater Basin

PONDSCAPING ZONE 3

New England Aster, Marsh Aster, Marsh Marigold, Tussock Sedge, Spotted Joe Pye Weed, Forget Me Nots, Inkberry, Willow species, Shrub Dogwood, Pin Oak, River Birch, Sycamore, Swamp White Oak.

PONDSCAPING ZONE 4

Purple Cone Flower, Birds Foot Trefoil, Slender Rush, Deer Tongue Grass, Switch Grass, Serviceberry, Gray Birch, Hackberry, Sweet Pepper Bush (Coastal Plain), Gray Stem Dogwood, Redosier Dogwood, Green Ash, Black Gum.

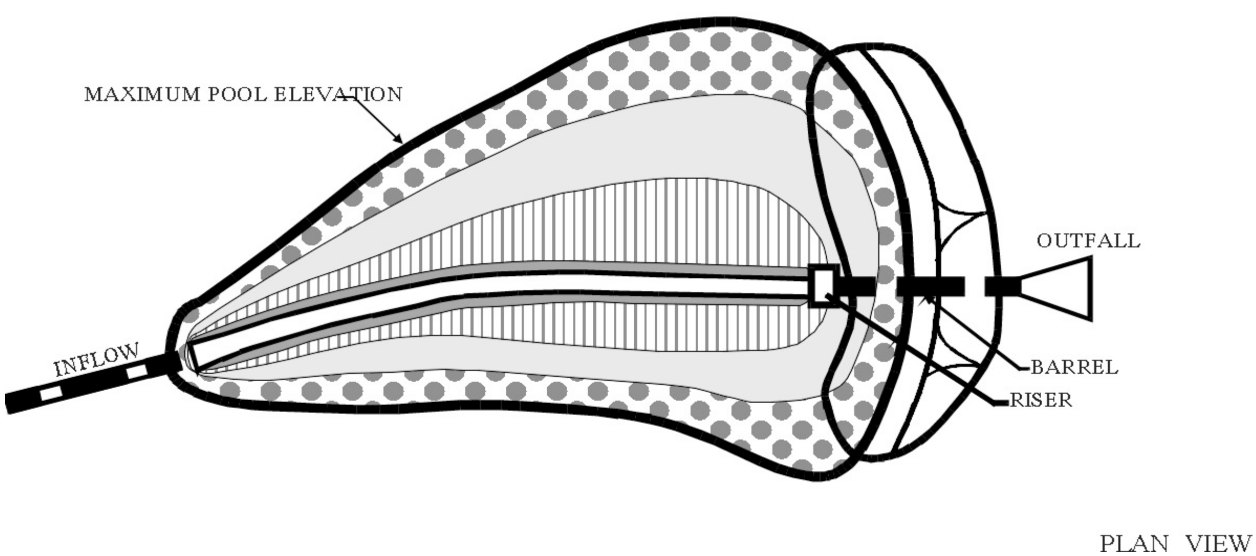
PONDSCAPING ZONE 5

Many wildflowers and native grasses. American Holly, Witch Hazel, Ninebark, Red Oak, American Elderberry, Lowbush Blueberry, Maple Leaf Viburnum, Nannyberry, Blackhaw Viburnum.

PONDSCAPING ZONE 6

(Floodplain) Mostly native ornamentals as long as soils drain well. Many natives. All species must be able to tolerate flood plain conditions. Hackberry, Pitch Pine, Sheep Fescue, Wildflowers, many native grasses.

Note: Tree and shrub setback requirements from the dam embankment, riser, and pipes should be strictly followed.



Source: Adapted from Schueler and Claytor 2000.

Figure 7-4: Plan View of a Shallow Marsh Planting

PONDSCAPING ZONE 1
12”-36” depth: Water Lily, Deep Water Duck Potato, Sago Pond Plant

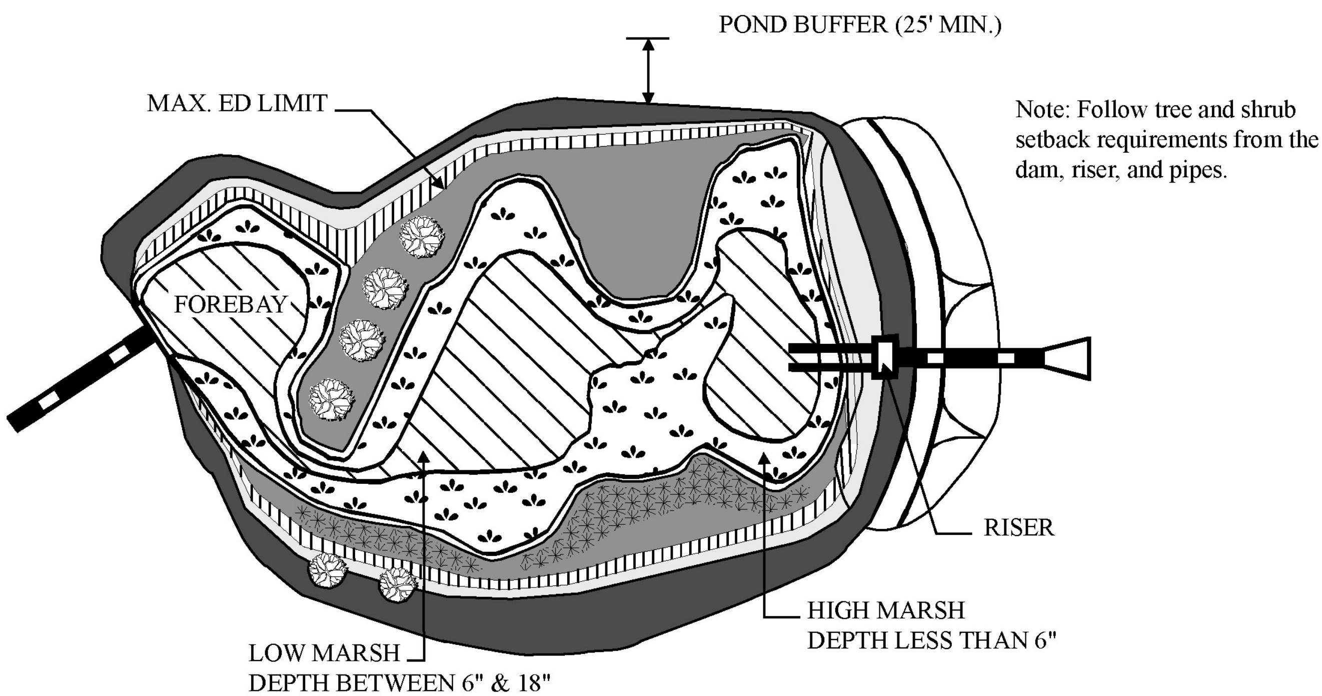
PONDSCAPING ZONE 2
0”-12” depth: Blue Flag Iris, Duck Potato, Flowering Bulrush, Softrush, Sedges

PONDSCAPING ZONE 3
New England Aster, Marsh Aster, Tussock Sedge, Spotted Joe Pye Weed, Inkberry, Shrub willow and Dogwood species, Pin Oak, River Birch, Sycamore, Swamp White Oak

PONDSCAPING ZONE 4
Slender Rush, Deer Tongue Grass, Switch Grass, Service Berry, Gray Birch, Hackberry, Sweet Pepper Bush, Gray Stem Dogwood, Red Osier Dogwood, Green Ash, Black Gum

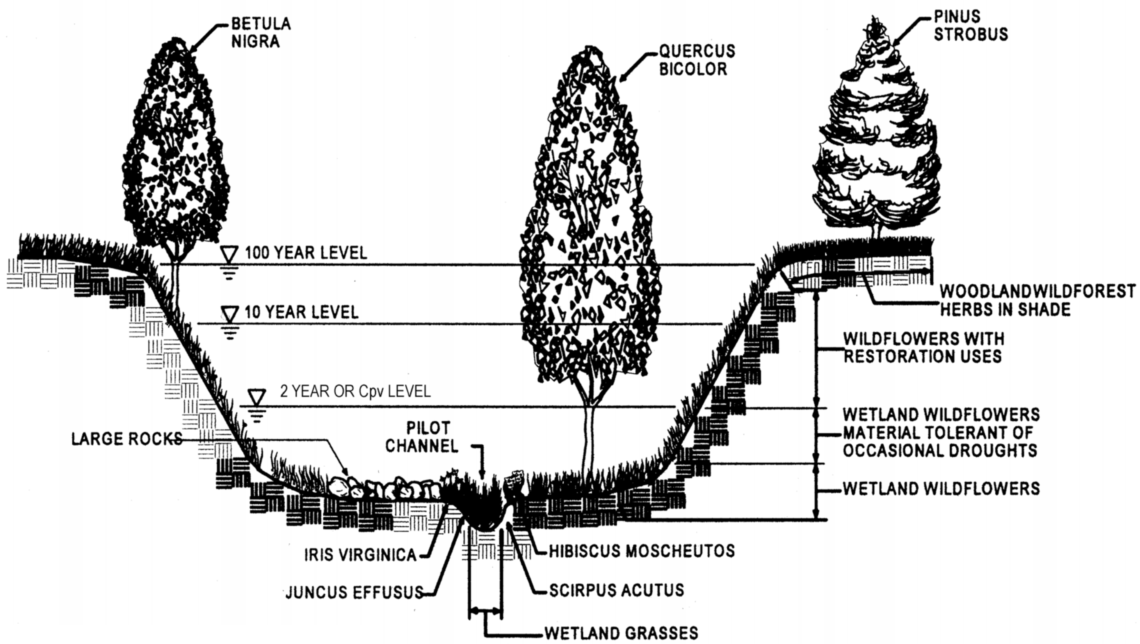
PONDSCAPING ZONE 5
(Many Wildflowers & Native Grasses), American Holly, Witch Hazel, Ninebark, Red Oak, American Elderberry, American Hemlock, Lowbush Blueberry, Nannyberry, Blackhaw Viburnum

PONDSCAPING ZONE 6
(Floodplain) Mostly ornamentals as long as soil drains well, many natives. All species must be able to tolerate floodplain conditions. Hackberry, Pitch Pine, Sheep Fescue, Wildflowers, Grasses



Source: Adapted from Schueler and Claytor 2000.

Figure 7-5: Section of a Typical Stormwater Management Detention Pond



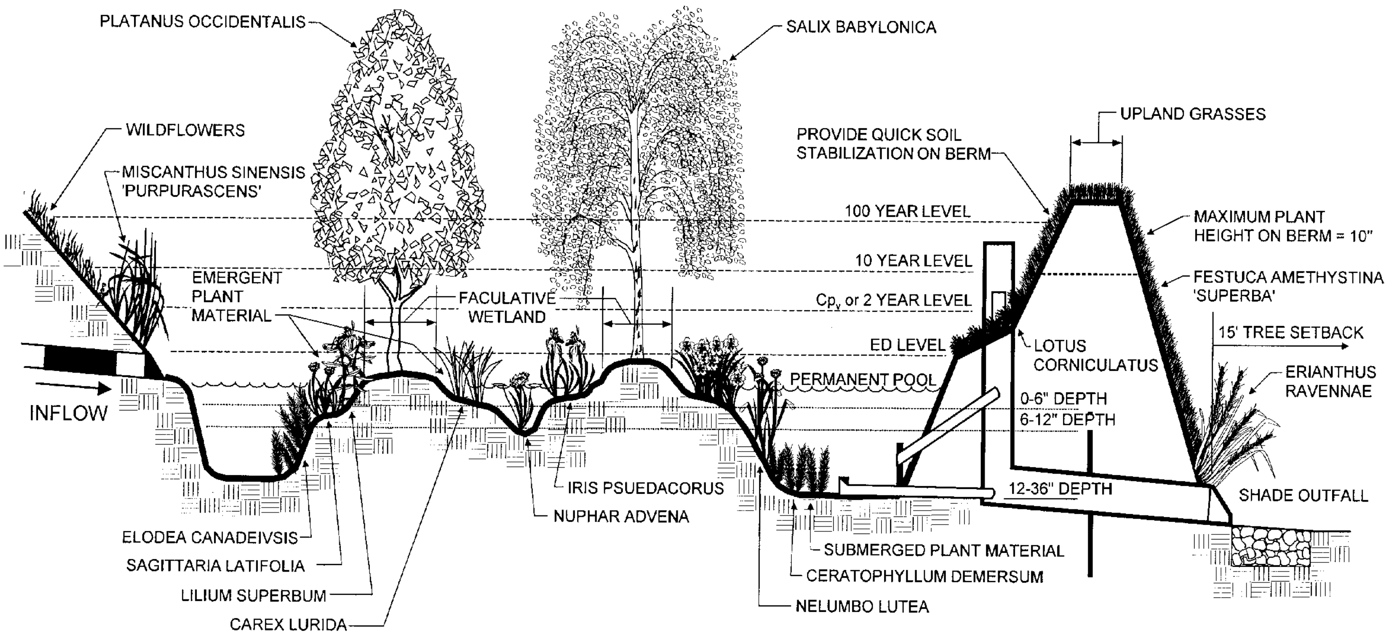
Source: Claytor and Schueler 1997.

Design Constraints

- Planting buffer strips of at least 20 feet will cause sediments to settle out before reaching the facility, thereby reducing the possibility of clogging.
- Determine areas that will be saturated with water as well as water table depth so that appropriate plants may be selected (hydrology will be similar to bioretention facilities, see Figure 7-7 and Table 7-4 for planting material guidance).
- Plants known to send down deep taproots should be avoided in systems where filter fabric is used as part of the facility design.
- Test soil conditions to determine whether soil amendments are necessary.
- Plants should be located to allow access for structure maintenance.
- Stabilize heavy flow areas with erosion control mats or sod.
- Temporarily divert flows from seeded areas until vegetation is established.

See Figure 7-6 for additional design considerations.

Figure 7-6: Section of Typical Shallow Extended Detention Marsh System



Source: Claytor and Schueler 1997.

Part 4: Bioretention

Soil Bed Characteristics

The characteristics of the soil for the bioretention facility are perhaps as important as the facility location, size, and treatment volume. The soil must be permeable enough to allow runoff to filter through the media, while having characteristics suitable to promote and sustain a robust vegetative cover crop. In addition, much of the nutrient pollutant uptake (nitrogen and phosphorus) is accomplished through absorption and microbial activity within the soil profile. Therefore, the soils must balance soil chemistry and physical properties to support biotic communities above and below ground.

Table 7-3: Common Emergent Wetland Plant Species Used for Stormwater Wetlands and on Aquatic Benches of Stormwater Ponds

Common Name	Scientific Name	Inundation Tolerance
Arrow arum	Peltandra virginica	up to 12″
Arrowhead/Duck potato	Saggitaria latifolia	up to 12″
Pickerelweed	Pontederia cordata	up to 12″
Blunt spike rush	Eleocharis obtusa	up to 3″
Bushy beardgrass	Andropogon glomeratus	up to 3″
Common three-square	Scirpus pungens	up to 6″
Iris (blue flag)	Iris versicolor	up to 6″
Marsh hibiscus	Hibiscus moscheutos	up to 3″
Spatterdock	Nuphar luteum	up to 36″
Sedges	Carex spp.	up to 6″
Soft rush	Juncus effusus	up to 6″
Switchgrass	Panicum virgatum	up to 3″
Note 1: Inundation tolerance is maximum inches below the normal pool; most plants prefer shallower depths than the maximum indicated. Note 2: For additional plant options, consult the stormwater planting list in Section 5. Other good sources include the NJDA Standards for Soil Erosion and Sediment Control in New Jersey, Design of Stormwater Wetland Systems (Schueler 1992), and Wetland Planting Guide for the Northeastern United States (Thunhorst 1993).		

Details of the planting soil are discussed in *Chapter 9.1 Standard for Bioretention Systems*. The soil should be free of stones, stumps, roots, or other woody material over 1 inch in diameter. Brush or seeds from noxious weeds, such as Johnson grass, Mugwort, Nutsedge, Purple loosestrife, and Canadian thistle should not be present in the soils. Placement of the planting soil should be in lifts of 12 to 18 inches, loosely compacted (tamped lightly with a dozer or backhoe bucket). Specific soil characteristics are presented in Table 7-4.

Mulch Layer

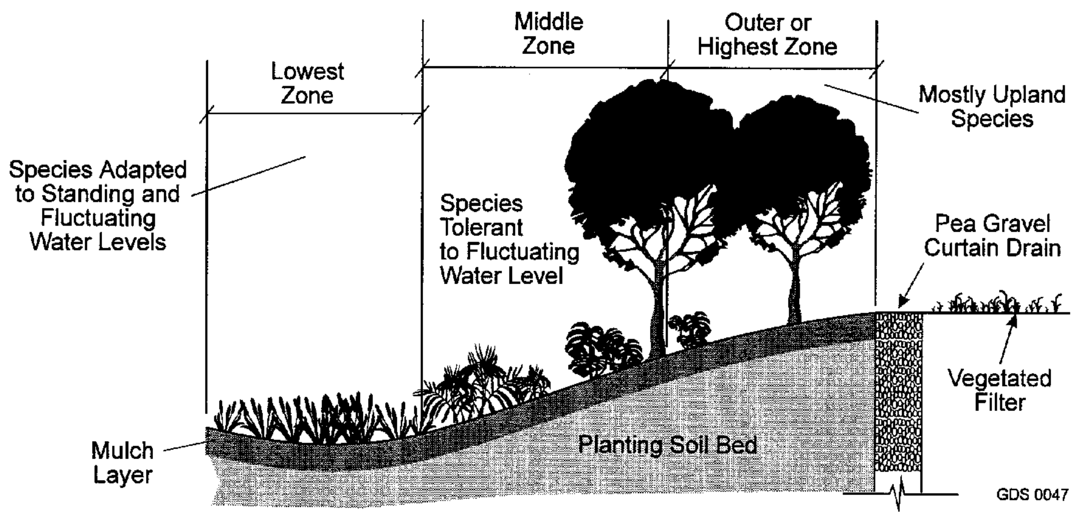
The mulch layer plays an important role in the performance of the bioretention system by helping to maintain soil moisture and avoiding surface sealing that reduces permeability. Mulch helps prevent erosion and provides a microenvironment suitable for soil biota at the mulch/soil interface. It also serves as a pre-treatment layer, trapping the finer sediments that remain suspended after the primary pretreatment.

The mulch layer should be standard landscape style, single or double, shredded hardwood mulch or chips. The mulch layer should be well aged (stockpiled or stored for at least 12 months), uniform in color, and free of other materials such as weed seeds, soil, roots, etc. The mulch should be applied to a maximum depth of 3 inches. Grass clippings should not be used as a mulch material.

Table 7-4: Planting Soil Characteristics

Parameter	Value
pH range	5.2 to 7.00
Organic matter	1.5 to 4.0%
Magnesium	35 lbs. per acre, minimum
Phosphorus (P205)	75 lbs. per acre, minimum
Potassium (K20)	85 lbs. per acre, minimum
Soluble salts	< = 500 ppm
Clay	10 to 25%
Silt	30 to 55%
Sand	35 to 60%
Source: Adapted from Schueler and Claytor 2000.	

Figure 7-7: Planting Zones for a Bioretention Facility



Source: Claytor and Schueler 1997.

Plant Material Guidance

Plant materials should conform to the American Nursery and Landscape Association publication American Standard Nursery Stock and be selected from certified, reputable nurseries. A landscape architect or other qualified designer should specify a sequence of construction, a description of the contractor's responsibilities, planting schedule and installation specifications, initial maintenance, and a warranty period stipulating expectations of plant survival. *Planting Guidance* below presents some typical issues for planting specifications.

Open Channels

Consult Table 7-7 for grass species that perform well in the stressful environment of an open channel. For more detailed information, consult the Standards for Soil Erosion and Sediment Control in New Jersey. If a BMP is likely to receive excessive amounts of de-icing salt, salt tolerant plants should be used.

Planting Guidance

Plant material selection should be based on the goal of simulating a terrestrial forested community of native species. Bioretention simulates an upland-species ecosystem. The community should be dominated by trees, but have a distinct community of understory trees, shrubs, and herbaceous materials. By creating a diverse, dense plant cover, a bioretention facility will be able to treat stormwater runoff and withstand urban stresses from insects, disease, drought, temperature, wind, and exposure.

Planting Plan Design Considerations

- Native plant species should be specified, not exotic or foreign species.
- Appropriate vegetation should be selected based on the zone of hydric tolerance (see Table 7-2).
- Species layout should generally be random and natural.
- A canopy should be established with an understory of shrubs and herbaceous materials.
- Woody vegetation should not be specified in the vicinity of inflow locations.
- Trees should be planted primarily along the perimeter of the bioretention area.
- Exotic (non-native) vegetation should not be specified.
- Urban stressors (e.g., wind, sun, exposure, insect and disease infestation, and drought) should be considered when laying out the planting plan.
- Aesthetics and visual characteristics should be a prime consideration.
- Traffic and safety issues must be considered.
- Existing and proposed utilities must be identified and considered.

The proper selection and installation of plant materials is key to a successful system. There are essentially three zones within a bioretention facility (Figure 7-7). The lowest elevation supports plant species adapted to standing and fluctuating water levels. The middle elevation supports plants that prefer drier soil conditions but can tolerate occasional inundation by water. The outer edge is the highest elevation and generally supports plants adapted to dryer conditions. A sample of appropriate plant materials for bioretention facilities is included in Table 7-5. The layout of plant material should be flexible, but should follow the general principals described in Table 7-6. The objective is to have a system that resembles a random and natural plant layout while maintaining optimal conditions for plant establishment and growth. For a more extensive bioretention plan, consult the Design Manual for Use of Bioretention in Stormwater Management (ETA&B 1993) or Design of Stormwater Filtering Systems (Claytor and Schueler1997).

Table 7-5: Commonly Used Species for Bioretention Areas

Trees	Shrubs	Herbaceous Species
Acer rubrum Red maple	*Clethra alnifolia* Sweet pepperbush	*Andropogon glomeratus* Lowland broomsedge
Betula nigra River birch	*Ilex verticillata* Winterberry	*Eupatorium purpureum* Sweet-scented Joe Pye weed
Juniperus virginiata Eastern red cedar	*Cephalathus occidentalis* Buttonbush	*Scripus pungens* Three square bulrush
Chionanthus virginicus Fringe-tree	*Hamemelis virginiana* Witch hazel	*Iris versicolor* Blue flag
Nyssa sylvatica Black gum	*Vaccinium corymbosum* Highbush blueberry	*Lobelia cardinalis* Cardinal flower
Diospyros virginiana Persimmon	*Ilex glabra* Inkberry	*Panicum virgatum* Switchgrass
Platanus occidentalis Sycamore	*Ilex verticillata* Winterberry	*Dichanthelium clandestinium* Deertongue
Quercus palustris Pin oak	*Viburnum dentatum* Arrowwood	*Rudbeckia laciniata* Cutleaf coneflower
Quercus phellos Willow oak	*Lindera benzoin* Spicebush	*Scirpus cyperinus* Woolgrass
Salix nigra Black willow	*Morella pennsylvanica* Bayberry	*Vernonia noveboracensis* New York ironweed
Note: For more plant section options for bioretention, consult Design Manual for Use of Bioretention in Stormwater Management (ETA&B 1993) or Design of Stormwater Filtering Systems (Claytor and Schueler 1997).		

Table 7-6: Planting Specification Issues for Bioretention Areas

Specification Element	Elements
Sequence of construction	Describe site preparation activities, soil amendments, etc.; address erosion and sediment control procedures; specify step-by-step procedure for plant installation through site clean up.
Contractor's responsibilities	Specify the contractor's responsibilities, such as watering, care of plant material during transport, timeliness of installation, repairs due to vandalism, etc.
Planting schedule and specifications	Specify the plants to be installed, the type of materials (e.g., B&B, bare root, containerized); time of year of installations, sequence of installation of types of plants; fertilization, stabilization seeding, if required; watering and general care.
Maintenance	Specify inspection periods; mulching frequency (annual mulching is most common); removal and replacement of dead and diseased vegetation; treatment of diseased trees; watering schedule after initial installation (once per day for 14 days is common); repair and replacement of staking and wires.
Warranty	Specify the warranty period, the required survival rate, and the expected condition of plant species at the end of the warranty period.

Table 7-7: Common Grass Species for Open Channels

Common Name	Scientific Name	Notes
Alkali saltgrass	Puccinellia distans	Cool, good for wet, saline swales
Fowl bluegrass	Poa palustris	Cool, good for wet swales
Canada bluejoint	Calamagrostis canadensis	Cool, good for wet swales
Creeping bentgrass	Agrostis palustris	Cool, good for wet swales, salt tolerant
Red fescue	Festuca rubra	Cool, not for wet swales
Redtop	Agrostis gigantea	Cool, good for wet swales
Rough bluegrass	Poa trivialis	Cool, good for wet, shady swales
Switchgrass	Panicum virgatum	Warm, good for wet swales, some salt tolerance
Wildrye	Elymus virginicus/riparius	Cool, good for shady, wet swales

Notes: These grasses are sod forming and can withstand frequent inundation, and are ideal for the swale or grass channel environment. A few are also salt-tolerant. Cool refers to cool season grasses that grow during the cooler temperatures of spring and fall. Warm refers to warm season grasses that grow most vigorously during the hot, mid-summer months.

Where possible, one or more of these grasses should be in the seed mixes. For a more thorough listing of seed mixes see Table 7-8 in Part 5 or consult the Standards for Soil Erosion and Sediment Control in New Jersey.

Vegetative Filters and Stream Buffers

For design and plant selection of vegetative filter strips and stream buffers, consult the USDA Natural Resources Conservation Service, New Jersey Conservation Practice Standards No. 342 “Critical Area Planting,” No. 393 “Filter Strip,” or No. 391 “Riparian Stream Buffers,” available on the web at www.nj.nrcs.usda.gov through the Electronic Field Office Technical Guide (eFOTG).

Part 5: Obtaining and Planting Native Wetland Plant Propagules

There are many ways to obtain plant materials for wetland revegetation, not all of which are appropriate for every project. The process of choosing which plants will be used, in what form, and how they will be obtained should be thought out as far ahead of time as possible. Several criteria will help you make these decisions:

- Have a clear idea of the project goals and objectives (as basic as whether restoration includes woody or herbaceous vegetation or both, and what wetland functions are desired – wildlife food and habitat, water quality improvement, or soil stabilization).
- Know the hydrology on site. Some plants will tolerate only certain water levels, and some plant materials can be established only under particular hydrologic regimes. For example, it makes no sense to select seeds of a shallow water emergent for an area with standing water over 3 feet deep. The seeds will not germinate, and even if they did, the plant would not tolerate those conditions.
- Determine other unique site factors. What are the soils like? Are there micro-topographies that can be exploited? Are geese or deer a problem? Is the site shaded or in full sun?

Once you have decided on the list of potential species for the site, you need to choose the appropriate plant form. Often, this decision is based on project budget, material cost, and the acceptable level of failure. Seeds are usually less expensive than container plants, but generally do not yield great successes and take longer to establish.

