PLAINVILLE

Low Impact Development and Stormwater Management Design Manual

Planimetrics
31 Ensign Drive, Avon, CT 06001 860-677-5267

Trinkaus Engineering, LLC
114 Hunters Ridge Road
Southbury, CT 06488
203-264-4558

This manual contains proprietary information developed by Steven Trinkaus, PE in addition to information obtained from authentic and highly regarded Low Impact Development sources, including results of independent observations of LID systems in the field. Sources are identified where this material has been used.

Any reuse of the information contained in this manual outside the Town of Plainville must provide a written acknowledgement to the “Town of Plainville; Low Impact Development and Stormwater Management Design Manual” and its author, Steven D. Trinkaus, PE.

This project was made possible by a grant from the Connecticut Department of Environmental Protection through the Farmington River Enhancement Grant Program.

The grant is intended to support the formation of a local committee to:

- review existing municipal regulations and ordinances, and
- draft recommended changes to remove barriers to low impact development (LID) and create opportunity for low impact development practices to be employed in Plainville.

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1.0 Overview of Water Resources in the Town of Plainville

The Town of Plainville is located in the southwest portion of Hartford County. The Pequabuck River is located in the northwest portion of the town and flows to the Farmington River. The balance of the town drains to the south and the Quinnipiac River. The Town has a mixture of residential, commercial and industrial development. Most of the more intensive development occurs along the central corridor of the town.

The surface water quality for the Pequabuck River near the Farmington town line is rated B/A as stated on the map entitled "Water Quality Classifications Map of Connecticut, compiled by James Murphy; 1987" prepared for the Connecticut Department of Environmental Protection. This classification means that the surface water quality may not be meeting the Class A water quality for one or more of the following uses: potential drinking water supply, fish and wildlife habitat, recreational use, agricultural and industrial supply and other legitimate uses including navigation. The goal for this classification is to meet Class A requirements.

The surface water quality for the southern portion of the Quinnipiac River is designated as Bc, which means that it is not meeting criteria for Class B water quality standards for one or more of the following uses: recreational, fish and wildlife habitat, agricultural and industrial and other legitimate uses, such as navigation. The goal is to meet the Class B standards.

The groundwater classification for the town is either GB/GAA or GB/GA. The GB/GAA classification states that the groundwater is not meeting the Class GAA water quality criteria. The GAA water quality classification means that the groundwater is or can be used for a public treating water supply with no need for treatment. The long term goal is to improve the groundwater quality such that it is suitable for use as a public drinking water supply.

The GB/GA rating means that the groundwater may not be suitable for direct human consumption without the need for treatment due to waste discharges, spills or leaks of chemicals or land use impacts. As noted above for the GB/GAA rating, the long term goal is to improve the groundwater quality such that it is suitable for use as a public drinking water supply.

The current stormwater management system for Plainville consists for the most part as standard catch basin/pipe systems which convey the runoff to the Pequabuck and Quinnipiac Rivers as quickly as possible. The central corridor of Plainville , where residential and non-residential development is concentrated has flat to slightly sloping terrain, which historically has lead to periodic flooding from the stormwater management system due to increased runoff volumes and specific hydraulic conditions. These hydraulic conditions include structural deficiencies such as inadequate pipe sizes, submerged outlets and backwater conditions within the pipes.

The current stormwater management system focuses on conveyance only and in general does not focus on reductions in either peak rate or runoff volume. There is also no focus on addressing the water quality in stormwater runoff.

In order to reduce the adverse impacts of increased stormwater runoff volumes, and improve the water quality of the stormwater which ultimately reaches the Pequabuck and Quinnipiac River, the Town of Plainville adopts Low Impact Development as a development and stormwater strategy for the town.

2.0 Introduction

2.1 Purpose of the Manual

Stormwater discharges in the Town of Plainville have clearly caused pollution and adverse impacts on the aquatic and natural environment. These impacts range from increased flows, which cause erosion of natural stream channels; to limitations on the use of certain waters for recreational uses due to high levels of pollutants in the water. The purpose of this manual is to provide the technical framework to implement development and stormwater strategies that will lead to the improvement of surface water quality and groundwater quality to achieve the water quality goals stated in Section 1.0 by the application of Low Impact Development (LID) Strategies. Without the implementation of the requirements in this manual, long term adverse impacts to both surface and groundwater will continue to occur in the Town of Plainville.

2.2 Applicability of the Manual

The standards and processes stated in this manual shall apply to all development projects proposed in the Town of Plainville, including those initiated by the town itself. Specific performance standards have been developed for new development, as well as commercial redevelopment and residential improvements which will increase the extent of impervious cover on a site. The manual is to be used by design engineers, property owners, developers, homeowners, municipal officials and others who are involved with the design of development and redevelopment projects in the Town of Plainville. While it cannot be required, it is strongly suggested that all of the stormwater management practices outlined in this manual be applied to the maximum extent practicable on existing approved single family lots that have not been build on as of the date of the adoption of this manual.

The specifications found in this manual shall be implemented by individuals with a demonstrated level of professional expertise in stormwater management, such as licensed professional engineers in the State of Connecticut. The manual can also be read by non-technical individuals who are interested in the stormwater management and LID fields, but the application of these stormwater requirements must be prepared by a licensed professional engineer in the State of Connecticut.

All designers must adhere to all of the applicable stormwater and performance standards found in the manual. The details provided for the various types of treatment and storage systems are schematic in nature and may be adjusted by the designer to fit the particular situation. Final design plans for any type of treatment or storage system must include all relevant design specifications for that particular system.

It is important that the homeowners and individuals who will have LID treatment systems on their property have an understanding of the adverse impacts of stormwater on our environment and how the LID systems can mitigate these impacts. LID systems are easy to install and easy to maintain over the long-term for the end users.

The standards and performance requirements have been specified to address the specific stormwater issues which exist or potentially exist in the Town of Plainville.

2.3 How to Apply this Manual

Low Impact Development represents a paradigm shift of the current processes which drive the development process. It is imperative that the professionals who will use this manual understand the concepts which created LID. Resources for this background information are provided in Appendix C.

The manual will be used by four main groups; design engineers, municipal land use agencies and staff, reviewers for regulatory programs, and property owners. Design engineers are the group that will use this manual the most. The design engineers need to familiarize themselves with all the stormwater requirements, performance goals and design parameters of the various treatment and storage systems.

The full benefits of LID can only be realized by the application of the processes outlined in this manual. LID is the site component of creating sustainable designs.

The manual has been divided into eight major technical sections, each of which is more fully described in this manual. The processes outlined in Section 4.0 must be followed as stated to realize the full benefits of Low Impact Development strategies.

2.4 What is Stormwater Runoff?

Before we can apply LID concepts, all users of this manual must have an understanding of the natural hydrologic cycle and how development affects the hydrologic cycle and causes adverse impacts to our environment.

The natural hydrologic cycle shows how water travels through our environment in the many forms that provide a myriad of environmental benefits. It is a continuous cycle of the movement of water in our environment.

There are five key elements to the hydrologic cycle: condensation, precipitation, infiltration, runoff, and evapotranspiration/rainfall abstraction. These occur simultaneously and, except for precipitation, continuously. The NASA's Observatorium website provides the following definitions for each element of the Hydrologic Cycle:

A. Condensation is the process of water changing from a vapor to a liquid. Water vapor in the air rises mostly by convection. This means that warm, humid air will rise, while cooler air will flow downward. As the warmer air rises, the water vapor will lose energy, causing its temperature to drop. The water vapor then has a change of state into liquid or ice.
B. Precipitation is water being released from clouds as rain, sleet, snow, or hail. Precipitation begins after water vapor, which has condensed in the atmosphere, becomes too heavy to remain in atmospheric air currents and falls. In many cases, precipitation evaporates as it falls through the atmosphere and returns as water vapor.
C. Infiltration is that portion of the precipitation that reaches the Earth's surface and seeps into the ground. The amount of water that infiltrates the soil varies with the degree of land slope, the amount and type of vegetation, soil type and rock type, and whether the soil is already saturated by water. The more openings in the surface (cracks, pores, joints), the more infiltration occurs. Water that doesn't infiltrate the soil flows on the surface as runoff.
D. Runoff is the amount of rainfall which is left after evapotranspiration and infiltration occur. Under natural conditions, 10-30% of the annual rainfall becomes runoff. As impervious areas increase, both evapotranspiration and infiltration are reduced, thus increasing runoff.

E. Evapotranspiration is water evaporating from the ground and transpiration by plants. Evapotranspiration is also the way water re-enters the atmosphere. Evaporation occurs when radiant energy from the sun heats water, causing the water molecules to become so active that some of them rise into the atmosphere as vapor. Transpiration occurs when plants take in water through the roots and release it through the leaves, a process that can clean water by removing contaminants and pollution. Rainfall Abstraction is the physical process of interception of rainfall by vegetation, evaporation from land surfaces & upper soil layers, evapotranspiration from plants, infiltration of rainfall into the soil surface and surface storage within natural depressions. Rainfall abstraction can be estimated as a depth of water on a site. (http://physics.ship.edu/~mrc/astro/NASA_Space_Science/observe.arc.nasa.gov/nasa/earth/hydrocycle/hydro1.html)

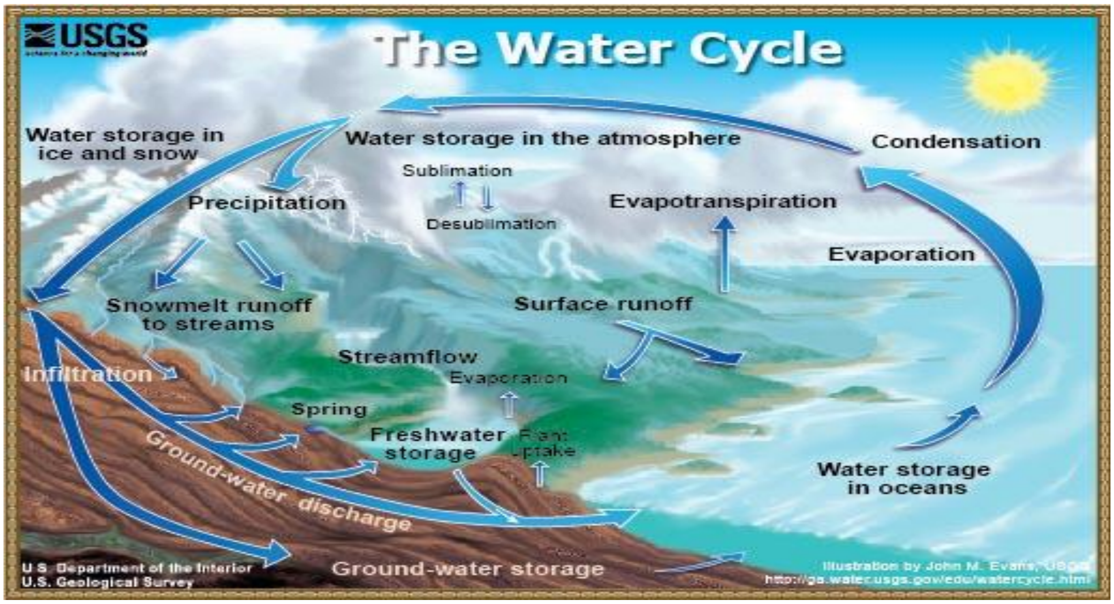


Figure 2.4.a – The Hydrologic Cycle

When development occurs on a site, many changes to the hydrologic cycle will result from the disturbance of the natural land form, the creation of impervious surfaces and the application of chemical compounds which can adversely affect our environment. All of these changes affect the stormwater which is generated on the site.

The 2004 Connecticut Stormwater Quality Manual prepared by the CT DEP defines stormwater as follows: **"Storm water runoff is a natural part of the hydrologic cycle, which is the distribution and movement of water between the earth's atmosphere, land and water bodies. Rainfall, snowfall, and other frozen precipitation send water to the earth's surfaces. Storm water runoff is surface flow from precipitation that accumulates in and flows through natural or man-made conveyance systems during and immediately after a storm event or upon snowmelt. Storm water eventually travels to surface water bodies as diffuse overland flow, a point discharge, or as groundwater flow. Water that seeps into the ground eventually replenishes groundwater aquifers and surface waters such as lakes, streams and oceans. Groundwater recharge also helps maintain water flow in streams and wetland moisture levels during dry weather. Water returned to the atmosphere through evaporation and transpiration to complete the cycle."**

When the stormwater is being generated by the natural environment, there are very little adverse impacts associated with stormwater. However, when development occurs on the land, there are profound impacts that occur which can significantly modify the natural hydrologic cycle. The adverse impacts can be summarized as reduced rates of infiltration, reduced evapotranspiration, increased rates and volumes of runoff, and increased pollutant loads in the runoff. These changes can be seen in Figure 2.4.b.

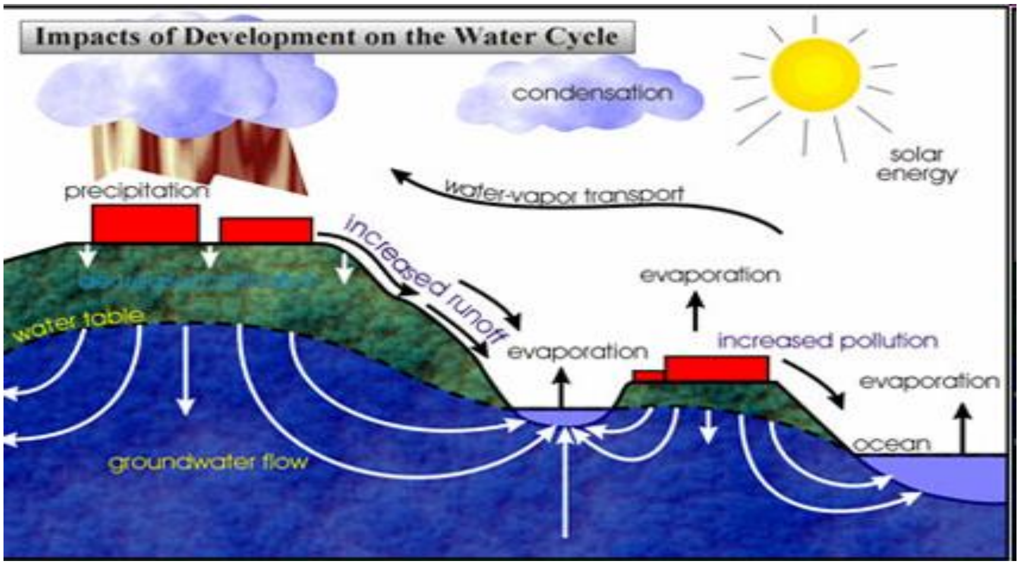


Figure 2.4.b – Changes to the Hydrologic Cycle as a result of development

It can be seen from Figure 2.4.c that as impervious cover increases, there is less base flow into the ground, less evapotranspiration from the vegetation and increased runoff from the impervious areas.

2.5 What are the Impacts of Development and Stormwater?

Land development has the potential to create many adverse impacts on the environment both during the construction period and after construction has been completed. When land is cleared, and stripped of the natural organic layer on top of the soil, the soil loses its ability to infiltrate runoff, thus more runoff is created, which in turn increases the likelihood of erosion of the soil and subsequent sedimentation. After construction has been completed, the large, interconnected impervious area prevents rainfall from infiltrating into the ground. Because of this, more of the rainfall is converted to runoff, which is demonstrated in Figure 2.5.a.

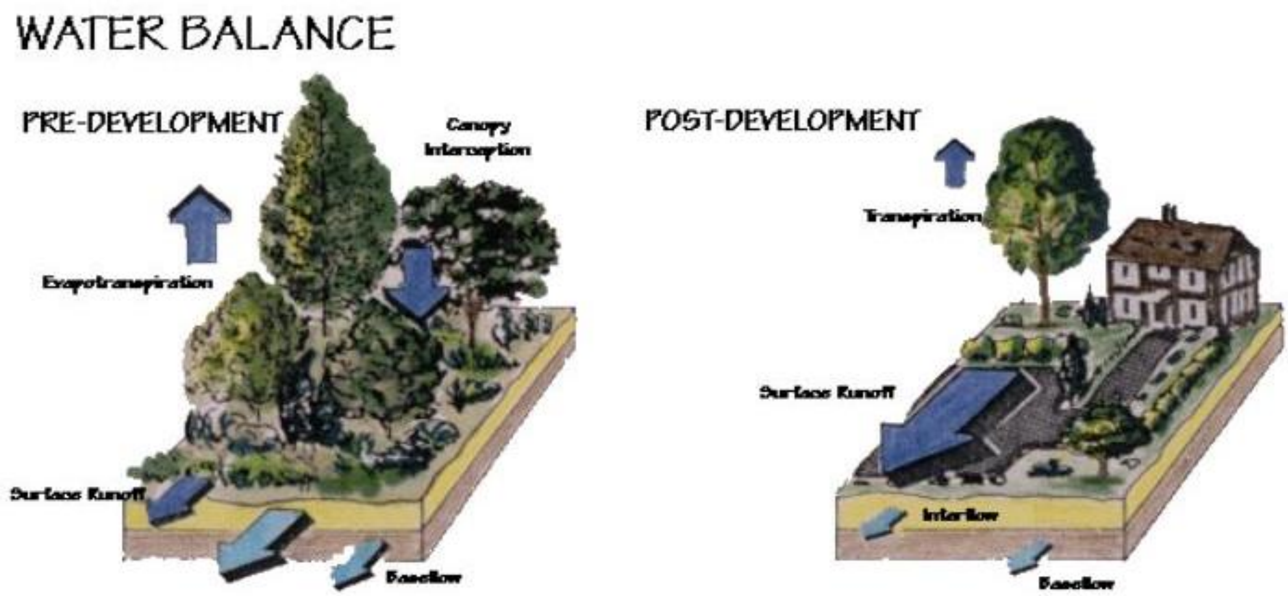


Figure 2.5.a – Effects of Impervious Cover on Water Balance

While the addition of a small amount of impervious area on a single lot may not appear to create an issue, the cumulative impact of many small increases of impervious area can quickly become significant. It has been well documented that when the total impervious cover in a watershed is between 10% and 25% that the natural aquatic environment can be adversely affected. Once the impervious coverage exceeds 25% in a watershed, the adverse impacts to the aquatic ecological systems are often irreversible. There have been some studies which have shown that adverse water quality impacts can occur with impervious cover being between 5 – 7% (RI DEM Stormwater Manual).

The following table highlights the typical percentages of impervious cover for various land uses.

Table 2.5.a – Typical Amounts of Impervious Cover Associated with Different Land Uses

Land Use	**Percent Impervious Cover**
Commercial & Business Districts	85%
Industrial	72%
High Density Residential (1/8 acre zoning)	65%
Medium-High Density Residential (1/4 acre zoning)	38%
Medium-Low Density Residential (1/2 acre zoning)	25%
Low Density Residential	
1 acre zoning	20%
2 acre zoning	12-16%
3 acre zoning	8%
5 acre zoning	5-8%
10 acre zoning	2.4%

(Source: RI DEM Stormwater Manual, April 2010)

The 2004 CT DEP Stormwater Quality Manual states the following adverse impacts which can occur in our environment due to changes in the Hydrologic Cycle:

Hydrologic:

- Increased runoff volume
- Increased peak discharges
- Decreased runoff travel time
- Reduced groundwater recharge
- Reduced stream baseflow
- Increased frequency of bankfull and overbank floods
- Increase flow velocity during storms
- Increase frequency and duration of high stream flows

Figure 2.5.a – Stream Channel Impact from increased runoff volumes (S. Hayden photo)

Stream Channel and Floodplain Impacts:

- Channel scour, widening and downcutting
- Streambank erosion and increased sediment loads
- Shifting bars of coarse sediment
- Burying of stream substrate
- Loss of poll/riffle structure and sequence
- Man-made stream enclosures or channelization
- Floodplain expansion

Figure 2.5.b – Stream Channel Impacts (R.Claytor file photo)

Figure 2.5.c – Deposition of sediment in a wetland (S. Hayden photo)

Water Quality Impacts:

- Excess Nutrients (Nitrogen and soluble phosphorous)
- Sediments
- Pathogens
- Organic Materials
- Hydrocarbons
- Metals
- Synthetic Organic Compounds
- Deicing Constituents
- Trash and Debris
- Thermal Impacts
- Freshwater discharge to estuarine systems

Figure 2.5.d – Nutrient impacts in freshwater river

The water quality impacts associated with storm water runoff is called non-point source pollution. The United States Environmental Protection Agency defines non-point source pollution as follows:

Non-point source (NPS) pollution, unlike pollution from industrial and sewage treatment plants, comes from many diffuse sources. NPS pollution is caused by rainfall or snowmelt moving over and through the ground. As the runoff moves, it picks up and carries away natural and human-made pollutants, finally depositing them into lakes, rivers, wetlands, coastal waters, and even our underground sources of drinking water. These pollutants include:

- *A. Excess fertilizers, herbicides, and insecticides from agricultural lands and residential areas;*
- *B. Oil, grease, and toxic chemicals from urban runoff and energy production;*
- *C. Sediment from improperly managed construction sites, crop and forest lands, and eroding stream banks;*
- *D. Salt from irrigation practices and acid drainage from abandoned mines;*
- *E. Bacteria and nutrients from livestock, pet wastes, and faulty septic systems;*
- *F. Atmospheric deposition and Hydromodification are also sources of non-point source pollution.*

The most common pollutants which are found in non-point source runoff are Litter, Sediment and Total Suspended Solids (TSS), Total Nitrogen (TN), Total Phosphorous (TP), Metals, such as Zinc (Zn) and Copper (Cu), Hydrocarbons, Thermal Impacts, Oxygen demanding substances and Pathogens. Each pollutant and its impact on the natural environment are stated below.

<u>Litter</u>

Litter while not causing toxic impacts on the environment, the presence of litter is an aesthetic issue that is not well received by the public.

Total Suspended Solids (TSS) and Sediment

Total Suspended Solids are particles dissolved in water. In excessive amounts it causes turbidity in water. The turbidity blocks light in the water column which causes reduced photosynthesis, which in turn reduces the oxygen levels in the water. Coarse and fine sediments can clog the gravel substrate in breeding streams thus affecting the biological community ability to reproduce. Common sources of TSS and sediment are runoff from construction sites, winter sanding operations, atmospheric deposition and decomposition of organic matter, such as leaves.

Nutrients

Excessive levels of Phosphorous in fresh water are a concern as these nutrients encourage excessive growth of plants and algae. When these plants die, the decomposition of the organic matter reduces oxygen levels in the water, thus adversely affecting the biological community in the water body. Nitrogen, in the form of nitrate, is a direct human health hazard and an indirect hazard in some areas where it leads to a release of arsenic from sediments. While not a major concern for freshwater systems, nitrate can cause environmental impacts in tidal regions, even though the source of nitrate can be far away from coastal regions. When the algae dies and sinks to the bottom, its decomposition consumes oxygen, depriving fish and shellfish in those deep waters of oxygen, a condition known as hypoxia. Sources of nutrients are organic and inorganic fertilizers, animal manure, biosolids and failing sewage disposal systems.

Metals

Metals in non-point source runoff are very toxic to aquatic life. The adverse effects of metals are far reaching for both aquatic and human health. Many metals can bioaccumulate in the environment, which can affect higher living organisms. While the concentration of zinc or copper in stormwater generally is not high enough to bother humans, these same concentrations can be deadly for aquatic organisms. Many microorganisms in soil are especially sensitive to low concentrations of cadmium. Cadmium is also very harmful to humans. Chromium is very toxic to fish and can cause birth defects in animals.

Of the above discussed metals, zinc and copper are the two metals which are found dominantly in non-point source runoff. Metals commonly bind themselves to sediment and organic matter in stormwater and thus are transported to the receiving waters. Since natural rainfall is slightly acidic, metal roofs or components on the roof can be a significant source of the metal concentrations in stormwater.

Hydrocarbons

Total Petroleum Hydrocarbons are highly toxic in the aquatic environment, especially to aquatic invertebrates. The primary sources of petroleum hydrocarbons are oil, grease and gas spills, along with vehicle exhaust. Polycyclic Aromatic Hydrocarbons are also toxic to aquatic life. The primary source of these hydrocarbons is the incomplete burning of fossil fuels. PAH's generally deposited by atmospheric deposition on an impervious surface, especially large flat roof areas. When it rains, the accumulations of pollutants due to atmospheric deposition are carried off in the stormwater.

Thermal Impacts

Impervious surfaces, such as roofs and paved areas can heat up during sunny days and hold onto this heat. When rainfall occurs on these heated surfaces, the resulting runoff has its temperature raised. As this heated runoff is discharged into receiving waters, the temperature of the receiving water is raised to a level which can exceed the tolerance limits for fish and invertebrates, thus lowering their survival rates. Elevated water temperatures will also contribute to reduced oxygen levels in the water.

Oxygen Demanding Substances

Oxygen demanding substances are plant debris and soil organic matter which when they decompose in an aquatic environment require a significant amount of oxygen for the chemical reaction. This results in less available oxygen in the water for other aquatic organisms. Generally oxygen levels less than 5 g O/m in the water will result in fish kills.

Pathogens

Pathogens are bacteria and viruses, which can cause disease in humans. Most pathogens are found in discharges from overflowing sanitary sewers or in combined sanitary/stormwater systems. Both fecal coliform and enterococci are used as indicators for the presence of pathogenic organisms, yet their presence does not mean a pathogen is present, just that there is a higher risk of being present.

3.0 Overview of Low Impact Development

3.1 What is LID?

Low Impact Development (LID) is an ecologically friendly approach to site development and stormwater management that aims to mitigate development impacts to land, water and air. This approach emphasizes the integration of site design and planning techniques that conserve natural systems and hydrologic functions on a site.

The concept of Low Impact Development (LID) utilizes five major tools to reduce the impact of development on the environment. These primary tools are:

i. Encourage Conservation Measures,
ii. Reduce Impervious Areas,
iii. Slow runoff by using landscape features,
iv. Use multiple measures to reduce and cleanse runoff,
v. Pollution prevention.

Each LID tool is enumerated below:

i. Encourage Conservation Measures

- Implement Open Space or Cluster Development Regulations to preserve large tracts of the site,
- Implement “Site Fingerprinting” to minimize land clearing & soil disturbance,
- Minimize soil compaction,

- Provide low maintenance landscaping & plant native species which will minimize the use of fertilizers and pesticides,
- Use Source Erosion Control measures.

ii. Reduce Impervious Areas

- Disconnect impervious coverage to the maximum extent practical to encourage overland flow conditions across vegetated surfaces,
- Reduce pavement widths for local roads,
- Use Permeable Pavement, Porous Concrete, and Open Course Pavers for parking areas and other low traffic areas,
- Use Porous Concrete for sidewalks.

iii. Slow runoff by using landscape features

- Maintain Pre-Development Time of Concentration by long flow paths on vegetated Surfaces,
- Minimize the extent of flow on impervious surfaces,
- Maintain and encourage overland flow conditions across vegetated areas for at least 75', where feasible.

iv. Use multiple measures to reduce and cleanse runoff

- Maintain pre-development infiltration rates by preserving those soils with moderate to high infiltrative capacities,
- Maintain existing vegetation to Maximum Extent Practical,
- Remove pollutants from runoff by flow thru vegetated systems, allow natural infiltration to occur,
- Encourage the use of rain gardens for roof runoff,
- Encourage the use of rain barrels or cisterns to collect & reuse runoff.

v. Pollution prevention

- Minimize applications of sand and salt on roads & parking areas,
- Use "Source Controls" such as weekly sweeping of large impervious areas,
- Minimize application of fertilizers on turf areas.

3.2 Measures to Evaluate the Effectiveness of LID

A primary objective of Low Impact Development is to mimic the pre-development hydrologic conditions on a site. At the current time, this objective is measured by two metrics. The first is the reduction of the post-development runoff volume to the pre-development runoff volume for the 90% rainfall event. The second metric is to match the Runoff Curve Numbers (RCN) for post-development conditions to pre-development conditions. Along with the matching of the RCN, it is also important to have the post-development time of concentration (Tc) match or closely approximate the pre-development Tc. By achieving the second metric, there should be no or little change in the post-development runoff rate, which minimizes the need for detention facilities. In either case, the overall goal is to have a developed site mimic or come as close as possible to the pre-development hydrologic conditions. This condition is known as “Hydrologic Transparency”.

