The Vermont Stormwater Management Manual
Volume II – Technical Guidance

Vermont Agency of Natural Resources
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INTRODUCTION TO VOLUME II

Volume I of the Vermont Stormwater Management Manual provides designers a general overview on how to size, design, select and locate STPs at a development site to comply with State stormwater performance goals. Volume II contains appendices with more detailed information on landscaping, STP construction specifications, and other assorted design tools.

Volume II of the Manual is organized as follows:

Appendix A. Landscaping Guidance/Plant Lists. Good landscaping can often be an important factor in the performance and community acceptance of many stormwater STPs. The Landscaping Guide provides general background on how to determine the appropriate landscaping region and hydrologic zone in Vermont. Appendix A also includes tips on how to establish more functional landscapes within stormwater STPs, and contains an extensive list of trees, shrubs, ground covers, and wetland plants that can be used to develop an effective and diverse planting plan.

Appendix B. STP Construction and Materials Specifications. Good designs only work if careful attention is paid to proper construction techniques and materials specifications. Appendix B contains detailed specifications for constructing ponds, infiltration practices and sand filters, bioretention areas and open channels and swales.

Appendix C. Assorted Design Tools. Appendix C provides an assortment of design tools that can be used by engineers and designers to develop effective stormwater management plans for a site. Guidance is provided on site testing requirements for specific practices, design details for compliance with practice performance criteria, estimating water quality peak flow, and critical erosive velocities.

APPENDIX A LANDSCAPING GUIDANCE AND PLANT LISTS

A.1. General Landscaping Guidance for All STPs

- Do not plant trees and shrubs within 15 feet of the toe of slope of a dam.
- Do not plant trees or shrubs known to have long tap roots within the vicinity of the earth dam or subsurface drainage facilities.
- Do not plant trees and shrubs within 15 feet of perforated pipes.
- Do not plant trees and shrubs within 25 feet of 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 allow visibility for the inspector who is looking for burrowing rodents that may compromise the integrity of the embankment.
- Provide slope stabilization methods for slopes steeper than 2:1, such as planted erosion control mats. Also, use seed mixes with quick germination rates in this area. Augment temporary seeding measures with container owns or root mats of more permanent plant material.
- Utilize erosion control mats and fabrics to protect channels that are subject to frequent washouts.
- Stabilize all water overflows with plant material that can withstand strong current flows. Root material should be fibrous and substantial but lacking a tap root.
- Sod channels that are not stabilized by erosion control mats.
- Divert flows temporarily from seeded areas until stabilized.
- Check water tolerances of existing plant materials prior to inundation of 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, when possible shade inflow and outflow channels as well as the southern exposures of pond.
- Avoid plantings that will require routine or intensive chemical applications (i.e. turf area).
- Have soil tested in planting areas to determine if there is a need for amendments; select plants that can thrive with on-site soil with no additional amendments or a minimum of amendments. See additional discussion of Soil Testing and Improvement in Section A.1.1.
- Avoid use of any plants included on ANR's Invasive Exotic Plants of Vermont List and the Agricultural Department's proposed Noxious Weed Quarantine List.
- Decrease the areas where turf is used. Use low maintenance ground cover to absorb run-off.
- When planting a mix of plant species, plant individual of same species in clumps (e.g., groups of three to five) rather than alternating species on a plant by plant basis.

- Plant stream and edge of water buffers with trees, shrubs, ornamental grasses, and herbaceous materials 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 or buffer unattractive views into the site.
- Use plants to prohibit pedestrian access to pools or slopes that may be unsafe.
- The designer should carefully consider the long term vegetation management strategy for the STP, keeping in mind the "maintenance" legacy for the future owners. Keep maintenance area open to allow future access for pond maintenance. Provide a planting surface that can withstand the compaction of vehicles using maintenance access roads. Make sure the facility maintenance agreement includes a maintenance requirement of designed plant material.
- Select salt tolerant plant material in areas that may receive wintertime salt applications (roads and parking lots).
- Provide signage for:
    - Stormwater Management Areas to help educate the public when possible.
    - Wildflower areas, when possible, to designate limits of mowing.
- Avoid the overuse of any plant materials.
- Preserve existing natural vegetation when possible.

A.1.1. Soil Testing and Improvement

It is often necessary to test the soil in which you are about to plant in order to determine the following:

- pH; whether acid, neutral, or alkali
- major soil nutrients; Nitrogen, Phosphorus, Potassium
- minerals; such as chelated iron, lime

Have soil samples analyzed by experienced and qualified individuals, such as those at the Agricultural Extension Office, who will explain in writing the results, what they mean, as well as what soil amendments would be required. Certain soil conditions can present serious constraints to the growth of plant materials and may require the involvement of qualified professionals. When poor soils can't be amended, seed mixes and plant material must be selected to establish ground cover as quickly as possible.

Areas that have recently been involved in construction can become compacted so that plant roots cannot penetrate the soil. The result is that often seeds lie on the surface of compacted soils, allowing them to be washed away or be eaten by birds. Instead, soils should be loosened to a minimum depth of two inches, preferably to a four-inch depth. Hard soils may require discing to a deeper depth. The soil should be loosened regardless of the ground cover. This will improve seed contact with the soil, providing greater germination rates, allowing the roots to penetrate into the soil. If the area is to be sodded; discing will allow the roots to penetrate into the soil. Weak or patchy crops can be prevented by providing good growing conditions.

Whenever possible, topsoil should be spread to a depth of four inches (two inch minimum) over the entire area to be planted. This provides organic matter and important nutrients for the plant material. This also allows the stabilizing materials to become established faster, while the roots are able to penetrate deeper and stabilize the soil, 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 desirable to test the soil for pH as well as microbial activity. If the microbial activity has been destroyed, it is necessary to inoculate the soil after application.

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

A.2. Ponds and Wetlands

For areas that are to be planted within a stormwater management facility it is necessary to determine what type of hydrologic zones will be created within the facility. The six zones presented in Table A-1 describe the different conditions encountered in stormwater management facilities. Every facility does not necessarily reflect all of these zones. The hydrologic zones designate the degree of tolerance the plant exhibits to differing degrees of inundation by water.

Table A-1. 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

Each zone has its own set of plant selection criteria based on the hydrology of the zone, the stormwater functions required of the plant and the desired landscape effect. The hydrologic zones are discussed in more detail below, see Figure A-1 for a schematic.

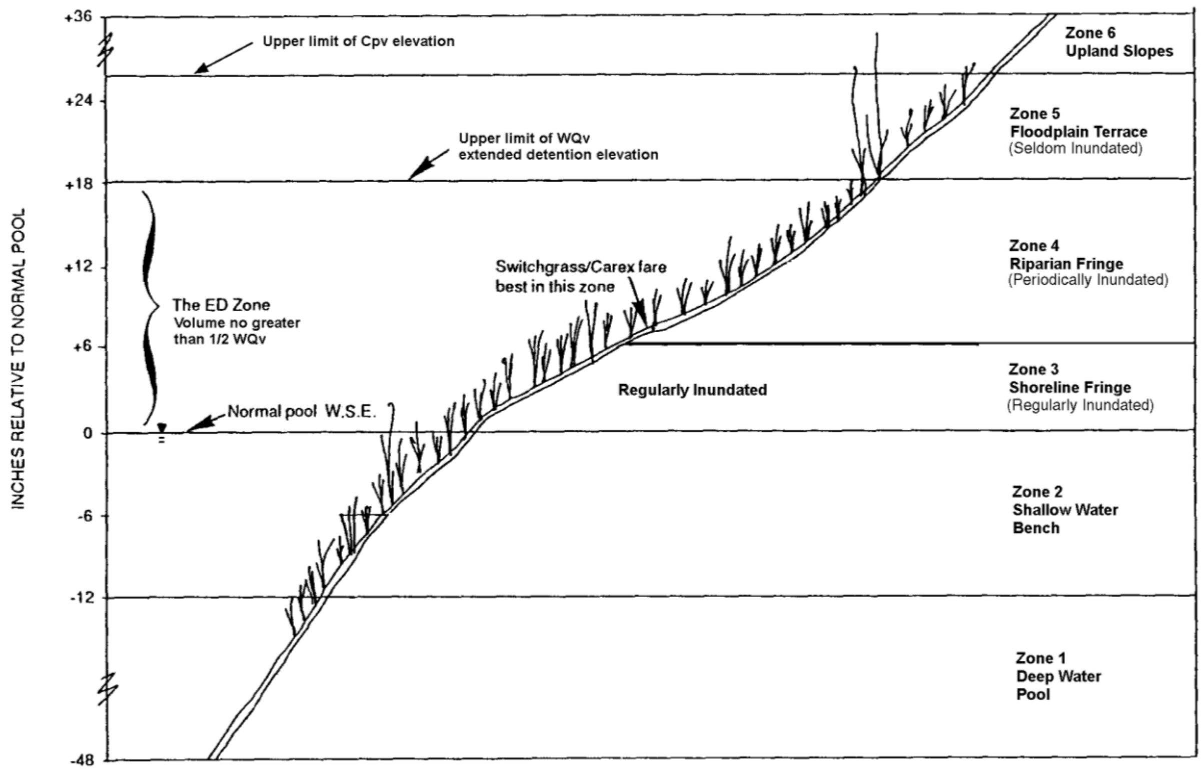

Figure A-1. Schematic of Pondscaping Zones

A.2.1. Zone 1: Deep Water Area (1- 6 Feet)

Ponds and wetlands both have deep pool areas that comprise Zone 1. These pools range from one to six 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 it is also feared that plants could clog the stormwater facility outlet structure. In many cases, these plants will gradually become established through natural recolonization (e.g., 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.

- Plant material must be able to withstand constant inundation of water of one foot or greater in depth.
- Plants may be submerged partially or entirely.
- Plants should be able to enhance pollutant uptake.
- Plants may provide food and cover for waterfowl, desirable insects, and other aquatic life.

A.2.2. Zone 2: Shallow Water Bench (Normal Pool To 1 Foot)

Zone 2 includes all areas that are inundated below the normal pool to a depth of one foot, and is the primary area where emergent plants will grow in a stormwater wetlands. Zone 2 also coincides with the aquatic bench found in stormwater ponds (Figure A.2.). 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 located below the surface of the water within the pond. When planted, Zone 2 can be an important habitat for many aquatic and nonaquatic animals, creating a diverse food chain. This food chain includes predators, allowing a natural regulation of mosquito populations.

- Plant material must be able to withstand constant inundation of water to depths between six inches and one foot deep.
- Plants will be partially submerged.
- Plants should be able to enhance pollutant uptake.
- Plants may provide food and cover for waterfowl, desirable insects and other aquatic life.

Plants will stabilize the bottom of the pond, as well as the edge of the pond, absorbing wave impacts and reducing erosion, when water levels fluctuate. Plants also slow water velocities and increase sediment deposition rates. Plants can reduce resuspension of sediments caused by the wind. Plants can also soften the engineered contours of the pond, and can conceal drawdowns during dry weather

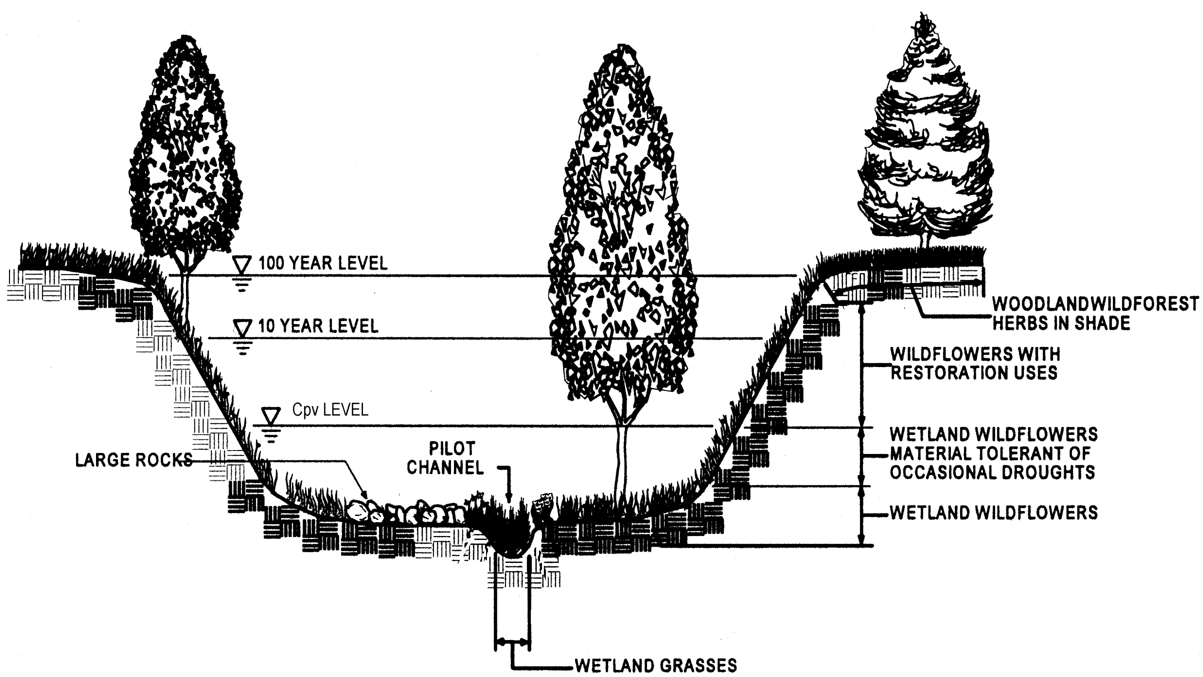

Figure A-2. Schematic Section of Typical Stormwater Management Detention Pond

A.2.3. Zone 3: Shoreline Fringe (Regularly Inundated)

Zone 3 encompasses the shoreline of a pond or wetland, and extends vertically about one foot in elevation from the normal pool. This zone includes the safety bench of a pond, and may also be periodically inundated if storm events are subject to extended detention. This zone occurs in a wet pond or shallow marsh (Figure A-3) and can be the most difficult to establish since plants must be able to withstand inundation of water during storms and prolonged drought conditions. In order to stabilize the soil in this zone, Zone 3 must have a vigorous cover. Planting a diverse mix of appropriate species is desirable, since hydrological conditions within this zone can be highly variable and hard to predict.

- Plants should stabilize the shoreline to minimize erosion caused by wave and wind action or water fluctuation.

- Plant material must be able to withstand occasional inundation of water. Plants will be partially submerged at this time.
- Plant material should, whenever possible, shade the shoreline, especially the southern exposure. This will help to reduce the water temperature.
- Plants should be able to enhance pollutant uptake.
- Plants may provide food and cover for waterfowl, songbirds, and wildlife. Plants can also be selected and located to control waterfowl.
- Plants should be located to reduce human access, where there are potential hazards, but should not block the maintenance access.
- Plants should have very low maintenance requirements, since they may be difficult or impossible to reach.
- Plants should be resistant to disease and other problems, which might require chemical applications.

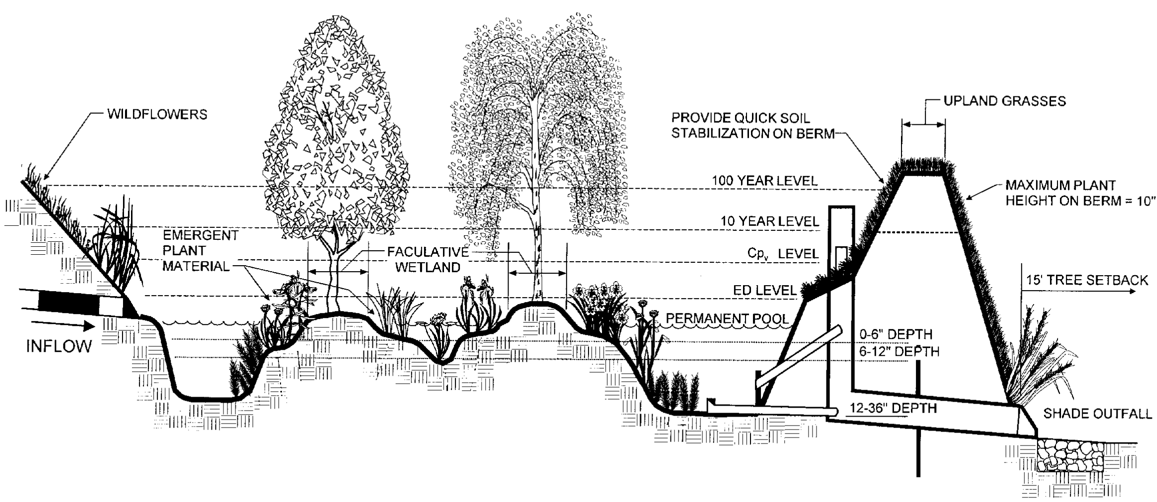

Figure A-3. Schematic Section of Shallow Marsh Wetland System

A.2.4. Zone 4: Riparian Fringe (Periodically Inundated)

Zone 4 extends from one to four feet in elevation above the normal pool. Plants in this zone are subject to periodic inundation during storms, and may experience saturated or partly saturated soils. Nearly all of the extended detention area is included within this zone.

- Plants must be able to withstand periodic inundation during storms, as well as occasional drought.
- Plants should stabilize the ground from erosion caused by run-off.
- Plants should be able to enhance pollutant uptake.
- Plant material should have very low maintenance, since they may be difficult or impossible to access.
- Plants may provide food and cover for waterfowl, songbirds and wildlife. Plants may also be selected and located to control waterfowl.

- Plants should be located to reduce pedestrian access to the deeper pools.

A.2.5. Zone 5: Floodplain Terrace (Infrequently Inundated)

Zone 5 is periodically inundated by flood waters that quickly recede in a day or less. Operationally, Zone 5 extends from the maximum 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 a low maintenance, natural vegetation.

- Plant material should be able to withstand occasional but brief inundation during storms, although typical moisture conditions may be moist, slightly wet, or dry.
- Plants should stabilize the basin slopes from erosion.
- Ground cover should be very low maintenance, since they may be difficult to access on steep slopes or if frequency of mowing is limited. A dense tree cover may help reduce maintenance and discourage resident geese.
- Plants may provide food and cover for waterfowl, songbirds, and wildlife.
- Placement of plant material in Zone 5 is often critical, as it often creates a visual focal point and provides structure and shade for a greater variety of plants.

A.2.6. Zone 6: Upland Slopes (Seldom or Never Inundated)

The last 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 material is capable of surviving the particular conditions of the site. Thus, it is not necessary to select plant material that will tolerate any inundation. Rather, plant selections should be made based on soil condition, light, and function within the landscape.
- Ground covers should emphasize 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.

The plant list in Appendix A.7 provides guidance on each plant's appropriate zones. The typical zones associated with each plant are shown in brackets “[ ].” In addition, there may be other zones listed outside of these brackets, which indicates that the plant materials may occur within these zones, but are not typically found in them.

A.3. Infiltration and Systems and Sand Filters

Infiltration systems include infiltration trenches and infiltration basins. Filter systems include sand filters. Properly planted, these systems blend into natural surroundings. If unplanted or improperly planted, they can become eyesores and liabilities.

- Do not plant trees or provide shade within 15 feet of infiltration or filtering area or where leaf litter will collect and clog infiltration area.
- Determine depth of water table to determine standing water conditions and depth to constant soil moisture.
- Planting turf over sand filters is allowed with prior approval of the reviewing public agency, on a case-by-case basis.
- Do not locate plants to block maintenance access to structures.
- Sod areas with heavy flows that are not stabilized with erosion control mats.
- Divert flows temporarily from seeded areas until stabilized.
- Planting of any filter requiring a filter fabric should include material selected with care to insure that no taproots will penetrate the filter fabric.

A.4. Bioretention

A.4.1. Mulch Layer

The mulch layer plays an important role in the performance of the bioretention system. The mulch layer helps maintain soil moisture and avoids surface sealing which reduces permeability. Mulch helps prevent erosion, and provides a micro-environment suitable for soil biota at the mulch/soil interface. Mulch also serves as a pretreatment layer, trapping the finer sediments which remain suspended after the primary pretreatment. The mulch layer should be shredded hardwood mulch that is well aged (stockpiled or stored for at least six (6) 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 three inches. Grass clippings should not be used as a mulch material.

Hardwood mulch can be very challenging to obtain in New England. Acceptable alternatives include mulching only around shrubs, and planting a conservation mix elsewhere to create a cover crop that can be mowed or weed-whacked; or planting two species of tall grasses and allowing the whole facility fill in. Regardless of the surface treatment chosen, it should outcompete or suppress weed growth, and minimize exposed soil.

Erosion control blankets installed across the bottom of the practice is not successful and should not be proposed.

A.4.2. Planting Plan Guidance

Plant material selection should be based on the goal of simulating a terrestrial forested community of native species. Bioretention simulates an ecosystem consisting of an upland-oriented community dominated by trees, but having a distinct community, or sub-canopy, of understory trees, shrubs and herbaceous materials. The intent is to establish a diverse, dense plant cover to treat stormwater runoff and withstand urban stresses from insect and disease infestations, drought, temperature, wind, and exposure.

The proper selection and installation of plant materials is key to a successful system. There are essentially three zones within a bioretention facility (Figure A-4). The lowest elevation supports plant species adapted to standing and fluctuating water levels. The middle elevation supports a slightly drier group of plants, but still tolerates fluctuating water levels. 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 A-2. For a more extensive bioretention plant list, consult ETAB, 1993 or Claytor and Schueler, 1997.

The layout of plant material should be flexible, but should follow the general principals described in Table A-3. The objective is to have a system which resembles a random and natural plant layout, while maintaining optimal conditions for plant establishment and growth.

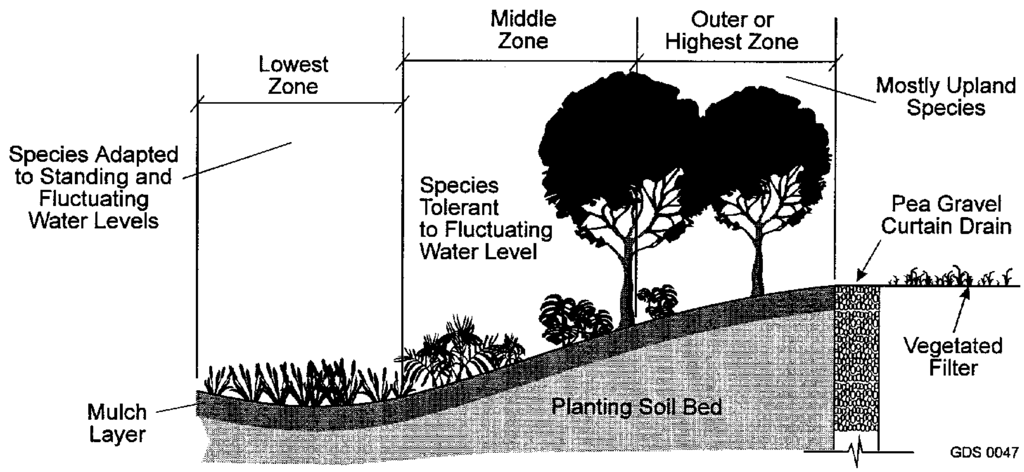

Figure A-4. Planting Zones for Bioretention Facilities

Table A-2. Native Plant Guide for Stormwater Bioretention Areas

Trees	Shrubs	Herbaceous Species
Acer rubrum Red Maple	*Hamemelis virginiana* Witch Hazel	*Iris versicolor* Blue Flag
Juniperus virginiata Eastern Red Cedar	*Ilex verticillata* Winterberry	*Lobelia cardinalis* Cardinal Flower
Platanus occidentalis Sycamore	*Viburnum dentatum* Arrowwood	*Rudbeckia laciniata* Cutleaf Coneflower
Salix nigra Black Willow	*Alnus serrulata* Brook-side Alder	*Scirpus cyperinus* Woolgrass
Pinus rigida *Pitch Pine*	*Cornus stolonifera* Redosier Dogwood	*Scirpus pungens* Three Square Bulrush
Note 1: For more options on plant selection for bioretention, consult Bioretention Manual (ETAB, 1993) or the Design of Stormwater Filtering Systems (Claytor and Schueler, 1996).		