Part of the choice of appropriate plant forms depends on what is available. See Tables 7-9 and 7-10 for a complete listing of plant species and available plant forms. Into this mix comes the issue of ecotypes. An ecotype is a population of plants that has become genetically differentiated in response to the conditions of a particular habitat, and it has a distinctive limit of tolerance to environmental factors. For example, wetland plants growing around a pond in Maine are likely to have later flowering times and be more cold hardy than plants of the same species growing around a pond in Florida. When restoring wetland vegetation, consider using local ecotypes as much as possible. Using plants that are already adapted to your conditions can contribute greatly to the success of a revegetation project.

Herbaceous Plants

Herbaceous (non-woody) plants such as grasses, sedges, rushes, and wildflowers are available in many forms, some of which you can readily assemble for a project.

Seed

Using seed to revegetate a wetland is often a low-cost technique, especially if you plan to collect seed yourself. Purchasing seed is more expensive than collecting, but a collection made by a professional ensures that you have good quality seed and allows you to use some species with which you may be unfamiliar. Seeding a wetland can be tricky, since water levels must be carefully controlled. Seed needs to remain close to the soil surface to receive the three elements necessary for germination: moisture (not inundation), heat, and light. Most herbaceous wetland seed requires some pre-germination treatment, either stratification, a period of exposure to cold, moist conditions, and/or scarification (abrasion of the seedcoat) before they will germinate. If seeds are planted in the fall right after cleaning, winter freeze-thaw and bacterial activity may take care of these requirements. For a spring seeding, it is important to know whether the seed has been treated. Generally, there is a greater chance for failure when using seeds rather than plants for revegetation, and little information is available for direct seeding many species. However, seeding can be used in conjunction with other planting methods to enhance restoration.

Dormant Propagules

Dormant propagules are overwintering, underground plant parts such as rhizomes, bulbs, corms, and tubers. These parts are fairly easy to work with; they can be purchased from vendors and transplanted into project sites. Revegetating a wetland with these materials is recommended over seeding because plant material is more likely to survive. Some important points to keep in mind:

- Store collected propagules in a cool, moist (not wet) location until needed. These materials have a much shorter shelf-life than seeds, so collect as close to planting time as possible.
- Dormant propagules are best purchased from local wetland plant vendors. This helps ensure that local ecotypes are used. Locally purchased plants are usually of high quality since long distance shipping is eliminated. When the plant materials shipment arrives, inspect the plants; propagules should be firm, not mushy. If they appear to be decomposing or smell bad, do not accept them.
- In temperate regions, wetland plant materials require a cold treatment to break dormancy. Planting propagules during fall, winter, or early spring will ensure that they receive the cold period necessary to develop normally.

Bare Root Plants and Plugs

Herbaceous plants are commonly grown in greenhouse flats, producing plants with a 2-inch root ball or "plug." Some, however, may be sold as bare-root clumps. Bare-root plants are best planted in the early spring, whereas plants grown in a potting mix can generally be planted through mid-summer. Some nurseries grow deeper rooting species such as warm-season grasses in cone shaped containers referred to as Cone-tainers™ or Deep '38s™ (referring to the number of plants in a flat).

Container Plants

Using container plants (quart size or larger) to restore vegetation on a site can be costly, but healthy plants with intact root balls have an advantage over other plant materials in that they do not need to expend energy on re-growing fine roots (as is the case with bareroot materials), germinating, and growing roots and shoots (as is the case with seeds and dormant vegetative propagules). Container materials can be planted at any time of the year, as long as the ground is not frozen and there is adequate moisture. Some nurseries only contract-grow container material since this size plant requires more time to grow.

Handling Herbaceous Plants

While you will most likely not be propagating and growing your own container plants, you may find, especially if a project is delayed, that you will have to pot up and store bareroot plants, dormant propagules, donor plugs, or even seeds that have limited longevity. Wetland plants are not particularly fussy, so they do not require special soil. Clean topsoil is fine for most species. Be careful not to use soil with a lot of weed seeds, or you may end up transporting problem plants into the wetland. If clean topsoil is not available, you can use bagged topsoil. A 1:1 mix of sand and peat is also useful, especially for germinating small seeds of herbaceous species. While many wetland plants can grow under normal watering regimes, you can cut down on watering and acclimate them to the intended site by letting containers sit in tubs partially filled with water.

In the normal scheme of things, you will be buying your container plants from a wetland plant vendor. As with the other materials discussed, try to find as local a supplier as possible to minimize any difficulties the plants will have adapting to local climate conditions. Inspect container plants for overall health and appearance – plant leaves should not appear pale or have yellowing or brown tips, and stems should be firm, not spindly. Look for evidence of pests or diseases – holes, wilting, or actual bug sightings should be cause to question the quality of materials. Pull plants from containers to look for strong root systems, with lots of white roots. If you specify particular sizes for materials, be sure that plants' roots fill the containers. Herbaceous materials can be sold in various sizes, but are most commonly available as plugs, quarts, or gallon sized containers. They are grown from seed, cuttings, vegetative propagules, or division. Containers may be made of plastic or biodegradable material such as peat, paper, or fiber.

Woody Plants

Woody plants for wetland revegetation are available in many of the same forms as herbaceous species; however, working with woody plants can take a bit more planning since they grow more slowly than herbaceous plants and it can take several growing seasons for materials to be ready for transplanting.

Seed

The advantages and disadvantages to working with woody plant seed are similar to those for herbaceous seed, that is, using seed is generally inexpensive, but can be tricky, particularly with species whose seed is preferred animal food (e.g., acorns).

Woody plant seed vendors can provide seeds for your project, but these suppliers are rare and, depending on your area, it may be difficult to obtain seed of local origin unless you collect it yourself. Try to get viability or germination information for any seeds you purchase.

Hardwood Cuttings

Stem cuttings from woody plants made during the dormant season are known as hardwood cuttings. These types of plant materials are particularly useful for revegetation on wetland edges and banks, just above the water line within the saturated soil zone. Cuttings are available to a limited extent from nurseries. Disadvantages to using hardwood cuttings include that they can dry out quickly, and that they may have high mortality rates, depending on site conditions.

The best candidates for hardwood cuttings are species of willow, poplar, and shrub dogwoods; these root readily without special treatment. Generally, cuttings are made from one to three-year-old stems, at least 18 inches long and .5 to 1.25 inches in diameter for best results; older materials do not root as readily.

Hardwood cuttings should be stored cold and moist until spring planting. To prime cuttings to form roots quickly after planting, soak cuttings in water for at least 24 hours prior to planting. This process swells the tissue that will expand from the cuttings to form roots.

Bareroot Plants

Bareroot trees and shrubs are commonly grown by native plant nurseries, and are fairly low-cost materials to work with. They are easy to store, transport, and plant, but survival is not as good as with materials that have intact roots.

When purchasing bareroot plants, look for good quality seedlings with a height of at least 18 inches and a root collar of 3/8 inches. Plants should have a substantial root mass left – about equal to the top. Do not accept materials that appear to have too much top growth to the amount of root. Plants should be firm and the growing layer underneath the bark should be green when a small area of the bark is scratched off.

Store bareroot plants in a cool, damp, dark location. Moist sawdust or soil can be packed loosely around the plants to prevent the roots from drying out. Bareroot plants can be stored successfully for several months prior to planting, as long as their roots do not dry out or freeze, and they do not leaf out.

Container Plants and Balled and Burlapped Material

The most expensive and cumbersome restoration materials, but also the most successful in terms of survival, are container plants. Balled and burlapped (B&B) plants are expensive, but can have lower survival rates because of the loss of roots when dug from nursery beds (similar to bareroot materials). Both types can be planted at any time of the year, so long as hydrologic conditions are favorable and the ground is not frozen.

There are probably few instances when you would actually go through the process of ordering container materials for a project, and it is therefore useful to know what to expect when you purchase trees and shrubs from commercial growers. Order early – as soon as you know what you need for a project, start shopping. It can take two growing seasons or longer to propagate woody plants, especially seedlings. Be sure to specify plant size: if you ask only for specific container sizes, you may end up with tiny plants.

Before you accept delivery of container or B&B stock, look at the quality of the materials, particularly the roots. With container plants, remove several plants from the pots and check roots to be sure they fill the pots and are large enough to support the top growth without being pot-bound. Large, thick roots circling inside the pots or girdling other roots are indicative of plants that have outgrown their containers and were not transplanted to larger pots in time. B&B plants should have solid root balls with enough of the root systems present to support the top growth of the plants.

Overall quality is important. Plants for revegetation sites need not be perfect landscape specimens, but they should be vigorous and healthy, with no leaf damage, wilting, or pest insects. Healthy plant material is most able to tolerate less than ideal conditions and survive on a restoration site.

Direct Seeding of Wetland Plants

Many wetland plants are very difficult to seed in the wild. Wetland plant seeds usually require three things to germinate: heat, water, and light. The need for light means that wetland plant seeds must be seeded on the surface and cannot be covered with soil. Planting the seed with a drill will cover the seed, especially if packer wheels or drag chains are used.

Many species have a very hard seed coat that takes up to a year or longer to break down enough for the embryo to germinate. Many species require special stratification treatments to prepare the seed for planting. These treatments include everything from acid wash to mechanical scarification, from pre-chilling to extremely high temperature soil conditions. Occasionally, dormant seeding (seeding during the late fall or winter after the plants have gone dormant) can be successful, but it depends on the species.

Not having absolute control of the water going into the wetland or riparian area is the most common mistake that occurs when seeding wetland plants. Without good water control, when water enters the system the newly planted seeds will float to the water surface and move to the water's edge, where wave action will deposit the seed in a very narrow zone. The seed will germinate here and the stand will generally be quite successful so long as the hydrologic conditions are maintained for the various species deposited there. With good water control, the seeds, for the most part, will stay in place, and the stand will cover the wetland bottom instead of just around the fringe.

Some species, when seeded in a greenhouse setting, require a cold-hot stratification environment for successful germination. This means that the seeds are placed in cold storage at 32-36º F for 30 to 60 days and are then planted in moist soil containers at about 100º F. Heat is one of the essential requirements for germination and growth.

Based on these difficulties, using direct seeding of herbaceous plants as the primary means of revegetating a site will require more attention to planning and control of site hydrology during the establishment period. It also means you will need to know the specific germination/stratification requirements (if any) the targeted species require. Typically, direct seeding of herbaceous species is not used as the primary means of active revegetation, but as a method to increase the overall species diversity in a wetland, especially around the perimeter, and to establish populations of specific target species. The use of wetland herbaceous plugs is recommended over the use of wetland seed. However, the grass seeding mixtures in Table 7-8 may be used to quickly vegetate newly prepared wetland or fringe areas. Seeding alone may also be used if natural regeneration of indigenous species is desired.

Table 7-8: Grass Mixtures for Quickly Vegetating Wetland Sites

Species	Common Name	Remarks
Agrostis gigantea	Redtop	SP,I,CG
Agrostis palustris	Creeping bentgrass	P,I,CG
Calamagrostis candensis	Canada bluejoint	P,N,CG
Cinna arundinacea	Wood reedgrass	P,N,CG
Dicanthelium clandestinum	Deertongue	P,N,WG
Elymus virginicus VA./riparius	Riparian wildrye	P,N,CG
Lolium multiflorum	Annual ryegrass	A,I,CG
Panicum virgatum	Switchgrass	P,N,WG
Poa trivialis	Rough bluegrass	P,I,CG
Poa palustris	Fowl bluegrass	P,N,CG
Puccinellia distans	Alkali saltgrass	P,N,CG
Tripsacum dactyloides	Eastern gamagrass	P,N,WG

Legend:
P = perennial CG = cool-season grass
A = annual WG = warm-season grass
I = introduced CL = cool-season legume
N = native SP = short-lived perennial

Note: Warm-season grass seeding rates are based on Pure Live Seed (PLS).

Suitable Seed Mixtures

SEED MIX 1: Warm-season mixture suitable for highly acid soils. Provides excellent wildlife value.

Blackwell switchgrass 3 lbs./ac. PLS
Tioga deertongue 5 lbs./ac. PLS
Annual ryegrass (nurse) 5 lbs./ac. PLS

SEED MIX 2: Cool-season mixture suitable for highly erosive areas. Provides fair wildlife value.

Canada bluejoint 2 lbs./ac.
Redtop 1 lbs./ac.

SEED MIX 3: All native mixture suitable for somewhat acid soils. Provides good to excellent wildlife value.

Blackwell switchgrass 3 lbs./ac. PLS
Tioga deertongue 5 lbs./ac. PLS
Wild rye 5 lbs./ac.

SEED MIX 4: Turfgrass mixture suitable for moist, shady areas.

Rough bluegrass	25 lbs./ac.
Creeping bentgrass	10 lbs./ac.

SEED MIX 5: Native grass mixture for shady sites/forested floodplains.

Wood reedgrass	2 lbs./ac.
VA or Riparian wildrye	5 lbs./ac.

SEED MIX 6: Mixture for providing quick, temporary cover in areas where planting may be delayed due to seasonal restrictions, e.g, seed in late fall, plant permanent vegetation the following spring. Excellent wildlife value.

Redtop	1 lbs./ac.
Annual ryegrass	8 lbs./ac.

SEED MIX 7: This mixture is suitable for wet, saline areas, i.e., along roadsides, adjacent to tidal areas.

Creeping bentgrass	10 lbs./ac.
Alkali saltgrass	5 lbs./ac.

SEED MIX 8: Permanent cover mix providing quick perennial cover for saturated areas that will not be planted with other species.

Eastern gamagrass	5 lbs./ac. PLS
Redtop or creeping bentgrass	2 lbs./ac.
Fowl bluegrass	5 lbs./ac.
Wild rye	8 lbs./ac.
Switchgrass	5 lbs./ac. PLS

If aesthetics are desired, the following wildflowers are tolerant of saturated conditions and any or all may be added to the above mixtures at the rates specified:

Asclepias incarnata (Swamp milkweed)	2 lbs./ac.
Aster novae-angliae (New England aster)	0.5 lb./ac.
Aster novi-belgii (New York aster)	0.5 lb./ac.
Bidens frondosa (Beggar's tick sunflower)	1 lb./ac.
Caltha palustris (Marsh marigold)	0.5 lb./ac.
Chelone glabra (Turtlehead)	1 lb./ac.
Eupatorium fistulosum (Joe-pye weed)	1 lb./ac.
Helenium autumnale (Sneezeweed)	1 lb./ac.
Lobelia cardinalis (Cardinal flower)	0.5 lb./ac.
Lobelia siphilitica (Blue lobelia)	0.5 lb./ac.
Mimulus ringens (Monkey flower)	1 lb./ac.
Rudbeckia laciniata (Green-headed coneflower)	1 lb./ac.
Solidago rugosa (Wrinkle-leaf goldenrod)	0.5 lb./ac.
Solidago patula (Rough goldenrod)	0.5 lb./ac.
Verbena hastata (Blue vervain)	1 lb./ac.
Vernonia noveboracensis (New York ironweed)	2 lbs./ac.

Wetland Transplanting with Plugs

Natural wetland systems normally have high species diversity. When selecting plant species for the project wetland, try to copy a nearby natural wetland using these techniques:

- Identify the particular hydrology in areas where the individual plant species are growing.
- Make note of how deep the water is.
- Try to imagine how long the plants will be inundated.
- Determine whether the plants are in flowing or relatively stagnant water.

Rarely will a natural wetland be totally stagnant through time. Generally, there is water flowing into the wetland from somewhere, either above ground or from groundwater. Spring and fall overturn, as well as wind mixing, helps to circulate the water.

Next, prepare the planting area. The easiest way to plant wetland species plugs is by flooding your planting site. Standing water is much easier to plant than dry soil (this also ensures that the watering system, whatever it may be, works before you plant). Make sure the soil is saturated enough so that you can dig a hole with your hand. This is more successful with fine soils than with coarse soils. Take the plug trays and place them in a Styrofoam cooler (you will not need the lid). Try to cover most of the roots with water while in transit. At the planting site, drain off most of the water so the cooler will float. Use the cooler to move the plugs around the wetland as you plant. Select a spot in your wetland to put a plug, reach into the water with your hand and dig out a hole deep enough for the plug to fit all the way in. Push the plug into the hole and pack around it with your hand. Make sure all of the roots are covered with soil. Be careful to not dislodge the plug and expose the roots when moving around. Start at one end of the planting site and work toward the opposite end.

Spacing of the plugs is a common concern. Research has indicated that many wetland plants will typically spread about 9 to 12 inches in a full growing season. Typically, wetland species are planted on 18 inch centers. Even though it takes fewer plants to plant an area at a wider spacing, plantings at wider spacing have less overall success than planting at a closer spacing. The exact reason for this is unknown, but it could be a sympathetic response to plants of the same species. If the project budget does not allow for the purchase of enough plants to cover the wetland bottom, plant the plugs on 18 inch centers, but plant them in copses or patches that are about 10 feet square or in diameter. Space the copses about 10 feet apart. The copses can be planted to different species according to the hydrology. For hydrologic Zone 2, Scheuler (1996) recommends planting at least five to seven species of emergent plants, three of which should be arrowhead (Sagittaria latifolia), three square (Scirpus pungens), and soft-stem bulrush (Scirpus tabernaemontanii). Based on experience, these three species will establish readily and spread quickly without being too aggressive. Over time, the plants will spread out into the unplanted areas. The additional species selected for the wetland system can be chosen to mimic natural wetlands in the area and/or enhance water quality, wildlife value, or aesthetics. Generally, it is best to keep water levels as shallow as possible to promote greater species diversity and assimilate a higher concentration of pollutants. High nutrient inflows and greatly fluctuating water levels tend to promote the more aggressive species such as reed canarygrass, cattails, and phragmites.

The optimum planting window for wetland plants is from March through late July. Planting plugs in the fall and winter has resulted in frost heaving of the plugs so that only about one-third of the plug remained in the ground. The availability of water is critical – wetland plants like it hot and wet. They tend to spread faster with warmer temperatures. If you plant in the spring, it will take the plants a while to get going, but they will have a longer establishment period. Fall planting will generally result in lower establishment success because of the shorter growing season and frost heaving damage.

The plants can be successfully established in a wide variety of soil textures. Successful wetland plantings have occurred in areas that are clay with no organic matter to gravelly textures. The biggest problem is digging the holes. The soil texture will often limit the equipment available to dig the holes. In clay bottoms, a small bulldozer or tractor with a ripper tooth can be used to dig lines across the bottom about 8 inches deep.

In general, fertilizer is not necessary, but its use depends on the site and the soils. If during construction the bottoms have been cut down to the subsoil and all of the naturally present nutrients have been removed, fertilization will probably be necessary unless the water coming into the wetland has a high nutrient load.

After planting, release the water into the site slowly. The young plants have not fully developed the aerenchymous material necessary for them to survive in anaerobic soils and standing water. After the initial planting, be careful not to raise the water level to more than about 1 inch above the substrate. Too much water at this time may stress the new plants. Maintain the water at about 1 inch for about one week, to inhibit the germination and growth of any terrestrial species that may be present in the restored wetland. The water level can then be lowered to the substrate surface for 15 to 20 days. This will expose the mud surface, stimulating any wetland seeds that were brought in with your transplants to germinate as well as increase the rate of spread of the transplants. You can then raise the water level 1 to 2 inches for another week. Then lower the water to the substrate surface for another 15 to 20 days. After this period, slowly raise the water level to 4 to 6 inches for three to five days. Continue to gradually increase the water depth to 6 to 8 inches. The aerenchymous tissues in the plant shoots are what supply the roots with oxygen, so be careful not to raise the water over the tops of the emergent vegetation. If the plants are not showing any stress, continue to carefully raise the water level to 12 to 20 inches, if possible. These suggested water level depths must be modified based on the species used. Some species will not tolerate inundation at these suggested depths or durations. When in doubt, defer to the hydrology conditions on natural reference sites where the species occurs. The goal here is to inundate the transition zone between wetland and upland as much as possible to control any invading terrestrial species. After about 20 days lower the water level to about 2 to 3 inches (Hammer 1992). For the rest of the growing season, adjust the water level to maximize the desired community type. The key to determining the appropriate water level is to monitor the emergent wetland plant community. Raise the water level if weed problems surface. Lower the water level to encourage emergent wetland plant growth and spread. The key is to fluctuate the water level. Natural wetlands rarely have a constant water level. Many species cannot tolerate a constant water level and will begin to die out; species more tolerant to standing water will increase, and the plant diversity that was so carefully planned for will be lost.

Management during the establishment year is important to ensure that the plants do not get too much water or too little. Weed control is important especially during the establishment year because of the low water levels and exposed, unvegetated areas. A good weed control plan needs to be in place before planting. Monitoring the planting for three to five years after the establishment year will help maintain the planting and provide useful information for future plantings.

Recommendations

- Always match the plant species to the hydrology associated with that species. In general, purchase the largest plugs you can. Planting technique will often determine the size of the plugs and the ease of planting.
- Plant the plugs on 18 to 24 inch centers. Plant in patches rather than wider spacing.
- Fertilizer is generally not necessary unless the water coming into the site is relatively clean or construction has cut into the subsoil.
- Plants will spread faster under saturated soil conditions than in standing water. However, terrestrial weeds will move in to saturated soils much faster than flooded soils. Fluctuating the water level helps the plants spread and decreases terrestrial weed establishment.

- Water control is extremely important during the establishment year.
- Weed control must be planned and budgeted at the beginning of the project.
- Monitoring is essential for the success of the project. Monitoring requires time and money allocated in the budget, and a specific person identified to carry it out.
- Successful wetland plantings take significant planning and a good understanding of the hydrology at each site.

Upland Seeding

There are three main factors to consider when planning the upland seeding phase o stormwater basin: season of seeding, seeding rates, and method of application. Season of seeding is important because some seed may require stratification before germination. Other seed, such as legume species, should probably not be seeded until spring. Seeding rate concerns both economics and plant competition. Too much seed on a site puts unnecessary cost into the total process and, at the same time, a thinner stand will emerge because of plant competition for nutrients traditionally in short supply on disturbed soils. Ideally, the site should have been prepared the previous fall if a spring seeding is desired. Usually, spring seedings are conducted between periods of wet and dry weather (commonly in March to the first of May). There may be a problem getting heavy equipment onto the site to prepare a seedbed in the early spring following a wet winter that has saturated the soil profile. (Refer to the USDA-NRCS Conservation Practice Standard-342 "Critical Area Planting" or the Standards for Soil Erosion and Sediment Control in New Jersey for seed mixtures and mulching information.)

Part 6: Other Considerations in Stormwater BMP Landscaping

Use or Function

In selecting plants, consider their desired function in the landscape. Is the plant needed as ground cover, soil stabilizer, or a source of shade? Will the plant be placed to frame a view, create focus, or provide an accent? Does the location require that you provide seasonal interest to neighboring properties? Does the adjacent use provide conflicts or potential problems and require a barrier, screen, or buffer? Nearly every plant and plant location should be provided to serve some function in addition to any aesthetic appeal.

Plant Characteristics

Certain plant characteristics, such as size and shape, are so obvious they may actually be overlooked in the plant selection. For example, tree limbs, after several years, can grow into power lines. A wide growing shrub may block an important line of sight to oncoming vehicular traffic. A small tree, when full grown, could block the view from a second story window. Consider how these characteristics can work for you or against you, today and in the future.

Other plant characteristics must be considered to determine how plants provide seasonal interest and whether plants will fit with the landscape today and through the seasons and years to come. Some of these characteristics are: color, texture, growth rate, and seasonal interest, i.e., flowers, fruit, leaves, and stems/bark.

Growth Rate

If shade is required in large amounts, quickly, a sycamore might be chosen over an oak. In urban or suburban settings, a plant's seasonal interest may be of greater importance. Residents living next to a stormwater system may desire that the facility be appealing or interesting to look at throughout the year. For example, willows are usually the first trees to grow leaves signaling the coming of spring. Pink and white dogwoods bloom in mid-spring to early summer, while witch hazel has a yellow bloom every fall, which can be contrasted with the red fall foliage of a sugar maple. Careful attention to the design and planting of a facility can result in greater public acceptance and increased property value.

Availability and Cost

Often overlooked in plant selection is the availability from wholesalers and the cost of the plant material. Many plants listed in landscape books are not readily available from local nurseries. Without knowledge of what is available, time spent researching and finding the one plant that meets all needs will be wasted. That plant may require shipping, making it more costly than the budget may allow. Some planting requirements may require a special effort to find the specific plant that fulfills the needs of the site and the functions of the plant in the landscape. In some cases, it may be cost effective to investigate nursery suppliers for the availability of wetland seed mixtures. Specifications of the seed mix should include wetland seed types and the relative proportion of each species. Some suppliers provide seed mixtures suitable for specific wetland, upland, or riparian habitat conditions. This option may best be employed in small stormwater facilities, such as pocket wetlands and open swales, or to complement woody vegetation plantings in larger facilities. A complete listing of wetland plant suppliers is available on the USDA-NRCS Plant Materials Program website (www.Plant-Materials.nrcs.usda.gov).

Vegetation Maintenance

To ensure grass vigor, maintain the copse as an upland meadow, which includes cutting no shorter than 6 to 8 inches high. If a more manicured lawn setting is desired, more mowing and special attention to turf health will be needed. Some communities consider the tall wetlands-type vegetation (typically, cattails or rushes) that may grow in dry ponds to be unaesthetic. Some of this vegetation is actually beneficial as it provides water quality benefits and wildlife habitat. Some vegetative needs include:

- pH adjustment (as required);
- pruning;
- pest control;
- reseeding;
- thatch removal; and
- weed removal.

Sediment Filtration

Vegetative cover outside of an embankment filters sediment from runoff as it flows into a pond. It also prevents erosion of the pond banks. A minimum vegetated filter strip BMP is ideal around wet ponds.

Surrounding Vegetation Fertilization (not recommended, except in special cases)

It is important not to over-fertilize the surrounding vegetation. Doing so could result in excess nutrients being washed into the pond, which can contribute to excessive algae growth. As a general rule, the nutrient needs of the surrounding vegetation should be evaluated by testing the pH and nutrient content of the soil prior to fertilization. The adjustment of pH may be necessary to maintain vegetation. Fertilization of all turf areas should occur in the fall.

Purple Loosestrife

If your wetland and/or stormwater management area becomes invaded with purple loosestrife, there are methods to reduce its presence. It is important to catch its presence early, which is evident by the long purple flowering head or inflorescence. To manually rid the wetland and/or stormwater management area of purple loosestrife, it is important to ensure that the rhizomes (large tuberous root systems) are removed as well as the plant (above ground portion) prior to flowering (June through September). Plant parts, immediately upon removal, should be placed in a bag to prevent further spread of the species. If it is not possible to do this, regularly remove the flower heads before the seeds are dispersed. This will help keep this plant at bay. Digging is not recommended as it creates disturbance, which may favor the spread of the species. Herbicides are generally not effective for purple loosestrife as its seeds are long-lived and this solution is therefore short-term. If herbicide applications are used, they will need to be repeated for several years. As a caution, purple loosestrife may be available at local nurseries. Do not introduce this plant into pond areas.

Cattails and Common Reeds (phragmites)

It is important to determine which plants were originally planted when the pond or stormwater wetland was constructed. Cattails planted in these areas are one of the most beneficial plants in improving water quality. It must be noted that ponds and stormwater wetlands were originally designed with the intent of retaining stormwater and/or treating stormwater. The concept of wildlife habitat was an ancillary benefit at best and not generally the goal prior to the mid-1990s.