3.3 Goals and Benefits of LID

The overriding goal of LID is to create developments which are in harmony with the natural environment while ensuring that the vision of the developer can also be achieved. The general goals for LID are listed below:

- Preservation of environmentally sensitive areas, and naturally vegetated systems to reduce changes to the hydrology of the watershed,
- Focus on maintaining natural drainage patterns as a key goal in the design of the site,
- Prevent direct adverse impacts to wetlands, watercourses (both perennial & intermittent), to the maximum extent practical,
- Minimize the extent of impervious cover and thus reduce the increases in runoff volume,
- Implement source controls for water quantity and water quality, while minimizing the extent of structural drainage systems,
- Create a landscape environment that is multi-functional for all users.

A primary benefit of LID is a better balance between Conservation of Natural Resources, Growth, Ecosystem Protection and the Public Health. There are many benefits associated with the adoption of Low Impact Development strategies for all of the stakeholders in the development field. The three primary stakeholders in the development field are the environment, the public, and the developer. The benefits of LID for each stakeholder group are stated below.

a. Environmental Benefits:
   i. Preserve the biological and ecological integrity of natural systems through the preservation of large extents of contiguous land,
   ii. Protect the water quality by reducing sediment, nutrient and toxic loads to the wetland/watercourse aquatic environments and also terrestrial plants and animals,
   iii. Reduce runoff volumes in receiving streams

b. Public Benefits:
   i. Increase collaborative public/private partnerships on environmental protection by the protection of regional flora and fauna and their environments,
   ii. Balance growth needs with environmental protections,
   iii. Reduce municipal infrastructure and utility maintenance costs (roads and storm water conveyance systems)

c. Developer Benefits:
   i. Reduce land clearing and earth disturbance costs, reduce infrastructure costs (roads, storm water conveyance and treatment systems),
   ii. Reduce storm water management costs by the reduction of structural components of a drainage system,
   iii. Increase quality of building lots and community marketability.

3.4 How to apply LID Strategies to land development projects

The analyses and calculations required in Section 4.0 is one part of the LID equation, the second part is the application of the stormwater strategies on the land. A sample process for application of LID stormwater strategies for residential and commercial / Industrial applications is provided below. These requirements do not apply to residential single family lots; however, supplemental provisions are recommended under Section 4.2 #10.

Residential Applications:

1. After the site analyses and processes required under **Section 8.0** – Environmental Site Designs have been applied to a site, and a Conceptual Development Plan has been done, the concept for handling stormwater can be developed for the site.
2. If road grades are less than 5% with a crown, the primary process would be to eliminate curbing and utilize vegetated swales (dry or wet) along both sides of the road. The swales can convey water to an appropriate LID treatment system. A grass filter strip could be utilized to convey flow to the swale.
3. If the road grades are less than 5% and used a uniform cross slope of 2%, runoff can be directed to a number of LID treatment systems, such as a filter strip, wet or dry swale, infiltration trench (with appropriate pretreatment), or Bioretention system.
4. If road grades are less than 5% with a crown or uniform cross slope with bituminous curbing, notches can be cut in the curbing (minimum length of notch = 24”) at appropriate intervals (minimum 50’ apart) to convey runoff to a LID treatment system along the road, such as a Bioretention system or wet swale.
5. For roads with grades greater than 5%, standard curbing with catch basins will likely be necessary to collect stormwater. However, instead of conveying the runoff down the road in a pipe system, an outlet pipe shall be installed from the rear of the catch basin to an appropriate LID treatment system(s). This is a form of “source control” and moves away from the “end of the pipe” treatment of stormwater.
6. Runoff from residential roofs can be handled in one of two ways: Rooftop disconnection which provides a minimum of 75’ of overland flow across a well vegetated surface, such as a well developed lawn area (average grade of less than 8%) or an undisturbed wooded area with an average grade of 15% or less; or connection of roof drains to Bioretention facility.
7. For those driveways which are located below the grade of the road, impervious disconnection which provides a minimum of 75’ of overland flow across a well vegetated surface, such as a well developed lawn area (average grade of less than 8%) or an undisturbed wooded area with an average grade of 15% or less can be used to treat and infiltrate runoff from the driveway.

8. For those driveways which drain toward to the road, runoff shall be intercepted prior to reaching the road and directed to a swale or Bioretention system.

Commercial / Industrial Applications:

1. Commercial / Industrial designs shall utilize LID site strategies, such as respecting the natural land form to the maximum extent practical. This will have the effect of reducing site grading requirements and the potential for erosion and sedimentation issues.
2. As parking / loading facilities are constructed with grades less than 5%, there are ample opportunities to grade the site to direct runoff to Bioretention facilities in parking islands or along the perimeter of the parking facility.
3. Permeable pavement can be used for parking spaces with standard bituminous concrete being used for driveways and parking aisles on commercial sites, such as office or retail uses. For industrial sites, any type of LID filtering or infiltration system must incorporate an impermeable liner and underdrain, which connects to a component of a structural drainage system.
4. Porous concrete can be used for both parking aisles and parking spaces. For industrial sites, any type of LID filtering or infiltration system must incorporate an impermeable liner.
5. On retail sites, open course pavers with either topsoil/grass or crushed stone can be utilized for those parking spaces which only may be needed during certain calendar periods.
6. The gravel storage layer under permeable pavement or porous concrete can be increased in depth to increase the storage volume for the runoff from commercial roofs. Pretreatment of runoff from large commercial / Industrial uses must be provided by a LID vegetated system.
7. Impervious area disconnection can be utilized if there is sufficient space on the parcel.

3.5 LID Systems for Water Quality Retrofits for Commercial Sites

In the Town of Plainville there may be some opportunities to apply stormwater retrofits in commercial areas of the town utilizing LID concepts to reduce runoff volumes and provide some attenuation of non-point source pollutants. The retrofits can be incorporated within the existing infrastructure in the commercial districts. LID planters, curb extensions, modular wetland systems, and Filterra Bioretention systems are acceptable LID systems for commercial retrofits. These systems are simply adaptations of proven LID technologies and designs for retrofit situations. An image of each type of system is provided below with more detailed design information provided in **Section 7.0** of this manual.

Figure 3.5.a – LID Planter (City of Portland, OR)

Figure 3.5.b – Curb Extension (City of Portland, OR)

Figure 3.5.c – Modular Wetland (Modularwetlands.com)

Figure 3.5.d – Filterra Bioretention (Filterra.com)

4.0 Stormwater Management Strategies

4.1 Overview of Strategies

The Town of Plainville has determined that the following requirements shall be met to protect the high quality surface and groundwater which is present today. The purposes of these requirements are to have developments work with the natural land form to the maximum extent practical and to maintain the natural hydrological conditions.

These requirements shall apply to new land development projects in the Town of Plainville. These projects shall include residential subdivisions, commercial and/or industrial projects as well as Re-development projects in conformance with Requirement #8 under Section 4.2.

4.2 Stormwater Management Requirements

Requirement #1: Environmental Site Design

A key aspect for the implementation of Low Impact Development is to work with the natural resources which exist on a site. All residential and commercial projects, unless otherwise exempt, must utilize the Environmental Site Design Strategies as provided in **Section 8.0** of this manual to the maximum extent possible to reduce the generation of stormwater runoff both in terms of volume and rate for new and redevelopment projects. The objective of the implementation of the LID design strategies is to provide a framework by which LID is applied at the earliest stages of the design process so that stormwater impacts are prevented instead of being mitigated. All development projects must complete and submit the "Stormwater Management Plan" checklist to demonstrate compliance with this standard. Written explanation must be provided for any section where compliance has not been provided.

Requirement #1 shall apply to all residential projects where the site area is greater than 5 acres and to rental or owner occupied multifamily housing and/or commercial, industrial or institutional sites greater than 2 acres.

Requirement #2: Groundwater Recharge

To maintain pre-development hydrology, post-development stormwater must be infiltrated to maintain the appropriate pre-development infiltration rate. The required Groundwater Recharge Volume is defined as a function of the annual pre-development recharge rate for site-specific soil conditions, the 90% rainfall event (1" of rain/24 hrs), and the extent of impervious cover on a site. Figure 4.2.2.a shows the generalized hydrologic soil groups in the Town of Plainville. This map shall be used for the preliminary evaluation of the Groundwater Recharge Volume only. The objective of this requirement is to maintain groundwater levels to protect the average depth of the groundwater, stream and/or wetlands, and general soil moisture levels. The infiltration of stormwater does provide significant water quality benefits, such as reducing the amount of nutrients, metals, and pathogens in the stormwater. By maintaining the pre-development recharge rate, compliance with this requirement can reduce the volumetric requirements for other sizing criteria (channel protection and flood protection). Groundwater recharge must occur in such a manner that protects groundwater quality. All stormwater must pass through a pre-treatment facility under this requirement. The requirement for the Groundwater Recharge is found in **Section 4.3** - Performance Standards for Stormwater.

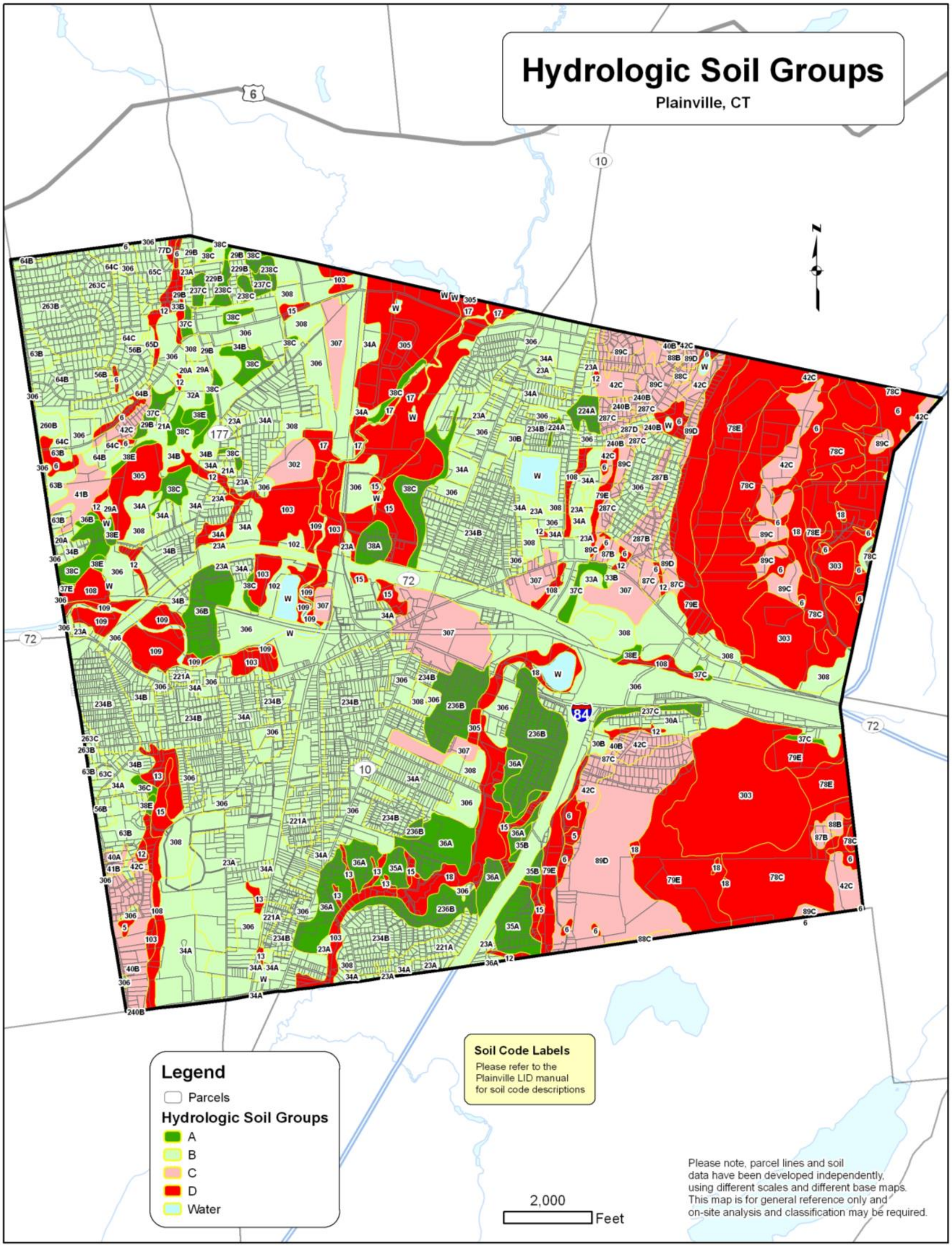


Figure 4.2.a – Hydrologic Soil Groups

Soil Unit Name	Hydrologic Soil Group	Map Unit Number
Willbraham Series	D	5, 6
Raypol	D	12
Walpole	D	13
Scarboro	D	15
Timakwa & Natchaug	D	17
Catden & Freetown	D	18
Ellington	B	20A
Ninigret & Tisbury	B	21A
Sudbury	B	23A
Agawam Series	B	29A, 29B
Branford Series	B	30A, 30B
Haven & Enfield	B	32A
Hartford Series	B	33A, 33B
Merrimac Series	B	34A, 34B
Penwood Series	A	35A, 35B
Windsor Series	A	36A, 36B, 36C
Manchester series	A	37C, 37E
Hinckley series	A	38A, 38C, 38E
Ludlow series	C	40A, 40B, 41B, 42C
Watchaug series	B	55A, 56B
Cheshire series	B	63B, 63C, 64B, 64C, 65C, 65D, 77D
Holyoke-Rock series	D	78C, 78E, 79E
Wethersfield series	C	87B, 87C, 88B, 88C, 89D
Pootatuck	B	102
Rippowam	D	103
Sacco	D	108
Fluvaquents	D	109
Ninigret-Urban	B	221A
Deerfield-Urban	A	224A
Agawam-Urban	B	229B
Merrimac-Urban	B	234B
Windsor-Urban	A	236B
Manchester-Urban	A	237C
Hinckley-Urban	A	238C
Ludlow-Urban	C	240B
Charlton-Urban	B	260B
Cheshire-Urban series	B	263B
Wethersfield-Urban series	C	287B, 287C, 287D
Udorthent series	B	306

Table 4.2.a – Town of Plainville Soil Names, Hydrologic Soil Group, & Map Unit Number (http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm)

Description of Hydrologic Soil Groups (NRCS):

Group A: Soils having a high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well drained to excessively well drained sands or gravelly sands. These soils have a high rate of water transmission.

Group B: Soils having a moderate infiltration rate when thoroughly wet. These soils consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.

Group C: Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.

Group D: Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

Requirement #3: Water Quality

Stormwater runoff from a site must be adequately treated prior to discharge to a receiving wetland or watercourse. Different stormwater treatment systems may be utilized, both non-structural and structural. The objective of this standard is to minimize the adverse water quality impacts from non-point runoff on receiving water systems. Pollutant removal performance standards must be achieved at each discharge location based upon the water quality volume from 1" of runoff which is the runoff generated from a rainfall event of 1.2" per 24 hours. This is known as the water quality storm. All stormwater must pass through a pre-treatment facility under this requirement. The Water Quality Volume and required pollutant removal efficiencies are specified in the **Section 4.3** - Performance Standards for Stormwater.

Requirement #4: Channel Protection Flow

Natural stream channels must be protected from both changes in the peak rate and volume of post-development stormwater. The matching of the pre-development infiltration rate can address one of the major adverse impacts to stream channel morphology, however, the other major adverse impact; increases in the peak rate of runoff must be addressed. The Channel Protection Flow addresses the increases in the peak rate of runoff and the adverse impacts on the hydromorphology of the stream channel.

One of two methods may be applied to achieve this goal as stated in the CT DEP 2004 Stormwater Quality Manual:

- Control the 2-year, 24-hour post-development peak flow rate to 50% of the 2-year, 24-hour pre-development level or,
- Control the 2-year, 24-hour post-development peak flow rate to the 1-year, 24-hour pre-development level.

The goal for this requirement is to maintain the depth and flow rate within a natural stream channel. This will minimize the adverse impacts to the stream channel itself as well as the benthic organisms which live in the bottom of the stream channel.

Requirement #5: Conveyance Flow

Open drainage or enclosed conveyance systems shall be designed to provide adequate capacity for the flows, leading to, from and through stormwater management systems for the 10-year, 24-hour storm event.

Requirement #6: Flood Protection

Storm events in excess of the 2-year, 24-hour storm can cause flood damage and other impacts. These types of impacts can be reduced by the detaining of the increased flows with the release of these flows in a gradual fashion that ensures the pre-development peak rates are not exceeded. The flood protection must be provided by the attenuation of the 10-year, 24-hour and potentially the 100-year, 24-hour design storm events. The specific standards are found in Section 4.3.5 of this manual. It must be demonstrated that the increased flow will be directed to properly sized facilities to meet this requirement. The objective of this requirement is to prevent the magnitude and frequency of overbank flooding and to protect downstream structures from flooding.

Requirement #7: Pollution Prevention

All development projects require the application of pollution prevention measures to minimize the impacts that the runoff from the project will have on stormwater quality. The objective of this requirement is to minimize or prevent to the maximum extent practicable, pollutants coming in contact with the stormwater runoff. An application shall clearly state what measures will be applied to the post-development conditions to achieve these requirements.

These measures include the following pollution prevention strategies:

- Minimal applications of sand and/or salt to large connected impervious areas, such as parking lots,
- Weekly sweeping of large connected impervious areas during the seasons when sand is applied to these surfaces,
- No or minimal application of fertilizers and pesticides on green spaces which are in close proximity to connected impervious areas,
- Prompt cleaning out of catch basin sumps during the spring after the snowmelt season.

Requirement #8: High Density Residential / Commercial / Industrial Redevelopment Projects

Many existing developed sites, particularly those containing high density residential, commercial, industrial or institutional uses lack adequate stormwater treatment measures to remove pollutants from stormwater. The purpose of this section is to identify which redevelopment projects are subject to the requirements of this manual and to what extent. This requirement will apply to high density multi-family, commercial, industrial and institutional projects and shall include redevelopment of existing structures and site features as well as new development on previously undeveloped portions of a property.

The extent of the existing impervious area of a project/property must be determined using an accurate as-built survey of the site. It may include multiple lots or parcels.

- Existing drainage systems serving existing impervious surface areas that are not redeveloped may remain.
- Any new development upon previously undeveloped land shall be subject to the requirements of this manual and separate LID stormwater treatments shall apply to newly developed area.
- Any structure or impervious site feature that is demolished in favor of redevelopment shall be considered a pervious surface and any such redevelopment of those areas shall be subject to the requirements of this manual.
- If an industrial redevelopment project is to consist of a use with a high pollutant load then the requirements found in Requirement #9 shall apply.

Requirement #9: Land Uses with High Pollutant Loads

Certain types of development have the potential for significantly higher pollutant loads. Care must be taken with the stormwater from these sites to prevent adverse impacts on surface and groundwater. Those uses shown in Table 4.2.b have the capability to generate high pollutant loads and need to be treated differently than other land uses.

Due to the potential of high pollutant loads in the stormwater, the Groundwater Recharge Volume for ground surface impervious areas do not have to be met for these sites, but the GRv shall be provided for the roof areas. The Water Quality Volume must be fully provided and adequately treated.

Table 4.2.b – Land Uses with High Pollutant Loads

1. Industrial Sites (Any use as defined under Section 2 (a) (35) of the Town of Plainville Aquifer Area Protection Regulations,
2. Outdoor storage and loading/unloading of hazardous substances,
3. Storage of road salt and associated loading areas (if unprotected from rainfall),
4. Gas stations, petroleum terminals,
5. Exterior vehicle maintenance and service facilities, & equipment storage areas

All filtering or infiltrating LID treatment systems must be equipped with impermeable liners and underdrains, which must discharge to conventional conveyance systems. Infiltrating treatment systems which are not lined are not permitted on these sites as the potential for groundwater contamination is high.

Requirement #10: Recommended Supplemental Provision to address Increases of Imperviousness in Residential Zones

The following are recommendations meant to encourage use of LID practices in otherwise exempt single family housing development including additions and accessory structures.

Building additions or other projects which incrementally increase the extent of imperviousness on residential parcels can have cumulative adverse impacts on both runoff volumes and water quality. To address these increases of impervious cover, the Groundwater Recharge Volume (GRv) and Water Quality Volume (WQv) should be provided by one of appropriate LID systems for GRv and WQv as specified in Section 7.0 for increases of impervious cover in a residential zone. This section should be used by residents who are considering impervious area improvements to their property.

If increases of impervious are proposed on a residential lot in the Town of Plainville, the Groundwater Recharge Volume and Water Quality Volume may be addressed as follows:

Bioretention*	20 sq.ft. of surface area per 100 sq.ft. of impervious area
Rain Barrel**	1 per 100 sq.ft. of impervious area

*Bioretention system must be constructed in accordance with the specifications found in Section 7.1 of the manual.

** Rain barrels shall be installed in accordance with the specifications found in Section 7.24 of the manual.

If Bioretention or rain barrels cannot be installed on a property, the following are alternative methods to address the increase of imperviousness on a property.

1. For properties located in the R-40 zone, the runoff from increases of impervious cover shall flow across a minimum of 75' of vegetated surface (lawn, meadow or woods) prior to reaching a conventional drainage system.
2. For Building additions without gutters, the installation a gravel drip bed around the foundation of the addition to infiltrate runoff from the roof. Design specifications for a gravel drip bed are provided in Section 7.25 of the manual.

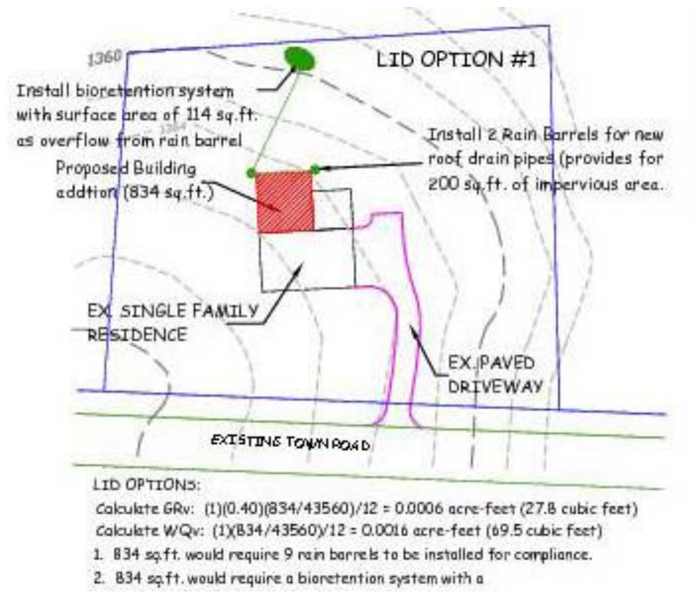


Figure 4.2.b.1 – Guide for the installation of LID treatment systems to address increases of imperviousness on residential properties. Option #1 shows how two rain barrels & one Bioretention system having a surface area of 114 sq.ft. will meet the GRv and WQv for an increase of 834 sq.ft. of impervious area.

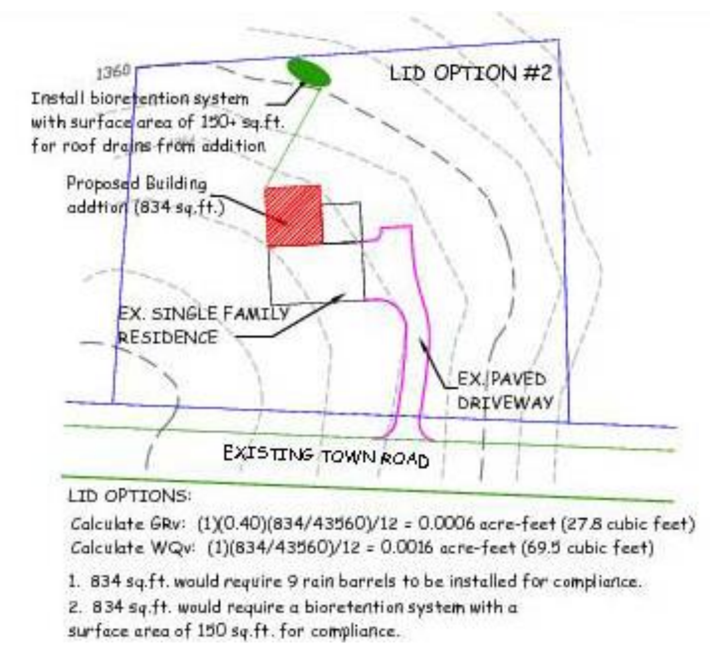


Figure 4.2.b.2 – Guide for the installation of LID treatment systems to address increases of imperviousness on residential properties. Option #2 shows how one Bioretention system having a surface area of 150 sq.ft. will meet the GRv and WQv for an increase of 834 sq.ft. of impervious area.

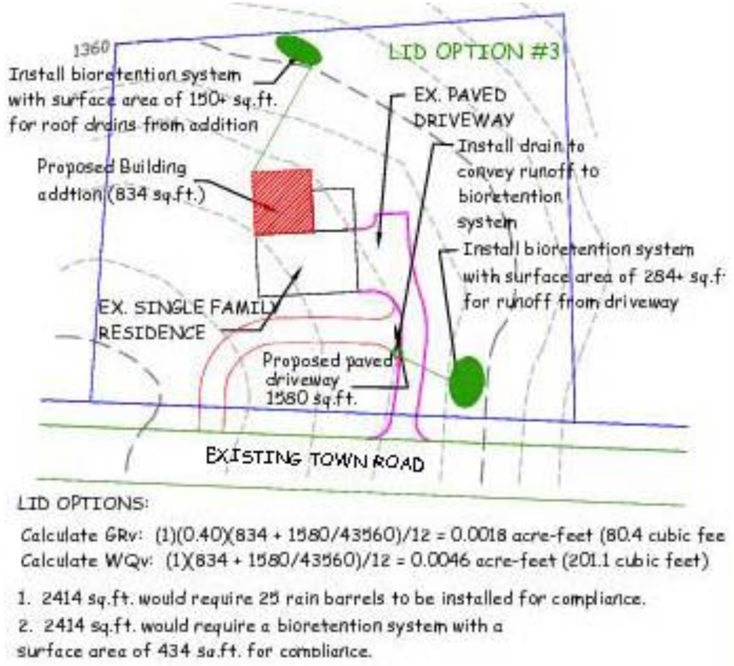


Figure 4.2.b.3 – Guide for the installation of LID treatment systems to address increases of imperviousness on residential properties. Option #3 shows two Bioretention systems to meet the GRv and WQv for a total increase of 2,414 sq.ft. of imperviousness.

4.3 Performance Standards for Stormwater

4.3.1 Groundwater Recharge (GRv)

The volume required for Groundwater Recharge shall be based upon the amount of impervious area. The recharge requirements are based upon the pre-development natural hydrologic soil group (HSG). The groundwater recharge volume is defined as follows:

$$GRv = (P)(D)(I)/12$$

Where:

GRv = Groundwater Recharge volume (acre-feet)
P = 1” (90% rainfall event)
D = Recharge Factor, see Table 4.3.1
I = Impervious area (acres)

Table 4.3.a Recharge Factors Based on Hydrologic Soil Group (HSG)

HSG	Recharge Factor (D)
A	0.60
B	0.40
C	0.25
D	0.10

The hydrologic soil group must be verified by field data in the vicinity of the proposed recharge system. This data can be provided by a Certified Soil Scientist's field inspection of the site or soil tests performed by a professional engineer. The groundwater recharge volume is part of the required water quality volume that must be provided for a project. Recharge must be provided in each separate, and distinct drainage area, where there is any impervious cover proposed. Runoff from a residential roof may be infiltrated without pre-treatment. Runoff from commercial or industrial roofs must be directed through a pre-treatment facility prior to infiltration.

4.3.2 Water Quality (WQv)

The Water Quality volume is the amount of runoff due to stormwater from a given storm that is required to be captured and treated in order to reduce a significant portion of the pollutants in the stormwater on an annual basis. The required WQv shall fully capture and treat the runoff volume for the storms which comprise over 90% of the annual rainfall. This is equal to runoff (1" of runoff) generated by 1.2" of rainfall on an impervious surface. The Water Quality volume is defined as follows:

$$WQv = (1'')(I)/12$$

Where:

WQv = Water Quality Volume (acre-feet)
I = Impervious area (acres)

For those developed sites, such as a golf course which have little or no impervious areas, a minimum WQv of 0.2 watershed inches (0.2" over the entire disturbed area) is required. This minimum treatment volume is necessary to fully treat the runoff from the pervious surfaces. For the sizing of facilities to fully treat the WQv, the basis for the hydrologic and hydraulic evaluation shall be as follows:

- Impervious coverage shall be measured from the site plan and shall include all impermeable surfaces (paved/gravel roads, driveway and parking lots, sidewalks, roof tops and patios set on a impermeable base)
- Any off-site area which is tributary to a proposed treatment facility must be accounted for the sizing of that specific practice. However, treatment is only required for the on-site areas. If there is a substantial off-site tributary area (>1 acre), the designer should design a by-pass system for the off-site drainage area.