Table A-3. Planting Plan Design Considerations

Native plant species should be specified over exotic or foreign species.
Appropriate vegetation should be selected based on the zone of hydric tolerance (see Figure A.4).
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.
Urban stressors (e.g., wind, sun, exposure, insect and disease infestation, drought) should be considered when laying out the planting plan.
Noxious weeds should not be specified (See ANR's Invasive Exotic Plants of Vermont List and the Agricultural Department's proposed Noxious Weed Quarantine List).
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.

A.4.3. Plant Material Guidance

Plant materials should conform to the American Standard Nursery Stock, published by the American Association of Nurserymen, and should be selected from certified, reputable nurseries. Planting specifications should be prepared by the designer and should include a sequence of construction, a description of the contractor's responsibilities, a planting schedule and installation specifications, initial maintenance, and a warranty period and expectations of plant survival. Table A-4 presents some typical issues for planting specifications.

Table A-4. 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 contractors responsibilities, such as watering, care of plant material during transport, timeliness of installation, repairs due to vandalism, etc.
Planting Schedule and Specifications	Specify the materials 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; removal of invasives; 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 expected condition of plant species at the end of the warranty period.

A.5. Open Channels

Consult Table A-5 for grass species that perform well in the stressful environment of an open channel.

Table A-5. Common Grass Species for Dry and Wet Swales & Grass Channels

Common Name	Scientific Name	Notes
Spreading Bentgrass	*Agrostis stolonifera*	Cool,
Red Fescue	*Festuca rubra*	Cool, not for wet swales
Bluejoint Reed grass	*Calamagrostis canadensis*	Cool, wet swales
Redtop	*Agrostis alba*	Cool
Notes: These grasses are sod-forming and can withstand frequent inundation, and are thus ideal for the swale or grass channel environment. Most are salt-tolerant, as well. Cool refers to cool season grasses. Where possible, one or more of these grasses should be in the seed mixes.		

A.6. Other Considerations in Stormwater STP 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 are so obvious, they may actually be overlooked in the plant selection. These are:

- Size

- Shape

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 could strategically block the a 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 the plant provides seasonal interest and whether the plant will fit with the landscape today and through the seasons and years to come. Some of these characteristics are:

- Color
- Texture
- Seasonal interest, i.e., flowers, fruit, leaves, stems/bark
- Growth rate

If shade is required in large amounts, quickly, a Planetree 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. Aesthetics is an important factor to consider in the design of these systems. Failure to consider the aesthetic appeal of a facility to the surrounding residents may result in reduced value to nearby lots. Careful attention to the design and planting of a facility can result in maintained or increased values of a property.

Availability and Cost

Often overlooked in plant selection is the availability from wholesalers and the cost of the plant material. There are many plants listed in landscape books that are not readily available from the nurseries. Without knowledge of what is available, time spent researching and finding the one plant that meets all the needs will be wasted. Some plants may require shipping, therefore, 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 function of the plant in the landscape.

A.7. Stormwater Plant Lists

The following pages present a detailed list of trees, shrubs, and herbaceous plants native to Vermont and suitable for planting in stormwater management facilities. The list is intended as a general guide for planning considerations. Local landscape architects/designers and nurseries may provide additional information for successful plant establishment.

The plant list is broken out into an herbaceous list and a woody list. Species are listed in alphabetical order, according to the common name. Scientific name and plant form (e.g., annual, perennial, grass, shrub, or tree) are also provided.

The recommended hydrologic zone(s) for each plant is provided to provide guidance on planting location. The most common zones are listed in brackets, “[ ]”, with additional zones listed indicating that a plant may survive over a range of hydrologic conditions.

A wetland indicator status is also listed to illustrate the likelihood of a species occurring in wetlands versus uplands (Reed, 1998). The indicator categories are defined as follows:

- **Obligate wetland (OBL):** plants, which nearly always (more than 99% of the time) occur in wetlands under natural conditions.

- **Facultative wetland (FACW):** plants, which usually (from 67% to 99% of the time) occur in wetlands, but occasionally found in nonwetlands.
- **Facultative (FAC)**: plants, which are equally likely to occur in wetlands and nonwetlands and are found in wetlands from 34% to 66% of the time.
- **Facultative upland (FACU):** plants, which usually occur in nonwetlands (from 67% to 99% of the time), but occasionally found in wetlands (from 1% to 33% of the time).
- **Upland (UPL):** plants, which almost always (more than 99% of the time) occur under natural conditions in nonwetlands.

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

An inundation tolerance indicator is provided to provide guidance on the sensitivity of plants to a depth and duration of flooding. Plants that can withstand a period of standing water are indicated with a "yes". Additional information is provided for depth of inundation and tolerance for seasonal inundation, saturated soil conditions, pollution, and salt. Additional research may be warranted to ensure successful plant establishment.

STORMWATER PLANT LIST A- HERBACEOUS VEGETATION

						TOLERANCE	
COMMON	**SCIENTIFIC**	**FORM**	**ZONE**	**INDICATOR**	**INUNDATION**	**POLLUTION**	**SALT**
ARROW-HEAD,BROAD-LEAF	*Sagittaria latifolia*	Perennial	[1,2],3	OBL	0-2'	No	No
ARROW-HEAD,GRASS-LEAF	*Sagittaria graminea*	Perennial	[1,2],3	OBL	0-1'	No	No
ARROW-HEAD,NORTHERN	*Sagittaria cuneata*	Perennial	[1,2],3	OBL	Yes	No	No
ARROW-HEAD,WAPATO DUCK POTATO	*Sagittaria latifolia*	Perennial	[1,2],3	OBL	0-2'	No	No
ASTER,CALICO	*Aster lateriflorus*	Perennial	[2,3,4]	FACW-	Seasonal	No	No
ASTER,FLAT-TOP WHITE	*Aster umbellatus*	Perennial	[2,3],4	FACW	Yes	No	No
ASTER,NEW ENGLAND	*Aster novae-angliae*	Perennial	[2,3],4	FACW	Yes	No	No
ASTER,NEW YORK	*Aster novi-belgii*	Perennial	[2,3],4	FACW+	Yes	No	No
ASTER,SWAMP	*Aster puniceus*	Perennial	1,[2,3]	OBL	Yes	No	No
ASTER,TRADESCANT	*Aster tradescanti*	Perennial	[2,3],4	FACW	Yes	No	No
ASTER,WHITE HEATH	*Aster ericoides*	Perennial	3,[4,5,6]	FACU	No	No	No
BEARDTONGUE	*Penstemon digitalis*	Perennial	3,4,5	FAC	No	No	No
BENTGRASS,PERENNIAL	*Agrostis perennans*	Grass	[4,5],6	FACU	Yes	No	No
BENTGRASS,SPREADING	*Agrostis stolonifera*	Grass	[2,3],4	FACW	Yes	No	No
BENTGRASS,WINTER	*Agrostis hyemalis*	Grass	[3,4],5	FAC	No	No	No
BERGAMOT,WILD	*Monarda fistulosa*	Perennial	[4,5,6]	UPL	No	No	No
BLACK-EYED SUSAN	*Rudbeckia hirta (yellow)*	Perennial	4,5,6	FACU-	No	No	No
BLOODROOT	*Sanguinaria canadensis*	Perennial	4,[5,6]	UPL,FACU-	No	No	No
BLUEGRASS,GROVE	*Poa alsodes*	Grass	2,[3,4],5	FACW-	Seasonal	No	No
BLUESTEM,BIG	*Andropogon gerardii*	Grass	[4,5],6	FAC	No	No	No
BULRUSH, HARDSTEMMED	*Scirpus acutus*	Perennial	[1,2],3	OBL	0-3'	No	No
BULRUSH, SOFTSTEM	*Scirpus validus*	Perennial	[1,2,],3	OBL	0-1'	No	No
BULRUSH,RIVER	*Scirpus fluviatilis*	Grass	[1,2],3	OBL	0-1'	No	No
BULRUSH,THREE-SQUARE	*Scirpus pungens*	Grass	[2,3],4	FACW+	0-6"	No	No
BURREED,AMERICAN	*Sparganium americanum*	Grass	[1,2],3	OBL	0-1'	No	No

						TOLERANCE	
COMMON	SCIENTIFIC	FORM	ZONE	INDICATOR	INUNDATION	POLLUTION	SALT
BURREED,GIANT	*Sparganium eurycarpum*	Grass	[1,2],3	OBL	Yes	No	No
CARDINAL FLOWER	*Lobelia cardinalis*	Perennial	1,[2,3],4	FACW+	Yes	No	No
CHOKEBERRY,BLACK	*Aronia melanocarpa*	Shrub	[4,5]	FAC	No	No	No
COLUMBINE,WILD	*Aquilegia canadensis*	Perennial	[3,4],5	FAC	No	No	No
CONEFLOWER,CUT-LEAF	*Rudbeckia laciniata*	Perennial	[2,3],4	FACW	Yes	No	No
CORDGRASS,PRAIRIE	*Spartina pectinata*	Grass	[1,2],3	OBL	Salt, Edge	No	Yes
CRANBERRY,HIGH BUS	*Viburnum trilobum*	Shrub	[3,4]	FACW	Yes	No	No
CUTGRASS,RICE	*Leersia oryzoides*	Grass	[1,2],3	OBL	0-6"	No	No
DOGWOOD,RED-OSIER	*Cornus stolonifera*	Shrub	[4]	FACW	Seasonal	No	No
DUCKWEED,LESSER	*Lemna minor*	Perennial	[1,2],3	OBL	Free Float	No	No
ELDERBERRY	*Sambucus candensis*	Shrub	[4]	FACW	Seasonal	No	No
FALSE-HELLEBORE,AMERICAN	*Veratrum viride*	Perennial	[2,3,4]	FACW+	Yes	No	No
FALSE-SOLOMON'S-SEAL,FEATHER	*Smilacina racemosa*	Perennial	[4,5],6	FACU-	No	No	No
FERN,CINNAMON	*Osmunda cinnamomea*	Fern	[2,3],4	FACW	Saturated	No	No
FERN,NEW YORK	*Thelypteris noveboracensis*	Fern	[3,4],5	FAC	Saturated	No	No
FERN,ROYAL	*Osmunda regalis*	Fern	[1,2],3	OBL	Saturated	No	No
FERN,SENSITIVE	*Onoclea sensibilis*	Fern	[2,3],4	FACW	Saturated	No	No
FESCUE,RED	*Festuca rubra*	Groundcover	[4,5]	FACU	No	No	No
GRASS,CANADA MANNA	*Glyceria canadensis*	Grass	[1,2],3	OBL	0-1'	No	No
GRASS,FOWL MANNA	*Glyceria striata*	Grass	[1,2],3	OBL	Seasonal	No	No
GRASS,ROUGH BARNYARD	*Echinochloa muricata*	Grass	[2,3],4	FACW+	Yes	No	No
HAREBELL	*Campanula rotundifolia*	Perennial	[5,6]	FACU		No	No
HOBBLEBUSH	*Viburnum alnifolium*	Shrub	[5]	FAC	No	No	No
HONEYSUCKLE,BUSH	*Diervilla lonicera*	Shrub	[6]	UPL	No	No	No
HORNWORT,COMMON	*Ceratophyllum demersum*	Perennial	[1,2],3	OBL	1-5'	No	No
HORSETAIL,ROUGH	*Equisetum hyemale*	Grass	[2,3],4	FACW	Yes	No	No
INDIAN-TOBACCO	*Lobelia inflata*	Perennial	[4,5,6]	FACU	No	No	No

COMMON	SCIENTIFIC	FORM	ZONE	INDICATOR	INUNDATION	TOLERANCE POLLUTION	SALT
IRIS, BLUE WATER	*Iris versicolor*	Perennial	[1,2],3	OBL	0-6"	No	No
JACK-IN-THE-PULPIT,SWAMP	*Arisaema triphyllum*	Perennial	[2,3],4	FACW	Seasonal	No	No
LILY,CANADA	*Lilium canadense*	Perennial	2,[3,4]	FAC+	Yes	No	No
LOBELIA,BROOK	*Lobelia kalmii*	Perennial	[1,2],3	OBL	Yes	No	No
LOBELIA,PALE-SPIKE	*Lobelia spicata*	Perennial	[3,4,5]	FAC-	No	No	No
LOBELIA,WATER	*Lobelia dortmanna*	Perennial	[1,2],3	OBL	Yes	No	No
LOVEGRASS,PURPLE	*Eragrostis pectinacea*	Grass	[4,5],6	FAC	No	No	No
MARSH MARIGOLD	*Caltha palustris*	Perennial	3,4	OBL	6"Saturate	No	No
MARSH SMARTWEED	*Polygonum puntatum*	Perennial	2,3	OBL	Saturated	No	No
MONKEY-FLOWER	*Mimulus ringens*	Perennial	[1,2],3	OBL	Yes	No	No
MUHLY,MARSH	*Muhlenbergia glomerata*	Grass	[2,3],4	FACW	Yes	No	No
PARTRIDGE-BERRY	*Mitchella repens*	Groundcover	[4,5],6	FACU	No	No	No
PENNSYLVANIA SMARTWEED	*Polygonum pensylvanicum*	Annual	[2,3]	FACW	0-6"	No	No
PICKERELWEED	*Pontederia cordata*	Perennial	2,3	OBL	0-1'	No	No
PITCHER PLANT	*Sarracenia purpurea*	Perennial	[3,4]	OBL	Yes	No	No
PONDWEED,CLASPING-LEAF	*Potamogeton perfoliatus*	Perennial	[1,2],3	OBL	1' Min-6'	No	No
PONDWEED,LONG-LEAF	*Potamogeton nodosus*	Perennial	[1,2]	OBL	1' Min-6'	No	No
PONDWEED,SAGO	*Potamogeton pectinatus*	Perennial	[1,2]	OBL	1' Min-24'	No	No
REEDGRASS,BLUE-JOINT	*Calamagrostis canadensis*	Grass	[1,2],3	FACW+	6"Saturate	No	No
ROSE,VIRGINIA	*Rosa virginiana*	Shrub	[5]	FAC	No	No	No
RUSH,NARROW-PANICLE	*Juncus brevicaudatus*	Grass	[1,2],3	OBL	Yes	No	No
RUSH,SOFT	*Juncus effusus*	Grass	[2,3],4	FACW+	0-1'	No	No
SAXIFRAGE,SWAMP	*Saxifraga pensylvanica*	Perennial	[1,2],3	OBL	Yes	No	No
SAXIFRAGE,VIRGINIA	*Saxifraga virginiensis*	Perennial	[4,5]	FAC-	No	No	No
SEDGE,BEARDED	*Carex comosa*	Grass	[1,2],3	OBL	6"Saturate	No	No
SEDGE,CRESTED	*Carex cristatella*	Grass	[1,2],3,4	FACW	Yes	No	No
SEDGE,FOX	*Carex vulpinoidea*	Grass	[1,2],3	OBL	Sat. 0-6"	No	No
SEDGE,FRINGED	*Carex crinita*	Grass	[1,2],3	OBL	Yes	No	No
SEDGE,GRACEFUL	*Carex gracillima*	Grass	[4,5],6	FACU	No	No	No

						TOLERANCE	
COMMON	SCIENTIFIC	FORM	ZONE	INDICATOR	INUNDATION	POLLUTION	SALT
SEDGE,HOARY	*Carex canescens*	Grass	[1,2],3	OBL	Yes	No	No
SEDGE,INLAND	*Carex interior*	Grass	1,[2,3]	OBL	Yes	No	No
SEDGE,LAKEBANK	*Carex lacustris*	Grass	[1,2],3	OBL	Sat.. 0-2'	No	No
SEDGE,LOOSE-FLOWERED	*Carex laxiflora*	Grass	[4,5,6]	FACU	No	No	No
SEDGE,RETRORSE	*Carex retrorsa*	Grass	[2,3],4	FACW+	Sat. 0-6"	No	No
SEDGE,SHALLOW	*Carex lurida*	Grass	[1,2],3	OBL	Yes	No	No
SEDGE,SWAN'S	*Carex swanii*	Grass	[4,5,6]	FACU	No	No	No
SEDGE,TUSSOCK	*Carex stricta*	Grass	[2,3,4]	OBL	Seasonal	No	No
SEDGE,UPTIGHT	*Carex stricta*	Grass	[1,2],3	OBL	Sat.0-6"	No	No
SEDGE,YELLOW-FRUIT	*Carex annectens*	Grass	[2,3,]4	FACW+	Yes	No	No
SPIKERUSH,BLUNT	*Eleocharis obtusa*	Grass	[1,2],3	OBL	0-6"	No	No
SPIKERUSH,CREEPING	*Eleocharis palustris*	Grass	[1,2],3	OBL	Seasonal	No	No
ST. JOHN'S-WORT,MARSH	*Triadenum fraseri*	Perennial	[1,2],3	OBL	Yes	No	No
STEEPLEBUSH	*Spirea tomentosa*	Shrub	[4]	FACW	Seasonal	No	No
SWAMP MILKWEED	*Asclepias incarnata*	Perennial	2,3	OBL	Saturated	No	No
SWAMP-LOOSESTRIFE,HAIRY	*Decodon verticillatus*	Perennial	[1,2],3	OBL	Yes	No	No
SWEETFLAG	*Acorus calmus*	Perennial	[2]	OBL	Yes	No	No
TRILLIUM,RED	*Trillium erectum*	Annual	[5,6]	FACU	No	No	No
TRILLIUM,WHITE	*Trillium grandiflorum*	Annual	[6]	UPL	No	No	No
TURTLEHEAD,WHITE	*Chelone glabra*	Perennial	[1,2],3	OBL	Yes	No	No
VERVAIN,BLUE	*Verbena hastata*	Perennial	2,3,4	FACW+	Yes	No	No
VIRGINIA WILD RYE	*Elymus virginicus*	Grass	2,[3,4]	FACW-	Yes	No	No
WATER ARUM	*Calla palustris*	Perennial	[2]	OBL		No	No
WATER SMARTWEED	*Polygonum amphibium*	Perennial	2,3	OBL	6"-Sat	No	No
WATER-LILY,WHITE	*Nymphaea tuberosa*	Perennial	[1,2],3	OBL	1-3'	No	No
WATER-LILY,YELLOW/ SPATTERDOCK	*Nuphar advena/luteum*	Perennial	[1,2],3	OBL	1-3'	No	No
WILD-LILY-OF-THE-VALLEY	*Maianthemum canadense*	Perennial	[4,5],6	FAC-	No	No	No
WINTERGREEN	*Gaultheria procumbens*	Shrub	[5,6]	FACU	No	No	No
WOOD-REEDGRASS,SLENDER	*Cinna latifolia*	Grass	[2,3,4]	FACW	Yes	No	No
WOODRUSH,COMMON	*Luzula multiflora*	Grass	[4,5,6]	FACU	No	No	No
WOOL-GRASS	*Scirpus cyperinus*	Grass	[2,3],4	FACW+	Seasonal	No	No

STORMWATER PLANT LIST B - WOODY VEGETATION

						TOLERANCE	
COMMON	**SCIENTIFIC**	**FORM**	**ZONE**	**INDICATOR**	**INUNDATION**	**POLLUTION**	**SALT**
ALDER,BROOK-SIDE	*Alnus serrulata*	Tree	[1,2],3	OBL	0-3"	No	No
ARROW-WOOD	*Viburnum dentatum*	Shrub	[3,4],5	FAC	Seasonal	No	Yes
ASH,BLACK	*Fraxinus nigra*	Tree	[2,3],4	FACW	Saturated	No	No
ASH,GREEN	*Fraxinus pennsylvanica*	Tree	[2,3],4	FACW	Seasonal	No	Yes
ASH,WHITE	*Fraxinus americana*	Tree	[4,5],6	FACU	No	No	No
ASPEN,BIG-TOOTH	*Populus grandidentata*	Tree	[4,5,6]	FACU	No	No	No
ASPEN,QUAKING	*Populus tremuloides*	Tree	[4,5],6	FACU	Yes	No	No
AZALEA,EARLY	*Rhododendron*	Shrub	[2,3,4],5	FAC,FAC+	Yes	No	No
BASSWOOD,AMERICAN	*Tilia americana*	Tree	3,[4,5],6	FACU	No	No	No
BEECH,AMERICAN	*Fagus grandifolia*	Tree	[4,5],6	FACU	No	No	No
BIRCH,GRAY	*Betula populifolia*	Tree	[3,4],5	FAC	Seasonal	No	No
BIRCH,PAPER	*Betula papyrifera*	Tree	[5,6]	FACU	No	No	No
BIRCH,YELLOW	*Betula alleghaniensis*	Tree	[3,4],5	FAC	Yes	No	No
BLADDERNUT, AMERICAN	*Staphylea trifolia*	Shrub-Tree	[3,4],5	FAC	Yes	No	No
BLUEBERRY,LOWBUSH	*Vaccinium angustifolium*	Shrub	3,[4,5,6]	FACU-,FACU	No	No	No
BLUEBERRY,VELVET-LEAF	*Vaccinium myrtilloides*	Shrub	1,2,[3,4,5]	FACU,FACW-	Yes	No	No
BOX-ELDER	*Acer negundo*	Tree	2,[3,4]	FAC+	Seasonal	No	No
BUFFALO-BERRY,CANADA	*Shepherdia canadensis*	Shrub	6	NI	No	No	Yes
BUTTERNUT	*Juglans cinerea*	Tree	[3,4,5,6]	FACU-,FACU+	Yes	No	No
BUTTONBUSH,COMMON	*Cephalanthus occidentalis*	Shrub	[1,2],3	OBL	0-3'	No	No
CEDAR,EASTERN RED	*Juniperus virginiana*	Shrub	4,5,6	FACU	No	Yes	No
CEDAR,NORTHERN WHITE	*Thuja occidentalis*	Tree	[2,3],4	FACW	Seasonal	No	No
CHERRY,BLACK	*Prunus serotina*	Tree	[4,5],6	FACU	No	No	No
CHERRY,CHOKE	*Prunus virginiana*	Tree	4,5,6	FACU	Yes	No	No
CHERRY,FIRE	*Prunus pensylvanica*	Tree	4,5,6	FACU	No	No	No

COMMON	SCIENTIFIC	FORM	ZONE	INDICATOR	INUNDATION	TOLERANCE POLLUTION	SALT
CHERRY,PIN	*Prunus pensylvanica*	Tree	[5]	FACU	No	No	No
COTTON-WOOD,EASTERN	*Populus deltoides*	Tree	[3,4],5	FAC	Seasonal	Yes	Yes
CRANBERRY,SMALL	*Vaccinium oxycoccos*	Shrub	[1,2],3	OBL	Yes	No	No
DOGWOOD,REDOSIER	*Cornus Stolonifera*	Shrub	3,4		Yes	No	No
DOGWOOD,SILKY	*Cornus amomum*	Shrub	[2,3],4	FACW	Seasonal	No	No
ELDER,EUROPEAN RED	*Sambucus racemosa*	Shrub	[3,4,5],6	FACU,FACU+	Yes	No	No
ELM,SLIPPERY	*Ulmus rubra*	Tree	[3,4],5	FAC	Yes	No	No
FIR,BALSAM	*Abies balsamea*	Tree	[5]	FAC	Seasonal	No	No
GERMANDER,AMERICAN	*Teucrium canadense*	Shrub	1,[2,3,4],5	FAC+,FACW	Yes	No	No
HACKBERRY,COMMON	*Celtis occidentalis*	Shrub-Tree	4,5,6	FACU	Seasonal	Yes	No
HAWTHORN,COCKSPUR	*Crataegus crus-galli*	Tree	2,[3,4,5],6	FACU,FAC	Yes	Yes	No
HAZEL-NUT,BEAKED	*Corylus cornuta*	Shrub	3,[4,5,6]	UPL,FACU	No	No	No
HEMLOCK,EASTERN	*Tsuga canadensis*	Tree	4,5,6	FACU	No	No	No
HICKORY,BITTER-NUT	*Carya cordiformis*	Tree	4,5,6	FACU+	No	No	No
HICKORY,SHAG-BARK	*Carya ovata*	Tree	[3,4,5,6]	FACU-,FACU+	Yes	No	No
HOP-HORNBEAM,EASTERN	*Ostrya virginiana*	Shrub-Tree	[3,4,5,6]	FACU-,FACU+	Yes	No	No
HORNBEAM,AMERICAN	*Carpinus caroliniana*	Tree	[3,4],5	FAC	Some	No	No
HUCKLEBERRY,BLACK	*Gaylussacia baccata*	Shrub	3,[4,5],6	FACU	No	No	No
LARCH/TAMARACK	*Larix laricina*	Tree	[4,5]	FACW	No	No	No
MAPLE,MOUNTAIN	*Acer spicatum*	Tree	4,5,6	FACU	No	No	No
MAPLE,RED	*Acer rubrum*	Tree	[3,4],5	FAC	Seasonal	No	No
MAPLE,SILVER	*Acer saccharinum*	Tree	[2,3],4	FACW	Seasonal	No	No
MAPLE,STRIPED	*Acer pensylvanicum*	Shrub-Tree	3,[4,5,6]	FACU-,FACU	No	No	No
MAPLE,SUGAR	*Acer saccharinum*	Tree	[5,6]	FACU	No	No	No
MEADOW-SWEET,NARROW-LEAF	*Spiraea alba*	Shrub	[1,2,3,4],5	FACW,FACW+	Yes	No	No
NANNYBERRY	*Viburnum lentago*	Shrub	[3,4],5	FAC	Seasonal	No	No
OAK, SCARLET	*Quercus coccinea*	Tree	6		No	No	No