Shallow water (less than 2 feet) will often be taken over by water loving plants. Dense, tall emergent vegetation, most commonly cattails and phragmites, may limit waterfowl use of a pond. Cattails provide good wildlife habitat, but can take over a shallow pond. Phragmites is much more invasive, taller, and generally does not provide for a scenic view. Once established, phragmites is very difficult to completely eradicate.

Dense stands of cattails and phragmites can reduce populations of invertebrates, amphibians, and reptiles, and may possibly increase mosquito populations. It is important to keep some areas of open water. Eradication of these species generally requires assistance from a natural resource professional. A natural resource professional is a person who has been trained in ecology and/or environmental assessment, including soils, plants, animals, air quality, human involvement, and water quantity and quality.

With respect to diversity, research has shown that lower pollutant inputs generally yield greater plant diversity. Conversely, higher pollutant inputs yield lower plant diversity. Hence, if your pond becomes populated with phragmites, cattails or both, it may indicate a high pollutant load. These species, among others, are two of the best plants for improving water quality.

Stormwater Plant Lists

The following pages present lists of herbaceous and woody vegetation native to New Jersey and suitable for planting in stormwater management facilities. The lists are intended as a guide for general planting purposes and planning considerations. Knowledgeable landscape designers and nursery suppliers may provide additional information for considering specific conditions for successful plant establishment and accounting for the variable nature of stormwater hydrology.

The planting lists are in alphabetical order according to the common name, with the scientific name also provided. Life forms indicate whether a plant species is an annual, perennial, grass, grass-like, fern, tree, or shrub.

Each plant species has a corresponding hydrology zone to indicate the most suitable planting location for successful establishment. While the most common zones for planting are listed in parenthesis, the listing of additional zones indicates that a plant may survive over a broad range of hydrological conditions.

The wetland indicator status has been included to show "the estimated probability of a species occurring in wetlands versus nonwetlands." The indicator categories are defined as follows:

- Obligate wetland (OBL): Plants that nearly always (more than 99 per cent of the time) occur in wetlands under natural conditions.
- Facultative Wetland (FACW): Plants that usually occur in wetlands (from 67 to 99 per cent of the time), but are occasionally found in nonwetlands.
- Facultative (FAC): Plants that are equally likely to occur in wetlands and nonwetlands and are found in wetlands from 34 to 66 per cent of the time.
- Facultative Upland (FACU): Plants that usually occur in nonwetlands (from 67 to 99 per cent of the time), but are occasionally found in wetlands (from 1 to 33 per cent of the time).
- Upland (UPL): Plants that almost always (more than 99 per cent of the time), under natural conditions, occur in nonwetlands.

A given indicator status shown with a "+" or a "-" means that the species is more (+) or less (-) often found in wetlands than other plants with the same indicator status without the "+" or "-" designation.

Since the wetland indicator status alone does not provide an indication of the depth or duration of flooding that a plant will tolerate, the "Inundation Tolerance" section is designed to provide further guidance. Where a plant species is capable of surviving in standing water, a "Yes" is designated in this column. Additional information is provided for depth of inundation for aquatic vegetation and tolerance for seasonal inundation, saturated soil conditions, or tolerance to salt. Because individual plants often have unique life requirements difficult to convey in a general listing, it will be necessary to research specific information on the plant species proposed in order to ensure successful plant establishment.

Commercial availability indicates whether the plant is available as seed, plant form (bare-root, plug, or container), or both. The plant form listed first is the most common form supplied by nurseries. The availability of some species varies from one year to the next. It is best to determine the quantity needed and the plant form desired for each individual species well ahead of time (at least six months).

Table 7-9, a list of herbaceous stormwater plants, begins on the next page, followed by Table 7-10, a list of woody vegetation.

Table 7-9: Stormwater Plant List – Herbaceous Vegetation

Common Name	Scientific Name	Plant Type	Hydrologic Zone	Wetland Indicator	Inundation Tolerance	Commercial Availability
Arrow arum	Peltandra virginica	Grass-like	[1,2],3	OBL	Yes	Plants, Seed
Arrowhead, bull-tongue	Sagittaria lancifolia	Perennial	[1,2],3	OBL	Yes	Plants
Arrowhead, duck potato	Sagittaria latifolia	Perennial	[1,2],3	OBL	0-2′	Plants, Bare-root, Seed
Arrowhead, grass-leaf	Sagittaria graminea	Perennial	[1,2],3	OBL	0-1′	Plants
Aster, calico	Aster lateriflorus	Perennial	[2,3,4]	FACW-	Seasonal	Seed, Plants
Aster, New England	Aster novae-angliae	Perennial	[2,3],4	FACW	Yes	Seed, Plants
Aster, New York	Aster novibelgil	Perennial	[2,3],4	FACW+	Yes	Seed, Plants
Aster, panicled	Aster simplex (lanceolatus)	Perennial	[2,3],4	FACW	Yes	Seed, Plants
Aster, white heath	Aster ericoides	Perennial	3,[4,5,6]	FACU	No	Seed
Aster, white wood	Aster divercatus	Perennial	4,[5,6]	NI	No	Plants
Beachgrass, American	Ammophila breviligulata	Grass	4[5,6]	FACU-	No	Dormant culms Plants
Beardtongue	Penstemon digitalis	Perennial	3,4,5	FAC	No	Plants, Seed
Beebalm	Monarda didyma	Perennial	3,[4,5]	FAC+	Saturated	Plants, Seed
Beggars-tick	Bidens connata	Annual	[2,3],4	FACW+	Yes	Seed
Beggars-tick	Bidens frondosa	Annual	2,[3,4]	FACW	Yes	Seed
Bentgrass, creeping	Agrostis palustris	Grass	[2,3],4	FACW	Yes	Seed
Bergamot, wild	Monarda fistulosa	Perennial	[4,5,6]	UPL	No	Plants, Seed
Black-eyed susan	Rudbeckia hirta	Perennial	4,[5,6]	FACU-	No	Plugs, Seed
Bladderwort, common	Utricularia macrorhiza	Perennial	[1,2],3	OBL	Yes	Plants
Blue lobelia	Lobelia siphilitica	Perennial	1,[2,3],4	FACW+	Yes	Plants, Seed
Bluebells, Virginia	Mertensia virginica	Perennial	[2,31,4	FACW	Yes	Plants, Seed
Bluegrass, fowl	Poa palustris	Grass	[2,3],4	FACW	Yes	Seed
Bluegrass, rough	Poa trivialis	Grass	2,[3,4],5	FACW	Seasonal	Seed
Bluestem, big	Andropogon gerardii	Grass	[4,5],6	FAC	No	Seed, Plants
Bluestem, little	Schizachyrium scoparium	Grass	6	FACU	No	Seed, Plants
Boneset	Eupatorium perfoliatum	Perennial	[2,3],4	FACW+	Yes	Plants, Seed
Broomsedge	Andropogon virginicus	Grass	[4,5],6	FACU	No	Seed
Broomsedge, lowland	Andropogon glomeratus	Grass	[2,3],4	FACW+	Yes	Plants
Bulrush, alkali	Scirpus robustus	Grass-like	1,[2],3	OBL	Salt, edge	Plants
Bulrush, chairmakers	Scirpus americanus	Grass-like	[1,2],3	OBL	0-6″	Plants, Seed
Bulrush, green	Scirpus atrovirens	Grass-like	[1,2,],3	OBL	Yes	Plants, Seed
Bulrush, hardstemmed	Scirpus acutus	Grass-like	[1,2],3	OBL	0-3′	Plants, Seed

Common Name	Scientific Name	Plant Type	Hydrologic Zone	Wetland Indicator	Inundation Tolerance	Commercial Availability
Bulrush, river	Scirpus fluviatilis	Grass-like	[1,2],3	OBL	0-1′	Seed
Bulrush, softstem	Scirpus tabermontanii	Grass-like	[1,2],3	OBL	0-1′	Plants, Seed
Bulrush, three-square	Scirpus pungens	Grass-like	[2,3],4	FACW+	0-6″	Plants, Seed
Burnet, Canada	Sanguisorba canadensis	Perennial	4,[5,6]	FACW+	Yes	Plants
Burreed, American	Sparganium americanum	Emergent Perennial	[1,2],3	OBL	0-1′	Plants, Seed
Burreed, giant	Sparganium eurycarpum	Emergent Perennial	[1,2],3	OBL	Yes	Plants, Seed
Bushclover, roundheaded	Lespedeza capitata	Legume	4,5,6	FACU	No	Seed, Plants
Butter-cup, yellow water	Ranunculus flabellaris	Perennial	[2,3,4]	FACW	Yes	Plants
Butterflyweed	Asclepias tuberosa	Perennial	[5,6]	NI	No	Plants, Seed
Cardinal flower	Lobelia cardinalis	Perennial	1,[2,3],4	FACW+	Yes	Plants, Seed
Celery, wild	Vallisneria americana	Perennial	[1,2],3	OBL	Yes	Plants, Seed
Club, golden	Orontium aquaticum	Perennial	[1,2],3	OBL	Yes	Plants
Columbine, wild	Aquilegia canadensis	Perennial	[3,4],5	FAC	No	Plants, Seed
Coneflower, brown-eyed	Rudbeckia triloba	Perennial	4,[5,6]	FACU	No	Plants, Seed
Coneflower, cut-leaf	Rudbeckia laciniata	Perennial	[2,3],4	FACW	Yes	Seed, Plants
Coneflower, orange	Rudbeckia fulgida	Perennial	[3,4],5	FAC	No	Seed
Cordgrass, big	Spartina cynosuroides	Grass	[1,2],3	OBL	Tidal-fresh	Plugs
Cordgrass, prairie	Spartina pectinata	Grass	[1,2],3	OBL	Tidal-fresh	Plants, Seed
Cordgrass, saltmarsh	Spartina alterniflora	Grass	[1,2],3	OBL	Salt, edge	Plants, Seed
Cordgrass, saltmeadow	Spartina patens	Grass	1,[2,3],4	FACW+	Salt, edge	Plants
Coreopsis, dwarf plains	Coreopsis tinctoria	Annual	3,[4,5],6	FAC-	No	Seed, Plants
Coreopsis, lance-leaved	Coreopsis lanceolata	Perennial	5,6	FACU	No	Seed, Plants
Coreopsis, pink	Coreopsis rosea	Perennial	2,[3,4]	FACW	Yes	Seed, Plants
Coreopsis, tall	Coreopsis tripteris	Perennial	[2,3],4	FAC	Yes	Plants, Seed
Cutgrass, rice	Leersia oryzoides	Grass	[1,2],3	OBL	0-6″	Plants, Seed
Dragon-head, false (obedient plant)	Physostegia virginiana	Perennial	2,[3,4],5	FAC+	Saturated	Plants, Seed
False-hellebore, American	Veratrum viride	Perennial	[2,3,4]	FACW+	Yes	Plants, Seed
False-solomon's-seal	Smilacina racemosa	Perennial	[4,5],6	FACU-	No	Seed
Fern, cinnamon	Osmunda cinnamomea	Fern	[2,3],4	FACW	Saturated	Plants
Fern, New York	Thelypteris noveboracensis	Fern	[3,4],5	FAC	Saturated	Plants, Seed
Fern, royal	Osmunda regalis	Fern	[1,2],3	OBL	Saturated	Plugs
Fern, sensitive	Onoclea sensibilis	Fern	[2,3],4	FACW	Saturated	Plants, Seed
Fescue, hard	Festuca duriuscula	Grass	[3,4,5,6]	NI	No	Seed
Fescue, red	Festuca rubra	Grass	[4,5]	FACU	No	Seed
Fescue, sheeps	Festuca ovina	Grass	[4,5],6	NI	No	Seed
Gamagrass, eastern	Tripsacum dactyloides	Grass	2,[3,4],5	FACW	Yes	Seed

Common Name	Scientific Name	Plant Type	Hydrologic Zone	Wetland Indicator	Inundation Tolerance	Commercial Availability
Goldenrod, roughleaf	Solidago patula	Perennial	1,[2,3,]	OBL	Yes	Seed
Goldenrod, seaside	Solidago sempervirens	Perennial	[2,3],4	FACW	Yes	Plants, Seed
Goldenrod, silverrod	Solidago bicolor	Perennial	5,6	NI	No	Plants, Seed
Goldenrod, stiff	Solidago rigida	Perennial	5,6	UPL	No	Plants, Seed
Goldenrod, wrinkleleaf	Solidago rugosa	Perennial	3,[4,5]	FAC	No	Plants, Seed
Grass, alkali	Puccinellia distans	Grass	[1,2],3	OBL	Yes	Seed
Grass, deertongue	Dichanthelium clandestinium	Grass	[2,3],4	FAC+	Seasonal	Seed
Grass, Japanese millet	Echinochloa frumentcea	Annual Grass	[2,3],4	NI	Yes	Seed
Grass, redtop	Agrostis gigantea	Grass	[2,3,],4	FACW	Yes	Seed
Hornwort, common	Ceratopliyilurn dernersurn	Perennial	[1,21,3	OBL	1-5	Plants
Horsetail, rough	Equisetum hyemale	Fern-like	[2,3],4	FACW	Yes	Plants
Indiangrass	Sorghastrum nutans	Grass	5,6	UPL	No	Seed, Plants
Iris, blue flag	Iris versicolor	Perennial	[1,2],3	OBL	0-6"	Plants, Seed
Iris, yellow flag	Iris pseudacorus	Perennial	[3,4],5	FAC	No	Plants, Seed
Ironweed, New York	Vernonia noveboracensis	Perennial	[2,3],4	FACW+	Yes	Plants, Seed
Jack-in-the-pulpit, swamp	Arisaerna triphyllurn	Perennial	[2,3],4	FACW	Seasonal	Plants
Jacob's ladder	Polemonium reptans	Perennial	[4,5],6	FACU	No	Seed
Jacob's-ladder, bog	Polernoniurn van-bruntlae	Perennial	[3,4],5	FAC+	Saturated	Plants
Joe-pye, purple	Eupatoriadelphus purpureus	Perennial	3,[4,5]	FAC	Yes	Plants, Seed
Joe-pye, spotted	Eupatorium maculatus	Perennial	2,[3,4]	FACW	Yes	Plants, Seed
Lily, turk's-cap	Lilium superbum	Perennial	[2,3,4]	FACW+	Yes	Plants, Seed
Lizards tail	Saururus cernuus	Perennial	2,3,4	OBL	0-1'	Plants
Lotus, American	Nelumbo lutea	Perennial	[1,2],3	OBL	1-5'	Plants, Seed
Lovegrass, purple/tumble	Eragrostis spectabilis	Grass	[5,6]	NI	No	Plants, Seed
Mallow, swamp rose	Hibiscus moscheutos	Perennial	2,3	OBL	0-3"	Plants
Mallow, Virginia seashore	Kosteletzkya virginica	Perennial	[1,2],3	OBL	Yes, saltedge	Plants
Managrass, American	Glyceria grandis	Grass	[1,2],3	OBL	Yes	Plants, Seed
Managrass, Atlantic	Glyceria obtusa	Grass	[1,2],3	OBL	0-1'	Plants, Seed
Managrass, fowl	Glyceria striata	Grass	[1,2],3	OBL	Seasonal	Plants, Seed
Managrass, rattlesnake	Glyceria canadensis	Grass	[1,2],3	OBL	0-1'	Plants, Seed
Marsh marigold	Caltha palustris	Perennial	3,4	OBL	6", saturated	Plants, Seed
Marsh-mallow, common	Althaea officinalis	Perennial	[1,2,3]	FACW+	Yes	Plants, Seed
Meadow-rue, tall	Thalictrum pubescens	Perennial	[2,3,4]	FACW+	Yes	Seed, Plants
Milkweed, swamp	Asclepias incarnata	Perennial	2,3	OBL	Saturated	Plants, Seed
Monkey-flower	Mimulus ringens	Perennial	[1,2],3	OBL	Yes	Plants, Seed

Common Name	Scientific Name	Plant Type	Hydrologic Zone	Wetland Indicator	Inundation Tolerance	Commercial Availability
Mountain-mint, slender	Pycnantheinum tenuifolium	Perennial	[2,3,4]	FACW	Yes	Plants, Seed
Nutsedge/ chufa	Cyperus esculentus	Grass-like	[2,3],4	FACW	Yes	Seed, Plants
Panicgrass, coastal	Panicum amarulum	Grass	3,4,[5,6]	FACU-	Yes	Seed, Plants
Partridge-berry	Mitchella repens	Groundcover	[4,5],6	FACU	No	Plants
Pennsylvania smartweed	Polygonum pensylvanicum	Annual	[2,3]	FACW	0-6″	Plants, Seed
Phlox, meadow	Phlox maculata	Perennial	[2,3,4]	FACW	Yes	Plants
Phlox, thick-leaf	Phlox carolina	Perennial	4,[5,6]	FACU	No	Plants
Pickerelweed	Pontederia cordata	Perennial	2,3	OBL	0-1′	Plants, Seed
Pondweed, long-leaf	Potamogeton nodosus	Perennial	[1,2]	OBL	1′ min-6′	Plants
Pondweed, sago	Potamogeton pectinatus	Perennial	[1,2]	OBL	1′ min-24′	Plants
Primrose, evening	Oenothera biennis	Perennial	4,[5,6]	FACU-	No	Seed
Reedgrass, bluejoint	Calamagrostis canadensis	Grass	1,[2,3]	FACW+	6″, saturated	Seed, Plants
Reedgrass, wood	Cinna arundinacea	Perennial	2,[3,4]	FACW+	Yes	Plants, Seed
Rush, baltic	Juncus balticus	Grass	[2,3],4	FACW	Yes	Plants, Seed
Rush, bayonet	Juncus militaris	Grass-like	[2,3],4	OBL	Yes	Plants, Seed
Rush, blackgrass	Juncus gerardili	Grass-like	[2,3],4	FACW+	Yes, saltedge	Plants, Seed
Rush, Canada	Juncus canadensis	Grass-like	[1,2],3	OBL	Yes	Plants, Seed
Rush, needlegrass	Juncus roemerianus	Grass-like	[1,2],3	OBL	Yes, saltedge	Plants, Seed
Rush, soft	Juncus effusus	Grass-like	[2,3],4	FACW+	0-1	Plants, Seed
Saltgrass, seashore	Distichlis spicata	Grass	[2,3,],4	FACW+	Salt, edge	Plants
Sedge, awl	Carex stipata	Grass-like	[4,5],6	NI	No	Plants, Seed
Sedge, bearded	Carex comosa	Grass-like	[1,2],3	OBL	6″ , saturated	Plants, Seed
Sedge, bladder	Carex intumescens	Grass-like	1,[2,3]	FACW+	Yes	Plants, Seed
Sedge, broom	Carex scoparia	Grass-like	[3,4],5	FACW	Yes	Plants, Seed
Sedge, fox	Carex vulpinoidea	Grass-like	[1,2],3	OBL	Sat. 0-6″	Plants, Seed
Sedge, fringed	Carex crinita	Grass-like	[1,2],3	OBL	Yes	Plants, Seed
Sedge, hop	Carex lupulina	Grass-like	[1,2],3	OBL	Yes	Seed
Sedge, lakebank	Carex lacustris	Grass-like	[1,2],3	OBL	Sat. 0-2	Plants, Seed
Sedge, pennsylvania	Carex pennsylvanica	Grass-like	[5,6]	NI	No	Plants
Sedge, shallow	Carex lurida	Grass-like	[1,2],3	OBL	Yes	Plants, Seed
Sedge, short's	Carex shortiana	Grass-like	3,[4,5]	FAC	Yes	Plants
Sedge, three-sided	Dulichium arundinaceum	Grass-like	1,[2,3]	OBL	Yes	Plants, Seed
Sedge, tussock	Carex stricta	Grass-like	[1,2],3	OBL	Sat, 0-6″	Plants, Seed
Sedge, yellow-fruit	Carex annectens	Grass-like	[2,3]4	FACW+	Yes	Plants, Seed
Seedbox	Ludwigia x lacustris	Annual	[1,2],3	OBL	Yes	Plants, Seed
Senna, Maryland	Cassia marilandica	Legume	3,[4,5]	FAC	Saturated	Seed

Common Name	Scientific Name	Plant Type	Hydrologic Zone	Wetland Indicator	Inundation Tolerance	Commercial Availability
Sneezeweed, common	Helenium autumnale	Perennial	[2,3],4	FACW+	Yes	Seed
Solomon's-seal, small	Polygonatum biflorum	Perennial	[4,5],6	FACU	No	Plants
Spikerush, blunt	Eleocharis obtusa	Grass-like	[1,2],3	OBL	0-6″	Plants
Spikerush, creeping	Eleocharis palustris	Grass-like	[1,2],3	OBL	Seasonal	Plants,Seed
Spikerush, square-stem	Eleocharis quadrangulata	Grass-like	[1,2],3	OBL	0-1′	Plants
St. John'swort, marsh	Triadenum virginicum	Perennial	[1,2],3	OBL	Yes	Seed
Swamp-loosestrife, hairy	Decodon verticillatus	Perennial	[1,2],3	OBL	Yes	Plants
Sweetflag	Acorus americanus	Perennial	1,[2,3]	OBL	Yes	Plants, Seed
Switchgrass	Panicum virgatum	Grass	2,[3,4],5	FAC	Seasonal	Seed & Plants
Turtlehead, red	Chelone obliqua	Perennial	[1,2],3	OBL	Yes	Plants
Turtlehead, white	Chelone glabra	Perennial	[1,2],3	OBL	Yes	Plants, Seed
Vervain, blue	Verbena hastata	Perennial	[2,3]4	FACW+	Yes	Plants, Seed
Virginia/riparian wild rye	Elymus virginicus/riparius	Grass	2,[3,4]	FACW-	Yes	Seed & Plants
Water-lily, white	Nymphaea odorata	Perennial	[1,2],3	OBL	1-3′	Plants
Water-lily, yellow (spatterdock)	Nuphars luteum	Perennial	[1,2],3	OBL	1-3′	Plants
Water-plantain	Alisma plantago-aquatica	Perennial	[2,3],4	OBL	Yes	Plants, Seed
Woolgrass	Scirpus cyperinus	Grass-like	[2,3],4	FACW	Yes	Plants, Seed

Table 7-10: Stormwater Plant List – Woody Vegetation

Common Name	Scientific Name	Form	Zone	Indicator	Inundation	Commercial Availability
Alder, brook-side	Alnus serrulata	Tree	[1,2],3	OBL	0-3"	Yes
Alder, speckled	Alnus rugosa	Tree	[2,3]	FACW+	Yes	Yes
Arrow-wood, southern	Viburnum dentatum	Shrub	[3,4],5	FAC	Seasonal	Yes
Ash, black	Fraxinus nigra	Tree	[2,3],4	FACW	Saturated	Yes
Ash, green	Fraxinus pennsylvanica	Tree	[2,3],4	FACW	Seasonal	Yes
Ash, white	Fraxinus americana	Tree	[4,5],6	FACU	No	Yes
Aspen, big-tooth	Populus grandidentata	Tree	[4,5,6]	FACU	No	Yes, limited
Aspen, quaking	Populus tremuloides	Tree	[4,5],6	FACU	Yes	Yes, limited
Azalea, dwarf	Rhododendron atlanticum	Shrub	[2,3,4],5	FAC	Yes	No
Azalea, smooth	Rhododendron arborescens	Shrub	[3,4],5	FAC	Yes	Yes
Azalea, swamp	Rhododendron viscosum	Shrub	[1,2,3],4	OBL	Seasonal	Yes
Basswood, American	Tilia americana	Tree	3,[4,5],6	FACU	No	Yes
Bayberry, northern	Myrica pennsylvanica	Shrub	[3,4],5	FAC	Seasonal	Yes
Bayberry, southern	Myrica cerifera	Shrub	2,[3,4],5	FAC	Reg.inunda	Yes
Beech, American	Fagus grandifolia	Tree	[4,5],6	FACU	No	Yes
Birch, gray	Betula populifolia	Tree	[3,4],5	FAC	Seasonal	Yes
Birch, river	Betula nigra	Tree	[2,3],4	FACW	Seasonal	Yes
Birch, yellow	Betula lutea	Tree	[3,4],5	FAC	Yes	No
Black gum, swamp tupelo	Nyssa sylvatica	Tree	1,[2,3]	FACW+	Seasonal	Yes
Black-haw	Viburnum prunifolium	Shrub	[3,4,5],6	FACU	Yes	Yes
Blueberry, bog	Vaccinium uliginosum	Shrub	2,3,4,5,6	FACU+	Yes	No
Blueberry, highbush	Vaccinium corymbosum	Shrub	[2,3]	FACW-	Seasonal	Yes
Blueberry, lowbush	Vaccinium angustifolium	Shrub	3,[4,5,6]	FACU-	No	Yes
Box-elder	Acer negundo	Tree	2,[3,4]	FAC+	Seasonal	Yes
Butternut	Juglans cinerea	Tree	[3,4,5,6]	FACU+	Yes	Yes
Buttonbush, common	Cephalanthus occidentalis	Shrub	[1,2],3	OBL	0-3'	Yes
Cedar, atlantic white	Chamaecyparis thyoides	Tree	[1,2],3	OBL	Saturated	Yes
Cedar, eastern red	Juniperus virginiana	Shrub	4,5,6	FACU	No	Yes
Cedar, northern wh1te	Thuja occidentalis	Tree	[2,3],4	FACW	Seasonal	Yes
Cherry, black	Prunus serotina	Tree	[4,5],6	FACU	No	Yes
Cherry, choke	Prunus virginiana	Tree	4,5,6	FACU	Yes	Yes
Cotton-wood, eastern	Populus deltoides	Tree	[3,4],5	FAC	Seasonal	Yes
Dangle-berry	Gaylussacia frondosa	Shrub	2,[3,4],5	FAC	Yes	Yes, limited