4.3.3 Pollutant Removal Performance Standards

Table 4.3.b Required Minimum Pollutant Removal Efficiencies

Pollutant Type	Minimum Pollu-tant Removal Rate
Total Suspended Solids	90%
Total Nitrogen	35%
Total Phosphorous	50%
Zinc	75%
Total Petroleum Hydrocarbons	80%
Dissolved Inorganic Nitrogen	35%

4.3.4 Water Quality Flow (WQf)

The Water Quality Flow is a peak rate associated with the water quality storm event. The WQf is used to design off-line treatment systems. These systems must have a mechanism to by-pass those flows greater than the WQf. The WQf calculation uses the WQv and a modified curve number for small storm events. The following equation shall be used to determine the modified CN. The modified CN will then be used in a standard TR-55 model to estimate the peak rate for small storm events.

Using the WQv, a modified CN is calculated by the equation shown below:

$$CN = 1000/[10 + 5P + 10Q * \sqrt{(Q * Q + 1.25 * QP)}]$$

Where:

P = Rainfall in inches (use 1.2” for Water Quality Storm that produces 1” of runoff)

Q = Runoff Volume, in watershed inches (equal to total WQv / total drainage area)

Professional Engineers can use a TR-55 spreadsheet to find the WQf. Using the CN from the above equation, the time of concentration (Tc) and drainage area (A), the peak rate discharge (WQf) for the water quality event can be determined by the following procedure:

1. Read initial abstraction (Ia) from TR-55 Table 4.1 or calculate using Ia = 200/CN – 2
2. Compute Ia/P (P = 1.2 inches)
3. Approximate the unit peak discharge (qu) from TR-55 Exhibit 4-III using Tc and Ia/P
4. Compute the peak discharge (WQf) using the following equation:

WQf = qu * A * Q

Where:

WQf = the peak discharge for water quality event in cubic feet per second (cfs)
qu = the unit peak discharge, in cfs/mi(squared)/inch
A = drainage area, in square miles
Q = runoff volume, in watershed inches (equal to WQv / A)

4.3.5 Flood Protection

The matching of the pre-development infiltration rate is an important metric measuring the effectiveness of a LID design. Once the volumetric requirement has been met, the designer can then focus on the metric measuring the matching of the RCN values and then the potential changes to the peak rates of runoff.

Those impervious areas which are directed to infiltration systems, which will fully contain and infiltrate the required WQv can be removed from the calculation of the impervious area for that subwatershed area. The total area of the subwatershed area shall remain unchanged, with only those connected impervious areas be included in the peak rate calculation for post-development conditions. The area of the excluded impervious area shall be considered as Forest in Fair Condition for the purposes of the hydrologic analysis.

For residential projects, where large extents of the site are preserved as undisturbed areas, this analysis will show how the RCN for post-development conditions can be reduced to become closer to or equal to the RCN for pre-development conditions. If the post-development calculation still shows an increase in the peak rate of runoff from the subwatershed area, then attenuation of the peak rate shall be required.

The increases in the peak rate of runoff for the 10-year, 24-hour and potentially the 100-year, 24-hour storm event must be reduced to the pre-development peak rate. These increases shall be reduced by the design and construction of appropriate structural measures.

- For those development areas less than 10 acres, with less than 30% total impervious coverage, the 10-year, 24-hour storm shall be used to design the facility.
- For those development areas less than 10 acres with more than 30% total impervious coverage, the 10-year, 24-hour and 100-year, 24-hour storm events shall be used to design the facility.
- For all development areas greater than 10 acres, the 10-year, 24-hour and 100-year, 24-hour storm events shall be used to design the facility.

The primary objective of these sizing criteria is to prevent the increase in magnitude and frequency of storm events which exceed the bank full condition and spread out into the flood plain. A secondary objective is to prevent flood damage from the infrequent, but very large storms, protect the integrity of the stormwater management practice as well as maintain the existing boundaries of the pre-development flood plain.

4.4 Waiver of LID Requirements

An applicant may apply for a waiver of any of the ten requirements found in Section 4.2 of this manual for a development application where owning to environmental conditions, it is not feasible or possible to meet one or more of the requirements. The applicant shall provide the necessary material to support the waiver request. Requests for waivers without supporting documentation will not be considered. The Commission shall obtain a professional opinion from the town engineer regarding the waiver request. The Commission may take one of the following actions:

i. The Commission may grant the waiver in part or in full,
ii. Deny the waiver,
iii. Offer the applicant the option of obtaining a third party review from a mutually agreed upon Professional Engineer. Use of this option does not guarantee approval or acceptance of the waiver request.

The third party review shall be provided by an independent professional engineer licensed in the State of Connecticut with expertise in stormwater management and with due consideration to the requirements of this manual. Costs associated with any such third party review shall be borne by the applicant/developer. Approval of selected consultant shall be based upon staff review of the chosen consultant's relative experience in stormwater management specifically with regard to the application of low impact development techniques.

5.0 Stormwater Treatment Practices to Meet Groundwater Recharge and Water Quality Goals

5.1 List of BMPS for Groundwater Recharge and Water Quality Treatment

FILTERING SYSTEMS

Bioretention: A shallow depression with vegetation that treats stormwater as it filters through a specific soil mixture. In order to be utilized for groundwater recharge, the bottom of the system must be unlined to infiltrate stormwater into the underlying soils.
Figure 5.1.a – Bioretention System

Tree Filter: A Bioretention system contained within a precast unit for use in retrofit situations in a commercial environment.
Figure 5.1.b – Filterra Tree Filter (www.filterra.com)

Surface Sand Filter: This system treats stormwater by the removal of coarse sediments in a sediment chamber or forebay, which is easily maintained prior to the storm-water filtering through a surface sand matrix. In order to be utilized for groundwater recharge, the bottom of the system must be unlined to infiltrate stormwater into the underlying soils.

Figure 5.1.c – Surface Sand Filter (UNHSC)

Organic Filter: This filtering practice uses an organic soil component such as compost or a sand/peat moss mixture to filter the stormwater. In order to be utilized for groundwater recharge, the bottom of the system must be unlined to infiltrate stormwater into the underlying soils.

Figure 5.1.d – Organic Filter

Dry Swale: These are vegetated open swales or depressions which are specifically designed to detail and infiltrate stormwater into the underlying soils. They use a modified soil mixture to enhance the infiltrative capacity of the system. In order to be utilized for groundwater recharge, the bottom of the system must be unlined to infiltrate stormwater into the underlying soils.

Figure 5.1.e – Dry Swale (UCONN NEMO)

INFILTRATION SYSTEMS

Infiltration Trenches: These are infiltration practices that store water volume in open spaces in a chamber or within the void spaces of crushed stone or clean gravel prior to the water being infiltrated into the underlying soils. These practices are permissible for runoff from residential roofs or small commercial roofs (<3,000 sq.ft.). For larger commercial roofs, pre-treatment via one of the filtering systems list above must be provided prior to discharge into this type of infiltration system.

5.1.f – Infiltration Trench (www.washco-md.net)

Infiltration Chambers: These are infiltration practices that store water volume in open spaces both within the chamber and the void spaces in the crushed stone.

Figure 5.1.g – Infiltration Chamber (www.tritonsws.com/Images/case-studies)

Infiltration Basin: This is an infiltration practice that stores stormwater in a flat, vegetated surface depression prior to infiltrating into the underlying soils.

Figure 5.1.h – Infiltration Basin – (www.wash-md.net)

Alternative Paving Surfaces: These are practices that will store and filter stormwater in the void spaces of a clean gravel base prior to infiltrating into the underlying soils.
Figure 5.1.i – Porous Pavements (www.stormwaterenvironments.com)

5.2 List of BMPs for Water Quality Treatment

WET VEGETATED TREATMENT SYSTEMS

Extended Detention Shallow Marsh: A stormwater basin that provides treatment by the utilization of a series of shallow, vegetated permanent pools within the basin in addition to shallow marsh areas.
Figure 5.2.a – Extended Detention Shallow Wetlands (www.wetlands.com.au)

Subsurface Gravel Wetlands: A stormwater system where water quality is provided by the movement of stormwater through a subsurface, saturated bed of gravel with the soil surface being planted with emergent vegetation.
Figure 5.2.b – Subsurface Gravel Wetlands (UNHSC)

Pond / Wetland System: A treatment system which combines the shallow, vegetated aspects of a marsh with at least one pond component.

Figure 5.2.c – Pond/Wetland System (www.starenvironmentalinc.com)

Wet Swale: This is a vegetated depression or open channel designed to retain stormwater or intercept groundwater to provide water quality treatment in a saturated condition.

Figure 5.2.d – Wet Swale (Dr. Bill Hunt, NCSU)

5.3 List of BMPs for Pretreatment for Water Quality Systems

Filter Strips: These vegetated systems that are designed to treat stormwater from adjacent impervious area which occurs as overland flow. These systems function by slowing flow velocities, which allows the removal of sediments and other pollutants.

5.3.a – Filter Strip (www.trinkausengineering.com)

Sediment Forebay: This is a depressed vegetated area prior to a larger stormwater treatment facility which will trap coarse sediments and reduce maintenance requirements of the larger treatment facility.
Figure 5.3.b – Sediment Forebay (www.vwrrc.vt.edu)

Deep Sump Catch Basin: These systems are modified structures that installed as part of a conventional stormwater conveyance system. They are designed to trap trash, debris and coarse sediments. While the hooded outlet provides the potential to trap oil and grease, frequent maintenance is required to remove the oils from the water surface.

Proprietary Treatment Devices: These are manufactured systems which were engineered to provide a cost-effective approach to stormwater quality in a contained space. These systems include oil/grit separators, hydrodynamic separators, and a wide range of filter systems with specialized media. Research by the Center for Watershed Protection, University of New Hampshire Stormwater Center in the past few years have shown that many of these systems are not able to achieve the water quality goals as specified in Section 4.3.3. They may be appropriate for pretreatment in some situations. In order to use a proprietary treatment device, independent research documentation must be provided to justify the pollutant removal efficiency.

5.4 List of BMPs for Water Quantity Control

Wet Extended Detention Pond: This practice is primarily designed to address stormwater quantity increases. They have a deep permanent pool, but do not effectively remove stormwater pollutants. These systems may be located in areas of seasonally high groundwater.
Figure 5.4.a – Wet Extended Detention Pond (NCSU)

Dry Detention Pond: This practice has a dry bottom and is also designed to address changes in stormwater quantity only.

Figure 5.4.b – Dry Detention Pond (www.dhn.iihr.uiova.edu)

5.5 List of BMPs for Commercial Water Quality Retrofits

LID Urban Planter: These systems provide a "greening" of the urban streetscape while providing pollutant attenuation and potential reductions of runoff volume

Figure 5.5.a – LID Urban Planter (City of Portland, OR)

LID Curb Extension: These systems are used to reduce runoff volumes by infiltration as well as pollutants from runoff. They provide a "greening" benefit to any green in addition to a traffic calming device

Figure 5.5.b – LID Curb Extensions (City of Portland, OR)

Modular Wetland System: This system provides treatment of urban runoff in a small footprint. It utilizes the benefits of a Gravel Wetlands along with proprietary filters to remove pollutants.

Figure 5.5.c – Modular Wetland (modularwetland.com)

Filterra Bioretention System: This system is a Bioretention facility for urban applications. By the flow through a proprietary media, the amount of pollutants in urban runoff are reduced.

Figure 5.5.d – Filtera Bioretention (Filterra.com)

5.6 List of Alternative BMPs for Residential Lots

Rain Barrel: A barrel made of PVC, metal or wood which is connected to a roof drain downspout to collect roof runoff from reuse for non-potable uses.

Figure 5.6.a – Rain Barrel (www.ferncreekdesign.org/images)

Gravel Drip Bed: A gravel drip bed is a system consists of crushed stone installed below the drip line of a residential roof without gutters to collect and infiltrate runoff from the roof into the ground (**no illustration**)

6.0 Pollutant Renovation Analysis

6.1 Pollutant Concentrations per Land Use Type:

A pollutant renovation analysis is necessary to demonstrate that the proposed stormwater treatment system will achieve the required water quality goals. Achievement of these goals is a function of an accurate assessment of the pollutant loads expected to be seen by the treatment system and the design of the actual treatment system. In order to achieve the pollutant removal efficiencies stated in section 8.2 for a particular practice, the practice must be designed and constructed in accordance with all of the required parameters as found in Section 7.0. Table 6.1.1 provides concentrations of the pollutants of concern for common land uses. All concentrations are in mg/l.

Table 6.1.a – Pollutant Concentration per Land Use Type

	Pollutant Concentration (mg/l)					
Land Use	TSS	TP	TN	Zn	TPH	DIN
Large Lot Residential (1 unit/5-10 ac)	60	0.38	2.1	0.161	0.50	0.51
Low Density Residential (1 unit/5 ac – 2 units/ac)	60	0.38	2.1	0.161	0.50	0.51
Medium Density Residential (2-8 units/ac.)	60	0.30	2.1	0.176	1.25	0.344
High Density Residential (8+ units/ac.)	60	0.30	2.1	0.218	1.5	0.344
Commercial	58	0.25	2.6	0.156	3.0	0.324
Industrial	80	0.23	2.1	0.671	3.0	0.569
Institutional (schools, churches, etc.)	58	0.27	2.0	0.186	3.0	0.521
Open Urban Land	50	0.25	1.3	0.0	0.0	0.0
Transportation (roads only)	99	0.25	2.3	0.156	3.0	0.375
Deciduous Forest	90	0.10	1.5	0.0	0.0	0.215
Evergreen Forest	90	0.10	1.5	0.0	0.0	0.215
Mixed Forest	90	0.10	1.5	0.0	0.0	0.215
Brush	90	0.38	1.5	0.0	0.0	0.215
Wetlands	0.0	0.38	1.5	0.0	0.0	0.10
Beaches	0.0	0.10	1.5	0.0	0.0	0.0
Bare Ground	1000	0.38	1.5	0.0	0.0	0.0
Row & Garden Crops	357	1.0	2.92	0.0	0.0	0.65
Cropland	357	1.0	2.92	0.0	0.0	0.215
Orchards/vineyards/horticulture	357	1.0	357	0.0	0.0	0.215
Pasture	145	0.38	2.2	0.0	0.0	0.65
Feeding Operations	145	0.38	2.2	0.0	0.0	0.8
Agricultural building, breeding & training facilities	145	0.38	2.2	0.0	0.0	0.8

6.2 Pollutant Removal Efficiencies for Treatment Systems:

Pollutant removal efficiencies are taken from the best available data for each type of treatment system. The sources of this information include the Center for Watershed Protection, the University of New Hampshire Stormwater Center, the EWRI/ASCE BMP Database, and the Massachusetts Stormwater Manual.

Table 6.2.a – Pollutant Removal Efficiencies (percent removal)

Type of System	Pollutant Removal Efficiencies (percent)					
	TSS	TN	TP	Zn	TPH	DIN
Extended Detention Shallow Wetlands	69	56	39	0	0	35
Subsurface Gravel Wetland	99	90	56	99	99	98
Pond/Wetland System	71	19	56	56	0	40
Wet Extended Detention Pond	80	35	55	69	0	36
Infiltration Basin	90	60	65	88	90	50
Infiltration Trenches/Chambers	80	55	60	99	99	50
Bioretention (Option 1 – see list below)	87	17	34	77	99	44
Bioretention (Option 2 – see list below)	87	60	34	77	99	60
Bioretention (Option 3 – see list below)	87	17	60	77	99	44
Bioretention (Option 4 – see list below)	87	60	60	77	99	60
Surface Sand Filter	87	32	59	77	98	33
Organic Filter	88	41	61	89	0	35
Dry Swale	50	0	8	50	81	0
Wet Swale	75	40	40	33	0	41
Vegetated Filter Strip	68	40	45	88	0	0
Permeable Pavement	99	0	60	75	99	0
Porous Concrete	97	0	40	99	99	0
Open Course Pavers	60	0	15	55	55	0
Deep Sump Catch Basins (48”)	9	0	0	0	14	0
Dry Detention Pond	57	0	0	46	82	33
Oil / Grit Separator	0	0	0	17	0	47
LID Urban Planter	99	29	5	99	99	29
LID Curb Extension	99	29	5	99	99	29
Modular Wetland System	82	80	5	79	90	70
Filterra Bioretention System	85	40	60	62	80	40

Bioretention Option 1 (P-Index greater than 30)
Bioretention Option 2 (P-Index greater than 30 with IWS)
Bioretention Option 3 (P-Index less than 30)
Bioretention Option 4 (P-Index less than 30 with IWS)

6.3 Equation and Process:

6.3.1 Equation

In 1987, Tom Schueler developed the Simple Method as a way to estimate pollutant loads for various chemical constituents on an annual basis. The Simple Method requires a small amount of information to be utilized; annual precipitation, pollutant concentrations, percent impervious cover and subwatershed areas. The formula of the Simple Method is as follows:

$L = [(P)(Pj)(Rv)]/12(C)(A)(2.72)$ or reduced to $L = 0.226(P)(Pj)(Rv)(C)(A)$, where

L = Pollutant load in pounds
P = Rainfall depth over desired time period (inches)
Pj = Factor that corrects P for storms that produce no runoff, use Pj = 0.9
Rv = Runoff coefficient, fraction of rainfall that turns to runoff,
$Rv = 0.05 + 0.009(I)$
I = Site Impervious coverage (percent)
C = Flow weighted mean concentration of pollutant (mg/l)
A = Area of site (acres)
0.226 = Unit Conversion Factor

The Simple Method provides reasonable estimates of changes in pollutant amounts resulting from different types of development. There are three aspects of the Simple Method that engineers need to keep in mind when using the equation.

1. It only estimates the pollutant load from storm events and does not consider pollutants from baseflow volumes. For large low density residential developments, where I < 5%, up to 75% of the annual runoff volume may be comprised of baseflow, the annual nutrient load associated with the baseflow may be equal to the annual load associated with the development.
2. Its primary usefulness is for calculating and comparing the relative storm water pollutant loads from various development concepts.
3. It provides an estimate of the pollutant loads that are likely close to the “true” but unknown value for a development project.

The Simple Method shall be used to calculate the pollutant load for the six pollutants required to be evaluated for stormwater discharges in the Town of Plainville. The following process shall be followed for the calculation of the pollutant loads and the effectiveness of the stormwater treatment systems.

6.3.2 Process

Pre-Development Conditions:

1. Delineate the watershed areas on the site for undeveloped conditions for each design point or point of interest. A design point would typically be the point where a watercourse or overland flow would leave the site boundary. A point of interest could also be the limit of a delineated wetland or watercourse, located within the site's boundary.
2. Label and determine the area of each watershed on the site.
3. Determine the type of land cover for each watershed area. (For a retrofit or redevelopment site, the design engineer needs to make an assumption as to the type of land use cover which existed on the site prior to any type of development)
4. Obtain annual rainfall amount in inches for the general location of the site.
5. Use the Simple Method to calculate the pollutants loads for the pre-development conditions.

Post-Development Conditions:

1. In order to fully integrate water quality into the site design, the type and location of the treatment systems need to be evaluated during the design phase and not at the end of the design period. The pollutant loading analysis should be prepared twice during the process; first during the Conceptual Design Phase in order to determine the type of treatment systems needed to achieve water quality goals. The second time is when the final site plan is complete and accurate values for impervious cover are available.
2. Prepare Conceptual Development Plan for project.
3. Delineate the watershed boundaries on the site for future conditions. Divide the watershed area into the area above the treatment system, which contributes to the treatment system, and the area below the treatment system.
4. Calculate area of each watershed area.
5. Based upon proposed land use, estimate impervious coverage within each watershed area above the treatment systems.
6. Calculate land area below the treatment system to the design point or point of concern. Only that area above the last treatment facility is run through the treatment system analysis. Pollutant loads from land below the last treatment system need to be calculated separately and can be added to the remaining load from the treatment system to determine the total load reaching the design point for future conditions. This is very important if TMDL limits are applicable to the receiving waterway.
7. Use the Simple Method to calculate preliminary pollutant loads for post-development conditions on the site based upon the Conceptual Development Plan.
8. After the loads have been calculated for post-development, use the pollutant removal efficiencies provided and the formula below to determine the type(s) of treatment systems needed to achieve water quality goals.
9. After the design engineer has determined what type of treatment system(s) are required, they can proceed with the final site design and incorporate the necessary storm water treatment system(s) as they prepare the final site design.

10. After the site design is complete, steps #3 through #8 are repeated with the accurate areas of the final watershed areas and impervious cover.
11. A final, written report shall be prepared by the design engineer clearly demonstrating that the required pollutant removal efficiencies are achieved for the entire site

Pollutant Removal Calculation Procedure

1. (total load * 1st removal efficiency)
2. (total load – (load removed in #1))*2nd removal efficiency
3. (total load – (load removed in #1 + #2))*3rd removal efficiency
4. (total load – (load removed in #1 + #2 + #3))*4th removal efficiency …

Total Percentage Removed by Treatment Systems

(load removed in #1+load removed in #2+load removed in #3….)/total load * 100

7.0 Design Requirements for Stormwater Systems

There are six categories for required design elements and guidelines for each type of stormwater recharge, water quality, pretreatment and water quantity systems. The categories are feasibility, conveyance, pretreatment, sizing criteria, treatment and maintenance. The following pages provide detailed design parameters for each type of LID treatment system to be used to address stormwater issues in the Town of Plainville.

As the LID approach to stormwater management focuses on treating runoff at its source, both short term and long term maintenance of these systems are very important. Legally binding maintenance agreements for these LID systems must be prepared and filed in the Office of the Town Clerk for the Town of Plainville. Each maintenance agreement must include the maintenance requirements as specified for each system.

Table 7.0.a and 7.0.b have been developed to assist the design engineer in determining the optimum configuration of treatment systems to meet stormwater and water quality goals as specified in Section 4.3 of this manual.

Table 7.0.a – Stormwater System Matrix

Stormwater Treatment Device Selection Matrix

Stormwater Treatment Systems	GRv	WQv	PT	FP
FILTERING SYSTEMS				
Bioretention (page 47)	■	■		
Tree Filter (page 50)	■	■		
Surface Sand Filter (page 52)	■	■		
Organic Filter (page 54)	■	■		
Dry Swales (page 56)	■	■		
INFILTRATION SYSTEMS				
Infiltration Trenches (page 58)	■	■		
Infiltration Chambers (page 60)	■	■		
Infiltration Basins (page 62)	■	■		
Alternative Paving Surface (page 64)	■	■		
WET VEGETATED TREATMENT SYSTEMS				
Extended Detention Shallow Wetlands (page 67)		■		■
Subsurface Gravel Wetlands (page 69)		■		
Pond / Wetland System (page 71)		■		■
Wet Swales (page 73)		■		
PRETREATMENT FOR WATER QUALITY SYSTEMS				
Filter Strip (page 75)			■	
Sediment Forebays (page 77)			■	
Deep Sump Catch Basins (page 79)			■	
Proprietary Treatment Devices (page 81)			■	
WATER QUANTITY CONTROL				
Wet Extended Detention Pond (page 83)				■
Dry Detention Pond (page 85)				■
WATER QUALITY CONTROL FOR COMMERCIAL RETROFITS				
LID Urban Planter (page 87)	■	■		
LID Curb Extension (page 89)	■	■		
Modular Wetland System (page 92)		■		
Filterra Bioretention System (page 94)		■		

GRv: Groundwater Recharge Volume
WQv: Water Quality Volume
PT: Pretreatment
FP: Flood Protection

Table 7.0.b – Treatment System Matrix

POLLUTANT REMOVAL RATE	Excellent	Very Good	Good	Fair	Poor
Pollutant Removal Efficiency	80 – 95%	70 – 80%	55 – 70%	40 – 55%	< 40%
Color Coded System	(dark green)	(yellow-green)	(bright green)	(orange)	(yellow)

Stormwater Treatment Systems	TSS	TN	TP	Zn	TPH	DIN
FILTERING SYSTEMS						
Bioretention (page 35) – Option 1	Excellent	Poor	Poor	Very Good	Excellent	Fair
Bioretention (page 35) – Option 2	Excellent	Good	Poor	Very Good	Excellent	Good
Bioretention (page 35) – Option 3	Excellent	Poor	Good	Very Good	Excellent	Fair
Bioretention (page 35) – Option 4	Excellent	Good	Good	Very Good	Excellent	Good
Tree Filter (page 39)	Excellent	Poor	Poor	Very Good	Excellent	Poor
Surface Sand Filter (page 41)**	Excellent	Poor	Good	Very Good	Excellent	Poor
Organic Filter (page 43)**	Excellent	Poor	Good	Excellent	Poor	Poor
Dry Swales (page 45)	Fair	Poor	Poor	Fair	Very Good	Poor
INFILTRATION SYSTEMS						
Infiltration Trenches (page 47)	Excellent	Good	Good	Excellent	Excellent	Fair
Infiltration Chambers (page 49)	Excellent	Good	Good	Excellent	Excellent	Fair
Infiltration Basins (page 51)**	Excellent	Good	Good	Excellent	Excellent	Fair
Permeable Pavement (page 53)	Excellent	Poor	Good	Very Good	Excellent	Poor
Porous Concrete (page 53)	Excellent	Poor	Poor	Excellent	Excellent	Poor
Open Course Pavers (page 53)	Good	Poor	Poor	Good	Good	Poor
WET VEGETATED TREATMENT SYSTEMS						
Extended Detention Shallow Wetlands (page 56)**	Very Good	Good	Poor	Poor	Poor	Poor
Subsurface Gravel Wetlands (page 58)**	Excellent	Excellent	Good	Excellent	Excellent	Excellent
Pond / Wetland System (page 60)**	Very Good	Poor	Good	Good	Poor	Poor
Wet Swales (page 62)	Very Good	Poor	Poor	Poor	Poor	Fair
PRETREATMENT FOR WATER QUALITY SYSTEMS						
Filter Strip (page 64)	Good	Poor	Fair	Excellent	Poor	Poor
Stand Alone Sediment Forebays (page 66)	Very Good	Poor	Poor	Good	Good	Poor
Deep Sump Catch Basins (page 68)	Poor	Poor	Poor	Poor	Poor	Poor
Oil/Grit Separator (page 70)	Poor	Poor	Poor	Poor	Poor	Poor
WATER QUANTITY CONTROL						
Wet Extended Detention Pond (page 72)**	Excellent	Poor	Fair	Good	Poor	Poor
Dry Detention Pond (page 74)**	Fair	Poor	Fair	Fair	Excellent	Poor
Stormwater Treatment Systems – Continued	**TSS**	**TN**	**TP**	**Zn**	**TPH**	**DIN**
WATER QUALITY CONTROL FOR COMMERCIAL RETROFITS						
LID Urban Planter (page 76)	Excellent	Poor	Poor	Excellent	Excellent	Poor
LID Curb Extension (page 78)	Excellent	Poor	Poor	Excellent	Excellent	Poor
Modular Wetland System (page 81)	Excellent	Very Good	Poor	Very Good	Excellent	Very Good
Filterra Bioretention System (page 83)	Excellent	Fair	Good	Good	Poor	Fair

TSS: Total Suspended Solids
TN: Total Nitrogen
TP: Total Phosphorous
Zn: Total Zinc
TPH: Total Petroleum Hydrocarbons
DIN: Dissolved Inorganic Nitrogen