COMMON	SCIENTIFIC	FORM	ZONE	INDICATOR	INUNDATION	TOLERANCE POLLUTION	SALT
OAK,BUR	*Quercus macrocarpa*	Tree	3,[4,5],6	FAC-	Yes	Yes	No
OAK,CHESTNUT	*Quercus prinus*	Tree	4,5,6	FACU	No	No	No
OAK,CHINKAPIN	*Quercus muhlenbergii*	Tree	[3,4],5	FAC	Yes	No	No
OAK,RED	*Quercus rubra*	Tree	6		No	Yes	No
OAK,SWAMP WHITE	*Quercus bicolor*	Tree	1,[2,3]	FACW+	Seasonal	No	No
OAK,WHITE	*Quercus alba*	Tree	[4,5,6]	FACU	Yes	No	No
PINE,EASTERN WHITE	*Pinus strobus*	Tree	4,5,6	FACU	No	Yes	Yes
PINE,PITCH	*Pinus rigida*	Tree	4,5,6	FACU	Seasonal	No	Yes
PLUM,CANADA	*Prunus nigra*	Tree	[6]	UPL	No	No	No
POPLAR,BALSAM	*Populus balsamifera*	Tree	[4]	FACW	Seasonal	No	No
RHODODENDRON	*Rhododendron canadense*	Shrub	1,[2,3,4],5	FACW	Yes	No	No
ROSEMARY,BOG	*Andromeda polifolia*	Shrub	[1,2],3	OBL	Yes	No	No
SASSAFRAS	*Sassafras albidum*	Tree	3,[4,5,6]	FACU-,FACU	No	No	No
SERVICE-BERRY,DOWNY	*Amelanchier arborea*	Shrub-Tree	2,[3,4,5],6	FAC-	Yes	No	No
SHEEP-LAUREL	*Kalmia angustifolia*	Shrub	3,[4,5],6	FAC	Yes	No	No
SPRUCE,WHITE	*Picea glauca*	Tree	[5,6]	FACU	No	No	No
STEEPLE-BUSH	*Spiraea tomentosa*	Shrub	1,[2,3,4],5	FACW	Yes	No	No
SUMAC,STAGHORN	*Rhus typhina*	Tree	[6]	UPL	No	No	No
SYCAMORE,AMERICAN	*Platanus occidentalis*	Tree	[2,3],4	FACW-	Saturated	No	No
TEABERRY	*Gaultheria procumbens*	Shrub	3,[4,5],6	FACU	No	No	No
VIBURNUM,MAPLE-LEAF	*Viburnum acerifolium*	Shrub	3,[4,5,6]	UPL,FACU	No	No	No
WILLOW,BLACK	*Salix nigra*	Tree	[2,3]	FACW+	Seasonal	No	No
WILLOW,PUSSY	*Salix discolor*	Tree	[3,4]	FACW	Seasonal	No	No
WILLOW,SILKY	*Salix sericea*	Shrub	[1,2],3	OBL	Yes	No	No
WILLOW,TALL PRAIRIE	*Salix humilis*	Shrub	3,[4,5],6	FACU	No	No	No
WINTERBERRY,COMMON	*Ilex verticillata*	Shrub	1,[2,3]	FACW+	Seasonal	No	No
WITCH-HAZEL, AMERICAN	*Hamamelis virginiana*	Shrub-Tree	3,[4,5],6	FAC-	No	Yes	No
WITHE-ROD	*Viburnum cassinoides*	Shrub	1,[2,3,4],5	FACW	Yes	No	No
YEW,AMERICAN	*Taxus canadensis*	Shrub	2,[3,4,5],6	FACU,FAC	Yes	No	No

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APPENDIX B STP CONSTRUCTION AND MATERIALS SPECIFICATIONS

B.1. Construction Standards and Specifications for Treatment Wetlands and Stormwater Basins

These standards and specifications are generally appropriate to earthen basins constructed for the purposes of stormwater management. Practitioners proposing to construct a dam or an excavation that will impound more than 500,000 cubic feet are regulated by state statute, 10 V.S.A. Chapter 43. Specifications for smaller stormwater impoundments (e.g., those which hold less than 500,000 cubic feet) with an embankment height of 3 feet or more, and those with an embankment height of less than 3 feet, are provided below. The height of the embankment is measured from the low point on the upstream toe of the embankment to the design high water elevation.

All references to ASTM and AASHTO specifications apply to the most recent version.

B.1.1. Site Preparation

Site preparation should be in accordance with VTrans specifications and the following provisions, as applicable:

- Areas designated for borrow areas, embankment, and structural works shall be cleared, grubbed and stripped of topsoil. All trees, vegetation, roots and other objectionable material shall be removed. Channel banks and sharp breaks shall be sloped to no steeper than 1:1. All trees shall be cleared and grubbed within 15 feet of the toe of the embankment, and within 25 feet of the principal spillway outlet.
- Areas to be covered by the impoundment will be cleared of all trees, brush, logs, fences, rubbish and other objectionable material unless otherwise designated on the plans. Trees, brush, and stumps shall be cut approximately level with the ground surface.
- All cleared and grubbed material shall be disposed of outside and below the limits of the dam and/or reservoir. When specified, a sufficient quantity of topsoil will be stockpiled in a suitable location for use on the embankment and other designated areas.

B.1.2. Earth Fill and Backfill for Stormwater Facilities with an Embankment Height of 3 Feet or More

Materials

Earth fill should be in accordance with VTrans specifications and the following provisions, as applicable:

- The fill material shall be taken from approved designated borrow areas. It shall be free of roots, stumps, wood, rubbish, stones greater than 6 inches, and frozen or other objectionable materials. Fill material for the center of the embankment, and cut off trench shall conform to Unified Soil Classification GC, SC, CH, or CL and must have at least 30% passing the #200 sieve. Consideration may be given to the use of other materials in the embankment if designed by a licensed geotechnical engineer. Such special designs must have construction supervised by a geotechnical engineer. Materials used in the outer shell of the embankment must have the capability to support vegetation of the quality required to prevent erosion of the embankment.

Execution

- Areas on which fill is to be placed shall be scarified prior to placement of fill.
- Fill materials shall be placed in maximum 8-inch thick (before compaction) layers which are to be continuous over the entire length of the fill. The most permeable borrow material shall be placed in the downstream portions of the embankment. The principal spillway must be installed concurrently with fill placement and not excavated into the embankment.

- The movement of the hauling and spreading equipment over the fill shall be controlled so that the entire surface of each lift shall be traversed by not less than one tread track of heavy equipment or compaction shall be achieved by a minimum of four complete passes of a sheepsfoot, rubber tired or vibratory roller. Fill material shall contain sufficient moisture such that the required degree of compaction (see next bullet) will be obtained with the equipment used. The fill material shall contain sufficient moisture so that if formed into a ball it will not crumble, yet not be so wet that water can be squeezed out.
    - The minimum required density shall not be less than 95% of maximum dry density with a moisture content within 2% of the optimum. Each layer of fill shall be compacted as necessary to obtain that density, and is to be certified by the Engineer at the time of construction. All compaction is to be determined by AASHTO Method T-99 (Standard Proctor).
- The cut-off trench shall be excavated into low hydraulic conductivity material to the depth specified along or parallel to the centerline of the embankment as shown on the plans. The bottom width of the trench shall be governed by the equipment used for excavation, with the minimum width being four feet. The depth shall be at least four feet below existing grade or as shown on the plans. The side slopes of the trench shall be 1:1 or flatter. The backfill shall be compacted with construction equipment, rollers, or hand tampers to assure maximum density and minimum permeability.
- The core shall be parallel to the centerline of the embankment as shown on the plans. The top width of the core shall be a minimum of four feet. The height shall extend up to at least the 100-year water elevation or as shown on the plans. The side slopes shall be 1:1 or flatter. The core shall be compacted with construction equipment, rollers, or hand tampers to assure maximum density and minimum permeability. In addition, the core shall be placed concurrently with the outer shell of the embankment.

Backfilling

Backfilling should be performed in accordance with VTrans specifications and the following provisions, as applicable.

- Backfill adjacent to pipes or structures shall be of the type and quality conforming to that specified for the adjoining fill material.
- The fill shall be placed in horizontal layers not to exceed four inches in thickness and compacted by hand tampers or other manually directed compaction equipment. The material needs to fill completely all spaces under and adjacent to the pipe.

Structure backfill may be flowable fill meeting the requirements of the Federal Highway Administration standards:

- The mixture shall have a 100-200 psi; 28-day unconfined compressive strength. The flowable fill shall have a minimum pH of 4.0 and a minimum resistivity of 2,000 ohm-cm.
- Material shall be placed such that a minimum of 6 inches (measured perpendicular to the outside of the pipe) of flowable fill shall be under (bedding), over and, on the sides of the pipe. It only needs to extend up to the spring line for rigid conduits.
- Average slump of the fill shall be 7 inches to assure flowability of the material.
- Adequate measures shall be taken (sand bags, etc.) to prevent floating the pipe.
- All metal pipe in areas backfilled with flowable fill shall be bituminous coated.
- Any adjoining soil fill shall be placed in horizontal layers not to exceed 4 inches in thickness and compacted by hand tampers or other manually directed compaction equipment.
- The material shall completely fill all voids adjacent to the flowable fill zone.

- At no time during the backfilling operation shall driven equipment be allowed to operate closer than four feet, measured horizontally, to any part of a structure.
- Under no circumstances shall equipment be driven over any part of a structure or pipe unless there is a compacted fill of 24 inches or greater over the structure or pipe.
- Backfill material outside the structural backfill (flowable fill) zone shall be of the type and quality conforming to that specified for the core of the embankment or other embankment materials.

B.1.3. Earth Fill and Backfill for Stormwater Facilities with an Embankment Height of Less Than 3 Feet

Materials

Fill material shall be furnished from designated borrow areas and shall be free of roots, stumps, wood, rubbish, stones greater than 6 inches, frozen or other objectionable materials. The embankment shall be formed of material conforming to ASTM D2487 Unified Soil Classification System SC, CL CH, MH, ML, or SM.

Execution

- Remove all unsuitable soil and scarify subgrade prior to placement of fill.
- Provide a key trench beneath the berm. Extend trench a minimum of 1 foot below grade with a minimum width of 2 feet.
- Place backfill and fill in layers not more than 8 inches in loose depth for material compacted by heavy compaction equipment, and not more than 4 inches in loose depth for material compacted by hand-operated tampers.
- Place the backfill and fill soils materials evenly on all sides up to the required elevations. Place the most permeable borrow material along the downstream portions of the embankment.
- Compact soil materials to not less than 95% of maximum dry density with a moisture content within 2% of optimum according to ASTM D1557.
- Embankment slopes shall not be steeper than 2:1 (H:V) with a minimum top width of 3 feet.

B.1.4. Pipe Conduits

All pipes shall be circular in cross section.

B.1.5. Corrugated Metal Pipe

Corrugated metal pipe should be in accordance with VTrans specifications and the following provisions, as applicable. All of the following criteria shall apply for corrugated metal pipe:

- *Polymer-coated Steel Pipe* - Steel pipes with polymeric coatings shall have a minimum coating thickness of 0.01 inch (10 mil) on both sides of the pipe. This pipe and its appurtenances shall conform to the requirements of AASHTO Specifications M-245 & M-246 with watertight coupling bands or flanges.
- *Aluminum-coated Steel Pipe* - This pipe and its appurtenances shall conform to the requirements of AASHTO Specification M-274 with watertight coupling bands or flanges. Aluminum Coated Steel Pipe, when used with flowable fill or when soil and/or water conditions warrant the need for increased durability, shall be fully bituminous coated per requirements of AASHTO Specification M-190 Type A. Any aluminum coating damaged or otherwise removed shall be replaced with cold applied bituminous coating compound. Aluminum

surfaces that are to be in contact with concrete shall be painted with one coat of zinc chromate primer or two coats of asphalt.

- *Aluminum Pipe* - This pipe and its appurtenances shall conform to the requirements of AASHTO Specification M-196 or M-211 with watertight coupling bands or flanges. Aluminum Pipe, when used with flowable fill or when soil and/or water conditions warrant for increased durability, shall be fully bituminous coated per requirements of AASHTO Specification M-190 Type A. Aluminum surfaces that are to be in contact with concrete shall be painted with one coat of zinc chromate primer or two coats of asphalt. Hot dip galvanized bolts may be used for connections. The pH of the surrounding soils shall be between 4 and 9.
- All appurtenances (e.g., coupling bands, anti-seep collars, end sections, etc.) must be composed of the same material and coatings as the pipe. Metals must be insulated from dissimilar materials with use of rubber or plastic insulating materials at least 24 mils in thickness.
- All connections with pipes must be completely watertight. The drain pipe or barrel connection to the riser shall be welded all around when the pipe and riser are metal. Anti-seep collars shall be connected to the pipe in such a manner as to be completely watertight. Dimple bands are not considered to be watertight.

All connections shall use a rubber or neoprene gasket when joining pipe sections. The end of each pipe shall be re-rolled an adequate number of corrugations to accommodate the bandwidth. The following type connections are acceptable for pipes less than 24 inches in diameter: flanges on both ends of the pipe with a circular 3/8 inch closed cell neoprene gasket, pre-punched to the flange bolt circle, sandwiched between adjacent flanges; a 12-inch wide standard lap type band with 12-inch wide by 3/8-inch thick closed cell circular neoprene gasket; and a 12-inch wide hugger type band with o-ring gaskets having a minimum diameter of 1/2 inch greater than the corrugation depth. Pipes 24 inches in diameter and larger shall be connected by a 24-inch long annular corrugated band using a minimum of 4 (four) rods and lugs, 2 on each connecting pipe end. A 24-inch wide by 3/8-inch thick closed cell circular neoprene gasket will be installed with 12 inches on the end of each pipe. Flanged joints with 3/8-inch closed cell gaskets the full width of the flange is also acceptable.

Helically corrugated pipe shall have either continuously welded seams or have lock seams with internal caulking or a neoprene bead.

- The pipe shall be firmly and uniformly bedded throughout its entire length. Where rock or soft, spongy or other unstable soil is encountered, all such material shall be removed and replaced with suitable earth compacted to provide adequate support.
- Backfilling shall conform to “Structure Backfill.”
- Other details (anti-seep collars, valves, etc.) shall be as shown on the drawings.

B.1.6. Reinforced Concrete Pipe

Reinforced concrete pipe should be in accordance with VTrans specifications and the following provisions, as applicable. All of the following criteria shall apply for reinforced concrete pipe:

- Reinforced concrete pipe shall have bell and spigot joints with rubber gaskets and shall equal or exceed ASTM C-361.
- Reinforced concrete pipe conduits shall be laid in a concrete bedding / cradle for their entire length. This bedding / cradle shall consist of high slump concrete placed under the pipe and up the sides of the pipe at least 50% of its outside diameter with a minimum thickness of 6 inches. Where a concrete cradle is not needed for structural reasons, flowable fill may be used as described in the "Structure Backfill" section of this standard. Gravel bedding is not permitted.

- Bell and spigot pipe shall be placed with the bell end upstream. Joints shall be made in accordance with recommendations of the manufacturer of the material. After the joints are sealed for the entire line, the bedding shall be placed so that all spaces under the pipe are filled. Care shall be exercised to prevent any deviation from the original line and grade of the pipe. The first joint must be located within 4 feet from the riser.
- Backfilling shall conform to "Structure Backfill".
- Other details (anti-seep collars, valves, etc.) shall be as shown on the drawings.

B.1.7. Plastic Pipe

Plastic pipe should be in accordance with VTrans specifications and the following provisions, as applicable. The following criteria shall apply for plastic pipe:

- PVC pipe shall be PVC-1120 or PVC-1220 conforming to ASTM D-1785 or ASTM D-2241. Corrugated High Density Polyethylene (HDPE) pipe, couplings and fittings shall conform to the following: 4 – 10 inch pipe shall meet the requirements of AASHTO M252 Type S, and 12 inch through 24 inch shall meet the requirements of AASHTO M294 Type S.
- Joints and connections to anti-seep collars shall be completely watertight.
- The pipe shall be firmly and uniformly bedded throughout its entire length. Where rock or soft, spongy or other unstable soil is encountered, all such material shall be removed and replaced with suitable earth compacted to provide adequate support.
- Backfilling shall conform to “Structure Backfill.”
- Other details (anti-seep collars, valves, etc.) shall be as shown on the drawings.

B.1.8. Drainage Diaphragms

When a drainage diaphragm is used, a VT-licensed PE or qualified designee will supervise the design and construction inspection.

B.1.9. Concrete

Concrete should meet the requirements of the VTrans specifications.

B.1.10. Rock Riprap

Rock riprap should be in accordance with VTrans specifications and the following provisions, as applicable.

Filter fabric placed beneath the riprap shall meet federal department of transportation requirements for a Class "C" filter fabric. Some acceptable filter fabrics that meet the Class "C" criteria include:

- Mirafi 180-N
- Amoco 4552
- Webtec N07
- Geolon N70
- Carthage FX-70S

This is only a partial listing of available filter fabrics. It is the responsibility of the engineer to verify the adequacy of the material, as there are changes in the manufacturing process and the type of fabric used, which may affect the continued acceptance.

B.1.11. Care of Water During Construction

All work on permanent structures shall be carried out in areas free from water. The Contractor shall construct and maintain all temporary dikes, levees, cofferdams, drainage channels, and stream diversions necessary to protect the areas to be occupied by the permanent works. The contractor shall also furnish, install, operate, and maintain all necessary pumping and other equipment required for removal of water from various parts of the work and for maintaining the excavations, foundation, and other parts of the work free from water as required or directed by the engineer for constructing each part of the work. After having served their purpose, all temporary protective works shall be removed or leveled and graded to the extent required to prevent obstruction in any degree whatsoever of the flow of water to the spillway or outlet works and so as not to interfere in any way with the operation or maintenance of the structure. Stream diversions shall be maintained until the full flow can be passed through the permanent works. The removal of water from the required excavation and the foundation shall be accomplished in a manner and to the extent that will maintain stability of the excavated slopes and bottom required excavations and will allow satisfactory performance of all construction operations. During the placing and compacting of material in required excavations, the water level at the locations being refilled shall be maintained below the bottom of the excavation at such locations which may require draining the water sumps from which the water shall be pumped.

B.1.12. Stabilization

All borrow areas shall be graded to provide proper drainage and left in a sightly condition. All exposed surfaces of the embankment, spillway, spoil and borrow areas, and berms shall be stabilized by seeding, liming, fertilizing and mulching in accordance with the *Vermont Standards and Specifications for Erosion Prevention and Sediment* Control. .

B.1.13. Erosion and Sediment Control

Construction operations will be carried out in such a manner that erosion will be controlled, and water and air pollution minimized. State laws concerning pollution abatement will be followed. Construction plans shall detail erosion and sediment control measures.

B.1.14. Operation and Maintenance

An operation and maintenance plan will be prepared for all Treatment Wetland facilities and basins with embankments that meet the dam criteria. As a minimum, a dam inspection checklist shall be included as part of the operation and maintenance plan and performed at least annually.

B.1.15. Supplemental Stormwater Basin and Treatment Wetland Specifications

1. It is preferred to use the same material in the embankment as is being installed for the core trench. If this is not possible because the appropriate material is not available, a dam core with a shell may be used. The cross-section of the stormwater facility should show the limits of the dam core (up to the 100-year water surface elevation) as well as the acceptable materials for the shell. The shape of the dam core and the material to be used in the shell should be specified by the design engineer.

2. If the compaction tests for the remainder of the site improvements are using Modified Proctor (AASHTO T-180), then to maintain consistency on-site, modified proctor may be used in lieu of standard proctor (AASHTO T-99). The minimum required density using the modified proctor test method shall be at least 92% of maximum dry density with a moisture content of ±2% of the optimum.

3. For all Treatment Wetland facilities and basins with dam embankments, a VT-licensed PE (civil) or qualified designee must be present to verify compaction in accordance with the selected test method. This information needs to be provided in a report to the design engineer, so that certification of the construction of the facility can be made.

4. A 4-inch layer of topsoil shall be placed on all disturbed areas of the dam embankment. Seeding, liming, fertilizing, mulching, etc. shall be in accordance with NRCS Soil Standards and Specifications and with VTrans specifications. The purpose of the topsoil is to establish a good growth of grass which is not always possible with some of the materials that may be placed for the embankment fill.

5. Fill placement shall not exceed a maximum of 8 inches. Each lift shall be continuous for the entire length of the embankment.

B.2. Construction Standards and Specifications for Gravel Wetlands

The specifications listed here were adapted from University of New Hampshire Stormwater Center (UNHSC -2009) and include only material specifications. The full design, system functionality, retrofit options and operation and maintenance, and other installation measures can be found at the following link:
http://www.unh.edu/unhsc/sites/unh.edu.unhsc/files/pubs_specs_info/unhsc_gravel_wetland_specs_6_09.pdf

B.2.1. Materials

B.2.1.1.1. Organic Soil (Optional)

The surface infiltration rates of the gravel wetland organic soil layer should be similar to a low hydraulic conductivity organic soil (0.1-0.01 ft/day). This soil can be manufactured using compost, sand, and some fine soils to blend to a high % organic matter content soil (>15% organic matter). Avoid using clay contents in excess of 15% because of potential migration of fines into subsurface gravel layer. Do not use geotextiles between the horizontal layers of this system as they will clog due to fines and may restrict root growth.

An intermediate layer of a graded aggregate filter (i.e., pea gravel) is needed to prevent the organic soil from migrating down into the gravel sublayer (Figure B-1) This is to prevent migration of the finer setting bed (organic soil) into the coarse sublayer. Material compatibility should be evaluated using Federal Highway Administration criteria (see Ferguson, 2005):

Criteria 1: $D_{15,\,COARSE\ \ SUBLAYER} \leq 5\,D_{85,\,SETTING\ \ BED}$

Criteria 2: $D_{50,\,COARSE\ \ SUBLAYER} \leq 25\,D_{50,\ SETTING\ \ BED}$

B.2.2. Gravel Layer

Below the organic soil and pea gravel is a gravel sublayer with a 24 in. minimum thickness. Angular gravel is needed with a minimum size ~3/4 in (2 cm). Large particle, angular coarse to very coarse gravel is needed to maintain system longevity.

B.2.3. Native Materials and Liner

If a low hydraulic conductivity native soil is not present below the gravel layer, a low permeability liner or soil should be used to minimize infiltration, preserve horizontal flow in the gravel, and maintain the emergent plants. If geotechnical tests confirm the need for a liner, acceptable options include: (a) 6 to 12 inches of clay soil (minimum 15% passing the #200 sieve and a minimum permeability of 1×10^{-5} cm/sec), (b) a 30 ml HDPE or PVC liner, (c) bentonite, or (d) a design prepared by a VT-licensed PE.

Geomembrane Liner (Optional)

If a geomembrane layer is used, it should be black HDPE with a textured surface and minimum thickness of 30 mils. The surface of the geomembrane must be free from pinholes or bubbles.