Common Name	Scientific Name	Form	Zone	Indicator	Inundation	Commercial Availability
Dog-hobble, coastal	Leucothoe axillaris	Shrub	[2,3,4],5	FACW+	Yes	Yes, limited
Dogwood, flowering	Cornus florida	Shrub-Tree	4,5,6	FACU-	No	Yes
Dogwood, gray	Cornus racemosa	Shrub	[3,4],5	UPL	Seasonal	Yes
Dogwood, redtwig	Cornus serecia	Shrub	1,2[3,4],5	FACW+	Yes	Yes
Dogwood, silky	Cornus amomum	Shrub	[2,3],4	FACW	Seasonal	Yes
Elm, slippery	Ulmus rubra	Tree	[3,4],5	FAC	Yes	Yes
Fetterbush	Leucothoe racemosa	Shrub	3,[4,5],6	FACW	Yes	Yes, limited
Fetter-bush	Lyonia lucida	Shrub	[2,3,4],5	FACW	Yes	Yes, limited
Germander, American	Teucrium canadense	Shrub	[2,3,4],5	FACW	Yes	No
Groundsel tree	Baccheris halimifolia	Shrub	[2,3],4	FACW	0-6"	Yes
Gum, sweet	Liquidambar styraciflua	Tree	[3,4],5	FAC	Yes	Yes
Hackberry, common	Celtis occidentalis	Shrub-Tree	4,5,6	FACU	Seasonal	Yes
Hawthorn, cockspur	Crataegus crus-galli	Tree	2,[3,4,5],6	FACU	Yes	No
Hawthorn, downy	Crataegus mollis	Tree	1,2,[3,4,5]	FACU	Yes	Yes, limited
Hawthorn, parsley	Crataegus marshallii	Tree	[1,2,3,4],5,	FACU+	Yes	Yes, limited
Hazel-nut, American	Corylus americana	Shrub	3,[4,5,6]	FACU-	No	Yes
Hazel-nut, beaked	Corylus cornuta	Shrub	3,[4,5,6]	FACU-	No	No
Hemlock, eastern	Tsuga canadensis	Tree	4,5,6	FACU	No	Yes
Hickory, big shellbark	Carya laciniosa	Tree	[3,4],5	FAC	Yes	Yes
Hickory, bitter-nut	Carya cordiformis	Tree	4,[5,6]	FACU+	No	Yes
Hickory, pecan	Carya illinoensis	Tree	[4,5],6	FACU	Yes	Yes
Hickory, red	Carya ovalis	Tree	4,[5,6]	FACU-	No	No
Hickory, shag-bark	Carya ovata	Tree	4,[5,6]	FACU-	Yes	Yes
Hickory, sweet pignut	Carya glabra	Tree	[4,5],6	FACU-	No	No
Holly, American	Ilex opaca	Shrub	4,5,6	FACU	Limited	Yes
Holly, deciduous	Ilex decidua	Shrub	1,[2,3,4,5]	FACW-, FACW	Seasonal	Yes
Hop-hornbeam, eastern	Ostrya virginiana	Shrub-Tree	[3,4,5,6]	FACU-	Seasonal	Yes
Hornbeam, American	Carpinus caroliniana	Tree	[3,4],5	FAC	Some	Yes
Huckleberry, black	Gaylussacia baccata	Shrub	3,[4,5],6	FACU	No	No
Huckleberry, dwarf	Gaylussacia dumosa	Shrub	2,[3,4],5	FAC	Yes	No
Hydrangea, wild	Hydrangea arborescens	Shrub	3,[4,5,6]	UPL, FACU	No	No
Inkberry	Ilex glabra	Shrub	[2,3],4	FACW-	Seasonal	Yes
Laurel, mountain	Kairnia latifolia	Shrub	4,5,6	FACU	No	Yes
Locust, black	Robinia pseudoacacia	Tree	4,[5,6]	FACU	Yes	Yes
Magnolia, sweet bay	Magnolia virginiana	Tree	[3,4],5	FAC	Yes	Yes
Maleberry	Lyonia ligustrina	Shrub	[2,3,4],5	FACW	Yes	Yes, limited
Maple, mountain	Acer spicaturn	Tree	4,5,6	FACU	No	No
Maple, red	Acer rubrurn	Tree	[3,4],5	FAC	Seasonal	Yes
Maple, silver	Acer saccharinum	Tree	[2,3],4	FACW	Seasonal	Yes

Common Name	Scientific Name	Form	Zone	Indicator	Inundation	Commercial Availability
Maple, striped	Acer pensylvanicum	Shrub-Tree	3,[4,5,6]	FACU	No	No
Marsh elder	Iva frutescens	Shrub	1,[2,3]	FACW+		Yes
Meadow-sweet, broad-leaf	Spiraea latifolia	Shrub	[2,3,4]	FACW+	Yes	Yes
Meadow-sweet, narrow-leaf	Spiraea alba	Shrub	[1,2,3,4],5	FACW+	Yes	No
Nannyberry	Vi burn urn lentago	Shrub	[3,4],5	FAC	Seasonal	Yes
Ninebark, eastern	Physocarpus opulifolius	Shrub	[2,3],4	FACW-	Yes	Yes
Oak, bur	Quercus rnacrocarpa	Tree	3,[4,5],6	FAC-	Yes	Yes
Oak, chestnut	Quercus prinus	Tree	4,5,6	FACU	No	Yes
Oak, chinkapin	Quercus rnuhlenbergii	Tree	[3,4],5	FAC	Yes	Yes
Oak, overcup	Quercus lyrata	Tree	[1,2],3	OBL	Yes	Yes
Oak, pin	Quercus palustris	Tree	[2,3],4	FACW	Seasonal	Yes
Oak, post	Quercus stellata	Tree	3,[4,5,6]	NI	No	Yes, limited
Oak, red	Quercus rubra	Tree	6	FACU-	No	Yes
Oak, scarlet	Quercus coccinea	Tree	6		No	Yes
Oak, shumard	Quercus shumardii	Tree	2,[3,4]	FAC+	Yes	Yes
Oak, swamp chestnut	Quercus michauxii	Tree	1,[2,3,4,5]	FACW	Yes	Yes
Oak, swamp white	Quercus bicolor	Tree	1,[2,3]	FACW+	Seasonal	Yes
Oak, water	Quercus nigra	Tree	[3,4],5	FAC	Seasonal	Yes
Oak, white	Quercus alba	Tree	[4,5,6]	FACU	Yes	Yes
Oak, willow	Quercus phellos	Tree	2,[3,4]	FAC+	Seasonal	Yes
Pepper-bush, sweet	Clethra alnifolia	Shrub	2[3,4]	FAC+	Seasonal	Yes
Pine, eastern white	Pinus strobus	Tree	4,5,6	FACU	No	Yes
Pine, loblolly	Pinus taeda	Tree	3,[4,5],6	FAC-	Seasonal	Yes
Pine, pitch	Pinus rigida	Tree	4,5,6	FACU	Seasonal	Yes
Pine, pond	Pinus serotina	Tree	[1,2],3	OBL	Yes	No
Pine, virginia	Pinus viginiana	Tree	6		No	Yes
Redbud, eastern	Cercis canadensis	Shrub-Tree	3[4,5,6]	UPL, FACU	No	Yes
Rh000dendron, rosebay	Rhododendron maximum	Shrub	[3,4],5	FAC	Yes	No
Rhododendron	Rhododendron canadense	Shrub	1,[2,3,4],5	FACW	Yes	Yes, limited
Rose, pasture	Rosa carolina	Shrub	[5,6]	NI	No	Yes
Rose, swamp	Rosa palustris	Shrub	[2,3]4	OBL	Yes	Yes
Rose, virginia	Rosa virginiana	Shrub	[3,4]5	FAC	Seasonal	Yes
Rosemary, bog	Andromeda polifolia	Shrub	[1,2],3	OBL	Yes	No
Sand-myrtle	Leiophyllum buxifolium	Shrub	3,4[5,6]	FACU-	No	No
Sassafras	Sassafras albidum	Tree	3,[4,5,6]	FACU-	No	Yes
Service-berry, downy	Amelanchier arborea	Shrub-Tree	2,[3,4,5]	FAC-	Yes	Yes
Sheep-laurel	Kalmia angustifolia	Shrub	3,[4,5],6	FAC	Yes	Yes

Common Name	Scientific Name	Form	Zone	Indicator	Inundation	Commercial Availability
Silver-berry, American	Elaeagnus commutata	Shrub	[6]	NI	No	No
Stagger-bush, piedmont	Lyonia mariana	Shrub	[3,4],5,6	FAC-	Yes	Yes, limited
Steeple-bush	Spiraea tomentosa	Shrub	1,[2,3,4],5	FACW	Yes	Yes
Strawberry-bush, American	Euonymus americanus	Shrub	1,[2,3,4,5]	FAC	Yes	Yes
Sugar-berry	Celtis laevigata	Shrub	1,[2,3,4,5],6	FACW	Yes	Yes
Sycamore, amer1can	Platanus occidentalis	Tree	[2,3],4	FACW-	Saturated	Yes
Teaberry	Gaultheria procumbens	Shrub	3,[4,5],6	FACU	No	Yes
Tree, tulip	Liriodendron tulipifera	Tree	[4,5],6	FACU	Yes	Yes
Viburnum, maple-leaf	Viburnum acerifolium	Shrub	3,[4,5,6]	NI	No	Yes
Viburnum, possum-haw	Viburnum nudum	Shrub	[1,2],3	OBL	Yes	Yes
Willow, black	Salix nigra	Tree	[2,3]	FACWI-	Seasonal	Yes
Willow, pussy	Salix discolor	Shrub	[2,3],4	FACW	Yes	Yes
Willow, silky	Salix sericea	Shrub	[1,2],3	OBL	Yes	Yes
Willow, tall prairie	Salix humilis	Shrub	3,[4,5],6	FACU	No	No
Willow, virginia	Itea virginica	Shrub	[1,2],3	OBL	0-6~	Yes
Winterberry, common	Ilex verticillata	Shrub	1,[2,3]	FACW+	Seasonal	Yes
Witch-alder, dwarf	Fothergilla gardenii	Shrub	1,[2,3,4],5	FACW	Yes	Yes
Witch-hazel, American	Hamamelis virginiana	Shrub-Tree	3,[4,5],6	FAC-	No	Yes
Withe-rod	Viburnum cassinoides	Shrub	1,[2,3,4],5	FACW	Yes	Yes
Yew, American	Taxus canadensis	Shrub	[3,4,5],6	FAC	Yes	Yes

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9.7 Small-Scale Bioretention Systems

Small-scale bioretention systems are stormwater management facilities used to address the stormwater quality and quantity impacts of land development. The system consists of a soil bed planted with vegetation; it can be underdrained, or runoff can infiltrate into the subsoil. Pollutants are treated through the processes of settling, plus uptake and filtration by the vegetation. Pollutants are also treated within the soil bed through infiltration. The total suspended solids (TSS) removal rate is 80 - 90%; this rate will depend on the depth of the soil bed and the type of vegetation selected.

N.J.A.C. 7:8 Stormwater Management Rules – Applicable Design and Performance Standards		
	Green Infrastructure	Yes
	Stormwater Runoff Quantity	Yes, when designed as an on-line system
GR	Groundwater Recharge	Yes, for systems designed to infiltrate into the subsoil
%	Stormwater Runoff Quality	80 - 90% TSS Removal, depending on vegetation selection and depth of the soil bed

Water Quality Mechanisms and Corresponding Criteria	
Settling	
Minimum Storage Volume	Entire Water Quality Design Storm Volume
Vegetative Uptake and Filtration	
Minimum Density of Vegetation	85%
Appropriate Species Selection	See Page 5 and *Chapter 7: Landscaping*
Depth of Soil Bed	1.5 - 2 feet, See Page 5
Infiltration	
Maximum Contributory Drainage Area	2.5 acres
Maximum Design Storm Drain Time	72 hours, Using Slowest Design Permeability Rate
Permeability Rate Factor of Safety	2
Minimum Subsoil Design Permeability Rate	0.5 inches/hour, tested in accordance with *Chapter 12: Soil Testing Criteria*

Introduction

Small-scale bioretention systems are vegetated stormwater management facilities that are used to remove a wide range of pollutants from land development sites; these pollutants include suspended solids, nutrients, metals, hydrocarbons and bacteria. Stormwater runoff entering the system is filtered through the soil bed before discharging downstream through an underdrain or infiltrating into the subsoil. Vegetation in the soil bed provides uptake of pollutants and runoff, and the root system helps maintain the infiltration rate in the soil bed. Small-scale bioretention systems may also be used to reduce peak runoff rates when designed as a multi-stage, multi-function facility.

In small-scale bioretention systems designed to infiltrate into the subsoil, the rate of infiltration is affected by the permeability of the subsoil, the distance separating the system bottom from the seasonal high water table (SHWT) and the area of the system bottom. While loss of subsoil permeability through soil compaction is a concern, transport of dissolved pollutants by highly permeable subsoils is of equal concern. Therefore, due to the potential for groundwater contamination, the use of small-scale bioretention systems designed to infiltrate into the subsoil is prohibited in areas where high pollutant or sediment loading is anticipated. For more information regarding stormwater runoff that may not be infiltrated, refer to N.J.A.C. 7:8-5.4(b)3. However, this prohibition is limited only to areas onsite where this type of loading is expected; runoff from areas onsite that are grade-separated may be collected in bioretention systems designed to infiltrate into the subsoil provided that the location of the bioretention system is not inconsistent with an NJDEP-approved remedial action work plan or landfill closure plan.

Small-scale bioretention systems designed to infiltrate into the subsoil may not be used where their installation would create a significant risk of adverse hydraulic impacts. These impacts may include exacerbating a naturally or seasonally high water table so as to cause surficial ponding, flooding of basements, interference with the proper operation of a subsurface sewage disposal system or other subsurface structure, or where their construction will compact the subsoil. Hydraulic impacts on the groundwater table must be assessed in accordance with N.J.A.C. 7:8-5.2(h). Additional guidance is available in *Chapter 13: Groundwater Table Hydraulic Impact Assessments for Infiltration BMPs*.

Small-scale bioretention systems manage stormwater runoff close to its source because their small scale and versatile nature allows them to fit into the limited space near the buildings or structures generating the runoff, where larger scale bioretention systems could not be used. They are used to remove a wide range of pollutants, which include suspended solids, nutrients, metals, hydrocarbons and bacteria. Additionally, they may be used to reduce the volume of runoff leaving the site. Many versions of small-scale bioretention systems exist, such as rain gardens, stormwater planters, stormwater islands, downspout planter boxes, street trenches, bioswales, enhanced and continuous tree pits or a number of other names that vary based on the shape, location and configuration of each system. Regardless of the name, small-scale bioretention systems all generally consist of a soil bed planted with vegetation, storage to temporarily detain the runoff generated by the design storm, and/or an optional outlet structure. Stormwater runoff entering the system must be evenly distributed in order to flow across the surface and then is filtered through the soil bed before discharging downstream through an underdrain system or infiltrating into the subsoil. Vegetation in the soil bed provides uptake of pollutants and runoff.

Small-scale bioretention systems function similarly to bioretention systems; however, because small-scale bioretention systems are smaller and may vary widely in shape, they are more easily incorporated into the design of sites with limited space. This flexibility allows small-scale bioretention systems to be used in various locations, including lawns, median strips, parking lot islands, and sidewalks. Because small-scale bioretention systems are intended to treat runoff close to its source, the maximum contributory inflow drainage area is 2.5 acres.

Finally, a small-scale bioretention system 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.

The following series of images depict different small-scale bioretention systems and highlight some of the features of those systems. These images are for illustrative purposes only. In urban settings, small-scale bioretention systems may look like small gardens situated on a portion of a lot, such as the small-scale bioretention systems, called rain gardens, shown in the following two photographs:

Alternatively, such systems may be constructed within a sidewalk or along a roadway, like those depicted in the following two photographs, which may be referred to as stormwater planters or rain gardens:

Small-scale bioretention systems may also be used as a conveyance system such as the bioswale in the parking median shown in the photograph below.

Small-scale bioretention systems may even be contained within a wooden or concrete box, generally called planter boxes or downspout planter boxes, as shown in the following photograph:

Applications

Pursuant to N.J.A.C. 7:8-5.2(a)(2), the minimum design and performance standards for groundwater recharge, stormwater runoff quality and stormwater runoff quantity at N.J.A.C. 7:8-5.4, 5.5 and 5.6 shall be met by incorporating green infrastructure in accordance with N.J.A.C. 7:8-5.3.

Small-scale bioretention systems may be designed to convey storm events larger than the Water Quality Design Storm (WQDS); however, regardless of the design storm chosen, all small-scale biortention systems must be designed for stability and in accordance with the *Standards for Soil Erosion and Sediment Control in New Jersey*.

Only small-scale bioretention systems designed to infiltrate into the subsoil may be used to meet the groundwater recharge requirements. If designed with an underdrain, a small-scale bioretention system cannot be used to meet these requirements. For more information on computing groundwater recharge, see *Chapter 6: Groundwater Recharge.*

The depth of the soil bed and the type of vegetation determine the TSS removal rate, as shown in the table below. To merit the approved TSS removal rate of 80%, small-scale bioretention systems must be designed to treat the Water Quality Design Storm and in accordance with all of the following criteria.

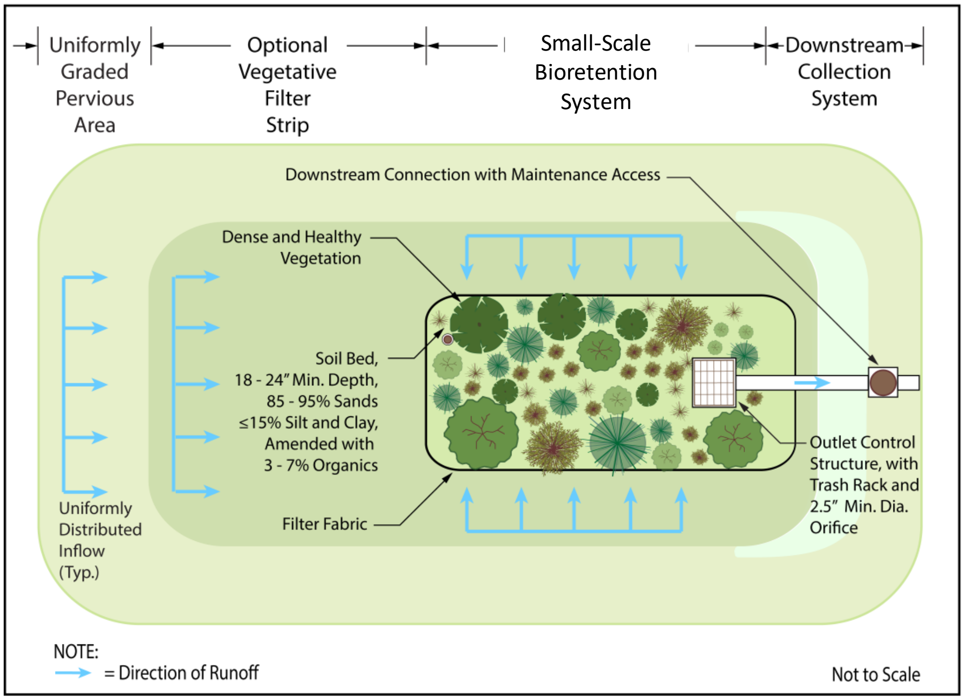
Desired TSS Removal Rate	**Design Parameters**	
	Minimum Depth of Soil Bed	**Small-scale Bioretention Vegetation**
80%	18 Inches	Terrestrial Forested Community
80%	24 inches	Site-Tolerant Grasses
90%	24 inches	Terrestrial Forested Community

Design Criteria

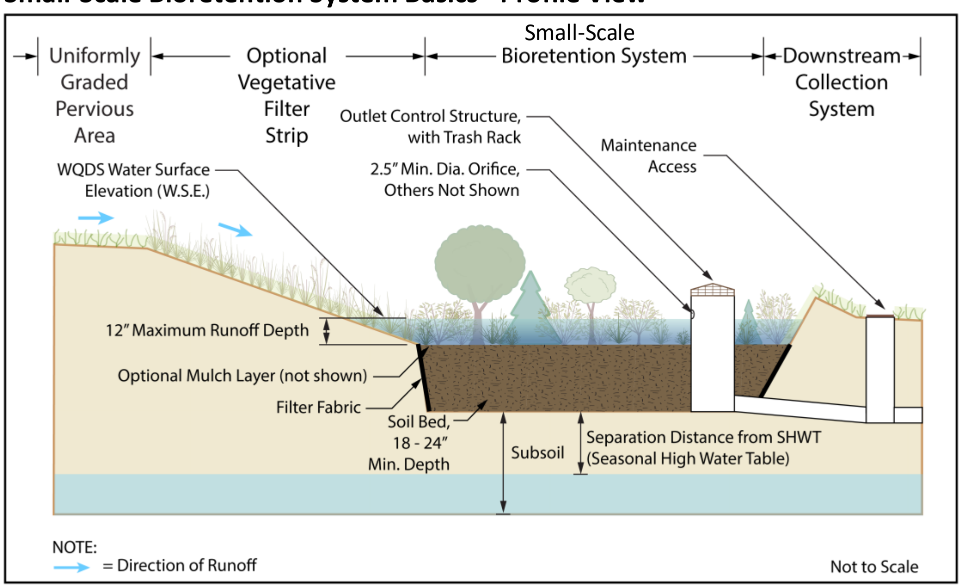
Basic Requirements

The following design criteria apply to all small-scale bioretention systems. Although the subsurface components differ, underdrained small-scale bioretention systems and those designed to infiltrate have common surface elements, which are shown below. In the following illustrations, a vegetative filter strip provides pretreatment and a downstream collection system receives runoff that does not infiltrate.

Small-Scale Bioretention System Basics - Plan View



Small-Scale Bioretention System Basics - Profile View



Additional design criteria may be found, beginning on Page 13, for a system with an underdrain and Page 17, for a system designed to infiltrate into the subsoil.

Contributory Drainage Area

- Pursuant to N.J.A.C. 7:8-5.3(b), the maximum contributory drainage area to a small-scale bioretention system is 2.5 acres.

- The entire contributory drainage area must be completely stabilized prior to use of the small-scale bioretention system.

Inflow

- All inflow must be stable and non-erosive and designed in accordance with the New Jersey Department of Agriculture's *Standards for Soil Erosion and Sediment Control in New Jersey* where applicable. A splash pad or gravel apron is recommended to prevent erosion or channelization of the soil bed.

- All inflow must be evenly distributed across the surface of the small-scale bioretention system to ensure all vegetation receives sufficient runoff during small rain events.

- For systems with multiple small-scale bioretention systems, inflow has to be distributed proportionally based on the surface area of each unit, especially when using small-scale bioretention systems in series, to ensure that each unit receives sufficient flow to support vegetation.

Storage Volume

- The system must have sufficient storage volume to contain the WQDS runoff volume without overflow.

- Small-scale bioretention systems may be constructed as either off-line or on-line systems. In off-line systems, most, or all, of the runoff from storms larger than the WQDS bypass the bioretention basin through an up-gradient diversion; this reduces the size of the required system storage volume, the system's long-term pollutant loading and associated maintenance. On-line systems receive runoff from all storm events; they provide treatment for the WQDS, and they convey the runoff from larger storms through an overflow. These on-line systems store and attenuate the larger storm events and provide runoff quantity control; in such systems, the invert of the lowest quantity control outlet is set at the water surface elevation of the WQDS.

- Small-scale bioretention systems must contain only the WQDS or smaller storm events below the first outlet control structure. See Page 13 for details pertaining to an underdrained system and Page 17 for a system designed to infiltrate.

- For the WQDS, the maximum depth of runoff is 12 inches in a flat-bottom bioretention system when designed in accordance with the other design criteria found in this chapter.

- Small-scale bioretention systems are intended to be free of standing water between storm events; therefore, the drain time for standing water present on the surface of soil bed, in the overflow structure, or in the underdrain pipe system must not exceed 72 hours after any rain event. Storage times in excess of 72 hours may render a small-scale bioretention system ineffective and may result in anaerobic conditions, odor, and both water quality and mosquito breeding issues. If the small-scale bioretention system is installed in an area subject to pedestrian traffic, such as sidewalk or pedestrian accessible area in parking lot, the drain time should be reduced to 24 hours.

Geometry

- The maximum side slope ratio for earthen embankments is 3:1.
- The system must have a sufficient surface area to prevent stormwater runoff depths in excess of the maximum depth requirement as well as ensure that stormwater runoff is able to spread out over the entire soil bed, i.e., the system footprint.

Vegetation

- Small-scale bioretention systems are designed with varying wetness zones; therefore, vegetation must be selected and placed based on specific water requirements and tolerances.
- The distribution of trees and shrubs must be based on specific site conditions. On average, the number of stems required per acre is 1,000, with trees and shrubs spaced 12 feet and 8 feet apart, respectively.
- For more information on appropriate vegetation for small-scale bioretention systems, see *Chapter 7: Landscapin*g. A table providing bloom information for various plants typically found in a small-scale bioretention system is included in this chapter. See Page 45.

Soil Bed

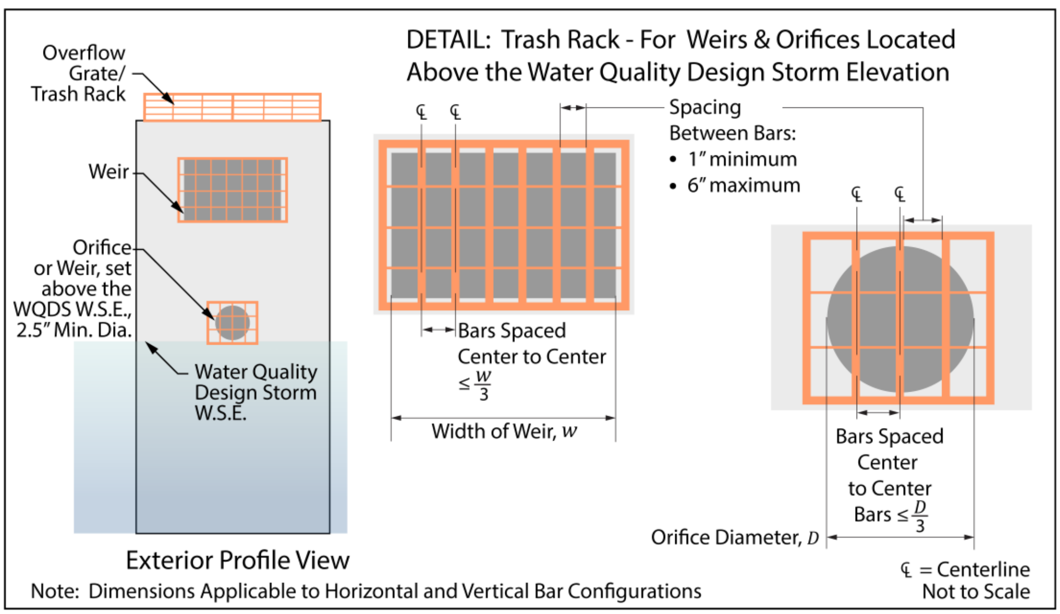
- The soil bed must be a minimum of 18 – 24 inches in depth, in accordance with the table on Page 5.
- The soil bed material must consist of the following mix, by volume: 85 to 95% sand, with no more than 25% of the sand as fine or very fine sands; no more than 15% silt and clay with 2% to 5% clay content. The entire mix must then be amended with 3 to 7% organics, by weight.
- The soil bed material shall be free of contaminants.
- Pre-mixed soil must be certified to be consistent with the requirement above by either the vendor or by a professional engineer licensed by the State of New Jersey. The content of any soil mixed on-site must be certified by a professional engineer licensed by the State of New Jersey; in addition, the engineer must be present while the soil is mixed.
- The pH of the soil bed material is recommended to range from 5.5 to 6.5.
- For the calculation of runoff retention, the porosity, the field capacity and the wilting point of the soil bed material must be obtained either from a published research article or tested in accordance with the ASTM D-6836 method or the Soil Survey Investigations Report No. 42, Kellogg Soil Survey Laboratory Methods Manual, published by NRCS.
- The soil bed material must be placed in lifts not to exceed 6 inches. Additional materials may be necessary to account for settling over time.