7.1 BIORETENTION (GRv & WQv)

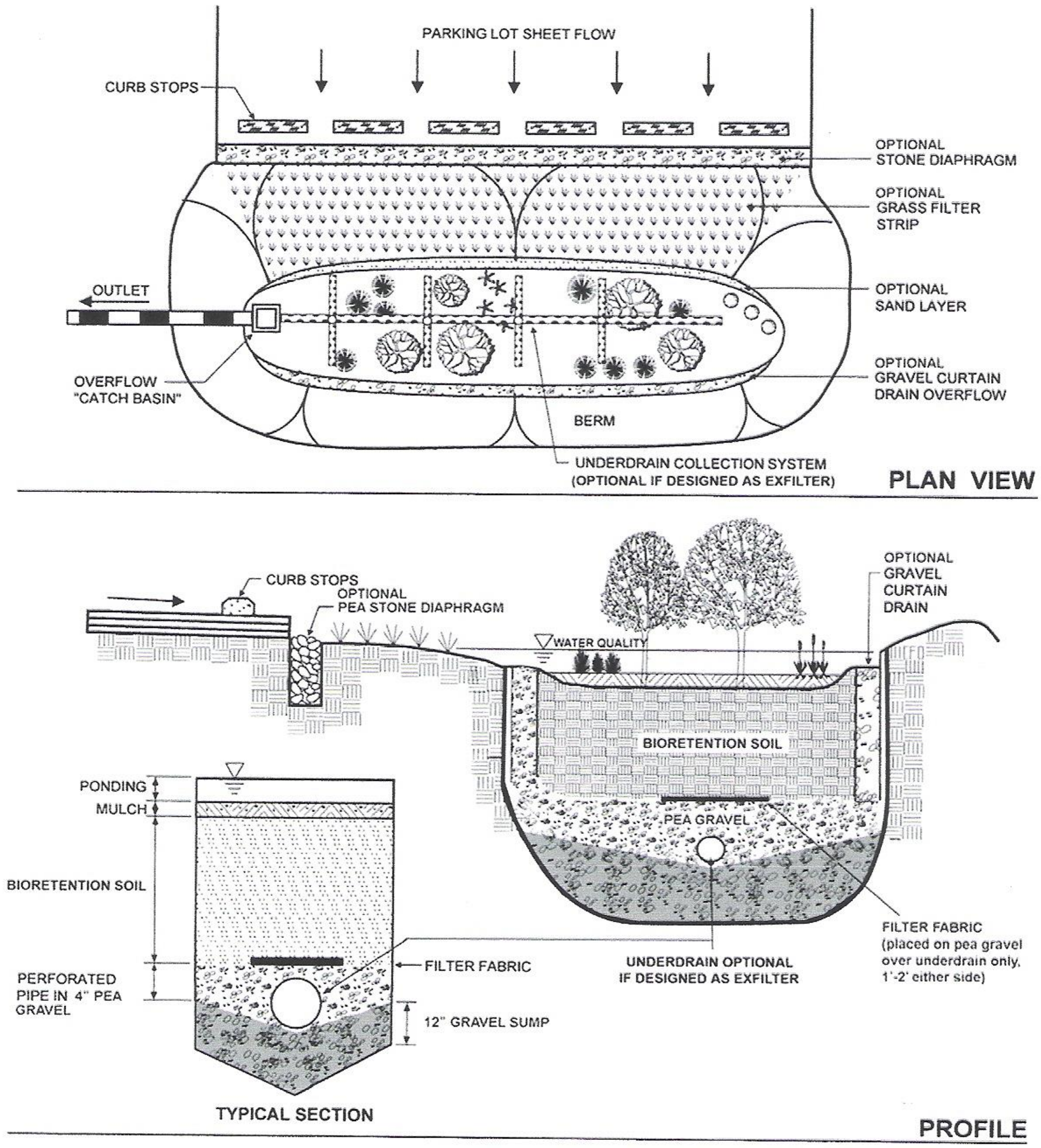
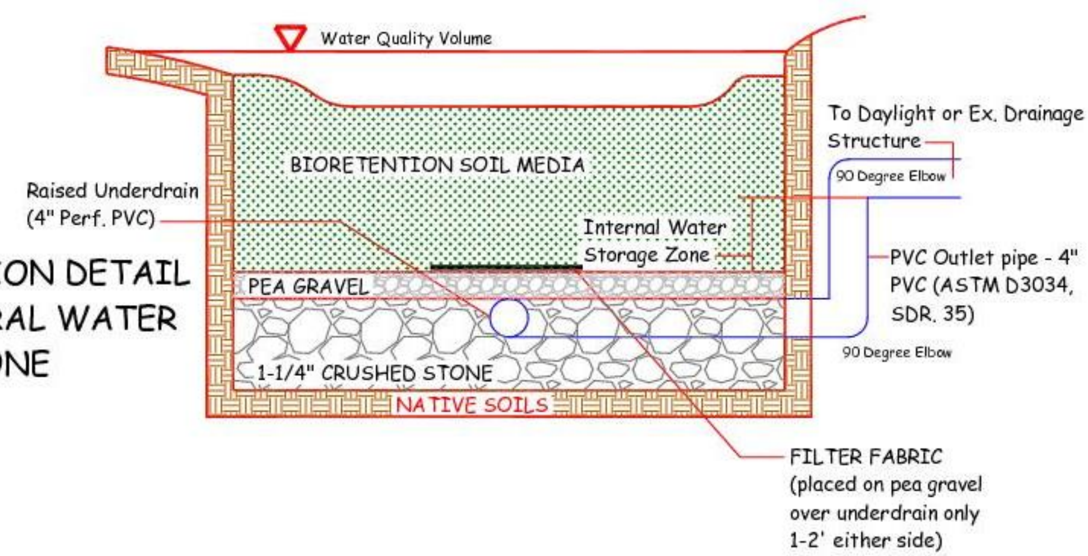


Figure 7.1.a – Typical Bioretention (RI DEM, 2010)

Table 7.1.a – Bioretention Design Parameters

Design Parameter	Residential Roof or Driveway Runoff	Runoff from Commercial Roof	Runoff from Commercial Driveway or Parking Area
Deep Test Pit	Yes, min. 6' in depth	Yes, min. 8' in depth	Yes, min. 8' in depth
Percolation Test	Yes, 24-30" deep	Yes, 30-36" deep	Yes, 30-36" deep
Depth of Soil Media	18"	24"	30"
Separation to SHGW from bottom of soil media	12" for A Soils 6" for B & C Soils*	24" for A Soils 6" for B & C Soils*	24" for A Soils 12" for B & C Soils*
Underdrain (raised)	Not required for A & B soils Required for C Soils	Not required for A soils Required for B & C Soils	Not required for A soils Required for B & C Soils
Depth of Pea Gravel Layer above underdrain	3"	3"	3"
Depth of 1-1/4" crushed stone for underdrain layer	12"	12"	12"
Enhanced Nitrogen Removal (Internal Water Storage)**	Saturate bottom 6" of Soil Media Layer	Saturate bottom 12" of Soil Media Layer	Saturate bottom 12" of Soil Media Layer
Overflow Provisions – Top of pipe set at max. ponding depth	No, for A Soils Yes, for B & C Soils	No, for A Soils Yes, for B & C Soils	No, for A Soils Yes, for B & C Soils

* Separation to SHGW may be reduced by 50% provided that the surface ponding depth is reduced by 50% and the surface area of the Bioretention facility is increased accordingly to contain required WQv.
** See Detail below for Internal Water Storage Design



BIORETENTION DETAIL WITH INTERAL WATER STORAGE ZONE
N.T.S.

Required Design Elements for Bioretention

FEASIBILITY:

- Invert of underdrain pipe (if provided) at or above Seasonal High Groundwater (SHGW) level for systems serving roads, parking lots & commercial roofs.
- Vertical separation from bottom of soil media to SHGW shall conform to the requirements found in Table 7.1.a
- The maximum drainage area to a Bioretention system shall be five (5) acres.
- Deep test pit and percolation test must be performed within 15' of proposed Bioretention system.

CONVEYANCE:

- Overflow provisions from the facility shall be provided for the 1-year storm event to either a structural conveyance system or to daylight onto a stable surface, where non-erosive velocities shall be provided (3-5 fps).
- Conveyance to the facility shall overland flow from the adjacent land area or via a 4-6" drain pipe (roof drain outlet) onto a pad of field stones to dissipate flow velocities.

PRETREATMENT:

- Pretreatment shall be required for runoff from connected impervious areas as flow across a vegetated filter strip or grass swale to the facility. A gravel diaphragm can be used for the discharge of sheet flow from the edge of a parking facility.
- No pretreatment is required for runoff from residential or small commercial building roofs (4,000 sq.ft. or less).

SIZING CRITERIA:

- The maximum permissible ponding depth shall be 12"(1.0') for a Class A soil, 9"(0.75') for a Class B soil and 6"(0.50') for a Class C soil. Bioretention systems shall not be permitted in Class D soils.
- The surface area of the Bioretention system shall be determined by the following equation:

SA = (WQv)/hf where:

SA = Surface area of filter bed (square feet)
WQv = Calculated water quality volume (cubic feet)
hf = Depth of ponding above soil surface in feet (use values above per soil class)

TREATMENT:

- The Bioretention facility must fully contain 100% of the required WQv for the contributing area.
- Depth of soil media shall be as specified in Table 7.1.a.
- Soil media shall have a **P-Index** (Phosphorous Index) of 0 – 30 (A low P-Index creates an enhanced environment to remove phosphorous from stormwater)
- Soil Mixture shall consist of sand (85%), Compost (10%), Organic soil (5%) [organic soil shall have no more than 2% clay].
- Mulch layer shall consist of well aged (6-12 month old) shredded hardwood mulch and shall only be placed around plant stems.
- A detailed planting plan shall be provided for each Bioretention system.
- Only native plants shall be used. Appropriate plants for the hydrologic conditions shall be taken from the plant lists found in Appendix B.

CONSTRUCTION AND MAINTENANCE REQUIREMENTS:

- The area of the facility shall be fenced off during the construction period to prevent disturbance of the soils.
- The design engineer shall oversee the preparation of the area and the installation of the various components of the Bioretention system (gravel storage zone, gravel filter course and modified soil mixture).
- The design engineer shall provide an as-built plan of the Bioretention system along with a certification that the system was designed in accordance with the specifications found in the Design Manual and installed in accordance with the approved plans.
- Facilities shall be inspected annually for proper growth of plant material. Dead plants shall be removed and replaced during the first two growing seasons. Plants shall be pruned as needed.
- Mulch shall be reapplied as needed to maintain a 2" thick layer around the plant stems.

Reserved

7.2 TREE FILTER (GRv & WQv)

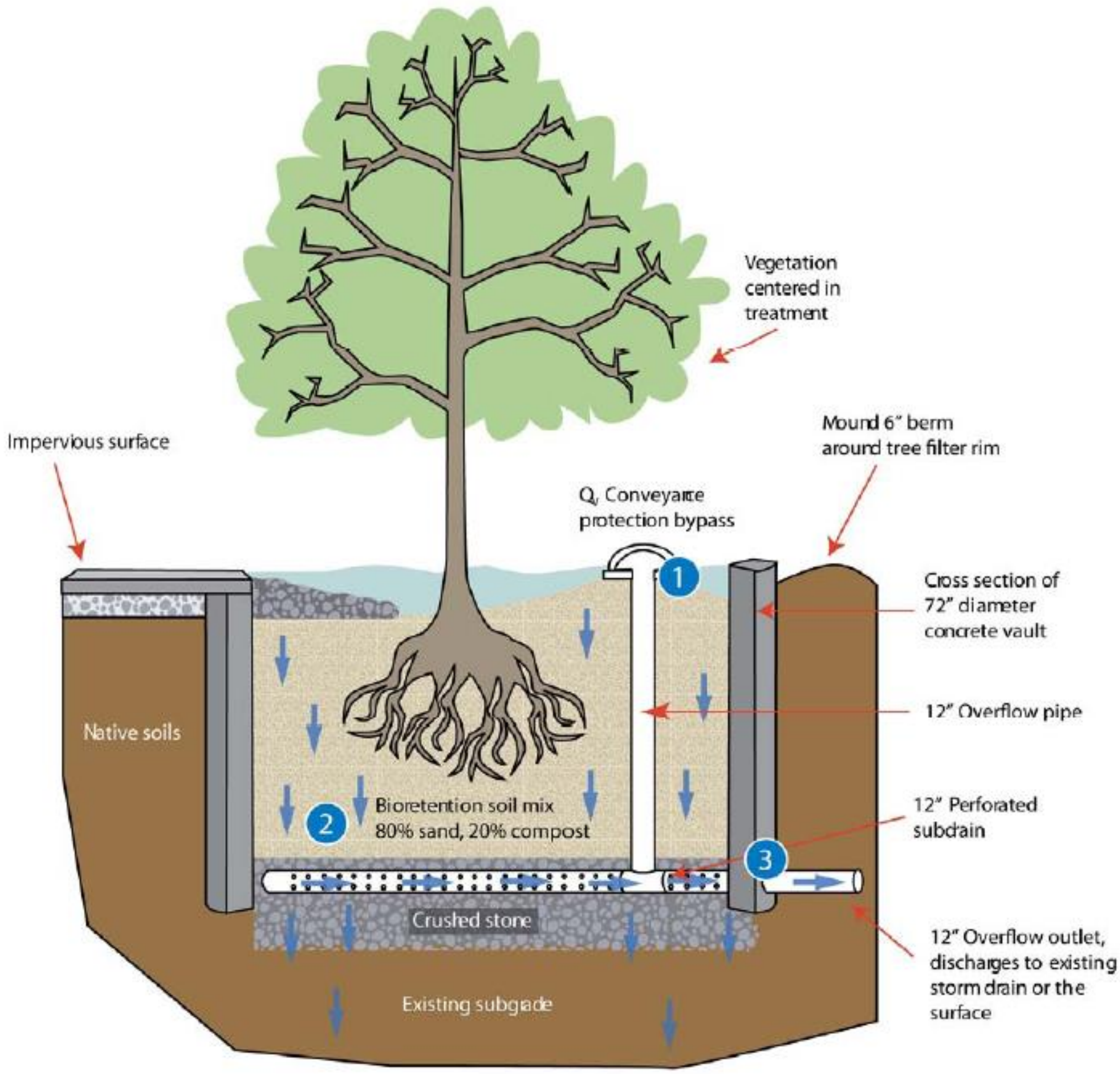


Figure 7.2.a - Tree Filter (UNHSC)

Required Design Elements for Tree Filter Systems

FEASIBILITY:
- Invert of underdrain pipe (if provided) at or above Seasonal High Groundwater (SHGW) level.
- Top of soil surface at least three (3) feet above SHGW.
- The maximum drainage area to a tree filter shall be 5,000 square feet (0.12 acres)

CONVEYANCE:
- Overflow provisions from the facility shall be provided for the 1-year storm event to either a structural conveyance system or to daylight onto a stable surface, where non-erosive velocities shall be provided (3-5 fps).
- At a minimum the underdrain pipe shall consist of 6" perforated PVC pipe. The minimum diameter of the overflow pipe shall be 6". The overflow pipe shall be sized to convey the Channel Protection Flow for each particular system.

PRETREATMENT:
- No pretreatment is required for a tree filter.

SIZING CRITERIA:
- The maximum permissible ponding depth shall be 12".
- A minimum surface area for ponding within the tree filter is 36 square feet (6' x 6').
- The stone reservoir, consisting of ¾" washed crushed stone (no fines) shall be 24" in depth.

TREATMENT:
- The tree filter system must fully contain 100% of the required WQv.
- Minimum depth of soil mixture shall be 48".
- Soil Mixture shall consist of sand (80%), and Compost (20%).
- Mulch layer shall consist of well aged (6-12 month old) shredded hardwood mulch and shall only be placed around tree stem.
- Only deciduous tress shall be used. Appropriate tree species shall be taken from the plant lists found in Appendix B.

CONSTRUCTION AND MAINTENANCE REQUIREMENTS:
- The area of the facility shall be fenced off during the construction period to prevent disturbance of the soils.
- The design engineer shall oversee the preparation of the area and the installation of the various components of the tree filter system (gravel storage zone, and modified soil mixture).
- The design engineer shall provide a certification that the system was designed in accordance with the specifications found in the Design Manual and installed in accordance with the approved plans.
- Facilities shall be inspected annually for proper growth of tree. Plants shall be pruned as needed.
- Mulch shall be reapplied as needed to maintain a 2" thick layer around the plant stems.

7.3 SURFACE SAND FILTER (GRv & WQv)

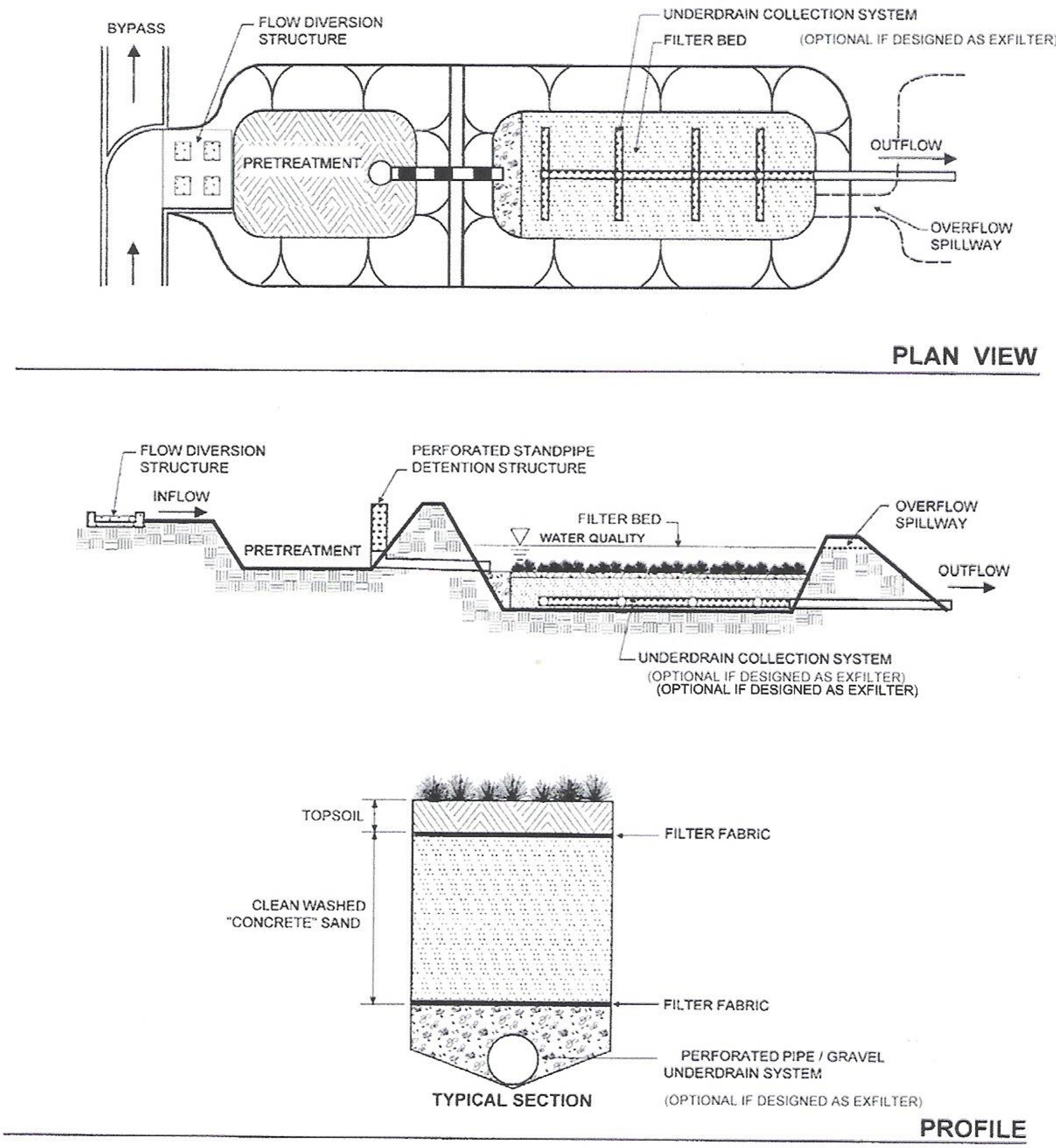


Figure 7.3.a – Surface Sand Filter (RI DEM, 2010)

Required Design Elements for Surface Sand Filters

FEASIBILITY:

- Invert of underdrain pipe (if provided) at or above Seasonal High Groundwater (SHGW) level.
- Top of soil surface at least three (3) feet above SHGW.
- The maximum drainage area to a surface sand filter shall be ten (10) acres.

CONVEYANCE:

- Surface sand filter must be designed as "off-line" if stormwater is delivered by standard pipe system.
- Only WQv shall be directed to "off-line" filter with by-pass for larger flows.
- Overflow provisions from the facility shall be provided for the 1-year storm event to either a structural conveyance system or to daylight onto a stable surface, where non-erosive velocities shall be provided (3-5 fps).
- The surface sand filter shall have an underdrain unless it is a fully exfiltrating system.

PRETREATMENT:

- Pretreatment shall be provided by a sediment forebay. The pretreatment area shall provide 25% of the required WQv.

SIZING CRITERIA:

- The surface area of the sand filter shall be determined by the following equation (RI DEM, 2010):

Af = (WQv)*(df)/[(k)*(hr + df)*(tf)] where:

Af = Surface area of filter bed (square feet)
WQv = Calculated water quality volume
df = Filter bed depth (sand media) (feet)
k = Coefficient of sand media, use k=3.5 ft/day
hf = Depth of ponding above soil surface in feet
tf = Design filter bed drain time (days), use tf = 1.0 for surface sand filter

TREATMENT:

- The surface sand filter including the pretreatment component must fully contain 100% of the required WQv. A porosity value of 0.33 shall be used to determine the storage volume within the media. Storage volume within the media can be used to meet the WQv requirement.
- Sand meeting ASTM C-33 specification must be used for filter media.
- Contributing area to surface sand filter must be permanently stabilized prior to directing runoff to filter.
- Minimum depth of sand shall be 24".
- A minimum diameter of 4" shall be used for the underdrain pipe.
- Surface of sand filter shall be planted with appropriate grass mixture. Grass must be able to sustain periods of frequent drought and inundation. See list in Appendix B.

CONSTRUCTION AND MAINTENANCE REQUIREMENTS:

- The area of the facility shall be fenced off during the construction period to prevent disturbance of the soils.
- The design engineer shall oversee the preparation of the area and the installation of the various components of the sand filter system (gravel storage zone, and sand treatment zone).
- The design engineer shall provide a certification that the system was designed in accordance with the specifications found in the Design Manual and installed in accordance with the approved plans.
- Removal of sediment from forebay when accumulated depth is 6".
- The surface of the filter shall be inspected every six months and trash/debris removed.
- If water is ponding for more than 2.0 days, the surface has likely become clogged with fine sediments. The surface shall be raked to a depth of 2" and reseeded. If clogging still occurs, the top 3" of material shall be removed and replaced with new sand meeting the design specification and reseeded.
- Facilities shall be inspected annually for proper growth of grass material.
- Grass shall be maintained at a height of 3 – 4".

7.4 ORGANIC FILTER (GRv & WQv)

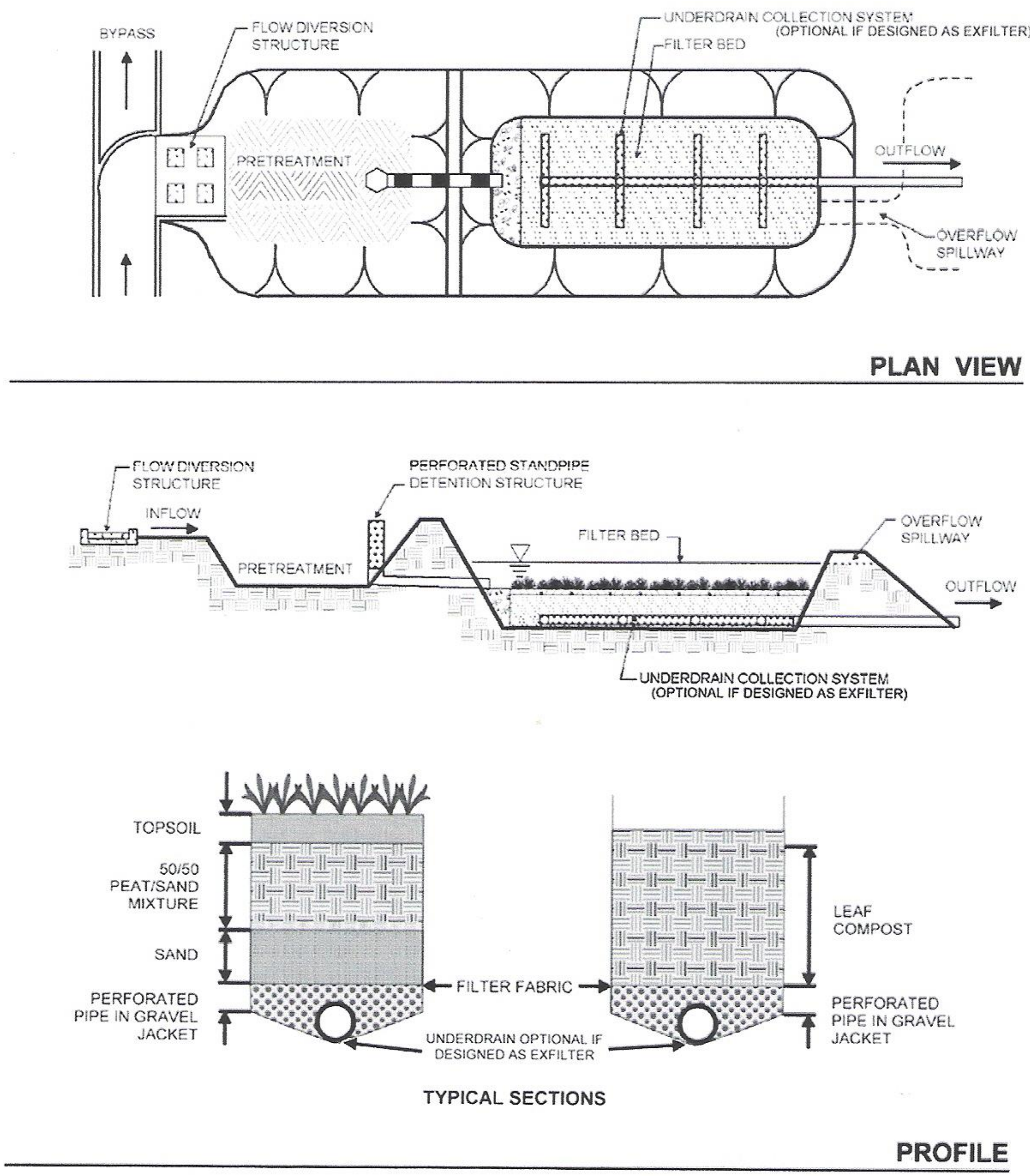


Figure 7.4.a – Organic Filter (RI DEM, 2010)

Required Design Elements for Organic Filters

FEASIBILITY:

- Invert of underdrain pipe (if provided) at or above Seasonal High Groundwater (SHGW) level.
- Top of soil surface at least three (3) feet above SHGW.
- The maximum drainage area to an organic filter shall be ten (10) acres.

CONVEYANCE:

- Organic filter must be designed as "off-line" if stormwater is delivered by standard pipe system.
- Only WQv shall be directed to "off-line" filter with by-pass for larger flows.
- Overflow provisions from the facility shall be provided for the 1-year storm event to either a structural conveyance system or to daylight onto a stable surface, where non-erosive velocities shall be provided (3-5 fps).
- The organic filter shall have an underdrain unless it is a fully exfiltrating system.

PRETREATMENT:

- Pretreatment shall be provided by a sediment forebay.
- 25% of the required WQv shall be provided by a sediment forebay.

SIZING CRITERIA:

- The surface area of the organic filter shall be determined by the following equation (RI DEM, 2010):

Af = (WQv)*(df)/[(k)*(hr + df)*(tf)] where:

Af = Surface area of filter bed (square feet)
WQv = Calculated water quality volume
df = Filter bed depth (sand media) (feet)
k = Coefficient of sand media, use k=3.5 ft/day, for peat use k = 2.0 ft/day, and for leaf compost, use k = 8.7 ft/day
hf = Depth of ponding above soil surface in feet
tf = Design filter bed drain time (days), use tf = 2.0 for organic filter

TREATMENT:

- The organic filter including the pretreatment component must fully contain 75% of the required WQv. A porosity value of 0.33 shall be used to determine the storage volume within the media. Storage volume within the media can be used to meet the WQv requirement.
- Soil mixture for organic filter shall be either a mix of sand/peat mix or leaf compost. Peat shall be a reed-sedge hemic peat (partially decomposed).
- Contributing area to organic filter must be stabilized prior to directing runoff to filter.
- Minimum depth of media material shall be 24".
- A minimum diameter of 4" shall be used for the underdrain pipe.
- Surface of organic filter shall be planted with appropriate grass mixture. Grass must be able to sustain periods of frequent drought and inundation. See list in Appendix B.