The geomembrane raw materials must be manufactured of polyethylene and be compounded and manufactured specifically for the intended purpose. The natural polyethylene resin without the carbon black must meet the requirements in Table B-1. Carbon black should be added to the resin if the resin is not compounded for ultra-violet resistance.

Table B-1. Resin Material Properties

Property	Test Method	HDPE Requirements
Density, g/ cc	ASTM D 4883, ASTM D 1505, or ASTM D 792	0.932 – 0.940
Melt Index, g/ 10 min.	ASTM D 1238 Condition E	<1.0

Supply the geomembrane in rolls with labels on each roll to identify the thickness of the material, the length and width of the roll, and name of manufacturer. The geomembrane liner roll quality control testing must meet the following requirements in Table B-2.

Figure B-1. Gravel Treatment Wetland Materials Cross-Section

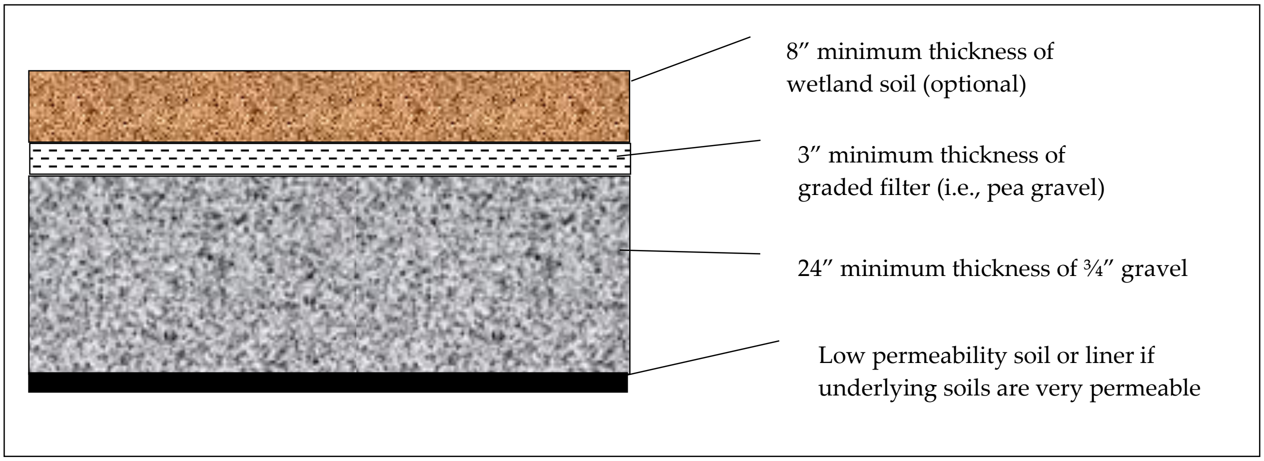

Table B-2. Geomembrane Material Properties

Property	Test Method	Minimum Average Values	Testing Frequency (min.)
Thickness (smooth sheet) Thickness (textured sheet) Minimum average Lowest individual of 10 readings	ASTM D 5199 ASTM D 5994	 30 27	Per roll
Asperity Height, mils Alternate the measurement side for double-sided texture sheet.	ASTM D 7466	16	Every second roll
Sheet Density, g/ cc	ASTM D 1505/D 792	0.94	200,000 lb
Tensile Properties[1] Yield Strength, lb/in Break Strength, lb/in Yield Elongation, % Break Elongation, %	ASTM D 6693	 68 66 12 100	20,000 lb
2% Modulus (LLDPE only)	ASTM D 5323	N/A	Per each formulation
Tear Resistance, lb	ASTM D 1004	24	45,000 lb
Puncture Resistance, lb	ASTM D 4833	65	45,000 lb
Axi-Symetric Break Strain (LLPDE only)	ASTM 5617	N/A	Per each formulation
Stress Crack Resistance[2], hrs	ASTM D 5397 (App.)	300	Per GRI GM10
Notched Constant Tensile Load (NCTL)[3], hrs	ASTM D 5397 (App.)	1000	N/A
Carbon Black Content[4], %	ASTM D1603	2.0-3.0	20,000 lb
Oxidative Induction Time (OIT) Standard OIT, minutes	ASTM D 3895	>140	200,000 lb
UV Resistance[6] High pressure OIT - % retained after 1600 hrs	GRIGM11 ASTM D 5885	 50	Per each formulation
Roll Dimensions Width (feet) Length (feet) Area (sq. feet)		 22.5 840 18,900	N/A

1. Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction. Yield elongation is calculated using a gauge length of 1.3 inches; Break elongation is calculated using a gauge length of 2.0 inches.
2. The yield stress used to calculate the applied load for the SP-NCTL test should be the mean value via MQC testing.
3. NCTL for HD Textured may be conducted on representative smooth membrane samples.
4. The condition of the test should be 20 hr. UV cycle at 75°C followed by 4 hr. condensation at 60°C.
5. UV resistance is based on percent retained value regardless of the original HP-OIT value.

B.3. Construction Standards and Specifications for Green Roofs

B.3.1. Materials

The following ASTM standards have been developed for green roof systems:

E2396-11 Standard Testing Method for Saturated Water Permeability of Granular Drainage Media [Falling-Head Method] for Vegetative (Green) Roof Systems

E2397-11 Standard Practice for Determination of Dead Loads and Live Loads Associated with Vegetative (Green) Roof Systems

E2398-11 Standard Test Method for Water Capture and Media Retention of Geocomposite Drain Layers for Vegetative (Green) Roof Systems

E2399-11 Standard Test Method for Maximum Media Density for Dead Load Analysis of Vegetative (Green) Roof Systems*

E2400-06 Standard Guide for Selection, Installation, and Maintenance of Plants for Green Roof Systems

E2777-14 Standard Guide for Vegetative (Green) Roof Systems

E2788-11 Standard Specification for Use of Expanded Shale, Clay and Slate (ESCS) as a Mineral Component in the Growing Media and the Drainage Layer for Vegetative (Green) Roof Systems

* Method E2399 includes tests to measure moisture retention potential and saturated water permeability of media, total porosity, and air content of media.

ASTM Standards are updated periodically, and the most current (or "active") version of these standards at the time of design and construction should be followed.

It is generally accepted that the most complete standards for green roof construction are those developed in Germany by the Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau (FLL). The FLL standards and guidelines include industry standard tests for the weight, moisture, nutrient content, and grain-size distribution of growing media. These guidelines are available in English translation directly from FLL http://www.fll.de/shop/?___store=english&___from_store=english. The 2002 FLL Standards can be downloaded here: http://www.greenroofsouth.co.uk/FLL%20Guidelines.pdf

Materials for green roofs will vary somewhat depending on the media thickness, intended uses, and desired appearance. The specifications provided below are for a 3 inch extensive green roof system.

B.3.2. Plant Materials and Landscaping

Plant materials should be chosen based on their ability to take up much of the water that falls on the roof and withstand micro-climate conditions. Since extensive green roofs are typically lightweight, they often contain ground cover that can thrive in very shallow soils with little to no maintenance.

The primary considerations for plant selection are design intent, aesthetics, climate, plant characteristics including longevity, rate of establishment and pest resistance, and media composition and depth.

Careful attention should be given to installation methods including pre-cultivation (followed by transplant to the roof) and/or direct seeding, and seasonal issues (Halsall, 2007).

Green roof plantings need to be able to withstand heat, cold, and high winds. After establishment, the plants should be self-sustaining and tolerant of drought conditions.

For extensive green roofs, a minimum of 50% of the plants should be varieties of Sedums, a succulent ground cover that is popular for use on green roofs in North America. To ensure diversity and viability, at least four different species of Sedum should be used. For an extensive green roof, the remainder of the plants should be herbs, shallow-rooting grasses, or hardy wildflowers, depending on the desired appearance. Green roofs in Vermont should include a significant percentage of evergreen plants to minimize erosion in winter months.

Sedum Cuttings

- Freshly cut Sedum. Harvested Sedum shall not be flowering.
- Ship so that the cuttings are enclosed for no more than 30 hours.

Plugs

- 3-in. deep, 72-cell plugs, propagated in sterile nursery medium, according to the plant provider's recommendations.
- "Harden off" plugs prior to planting by gradually eliminating irrigation over a period of one week.

When fully established, the selected plantings should thoroughly cover the growing medium.

B.3.3. Growing Medium

Green roof growing medium should be a lightweight mineral material with a minimum of organic material and shall meet the following standards:

- Moisture content at maximum water holding capacity (per ASTM E2399): ≥ 35%
- Porosity at maximum water holding capacity (per ASTM E2399): ≥ 6%
- Total organic matter (per FLL) ≤ 4%
- pH (per FLL): 6.5-8.0
- Soluble salts (per FLL): ≤ 5.5 mmho/cm
- Water permeability (ASTM E2399): ≥ 0.5 in/min
- Grain-size distribution (ASTM D422):

a. Clay fraction (2 micron)	≤ 2%
b. Pct. Passing US#200 sieve (i.e., silt fraction)	≤ 5%
c. Pct. Passing US#60 sieve	≤ 10%
d. Pct. Passing US#18 sieve	5 - 50%
e. Pct. Passing 1/8-inch sieve	30 - 80%
f. Pct. Passing 3/8-inch sieve	75 -100%

The nutrients shall be initially incorporated in the formulation of a suitable mix sufficient to meet the minimum needs of the specified plant materials.

B.3.4. Filter Layer

Filter layer or separation fabric shall allow root penetration, but prevent the growth medium from passing through into the drainage layer. The filter layer will be comprised of one or two layers of a non-woven polypropylene geotextile meeting VTrans specification.

Extensive green roofs usually employ plants with easy-to-control roots, whereas intensive green roofs may contain deeper rooting plants requiring multiple filter layers. Since root and media particle diameters can vary, filters should be specified for different media and plant types to ensure adequate flow rates for a given planting mix without losing too much silt or allowing excessive root penetration. The fabric should be a non-woven polypropylene geotextile.

B.3.5. Drain Layer

A drain layer is required to promote aerated conditions in the planting medium and to convey excess runoff during large rainfall events. The drain layer must prevent surface ponding of runoff into the planting medium during the peak intensity rainfall associated with the one-year storm (NRCS Type II Storm – between hr 11.5 and 12.5).

For vegetated roof cover assemblies with thicknesses of less than 5 inches synthetic drain layers may be used in lieu of granular drain layers.

For vegetated cover assemblies with an overall thickness of ≥ 5 inches, the drain layer shall meet the following specifications:

- Abrasion resistance (ASTM-C131-96): ≤ 25%loss
- Soundness (ASTM-C88): ≤ 5% loss
- Porosity (ASTM-C29): ≥ 25%
- Percent of particles passing 1/2-inch sieve (ASTM-C136) ≥ 75%
- The minimum thickness of the granular layer shall be 2 inches. The granular layer may be installed in conjunction with a synthetic reservoir sheet.

B.3.6. Waterproof Membrane/Root Barrier

PVC, EPDM, and thermal polyolefin (TPO) are inherently root resistant; other common waterproofing materials might require a root barrier between waterproofing and vegetative cover.

The use of herbicides to prevent root penetration of waterproofing is not acceptable. Bituminous roof membranes manufactured with herbicides embedded shall be avoided.

B.4. Construction Standards and Specifications for Permeable Pavements

B.4.1. Porous Asphalt

The specifications listed herein were adapted from the University of New Hampshire Stormwater Center (UNHSC 2014) Design Specifications for Porous Asphalt Pavements and Infiltration Beds, as modified following technical review. This section includes only material specifications. The full design and implementation specification, including submittals, QA/QC procedures, batch mixing production procedures, and other installation measures can be found at the following link:
http://www.unh.edu/unhsc/sites/unh.edu.unhsc/files/UNHSC%20PA%20Spec%20update-%20FEB-2014.pdf.

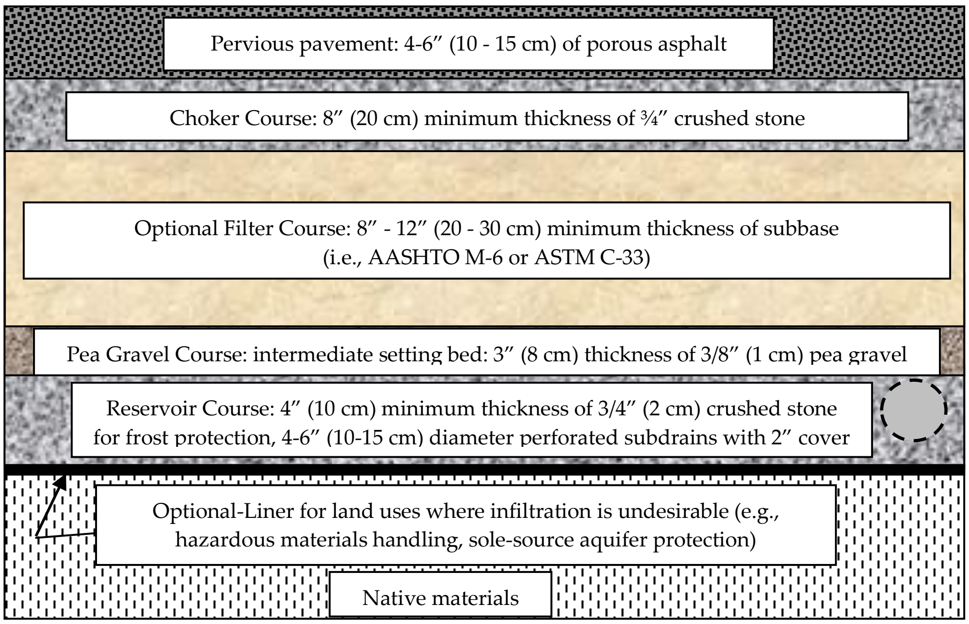

Figure B-2. Typical Parking Area Cross-Section for Pervious Pavement System

B.4.1.1. Materials

A. Porous Asphalt Mix

A.1 Mix Materials

Mix materials consist of modified performance grade asphalt binder (PGAB), coarse and fine aggregates, and optional additives such as silicone, fibers, mineral fillers, fatty amines, and hydrated lime. Materials shall meet the requirements of the NAPA’s Design, Construction, and Maintenance of Open-Graded Friction Courses, Information Series 115 (2002), except where noted otherwise below or approved in writing by the Engineer.

A.2 Polymer Modified PGAB and Mix Designs

The asphalt binder shall be a polymer and/or fiber modified Performance Graded Asphalt Binder (PGAB) used in the production of Superpave Hot Mix Asphalt (HMA) mixtures. Ideally for maximum durability, the PGAB shall be two grades stiffer than that required for dense mix asphalt (DMA) parking lot installations, which is often achieved by adding a polymer and/or fiber. Mix designs will meet or exceed criteria listed in Table B-3. The PGAB polymer modifiers are to be either styrene butadiene rubber (SBR) or styrene butadiene styrene (SBS). SBS is typically reserved for large projects as terminal pre-blending is required. SBR is feasible for smaller projects as it can be blended at the plant or terminal blended. The quantity of rubber solids in the SBR shall typically be 1.5-3% by weight of the bitumen content of the mix. The dosage of fiber additives shall be either 0.3 percent cellulose fibers or 0.4 percent mineral fibers by total mixture mass. Fibers are a simple addition either manually for a batch plant or automated for larger drum plants. The binder shall meet the requirements of AASHTO M320.

The PGAB may be pre-blended or post-blended. The pre-blended binder can be pre-blended at the source or at a terminal. For post-blended addition, the modifier can either be in-line blended or injected into the pugmill at the plant.

The following asphalt mix designs are recommended (listed in order of increasing strength):

1. PG 64-28 with 5 pounds of fibers per ton of asphalt mix. This mix is no longer considered suitable for PA wearing course applications in any development. It may be used as a base course where approved by the engineer for smaller projects with lower traffic counts or loading potential.

2. Post-Blended PG 64-28 SBR (to effectively obtain PG 76 -22) at 1.5% by volume with 5 pounds of fibers per ton of asphalt mix. This mix is recommended for large projects (> 1 acre) where high durability pavements are needed. The SBR will be supplied by an approved PGAB supplier holding a Quality Control Plan approved by VTrans. A Bill of Lading (BOL) will be delivered with each transport of PG 64-28 SBR. A copy of the BOL will be furnished to the QA inspector at the Plant. A Post-Blended SBR Binder Quality Control Plan will be submitted to the Engineer for approval at least 10 working days prior to production.

3. Pre-Blended PG 76-28 modified with SBS (this mix has been used with great success since 2011 in New England). This mix is recommended for large sites anticipating high wheel load (H-20) and traffic counts for maximum durability. The SBS will be supplied by an approved PGAB supplier holding a Quality Control Plan approved by VTrans. A Bill of Lading (BOL) will be delivered with each transport of PG 76-28 SBS. A copy of the BOL will be furnished to the QA inspector at the Plant.

A.3 Anti-Stripping Mix Additives

The mix shall be tested for moisture susceptibility and asphalt stripping from the aggregate by AASHTO T283, or improved updated method. If the retained tensile strength (TSR) < 80% upon testing, a heat stable additive shall be furnished to improve the anti-stripping properties of the asphalt binder. Test with one freeze-thaw cycle (rather than five recommended in NAPA IS 115). The amount and type of additive (e.g. fatty amines or hydrated lime) to be used shall be based on the manufacturer's recommendations, the mix design test results, and shall be approved by the Engineer.

Silicone shall be added to the binder at the rate of 1.5 mL/m^3 (1 oz. per 5000 gal).

Fibers may be added per manufacturer and NAPA IS 115 recommendation if the draindown requirement cannot be met (<0.3% via ASTM D6390) provided that the air void content requirement is met (>18%, or >16% as tested with CoreLok device).

Additives should be added per the relevant VTrans specification and NAPA IS 115.

A.4 Coarse Aggregate

Coarse aggregate shall be that part of the aggregate retained on the No. 8 sieve; it shall consist of clean, tough, durable fragments of crushed stone, or crushed gravel of uniform quality throughout.

Coarse aggregate shall be crushed stone or crushed gravel and shall have a percentage of wear as determined by AASHTO T96 of not more than 40 percent. In the mixture, at least 75 percent, by mass (weight), of the material coarser than the 4.75 mm (No. 4) sieve shall have at least two fractured faces, and 90 percent shall have one or more fractured faces (ASTM D5821). Coarse aggregate shall be free from clay balls, organic matter, deleterious substances, and not more than 8.0% of flat or elongated pieces (>3:1) as specified in ASTM D4791.

A.5 Fine Aggregate

Fine aggregate shall be that part of the aggregate mixture passing the No. 8 sieve; it shall consist of sand, screenings, or combination thereof with uniform quality throughout. Fine aggregate shall consist of durable particles, free from injurious foreign matter. Screenings shall be of the same or similar materials as specified for coarse aggregate. The plasticity index of that part of the fine aggregate passing the No. 40 sieve shall be not more than 6 when tested in accordance with AASHTO T90. Fine aggregate from the total mixture shall meet plasticity requirements.

A.6 Recycled Asphalt (RAP)

Recycled asphalt can be used to supplement, or in place of, fine aggregate. RAP should be a ½" minus or properly managed product with known asphalt content in quantities not to exceed more than 10% by weight.

A.7 Porous Asphalt Mix Design Criteria

The mixture will be designed according to the NAPA IS 131, with the exception of testing for air void content. Bulk specific gravity (SG) used in air void content calculations shall not be determined and results will not be accepted using AASHTO T166 (saturated surface dry), since it is not intended for open graded specimens (>10% AV). Bulk SG shall be calculated using AASHTO T275 (paraffin wax) or ASTM D6752 (automatic vacuum sealing, e.g. CoreLok). Air void content shall be calculated from the bulk SG and maximum theoretical SG (AASHTO T209) using ASTM D3203.

The materials shall be combined and graded to meet the composition limits by mass (weight) as shown in Table B-3.

Table B-3. Porous Asphalt Mix Design Criteria

Sieve Size (inch/mm)	Percent Passing (%)
0.75/19	100
0.50/12.5	85-100
0.375/9.5	55-75
No.4/4.75	10-25
No.8/2.36	5-12
No.200/0.075 (#200)	2-4
Binder Content (AASHTO T164)	5.8 - 6.5%
Air Void Content (ASTM D6752)*	16.0-22.0%
Draindown (ASTM D6390)**	≤ 0.3 %
Retained Tensile Strength (AASHTO 283)***	≥ 80 %
Cantabro abrasion test on unaged samples	≤ 20%
Cantabro abrasion test on 7 day aged samples	≤ 30%

* Air content is for parking lots and light duty roadways, higher traffic/higher loading roads may have reduced air content to not less than 12%.

** Either method is acceptable

***Cellulose, mineral, or polyester fibers may be used to reduce draindown.

****If the TSR (retained tensile strength) values fall below 80% when tested per NAPA IS 131 (with a single freeze thaw cycle rather than 5), then in Step 4, the contractor shall employ an anti-strip additive, such as hydrated lime (ASTM C977) or a fatty amine, to raise the TSR value above 80%.

B. Porous Media Infiltration Beds

Below the porous asphalt itself are located the porous media infiltration beds (Figure B-2), from top to bottom: an 8″ (20 cm) (minimum) thick layer of choker course of double washed crushed stone; an optional 8″ to 12″ (20 cm to 30 cm) minimum thickness layer of filter course of poorly graded sand; a 3″ (8 cm) minimum thickness pea gravel course that is an intermediate setting bed; and a reservoir course of double washed crushed stone, thickness dependent on required storage and underlying native materials. Alternatively, the pea gravel layer could be thickened and used as the reservoir course depending upon subsoil suitability. This alternative simplifies subbase construction. For lower permeability native soils, the optional perforated or slotted drain pipe is located in the stone reservoir course for drainage. This drain pipe can be daylighted to other stormwater management infrastructure.

B.1. Choker Course

Material for the choker course and reservoir course shall meet the following:

1. Maximum Wash Loss of 0.5%
2. Minimum Durability Index of 35
3. Maximum Abrasion Loss of 10% for 100 revolutions, and maximum of 50% for 500 revolutions.
4. Material for the choker course shall have the AASHTO No. 57 gradation, as specified in Table B-4. AASHTO No. 3 is also suitable for the choker course.

B.2. Optional Filter Course Material

Filter course material shall have a hydraulic conductivity (also referred to as coefficient of permeability) of 10 to 60 ft/day at 95% standard proctor compaction unless otherwise approved by the Engineer. Great care needs to be used to not over compact materials. Over-compaction results with loss of infiltration capacity. The filter course material is a medium sand. In order to select an appropriate gradation, coefficient of permeability may be estimated through an equation that relates gradation to permeability, such as described in *Correlations of Permeability and Grain Size* (Shepherd, 1989) or in Section 8.7 of *Estimation of Saturated Hydraulic Conductivity* (Freeze and Cherry, 1979). The hydraulic conductivity should be determined by ASTM D2434 and reported to the Engineer.

B.3. Pea Gravel Material

A pea gravel material between the filter course and the reservoir course shall be an intermediate size between the finer filter course above, and the coarser reservoir course below, for the purpose of preventing the migration of a fine setting bed into the coarser reservoir material. An acceptable gradation shall be calculated based on selected gradations of the filter course and reservoir course using criteria outlined in the HEC 11 (Brown and Clyde, 1989). A pea-gravel with a median particle diameter of 3/8" (9.5 mm) is commonplace.

B.4. Reservoir Course and Optional Perforated Subdrainage Pipe

The reservoir course shall be a minimum 4" thickness of ¾" double washed crushed stone that acts as a capillary barrier for frost heave protection. Material for the reservoir course shall have the AASHTO No. 3 gradation, as specified in Table B-4. If the AASHTO No. 3 gradation cannot be met, AASHTO No. 5 is acceptable with approval of the Engineer. Thickness beyond 4" shall be as needed to provide sufficient void space to store the design storm. In addition, the entire pavement system and subbase thickness shall be ≥ 0.65 times the design frost depth for the area.

The optional subdrainage pipe shall be elevated a minimum of 4" from the bottom of the reservoir course to provide storage and infiltration for the water quality volume. Subdrainage piping shall be a minimum of rigid schedule 40 PVC in accordance with ASTM D 1785 or AASHTO M-278 and VTrans Specifications.