Safety

- All small-scale bioretention systems must be designed to safely convey overflows to downstream drainage systems. The design of any overflow structure should be sufficient to provide safe, stable discharge of stormwater in the event of an overflow. Safe and stable discharge minimizes the possibility of adverse impacts, including erosion and flooding in down-gradient areas. Therefore, discharge in the event of an overflow must be consistent with the *Standards for Off-Site Stability* found in the *Standards for Soil Erosion and Sediment Control in New Jersey*.
- Small-scale bioretention basins that are classified as dams under the NJDEP Dam Safety Standards at N.J.A.C. 7:20 must meet the overflow requirements under these regulations. Overflow capacity can be provided by a hydraulic structure, such as a weir or orifice, or a surface feature, such as a swale or open channel.

Outlet Structure

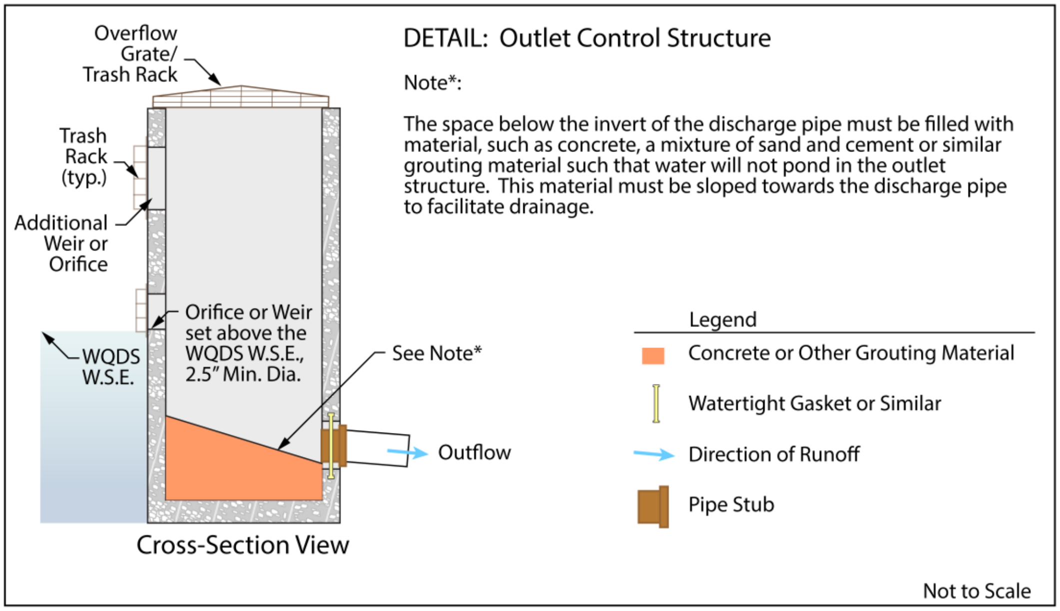
- For systems designed with an outlet structure, trash racks must be installed at the intake to the outlet structure. The outlet structure must meet the following criteria illustrated below:
  - □ Parallel bars with 1-inch spacing between the bars up to the elevation of the Water Quality Design Storm (WQDS);
  - □ Parallel bars higher than the elevation of the WQDS must be spaced no greater than one-third the width of the diameter of the orifice or one-third the width of the weir, with minimum spacing between bars of 1 inch and a maximum spacing between the bars of six inches;
  - □ The trash rack must be designed so as not to adversely affect the hydraulic performance of the outlet pipe or structure;
  - □ Constructed of rigid, durable and corrosion-resistant material; and
  - □ Designed to withstand a perpendicular live loading of 300 lbs/sf.



- An overflow grate is designed to prevent obstruction of the overflow structure. If an outlet structure has an overflow grate, the grate must comply with the following requirements:

- ▫ The overflow grate must be secured to the outlet structure but removable for emergencies and maintenance;
- ▫ The overflow grate spacing must be no greater than 2 inches across the smallest dimension; and
- ▫ The overflow grate must be constructed of rigid, durable, and corrosion resistant material and designed to withstand a perpendicular live loading of 300 lbs/sf.

- The space below the invert of the discharge pipe must be filled with material, such as concrete, a mixture of sand and cement, or similar grouting material, such that water will not pond in the outlet structure. This material must be sloped towards the discharge pipe to facilitate drainage, as shown on the next page.

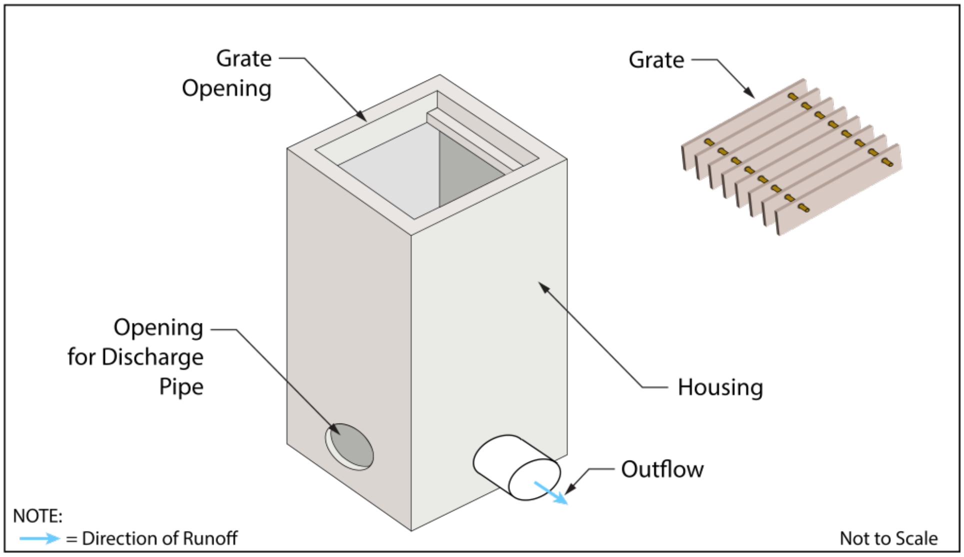


- The minimum diameter of any overflow orifice is 2.5 inches.

- Blind connections to downstream facilities are prohibited. Any connection to down-gradient stormwater management facilities must include access points such as inspections ports and manholes, for visual inspection and maintenance, as appropriate, to prevent blockage of flow and ensure operation as intended. All entrance points must adhere to all Federal, State, County and municipal safety standards such as those for confined space entry.

- For a smaller-sized small-scale bioretention system, a domed riser or drain specifically designed for soil beds or yards may be used as an outlet structure, such as, but not limited to, the square yard drain detail provided on the following page. Calculations must be included to demonstrate the selection complies with all other design criteria.

Square Yard Drain Detail



- In instances where the lowest invert in the outlet or overflow structure is below the flood hazard area design flood or tide elevation in a downstream waterway or stormwater collection system, the effects of tailwater on the hydraulic design of the underdrain and overflow systems, as well as any stormwater quantity control outlets, must be analyzed. Two methods to analyze tailwater are:

  - A simple method entails inputting flood elevations for the 2-, 10- and 100-year events as static tailwater during routing calculations for each storm event. These flood elevations are either obtained from a Department flood hazard area delineation or a FEMA flood hazard area delineation that includes the 100-year flood elevation or derived using a combination of NRCS hydrologic methodology and a standard step backwater analysis or level pool routing, where applicable. In areas where the 2- or 10-year flood elevation does not exist in a FEMA or Department delineation, it may be interpolated or extrapolated from the existing data. If this method demonstrates that the requirements of the regulations are met with the tailwater effect, then the design is acceptable. If the analysis shows that the requirements are not met with the tailwater effects, the detailed method below can be used or the BMP must be redesigned.
  - A detailed method entails the calculation of hydrographs for the watercourse during the 2-, 10- and 100-year events using NRCS hydrologic methodology. These hydrographs are input into a computer program to calculate rating curves for each event. Those rating curves are then input as a dynamic tailwater during the routing calculations for each of the 2-, 10- and 100-year events. This method may be used in all circumstances; however, it may require more advanced computer programs. If this method demonstrates that the requirements of the regulations are met with the tailwater effect, then the design is acceptable. If the analysis shows that the requirements are not met with the tailwater effects, the BMP must be redesigned.

- Under no circumstances may a drain-down valve or other dewatering measure be included in the design of the small-scale bioretention system, even if it was intended to remain open or unused during normal operation.

Construction Requirements

- During clearing and grading of the site, measures must be taken to eliminate soil compaction at the location of the proposed small-scale bioretention system.

- The location of the proposed small-scale bioretention system must be cordoned off during construction to prevent compaction of the subsoil by construction equipment or stockpiles.

- Excavation and construction of a small-scale bioretention system designed to infiltrate must be performed with equipment placed outside the limits of the basin.

- The location of the proposed small-scale bioretention system should not be used to provide sediment control during construction; however, when unavoidable, the bottom of the sediment control basin should be at least 2 feet above the final design elevation of the bottom of the soil bed in the small-scale bioretention basin.

- The excavation to the final design elevation of the small-scale bioretention system bottom may only occur after all construction within its contributory drainage area is completed and the drainage area is stabilized. If construction of the small-scale bioretention system cannot be delayed, berms must be placed around the perimeter of the system during all phases of construction to divert all flows away from the bioretention system. The berms may not be removed until all construction within the drainage area is completed and the area is stabilized.

- The contributing drainage area must be completely stabilized prior to bioretention system use.

- Post-construction testing must be performed on the as-built small-scale bioretention system in accordance with the Construction and Post-Construction Oversight and Soil Permeability Testing section in *Chapter 12: Soil Testing Criteria* of this manual. To ensure that the as-built system functions as designed, post-construction testing must include a determination of the permeability rates of the soil bed and the hydraulic capacity of the underdrain, in underdrained systems, or the permeability of the subsoil, in infiltration systems. Where as-built testing results in longer drain times than designed, corrective action must be taken. The drain time is defined as the time it takes to fully infiltrate the maximum design storm runoff volume through the most hydraulically restrictive layer.

Access Requirements

- An access roadway must be included in the design to facilitate monitoring and maintenance. If the access roadway is constructed of impervious material, take note that it may be subject to the stormwater quality, quantity, and/or groundwater recharge requirements at N.J.A.C. 7:8-5.4, 5.5 and 5.6.

- Additional steps may be necessary to eliminate vehicular intrusion into the system footprint, such as from all-terrain vehicles and utility trucks.

Types of Small-Scale Bioretention Systems

Small-scale bioretention systems can be divided into two subtypes based on how runoff is discharged from the system. There are two types of small-scale bioretention systems:

1. Small-Scale Bioretention Systems with Underdrains
2. Small-Scale Bioretention Systems Designed to Infiltrate into the Subsoil

Individual Types of Small-Scale Bioretention Systems

The following section provides detailed design requirements for each type of small-scale bioretention system. The illustrations show possible configurations and flow paths and are not intended to limit the design. Additional design requirements specific to unique classes of small-scale bioretention systems are found beginning on Page 21.

Small-Scale Bioretention Systems with Underdrains

- Take note that this type of system cannot be used to infiltrate stormwater runoff into the subsoil or provide groundwater recharge. Routing calculations may not include exfiltration as a form of discharge.

- Filter fabric is required along both the sides and the bottom of the basin to prevent the migration of fine particles from the surrounding soil, if an earthen embankment is used.

- Unlike a larger bioretention basin, the soil bed of an underdrained small-scale bioretention system is not designed to drain quickly, but to retain some volume of stormwater below the surface in the soil bed; therefore, the soil mix should fall into the category of loam or silt loam in the USDA soil textural triangle, which will be most capable of retaining stormwater while still maintaining a sufficient infiltration rate. Refer to the post-construction testing requirements found on Page 13 which must confirm the constructed system functions as designed.

- The underdrain consists of three components – the sand layer, gravel layer and the network of pipes that collect stormwater runoff and transport it to the outflow section of the system.
  - The sand layer, which acts as a transition between the soil bed and the subsequent layers, must be at least 6 inches in depth and must consist of clean, medium-aggregate concrete sand (AASHTO M-6/ASTM C-33). To ensure proper system operation, the permeability rate of the sand layer must be at least twice the design permeability rate of the soil bed.
  - The gravel layer must have sufficient depth to provide at least 3 inches of gravel both above and below the pipe network and must consist of 0.5 to 1.5 inch clean, broken stone or pea gravel (AASHTO M-43). The sides of the underdrain pipes should similarly be protected by the same gravel. To ensure proper system operation, the permeability rate of the gravel layer must be at least twice the design permeability rate of the sand layer.
  - If the small-scale bioretention system with underdrain does not have an earthen bottom, .e.g. a wood box or a concrete slab, the 3 inch gravel layer below the underdrain pipe network is not required.

- □ Within the gravel layer, the network of pipes, excluding any manifolds and cleanouts, should be perforated. All remaining pipes should be non-perforated. To ensure proper system operation, the network of pipes should have a conveyance rate at least twice as fast as the design flow rate of the soil bed.
- □ Inspection ports must be located at the upstream and downstream ends of the perforated section of the network of pipes and extend above the surface of the soil bed. The inspection port exterior must be covered in such a way as to prevent the migration of material into the structure. The depth of runoff generated by the maximum design storm must be marked on all inspection ports and those levels included in the design report and maintenance plan.
- □ The overflow pipe should not be connected to the perforated portion of the underdrain pipe. However, the overflow pipe and the underdrain pipe may discharge to same conveyance system downstream of the small-scale bioretention system, provided that the overflow discharge will not backup to the perforated portion of the underdrain pipe nor affect the drainage capacity of the underdrain pipe system.
- □ Flexible corrugated perforated plastic drain pipe should not be used as underdrain pipe.

- ▪ The volume of stormwater runoff generated by the WQDS is the maximum storm to be used to calculate the area, also known as the footprint, of the bottom of the small-scale bioretention system designed with an underdrain, in conjunction with the appropriate maximum depth discussed on Page 7. The invert of the lowest discharge orifice must be set at an elevation that allows the entire volume of stormwater runoff generated by the WQDS to be filtered through the soil bed, followed by the sand layer and lastly into the underdrain pipe network. **Under no circumstances may exfiltration (infiltration into the soil below the system) be included in the routings for stormwater runoff quantity control for any small-scale bioretention system designed with an underdrain**.

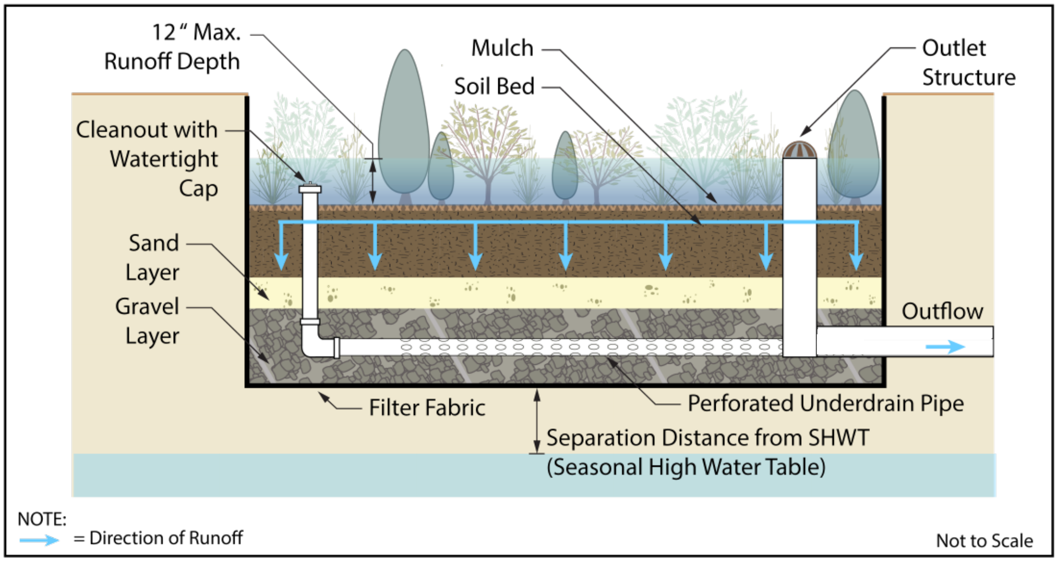
- ▪ The capacity of the underdrain must be sufficient to allow the system to drain within 72 hours, while still retaining moisture below the surface for uptake by vegetation. If the small-scale bioretention system with underdrain is installed in an area subject to pedestrian traffic, the drain time should be reduced to 24 hours.

- ▪ The seasonal high water table (SHWT) must be at least 1 foot below the bottom of the gravel layer. For small-scale bioretention systems located entirely at or above-grade and situated on impervious structures, such as those made of concrete, asphalt, or wood, this groundwater separation requirement is not applicable.

- ▪ All points of access should also be covered in such a way as to prevent sediment or other material from entering the system and to prevent the accumulation of standing water, which could lead to mosquito breeding.

The graphic below shows a configuration of a small-scale bioretention system with an underdrain. Although not labeled, the perforated underdrain pipe must have the 3 inch minimum thickness of gravel cover above and below. The outlet control structure also serves as the down-gradient inspection port. Additional maintenance access is provided at the connection to the downstream stormwater collection system.

Flat Bottom Small-Scale Bioretention System with Underdrain - Profile View



- **Volume Reduction in Small-Scale Bioretention Systems with an Underdrain**

The soil bed in a small-scale bioretention system with an underdrain will absorb and retain a portion of the runoff that is directed into it, thus reducing the volume of runoff that will reach downstream facilities. The maximum amount of water that the soil bed is capable of retaining is called the field capacity. However, in order to absorb and retain the entire field capacity, the soil bed material would need to be entirely dry at the beginning of the storm event. Since the soil bed is intended to support plant life, the soil bed material can never be completely dry or the plants would die.

The available water capacity is defined as the field capacity minus the wilting point of the plants. As such, the available water capacity is the maximum amount of water that could be retained during a storm event by a functioning small-scale bioretention system. The available water capacity is determined based upon the selected soil bed material; therefore, during design, consideration must be given to the volume reduction goals of the project. Take note the assumption that the entire available water capacity can be absorbed during each storm event assumes that the soil bed has dried to the wilting point of the plants between each storm event. Since this is unlikely to occur, a factor of safety should be applied to the available water capacity to account for the moisture above the wilting point that has been retained from the previous storm events.

Unlike the soil bed, the gravel layer does not directly support plant life and is intended to dry out entirely; therefore, the field capacity of the gravel layer is equal to the volume reduction it provides. While the gravel layer is intended to dry out completely between storm events, there is no guarantee that it will do so; therefore, a factor of safety should also be applied to the field capacity of the gravel layer.

A table providing the soil bed parameters discussed above for small-scale bioretention systems designed with an underdrain is found on the following page. This information is incorporated into the examples found on Pages 23 through 40.

Soil Parameters for Small-Scale Bioretention Systems Designed with an Underdrain

Soil Type	Total Porosity (cf/cf)	Field Capacity (cf/cf)	Wilting Point (cf/cf)	Available Water Capacity (cf/cf)	Effective Porosity (cf/cf)
Sand	0.437	0.062	0.024	0.038	0.375
Loamy Sand	0.437	0.105	0.047	0.058	0.332
Sandy Loam	0.453	0.190	0.085	0.105	0.263
Loam	0.463	0.232	0.116	0.116	0.231
Silt Loam	0.501	0.284	0.135	0.149	0.217
Sandy Clay Loam	0.398	0.244	0.136	0.108	0.154
Clay Loam	0.464	0.310	0.187	0.123	0.154
Silty Clay Loam	0.471	0.342	0.210	0.132	0.129
Sandy Clay	0.430	0.321	0.221	0.100	0.109
Silty Clay	0.479	0.371	0.251	0.120	0.108
Clay	0.475	0.378	0.265	0.113	0.097

Small-Scale Bioretention Systems Designed to Infiltrate into the Subsoil

- Exfiltration can be used in the design of a small-scale bioretention system designed to infiltrate, provided all of the conditions regarding the use of exfiltration in stormwater runoff calculations, as published in *Chapter 5: Stormwater Management Quantity and Quality Standards and Computations* are met. This information is published in the section beginning on Page 7 of *Chapter 5*, entitled "*Conditions Regarding the Use of Exfiltration in Stormwater Runoff Calculations*."

Pretreatment is a requirement for small-scale bioretention systems designed to infiltrate into the subsoil that include exfiltration in the stormwater routing calculations for the 2-, 10- and 100-year design storms.

- Pretreatment may consist of a forebay or any of the 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 may be earthen, constructed of riprap, or made of concrete and 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 WQDS and be sized to hold the sediment volume expected between clean-outs.
  - The forebay 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.

- For systems with inflow that is in the form of sheet or overland flow, a five foot wide gravel or stone filter strip, with a slope of no greater than 10 percent, can be substituted for the required pretreatment when exfiltration is used in the routing calculations.

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

- Any roof runoff that discharges to the bioretention system 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.*

  - The 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.

The following design standards apply to small-scale bioretention systems designed to infiltrate:

- The bottom of a small-scale bioretention system must be as level as possible in order to allow runoff to uniformly infiltrate into the subsoil.

- Like larger bioretention basin, the soil bed of a small-scale bioretention system designed to infiltrate into the subsoil is designed to drain quickly while still supporting plant life; therefore, the soil mix should fall into the category of loamy sand in the USDA soil textural triangle, which will be most capable of supporting plant life while still maintaining a high infiltration rate.

- The following permeability requirements apply:

  - The permeability of the subsoil must be sufficient to allow the system to drain within 72 hours; however, if the small-scale bioretention system is installed in an area subject to pedestrian traffic, the drain time should be reduced to 24 hours.
  - Soil tests are required at the exact location of the proposed basin in order to confirm its ability to function as designed. Take note that permits may be required for soil testing in regulated areas, such as areas regulated under the Flood Hazard Area Control Act Rules (N.J.A.C. 7:13), the Freshwater Wetlands Protection Act Rules (N.J.A.C. 7:7A), the Coastal Zone Management Rules (N.J.A.C. 7:7), and the Highlands Water Protection and Planning Rules (N.J.A.C. 7:38).
  - The testing of all permeability rates must be consistent with *Chapter 12: Soil Testing Criteria* in this manual, including the required information to be included in the soil logs, which can be found in section *2.b Soil Logs*. In accordance with *Chapter 12*, the slowest tested hydraulic conductivity must be used for design purposes.
  - Since the actual permeability rate may vary from soil testing results and may decrease over time, a factor of safety of 2 must be applied to the slowest tested permeability rate to determine the design permeability rate. The design permeability rate would then be used to compute the system's drain time for the maximum design volume. The drain time is defined as the time it takes to fully infiltrate the maximum design storm runoff volume through the most hydraulically restrictive layer.
  - The maximum design permeability rate is 10 inches/hour for any tested permeability rate of 20 inches/hour or more.
  - The minimum design permeability rate of the subsoil is 0.5 inches/hour, which equates to a minimum tested permeability rate of 1.0 inch/hour.

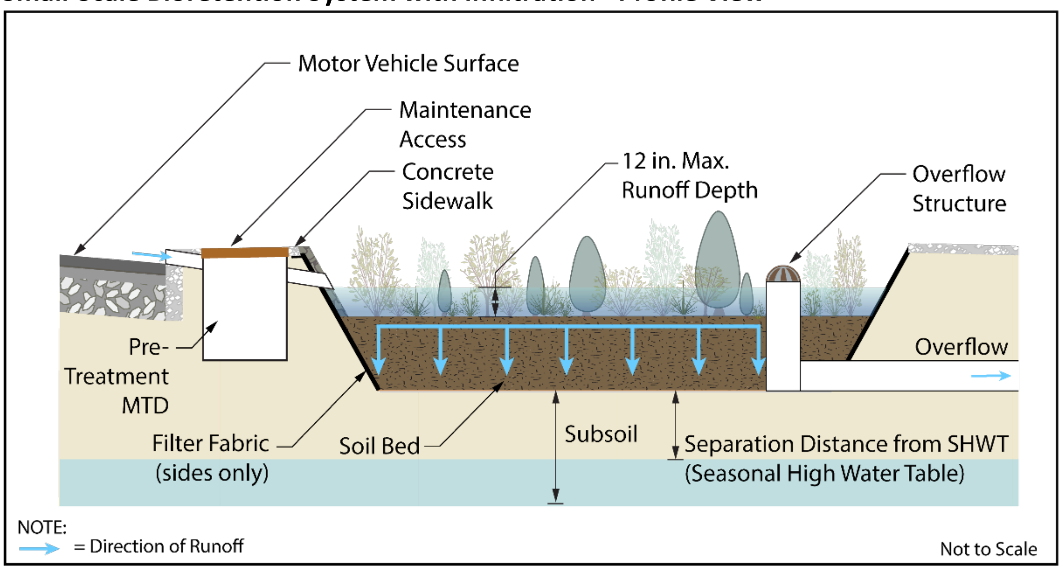
- Filter fabric is required along the sides of the soil bed to prevent the migration of fine particles from the surrounding soil if the small-scale bioretention system is located below grade and is not contained within a structure. However, unlike systems with underdrains, filter fabric may not be used along the bottom of the soil bed because it may result in a loss of permeability.

- As with any infiltration BMP, groundwater mounding impacts must be assessed, as required by N.J.A.C. 7:8-5.2(h). This includes an analysis of the reduction in permeability rate when groundwater mounding is present.

- □ Additional trials may be required, including using a reduced recharge rate in accordance with the method published in *Chapter 5*, should the calculations demonstrate an adverse impact is produced. Refer to the information labeled "Steps to Follow When an Adverse Impact is Encountered" found on Page 53 of *Chapter 5*.
- □ Where the mounding analysis identifies adverse impacts, the small-scale bioretention system must be redesigned or relocated, as appropriate. The mounding analysis must provide details and supporting documentation on the methods used and assumptions made, including values used in calculations. For further information on the required groundwater mounding assessment, *see Chapter 13: Groundwater Table Hydraulic Impact Assessments for Infiltration BMPs*.

The illustration below shows a small-scale bioretention system designed as a rain garden to infiltrate into the subsoil. Note that an MTD is used for pretreatment so that exfiltration may be used in the stormwater routing calculations.