CONSTRUCTION AND MAINTENANCE REQUIREMENTS:

- The area of the facility shall be fenced off during the construction period to prevent disturbance of the soils.
- The design engineer shall oversee the preparation of the area and the installation of the various components of the organic filter system (gravel storage zone, and media treatment zone).
- The design engineer shall provide a certification that the system was designed in accordance with the specifications found in the Design Manual and installed in accordance with the approved plans.
- Removal of sediment from forebay when accumulated depth is 6".
- The surface of the organic shall be inspected every six months and trash/debris removed.
- If water is ponding for more than 4.0 days, the surface has likely become clogged with fine sediment. The top 6"(minimum) of material shall be removed and replaced with new media meeting the design specification and re-planted.
- Facilities shall be inspected annually for proper growth of grass material.
- The height of vegetation on the surface of an organic filter shall not exceed 18".

7.5 DRY SWALES (GRv & WQv)

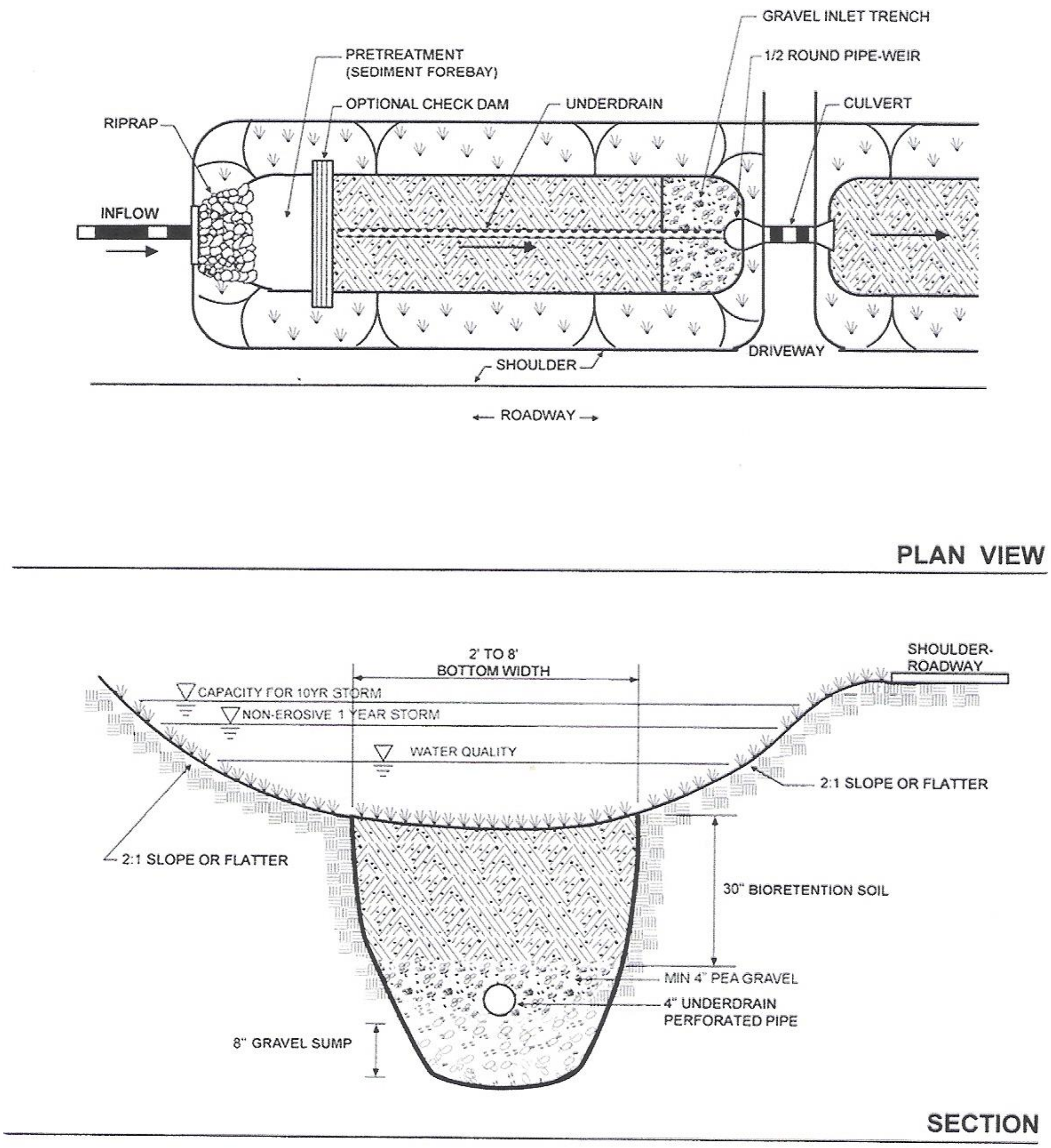


Figure 7.5.a – Dry Swale (RI DEM, 2010)

Required Design Elements for Dry Swales

FEASIBILITY:

- Maximum slope along flow length shall be 4.0% without check dams.
- Invert of underdrain pipe (if provided) or bottom of soil mixture shall be at or above Seasonal High Groundwater (SHGW) level.
- Top of soil surface at least three (3) feet above SHGW.
- The maximum drainage area to a dry swale shall be five (5) acres to one inlet.
- Primary use is along linear systems, such as roads, residential development and pervious areas, such as ballfields.

CONVEYANCE:

- Swale shall be able to handle 10-year, 24-hour peak rate from contributing area.
- Swale side slopes shall be a minimum of 3:1. If there are space constraints, then 2:1 slopes may be used.
- Non-erosive velocities shall be provided (3-5 fps) for 1-year, 24-hour storm event.
- Temporary ponding within the dry swale shall drain within 48 hours. If necessary, an underdrain shall be utilized to achieve this requirement. An underdrain is not required if it is a fully exfiltrating system.

PRETREATMENT:

- Pretreatment shall be required as ponding behind stone check dams located within the swale itself.
- Flow across a vegetated filter strip along a road shall be appropriate pretreatment measure.
- 10% of the required WQv shall be provided by an appropriate pretreatment system.

SIZING CRITERIA:

- The surface area of the filter bed (bottom of swale) shall be determined by the following equation (RI DEM, 2010):

  Af = (WQv)*(df)/[(k)*(hr + df)*(tf)] where:

  Af = Surface area of filter bed (square feet)
  WQv = Calculated water quality volume
  df = Filter bed depth (sand media) (feet)
  k = Coefficient of Bioretention soil mixture (1.0 feet/day)
  hf = Average height of water above swale surface (feet)
  tf = Design filter bed drain time (days), use tf = 2.0 for dry swale

- Bottom width of swale shall not be greater than eight (8) feet nor less than two (2) feet.

TREATMENT:

- Soil Mixture shall consist of sand (85%), compost (10%), and organic soil (5%) [organic soil shall have no more than 2% clay].
- Appropriate grass mixtures shall be used for the bottom and side slopes of a Dry Swale.
- Contributing area to dry swale must be stabilized prior to directing runoff to filter.
- Minimum depth of Bioretention soil mixture shall be 30”.
- Surface of dry swale shall be planted with appropriate grass mixture. Grass must be able to sustain periods of frequent drought and inundation. See list in Appendix B.

CONSTRUCTION AND MAINTENANCE REQUIREMENTS:

- The area of the facility shall be fenced off during the construction period to prevent disturbance of the soils.
- The design engineer shall oversee the preparation of the area and the installation of the various components of the organic filter system (gravel storage zone, and media treatment zone).
- The design engineer shall provide a certification that the system was designed in accordance with the specifications found in the Design Manual and installed in accordance with the approved plans.
- Shall be inspected annually and after storms greater than 1-year, 24-hour storm event
- Removal of sediment, when accumulation exceeds 25% of the WQv storage value.
- Vegetation shall be mowed as necessary to maintain 4-6” height. Woody vegetation shall be removed from the dry swale.
- If ponded water is regularly observed more than 48 hours after a rainfall event, then the surface shall be roto-tilled to a depth of 12” and reseeded.

7.6 INFILTRATION TRENCHES (GRv & WQv)

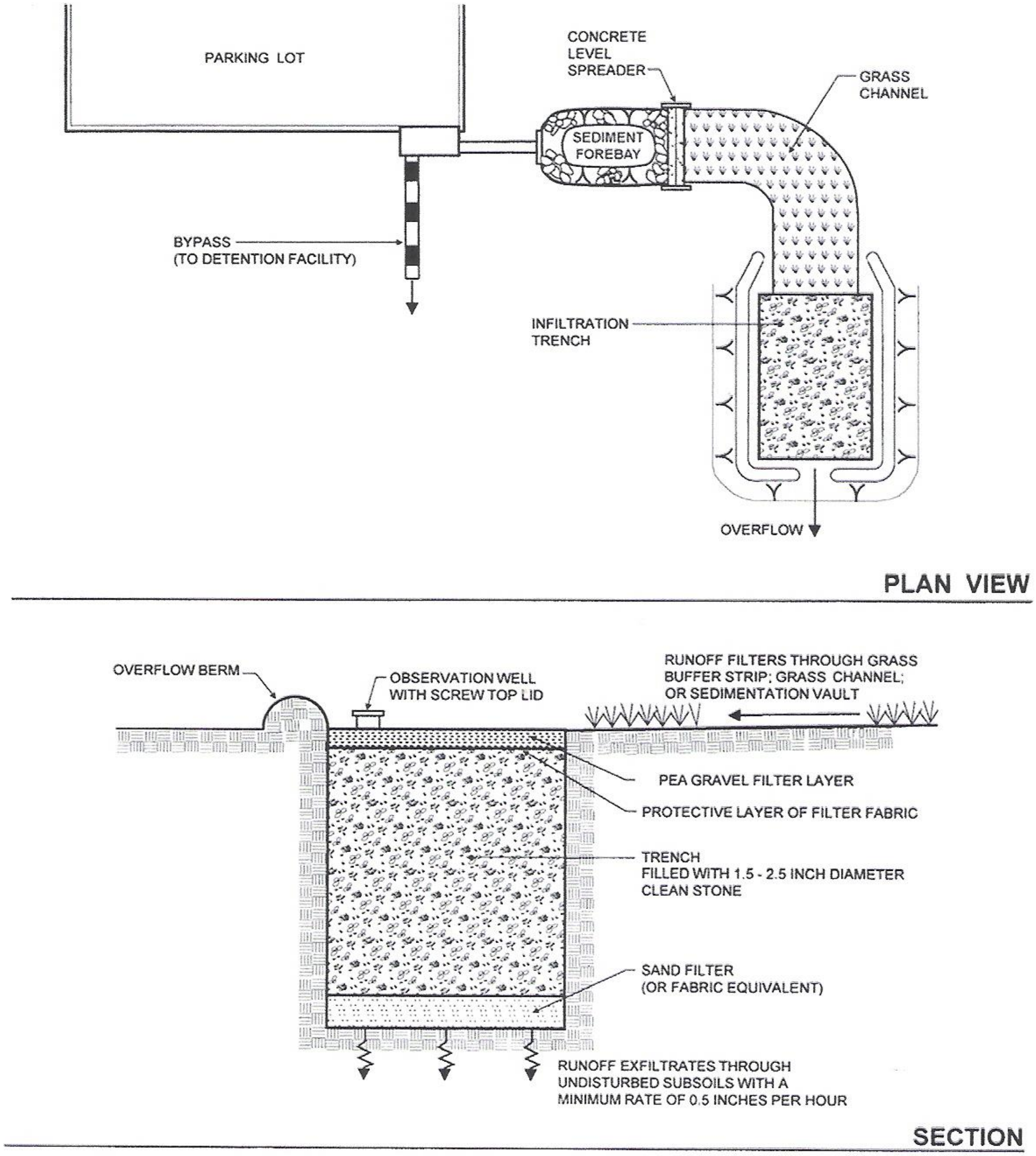


Figure 7.6.a – Infiltration Trench (RI DEM, 2010)

Required Design Elements for Infiltration Trench

FEASIBILITY:

- Three (3) foot vertical separation from bottom of infiltration trench to SHGW and bedrock. For residential applications, this separation can be reduced to two (2) feet.
- Must be installed on slopes < 15% and parallel to contours.
- Native soils must have less than 20% clay and 40% silt/clay. This shall be determined by a dry sieve analysis by a qualified soils lab.
- Native soils must have an in-situ infiltration rate of 0.5 inches per hour based upon NRCS soil textural classification. Must be verified by field infiltration tests.
- The maximum drainage area to an infiltration trench shall be five (5) acres.

CONVEYANCE:

- Infiltration trench must be designed as "off-line" if stormwater is delivered by standard pipe system.
- Overflow provisions from the facility shall be provided for the 1-year storm event to either a structural conveyance system or to daylight onto a stable surface, where non-erosive velocities shall be provided (3-5 fps).
- All infiltration trenches shall be designed to fully dewater the entire WQv 48 hours after the rainfall event.

PRETREATMENT:

- Pretreatment shall be required as flow across a vegetated filter strip, grass swale or through a sediment forebay.
- 25% of the required WQv shall be provided by an appropriate pretreatment system.
- Flow velocities from pretreatment system to infiltration must be non-erosive for 1-yr storm event.
- The sides of the infiltration trench shall be lined with a non-woven filter fabric to prevent soil piping.

SIZING CRITERIA:

- The bottom area of an infiltration trench shall be determined by the following equation (RI DEM, 2010):

$Ap = V / (ndt = fct/12)$ where:

Ap = Surface area at the bottom of the trench (square feet)
V = Design volume (WQv) (cubic feet)
n = Porosity of gravel fill (use 0.33)
dt = Trench depth (feet)
fc = Design infiltration rate (in/hr)
t = Time to fill trench (hours), assume $t = 2.0$

TREATMENT:

- Infiltration trench shall be designed to fully exfiltrate the entire WQv through the bottom of the trench only.
- Design infiltration rates (fc) for above sizing equation shall be taken from the following table.

Table 7.6 Design Infiltration Rates for Various Soil Textures (Rawls et al., 1982)

USDA Soil Texture	Design Infiltration Rate (fc) (in/hr)
Sand	8.27
Loamy Sand	2.41
Sandy Loam	1.02
Loam	0.52
Silt Loam	0.27

CONSTRUCTION AND MAINTENANCE REQUIREMENTS:

- Infiltration trenches shall never be used for sediment control during an active construction period.
- The area of the infiltration trench must be marked off by appropriate fencing to prevent the movement of construction vehicles over and the possible compaction of the natural soils.
- The erosion control plan for the project must clearly define how sediment will be prevented from entering the area of the infiltration trench.
- Inspections of an infiltration trench shall be made after any storm greater than the 1-year, 24-hour storm.
- The design engineer shall oversee the preparation of the area and the installation of the stone filter.
- The design engineer shall provide a certification that the system was designed in accordance with the specifications found in the Design Manual and installed in accordance with the approved plans.

7.7 INFILTRATION CHAMBERS (GRv & WQv)

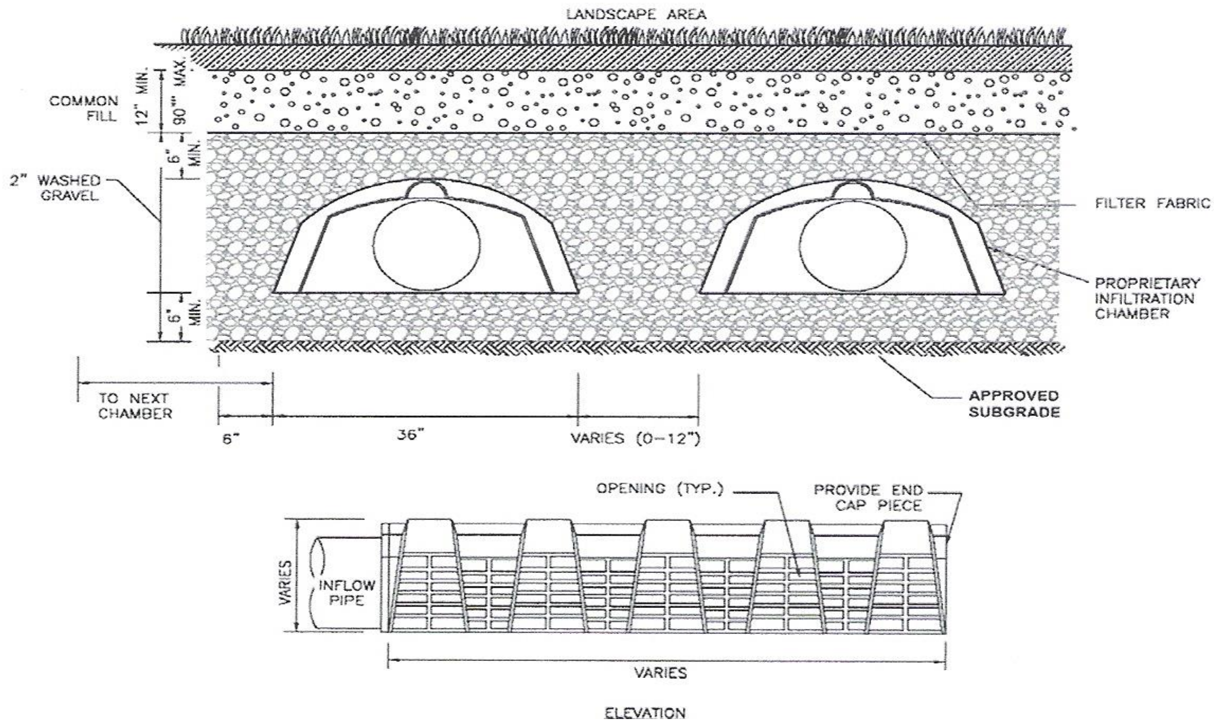


Figure 7.7.a – Infiltration Chamber (RI DEM, 2010)

Table 7.7.a Minimum Setbacks for Infiltration Systems (horizontal measurement in feet) (RI DEM 2010)

	Infiltration Systems for Single Family Residential Uses	Infiltration Systems for all other uses
Public Potable Water Supply Well (Drilled)	200	200
Public Potable Water Supply Well (Gravel well)	400	400
Private Potable Wells	25	100
Potable Water Supply Reservoir	100	200
Streams which are tributary to Water Supply Reservoir	50	100
Other Surface Waters	50	50
Top of 15%+ Slopes	50	50
Buildings (up-gradient)	10	25
Buildings (down-gradient)	10	50
On-site Subsurface Sewage Disposal Systems	25	25

Note: These setback requirements shall apply to Infiltration Trenches, Infiltration Chambers, and Infiltration Basins

Required Design Elements for Infiltration Chambers

FEASIBILITY:

- Three (3) foot vertical separation from bottom of crushed stone under the infiltration chambers to SHGW and bedrock. For residential applications, this separation can be reduced to two (2) feet.
- Must be installed on slopes < 15%.
- Native soils must have less than 20% clay and 40% silt/clay. This shall be determined by a dry sieve analysis by a qualified soils lab.
- Native soils must have an in-situ infiltration rate of 0.5 inches per hour based upon NRCS soil textural classification.
- The maximum drainage area to infiltration chambers shall be five (5) acres.

CONVEYANCE:

- Infiltration chambers must be designed as "off-line" if stormwater is delivered by standard pipe system.
- Overflow provisions from the facility shall be provided for the 1-year storm event to either a structural conveyance system or to daylight onto a stable surface, where non-erosive velocities shall be provided (3-5 fps).
- All infiltration chambers shall be designed to fully dewater the entire WQv 72 hours after the rainfall event.

PRETREATMENT:

- Pretreatment shall be required as flow across a vegetated filter strip, grass swale or through a sediment forebay for infiltration chambers. This requirement shall not apply to runoff from a residential roof.
- 25% of the required WQv shall be provided by an appropriate pretreatment system for infiltration chambers.
- The sides of the infiltration chambers shall be lined with a non-woven filter fabric to prevent soil piping.

SIZING CRITERIA:

- One method to calculate the storage volume of manufactured chambers is as follows (RI DEM, 2010):

$$V = L*[(wdn) - (\#Acn) + (\#Ac) + (wfct/12)]$$ where:

V = Design volume (WQv) (cubic feet)
L = Length of infiltration facility (feet)
w = Width of infiltration facility (feet)
d= Depth of infiltration facility (feet)
# = Number of rows of chambers
Ac = Chamber cross sectional area (square feet) (see manufacturers specifications)
n = Porosity (use 0.33)
fc = Design infiltration rate (in/hr)
t = time to fill chambers (use 2 hours for design)

TREATMENT:

- Infiltration chambers shall be designed to fully exfiltrate the entire WQv through the bottom of the facility only.
- Design infiltration rates (fc) for above sizing equation shall be taken from Table 7.6 above.

CONSTRUCTION AND MAINTENANCE REQUIREMENTS:

- Infiltration chambers shall never be used for sediment control during an active construction period.
- The area of the infiltration trench must be marked off by appropriate fencing to prevent the movement of construction vehicles over and the possible compaction of the natural soils.
- The erosion control plan for the project must clearly define how sediment will be prevented from entering the area of the infiltration chambers.
- The design engineer shall oversee the preparation of the area and the installation of the infiltration chambers.
- The design engineer shall provide a certification that the system was designed in accordance with the specifications found in the Design Manual and installed in accordance with the approved plans.

7.8 INFILTRATION BASIN (GRv & WQv)

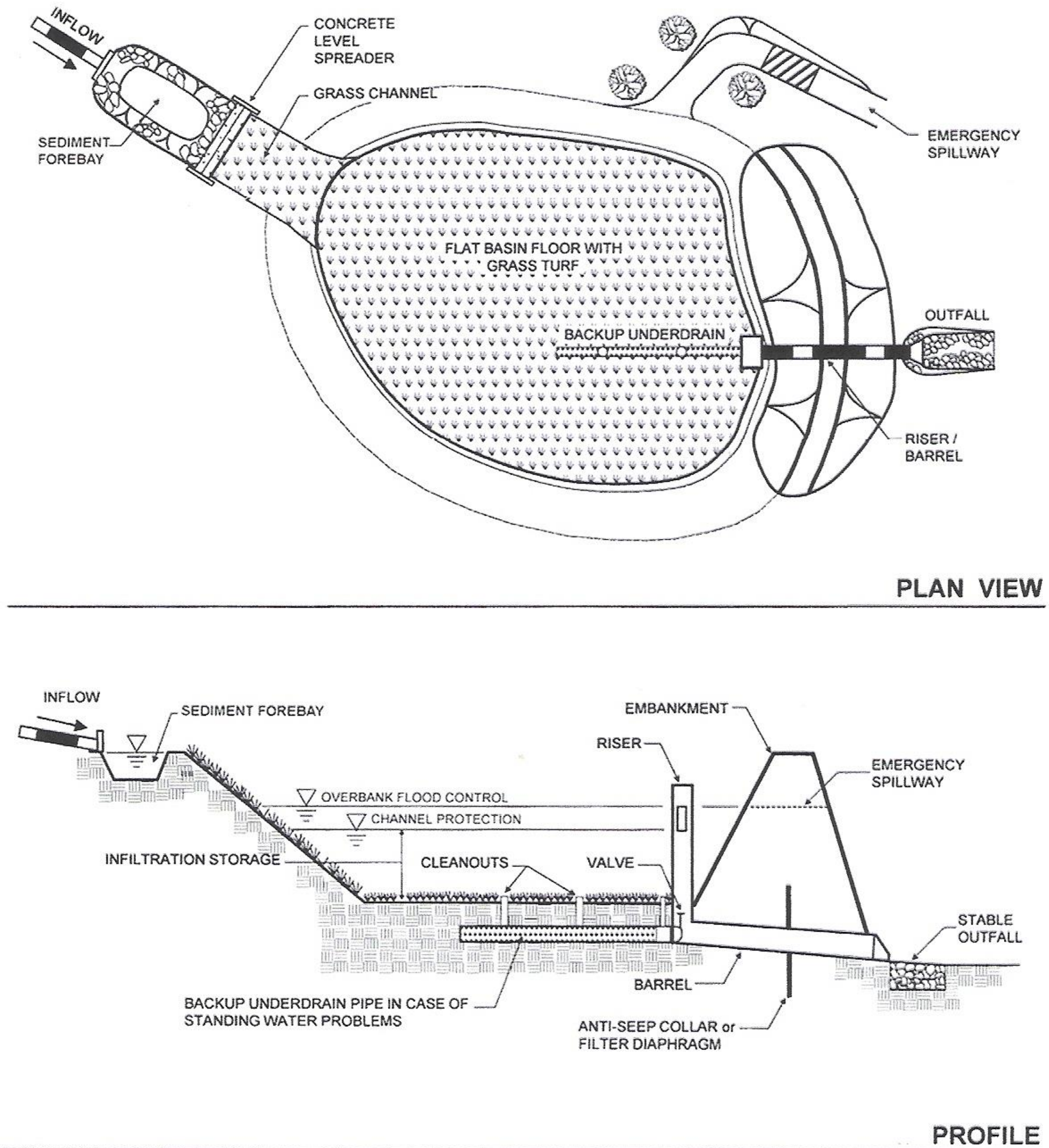


Figure 7.8.a – Infiltration Basin (RI DEM, 2010)

Required Design Elements for Infiltration Basin

FEASIBILITY:

- Three (3) foot vertical separation from bottom of infiltration trench to SHGW and bedrock.
- Must be installed on slopes < 15%.
- Native soils must have less than 20% clay and 40% silt/clay. This shall be determined by a dry sieve analysis by a qualified soils lab.
- Native soils must have an in-situ infiltration rate of 0.5 inches per hour based upon NRCS soil textural classification. Must be verified by field infiltration tests.
- The bottom of the infiltration basin shall be constructed in either the A or B soil horizon.
- The maximum drainage area to an infiltration trench shall be ten (10) acres.

CONVEYANCE:

- Infiltration basin must be designed as “off-line” if stormwater is delivered by standard pipe system.
- Overflow provisions from the facility shall be provided for the 1-year storm event to either a structural conveyance system or to daylight onto a stable surface, where non-erosive velocities shall be provided (3-5 fps).
- Infiltration basins shall be designed to fully dewater the entire WQv 48 hours after the rainfall event.

PRETREATMENT:

- Pretreatment shall be required as flow across a vegetated filter strip, grass swale or through a sediment forebay. Exit velocities from the pretreatment facility must be non-erosive (3.5 – 5.0 fps)
- A minimum of 25% of the required WQv shall be provided by an appropriate pretreatment system.

SIZING CRITERIA:

- Maximum ponding depth above soil surface shall be 2’.
- The bottom area of an infiltration basin shall be determined by the following equation:

Ab = V/d Where:
Ab = Surface area at the bottom of the basin (square feet)
V = Design Volume (WQv)
d = Depth of basin (feet)

TREATMENT:

- If the in-situ soil infiltration rate is greater than 8.27 in/hr, then the entire WQv shall be fully treated by an appropriate measure prior to the infiltration basin.
- Infiltration basin shall be designed to fully exfiltrate the entire WQv through the bottom of the basin only.
- Design infiltration rates (fc) for above sizing equation shall be taken from Table 7.6 above.

CONSTRUCTION AND MAINTENANCE REQUIREMENTS:

- Infiltration basins shall never be used for sediment control during an active construction period.
- The area of the infiltration basin must be marked off by appropriate fencing to prevent the movement of construction vehicles over and the possible compaction of the natural soils.
- The erosion control plan for the project must clearly define how sediment will be prevented from entering the area of the infiltration basin.
- If there is an accumulation of organic debris or sediment on the surface of the basin, the top 6” shall be removed, and the exposed soil surface roto-tilled to a depth of 12”. After this work has been done, the bottom of the basin shall be restored to its original condition.
- Inspections of an infiltration basin shall be made after any storm greater than the 1-year, 24-hour storm.
- The design engineer shall oversee the preparation of the area and the construction of the infiltration basin.
- The design engineer shall provide a certification that the system was designed in accordance with the specifications found in the Design Manual and installed in accordance with the approved plans.

7.9 ALTERNATIVE PAVING SURFACES (GRv & WQv)

Refer to UNHSC Design Specifications for Porous Asphalt Pavement and Infiltration Beds – Rev. October 2009 for more information as found in Appendix "C" of this manual.

Open Course Pavers with gravel or topsoil/grass

Required Design Elements for Open Course Pavers

FEASIBILITY:

- Three (3) foot vertical separation from bottom of reservoir base to SHGW and bedrock.
- Use on gentle slope (<5%)
- Native soils must have an in-situ infiltration rate of 0.5 inches per hour based upon NRCS soil textural classification. Must be verified by field infiltration tests.
- Native soils must have less than 20% clay and 40% silt/clay. This shall be determined by a dry sieve analysis by a qualified soils lab.
- The bottom of the reservoir base shall be constructed in either the A or B soil horizon.