B.5. Optional Bottom Liner

Bottom liner is only recommended for aquifer protection or infiltration prevention. This liner is to be located at the interface between subbase and native materials and is dependent upon the following:

1. As with any infiltration system, care must be taken when siting porous asphalt systems close to locations where hazardous materials are handled/trafficked, or where high contaminant loading may threaten groundwater, or where infiltration is undesirable (nearby foundations, slope stability, etc.).
2. Suitable liners may include Hydrologic Group D soils, HDPE liners, or suitable equivalent. Liner permeability shall be no greater than = 0.4 inch/day = 1 cm/day.
3. Filter fabrics or geotextile liners are not recommended for use on the bottom of the porous asphalt system (at the base of the stone reservoir subbase) if designing for infiltration. Filter fabric usage in stormwater filtration has been known to clog prematurely. Graded stone filter blankets are recommended instead.
4. Geotextile filter fabrics may be used if designing on poor structural, and low conductivity soils. Fabric usage would be limited to the bottom and sides of the excavation. No fabric is to be used within the subbase, only on the perimeter.

Table B-4. Gradations and Compaction of Choker, Filter, and Reservoir Course Materials

US Standard Sieve Size (inches/mm)	Percent Passing (%)			
	Choker Course (AASHTO No. 57)	Pea Stone Course (AASHTO No. M-6)	Reservoir Course (AASHTO No.3)	Reservoir Course Alternative* (AASHTO No.5)
6/150	-		-	
2½/63	-		100	-
2 /50	-		90 – 100	-
1½/37.5	100		35 – 70	100
1/25	95 - 100		0 – 15	90 – 100
¾/19	-		-	20 - 55
½/12.5	25 - 60		0 - 5	0 - 10
3/8/9.5	-	100	-	0 - 5
#4/4.75	0 - 10	70-100	-	
#8/2.36	0 - 5		-	
#200/0.075	0 -2	0 – 6**		
% Compaction ASTM D698 / AASHTO T99	95	95	95	95

* Alternate gradations (e.g. AASHTO No. 5) may be accepted upon Engineer's approval.

** Preferably less than 4% fines

B.6. Non-Woven Geotextile Filter Fabric

Filter fabric is only recommended for the sloping sides of the porous asphalt system excavation. It shall be Mirafi 160N, or approved equal and shall conform to the specifications in Table B-5 and Table B-6. Mirafi ® 160N is a non-woven geotextile composed of polypropylene fibers, which are formed into a stable network such that the fibers retain their relative position. 160N is inert to biological degradation and resists naturally encountered chemicals, alkalis, and acids.

Table B-5. Non-Woven Geotextile Filter Fabric Mechanical Properties

Mechanical Properties	Test Method	Unit	Minimum Average Roll Values	
			MD*	CD**
Grab Tensile Strength	ASTM D 4632	kN (lbs)	0.71 (160)	0.71 (160)
Grab Tensile Elongation	ASTM D 4632	%	50	50
Trapezoid Shear Strength	ASTM D 4533	kN (lbs)	0.27 (60)	0.27 (60)
Mullen Burst Strength	ASTM D 3786	kPa (psi)	2100 (305)	2100 (305)
Puncture Strength	ASTM D 4833	kN (lbs)	0.42 (95)	0.42 (95)
Apparent Opening Size (AOS)	ASTM D 4751	mm (US Sieve)	0.212 (70)	0.212 (70)
Permittivity	ASTM D 4491	sec^{-1}	1.4	1.4
Permeability	ASTM D 4491	cm/sec	0.22	0.22
Flow Rate	ASTM D 4491	lpm/m^2 (gpm/ft^2)	4,477 (110)	4,477 (110)
UV Resistance (at 500 hours)	ASTM D 4355	% strength retained	70	70

*MD - Machine Direction
**CD - Cross-machine Direction

Table B-6. Non-Woven Geotextile Filter Fabric Physical Properties

Physical Properties	Test Method	Unit	Typical Value
Weight	ASTM D 5261	g/m^2 (oz/yd^2)	217 (6.4)
Thickness	ASTM D 5199	mm (mils)	1.9 (75)
Roll dimension (width x length)		m (ft)	4.5 x 91 (15 x 300)
Roll area		m^2 (yd^2)	410 (500)
Estimated roll weight		kg (lb)	99 (217)

References

CalTrans, January 2003, California Stormwater BMP Handbook 3 of 8 New Development and Redevelopment, California Dept. of Transportation, Sacramento, CA www.cabmphandbooks.com

USEPA, September, 1999, Storm Water Technology Fact Sheet: Infiltration Drainfields, Number: 832F99018 USEPA, Office of Water, Washington, DC http://www.epa.gov/npdes/pubs/infltdrn.pdf

USEPA, September 2004, Stormwater Best Management Design Guide: Volume 1 General Considerations, Office of Research and Development, EPA/600/R-04/121, Washington, D.C.

Vermont Agency of Transportation, 2011, 2011 Standard Specifications for the Construction Book. http://vtranscontracts.vermont.gov/construction-contracting/2011-standard-specifications

Wisconsin Department of Natural Resources, Feb. 2004, Site Evaluation for Stormwater Infiltration (1002), Wisconsin Department of Natural Resources Conservation Practice Standards Madison, WI

B.4.2. Portland Cement Pervious Concrete Pavement

Pervious concrete pavement does not look or behave like typical concrete pavements. The finished surface is not tight and uniform, but is open and varied. Surface irregularities and minor amounts of surface raveling are normal. Traditional concrete testing procedures for strength and slump are not applicable. Pervious concrete is tested instead for consistency, void content and thickness. The specifications contained herein include only material specifications. Full construction specifications and technical assistance and installation training is available from your local cement and concrete associations. Planning, design, materials and construction information can be provided. The following associations can provide guidance:

Northern New England Concrete Promotion Association
50 Market Street
Suite 1A #221
South Portland, ME 04106
Phone: (888)875-3232
Fax: (207)221-1126
Email: info@nnecpa.org
Web: www.nnecpa.org

Northeast Cement Shippers Association
1580 Columbia Turnpike
Building 1, Suite 1
Castleton, NY 12033
Phone: (518) 477-4925 / 4926
Fax: (518) 477-4927
Web: www.necementshippers.com

National Ready Mix Concrete Association
900 Spring Street
Silver Spring, MD 20910
Phone: 301-587-1400 or 888-84NRMCA (846-7622)
Fax: 301-585-4219
Email: info@nrmca.org
Web: www.perviouspavements.org

MATERIALS

Cement:

Portland Cement Type II or V conforming to ASTM Cl50 or Portland cement Type IP or IS conforming to ASTM C595.

Supplementary Cementitious Materials:

1. Class F Fly ash conforming to ASTM C618
2. Ground Iron Blast-Furnace Slag conforming to ASTM C989

Chemical Admixtures:

1. Air entraining agents shall comply with ASTM C260.
2. Chemical Admixtures shall comply with ASTM C494.

3. Hydration stabilizers are permitted to be used when it is necessary to increase concrete placement time to 90 minutes and improve finishing operations.

Aggregates:

1. Coarse aggregate shall comply with ASTM C33. Size 8 (3/8" to No. 16) or Size 89 (3/8 in. to No. 50) shall be used unless an alternate size is approved for use based on meeting the project requirements. Fine aggregate complying with ASTM C33, if used, shall not exceed 3 cu. ft.

2. Larger aggregate sizes may increase porosity but can decrease workability. Avoid well graded aggregates as they may reduce porosity, and may not provide adequate void content.

3. Where available, natural rounded aggregates are recommended.

Water:

Water shall comply with ASTM C 1602.

Mixture Proportions:

The composition of the proposed concrete mixtures shall be submitted to the owner's representative for review and/or approval and shall comply with the following provisions unless an alternative composition is demonstrated to comply with the project requirements.

1. Cementitious Content: For vehicle pavements, total cementitious content shall not be less than 630 lbs/cy. For pedestrian pavements, total cementitious shall not be less than 600 lbs/cy.

2. Supplementary cementitious content: Fly ash: 25% maximum. Slag: 50% maximum

3. Water / Cementitious Ratio: Maximum 0.30 for vehicle pavements and 0.35 for pedestrian pavements.

4. Aggregate Content: The bulk volume of aggregate per cubic yard shall be equal to 27 cubic foot when calculated from the dry rodded density (unit weight) determined in accordance with ASTM C29 jigging procedure.

5. Admixtures: Admixtures shall be used in accordance with the manufacturer's instructions and recommendations.

6. Mix Water: The quantity of mixing water shall be established to produce a pervious concrete mixture of the desirable workability to facilitate placing, compaction and finishing to the desired surface characteristics.

<u>**References**</u>

American Concrete Institute

- ACI 305 "Hot Weather Concreting"
- ACI 522 "Report on Pervious Concrete"
- ACI Flatwork Finisher Certification Program
- ACI Field Technician Certification Program

American Society for Testing and Materials

- ASTM C29 "Test for Bulk Density (Unit Weight) and Voids in Aggregate"
- ASTM C33 "Specification for Concrete Aggregates"

- ASTM C42 "Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete."
- ASTM C94 Specification for Ready-Mixed Concrete
- ASTM C 117 "Test Method for Material Finer than 75-Jlm (No. 200) Sieve in Mineral Aggregates by Washing."
- ASTM Cl38 "Test Method for Density (Unit Weight), Yield and Air Content (Gravimetric) of Concrete."
- ASTM CI40 "Test Methods for Sampling and Testing Concrete Masonry Units and Related Units"
- ASTM C150 "Specification for Portland Cement"
- ASTM C 172 "Practice for Sampling Freshly Mixed Concrete"
- ASTM C260 "Specification for Air-Entraining Admixtures for Concrete"
- ASTM C494 "Specification for Chemical Admixtures for Concrete"
- ASTM C595 "Specification for Blended Hydraulic Cements"
- ASTM C618 "Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use as a Mineral Admixture in Portland Cement Concrete."
- ASTM C989 "Specification for Ground Granulated Blast-Furnace Slag for Use in Concrete and Mortars."
- ASTM C1077 "Practice for Laboratories Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Laboratory Evaluation."
- ASTM C1602 "Specification for Mixing Water Used in the Production of Hydraulic Cement Concrete"
- ASTM 01557 "Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbs/ft^3)."
- ASTM 03385 "Test Method for Infiltration Rate of Soils in Field Using Double-Ring Infiltrometer"
- ASTM E329 "Specification for Agencies Engaged in the Testing and/or Inspection of Materials Used in Construction."

B.5. Construction Specifications for Infiltration Practices

B.5.1. Infiltration Trench General Notes and Specifications

The infiltration trench systems may not receive run-off until the entire contributing drainage area to the infiltration system has received final stabilization.

- Heavy equipment and traffic should be restricted from traveling over the infiltration trench to minimize compaction of the soil.
- Excavate the infiltration trench to the design dimensions. Excavated materials should be placed away from the trench sides to enhance trench wall stability. Large tree roots must be trimmed flush with the trench sides in order to prevent fabric puncturing or tearing of the filter fabric during subsequent installation procedures. The side walls of the trench should be roughened where sheared and sealed by heavy equipment.
- A Class "C" geotextile or better should interface between the trench side walls and between the stone reservoir and gravel filter layers. A partial list of non-woven filter fabrics that meet the Class "C" criteria is contained below. Any alternative filter fabric must be approved by the review agency.
    - Mirafi 180-N
    - GEOLON N70
    - Amoco 4552
    - Carthage FX-80S
    - WEBTEC N70

  The width of the geotextile must include sufficient material to conform to trench perimeter irregularities and for a 6-inch minimum top overlap. The filter fabric should be tucked under the sand layer on the bottom of the infiltration trench for a distance of 6 to 12 inches. Stones or other anchoring objects should be placed on the fabric at the edge of the trench to keep the trench open during windy periods. When overlaps are required between rolls, the uphill roll should lap a minimum of 2 feet over the downhill roll in order to provide a shingled effect.
- A 6 inch sand filter layer may be placed on the bottom of the infiltration trench in lieu of filter fabric, and should be compacted using plate compactors. The sand for the infiltration trench should be washed and meet AASHTO Std. M-43, Size No. 9 or No. 10. Any alternative sand gradation must be approved by the Engineer or the review agency.
- The stone aggregate should be placed in lifts and compacted using plate compactors. A maximum loose lift thickness of 12 inches is recommended. The aggregate for infiltration trenches should consist of clean, washed aggregate between 2 and 5 inches in diameter. The aggregate should be graded such that there will be few aggregates smaller than the selected size.
- Following the stone aggregate placement, the filter fabric should be folded over the stone aggregate to form a 6-inch minimum longitudinal lap. The desired fill soil or stone aggregate should be placed over the lap at sufficient intervals to maintain the lap during subsequent backfilling.
- Care should be exercised to prevent natural or fill soils from intermixing with the stone aggregate. All contaminated stone aggregate should be removed and replaced with uncontaminated stone aggregate.
- Voids can be created between the fabric and the excavation sides and should be avoided. Removing boulders or other obstacles from the trench walls is one source of such voids, therefore, natural soils should be placed in

these voids at the most convenient time during construction to ensure fabric conformity to the excavation sides.

- Vertically excavated walls may be difficult to maintain in areas where soil moisture is high or where soft cohesive or cohesionless soils are predominate. These conditions may require laying back of the side slopes to maintain stability.
- PVC distribution pipes should be Schedule 40 and meet ASTM Std. D 1784. All fittings and perforations (1/2 inch in diameter) should meet ASTM Std. D 2729. A perforated pipe should be provided only within the infiltration trench and should terminate 1 foot short of the infiltration trench wall. The end of the PVC pipe should be capped.
- The corrugated metal distribution pipes should conform to AASHTO Std. M-36, and should be aluminized in accordance with AASHTO Std. M-274. Coat aluminized pipe in contact with concrete with an inert compound capable of affecting isolation of the deleterious effect of the aluminum on the concrete. Perforated distribution pipe should be provided only within the infiltration trench and should terminate 1 foot short of the infiltration trench wall. An aluminized metal plate should be welded to the end of the pipe.
- If a distribution structure with a wet well is used, a 4-inch PVC drain pipe should be provided at opposite ends of the infiltration trench distribution structure. Two (2) cubic feet of porous backfill meeting AASHTO Std. M-43 Size No. 57 should be provided at each drain.
- The observation well is to consist of 6-inch diameter PVC Schedule 40 pipe (ASTM Std. D 1784) with a cap set flush with the ground level and located near the longitudinal center of the infiltration trench. The pipe should be perforated (1/2 inch in diameter) and placed vertically within the gravel portion of the infiltration trench and a cap provided at the bottom of the pipe. The bottom of the cap should rest on the infiltration trench bottom. Preferably the observation well will not be located in vehicular traffic areas. The pipe should have a plastic collar with ribs to prevent rotation when removing cap. The screw top lid should be a "Panella" type cleanout with a locking mechanism or special bolt to discourage vandalism.
- If a distribution structure is used, the manhole cover should be bolted to the frame.

NOTE: PVC pipe with a wall thickness classification of SDR-35 meeting ASTM standard D3034 is an acceptable substitution for PVC Schedule 40 pipe.

B.5.2. Infiltration Basins Notes and Specifications

- The sequence of various phases of basin construction should be coordinated with the overall project construction schedule. A program should schedule rough excavation of the basin with the rough grading phase of the project to permit use of the material as fill in earthwork areas. The partially excavated basin, however, **cannot** serve as a sedimentation basin.
- Specifications for basin construction should state: (1) the earliest point in progress when storm drainage may be directed to the basin, and (2) the means by which this delay in use is to be accomplished. Due to the wide variety of conditions encountered among projects, each should be separately evaluated in order to postpone use as long as is reasonably possible.
- Initial basin excavation should be carried to within 1 foot of the final elevation of the basin floor. Final excavation to the finished grade should be deferred until all disturbed areas on the watershed have been stabilized or protected. The final phase excavation should remove all accumulated sediment. Relatively light tracked equipment is recommended for this operation to avoid compaction of the basin floor. After the final grading is completed, the basin provide a well-aerated, highly porous surface texture.

- Infiltration basins may be lined with a 6- to 12-inch layer of filter material such as coarse sand (AASHTO Std. M-43, Sizes 9 or 10) to help prevent the buildup of impervious deposits on the soil surface. The filter layer can be replaced or cleaned when it becomes clogged. When a 6-inch layer of coarse organic material is specified for discing (such as hulls, leaves, stems, etc.) or spading into the basin floor to increase the permeability of the soils, the basin floor should be soaked or inundated for a brief period, then allowed to dry subsequent to this operation. This induces the organic material to decay rapidly, loosening the upper soil layer.

- Establishing dense vegetation on the basin side slopes and floor is recommended. A dense vegetative stand will not only prevent erosion and sloughing, but will also provide a natural means of maintaining relatively high infiltration rates. Erosion protection of inflow points to the basin should also be provided.

- Selection of suitable vegetative materials for the side slope and all other areas to be stabilized with vegetation and application of required lime, fertilizer, etc. should be done in accordance with the NRCS Standards and Specifications or your local Standards and Specifications for Soil Erosion and Sediment Control.

- Grasses of the fescue family are recommended for seeding primarily due to their adaptability to dry sandy soils, drought resistance, hardiness, and ability to withstand brief inundations. The use of fescues will also permit long intervals between mowings. This is important due to the relatively steep slopes that make mowing difficult. Mowing twice a year, once in June and again in September, is generally satisfactory. Refertilization with 10-6-4 ratio fertilizer at a rate of 500 lb per acre (11 lb per 100 sq ft) may be required the second year after seeding.

B.6. Construction Specifications for Sand Filters

B.6.1. Material Specifications for Sand Filters

The allowable materials for sand filter construction are detailed in Table B-7.

B.6.2. Sand Filter Testing Specifications

Underground sand filters, facilities within sensitive groundwater aquifers, and filters designed to serve urban hot spots are to be tested for water tightness prior to placement of filter layers. Entrances and exits should be plugged and the system completely filled with water to demonstrate water tightness.

All overflow weirs, multiple orifices and flow distribution slots to be field-tested as to verify adequate distribution of flows.

B.6.3. Sand Filter Construction Specifications

Provide sufficient maintenance access; 12-foot-wide road with legally recorded easement. Vegetated access slopes to be a maximum of 10%; gravel slopes to 15%; paved slopes to 25%.

Absolutely no runoff is to enter the filter until all contributing drainage areas have been stabilized.

The surface of the filter bed should be completely level.

All sand filters should be clearly delineated with signs so that they may be located when maintenance is due.

Surface sand filters should be planted with appropriate grasses as specified in local NRCS Standards and Specifications guidance or other comparable guidance.

Pocket sand filters should be sized with an ornamental stone window covering approximately 10% of the filter area. This surface should be 2″ to 5″ size stone on top of a pea gravel layer (3/4 inch stone) approximately 4″ to 6″ in depth.

B.6.4. Specifications Pertaining to Underground Sand Filters

Provide manhole and/or grates to all underground and below grade structures. Manholes should be in compliance with standard specifications for each jurisdiction but diameters should be 30″ minimum (to comply with OSHA confined space requirements) but not too heavy to lift. Aluminum and steel louvered doors are also acceptable. Ten-inch long (minimum) manhole steps (12″ o.c.) should be cast in place or drilled and mortared into the wall below each manhole. A 5′ minimum height clearance (from the top of the sand layer to the bottom of the slab) is required for all permanent underground structures. Lift rings are to be supplied to remove/replace top slabs. Manholes may need to be grated to allow for proper ventilation; if required, place manholes away from areas of heavy pedestrian traffic.

Underground sand filters should be constructed with a dewatering gate valve located just above the top of the filter bed should the bed clog.

Underground sand beds should be protected from trash accumulation by a wide mesh geotextile screen to be placed on the surface of the sand bed. The screen is to be rolled up, removed, cleaned and re-installed during maintenance operations.

Table B-7. Sand Filter Material Specifications

Parameter	Specification	Size	Notes
Sand	clean AASHTO M-6 or ASTM C-33 concrete sand	0.02” to 0.04”	Sand substitutions such as Diabase and Graystone #10 are not acceptable. No calcium carbonated or dolomitic sand substitutions are acceptable. Rock dust cannot be substituted for sand.
Underdrain Gravel	AASHTO M-43	0.25” to 0.75”	
Geotextile Fabric (if required)	ASTM D-4833 (puncture strength - 125 lb.) ASTM D-1117 (Mullen Burst Strength - 400 psi) ASTM D-4632 (Tensile Strength - 300 lb.)	0.08” thick equivalent opening size of #80 sieve	Must maintain 125 gpm per sq. ft. flow rate. Note: a 4” pea gravel layer may be substituted for geotextiles meant to separate sand filter layers.
Impermeable Liner (if required)	ASTM D-4833 (thickness) ASTM D-412 (tensile strength 1,100 lb., elongation 200%) ASTM D-624 (Tear resistance - 150 lb./in) ASTM D-471 (water adsorption: +8 to -2% mass)	30 mil thickness	Liner to be ultraviolet resistant. A geotextile fabric should be used to protect the liner from puncture.
Underdrain Piping	ASTM D-1785 or AASHTO M-278	6” rigid schedule 40 PVC	3/8” perf. @ 6” on center, 4 holes per row; minimum of 3” of gravel over pipes; not necessary underneath pipes
Concrete (Cast-in-place)	See local AOT Standards and Specs. f’c = 3,500 psi, normal weight, air-entrained; re-enforcing to meet ASTM 615-60	n/a	on-site testing of poured-in-place concrete required: 28 day strength and slump test; all concrete design (cast-in-place or pre-cast) *not using previously approved State or local standards* requires design drawings sealed and approved by a licensed professional structural engineer.
Concrete (pre-cast)	per pre-cast manufacturer	n/a	SEE ABOVE NOTE
Non-Rebar Steel	ASTM A-36	n/a	structural steel to be hot-dipped galvanized ASTM A-123

B.7. Construction Specifications for Bioretention

B.7.1. Material Specifications

The allowable materials to be used in bioretention area are detailed in Table B-8.

B.7.2. Planting Soil

The soil should be a uniform mix, free of stones, stumps, roots or other similar objects larger than two inches. No other materials or substances should be mixed or dumped within the bioretention area that may be harmful to plant growth, or prove a hindrance to the planting or maintenance operations. The bioretention soil should be free of noxious weeds.

The bioretention system shall utilize planting soil having a composition as follows:

- Sand: 85-88%
- Soil fines: 8 to 12% (no more than 2% clay)
- Organic Matter: 3 to 5%

A textural analysis is required to ensure the bioretention soil meets the specification listed above. The bioretention soil should also be tested for the following criteria:

- pH range 5.2 - 7.0
- magnesium not to exceed 32 ppm
- phosphorus P_2O_5 not to exceed 69 ppm
- potassium K_2O not to exceed 78 ppm
- soluble salts not to exceed 500 ppm

All bioretention areas should have a minimum of one test. Each test should consist of both the standard soil test for pH, phosphorus, and potassium and additional tests of organic matter, and soluble salts.

Since different labs calibrate their testing equipment differently, all testing results should come from the same testing facility.

Should the pH fall out of the acceptable range, it may be modified (higher) with lime or (lower) with iron sulfate plus sulfur.

B.7.3. Mulch Layer Specifications

The mulch layer should be shredded hardwood mulch that is well aged (stockpiled or stored for at least 6 months), uniform in color, and free of other materials, such as weed seeds, soil, roots, etc. A finely shredded, well-aged organic hardwood mulch is the preferred accepted mulch; a finely shredded, well-aged organic dark pine mulch may be accepted on a case-by- case basis. The mulch should be applied to a maximum depth of 3 inches. Bark dust mulches and wood chips will float and move to the perimeter of the bioretention area during a storm event and are not acceptable. Grass clippings should not be used as a mulch material.

Mix approximately 1⁄2 the specified mulch layer into the planting soil to a depth of approximately 4 inches to help foster a highly organic surface layer.

Hardwood mulch can be very challenging to obtain in New England. Acceptable alternatives include mulching only around shrubs, and planting a conservation mix elsewhere to create a cover crop that can be mowed or weed-whacked; or planting two species of tall grasses and allowing the whole facility fill in. Regardless of the surface treatment chosen, it should outcompete or suppress weed growth, and minimize exposed soil.