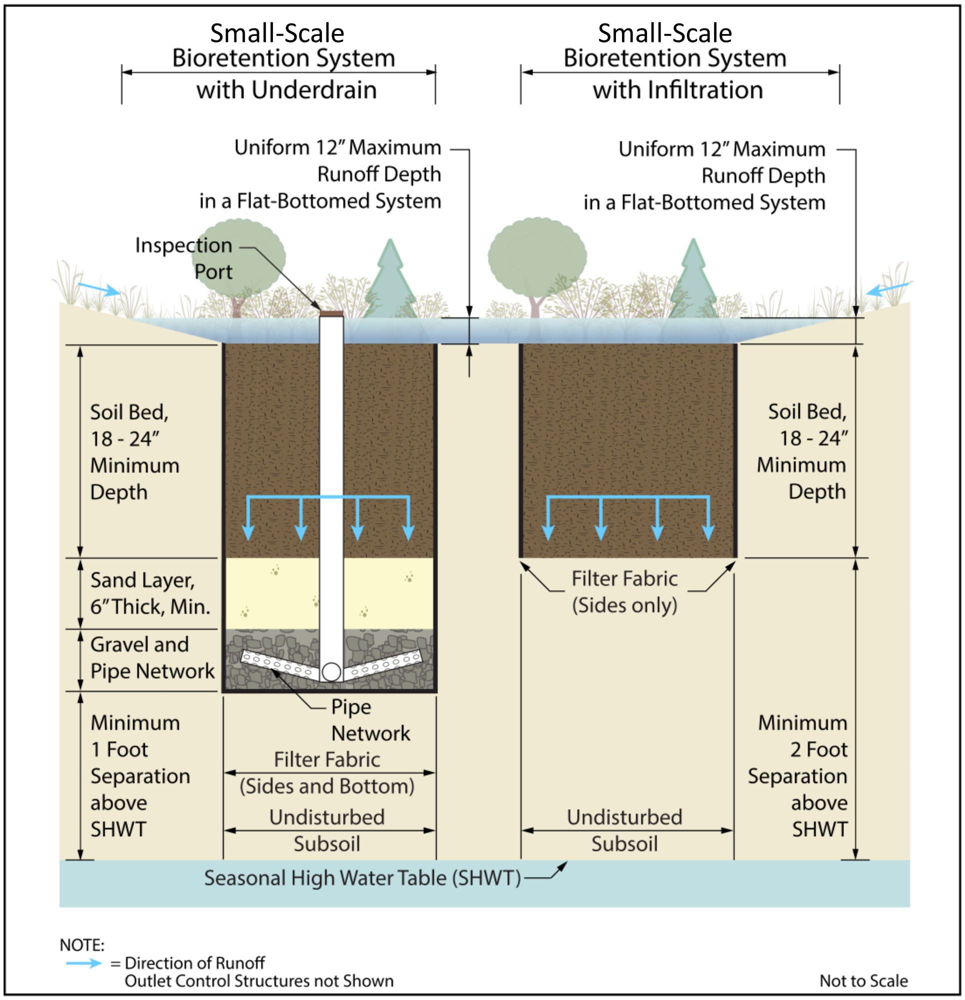
Small-Scale Bioretention System with Infiltration - Profile View



A Side by Side Comparison of the Two Types of Small-Scale Bioretention Systems

The following illustration shows the differences between the basic components of a small-scale bioretention system with an underdrain and one designed to infiltrate.

Cross Section Views – A Comparison of the Two Types of Small-Scale Bioretention Systems



Specific Design Requirements for Different Classes of Small-Scale Bioretention Systems

In addition to the design requirements listed below, the designer may wish to incorporate or otherwise address the additional items and recommendations listed in the Considerations section, which begins on Page 41.

Aboveground Planter Box (Raised Planter Box or Downspout Planter Box)

- The downspout must have flow diversion mechanism to allow roof runoff from storms larger than the design storm to bypass the planter box.

- Overflow from the planter box must not cause surface flooding. The ground surface around the planter box must be properly graded to direct flow to a nearby stormwater collection system, lawn area, grass swale or other drainage facility.

- The voids occurring between the granular components of a planter box can be included in the total storage volume of the system, as follows:
  - those located in the soil bed above the subsoil for small-scale bioretention systems designed to infiltrate into the subsoil, or
  - those in the soil bed, sand and gravel layers in small-scale bioretention systems with underdrains.

- The effective porosity shall be used to approximate the voids in the soil layers available to store runoff.
  - The effective porosity is the total porosity subtracted by the field capacity. Field capacity is discussed under volume reduction, beginning on Page 15.
  - The percentage of voids in the gravel layer is dependent on the exact gravel specification and can be looked up in a reference document. Typically, No. 2 aggregate is used, which has a void percentage of approximately 40%.

Bioretention Swale

- In sloped-bottom systems, the maximum longitudinal slope is 10%.

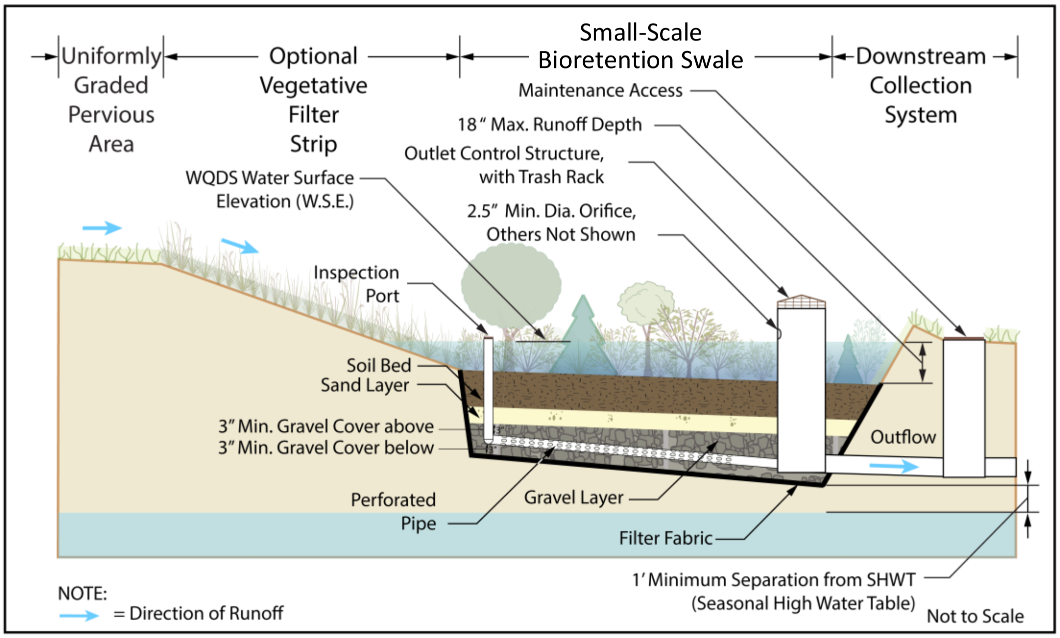
- If the inlet to a bioretention swale consists of a trench cut across a sidewalk, the trench must be covered by a heavy duty grate or solid cover to ensure pedestrian safety. The cover must be removable to allow maintenance of the trench.

- If the inflow to a bioretention swale consists of a curb-cut, depressed curb or other type of inlet to intercept and collect runoff directly from the street or parking lot surface, provisions must be included in the design to ensure that runoff does not pond around the inlet in such a manner that could be hazardous to vehicular and pedestrian traffic.

- For the WQDS, the maximum depth of runoff is 18 inches at the down-gradient end of a sloped-bottom system, when designed in accordance with the other design criteria found in this chapter.

- The graphic below shows a configuration of a small-scale bioretention swale with an underdrain. Note that the system has a sloped bottom. The perforated underdrain pipe must have the 3 inch minimum thickness of gravel cover above and below. The outlet control structure also serves as the down-gradient inspection port. Additional maintenance access is provided at the connection to the downstream stormwater collection system.

Sloped-Bottom Small-Scale Bioretention Swale with Underdrain - Profile View



Stormwater Tree Pit

- A stormwater tree pit is more than a tree pit that is normally constructed on sidewalk for landscaping purposes. A stormwater tree pit must have a soil bed, as described on Page 5. Since the soil bed must support the growth of the tree, the minimum depth of 18 inches may not be sufficient. A gravel-filled storage bed for storing stormwater may also be included. Furthermore, a curb-cut, or other means, is necessary to direct street runoff into the stormwater tree pit.

- Like any other small-scale bioretention system discussed in this chapter, a stormwater tree pit may be designed to infiltrate runoff from storms less than or equal to the Water Quality Design Storm into the subsoil or to be drained through an underdrain system. Volume reduction resulting from a stormwater tree pit must be calculated as indicated in the appropriate section above, depending on whether it is designed with or without an underdrain.

- The inlet must be designed in such a manner that runoff does not pond as this would create a hazardous situation for vehicular or pedestrian traffic.

Designing a Small-Scale Bioretention System

The following examples show how to design various small-scale bioretention systems to treat the runoff generated by the Water Quality Design Storm (WQDS). The examples below represent some of the many possible ways to configure these systems and are not intended to limit the design.

Example 1: **Aboveground Planter Boxes (Downspout Planter Boxes) for Treating Roof Runoff**

An existing building is to be replaced with a garage with rooftop parking spaces. The building is part of a major development that has more than both an acre of disturbance and a quarter acre increase of motor vehicle surface. The project is located in an urban redevelopment area that has Hydrologic Soil Group D; therefore, a traditional BMP that infiltrates runoff into the subsoil would not be feasible. Because the building is in an urban area, the aesthetic appearance of the stormwater BMP is also one of the design concerns. Under these circumstances, an aboveground planter box system with underdrain is to be designed to receive stormwater runoff from the WQDS falling on the roof. Large storms will be bypassed and directed to other downstream BMPs, along with stormwater runoff generated by the access ramp and driveway.

Runoff from the parking deck will be collected by a roof drain and directed via a downspout to the planter boxes. Treated runoff will be conveyed to an underground drainage pipe to an existing stormwater collection system. The following parameters apply:

Each Inflow Drainage Area = 7,650 sf
Four (4) downspouts convey runoff to the planter boxes

Step 1: Runoff Calculations

Using the NRCS method described in *National Engineering Handbook, Part 630 (NEH)* and discussed in *Chapter 5: Stormwater Runoff Water Quantity Standards and Computations*, the volume of runoff produced by the WQDS was calculated to be 660 cf, based upon an NRCS Curve Number (CN) of 98 for impervious surfaces.

Step 2: Sizing of the Planter Boxes

a. General Capacity Calculation

Soil Bed Depth =	18 in (21.7% effective porosity for silt loam)
Assumed Design Permeability of Soil bed	1 in/hr
Sand layer =	6 in (37.5% effective porosity)
Gravel layer =	12 in (40% effective porosity)

The depth of runoff above the surface of the soil bed is 12 in. Each planter box is designed to be of uniform length and 5 ft wide. The storage volume provided by a planter box measuring internally 1 ft in length is calculated as follows:

Storage Layer	Depth (ft)	Width (ft)	Volume (cf)	Effective Volume (Effective Porosity x Volume) (cf)
Surface	1	5	5.0	100% x 5.0 = 5.0
Soil Bed	1.5	5	7.5	21.7% x 7.5 = 1.62
Sand	0.5	5	2.5	37.5% x 2.5 = 0.94
Gravel	1.0	5	5.0	40% x 5.0 = 2
Effective Volume for 1-foot long Planter Box =				**9.56 cf**

The required total length, L, of planter boxes, measured in ft, required to provide sufficient storage volume is calculated as:

$$(9.56\ x\ L)\ cf \geq 660\ cf$$, which simplifies to L = 69.03 ft

Instead of one long box, a total of 12 planter boxes, each 6 ft in internal length would meet our needs. Each downspout will direct runoff to 3 planter boxes.

b. Calculate the Conveyance Rate of the Underdrain Pipe and Infiltration Rate of each Layer

The underdrain pipe and the perforations must have at least twice the conveyance rate as the infiltration based on the design permeability rate of the sand layer, which is also twice the permeability rate of the soil bed (1 in/hr in this example). Therefore, calculations for the hydraulic capacity of the underdrain must be at least the 4 times of the infiltration rate provided by the soil bed (1 in/hr).

c. Design of the Connection Orifice and Pipe between the Planter Boxes

Roof-generated runoff flows into each box through a distribution manifold, which must be designed to evenly distribute runoff throughout all of the planter boxes. Runoff that cannot be infiltrated through the soil bed will fill up the storage space above the soil bed. The water depth above the soil bed should not exceed the maximum design depth of 12 inches, so an optional interconnecting pipe is used in this example to prevent overtopping of an individual unit during the maximum design storm. For the purposes of this example, assume a hydraulic analysis of the pipe was performed to ensure the passage of runoff will not overflow the tops of the planter boxes until the maximum design storm is exceeded.

Step 3: Check the surface water drain time

The soil bed permeability rate is 1 in/hr. The infiltration rate of the soil bed, for each planter box, is

$$\begin{matrix} Soil\ Bed \\ Infiltration\ Rate \end{matrix} = 6\ ft\ x\ 5\ ft\ x\ \frac{1\ in/hr}{(12\ \ in/ft)} = 2.5\text{ cf/hr, and}$$

the drain time for the system of 12 planter boxes is calculated as shown on the following page:

$$Drain\ Time = \frac{659\ cf}{(12\ boxes\ x\ 2.5\ cf/hr)} = 21.97\text{ hr}$$

Note that the calculated drain time is less than the 24-hour maximum for public areas exposed to pedestrian and driving traffic.

Step 4: Planting Plan

The plants to be considered need to tolerate inundation and grow perennially. The list below shows examples of native New Jersey plants that should be considered. A mix of the plants to prolong the period of bloom should be considered for aesthetic appearance. Additional information regarding plant choice is found in the Considerations section. The plants in the table are arranged by start of the bloom period, followed by the end of the bloom period, and then alphabetically by the most common name. An example of the planting might be as follows:

Sweet Fern (*Comptonia peregrina*)
Shrub, tolerating wet or drought conditions, blooming from April to May, green year round

Red Bearberry (*Arctostaphylos uva-ursi*)
Groundcover; well-drained soil only, perimeter planting; blooms April, May, June; evergreen year round

Common Winterberry (*Ilex verticillata*)
Shrub; tolerating inundation, blooms in April, May, June, July; fruit late fall through winter; green year round

Swamp Milkweed (*Asclepias incarnata)*
Herbaceous perennial; tolerating inundation; blooms in May, June

American Tiger Lily (*Lilium superbum*)
Herbaceous perennial; tolerating inundation; blooms in July, August, September

White Turtlehead (*Chelone glabra*)
Herbaceous perennial; tolerating seasonal inundation; blooms in July, August, September

Great Blue Lobelia (*Lobelia siphilitica*)
Herbaceous perennial; tolerating inundation; blooms in July, August, September, October

New England Aster (*Symphyotrichum novae-angliae*)
Herbaceous perennial; tolerating inundation; blooms in August, September, October

The planter boxes are designed as an offline system to take runoff from storms no larger than 1 inch of rain in 24 hours. Therefore, a flow diversion or bypass mechanism must be installed in the downspout before the first planter box. The bypass pipe must be designed with capacity sufficient to convey the 100-year design storm runoff.

Step 5: Reduced Runoff Volume Calculations

The volume retained in the planter boxes is determined by the available water capacity of soil bed and sand layer, and the field capacity of the gravel layer. As stated above, the available water capacity is the difference between the field capacity and the wilting point. These values can be found in the table on Page 16. For this example, the wilting point, field capacity and available water capacity for the soil bed, sand and gravel layer are shown in the table found at the top of the next page:

Layer	Field Capacity (cf/cf)	Wilting Point (cf/cf)	Available Water Capacity (cf/cf)
Soil Bed (Silt Loam)	0.284	0.135	0.149
Sand	0.062	0.024	0.038
Gravel	0.02	-	0.02

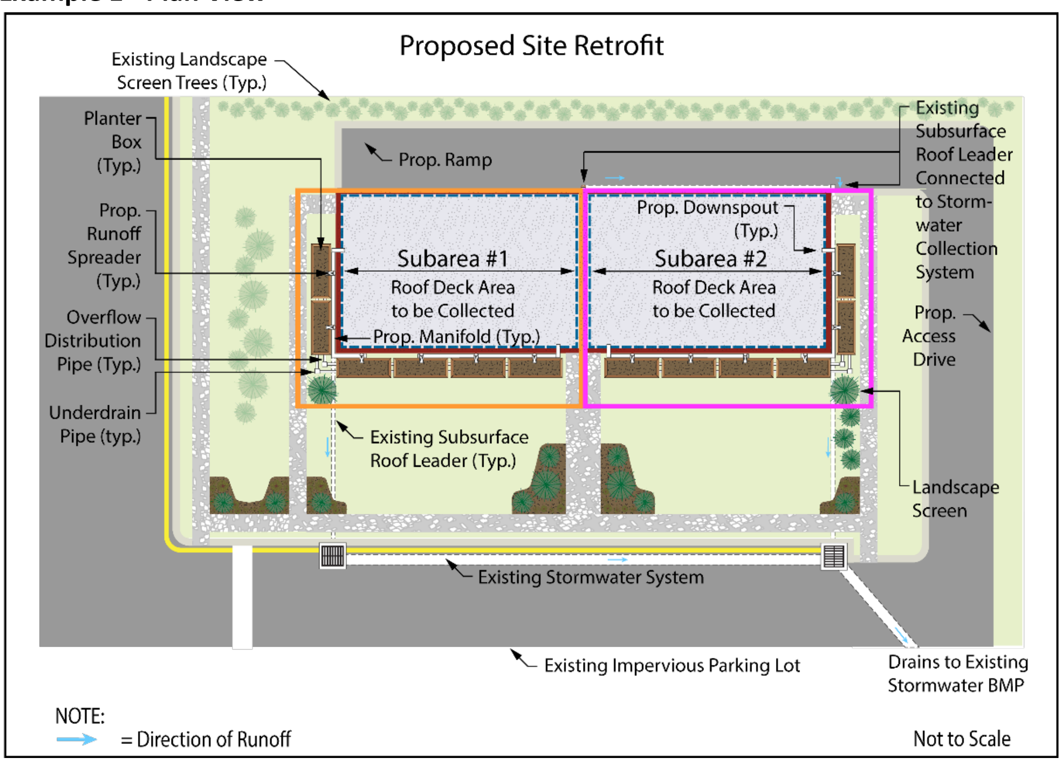
A factor of safety of 0.5 is applied to the available water capacity of the soil and sand. Therefore, the volume reduction provided by the planter boxes can be calculated from the product of the volume of the layers and the available water capacity. The result is shown below:

Layer	Layer Volume (= # of Units x L x W x D) (cf)	Available Water Capacity (cf/cf)	Runoff Retention Volume (cf)
Soil Bed	12 x 6 x 5 x 1.5 = 540	0.149 x 0.5 = 0.0745	40.23
Sand	12 x 6 x 5 x 0.5 = 180	0.038 x 0.5 = 0.019	3.42
Gravel	12 x 6 x 5 x 1 = 360	0.02	7.2
		Total =	**50.85**

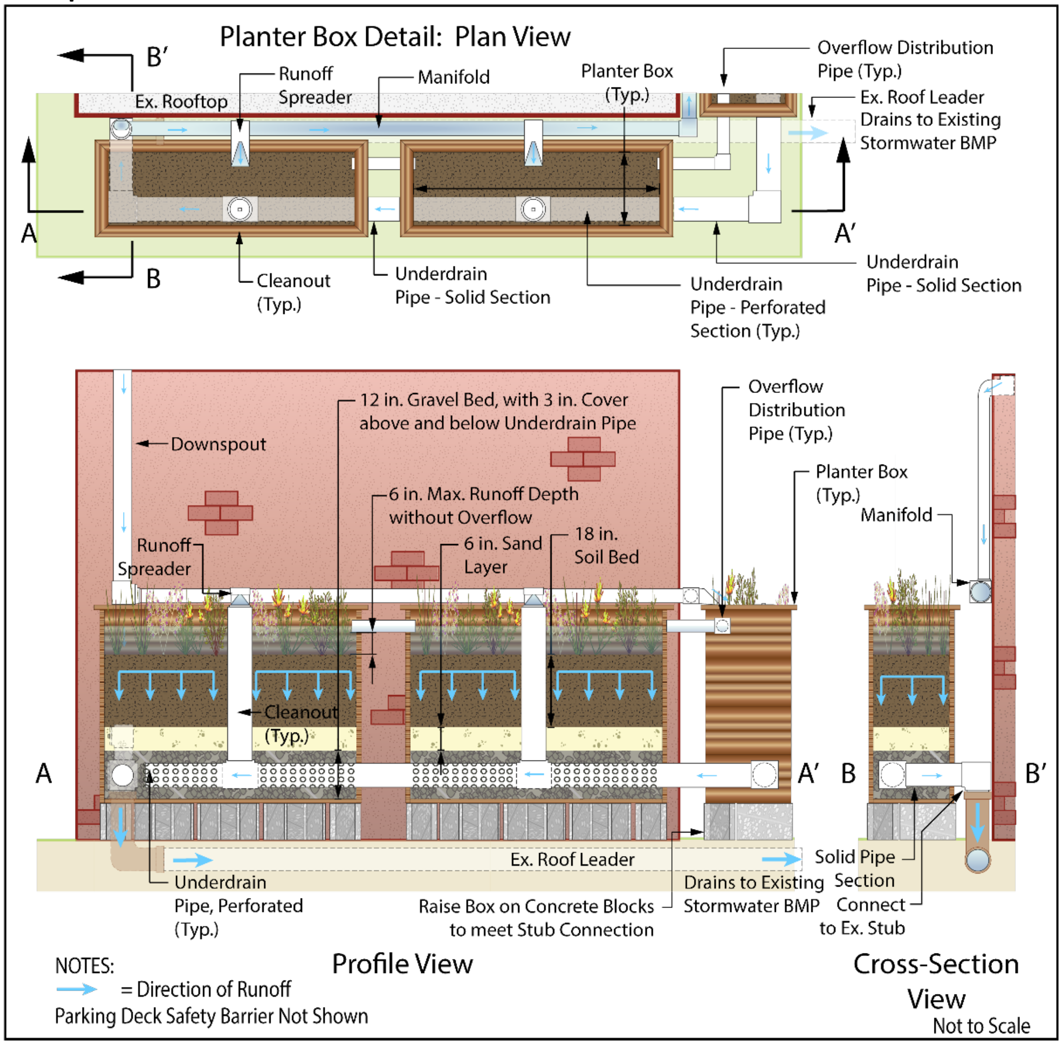
Therefore, the average volume reduction provided by the system is approximately 50.85 cf. This volume is subtracted from the 660 cf of runoff shown above to determine the volume of runoff leaving the site. This means that 609.15 cf of runoff would leave the site in this example.

Illustrations of the planter box system are found below and on the following page.

Example 1 - Plan View



Example 1 – Detail Views



Example 2: Parking Lot Rain Garden Designed to Infiltrate into the Subsoil

This example demonstrates how to design a rain garden as a parking lot island that collects runoff from a 0.25 acre asphalt parking area situated within a redevelopment area. The design storm to be infiltrated is the WQDS. Runoff generated by storms larger than the design storm will be conveyed across the surface of the rain garden to down-gradient stormwater catch basins which, in turn, discharge to the stormwater collection system. The following parameters apply:

Tested subsoil permeability rate	8 in/hr
Assumed soil bed design infiltration rate	10 in /hr
Soil Bed Depth =	24 in

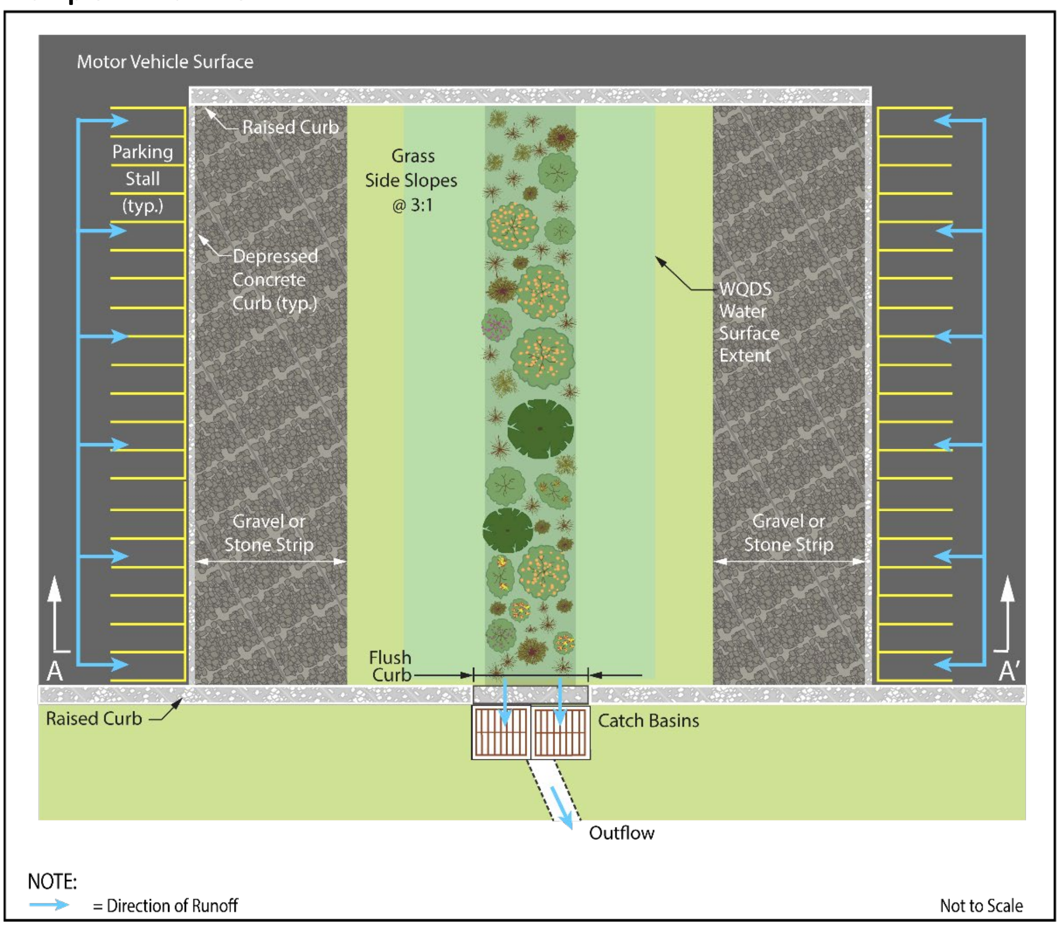
Step 1: Runoff Calculations

Using the NRCS method described in *National Engineering Handbook, Part 630 (NEH)* and discussed in *Chapter 5*, the volume of runoff produced by the WQDS was calculated to be 939 cf based upon an NRCS Curve Number (CN) of 98 for asphalt.

Step 2: Sizing of the Rain Garden

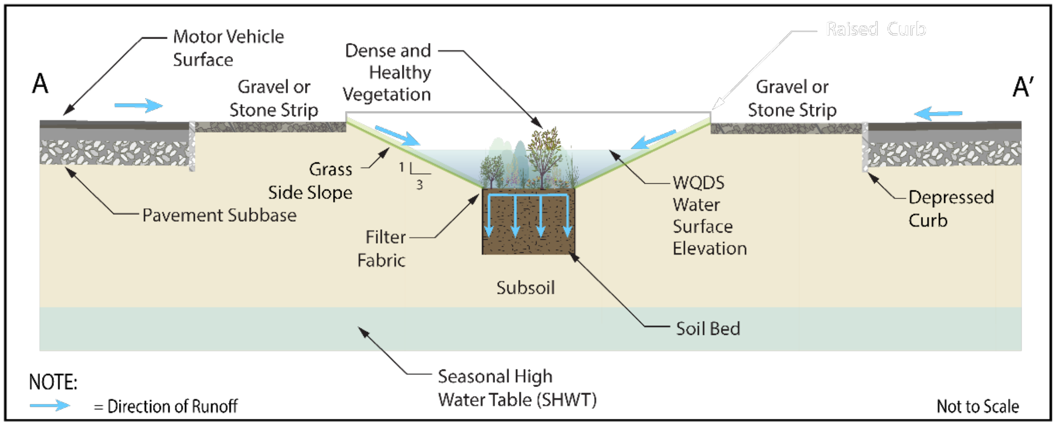
The rain garden is in the center of the parking area, separating two rows of parking spaces. A plan view of the design is provided below:

Example 2 - Plan View



A section view at the lower limit of the rain garden is shown below. For simplicity, fencing or another barrier to prevent vehicular intrusion into the system are omitted.