CONVEYANCE:

- Open course pavers shall only treat runoff generated from the actual area of the practice. Runoff from adjacent areas shall not to be treated by the open course pavers.
- Open course paver systems shall fully dewater the entire WQv 24 hours after a storm event.

PRETREATMENT:

- Pretreatment is not required for open course pavers.
- Frequent maintenance is required to prevent clogging of the open course pavers.

SIZING CRITERIA:

- The surface area of the open course pavers shall be determined by the following equation (RI DEM, 2010):

Ap = V / (n8dt + fct/12) Where:
Ap = Surface area (square feet)
V = Design volume (WQv) (cubic feet)
n = Porosity of gravel (assume 0.33)
dt = Depth of gravel base (feet)
fc = Design infiltration rate (in/hr), see Table 7.6
t = Time to fill (hours) (use 2 hours for design purposes)

TREATMENT:

- Topsoil mix shall consist of 50% sand, 35% compost and 15% native soils. Alternative surface shall be pea gravel.
- Open course paver systems shall fully exfiltrate the entire WQv through the bottom of the practice.
- The reservoir course shall be 12 – 24" in depth. The base course shall consist of native bank run sand and gravel. It shall be sufficiently compacted to provide the required bearing capacity.
- Area of open course pavers must be protected from compaction and erosion during the construction period.
- This system is best used with other systems to address other stormwater issues such as flood protection.
- Vegetation used with open course pavers shall be drought tolerant species.
- To account for the use of open course pavers in hydrologic models in determining the Channel Protection Flow and Flood Protection Flow rates, the following Curve Number values shall be applied.

Table 7.9.a – Curve Numbers for Infiltrating Permeable Pavement Surfaces (MDE, 2009)

Reservoir Depth	Hydrologic Soil Group			
(inches)	A	B	C	D
6	76	84	93	-
12	62	65	77	-
>12	40	55	70	-

CONSTRUCTION AND MAINTENANCE REQUIREMENTS:

- The area of open course pavers shall never be used for sediment control during an active construction period.

- The area of the open course pavers must be marked off by appropriate fencing to prevent the movement of construction vehicles over and the possible compaction of the natural soils.
- The erosion control plan for the project must clearly define how sediment will be prevented from entering the area of the open course pavers.
- Attach rollers to bottom of plows to prevent the catching of paver edges during snow removal operations.
- Do not stockpile snow on areas of open course pavers.
- The design engineer shall oversee the preparation of the area and the installation of the alternative paving surface.
- The design engineer shall provide a certification that the system was designed in accordance with the specifications found in the Design Manual and installed in accordance with the approved plans.

Permeable Pavement or Porous Concrete

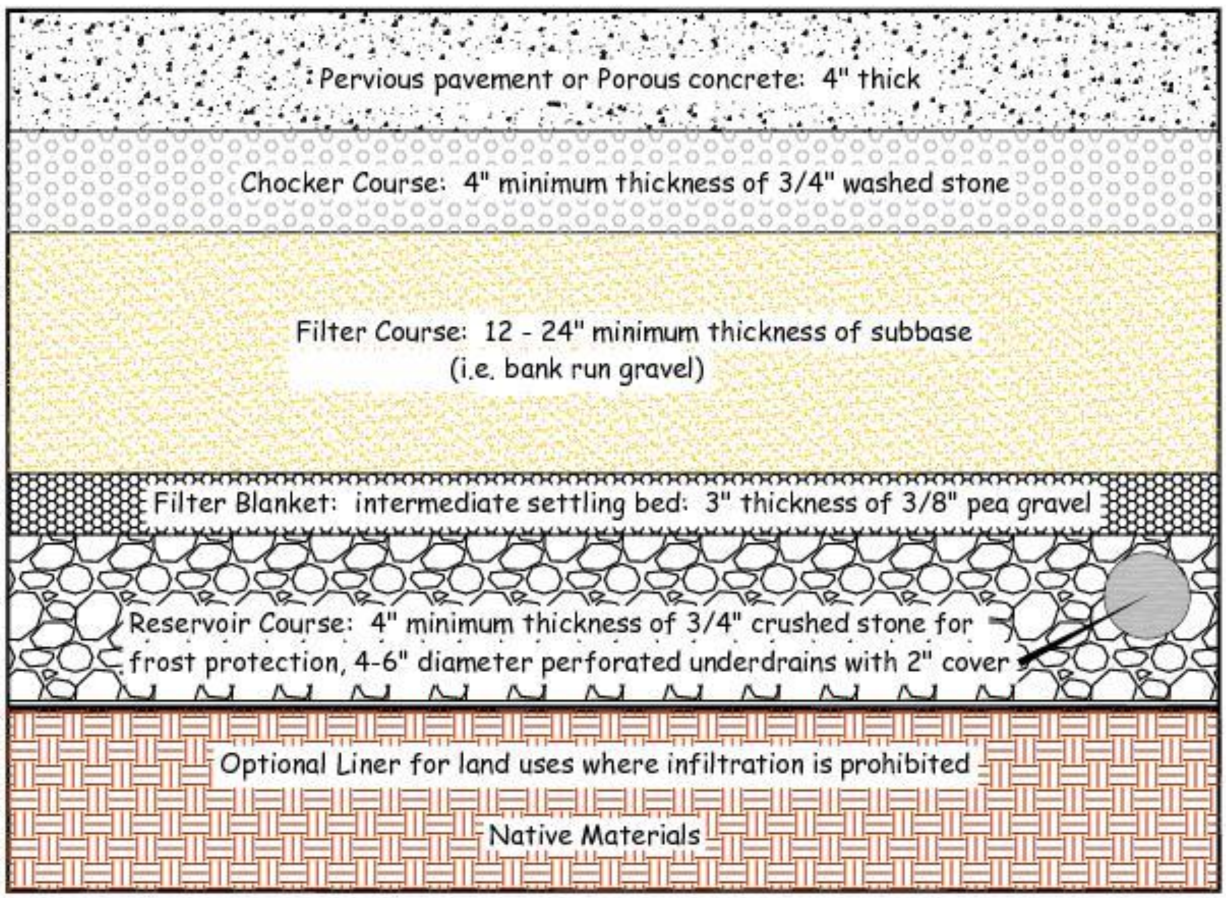


Figure 7.9.a – Permeable Pavement (UNHSC)

Required Design Elements for Permeable Pavement or Porous Concrete

FEASIBILITY:

- Three (3) foot vertical separation from bottom of reservoir base to SHGW and bedrock.
- Use on gentle slope (<5%)
- Native soils must have an in-situ infiltration rate of 0.5 inches per hour based upon NRCS soil textural classification. Must be verified by field infiltration tests.
- Native soils must have less than 20% clay and 40% silt/clay. This shall be determined by a dry sieve analysis by a qualified soils lab.
- The bottom of the reservoir base shall be constructed in either the A or B soil horizon.

CONVEYANCE:

- Permeable pavement or porous concrete shall only treat runoff generated from the actual area of the practice. Runoff from adjacent areas shall not to be treated by permeable pavement or porous concrete. These systems shall fully dewater the entire WQv 24 hours after a storm event.

PRETREATMENT:

- Pretreatment is not required for permeable pavement or porous concrete.
- Frequent maintenance is required to prevent clogging of the permeable pavement or porous concrete.

SIZING CRITERIA:

- The surface area of the permeable surface shall be determined by the following equation (RI DEM, 2010):

Ap = V / (n8dt + fct/12) Where:
Ap = Surface area (square feet)
V = Design volume (WQv) (cubic feet)
n = Porosity of gravel (assume 0.33)
dt = Depth of gravel base (feet)
fc = Design infiltration rate (in/hr), see Table 7.6
t = Time to fill (hours) (use 2 hours for design purposes)

TREATMENT:

- Permeable pavement or porous concrete shall fully exfiltrate the entire WQv through the bottom of the practice.
- The reservoir course shall be 12 – 24" in depth. The reservoir course shall consist of native bank run sand and gravel. It shall be sufficiently compacted to provide the required bearing capacity. A filter blanket shall be provided between the filter course and the reservoir course.
- An impermeable liner with an underdrain may be provided if underlying soils lack adequate infiltrative capacity for WQv.
- This system is best used with other systems to address other stormwater issues such as flood protection.
- To account for the use of open course pavers in hydrologic models in determining the Channel Protection Flow and Flood Protection Flow rates, see Table 7.9 above.

CONSTRUCTION AND MAINTENANCE REQUIREMENTS:

- The area of permeable pavement or porous concrete shall never be used for sediment control during an active construction period.
- The area of the permeable pavement or porous concrete must be marked off by appropriate fencing to prevent the movement of construction vehicles over and the possible compaction of the natural soils.
- The erosion control plan for the project must clearly define how sediment will be prevented from entering the area of permeable pavement or porous concrete.
- Every three months, the permeable surface shall be vacuum swept to minimize the potential of clogging.
- Do not stockpile snow on areas of permeable pavement or porous concrete.
- Sand shall not be applied to permeable pavement or porous concrete surface.
- The design engineer shall oversee the preparation of the area and the installation of permeable pavement or porous concrete.
- The design engineer shall provide a certification that the system was designed in accordance with the specifications found in the Design Manual and installed in accordance with the approved plans.
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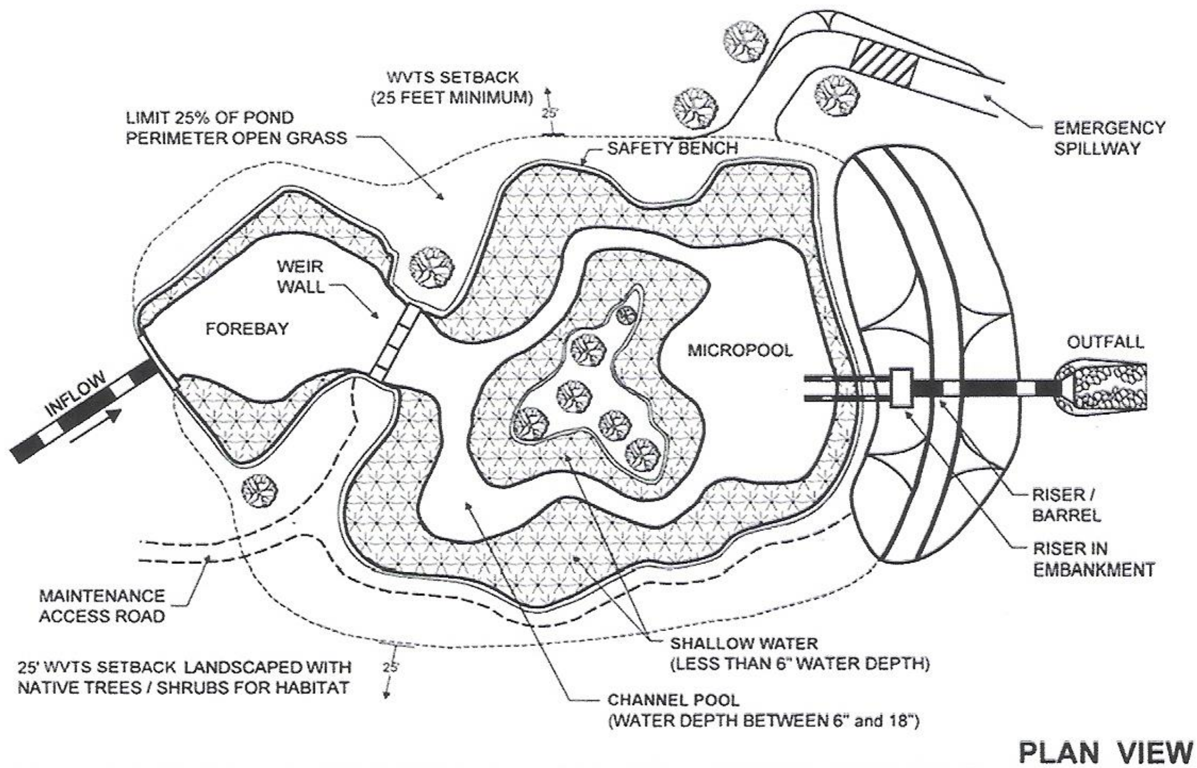
Reserved

7.10 EXTENDED DETENTION SHALLOW WETLANDS (WQ treatment)



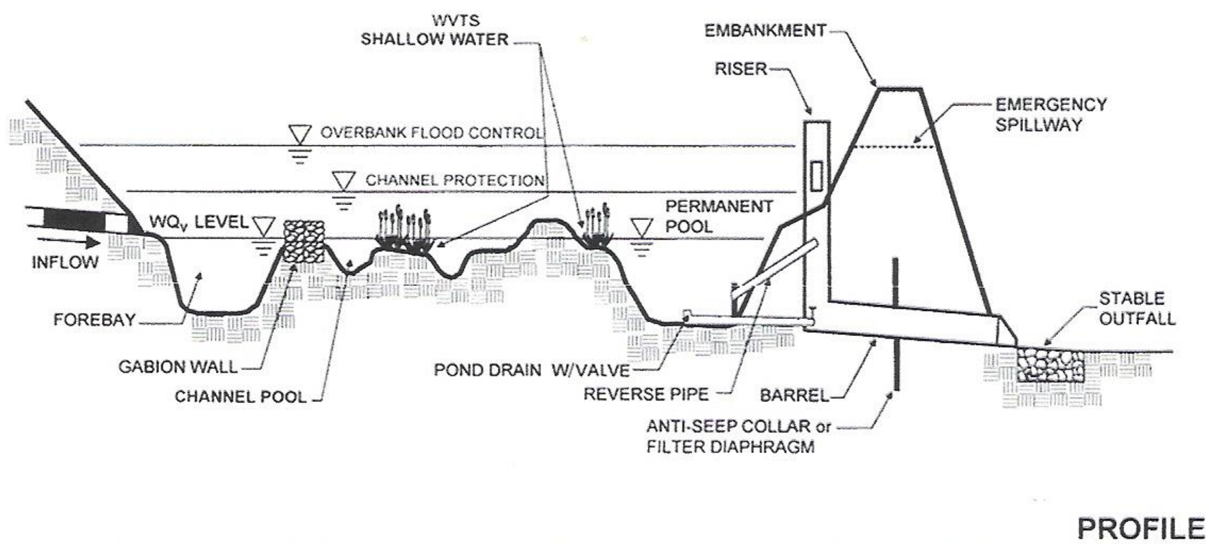


Figure 7.10.a – Extended Detention Shallow Wetland (RI DEM, 2010)

Required Design Elements for Extended Detention Shallow Wetland

FEASIBILITY:

- Shall not be located within limits of delineated inland wetlands and watercourses.
- Siting shall be done in such a manner as to maintain the height of the berm over the original grade to less than four (4) feet to avoid classification as a dam.
- Discharge from basin shall be required to travel across a length of 100' linear feet of vegetated surface prior to entering a wetland or watercourse.
- The minimum drainage area to extended detention shallow wetlands shall be ten (10) acres.

CONVEYANCE:

- Flows within the system shall be maximized by the use of islands and submerged berms.
- Discharges from the basin shall be directed toward an established watercourse wherever possible. Appropriately designed outlet protection (2002 Guidelines for Soil Erosion and Sediment Control) shall be provided. The outlet protection shall be sized for the 10-year, 24 hour peak rate discharge.
- Non-erosive velocities shall be provided (3-5 fps) shall be provided for all discharges.

PRETREATMENT:

- A sediment forebay, designed in accordance with the specifications found in Section 8.5 shall be provided for the basin. Exit velocities from the pretreatment facility must be non-erosive (3.5 – 5.0 fps).
- A minimum of 10% of the required WQv shall be provided by a sediment forebay.
- If there is more than one inlet, then each inlet shall have a sediment forebay.

SIZING CRITERIA:

- The surface area of an extended detention shallow wetland shall be a minimum of 1.5% of the tributary drainage area. Curvilinear configurations shall be used for the basin.
- 65% of the total surface area of the basin shall have a depth of less than 18".
- 35% of the total surface area of the basin shall have a depth of less than 6".
- Deep water areas within the basin shall provide a minimum of 25% of the required WQv, where the depth is greater than 4.0'.
- The minimum length to width ratio shall be 3:1 from inlet to outlet.

TREATMENT:

- If site conditions permit, the extended detention shallow wetland shall be located "off-line". If this is not feasible, then both the Channel Protection Flow and Flood Protection requirements shall be designed into the basin.
- Appropriate vegetation shall be specified for all of the various hydrologic regimes within the basin.

CONSTRUCTION AND MAINTENANCE REQUIREMENTS:

- The design engineer shall oversee the preparation of the area and the construction of an Extended Detention Shallow Wetland.
- The design engineer shall provide a certification that the system was designed in accordance with the specifications found in the Design Manual and constructed in accordance with the approved plans.
- Appropriate access easements for maintenance shall be provided for the basin.
- Inspections of the basin shall be made annually and after all storm events greater than the 1-year, 24 hour event.
- It shall be required that sediment is removed from the forebay either every 5 years or when the accumulation of sediment is 50% of the total forebay capacity.
- Slopes of the basin shall be inspected for erosion and stability on an annual basis. Areas of concern shall be repaired promptly as required.

7.11 SUBSURFACE GRAVEL WETLANDS (WQ Treatment)

Refer to UNHSC Subsurface Gravel Wetland Design Specifications – June 2009 for more information as found in Appendix "C" of this manual.

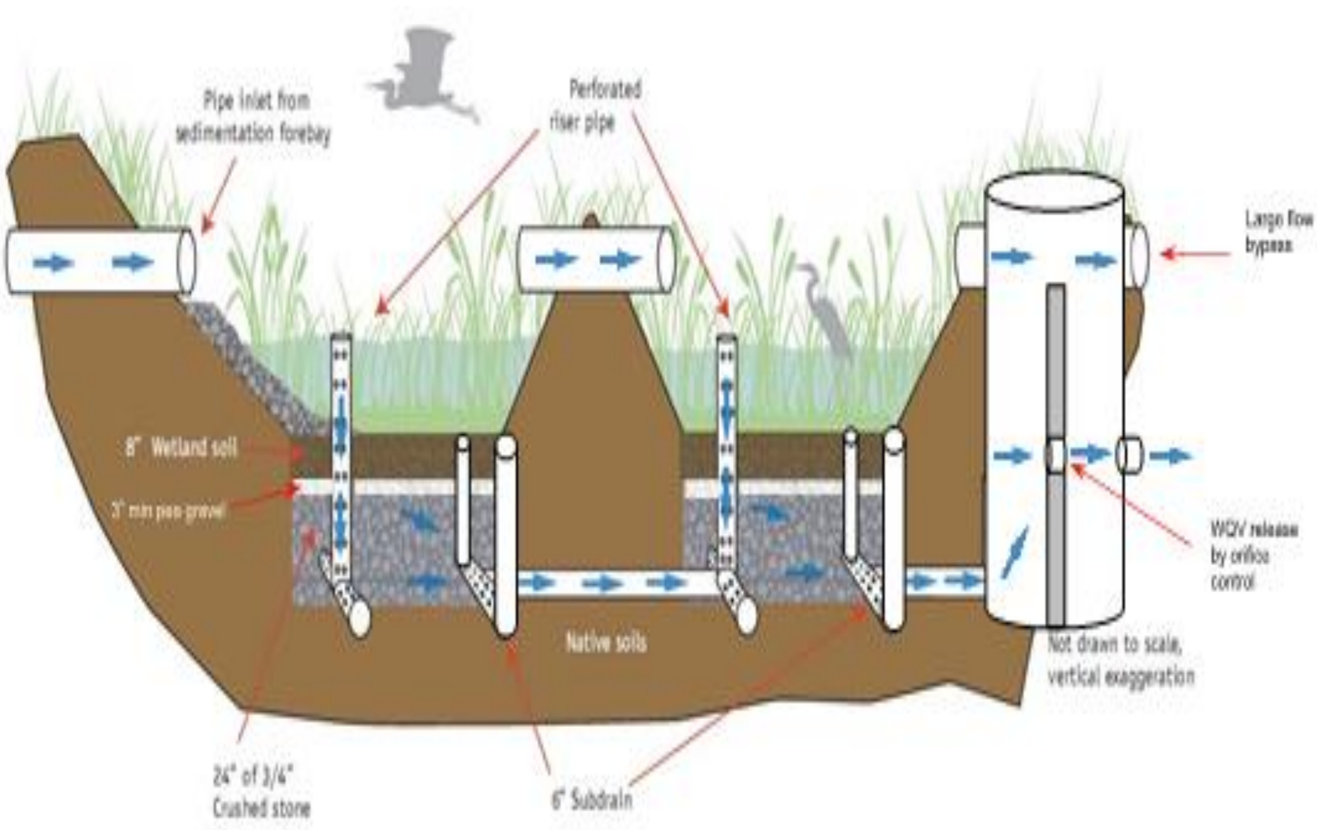


Figure 7.11.a – Subsurface Gravel Wetland (UNHSC)

Required Design Elements for Subsurface Gravel Wetlands

FEASIBILITY:

- Shall be located in soil with low infiltrative capacities or the system bottom & sides shall be lined with impermeable liner or soil with permeability being less than 0.03 ft/day.
- Must be installed on slopes < 5%. Level sites are best.
- The maximum drainage area to an infiltration trench shall be ten (10) acres.

CONVEYANCE:

- Subsurface gravel wetland can be designed as “online” system. System can also provide required Channel Protection Flow above WQv.
- Overflow provisions from the facility shall be provided for the 1-year storm event to either a structural conveyance system or to daylight onto a stable surface, where non-erosive velocities shall be provided (3-5 fps).

PRETREATMENT:

- Pretreatment shall be provided with a sediment forebay (Section 7.15).
- Exit velocities from the pretreatment facility must be non-erosive (3.5 – 5.0 fps).

SIZING CRITERIA:

- Forebay provides 10% of the required WQv, each treatment cell provides 45% of the required WQv. The full required WQv must be retained and filtered through the system.
- The invert of primary outlet pipe shall be set 4” below surface of wetland soil to maintain saturated conditions.
- An overflow outlet shall be provided with adequate capacity to handle the peak rate of the 10-year, 24-hour storm event.

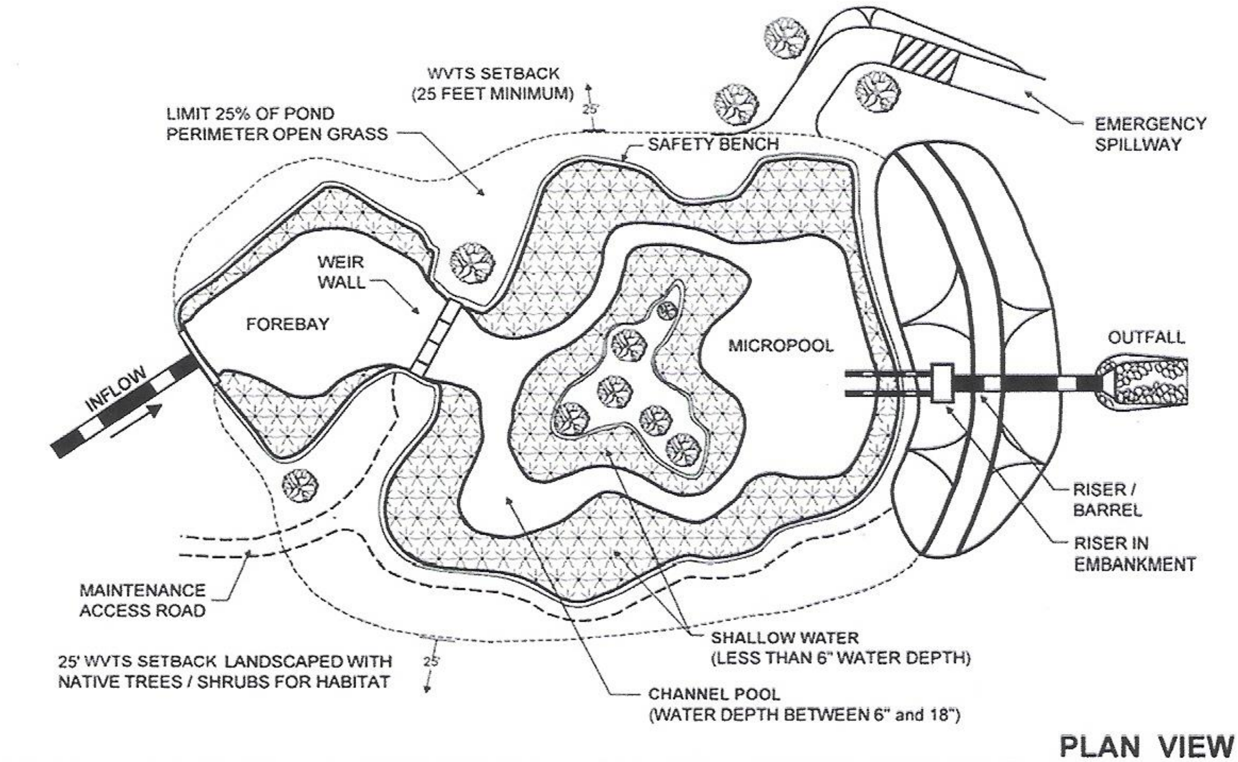
TREATMENT:

- Top layer of system is growing media (wetland soil) shall be eight (8) inches in depth with zero slope.
- Intermediate layer is pea gravel three (3) inches thick.
- Treatment layer is 24” in thickness of ¾” crushed stone.
- Berms and weir shall be constructed of non-conductive soils to prevent seepage or piping.
- Length to width ratio for gravel treatment shall be 0.5 (L:W) with a minimum length of fifteen (15) feet.
- Vertical perforated risers shall direct stormwater to treatment layer. Top of vertical riser shall be set at water surface elevation where WQv is provided. Minimum diameter of vertical riser shall be six (6) inches, can be increased to eight (8) inches to minimize clogging potential.
- Vegetation shall consist of obligate and facultative wetland species consisting of grasses, forbs, shrubs.

CONSTRUCTION AND MAINTENANCE REQUIREMENTS:

- The design engineer shall oversee the preparation of the area and the construction of a Subsurface Gravel Wetland.
- The design engineer shall provide a certification that the system was designed in accordance with the specifications found in the Design Manual and constructed in accordance with the approved plans.
- Inspect system to ensure that the ponded water drains down to the soil surface within 24-72 hours after any storm event greater than 1.2” of rain in 24-hours.
- Inspect plants, water plants during 1st year, replace plants as needed, ensure good root establishment across the wetland surface during 1st two years.
- Check stability of slopes during 1st year, repair as needed.
- Inspect inlets, vertical riser pipes and outlet system twice a year.
- It shall be required that sediment is removed from the forebay either every 5 years or when the accumulation of sediment is 50% of the total forebay capacity.
- Remove decaying vegetation, litter and debris.

7.12 POND / WETLAND SYSTEM (WQ Treatment)



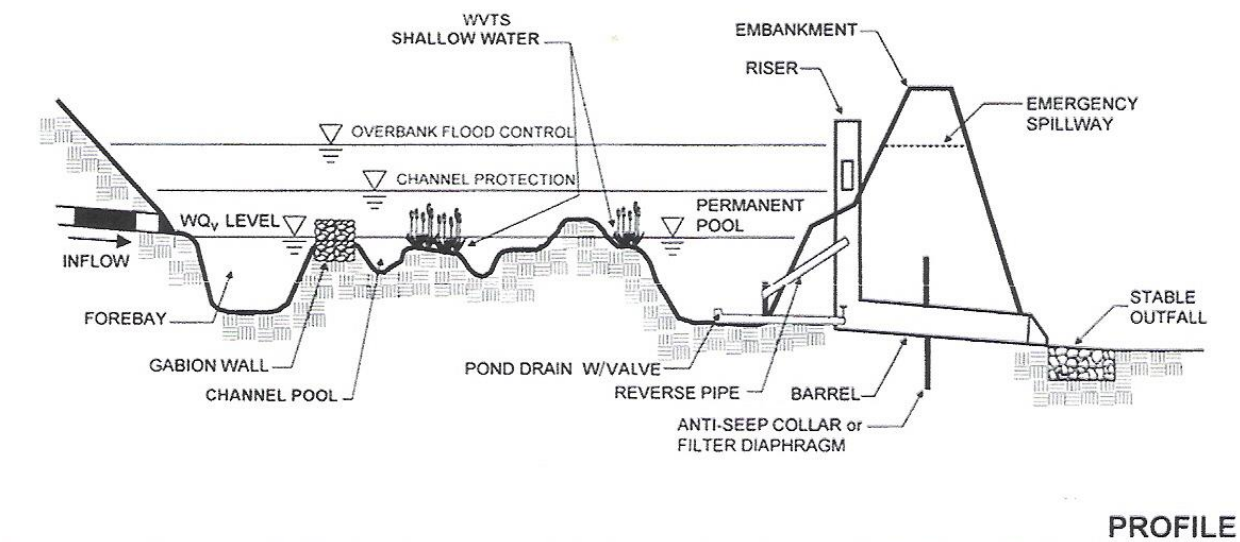


Figure 7.12.a - Pond / Wetland System (RI DEM, 2010)

Required Design Elements Pond / Wetland system

FEASIBILITY:

- Shall not be located within limits of delineated inland wetlands and watercourses.
- Siting shall be done in such a manner as to maintain the height of the berm over the original grade to less than four (4) feet to avoid classification as a dam.
- Discharge from basin shall be required to travel across a length of 100’ linear feet of vegetated surface prior to entering a wetland or watercourse.
- The minimum drainage area to a pond / wetland system shall be twenty five (25) acres.