Erosion control blankets installed across the bottom of the practice is not successful and should not be proposed.

B.7.4. Compaction

It is very important to minimize compaction of both the base of the bioretention area and the required backfill. When possible, use excavation hoes to remove original soil. If bioretention area is excavated using a loader, the contractor should use wide track or marsh track equipment, or light equipment with turf type tires. Use of equipment with narrow tracks or narrow tires, rubber tires with large lugs, or high pressure tires will cause excessive compaction resulting in reduced infiltration rates and storage volumes and is not acceptable. Compaction will significantly contribute to design failure.

Compaction can be alleviated at the base of the bioretention facility by using a primary tilling operation such as a chisel plow, ripper, or subsoiler. These tilling operations are performed to refracture the soil profile through the 12-in compaction zone. Substitute methods must be approved by the engineer. Rototillers typically do not till deep enough to reduce the effects of compaction from heavy equipment.

When backfilling the bioretention facility, place soil in lifts 12 inches or greater. Do not use heavy equipment within the bioretention basin. Heavy equipment can be used around the perimeter of the basin to supply soils and sand. Grade bioretention materials with light equipment such as a compact loader or a dozer/loader with marsh tracks.

B.7.5. Plant Installation

The plant root ball should be planted so 1/8th of the ball is above final grade surface. Root stock of the plant material should be kept moist during transport and on-site storage. The diameter of the planting pit should be at least six inches larger than the diameter of the planting ball. Set and maintain the plant straight during the entire planting process. Thoroughly water ground bed cover after installation.

Trees should be braced using 2 in x 2 in stakes only as necessary and for the first growing season only. Stakes are to be equally spaced on the outside of the tree ball.

Grasses and legume seed should be tilled into the soil to a depth of at least one inch. Grass and legume plugs should be planted following the non-grass ground cover planting specifications.

The planting soil specifications provide enough organic material to adequately supply nutrients from natural cycling. The primary function of the bioretention structure is to improve water quality. Adding fertilizers defeats, or at a minimum, impedes this goal. Only add fertilizer if compost or mulch is used to amend the soil. Rototill urea fertilizer at a rate of 2 pounds per 1,000 square feet.

B.7.6. Underdrains

Underdrains should be placed on a 3’-0” wide section of filter cloth. Pipe is placed next, followed by the gravel bedding. The ends of underdrain pipes not terminating in an observation well should be capped.

The main collector pipe for underdrain systems should be constructed at a minimum slope of 0.5%. Observation wells and/or clean-out pipes must be provided (one minimum per every 1,000 square feet of surface area).

B.7.7. Miscellaneous

The bioretention facility may not be constructed until all contributing drainage area has been stabilized.

Table B-8. Bioretention Material Specifications

Parameter	Specification	Size	Notes
Plantings	see Table A-2 or local NRCS Standards and Specifications guidance.	n/a	plantings are site-specific
Planting Soil [2.5' to 4' deep]	sand 85-88% soil fines 8 - 12% (≤ 2% clay) organics 3 - 5%	n/a	USDA soil types sand, loamy sand
Mulch	shredded hardwood mulch preferred		aged 6 months, minimum
Geotextile	Class "C" apparent opening size (ASTM-D-4751) grab tensile strength (ASTM-D-4632) burst strength (ASTM-D-4833)	n/a	for use over underdrains (extend 1 – 1.5 ft each side) and as necessary on sides of bioretention basin
Sand (2"-4" layer over choker stone)	AASHTO M-6 or ASTM C-33	0.02" to 0.04"	Sand substitutions such as Diabase and Graystone #10 are not acceptable. No calcium carbonated or dolomitic sand substitutions are acceptable. No rock dust can be used for sand.
Choking Stone Layer (4" layer pea gravel)	AASHTO M43 (ASTM D 448) No. 8 or 89 gravel	0.375" to 0.75"	
Underdrain gravel	AASHTO M-43	1.0"	Double washed and clean of fines
Underdrain piping	ASTM D 1785 or AASHTO M-278	6" rigid schedule 40 PVC	3/8" perf. @ 6" on center, 4 holes per row; minimum of 3" of gravel over pipes; not necessary underneath pipes
Poured in place concrete (if required)	See local AOT Standards and Specs.; f'c = 3,500 lb. @ 28 days, normal weight, air-entrained; re-enforcing to meet ASTM 615-60	n/a	on-site testing of poured-in-place concrete required: 28 day strength and slump test; all concrete design (cast-in-place or pre-cast) *not using previously approved State or local standards* requires design drawings sealed and approved by a licensed professional structural engineer.

B.8. Specifications for Open Channels

B.8.1. Material Specifications

The recommended construction materials for open channels are detailed in Table B-9.

B.8.2. Dry Swales

- Roto-till soil/gravel interface approximately 6” to avoid a sharp soil/gravel interface.
- Permeable soil mixture (24” to 48" deep) should meet the bioretention planting soil specifications.
- Check dams, if required, should be placed as specified.
- System to have 6” of freeboard, minimum.
- Side slopes to be 3:1 minimum; (4:1 or greater preferred).
- No gravel or perforated pipe is to be placed under driveways.
- Bottom of facility to be above the seasonably high water table.
- Seed with flood/drought resistant grasses; see your local NRCS Standards and Specifications guidance.
- Longitudinal slope to be 1 to 2%, maximum [up to 6% with check dams].
- Bottom width to be 8′ maximum to avoid braiding; larger widths may be used if proper berming is supplied. Width to be 2′ minimum.

B.8.3. Wet Swales

Follow above information for dry swales, with the following exceptions: the seasonally high water table may inundate the swale; but not above the design bottom of the channel [NOTE: if the water table is stable within the channel; the WQ_v storage may start at this point]

Excavate into undisturbed soils; do not use an underdrain system.

Table B-9. Open Vegetated Swale and Filter Strip Material Specifications

Parameter	Specification	Size	Notes
Dry swale soil	sand 85-88% soil fines 8 - 12% (≤ 2% clay) organics 3 - 5%	n/a	USDA soil types sand, loamy sand
Dry Swale sand	ASTM C-33 fine aggregate concrete sand	0.02" to 0.04"	
Check Dam (pressure treated)	AWPA Standard C6	6" by 6" or 8" by 8"	*do not* coat with creosote; embed at least 3' into side slopes
Check Dam (natural wood)	Black Locust, Red Mulberry, Cedars, Catalpa, White Oak, Chestnut Oak, Black Walnut	6" to 12" diameter; notch as necessary	*do not* use the following, as these species have a predisposition towards rot: Ash, Beech, Birch, Elm, Hackberry, Hemlock, Hickories, Maples, Red and Black Oak, Pines, Poplar, Spruce, Sweetgum, Willow
Pea gravel diaphragm and curtain drain	ASTM D 448	varies (No. 6) or (1/8" to 3/8")	use clean bank-run gravel
Underdrain gravel	AASHTO M-43	1.0"	Double washed and clean of fines
Underdrain piping	ASTM D 1785 or AASHTO M-278	6" rigid schedule 40 PVC	3/8" perf. @ 6" on center, 4 holes per row; minimum of 3" of gravel over pipes; not necessary underneath pipes
Geotextile	Class "C" apparent opening size (ASTM-D-4751) grab tensile strength (ASTM-D-4632) burst strength (ASTM-D-4833)	n/a	for use over underdrains (extend 1 – 1.5 ft each side) and as necessary on sides of dry swale
Rip rap	per local AOT criteria	size per Vermont AOT requirements based on 10-year design flows	

APPENDIX C ASSORTED DESIGN TOOLS

C.1. Soil Testing Requirements for Infiltration and Filtering Practices

C.1.1. General Notes Pertinent to All Testing

- For infiltration-based practices (including but not limited to infiltration trenches/basins, permeable pavements, bioretention, and dry swales), a minimum field infiltration rate (f_c) of 0.5 inches per hour is required. Areas yielding a lower infiltration rate preclude the design of these practices as infiltration systems. While disconnection-based practices (rooftop disconnection and disconnection to filter strips or vegetated buffers) may be used on most soil types, site-specific testing is required to determine the proper disconnection flow path length.
- No minimum infiltration rate is required if the proposed treatment practices are to be designed with a "day-lighting" underdrain system.
- The number of required test pits/soil borings and infiltration tests is based on the size of the proposed facility (Table C-1).
- Testing is to be conducted by a qualified professional. This professional must either be a registered professional engineer or licensed Site Designer in the State of Vermont, or a qualified soil scientist, geologist, or hydrogeologist.

C.1.2. Initial Feasibility Testing

Feasibility testing should be conducted to determine whether full-scale testing is necessary, and is meant to screen unsuitable sites and reduce testing costs. Soil borings or test pits are not required at this stage.

Initial feasibility testing could include either one field test per facility, regardless of type or size, or previous testing data such as the following:

- Septic system test pits or percolation testing on-site, within 200 feet of the proposed STP location, and on the same contour (can establish initial infiltration rate, water table, and/or depth to bedrock)
- Previous written geotechnical reporting on the site location as prepared by a qualified geotechnical consultant
- NRCS Soil Survey mapping showing an unsuitable soil group, such as widespread presences of a hydrologic group "D" soil

If the results of initial feasibility testing as determined by a qualified professional show that an infiltration rate of greater than 0.2 inches per hour is probable, then the number of design test pits and infiltration tests should be per Table C-1. An encased soil boring may be substituted for a test pit, if desired.

Table C-1. Soil Characterization and Infiltration Testing Summary

Type of Practice	Contributing Area Land Use	Design Soil Testing Requirements
Infiltration Practices (Infiltration Basin, Permeable Pavement, Bioretention, etc.)	Residential Rooftops	1 infiltration test and 1 test pit per 5 lots, assuming consistent terrain and NRCS soil series. If terrain and soil series are not consistent, 1 infiltration test and 1 test pit are required per individual lot.
	All Other Land Uses	1 infiltration test and 1 test pit per 5,000 ft^2 of expected facility area
Linear Infiltration Practices (Infiltration Trench, Dry Swale)	All Land Uses	1 infiltration test and 1 test pit per 200 ft of expected practice length (no underdrains required for dry swales if infiltration rate > 0.5 in/hr[b])
Filtering Practices[a]	All Land Uses	1 infiltration test and 1 test pit per 5,000 ft^2 (no underdrains required if infiltration rate > 0.5 in/hr[b])

a. When proposed as a treatment/infiltration system. If proposed as strictly a filtration practice, infiltration testing analysis is not required, but a test pit or boring is required to verify depth to seasonal high groundwater or bedrock.

b. Underdrain installation still strongly suggested.

C.1.3. Test Pit/Boring Requirements

- The location of the test pit or boring shall correspond to the facility location; test pit/soil boring stakes are to be left in the field for inspection purposes and shall be clearly labeled as such.
- Excavate a test pit or dig a standard soil boring to a depth of at least 4 feet below the proposed facility bottom.
- Soil descriptions shall include USDA or Unified Soil Classification System textures for all soil horizons. Soil profile descriptions shall be provided consistent with the Vermont Wastewater System and Potable Water Supply Rules, §1-902(b)(2) and Appendix 2-A. Test pit or soil boring logs should include annotations calling out soil characteristics at the proposed bottom and 4 feet below the bottom of the proposed practice.
- Determine depth to groundwater table (if within 4 feet of proposed bottom) upon initial digging or drilling, and again 24 hours later when conducting soil borings or drilling wells. A Vermont-registered P.E., Licensed Designer, or qualified soil scientist or geologist may establish seasonal high groundwater depth in test pits based on redoximorphic features and need not revisit the site 24 hours later.
- Determine depth to bedrock (if within 4 feet of proposed facility bottom).

C.1.4. Infiltration Testing Requirements and Documentation

Field infiltration test methods to assess saturated hydraulic conductivity must simulate the "field-saturated" condition (see ASTM D5126-90 *Standard Guide for Comparison of Field Methods for Determining Hydraulic Conductivity in the Vadose Zone*). Infiltration test locations shall correspond to the proposed treatment practice locations, and infiltration tests must be conducted at the depth of the bottom of the proposed infiltrating practice. Design infiltration rates shall be determined by using a factor of safety of 2 from the field-derived value. The saturated hydraulic conductivity analysis must be conducted by the Vermont-registered P.E., Licensed Designer, or qualified soil scientist or geologist. Percolation tests are not acceptable in place of testing for saturated hydraulic conductivity, as they overestimate saturated hydraulic conductivity values. Acceptable tests include:

- Guelph permeameter - ASTM D5126-90 Method
- Falling head permeameter – ASTM D5126-90 Method
- Double ring permeameter or infiltrometer - ASTM D3385-09, D5093-02, D5126-90 Methods

- Amoozemeter or Amoozegar permeameter – Amoozegar 1992
- Borehole Infiltration Test as described below:
  - Install casing (solid 6 inch diameter) to 24" below proposed practice bottom.
  - Remove any smeared soiled surfaces and provide a natural soil interface into which water may percolate. Remove all loose material from the casing. Upon the tester's discretion, a two (2) inch layer of coarse sand or fine gravel may be placed to protect the bottom from scouring and sediment. Fill casing with clean water to a depth of 24" and allow to pre-soak for up to twenty-four hours.
  - Refill casing with another 24" of clean water and monitor water level (measured drop from the top of the casing) for 1 hour. Repeat this procedure (filling the casing each time) three additional times, for a total of four observations. Upon the tester's discretion, the final field rate may either be the average of the four observations, or the value of the last observation. All observations shall be reported. The final rate should be reported in inches per hour.
  - This test may be completed in a soil boring or in an open excavation.
  - Upon completion of the testing, the casings should be immediately pulled, and the test pit should be back-filled.

Infiltration testing methods and results shall be documented, including a short narrative description of the infiltration testing method utilized to ensure that the tester understands the procedure.

C.1.5. Laboratory Testing

Grain-size sieve analysis (and hydrometer tests where appropriate) may be used to determine USDA soils classification and textural analysis. Visual field inspection by a qualified professional may also be used, provided it is documented. The use of laboratory testing to establish infiltration rates is prohibited.

C.1.6. Groundwater Mounding Analysis

Groundwater mounding, the process by which a mound of water forms on the water table as a result of concentrated recharge applied at or near the ground surface, can be a limiting factor in the design and performance of infiltration practices. A minimum of 3 feet of separation between the bottom of the infiltration practice and seasonally saturated soils (or from bedrock) is required to maintain the hydraulic capacity of the practice and provide adequate water quality treatment. A groundwater mounding analysis is recommended to verify this separation for infiltration–based practices.

A groundwater mounding analysis is required when the vertical separation from the bottom of an infiltration system to seasonal high groundwater is less than 4 feet, and the infiltration system is proposed to attenuate the peak discharge from a 10-year or higher 24-hour storm (e.g., 10-year, or 100-year 24-hour storm). In such cases, the mounding analysis must demonstrate that the required design volume can be fully dewatered within 72 hours (so the next storm can be stored for infiltration). The mounding analysis must also demonstrate that the groundwater mound that forms under the infiltration system will not break out above the land or the water surface of a wetland.

The most widely known and accepted analytical methods to solve for groundwater mounding are based on the work by Hantush (1967) and Glover (1960). The Hantush method or other equivalent method may be used to conduct the mounding analysis. The Hantush method predicts the maximum height of the groundwater mound beneath a rectangular or circular recharge area. It assumes unconfined groundwater flow, and that a linear relation exists between the water table elevation and water table decline rate. It results in a water table recession hydrograph depicting exponential decline. The Hantush method is available in proprietary software and free online calculators on the Web in automated format. If the analysis indicates the mound will prevent the infiltration BMP from fully draining within the 72-hour period, an iterative process must be employed to determine an alternative design that drains within the 72-hour period.

Detailed ground water mounding analysis should be conducted by a qualified hydrogeologist or equivalent as part of the site design procedure.

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C.2. Documentation of STP Ability to Meet Pollutant Removal Requirements

[To be inserted by DEC, or deleted.]

C.3. 90th Percentile Rainfall Analysis

Vermont's water quality treatment standard (WQTS) is based on treatment of the 90th percentile storm, which is defined in the 2002 Stormwater Management Manual is 0.9 inches of rainfall across the entire state. This value was based on a rainfall frequency analysis performed by the Center for Watershed Protection using data collected between 1949 and 1999 from five geographically diverse weather stations, see Figure C-1.

In updating this Manual, to account for changing climate trends, rainfall data was sought from the same five weather stations for the most recent 30-year period – from January 1, 1985 to December 31, 2015. Four of the five stations used in the original analysis were found to still be operating; the Bellows Falls is no longer operational. A weather station in Walpole, New Hampshire – roughly five miles southeast of the former Bellows Falls station – was identified as the nearest with a sufficiently long precipitation record to complete the analysis. Thus the rainfall frequency analysis was updated using data from this slightly modified set of five stations and following a protocol similar to as was observed in 2002, which is as follows:

- Daily precipitation, snowfall, and temperature record were obtained from the National Oceanic and Atmospheric Administration (NOAA 2015).
- The analysis was conducted using the total precipitation (rain and snow) record.
- All precipitation depths of 0.1 inches or less were discarded. This is based on the assumption that the majority of precipitation events that are 0.1 inches or less generally will not generate a measurable amount of runoff. While the actual depth may vary from site to site, 0.1 inches is frequently used as the cutoff point in rainfall frequency analysis.

The results of this analysis area presented in Table C-2, below. All stations experienced a 0.05" to 0.11" increase in the 90th percentile storm when compared to the original analysis. This supports the recommendation to increase the depth of the water quality storm in the 2015 Vermont Stormwater Management Manual from 0.9" to 1".

Table C-2. 90th Percentile Rainfall Analysis for Selected Vermont Weather Stations

Name	Area of State	Elevation (ft)	90th Percentile Precipitation Event (inches)	
			1949-1999	1985-2014
Bellows Falls, VT	Southeast	270.0	1.03	–
Burlington, VT	Northwest	330.1	0.83	0.94
Montpelier, VT	Central	1126.0	0.88	0.93
Rutland, VT	Southwest	620.1	0.90	1.01
St Johnsbury, VT	Northeast	700.1	0.82	0.87
Walpole 3, NH	Southeast	930.1	–	1.12
Mean Precipitation (inches)			**0.89**	**0.97**

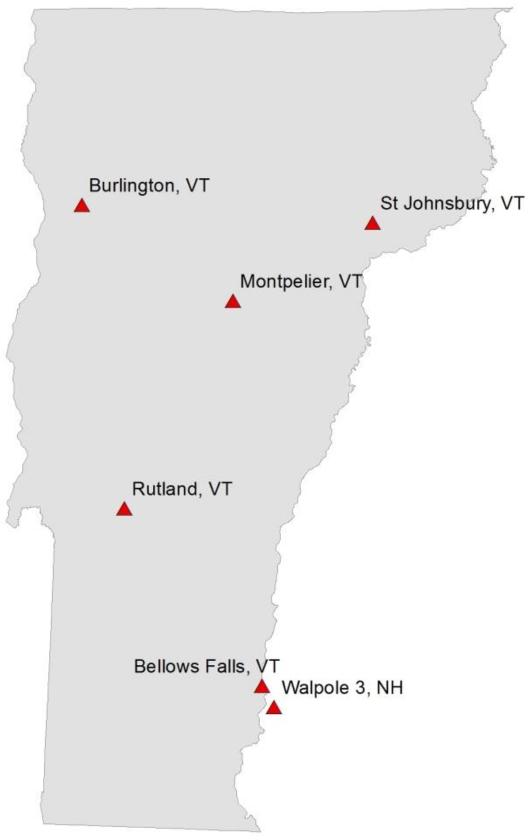


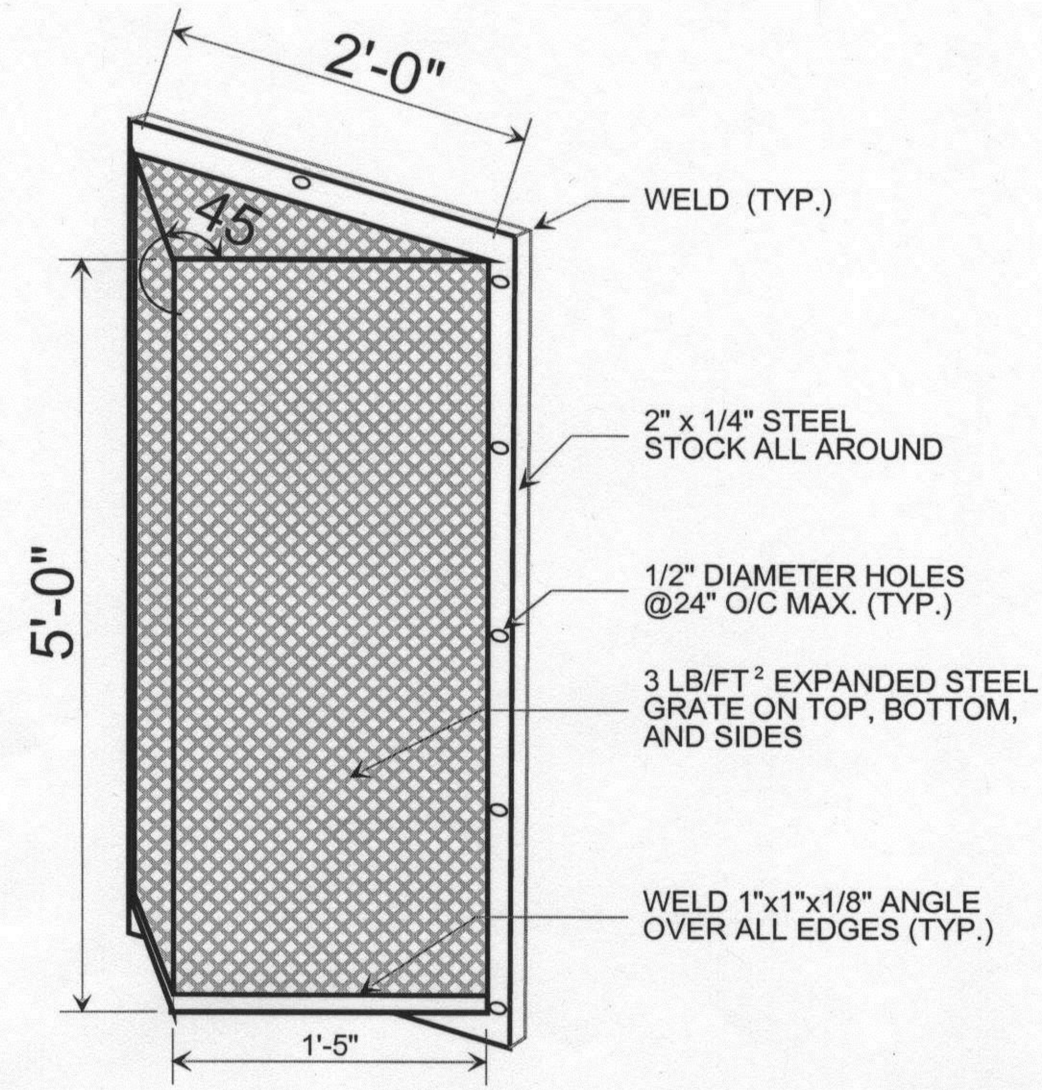
Figure C-1. Weather Stations used in 90th Percentile Rainfall Analysis

Source:

National Oceanic and Atmospheric Administration. (2015.) *GHCN (Global Historical Climatology Network) – Daily* [online database]. Retrieved from the web January 16th, 2015. http://www.ncdc.noaa.gov/cdo-web/

C.4. Miscellaneous Details

Miscellaneous Design Schematics for Compliance with Performance Criteria



NOTES FOR TRASH RACK

1. TRASH RACK TO BE CENTERED OVER OPENING.
2. STEEL TO CONFORM TO ASTM A-36.
3. ALL SURFACES TO BE COATED WITH ZRC COLD GALVANIZING COMPOUND AFTER WELDING.
4. TRASH RACK TO BE FASTENED TO THE WALL WITH 1/2" MASONRY ANCHORS. TRASH RACK TO BE REMOVABLE.