Example 2 - Section View



The rain garden is designed with grassed side slopes of 3:1 (horizontal distance to vertical distance) on the sides adjacent to the parking stalls. The footprint of the soil bed is 465 sf or 3 ft wide by 155 ft long. The width of the rain garden becomes 9 feet and 12 feet at the elevations of 1 foot and 1.5 feet above the soil bed.

The tested soil permeability rate of the subsoil is 8 in/hr. The design soil permeability will be 4 in/hr. Exfiltration is incorporated into the routing calculations for the rain garden and occurs only within the footprint of the soil bed within the rain garden. No exfiltration is allowed on the side slopes. Therefore, the exfiltration flow through the bottom of the rain garden shall not exceed the flow rate produced by multiplying the footprint of 465 sf with the design soil permeability of 4 in/hr, which results in a flow rate of 0.04 cfs. Note that a 5 ft wide gravel or stone strip, with a slope of no greater than 10 percent, is installed on the edge of pavement adjacent to the rain garden to provide pretreatment of the distributed inflow because exfiltration is used in the design calculation. The routing calculation for the proposed rain garden is performed to determine the required footprint. From the hydrograph, it is known that the maximum water level produced by the WQDS is 0.85 ft above the soil bed. Results for the WQDS are shown on the following page as reprints from a hydrologic modelling software package using the NRCS methodology.

WQDS Summary Report

Inflow Area = 10,890 sf,100.00% Impervious, Inflow Depth = 1.03" for WQ event
Inflow = 0.73 cfs @ 1.11 hrs, Volume= 939 cf
Outflow = 0.04 cfs @ 0.66 hrs, Volume= 939 cf, Atten= 95%, Lag= 0.0 min
Discarded = 0.04 cfs @ 0.66 hrs, Volume= 939 cf
Primary = 0.00 cfs @ 0.00 hrs, Volume= 0 cf

Routing by Stor-Ind method, Time Span= 0.00-48.00 hrs, dt= 0.01 hrs
Peak Elev= 0.85' @ 1.86 hrs Surf.Area= 1,252 sf Storage= 727 cf

Plug-Flow detention time= 158.0 min calculated for 939 cf (100% of inflow)
Center-of-Mass det. time= 158.0 min (228.3 - 70.3)

Volume	Invert	Avail.Storage	Storage Description
#1	0.00'	1,744 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
0.00	465	0	0
1.00	1,395	930	930
1.50	1,860	814	1,744

Device	Routing	Invert	Outlet Devices
#1	Discarded	0.00'	**0.04 cfs Exfiltration at all elevations**
#2	Primary	0.85'	**4.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads

Discarded OutFlow Max=0.04 cfs @ 0.66 hrs HW=0.02' (Free Discharge)
↑**1=Exfiltration** (Exfiltration Controls 0.04 cfs)

Primary OutFlow Max=0.00 cfs @ 0.00 hrs HW=0.00' (Free Discharge)
↑**2=Orifice/Grate** (Controls 0.00 cfs)

Source: HydroCAD® Summary Report; HydroCAD is a registered trademark of HydroCAD Software Solutions LLC. Used with permission.

WQDS Routing Table

Time (hours)	Inflow (cfs)	Elevation (feet)	Outflow (cfs)	Discarded (cfs)
0.00	0.00	0.00	0.00	0.00
0.10	0.00	0.00	0.00	0.00
0.20	0.00	0.00	0.00	0.00
0.30	0.00	0.00	0.00	0.00
0.40	0.00	0.00	0.00	0.00
0.50	0.02	0.00	0.01	0.01
0.60	0.04	0.01	**0.03**	**0.03**
0.70	0.05	0.02	**0.04**	**0.04**
0.80	0.07	0.03	0.04	0.04
0.90	0.16	0.08	0.04	0.04
1.00	0.46	0.22	0.04	0.04
1.10	**0.73**	0.49	0.04	0.04
1.20	**0.40**	0.69	0.04	0.04
1.30	0.19	0.76	0.04	0.04
1.40	0.11	0.79	0.04	0.04
1.50	0.10	0.81	0.04	0.04
1.60	0.08	0.82	0.04	0.04
1.70	0.07	0.83	0.04	0.04
1.80	0.07	**0.84**	0.04	0.04
1.90	0.03	**0.85**	0.04	0.04
2.00	0.02	0.84	0.04	0.04

Source: HydroCAD® Routing Table; HydroCAD is a registered trademark of HydroCAD Software Solutions LLC. Used with permission

Step 3: Check Drain Time

The soil bed permeability rate is 10 in/hr, but the subsoil design infiltration rate (1/2 the tested rate) is 4 in/hr. Therefore, the drain time must be calculated based on the subsoil design permeability rate. The area for infiltration is 465 sf. The infiltration rate is calculated to be:

$$Infiltration\ Rate = 465\ ft\ x\ \frac{4\ in/hr}{12\ in/ft} = 155\ \text{cf/hr}$$

For the WQDS producing 939 cf of stormwater runoff, the drain time is as follows:

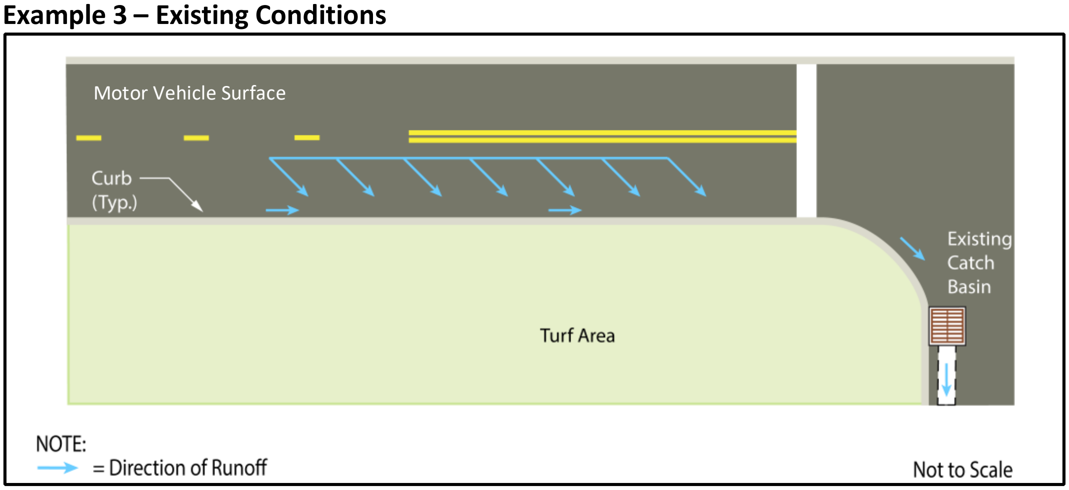
$$Drain\ Time = \frac{939\ cf}{155\ cf/hr} = 6.06\ \text{hr}$$

Note that the calculated drain time is less than the recommended 24-hour maximum for public areas exposed to pedestrian and vehicular traffic. A groundwater mounding analysis is required for all infiltration BMPs. The guidance for conducting a groundwater mounding analysis is available at *Chapter 13*. It is not shown here.

Example 3: For a new two-lane curbed roadway in an area outside the coastal plain, illustrated below, design a bioretention basin to infiltrate the runoff generated by the WQDS. Runoff will enter the proposed system as flow piped from a new shallow catch basin situated along the curb line and overflow will discharge to the existing stormwater collection system. The following parameters apply:

Inflow Drainage Area =	0.25 ac of motor vehicle surface
Pavement NRCS Curve Number (CN) =	98
Soil Bed Depth =	18 in
Side Slope above Soil Bed =	3:1 (horizontal to vertical)
Tested Permeability of Soil Bed =	8 in/hr
Tested Permeability of Subsoil =	2 in/hr
Depth to the Seasonal High Water Table (SHWT) =	8 ft below existing ground level

Example 3 – Existing Conditions



Step 1: Runoff Calculations

Using the NRCS method described in *National Engineering Handbook, Part 630 (NEH)* and discussed in *Chapter 5*, the volume of runoff produced by the WQDS was calculated to be 939 cf.

Step 2: Sizing the pretreatment

Because exfiltration is incorporated in the routing calculaiton, pretreatment is required. An MTD is incorporated down-gradient of the catch basin and before the runoff enters the proposed basin. The MTD must be sized to handle the flowrate of the WQDS, which is 0.74 cfs in this example. An MTD that has 50% TSS removal rate can be selected from the list of certified MTDs available at https://www.nj.gov/dep/stormwater/treatment.html.

In accordance with the design criteria for this type of system, the maximum depth of runoff above the surface of the soil bed is 1 ft. The exfiltration rate, 1 in/hr, is one half the tested soil permeability rate. By trial and error, a bioretention basin is designed with a 600 sf soil bed area, or "footprint,' and the depth of stormwater runoff is approximately 1 ft as the initial configuration. The side slopes are set at the limit of 3:1 (horizontal to vertical) above the soil bed. Assuming the soil bed is 6 ft wide and 100 ft long resulting in 600 sf of footprint of the basin. The surface area will be 1200 sf (100 ft by 12 ft) and 1500 sf (100 ft by 15 ft) due to the side slope, at 1 and 1.5 ft above the basin bottom, respectively. Exfiltration is allowed only within the footprint of the basin. No exfiltration is allowed on the side slopes. Therefore, the exfiltration flow through the bottom of the basin shall not exceed the flow rate produced by multiplying the footprint 600 sf with the design soil permeability 1 in/hr, which results in a flow rate of 0.01 cfs through the footprint of the basin. The hydrograph shows that the stormwater runoff in the basin during the WQDS reaches 0.98 ft above the soil bed. The depth of stormwater runoff generated is less than the maximum allowable depth of 1 ft. A riser with an orifice diameter of 6 inches is designed at an invert at 0.98 feet above the soil bed to bypass the stormwater runoff generated by storms larger than the WQDS.

The routing table is shown to the right, with the summary report depicted on the next page.

Routing Table

Time (hours)	Inflow (cfs)	Elevation (feet)	Outflow (cfs)	Discarded (cfs)
0.00	0.00	0.00	0.00	0.00
0.10	0.00	0.00	0.00	0.00
0.20	0.00	0.00	0.00	0.00
0.30	0.00	0.00	0.00	0.00
0.40	0.00	0.00	0.00	0.00
0.50	0.02	0.01	0.00	**0.00**
0.60	0.04	0.02	0.01	**0.01**
0.70	0.05	0.04	0.01	0.01
0.80	0.07	0.07	0.01	0.01
0.90	0.16	0.12	0.01	0.01
1.00	0.46	0.25	0.01	0.01
1.10	**0.73**	0.52	0.01	0.01
1.20	**0.40**	0.74	0.01	0.01
1.30	0.19	0.83	0.01	0.01
1.40	0.11	0.87	0.01	0.01
1.50	0.10	0.90	0.01	0.01
1.60	0.08	0.92	0.01	0.01
1.70	0.07	0.95	0.01	0.01
1.80	0.07	0.97	0.01	0.01
1.90	0.03	0.98	0.01	0.01
2.00	0.02	**0.98**	**0.01**	0.01
2.10	0.01	**0.98**	**0.01**	0.01
2.20	0.00	0.98	0.01	0.01
2.30	0.00	0.98	0.01	0.01
2.40	0.00	0.98	0.01	0.01
2.50	0.00	0.97	0.01	0.01

Source: HydroCAD® Routing Table; HydroCAD is a registered trademark of HydroCAD Software Solutions LLC. Used with permission.

WQDS Summary Table

Inflow Area =	10,890 sf,100.00% Impervious,	Inflow Depth = 1.03" for WQ event	
Inflow =	0.73 cfs @ 1.11 hrs,	Volume=	939 cf
Outflow =	0.01 cfs @ 2.09 hrs,	Volume=	939 cf, Atten= 99%, Lag= 59.3 min
Discarded =	0.01 cfs @ 0.59 hrs,	Volume=	939 cf
Primary =	0.00 cfs @ 2.09 hrs,	Volume=	0 cf

Routing by Stor-Ind method, Time Span= 0.00-48.00 hrs, dt= 0.01 hrs
Peak Elev= 0.98' @ 2.09 hrs Surf.Area= 1,190 sf Storage= 880 cf

Plug-Flow detention time= 742.4 min calculated for 939 cf (100% of inflow)
Center-of-Mass det. time= 742.5 min (812.8 - 70.3)

Volume	Invert	Avail.Storage	Storage Description
#1	0.00'	1,575 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
0.00	600	0	0
1.00	1,200	900	900
1.50	1,500	675	1,575

Device	Routing	Invert	Outlet Devices
#1	Discarded	0.00'	**0.01 cfs Exfiltration at all elevations**
#2	Primary	0.98'	**6.0" Vert. Orifice/Grate** C= 0.600

Discarded OutFlow Max=0.01 cfs @ 0.59 hrs HW=0.02' (Free Discharge)
↑**1=Exfiltration** (Exfiltration Controls 0.01 cfs)

Primary OutFlow Max=0.00 cfs @ 2.09 hrs HW=0.98' (Free Discharge)
↑**2=Orifice/Grate** (Orifice Controls 0.00 cfs @ 0.20 fps)

Source: HydroCAD® Summary Report; HydroCAD is a registered trademark of HydroCAD Software Solutions LLC. Used with permission.

Step 3: Estimated Drain Time Calculation

For this step, the time it takes to drain the collected stormwater runoff below the surface of the soil bed must be calculated to verify it is less than the maximum of 72 hours. The drain time is determined by the permeability of the soil bed and the subsoil. The tested permeability of the subsoil is 2 in/hr, which results in a design permeability of 1 in/hr. The design permeability of the soil bed is 4 in/hr; therefore, the permeability of the subsoil is the limiting factor. For the WQDS, the drain time is calculated as follows:

$$Drain\ Time = \frac{Water\ Quality\ Design\ Storm\ Runoff\ Volume}{System\ Infiltration\ Area\ x\ Subsoil\ Design\ Permeability\ Rate}$$

$$= \frac{939\ cf}{(600\ sf\ x\ 1\ in/hr\ x\ 1\ ft/12\ in)} = 18.78\text{ hr}$$

Since 18.78 hr is less than the allowable maximum drain time of 72 hr, the small-scale bioretention system appears, at this stage, to meet the drain time requirements.

Step 4: Check Separation from SHWT

The vertical distance between the lowest elevation of the soil bed and the SHWT must be checked to ensure it meets the minimum separation requirement. By inspection, the sum of the 1.5 ft basin depth and the 1.5 ft soil bed depth equals a lowest point of the basin depth of 3 ft below the existing ground level. As stated previously, the SHWT is 8 ft below ground level. The elevation difference between the basin bottom and the SHWT is 5 ft, which is greater than the 2 ft mimimum separation requirement.

Step 5: Groundwater Mounding Analysis

Calculate the height of the groundwater mounding caused by the infiltration of stormwater runoff to ensure that doing so will neither impact the system, meaning prevent infiltration, nor impact nearby structures. For information on conducting a groundwater mounding analysis, see *Chapter 13*. For this example, the recharge rate is the design permeability rate of 1.0 in/hr. The horizontal hydraulic conductivity is also 1 in/hr since the site is outside the coastal plain. One-half of the length and width of the soil bed area, 50 and 3 ft, respectively, are the values to be input for x and y. The duration of infiltration period, for analyzing the WQDS, is the drain time, 18.78 hr, as calculated in Step 3. The results calculated by using the *Hantush Spreadsheet* are shown below.

Example 3: Input Section of the *Hantush Spreadsheet* and Calculated Δh(max)

	A	B	C	D
6	Input Values			
7	*1.00*	*R*		Recharge rate (permeability rate) (in/hr)
8	*0.150*	Sy		Specific yield, Sy (dimensionless) default value is 0.15; max value is 0.2 provided that a lab test data is submitted
9	1.00	Kh		Horizontal hydraulic conductivity (in/hr) Kh = 5xRecharge Rate (R) in the costal plan; Kh=R outside the coastal plan
10	50.000	x		1/2 length of basin (x direction, in feet)
11	3.000	y		1/2 width of basin (y direction, in feet)
12	18.78	t		Duration of infiltration period (hours)
13	10.00	hi(0)		Initial thickness of saturated zone (feet)
14				
15	12.861	h(max)		Maximum thickness of saturated zone (beneath center of basin at end of infiltration period)
16	2.861	Δh(max)		Maximum groundwater mounding (beneath center of basin at end of infiltration period)

The SHWT is 8.0 ft below the basin bottom. The maximum mounding height is 2.861 ft above the SHWT, meaning the highest point of the mounding is located 5.139 ft below ground level. The bottom of the soil bed is 3 feet below the ground level. Therefore, the temporarily increased elevation in the groundwater level, produced by infiltrating stormwater runoff generated by the WQDS, will not interfere with the drainage of the proposed bioretention system.

Step 6: Overflow Configuration

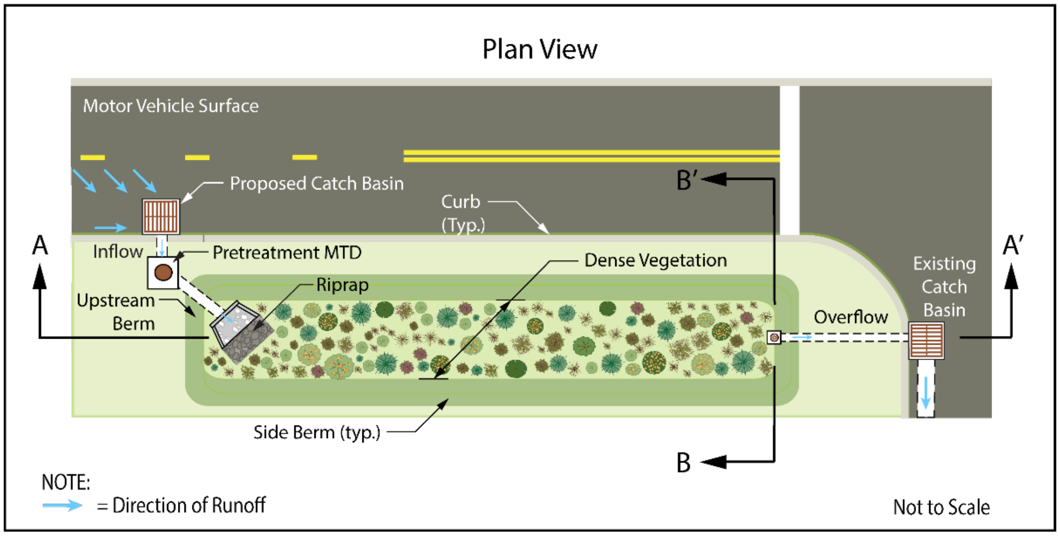
The small-scale bioretention system in this example is an on-line system. On-line systems receive runoff from all storms events and they convey the runoff from larger storms through an overflow, which, in this example, consists of a berm and an overflow riser. The opening in the riser is set at an elevation 1 ft above the surface of the soil bed; this design allows the accumulation of runoff up to the elevation of stormwater runoff generated by the WQDS to infiltrate; excess runoff discharges through the overflow pipe, which is fitted with a debris cap to protect the opening from becoming clogged with vegetative matter and trash.

Step 7: Refinements to Design

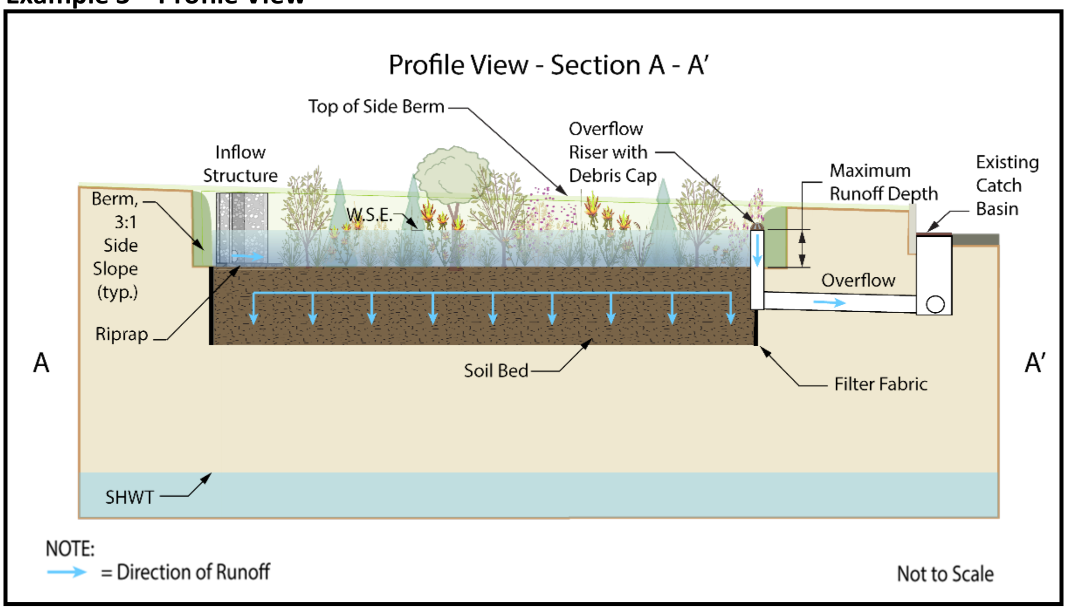
The small-scale bioretention system in this example includes earthen embankments. Therefore, the overall size of the system will have to account for the required 3:1 minimum side slopes. As-built testing must be conducted to validate the permeability rate of the soil bed, confirm the design permeability rate of the subsoil and memorialize the design drain time of the system in the maintenance plan.

The following illustrations show this small-scale bioretention system in plan, profile and cross sectional views. Take note that the horizontal distance between the inflow and outflow riser allows for maximum contact time between the runoff and the vegetation, which promotes greater pollutant removal.

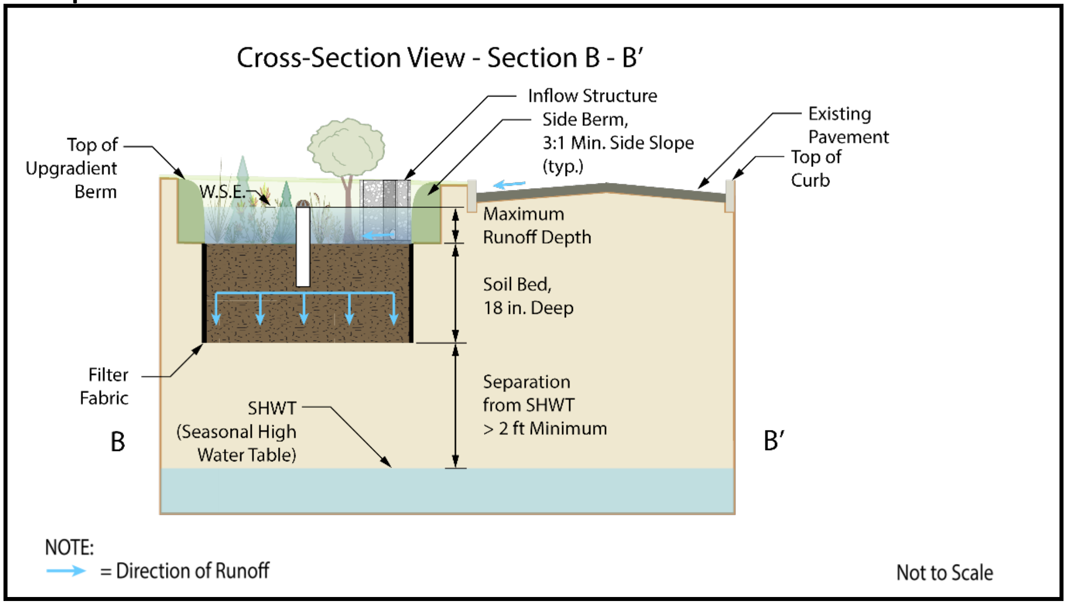
Example 3 – Plan View



Example 3 – Profile View



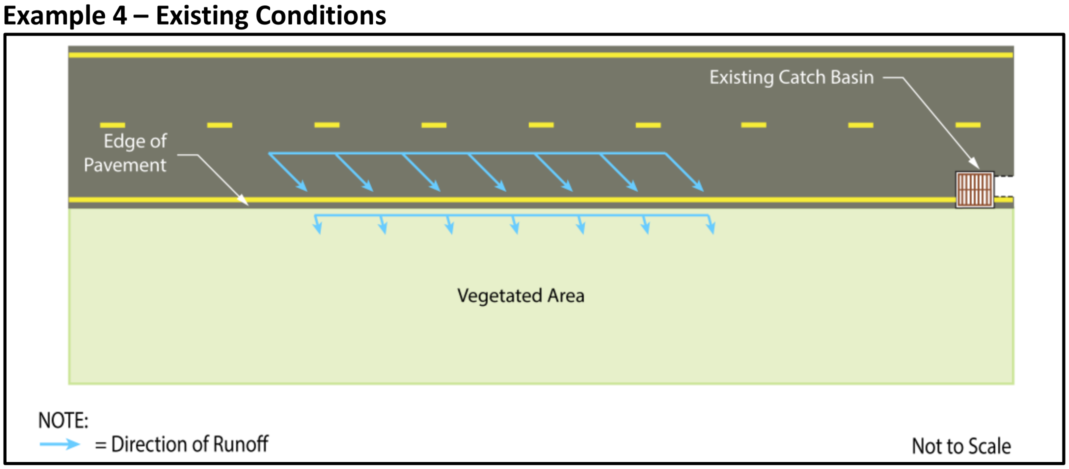
Example 3 – Cross-Section View



Example 4: For the existing uncurbed section of motor vehicle surface illustrated below, design a small-scale bioretention swale with an underdrain to treat the runoff generated by the WQDS. Runoff will enter the proposed system as overland flow from the adjacent road surface. Additionally, a connection to the existing downstream stormwater collection system will be required in order to maintain safe travel conditions. The following parameters apply:

Inflow Drainage Area =	5,000 sf of paved road surface
Pavement NRCS Curve Number (CN) =	98
Soil Bed Depth =	18 in
Assumed Design Permeability of Soil Bed =	4 in/hr
WQDS Depth =	18 in = 1.5 ft

Example 4 – Existing Conditions



Step 1: Runoff Calculations

Using the NRCS Methodology described in National Engineering Handbook, Part 630 (NEH) and discussed in *Chapter 5: Stormwater Runoff Water Quantity Standards and Computations*, the WQDS stormwater runoff volume is calculated to be 431 cf.