CONVEYANCE:

- Flows within the system shall be maximized by the use of submerged berms and microtopography.
- Discharges from the basin shall be directed toward an established watercourse wherever possible. Appropriately designed outlet protection (2002 Guidelines for Soil Erosion and Sediment Control) shall be provided. The outlet protection shall be sized for the 10-year, 24 hour peak rate discharge.
- Non-erosive velocities shall be provided (3-5 fps) shall be provided for all discharges.

PRETREATMENT:

- A sediment forebay, designed in accordance with the specifications found in Section 8.5 shall be provided for the basin. Exit velocities from the pretreatment facility must be non-erosive (3.5 – 5.0 fps).
- A minimum of 10% of the required WQv shall be provided by a sediment forebay.
- If there is more than one inlet, then each inlet shall have a sediment forebay.

SIZING CRITERIA:

- The surface area of an extended detention shallow wetland shall be a minimum of 1.5% of the tributary drainage area. Curvilinear configurations shall be used for the basin.
- The outlet pool shall also provide a minimum of 10% of the required WQv and shall be 4-6’ in depth.
- 35% of the total surface area of the basin shall have a depth of less than 6”.
- 50% of the total surface area of the basin shall have a depth of less than 18”.
- The minimum length to width ratio shall be 3:1 from inlet to outlet.

TREATMENT:

- Long, irregular flow paths shall be created by the location and height of the marsh components to increase contact time with vegetation and enhance pollutant removal.
- Appropriate vegetation shall be specified for all of the various hydrologic regimes within the basin.

CONSTRUCTION AND MAINTENANCE REQUIREMENTS:

- The design engineer shall oversee the preparation of the area and the construction of a Pond / Wetland System
- The design engineer shall provide a certification that the system was designed in accordance with the specifications found in the Design Manual and constructed in accordance with the approved plans.
- Appropriate access easements for maintenance shall be provided for the basin.
- Inspections of the basin shall be made annually and after all storm events greater than the 1-year, 24 hour event for the first year.
- It shall be required that sediment is removed from the forebay either every 5 years or when the accumulation of sediment is 50% of the total forebay capacity.
- Slopes of the basin shall be inspected for erosion and stability on an annual basis. Areas of concern shall be repaired promptly as required.
- The erosion control plan for the project must clearly define how sediment will be prevented from entering the area of the infiltration basin.
- Vegetation in the basin shall be inspected annually for two growing seasons. Plants shall be replaced during this period as necessary.

7.13 WET SWALES (WQ Treatment)

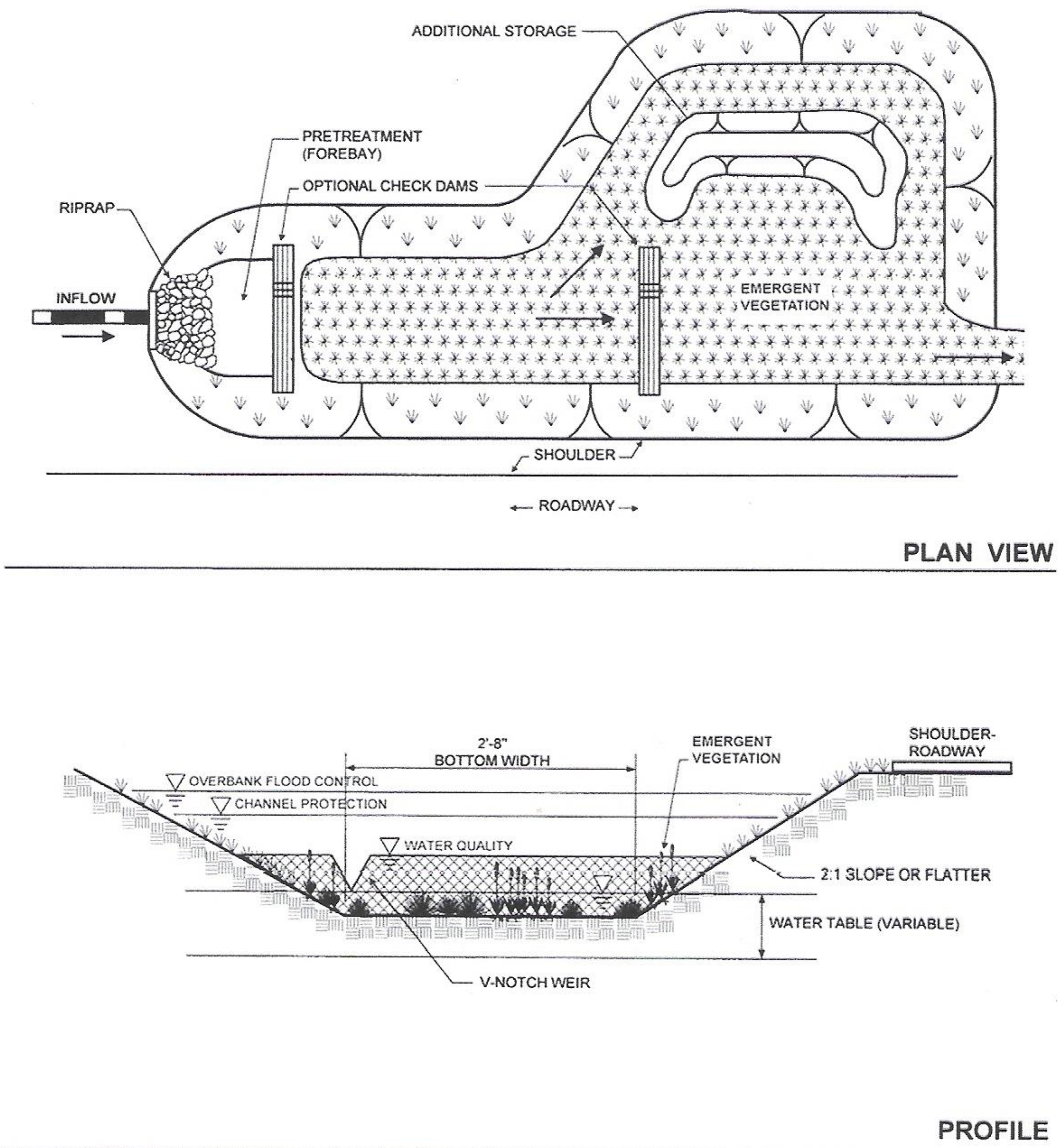


Figure 7.13.a - Wet Swale (RI DEM, 2010)

Required Design Elements for Wet Swales

FEASIBILITY:

- Maximum slope along flow length shall be 4.0% without check dams.
- Wet swales must intercept shallow groundwater level.
- The maximum drainage area to a wet swale shall be five (5) acres.
- Primary use is along linear systems, such as roads, residential development and pervious areas, such as ballfields.

CONVEYANCE:

- Swale shall be able to handle 10-year, 24-hour peak rate from contributing area.
- Swale side slopes shall be a minimum of 3:1. If there are space constraints, then 2:1 slopes may be used.
- Non-erosive velocities shall be provided (3-5 fps) for 1-year, 24-hour storm event.

PRETREATMENT:

- Pretreatment shall be required as ponding behind stone check dams are located within the swale itself.
- Flow across a vegetated filter strip along a road shall be an appropriate pretreatment measure.
- 10% of the required WQv shall be provided by an appropriate pretreatment system.

SIZING CRITERIA:

- The required WQv shall be provided as surface ponding within the wet swale. The length, width and depth shall be designed to achieve this requirement.
- Wet swales shall be designed to provide for a maximum 12” ponded depth.
- Bottom width of swale shall not be greater than eight (8) feet nor less than two (2) feet.

TREATMENT:

- Appropriate emergent plants shall be used for the bottom and side slopes of a wet swale.
- Contributing area to wet swale must be stabilized prior to directing runoff to the wet swale.

CONSTRUCTION AND MAINTENANCE REQUIREMENTS:

- The design engineer shall oversee the preparation of the area and the construction of a Wet Swale.
- The design engineer shall provide a certification that the system was designed in accordance with the specifications found in the Design Manual and constructed in accordance with the approved plans.
- The Wet Swale shall be inspected annually and after storms greater than 1-year, 24-hour storm event.
- Sediment shall be removed when accumulation exceeds 25% of the WQv storage value.
- Plant shall be inspected annually for 1^{st} two growing seasons. Dead or dying plants shall be replaced as necessary.

7.14 FILTER STRIPS (Pretreatment)

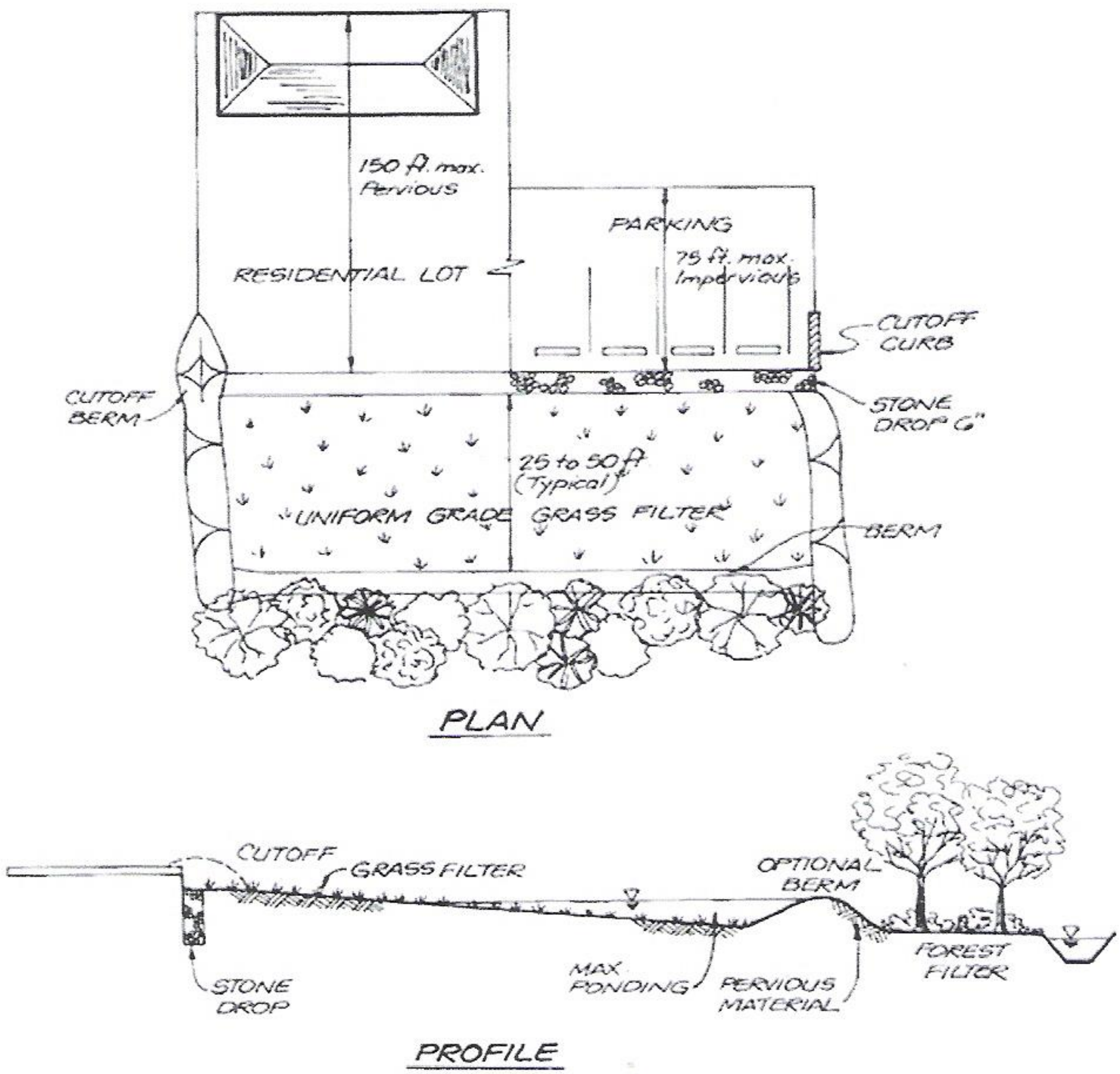


Figure 7.14.a - Filter Strip (RI DEM, 2010)

Required Design Elements for Filter Strip

FEASIBILITY:

- The best application for filter strips is for treating stormwater from roads, small parking areas and roof runoff.
- They can be used as a pretreatment system for other stormwater practices.
- Maximum contributing area to a single filter strip is 0.5 acres.

CONVEYANCE:

- Flows across filter strips must occur as overland flow.
- A stone diaphragm or concrete edge shall be used to ensure uniform overland flow from impervious area.
- If no edge treatment is used, the top of the soil mixture shall be set a minimum of 1" below the pavement edge to allow runoff to "fall off" the impervious edge onto the filter strip.

PRETREATMENT:

- This is a pretreatment system.

SIZING CRITERIA:

- Filter strips shall not be permissible on soils with high clay content.
- Filter strips shall be designed in accordance with the following Table.

Table 8.4 – Sizing Criteria for Filter Strips

Design Parameter	Impervious Area	Pervious Area
Max. allowable flow length	75'	150'
Filter Strip Slope	4.0%	4.0%
Min. length of filter strip	35'	15'

TREATMENT:

- Sediment is trapped within the grass matrix. If a stone diaphragm is used, this will improve the removal of sediment.

CONSTRUCTION AND MAINTENANCE REQUIREMENTS:

- The design engineer shall oversee the preparation of the area and the construction of a Filter Strip.
- The design engineer shall provide a certification that the system was designed in accordance with the specifications found in the Design Manual and constructed in accordance with the approved plans.
- Grass must become established as soon as possible. If one species does not grow well, it shall be promptly replaced with an alternative species.
- The majority of trapped sediment will occur at the beginning of the filter strip. Sediment shall be removed from this area on an annual basis.
- The area of the filter strip must be marked off by appropriate fencing to prevent the movement of construction vehicles over and the possible compaction of the natural soils.
- The erosion control plan for the project must clearly define how sediment will be prevented from entering the area of the filter strip.
- The height of the grass shall be maintained at 4".

7.15 SEDIMENT FOREBAYS (Pretreatment)

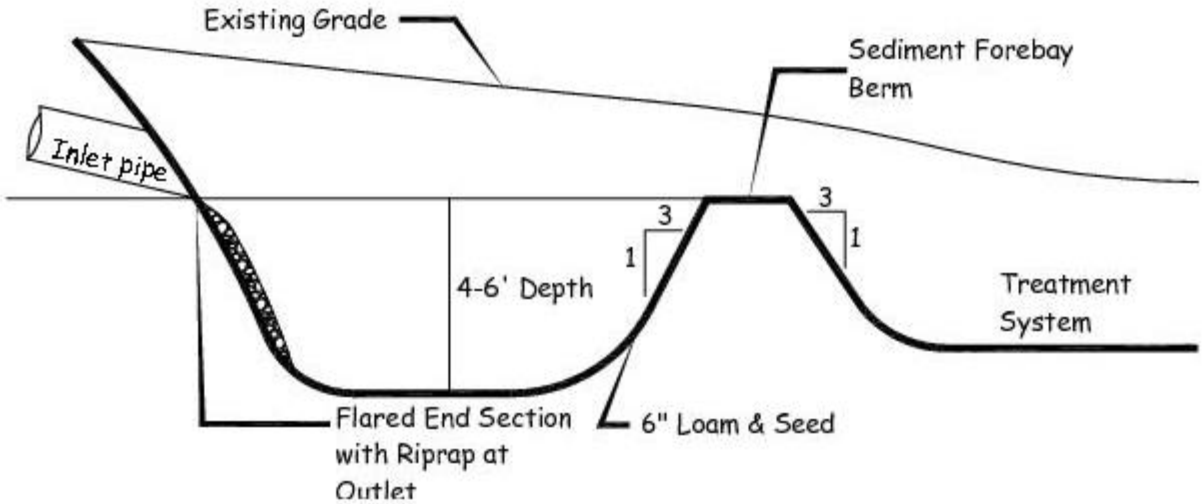


Figure 7.15.a - Forebay (RI DEM, 2010)

Required Design Elements for Sediment Forebay

FEASIBILITY:

- This is a pretreatment practice whose primary purpose is to minimize maintenance requirements of other stormwater treatment systems.
- The sediment forebay shall be made part of another stormwater treatment system and shall not be constructed as a standalone device.

CONVEYANCE:

- A riprap pad shall be utilized at the inlet to the forebay to reduce flow velocities to non-erosive levels (3-5 fps).

PRETREATMENT:

- This is a pretreatment system for other stormwater management practices.

SIZING CRITERIA:

- A minimum of 10% of the required WQv shall be provided within the sediment forebay.
- The length to width ratio of the sediment forebay shall be 3:1. If site constraints exists this ratio may be reduced to 2:1.
- The forebay shall be a minimum of four (4) feet in depth with a preferred depth of six (6) feet.
- A barrier shall separate the sediment forebay from the treatment facility. The barrier shall be armored as necessary to prevent erosion.
- The invert of the inlet pipe shall be set at the water surface elevation for 10% of the WQv.
- The outlet from the sediment forebay shall be designed in an appropriate manner to convey the flow. This could be a culvert, weir or spillway.
- The outlet elevation must be set, so that the 10% of the required WQv is provided below this elevation.

CONSTRUCTION AND MAINTENANCE REQUIREMENTS:

- The design engineer shall oversee the preparation of the area and the installation of a sediment forebay.
- The design engineer shall provide a certification that the system was designed in accordance with the specifications found in the Design Manual and constructed in accordance with the approved plans.
- Access must be provided to the sediment forebay to facilitate removal of accumulated sediments.
- A fixed vertical marker shall be installed in the sediment forebay to allow the depth of sediment to be easily measured and observed.
- The depth of the sediment in the forebay shall be inspected annually and removed when the depth is more than 25% of the total depth of the sediment forebay.

7.16 DEEP SUMP CATCH BASIN (Pretreatment)

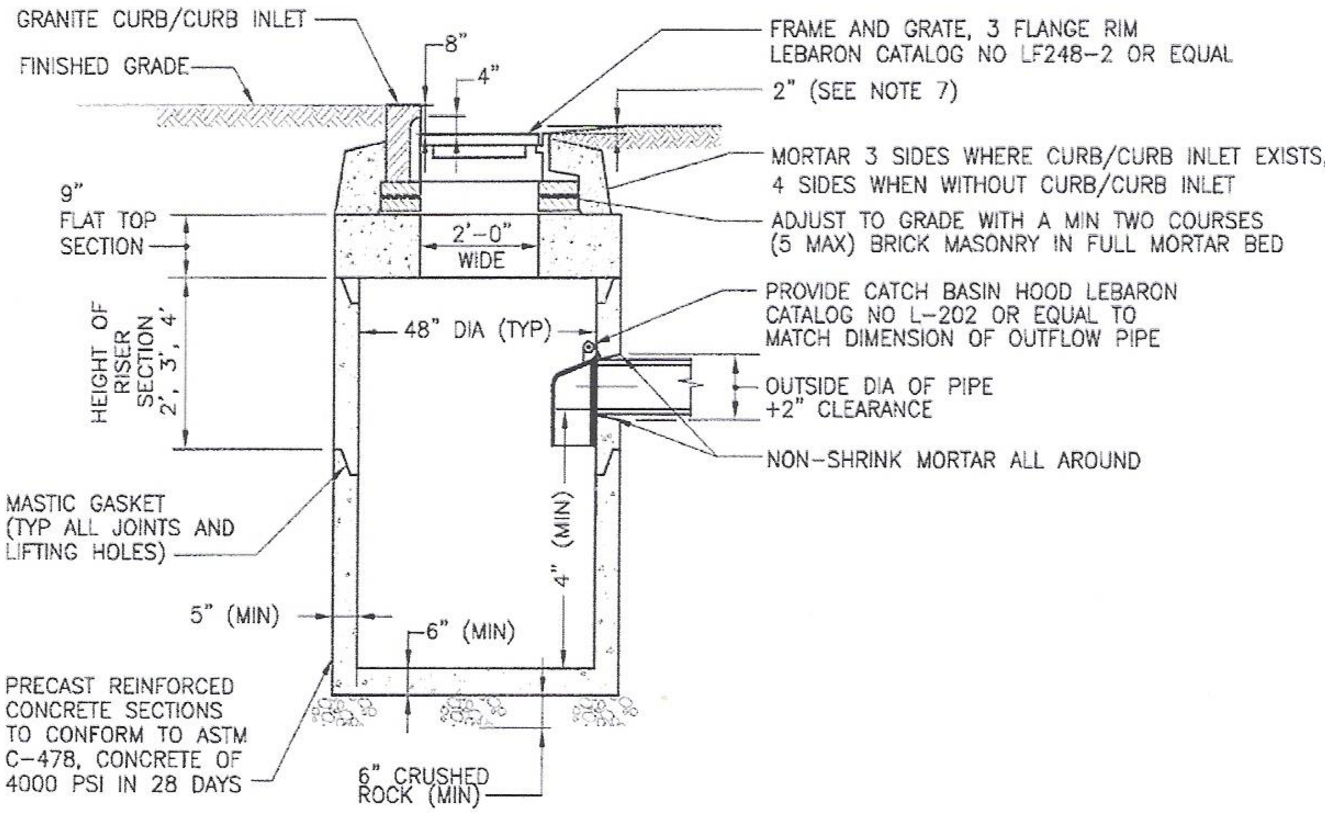


Figure 7.16.a - Deep Sump Catch Basin (RI DEM, 2010)

Required Design Elements for Deep Sump Catch Basins

FEASIBILITY:

- A deep sump catch basin shall be used in a catch basin to manhole alignment as a by-pass.
- The maximum drainage area to a deep sump catch basin shall be 0.5 acres.

CONVEYANCE:

- The deep sump catch basin will see the Water Quality Flow.
- Larger flow rates will by-pass this structure by the utilization of the manhole configuration.
- Hooded outlets shall be used on all deep sump catch basins to trap litter and lighter than water emulsions.

PRETREATMENT:

- This is a pretreatment system.

SIZING CRITERIA:

- The invert of the outlet pipe from a deep sump catch basin shall be set a minimum of four (4) feet above the bottom of the structure.
- The hooded outlet shall be installed in such a manner as to facilitate the easy removal and replacement of the hood.

TREATMENT:

- Coarse grained sediments will settle out in the deep sump.
- Litter and lighter than water emulsions (oils and grease) will be trapped on the water surface by the hooded outlet.

CONSTRUCTION AND MAINTENANCE REQUIREMENTS:

- The Design Engineer shall inspect the installed Deep Sump Catch Basin and certify that the required design elements have been provided.
- Inspections shall be made twice a year (fall and spring).
- Sediment shall be removed when it has reached two (2) feet in depth.
- Sufficient access into the structure shall be provided from the grate to facilitate maintenance.

7.17 PROPRIETARY TREATMENT DEVICES (Pretreatment)

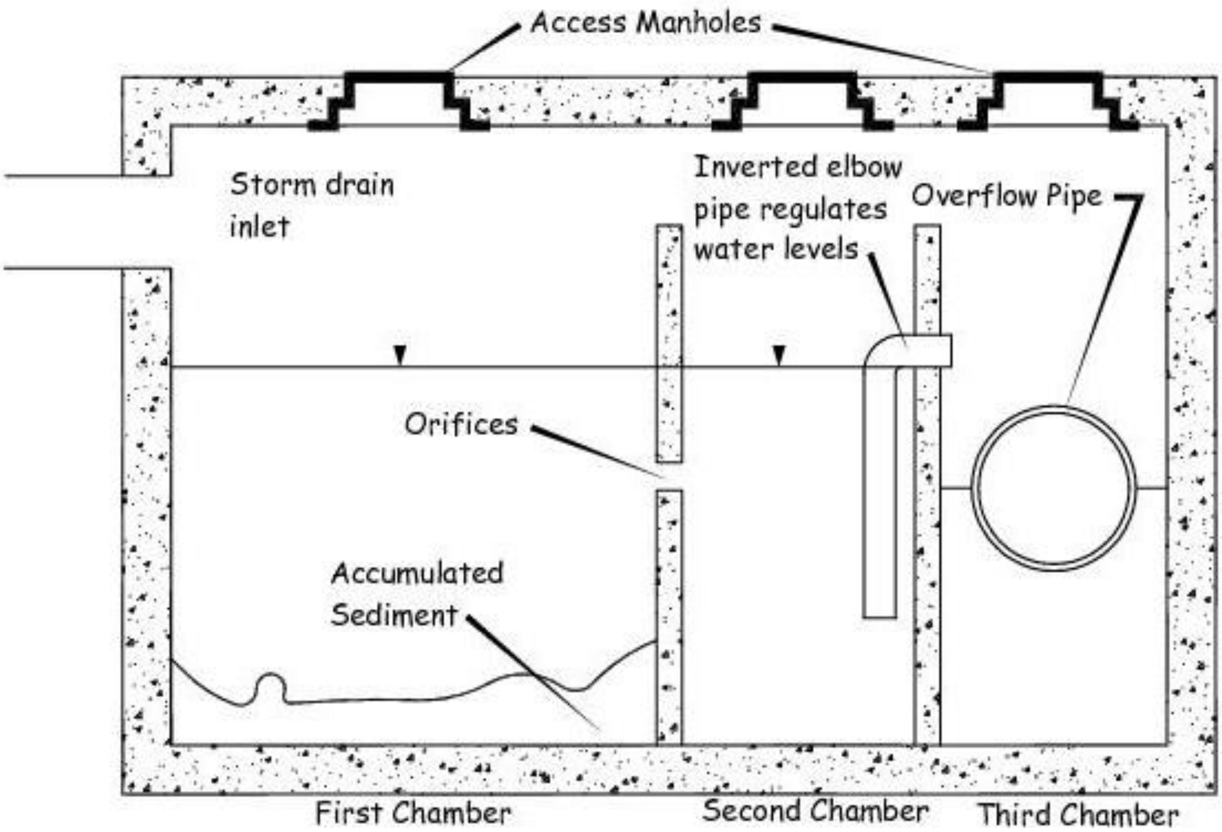


Figure 7.17.a - Oil Grit Separator (Mass Highway 2004)

Required Design Elements for Proprietary Treatment Devices

FEASIBILITY:
- System must be capable of removing a minimum of 25% of Total Suspended Solids to be considered an appropriate pretreatment device. This requirement must be independently verified and supported by necessary written documentation.
- Systems must be designed in accordance with the manufacturer's specifications.
- Contributing area to system shall not exceed one (1) acre of impervious area.

CONVEYANCE:
- System shall be designed as "off-line" to treat full water quality flow. Flows in excess of the water quality flow shall be by-passed around the system.

PRETREATMENT:
- This is a pretreatment device.

SIZING CRITERIA:
- The full water quality flow must be treated by the system.
- A minimum detention time of 60 seconds is required for the water quality flow.

TREATMENT:
- These devices are capable of trapping coarse sediments, litter and lighter than water emulsions by proprietary treatment systems by each manufacturer.

CONSTRUCTION AND MAINTENANCE REQUIREMENTS:
- The design engineer shall oversee the installation of an Oil Grit Separator.
- The design engineer shall provide a certification that the system was designed in accordance with the specifications found in the Design Manual and constructed in accordance with the approved plans.
- Maintenance shall be performed in accordance with manufacturer's requirements.
- The devices shall be sited in such a manner as to provide quick, easy access for emergency removal of oils.
- Inspections shall be performed twice a year and cleaned twice a year.
- Debris removed from these systems is considered a hazardous material and must be removed and disposed off by a properly licensed contractor.