Figure C-2. Trash Rack Protection for Low Flow Orifice

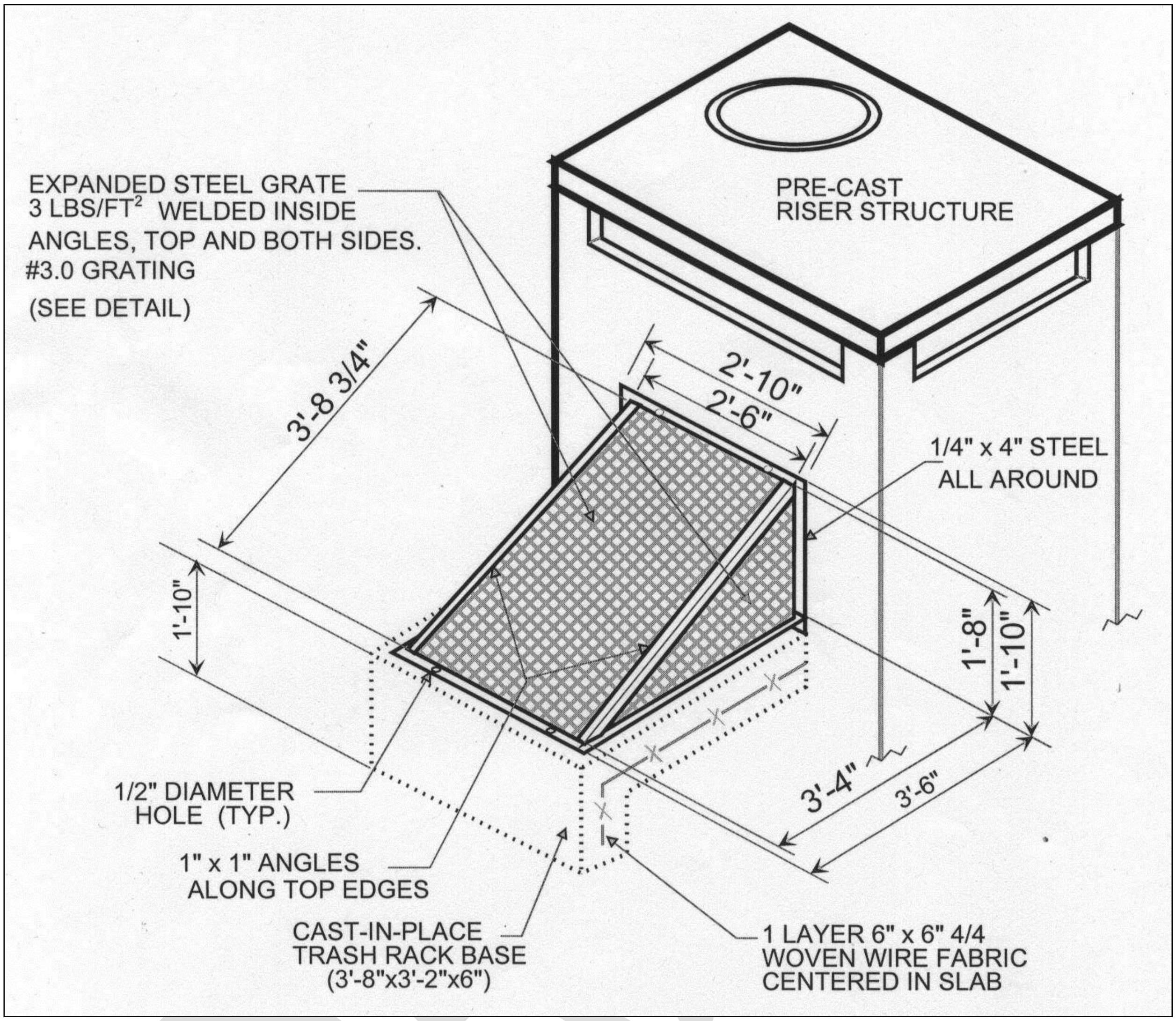


Figure C-3. Expanded Trash Rack Protection for Low Flow Orifice

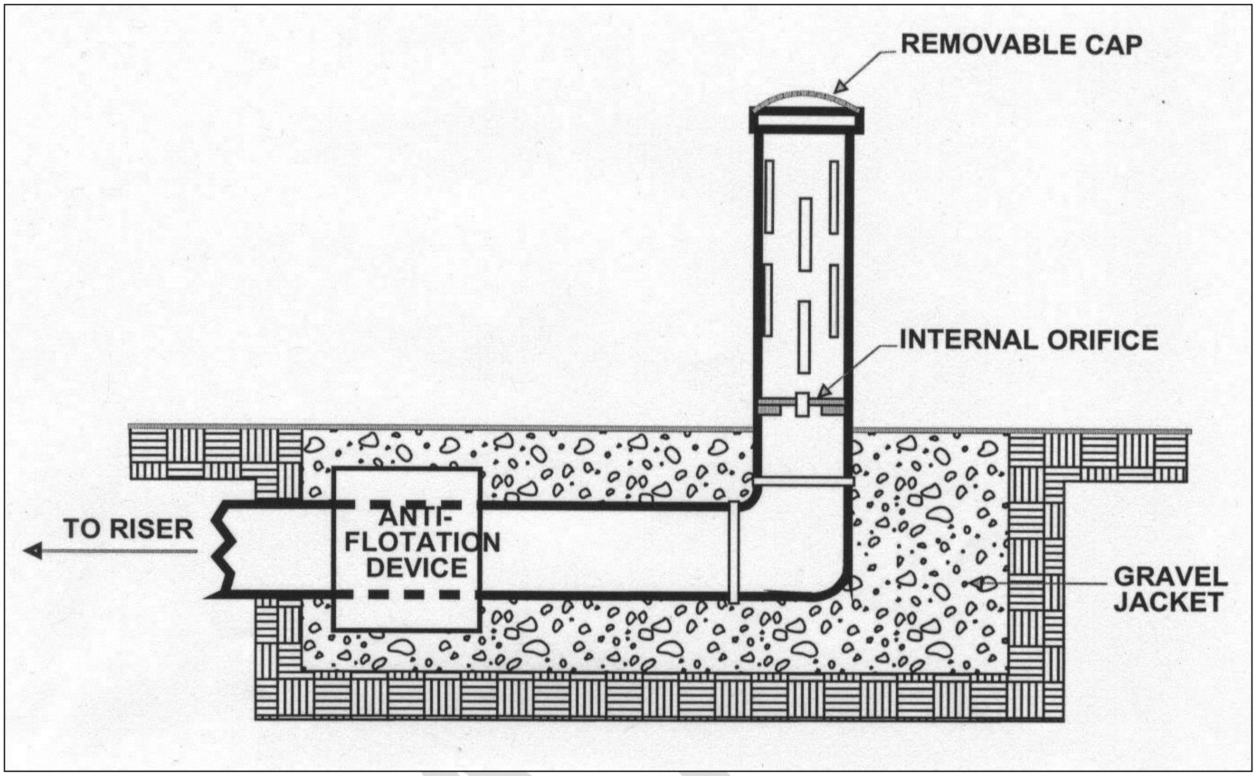
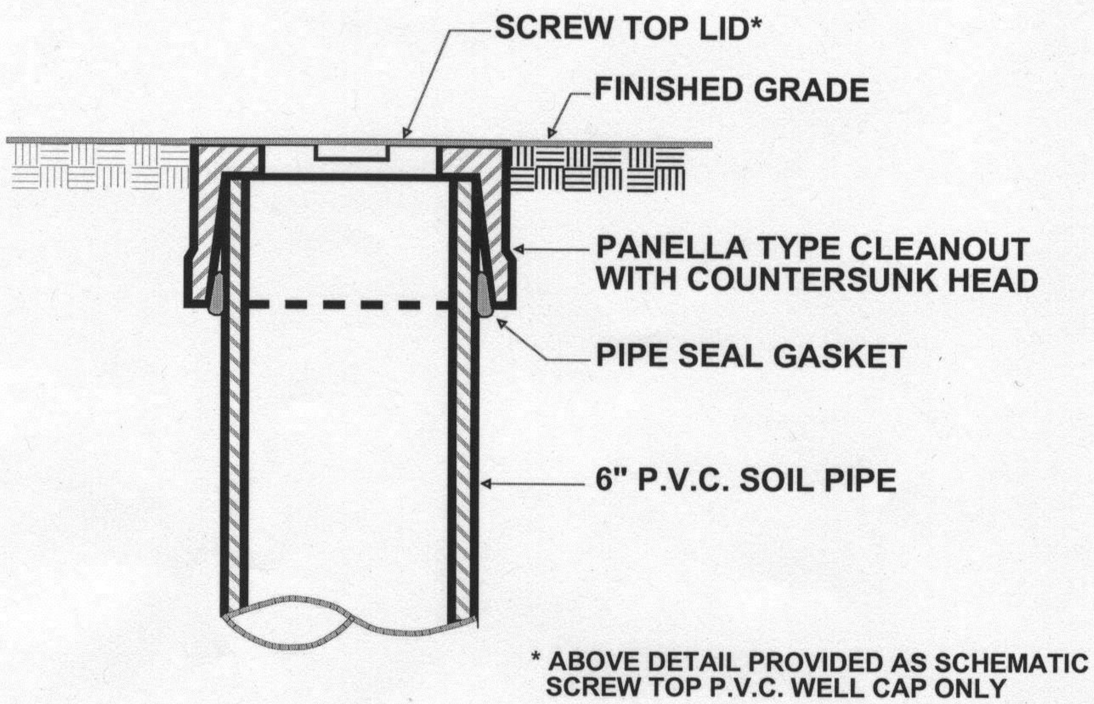


Figure C-4. Internal Control for Orifice Protection



EACH OBSERVATION WELL / CLEANOUT SHALL INCLUDE THE FOLLOWING:

1. FOR AN UNDERGROUND FLUSH MOUNTED OBSERVATION WELL / CLEANOUT, PROVIDE A TUBE MADE OF NON-CORROSIVE MATERIAL, SCHEDULE 40 OR EQUAL, AT LEAST THREE FEET LONG WITH AN INSIDE DIAMETER OF AT LEAST 6 INCHES.
2. THE TUBE SHALL HAVE A FACTORY ATTACHED CAST IRON OR HIGH IMPACT PLASTIC COLLAR WITH RIBS TO PREVENT ROTATION WHEN REMOVING SCREW TOP LID. THE SCREW TOP LID SHALL BE CAST IRON OR HIGH OMPACT PLASTIC THAT WILL WITHSTAND ULTRA-VIOLET RAYS.