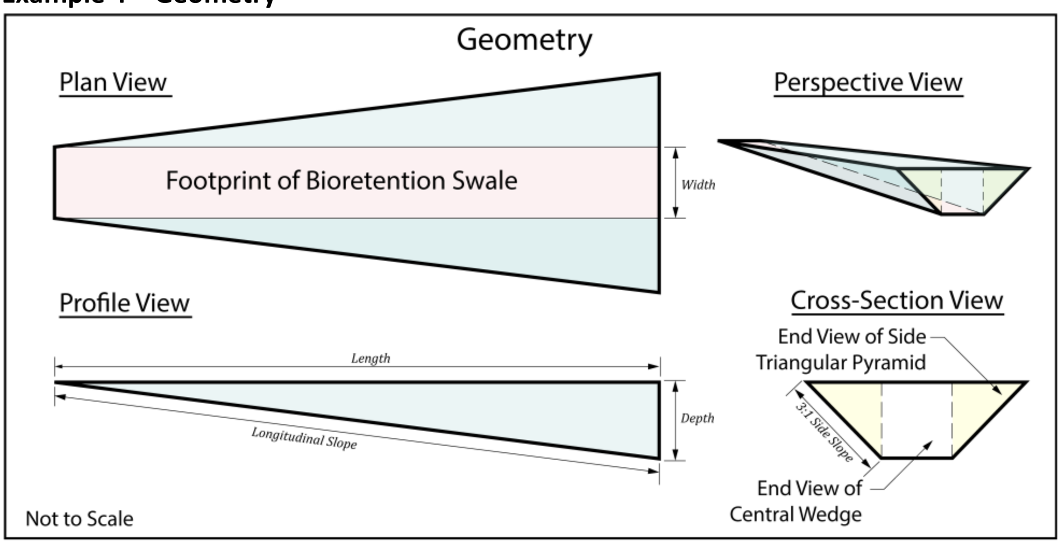
Step 2: Preliminary Shape and Size of the Bioretention Swale

For an initial approximation, a simple shape is selected. If the swale is represented by a wedge shape, the surface area of the soil bed can be estimated by dividing the runoff volume from Step 1 by the average depth of runoff in the swale. For the WQDS, the upstream depth is set at zero, and the surface area is calculated as follows:

$$Surface\ Area = \frac{431\ cf}{(0.5\ x\ 1.5\ ft)} = 575\text{ sf}$$

However, the swale cross-section cannot be rectangular. That would create a sharp drop-off adjacent to the roadway, resulting in erosion of the soil bed. The nature of the flow as it enters the bioretention swale, as well as the nature of future maintenance tasks that will be required, must be taken into account when designing a bioretention swale. A more complex shape must be evaluated and checked for compliance with the minimum SHWT separation requirement; therefore, the assumed shape is a flat-bottom swale with sloping sides. In this configuration, the longitudinal slope directs runoff toward the downstream end, and the collected runoff forms a prismatic shape with a trapezoidal downstream face. This shape can be thought of as a central wedge flanked by two symmetrical triangular pyramids, shown in the following illustration. The ends of the two pyramids are shaded in yellow and that of the central wedge in white in the cross-section view.

Example 4 – Geometry



Runoff will occupy not only the footprint of the swale, shown in pink in the plan view portion of the above illustration, but also the two side pyramids shown in blue. Failure to account for this additional volume results in both an oversized swale and the infiltration, during larger storm events, of more volume than allowed. Calculating the volume of this complex shape by hand, although possible, is beyond the scope of this chapter and is easily performed by computer programs.

Step 3: Estimated Drain Time Calculation

Since there is no infiltration into the subsoil, the limiting factor in the drain time calculation is the permeability rate of the soil bed. If the method employed in Step 3 of Example 1 was followed, the assumed soil bed design permeability and the footprint area shaded above in pink would determine the drain time. Following Example 3, an estimate of the drain time for the Water Quality Design Storm would be calculated as follows:

$$Drain\ Time = \frac{Water\ Quality\ Design\ Storm\ Runoff\ Volume}{System\ Infiltration\ Area\ x\ Subsoil\ Design\ Permeability\ Rate}$$

However, the above method cannot be used because the swale has a sloped bottom, meaning the area available for infiltration will vary with time as the water level decreases. The area available for infiltration that is present at any given moment is a function of the depth of the runoff in the swale at that moment. The drain time calculation could be written as a summation of all the incremental volumes divided by the soil bed permeability rate, but in the end, the maximum design depth governs the calculation. The drain time estimate is therefore as follows:

$$Drain\ Time = \frac{Maximum\ Runoff\ Depth}{Subsoil\ Design\ Permeability\ Rate}$$

$$= \frac{18\ in}{4\ in/hr} = 4.5\text{ hr}$$

Since this is less than the allowable maximum drain time of 72 hours, the small-scale bioretention system appears, at this stage, to be sized correctly to meet the drain time requirements.

Step 4: Overflow Configuration

The small-scale bioretention swale in this example is an on-line system. On-line systems receive runoff from all storms events, and they convey the runoff from larger storms through an overflow, which, in this example, consists of a berm and an overflow riser. The opening in the riser is set at an elevation 1.5 feet above the surface of the soil bed; this design allows the accumulation of runoff up to the Water Quality Design Storm elevation to infiltrate; excess runoff discharges through the overflow pipe, which is fitted with a debris cap to protect the opening from becoming clogged with vegetative matter and trash.

Step 5: Underdrain Design

To ensure that the underdrain does not provide the hydraulic control of the system, the pipe network must be designed with conveyance rates at least twice as fast as the design flow rate through the sand layer. Additionally, the pipes must be sloped for complete drainage. The required clearances within the gravel layer must also be provided.

Step 6: Check Separation from SHWT

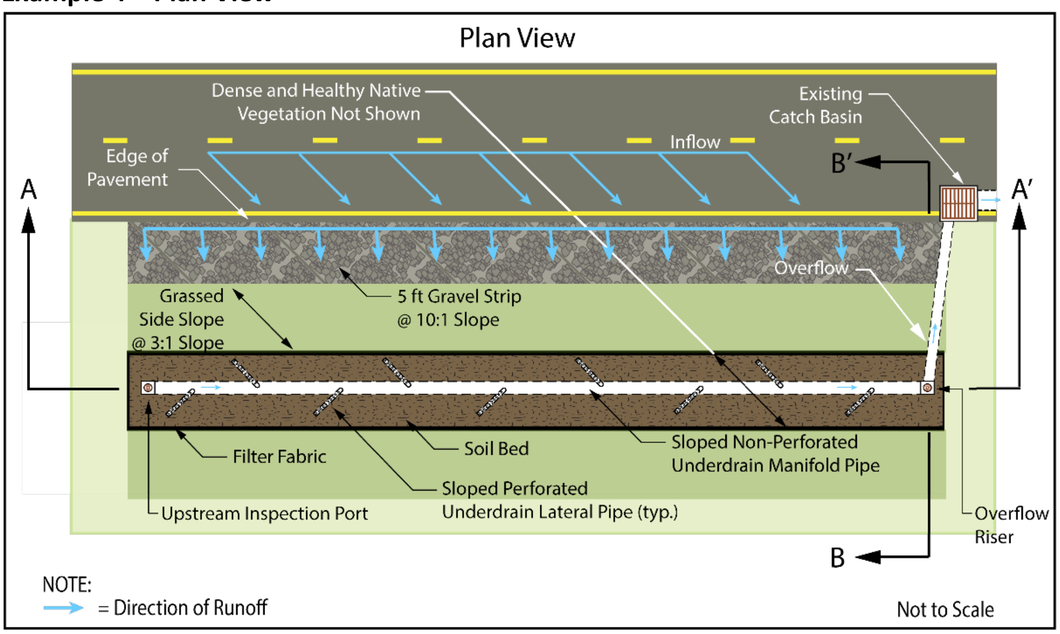
The vertical distance between the lowest elevation of the gravel layer and the SHWT must be checked to ensure it meets the minimum 1 ft separation requirement.

Step 7: Refinements to the Design

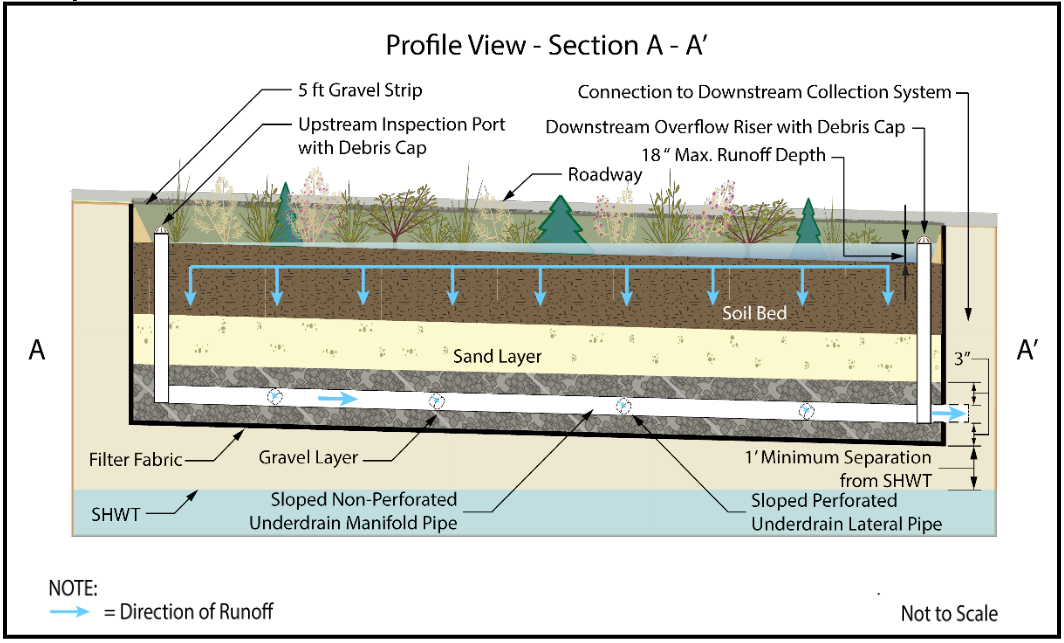
The overall size of the system will have to account for the two triangular pyramids on the sides which have a 3:1 slope. Additionally, the 5 ft wide gravel apron is placed between the bioretention swale and the edge of pavement to prevent erosion. Prior to installation of the soil bed, permeability testing is not feasible; therefore, for design calculations, a permeability rate of 4 in/hr was assumed. This assumed permeability rate included the required factory of safety, which translates to an assumed tested permeability rate of 8 in/hr. As-built testing must be conducted to validate this assumption and establish the design drain time of the system, which must also be included in the maintenance plan.

The illustrations on the following two pages show this small-scale bioretention swale in plan, profile and cross sectional views. In this example, an additional vertical space above the outflow riser, although not required, is included. This additional vertical space is intended to ensure that the swale does not flood the roadway in the event that debris partially clogs the cap on the overflow riser. This additional space does not increase the volume of runoff infiltrated, as the opening in the outflow riser directs excess runoff to the down-gradient collection system. The overall size of the swale in this example includes end berms as transition areas to the existing grade elevation to account for this additional depth.

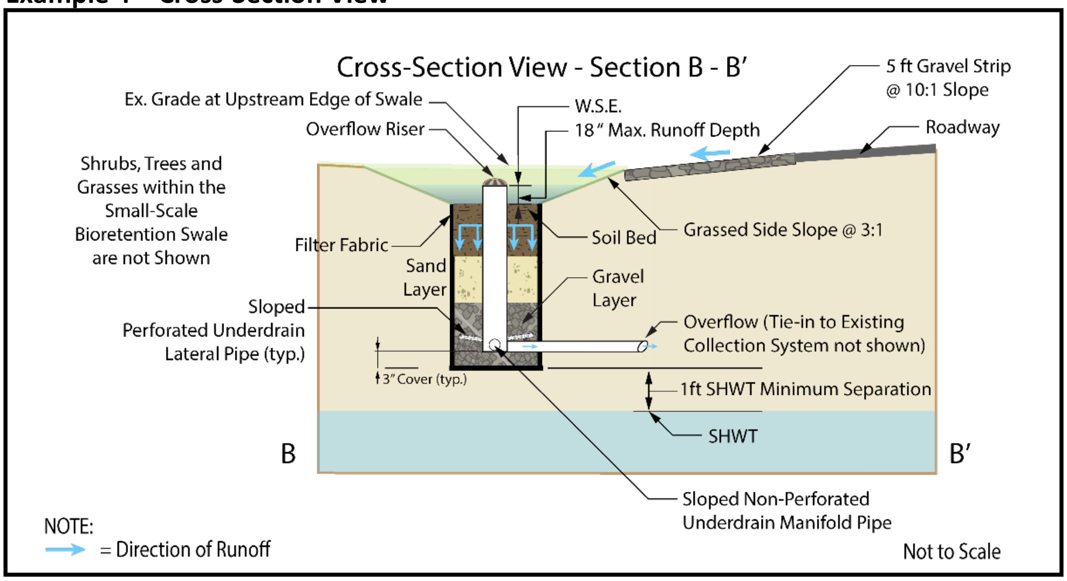
Example 4 – Plan View



Example 4 – Profile View



Example 4 – Cross-Section View



Considerations

When planning a small-scale bioretention system designed to infiltrate into the subsoil, consideration should be given to soil characteristics, depth to the groundwater table, sensitivity of the region, and inflow water quality. It is also important to note that the use of systems designed to infiltrate into the subsoil is recommended in this manual only where the Water Quality Design Storm or smaller storm events are contained below the first outlet control structure. Use of these systems to store larger volumes below the first outlet control structure should only be considered when another applicable rule or regulation requires the infiltration of a larger storm event. In such a case, the small-scale bioretention system should be designed to store the minimum storm event required to address that rule or regulation, below the first outlet control structure..

In addition to the prohibition of recharge in the areas with high pollutant loading or with runoff exposed to source material as defined in N.J.A.C. 7:8-5.4(b)3, the utilization of small-scale bioretention systems should consider the impact of infiltration on subsurface sewage disposal systems, water supply wells, groundwater recharge areas protected under the Ground Water Quality Standards rules at N.J.A.C 7:9C, streams under antidegradation protection by the Surface Water Quality Standards rules at N.J.A.C. 7:9B or similar facilities or areas geologically and ecologically sensitive to pollutants or hydrological changes. Furthermore, the location and minimum distance of the bioretention basin from other facilities or systems shall also comply with all applicable laws and rules adopted by Federal, State and local government entities.

Geology

The presence or absence of Karst topography is an important consideration when designing a small-scale bioretention system designed to infiltrate into the subsoil; in areas of the State with this type of geology, the bedrock is composed of highly soluble rock. If Karst topography is present, infiltration of runoff may lead to subsidence and sinkholes; therefore, only bioretention systems designed with underdrains should be used in these areas. For more information on design and remediation in areas of Karst topography, refer to the *Standards for Soil Erosion and Sediment Control in New Jersey: Investigation, Design and Remedial Measures for Areas Underlain by Cavernous Limestone.*

Pretreatment

As with all other best management practices, pretreatment may extend the functional life and increase the pollutant removal capability of a small-scale bioretention system by reducing incoming velocities and capturing coarser sediments. Note that pretreatment is not optional for small-scale bioretention systems designed to infiltrate into the subsoil that include exfiltration in the stormwater routing calculations.

- Pretreatment may consist of a forebay or any of the 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 may be earthen, constructed of riprap, or made of concrete and 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 WQDS and be sized to hold the sediment volume expected between clean-outs.
- ◻ The forebay 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 another BMP for pretreatment, it must be designed in accordance with the design requirements outlined in its respective chapter. For additional information on the design requirements of each BMP, refer to the appropriate chapter in this manual.

- Any roof runoff that discharges to the small-scale bioretention system 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.*

Mulch Layer

The mulch layer on the surface of the soil bed may enhance the performance of the small-scale bioretention system. Mulch can aid in plant growth by retaining moisture and by providing an environment for microorganisms that decompose incoming organic matter. Additionally, the mulch layer can act as a filter for finer particles in runoff preventing these particles from clogging the soil bed.

- Care should be taken to ensure that the mulch layer does not reduce the design permeability rate of the surface.

- The mulch layer should consist of standard 1 to 2 inch shredded hardwood or chips.

- The mulch layer should be 2 to 4 inches in depth and replenished as necessary.

- To determine whether a mulch layer is appropriate for on-line systems, consideration should be given to issues such as scour and floatation of the mulch during large storm events.

Enhancing Pollutant Removal

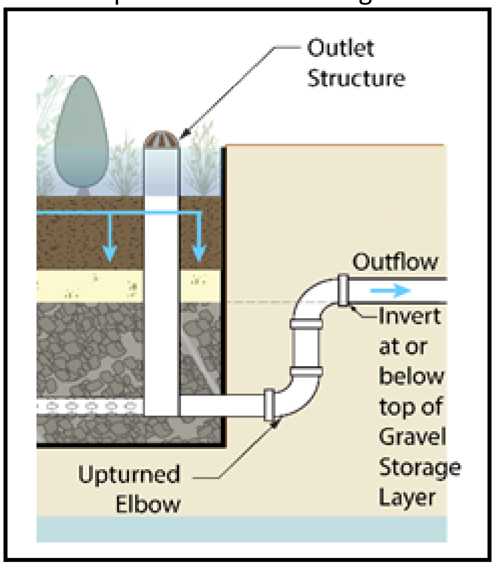
- Maximizing the horizontal distance between inflow and overflow structures in a small-scale bioretention system may increase contact time for stormwater runoff with the system vegetation and soil bed, where pollutant-removing chemical and biological processes occur. Grouping inflows near outflows may locally decrease the capacity of the soil bed to remove metals and other dissolved nutrients as well as the ability of the plants to uptake pollutants.

- Increasing the soil bed depth to 25 - 36 inches may enhance pollutant removal and accommodate more deeply-rooted plants.

- The designer may wish to include soil amendments to target the removal of pollutants of concern. For example, biochar is one such soil amendment. If this is the case, links or references to the supporting research should be included in the stormwater management report narrative. The designer is encouraged to contact the Department to discuss this issue further. The maintenance plan must include costs and tasks associated with periodic replacement of any amendments.

- For systems with an underdrain, the designer may wish to include the upturned elbow configuration shown in the illustration below to slow the discharge and increase the potential for increased biological processes to occur in the gravel layer.

Detail: Upturned Elbow Configuration



Soil Characteristics

For small-scale bioretention systems designed to infiltrate into the subsoil, soils are perhaps the most important consideration for site suitability. In general, County Soil Surveys may be used to obtain necessary soil data for planning and preliminary design of bioretention systems. However, as previously mentioned, for final design and construction, soil tests are required at the exact location of the proposed system in order to confirm its ability to function properly without failure. In order to confirm reasonable data consistency, the results of soil testing should be compared with the County Soil Survey data that was used in the computation of runoff rates and volumes and the design of on-site BMPs. If significant differences exist between the soil test results and the County Soil Survey data, additional soil tests are recommended to determine and evaluate the extent of the data inconsistency and whether there is a need for revised site runoff and BMP design computations. All significant inconsistencies should be discussed with the local Soil Conservation District prior to proceeding with such a redesign to help ensure that the final site soil data is accurate.

Vegetation

- When selecting vegetation, the designer should consider the aesthetic appearance of the vegetation in different seasons. Refer to the table on the following pages for additional information on the bloom period of plants that may be incorporated into a small-scale bioretention system. These perennial plants are suited to frequent inundation.

- Location of a small-scale bioretention system is an important factor when selecting vegetation. The following factors should be considered:
  - Small-scale bioretention systems near buildings or large trees that result in shading will require different vegetation than a small-scale bioretention system that receives full sun. This is particularly important in large small-scale bioretention systems because sunlight duration may vary widely from one section to another.
  - Overhangs that prevent precipitation from falling directly on vegetation may adversely impact growth and survival; therefore, these areas should be avoided when determining small-scale bioretention system locations.
  - When designing a small-scale bioretention system that will include trees, care should be taken to prevent inadvertent damage to the tree roots, which can be fatal. Otherwise, new roots may inadvertently spread into or under adjacent structures. One scenario that will cause root damage, or even tree death, is by the placement of additional plants and landscape materials, not part of the original design, within the confines of a tree pit. This results in accidental smothering by starving the roots of soil moisture and halting the free exchange of gases throughout the root zone. Nearby utility work or excavation may also damage tree roots. Using structural soil, which is stone aggregate whose voids are filled with soil that can be mixed with a moisture retaining gel to provide a matrix for sustainable root growth, and including a geogrid as a permeable cover on top of this structural soil, may be one . The added strength of this mixture reduces the likelihood of damage to the tree by nearby utility work.

Bloom Information for Various Small-scale Bioretention System Plants						
Common Name	**Genus**	**Species**	**Height**	**Bloom Color**	**Bloom Start**	**Bloom End**
Spicebush, Wild allspice	*Lindera*	*benzoin*	6 – 12’	white, yellow	April	April
Marsh marigold, Yellow marsh marigold, Cowslip	*Caltha*	*palustris*	1 – 3’	yellow	April	May
Kinnikinnick, Red bearberry	*Arctostaphylos*	*uva-ursi*	1 – 3’	white, pink	March	June
Common Winterberry	*Ilex*	*verticillata*	6 – 12’	white flowers, red berries	April	July
Highbush blueberry	*Vaccinium*	*corymbosum*	6 – 12’	pink, white	May	June
Arrowwood	*Viburnum*	*dentatum*	6 – 12’	white	May	July
Harlequin blueflag, Northern blue flag, Large blue iris	*Iris*	*versicolor*	1 – 3’	blue, purple	May	August
Sweet fern	*Comptonia*	*peregrina*	3 – 6’	white, green	May	August
Deertongue	*Dichanthelium*	*clandestinum*	3 – 6’	green stems	May	September
Cardinal flower	*Lobelia*	*Cardinalis*	3 – 6’	red	May	October
Allegheny monkeyflower, Monkeyflower, Square-stemmed monkeyflower	*Mimulus*	*ringens*	1 – 3’	blue, purple	June	September
Common Buttonbush	*Cephalanthus*	*occidentalis*	6 – 12’	white, pink	June	September
Inkberry	*Ilex*	*glabra*	6 – 12’	white flowers, black berries	June	September
Woolgrass, Cottongrass bulrush	*Scirpus*	*cyperinus*	3 – 6’	green, brown	June	September
Swamp milkweed, Pink milkweed	*Asclepias*	*incarnata*	3 – 6’	pink, purple	June	October
Blue vervain, Swamp verbena	*Verbena*	*hastata*	3 – 6’	blue, purple	June	October
Clethra, Summersweet	*Clethra*	*alnifolia*	3 – 6’ 6 – 12’	white, pink	July	August
Beggar's tick sunflower, Devil's beggartick, Spanish needles	*Bidens*	*frondosa*	0 – 1’ 1 – 3’	yellow	July	August
American tiger lily, Turk's cap lily, Swamp lily	*Lilium*	*superbum*	3 – 6’	red, orange, yellow	July	September

Legend: Shrub | Grass or Sedge | Herb

Bloom Information for Various Small-scale Bioretention System Plants (*cont'd.*)						
Common Name	**Genus**	**Species**	**Height**	**Bloom Color**	**Bloom Start**	**Bloom End**
Common threesquare, American bulrush	*Schoenoplectus*	*pungens*	3 – 6'	brown spikelets	July	September
Joe Pye weed, Trumpetweed,	*Eutrochium*	*fistulosum*	3 – 6' 6 – 12'	pink, purple	July	September
Purple Joe Pye weed Sweet Joe Pye weed	*Eutrochium*	*purpureum*	3 – 6'	pink, purple	July	September
Turtlehead, White turtlehead	*Chelone*	*glabra*	3 – 6'	white, pink	July	September
Northern Bayberry	*Morella*	*pennsylvanica*	6 – 12'	yellow flowers, blueish white berries	July	October
Common sneezeweed, Fall sneezeweed, Autumn sneezeweed	*Helenium*	*autumnale*	1 – 3' 3 – 6'	yellow	July	October
Cutleaf coneflower, Green-headed coneflower	*Rudbeckia*	*laciniata*	3 – 6'	yellow	July	October
Great blue lobelia	*Lobelia*	*siphilitica*	1 – 3'	blue	July	October
New York aster	*Symphyotrichum*	*novi-belgii*	3 – 6'	blue	July	October
Roundleaf goldenrod	*Solidago*	*patula*	3 – 6'	yellow	July	October
New York ironweed	*Vernonia*	*novaboracensis*	3 – 6'	red, purple	August	September
Lowland broomsedge, Bushy bluestem	*Andropogon*	*glomeratus*	3 – 6'	white, brown	August	November
New England aster, New England American aster	*Symphyotrichum*	*novae-angliae*	3 – 6'	pink, purple	August	October
Switchgrass	*Panicum*	*Virgatum*	3 – 6'	green, brown	August	November
Wrinkleleaf goldenrod, Wrinkle-leaf goldenrod, Rough-leaved goldenrod	*Solidago*	*rugosa*	3 – 6'	yellow	September	September
Witch hazel	*Hamemelis*	*virginiana*	6 – 12'	orange, yellow	September	December

Legend: Shrub | Grass or Sedge | Herb

Maintenance

Regular and effective maintenance is crucial to ensure effective small-scale bioretention system performance. 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 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 bioretention systems are presented below; these requirements must be included in the maintenance plan. Detailed inspection and maintenance logs must be maintained.

General Maintenance

- Proper and timely maintenance is essential to continuous, effective operation; therefore, an access route must be incorporated into the design, and it must be properly maintained.
- 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 four times annually, as well as after every storm exceeding 1 inch of rainfall.
- Sediment removal must take place when all runoff has drained from the planting bed and the basin is dry.
- 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.
- In systems with underdrains, the underdrain piping must be connected, in a manner that is easily accessible for inspection and maintenance, to a downstream location.
- Access points for maintenance are required on all enclosed areas within a small-scale bioretention system; these access points must be clearly identified in the maintenance plan. In addition, any special training required for maintenance personnel to perform specific tasks, such as confined space entry, must be included in the plan.
- Stormwater BMPs may not be used for stockpiling of plowed snow and ice, compost, or any other material.
- A detailed, written log of all preventative and corrective maintenance performed on the small-scale bioretention system must be kept, including a record of all inspections and copies of maintenance-related work orders. Additional maintenance guidance can be found at https://www.njstormwater.org/maintenance_guidance.htm.

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 ensure the health, density and diversity of the vegetation.
- Mowing/trimming of vegetation 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.

- Grasses within the small-scale bioretention system must be carefully maintained with lightweight equipment, such as a hand-held line trimmer, in order to maintain the permeability of the system.

- Vegetative cover must be maintained at 85%; damage must be addressed through replanting in accordance with the original specifications.

- 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.

- All use of fertilizers, pesticides, mechanical treatments and other means to ensure optimum vegetation health must not compromise the intended purpose of the bioretention system.

Drain Time

- The planting bed should be inspected at least twice annually to determine if the permeability of the bed has decreased.

- The design drain time for the maximum design storm runoff volume must be indicated in the maintenance manual.

- If the actual drain time is significantly different from the design drain time, the components must be evaluated, and appropriate measures taken to return the bioretention system to the original tested as-built condition.

- If the bioretention system fails to drain the Water Quality Design Storm within 72 hours, corrective action must be taken and the maintenance manual revised accordingly to prevent similar failures in the future.

- The water surface elevation for each of the design storms must be indicated on the maintenance plan and in the maintenance logs to facilitate inspections. It is suggested that indelible markings be drawn or physical markers be set on the inside of the outlet control structure as visual indicators of the design storm water surface elevations.

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