Figure C-5. Observation Well for Infiltration Practices

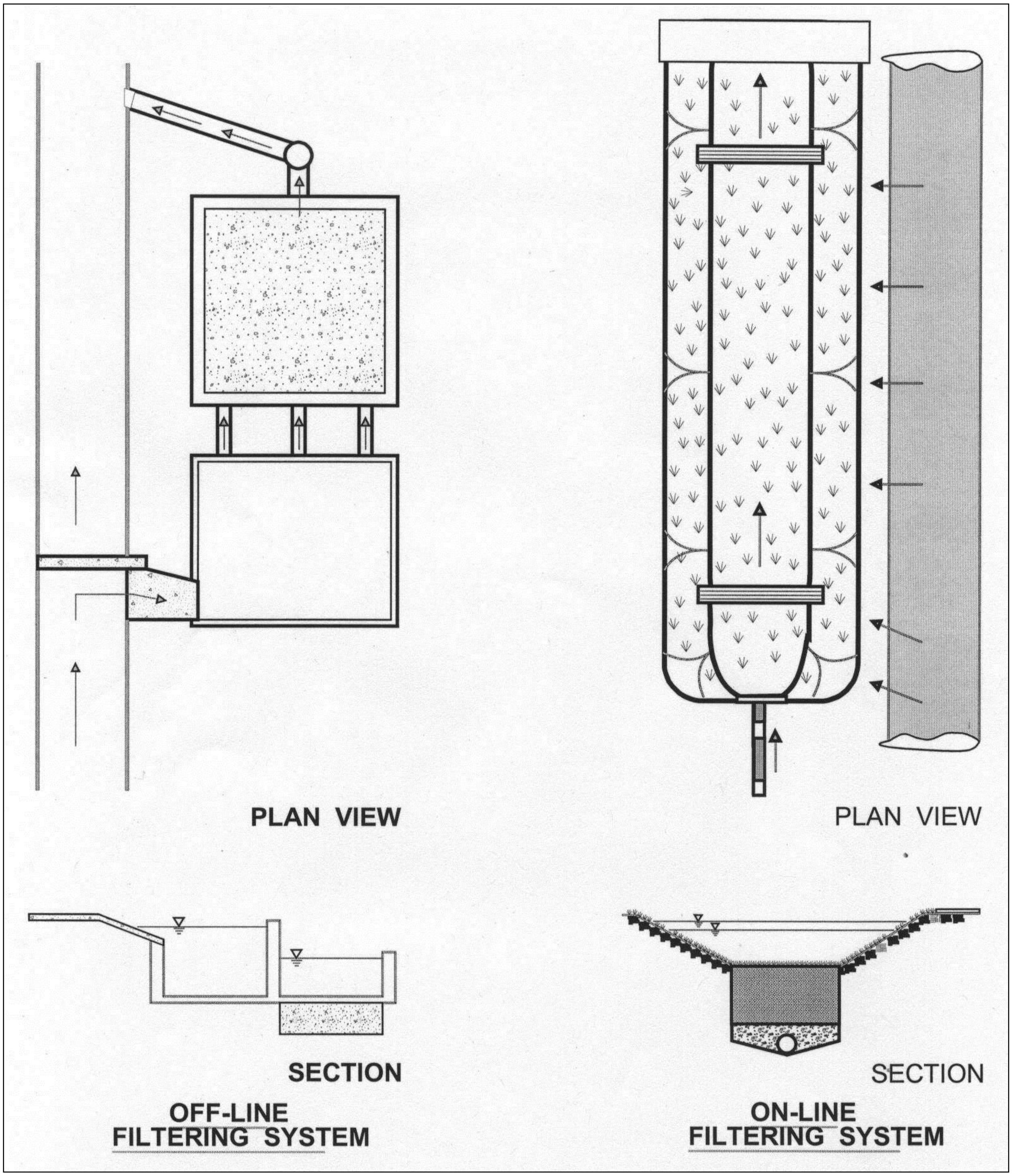


Figure C-6. On-Line Versus Off-Line Schematic

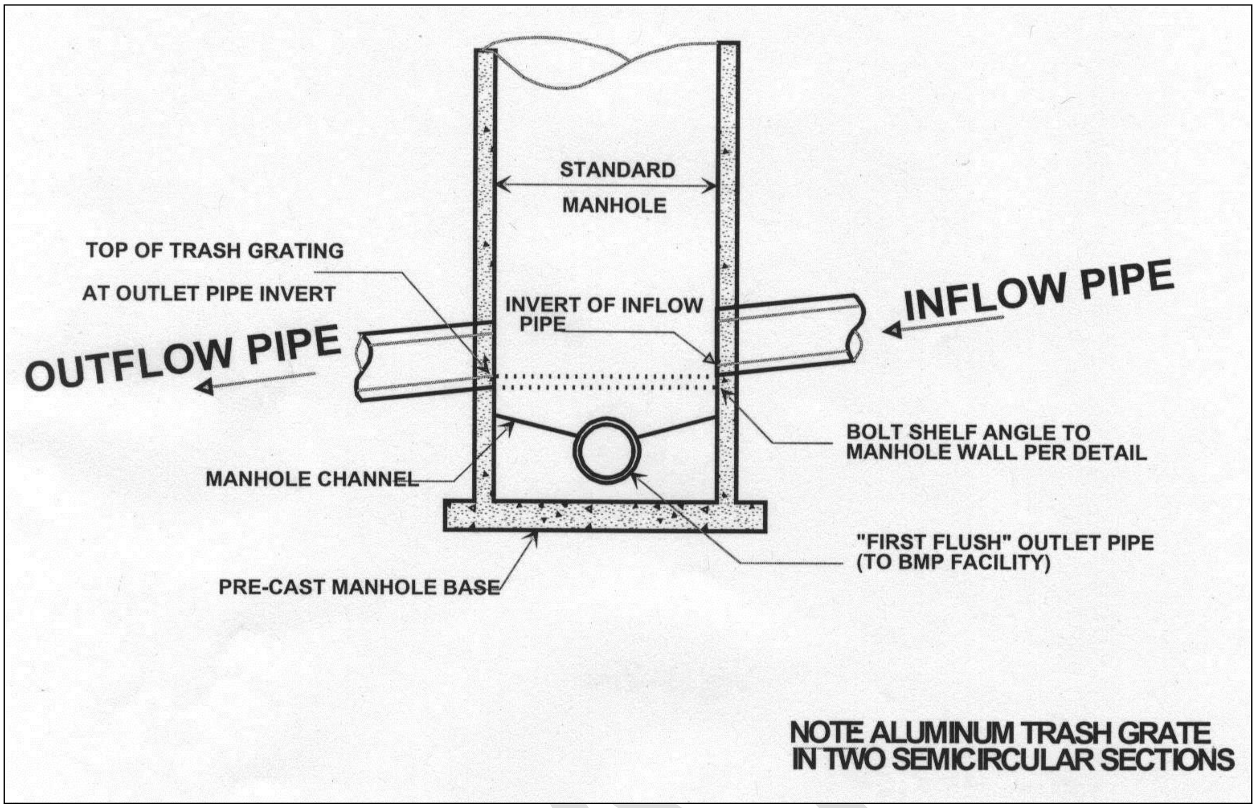


Figure C-7. Isolation Diversion Structure

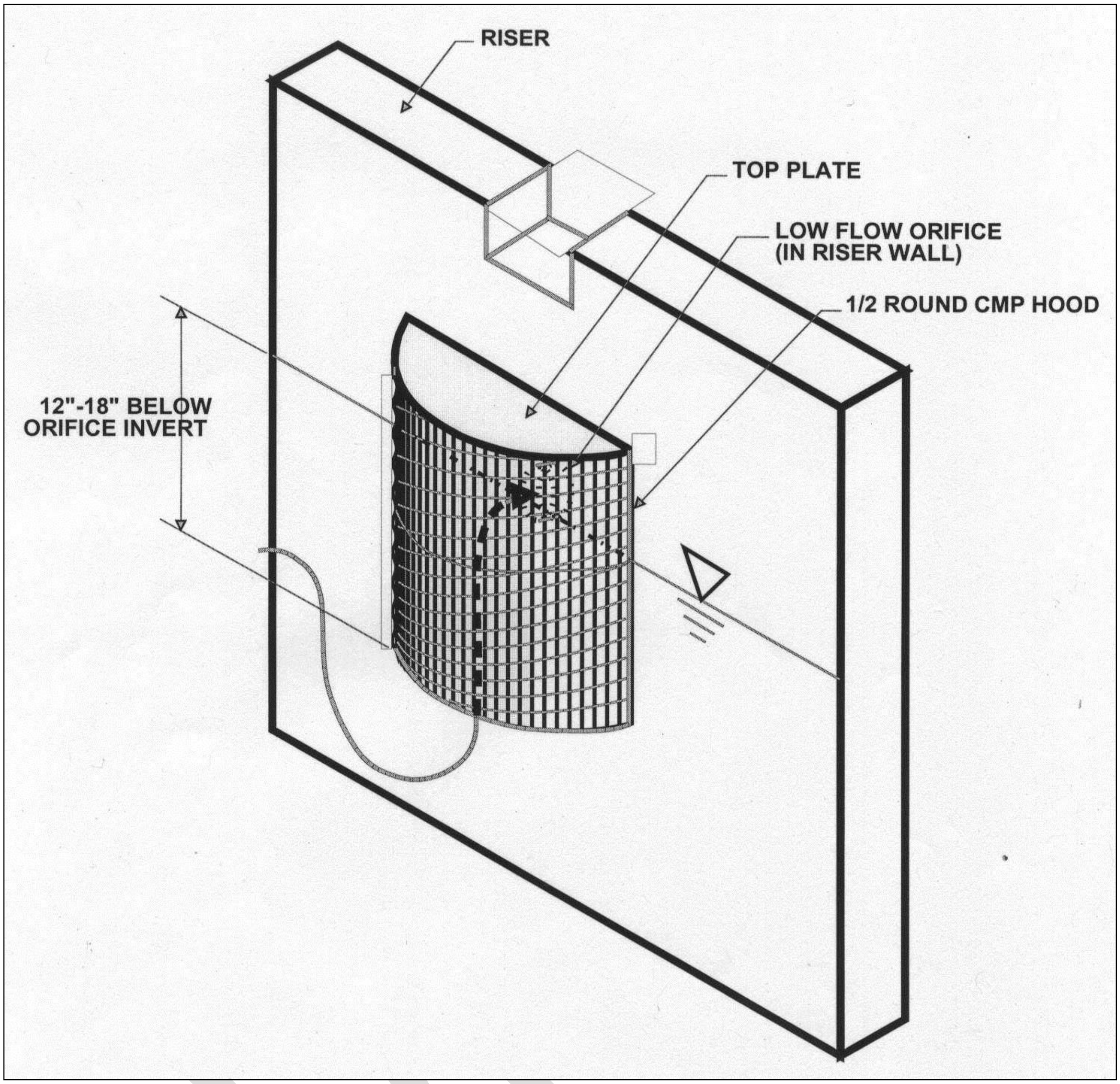


Figure C-8. Half Round CMP Hood

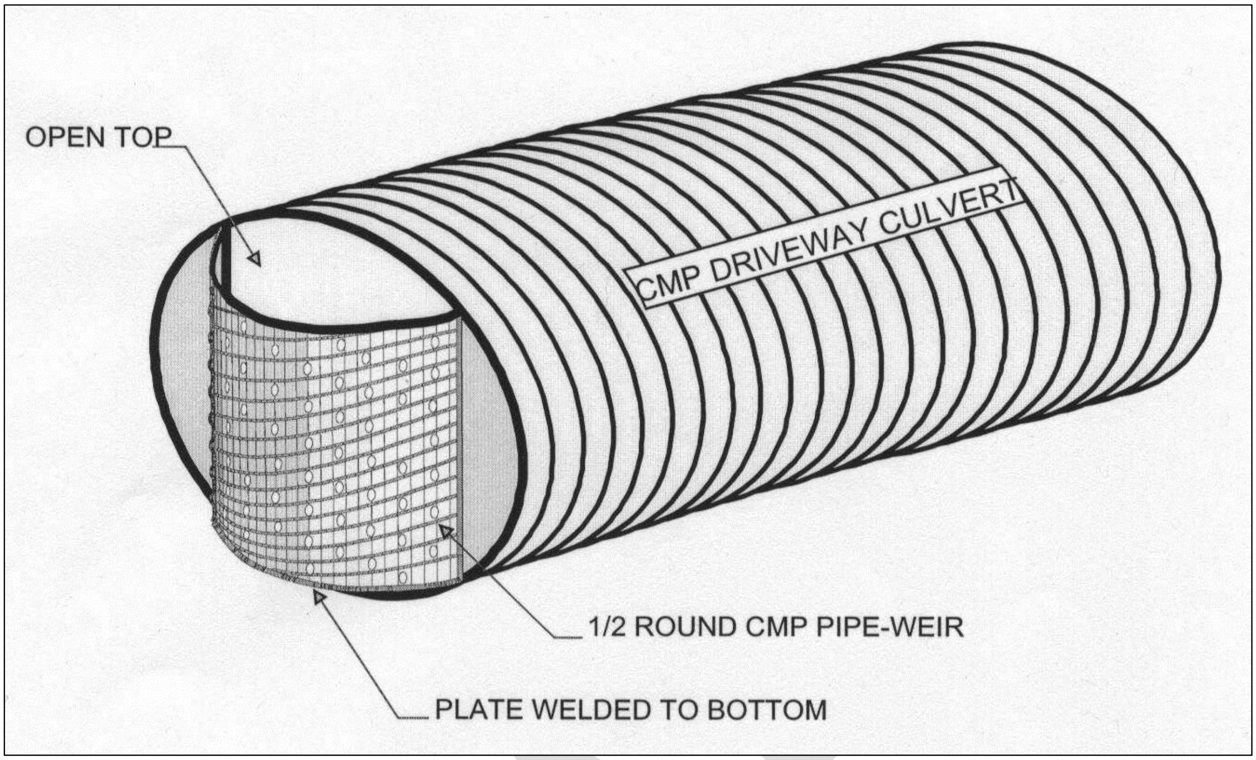


Figure C-9. Half Round CMP Weir

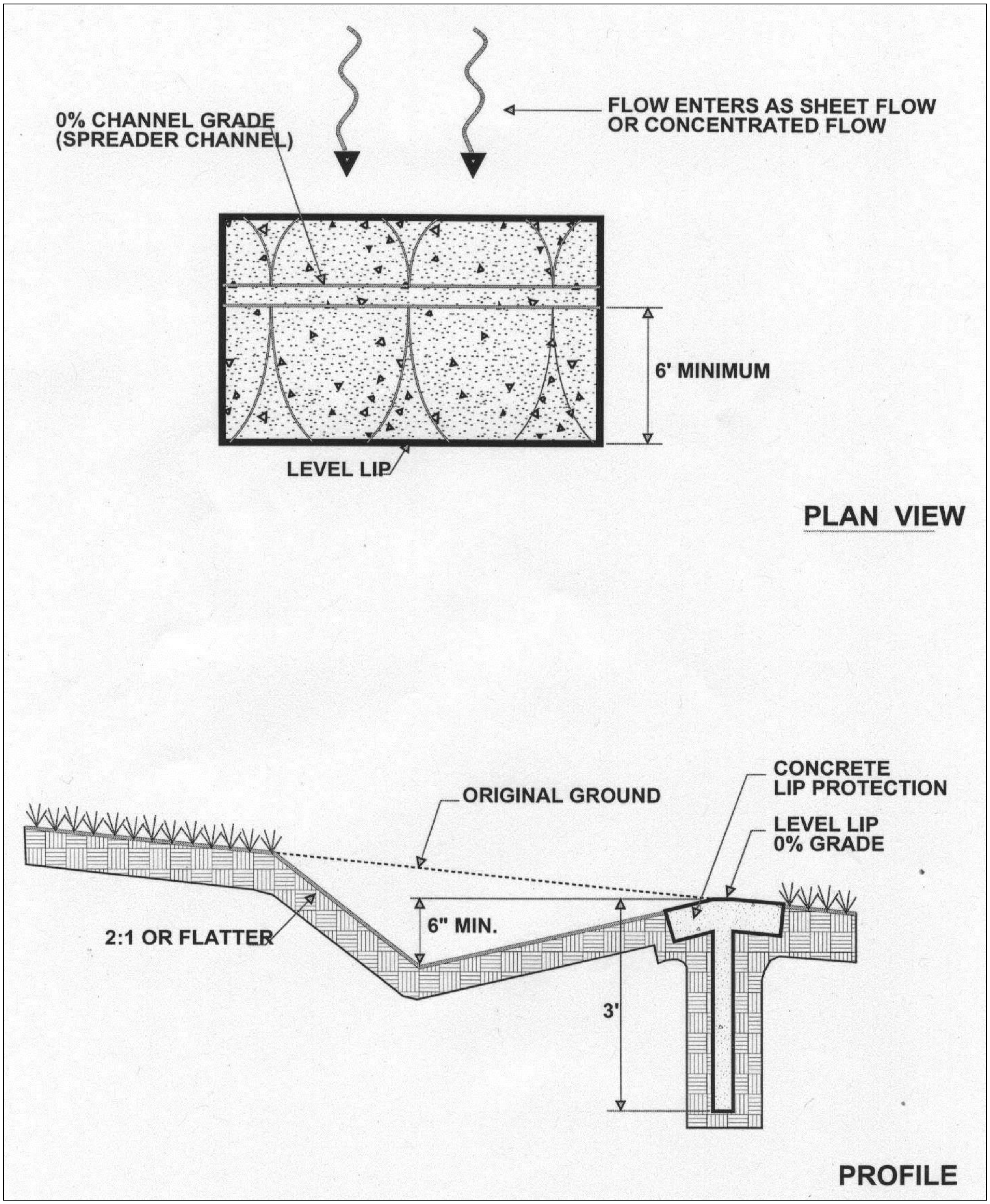


Figure C-10. Concrete Level Spreader

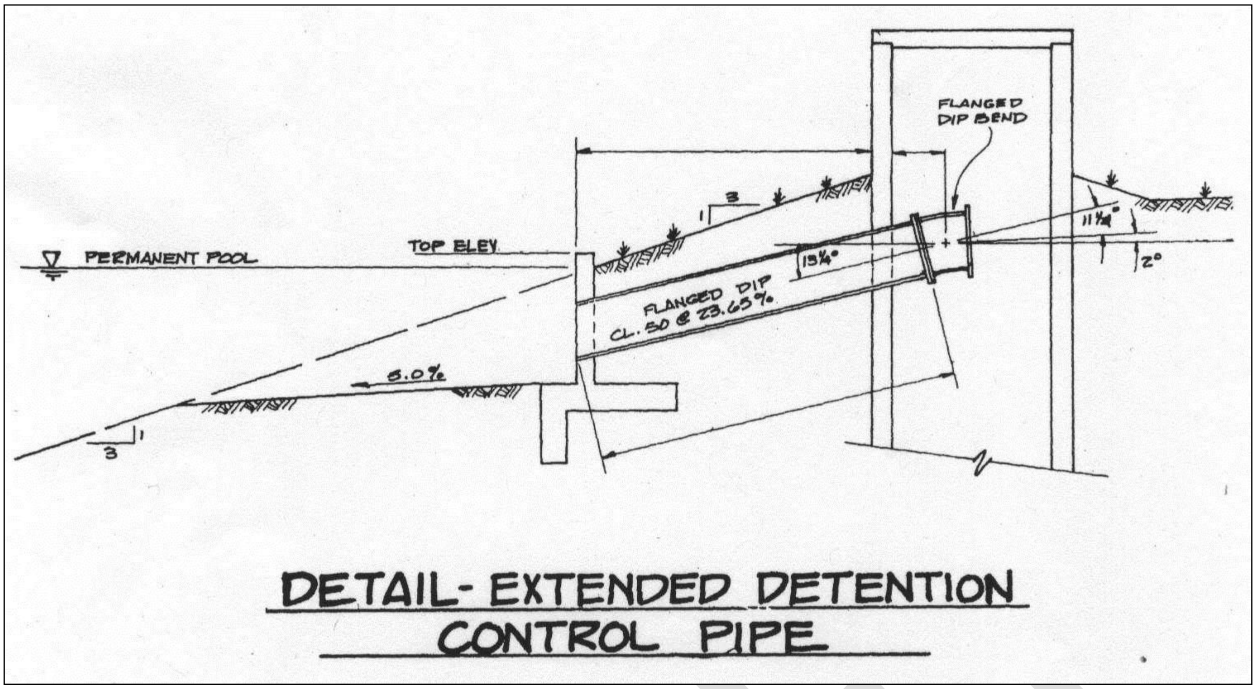


Figure C-11. Example of Reverse Slope Pipe

C.5. Hydrologic Analysis Tools

This Appendix presents two hydrologic and hydraulic analysis tools that can be used to size stormwater treatment practices (STPs). The first is the TR-55 "short-cut" sizing technique, used to size practices designed for extended detention, slightly modified to incorporate the flows necessary to provide channel protection. The second is a method used to determine the peak flow from water quality storm events. (This is often important when the water quality storm is diverted to a water quality practice, with other larger events bypassed).

C.5.1. Storage Volume Estimation

This section presents a modified version of the TR-55 (NRCS, 1986) short cut sizing approach. The method was modified by Harrington (1987), for applications where the peak discharge is very small compared with the uncontrolled discharge. This often occurs in the 1-year, 24-hour detention sizing.

Using TR-55 guidance, the unit peak discharge (q_u) can be determined based on the Curve Number and Time of Concentration (Figure C-12). Knowing q_u and T (extended detention time), q_o/q_i (peak outflow discharge/peak inflow discharge) can be estimated from Figure C-13.

Then using q_o/q_i, Figure C-14 can be used to estimate V_s/V_r. For a Type II or Type III rainfall distribution, V_s/V_r can also be calculated using the following equation:

$$\frac{V_s}{V_r} = 0.682 - 1.43\left(\frac{q_o}{q_i}\right) + 1.64\left(\frac{q_o}{q_i}\right)^2 - 0.804\left(\frac{q_o}{q_i}\right)^3$$

Where:

V_S = required storage volume (acre-feet)

V_r = runoff volume (acre-feet)

q_o = peak outflow discharge (cfs)

q_i = peak inflow discharge (cfs)

The required storage volume can then be calculated by:

$$V_s = \frac{\left(\frac{V_s}{V_r}\right)(Q_d)(A)}{12}$$

Where:

V_S and V_r are defined above

Q_d = the developed runoff for the design storm (inches)

A = total drainage area (acres)

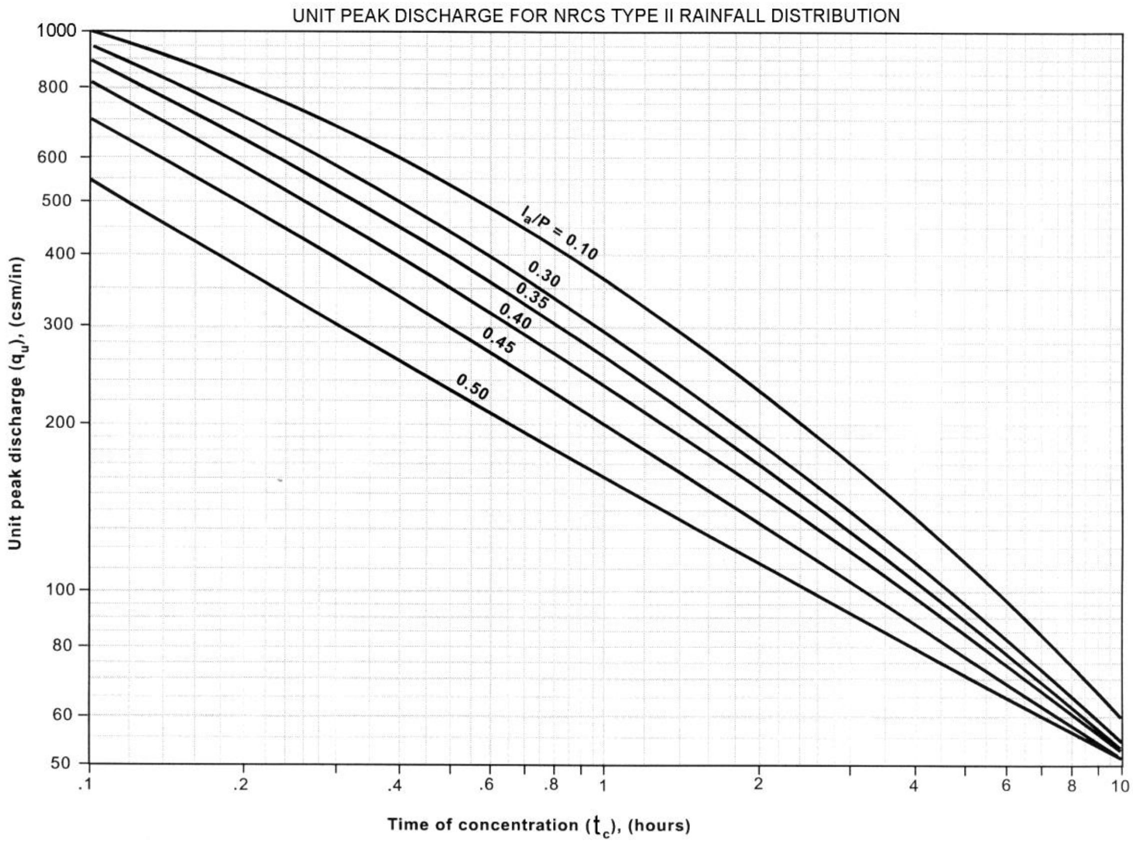


Figure C-12. Unit Peak Discharge for Type II Rainfall Distribution (Source: NRCS, 1986)

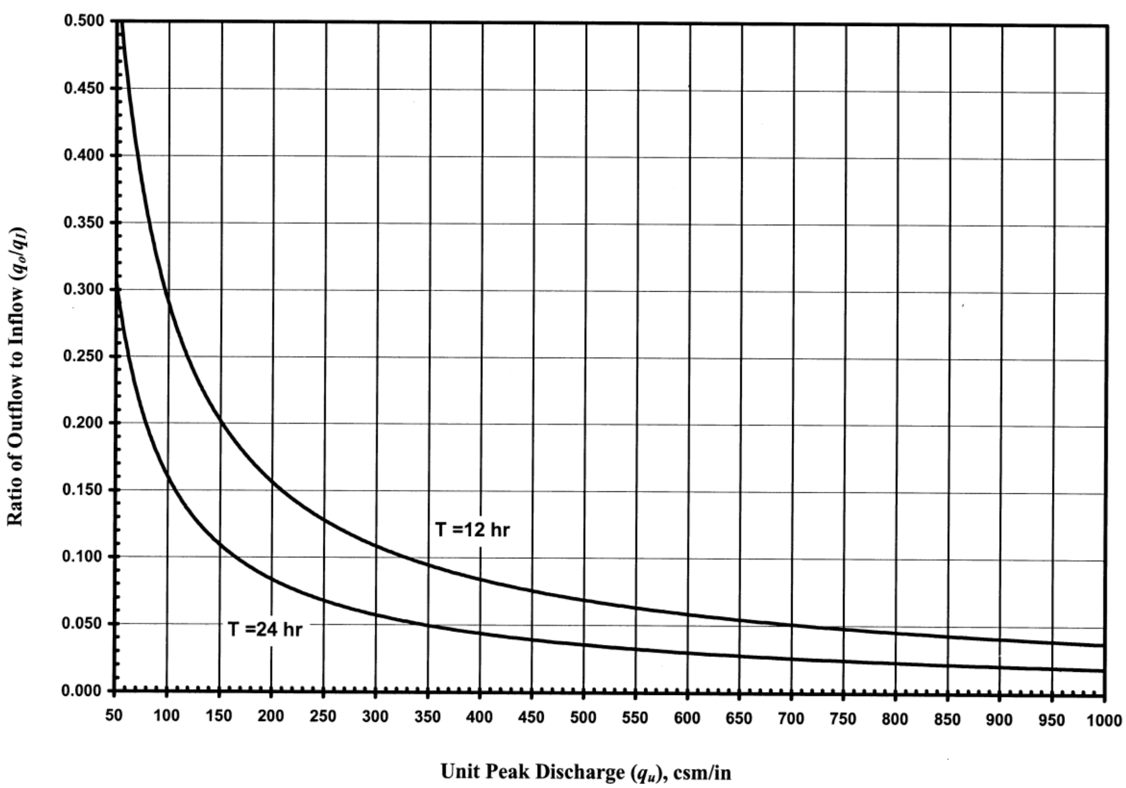


Figure C-13. Detention Time vs. Discharge Ratios (Source: Harrington, 1987)

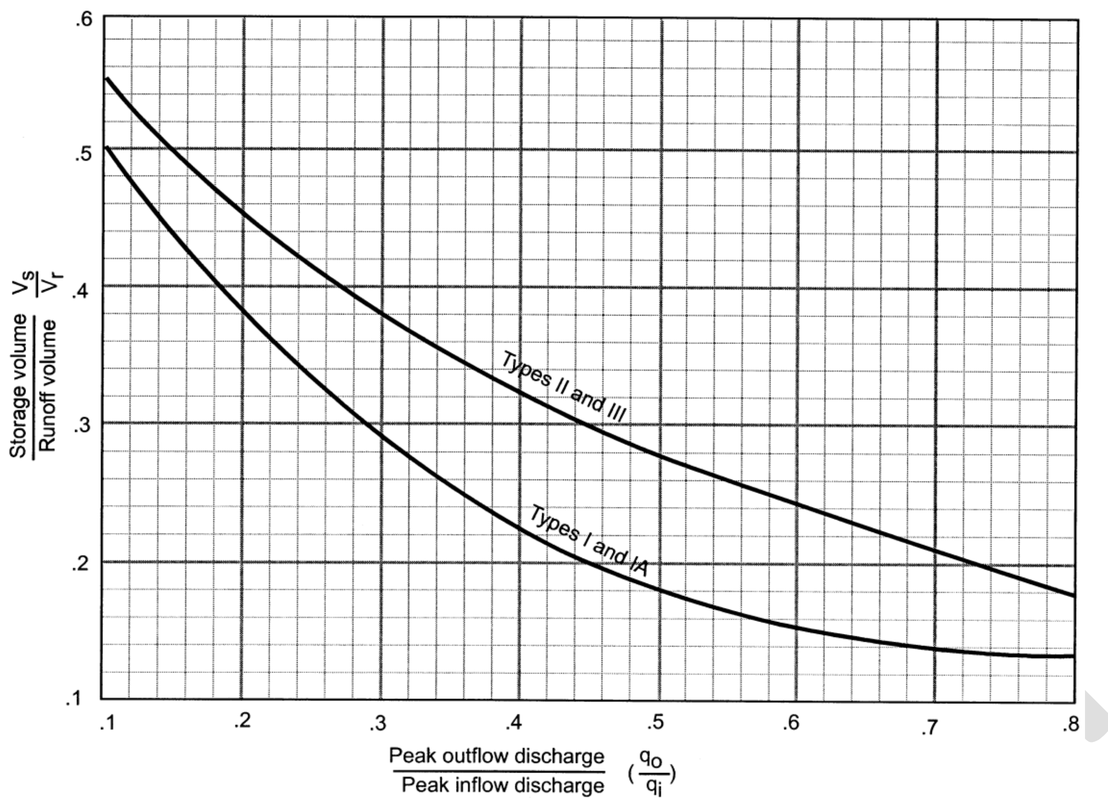


Figure C-14. Approximate Detention Basin Routing For Rainfall Types I, IA, II, and III. (Source: NRCS, 1986)

C.5.2. Water Quality Peak Flow Calculation

The peak rate of discharge for the water quality design storm is needed for the sizing of off-line diversion structures, such as sand filters and grass channels. Conventional NRCS methods have been found to underestimate the volume and rate of runoff for rainfall events less than 2". This discrepancy in estimating runoff and discharge rates can lead to situations where a significant amount of runoff by-passes the filtering treatment practice due to an inadequately sized diversion structure and leads to the design of undersized bypass channels.

The following procedure can be used to estimate peak discharges for small storm events. It relies on the water quality volume and a modified approach to the NRCS peak flow estimating method. A brief description of the calculation procedure is presented below.

Using the water quality volume (WQV), a corresponding Curve Number (CN) is computed utilizing the following equation:

$$CN = \frac{1000}{[10 + 5P + 10Q_a - 10(Q_a^2 + 1.25Q_aP)^{1/2}]}$$

Where

P = rainfall, in inches (use the Water Quality Storm depth, 1")
Q_a = runoff volume, in inches (equal to WQ_V ÷ area)

Once a CN is computed, the time of concentration (t_c) is computed (based on the methods identified in TR-55 and Section 2 of this Manual).

Using the computed CN, t_c and drainage area (A), in acres; the peak discharge (Q_{wq}) for the water quality storm event is computed as follows.

Read initial abstraction (I_a), compute I_a/P

Read the unit peak discharge (q_u) for appropriate t_c

Using the water quality volume (WQ_V), compute the peak discharge (Q_{wq})

$$Q_{wq} = q_u \times A \times WQ_v$$

where

Q_{wq}	=	the peak discharge, in cfs
q_u	=	the unit peak discharge, in cfs/mi²/inch
A	=	drainage area, in square miles
WQ_V	=	Water Quality Volume, in watershed inches

C.6. Critical Erosive Velocities for Grass and Soil

C.6.1. Velocity

Maximum permissible velocities of flow in vegetated channels absent of permanent turf reinforcement matting must not exceed the values shown in the following table:

Table C-3. Permissible Velocities for Channels Lined with Vegetation

Channel Slope	Lining	Permissible Velocity[1] (ft/sec)
0-5%	Tall fescue Kentucky bluegrass	5
	Grass-legume mixture	4
	Red fescue Redtop Serices lespedeza Annual lespedeza Small grains	2.5
5-10%	Tall fescue Kentucky bluegrass	4
	Grass-legume mixture	3
Greater than 10%	Tall fescue Kentucky bluegrass	3
Source: Schwab, G. O., D.D. Fangmeier, W. J. Elliot, and R. K. Frevert, 1992. Soil and Water Conservation Engineering. John Wiley & Sons. 528 pp.		

For vegetated earth channels having permanent turf reinforcement matting, the permissible flow velocity must not exceed 8 ft/sec. Turf reinforcement matting must be a machine produced mat of non-degradable fibers or elements having a uniform thickness and distribution of weave throughout. Matting must be installed per manufacturer's recommendations with appropriate fasteners as required. Examples of acceptable products include but are not limited to:

- North American Green "C350" or "P300"
- Greenstreak "PEC-MAT"
- Tensar "Erosion Mat"

[1] For highly erodible soils, permissible velocities should be decreased 25%. An erodibility factor (K) greater than 0.35 would indicate a highly erodible soil. Erodibility factors (K-factors) can be obtained from local NRCS offices.

C.6.2. Manning's n value

The roughness coefficient, n, varies with the type of vegetative cover and flow depth. At very shallow depths, where the vegetation height is equal to or greater than the flow depth, the n value should be approximately 0.15. This value is appropriate for flow depths up to 4 inches typically. For higher flow rates and flow depths, the n value decreases to a minimum of 0.03 for grass channels at a depth of approximately 12 inches. The n value must be adjusted for varying flow depths between 4" and 12" (see Figure C-15).

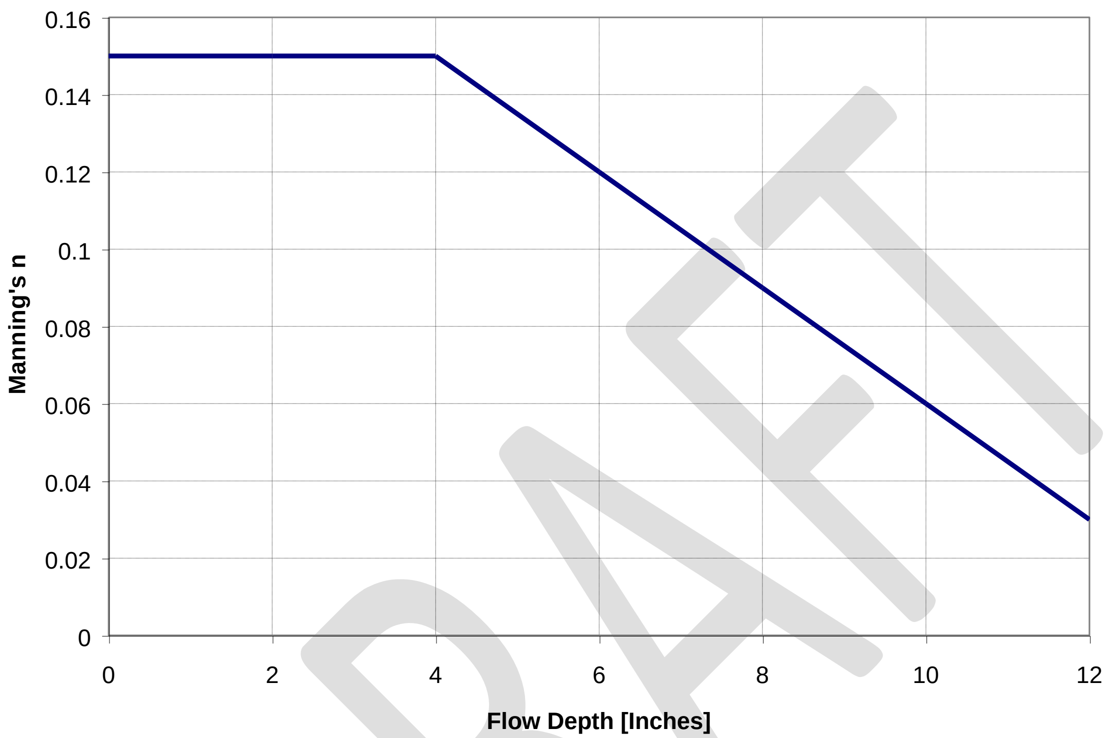


Figure C-15. Manning's n Value with Varying Flow Depth (Source: Claytor and Schueler, 1986)