7.18 WET EXTENDED DETENTION POND (Water Quantity Control)

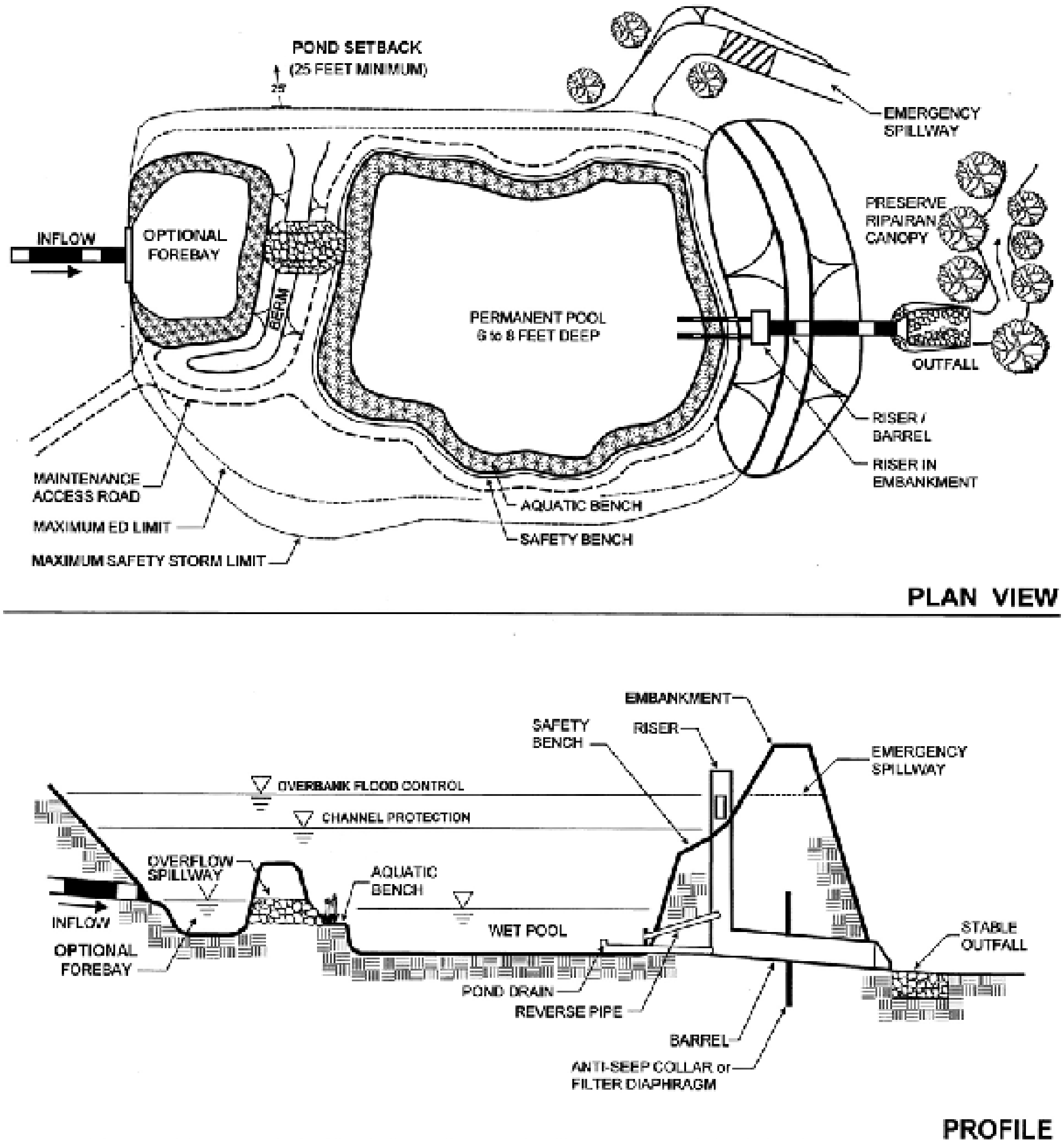


Figure 7.18.a - Wet Extended Detention Pond (RI DEM, 2010)

Required Design Elements for Wet Extended Detention Pond

FEASIBILITY:

- Shall not be located within limits of delineated inland wetlands and watercourses.
- Siting shall be done in a manner as to maintain the height of the berm over the original grade to less than four (4) feet to avoid classification as a dam.
- Discharge from basin shall be required to travel across a length of 100' linear feet of vegetated surface prior to entering a wetland or watercourse.
- The minimum drainage area to a Wet Extended Detention Pond shall be twenty five (25) acres.

CONVEYANCE:

- The outlet of the inlet pipe shall be stabilized to provide non-erosive velocities.
- Discharges from the basin shall be directed toward an established watercourse wherever possible. Appropriately designed outlet protection (2002 Guidelines for Soil Erosion and Sediment Control) shall be provided. The outlet protection shall be sized for the 10-year, 24 hour peak rate discharge.
- Non-erosive velocities shall be provided (3-5 fps) for all discharges.
- An emergency spillway, sized to handle the 100-year, 24-hour storm event must be provided.

PRETREATMENT:

- A sediment forebay, designed in accordance with the specifications found in Section 8.5 shall be provided for the basin. Exit velocities from the pretreatment facility must be non-erosive (3.5 – 5.0 fps).
- A minimum of 10% of the required WQv shall be provided by a sediment forebay.
- If there is more than one inlet, then each inlet shall have a sediment forebay.

SIZING CRITERIA:

- The outlet control system of the wet extended detention pond shall provide for the Channel Protection Flow as well as meet the Flood Protection requirement.
- The wet extended detention pond shall not be considered as a water quality treatment system.
- Water quality treatment shall be provided upstream as an "off-line" system.
- The wet extended detention pond shall utilize curvilinear geometry.
- 65% of the total surface area of the basin shall have a depth of less than 18".
- 35% of the total surface area of the basin shall have a depth of less than 6".
- Deep water areas within the basin shall provide a minimum of 25% of the required WQv, where the depth is greater than 4.0'.
- The minimum length to width ratio shall be 3:1 from inlet to outlet.

TREATMENT:

- If site conditions permit, the extended detention shallow wetland shall be located "off-line". If this is not feasible, then both the Channel Protection Flow and Flood Protection requirements shall be designed into the basin.
- Appropriate vegetation shall be specified for all of the various hydrologic regimes within the basin.

CONSTRUCTION AND MAINTENANCE REQUIREMENTS:

- The design engineer shall oversee the construction of a Wet Extended Detention Pond.
- The design engineer shall provide a certification that the system was designed in accordance with the specifications found in the Design Manual and constructed in accordance with the approved plans.
- Appropriate access easements for maintenance shall be provided for the pond.
- Inspections of the basin shall be made annually and after all storm events greater than the 1-year, 24 hour event.
- It shall be required that sediment is removed from the forebay either every 5 years or when the accumulation of sediment is 50% of the total forebay capacity.
- Slopes of the pond shall be inspected for erosion and stability on an annual basis. Areas of concern shall be repaired promptly as required.
- Inspections of the wet extended detention pond shall be made after any storm greater than the 1-year, 24-hour storm.

7.19 DRY DETENTION POND (Water Quantity Control)

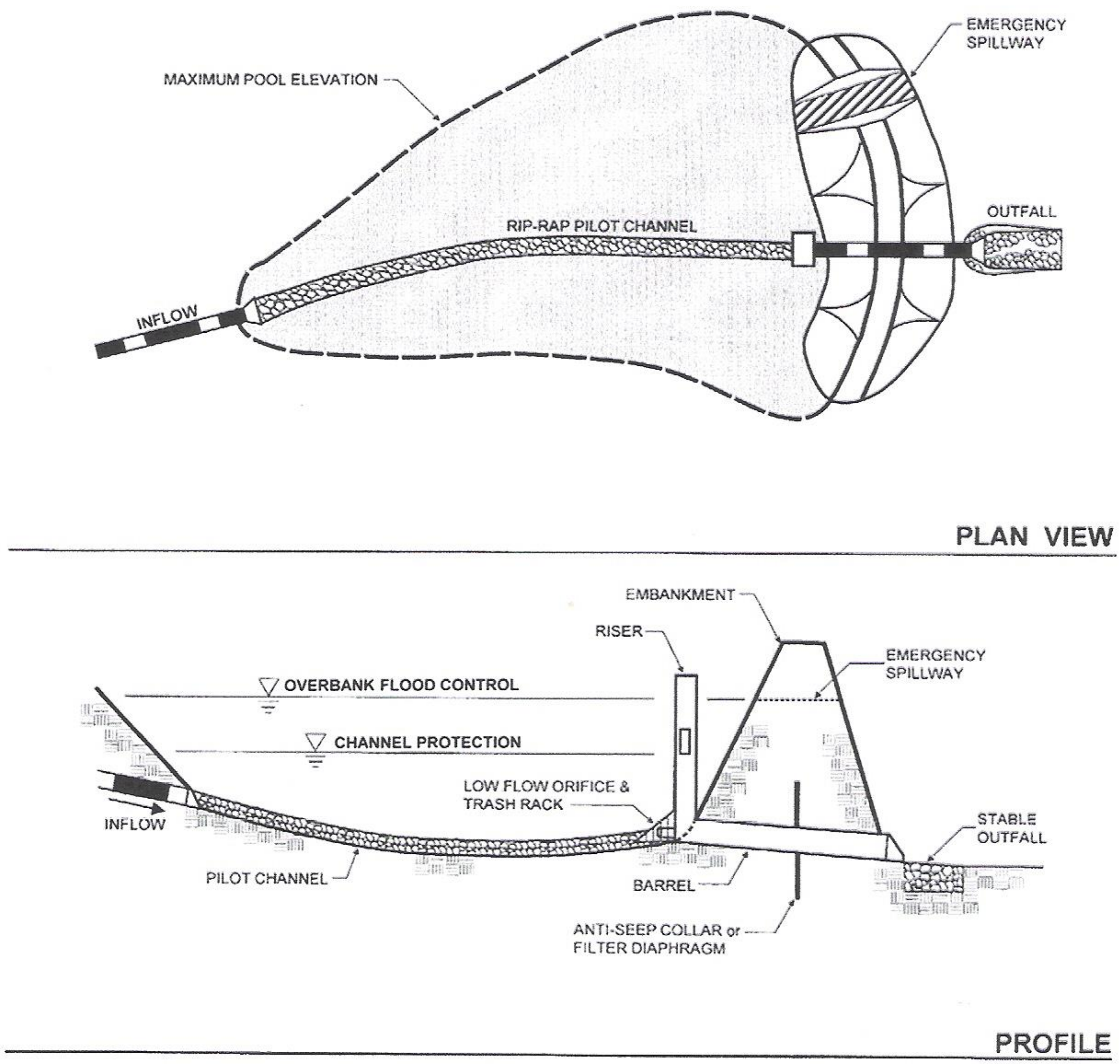


Figure 7.19.a - Dry Detention Pond (RI DEM, 2010)

Required Design Elements for Dry Detention Pond

FEASIBILITY:

- Must be installed on slopes < 15%.
- Shall not be located within limits of delineated inland wetlands and watercourses.
- Siting shall be done in a manner as to maintain the height of the berm over the original grade to less than four (4) feet to avoid classification as a dam.
- Discharge from basin shall be required to travel across a length of 100' linear feet of vegetated surface prior to entering a wetland or watercourse.
- The maximum drainage area to a dry detention basin shall be twenty five (25) acres.

CONVEYANCE:

- Infiltration basin must be designed as "off-line" if stormwater is delivered by standard pipe system.
- Overflow provisions from the facility shall be provided for the 1-year storm event to either a structural conveyance system or to daylight onto a stable surface, where non-erosive velocities shall be provided (3-5 fps).

PRETREATMENT:

- Pretreatment shall be required as flow across a vegetated filter strip, grass swale or through a sediment forebay. Exit velocities from the pretreatment facility must be non-erosive (3.5 – 5.0 fps).
- A minimum of 10% of the required WQv shall be provided by an appropriate pretreatment system.

SIZING CRITERIA:

- The storage capacity of a dry detention pond shall be sufficient to detain the increases in the peak rate of runoff for the 10-year, 24-hour storm and potentially the 100-year, 24-hour storm event as necessary.

TREATMENT:

- A dry detention pond is used for water quantity control only.

CONSTRUCTION AND MAINTENANCE REQUIREMENTS:

- The design engineer shall oversee the installation of a Dry Detention Pond.
- The design engineer shall provide a certification that the system was designed in accordance with the specifications found in the Design Manual and constructed in accordance with the approved plans.
- A dry detention pond can be used for sediment control during an active construction period.
- The erosion control plan for the project must clearly define how sediment will be prevented from entering the area of the infiltration basin.
- If there is an accumulation of organic debris or sediment on the surface of the basin, it shall be removed and the area reseeded.
- Inspections of a dry detention basin shall be made after any storm greater than the 2-year, 24-hour storm.

7.20 LID URBAN PLANTER (Commercial Retrofit)

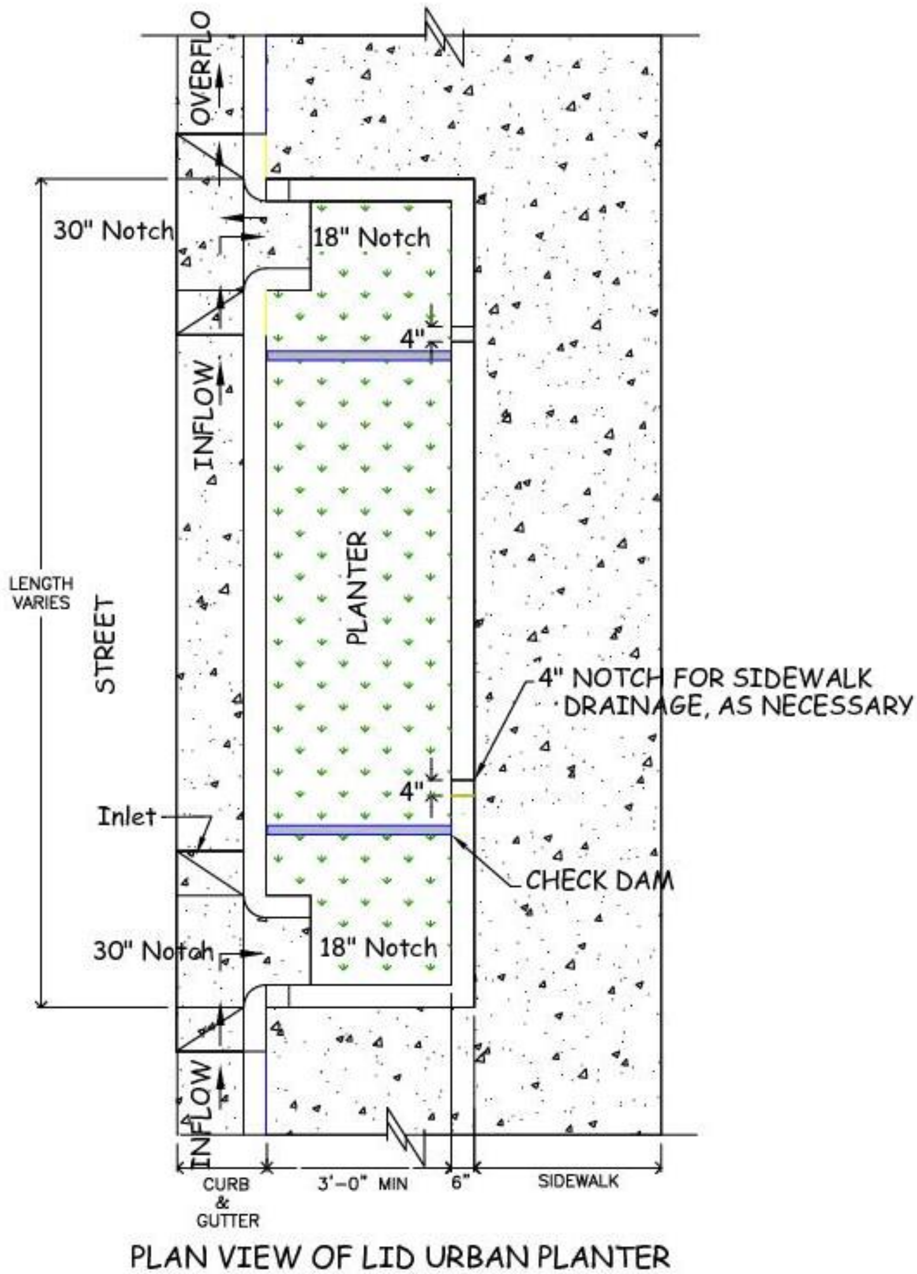


Figure 7.20.a – LID Urban Planter (City of Portland, OR)

Required Design Elements for LID Urban Planter

FEASIBILITY:
- Must be installed on slopes < 5%.
- Shall not be located closer than ten (10) feet to the foundation of a building, unless the system is lined with an impermeable liner.
- The maximum drainage area to a LID Urban Planter shall be 10,000 square feet (0.22) acres.

CONVEYANCE:
- Conveyance to a LID Urban Planter shall be via notches installed in the existing curb along the pavement edge as shown.
- An overflow pipe shall be installed in the system that will provide a freeboard of 4" prior to overtopping the curb height.

PRETREATMENT:
- No pretreatment is required.

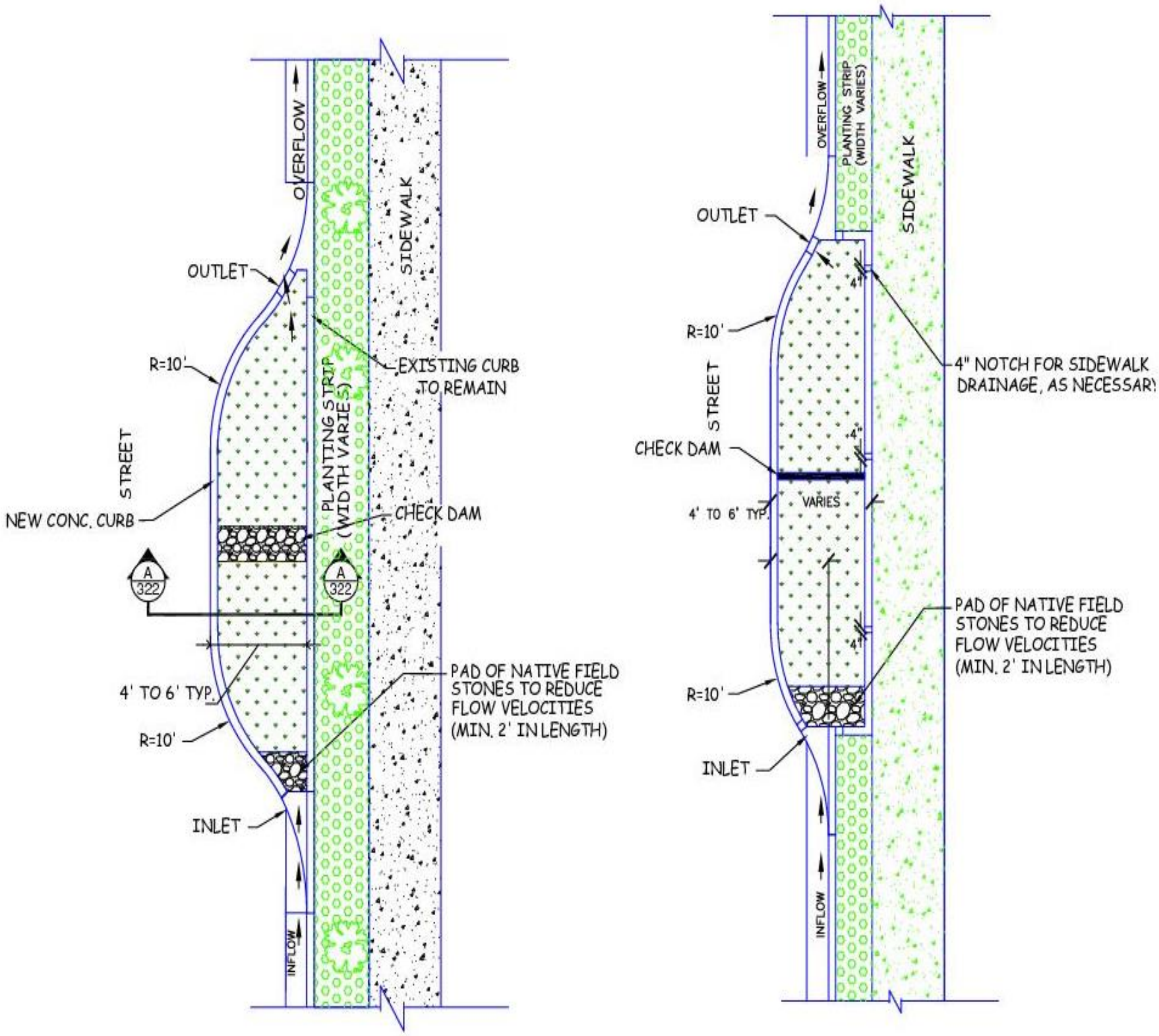
SIZING CRITERIA:
- At least 50% of the required water quality volume (WQv) of the drainage area shall be provided as fixed storage with the LID Urban Planter.
- The surface area of the bottom of the LID Urban Planter system shall be determined by the following equation:

SA = (WQv)*(.50)/hf where:
SA = Surface area of filter bed (square feet)
WQv = Calculated water quality volume (cubic feet)
hf = Depth of maximum ponding above soil surface in feet (0.67')

TREATMENT:
- Minimum depth of soil mixture shall be 18". The maximum depth shall be 24"
- Soil Mixture shall consist of sand (85%), compost (10%), and organic soil (5%) [organic soil shall have no more than 2% clay].
- Mulch layer shall consist of well-aged (6-12 month old) shredded hardwood mulch and shall only be placed around plant stems.
- A detailed planting plan shall be provided for each LID Urban Planter system.
- Only native plants shall be used. Appropriate plants for the hydrologic conditions shall be taken from the plant lists found in Appendix B.

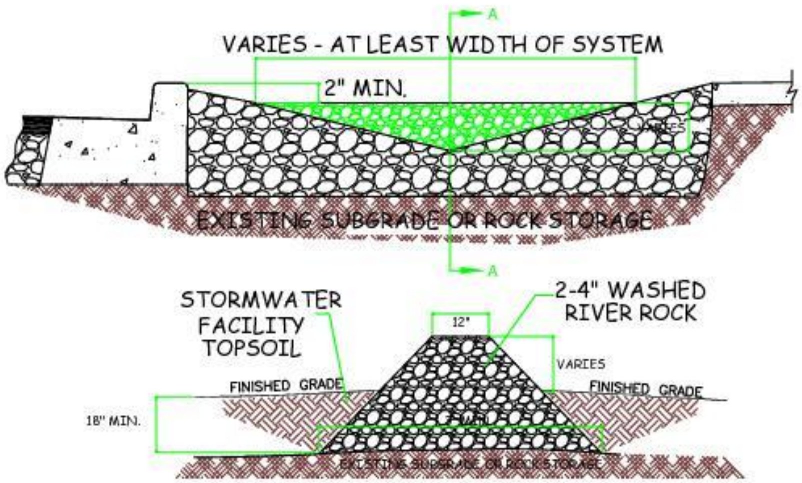
CONSTRUCTION AND MAINTENANCE REQUIREMENTS:
- The area of the facility shall be fenced off during the construction period to prevent disturbance of the soils.
- The design engineer shall oversee the preparation of the area and the installation of the various components of the LID Urban Planter system (gravel storage zone, gravel filter course and modified soil mixture).
- The design engineer shall provide an as-built plan of the LID Urban Planter system along with a certification that the system was designed in accordance with the specifications found in the Design Manual and installed in accordance with the approved plans.
- Facilities shall be inspected annually for proper growth of plant material. Dead plants shall be removed and replaced during the first two growing seasons. Plants shall be pruned as needed.
- Mulch shall be reapplied as needed to maintain a 2" thick layer around the plant stems.

7.21 LID CURB EXTENSION (Commercial Retrofit)

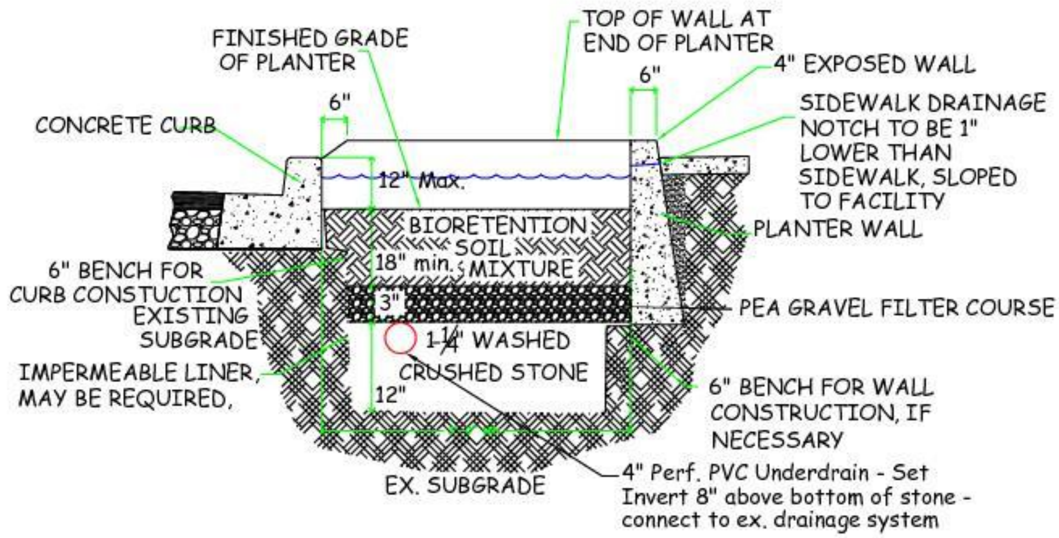


PLAN VIEW OF LID CURB EXTENSION IN ROAD   PLAN VIEW OF LID CURB EXTENSION IN ROAD

Figure 7.21.a – LID Curb Extension (City of Portland, OR)



STONE CHECK DAM TYPICAL DETAIL



CROSS SECTION VIEW OF LID URBAN PLANTER

Figure 7.21.b – Cross Section of LID Curb Extension / LID Urban Planter (City of Portland, OR)

Required Design Elements for LID Curb Extensions

FEASIBILITY:
- Must be installed on slopes < 5%.
- Must not interfere with existing underground utilities.
- The maximum drainage area to a LID Urban Planter shall be 0.5 acres.

CONVEYANCE:
- Conveyance to a LID Curb Extension shall be via a new inlet located on the existing gutter line of the street.
- An outlet shall discharge larger storm flow back to the existing gutter line.

PRETREATMENT:
- No pretreatment is required.

SIZING CRITERIA:
- At least 10% of the required water quality volume (WQv) of the drainage area shall be provided as fixed storage with the LID Urban Planter.
- Stone check dams shall be constructed as needed to provide the required storage water quality volume.
- The surface area of the bottom of the LID Curb Extension system shall be determined by the following equation:

SA = (WQv)*(0.10)/hf where:
SA = Surface area of filter bed (square feet)
WQv = Calculated water quality volume (cubic feet)
hf = Depth of maximum ponding above soil surface in feet (0.5')

TREATMENT:
- Minimum depth of soil mixture shall be 18". The maximum depth shall be 24"
- Soil Mixture shall consist of sand (85%), compost (10%), and organic soil (5%) [organic soil shall have no more than 2% clay].
- Mulch layer shall consist of well-aged (6-12 month old) shredded hardwood mulch and shall only be placed around plant stems.
- A detailed planting plan shall be provided for each LID Curb Extension system.
- Only native plants shall be used. Appropriate plants for the hydrologic conditions shall be taken from the plant lists found in Appendix B.

CONSTRUCTION AND MAINTENANCE REQUIREMENTS:
- The area of the facility shall be fenced off during the construction period to prevent disturbance of the soils.
- The design engineer shall oversee the preparation of the area and the installation of the various components of the LID Curb Extension system (gravel storage zone, gravel filter course and modified soil mixture).
- The design engineer shall provide an as-built plan of the LID Curb Extension system along with a certification that the system was designed in accordance with the specifications found in the Design Manual and installed in accordance with the approved plans.
- Facilities shall be inspected annually for proper growth of plant material. Dead plants shall be removed and replaced during the first two growing seasons. Plants shall be pruned as needed.
- Mulch shall be reapplied as needed to maintain a 2" thick layer around the plant stems.

Reserved

7.22 MODULAR WETLAND SYSTEM (Commercial Retrofit)

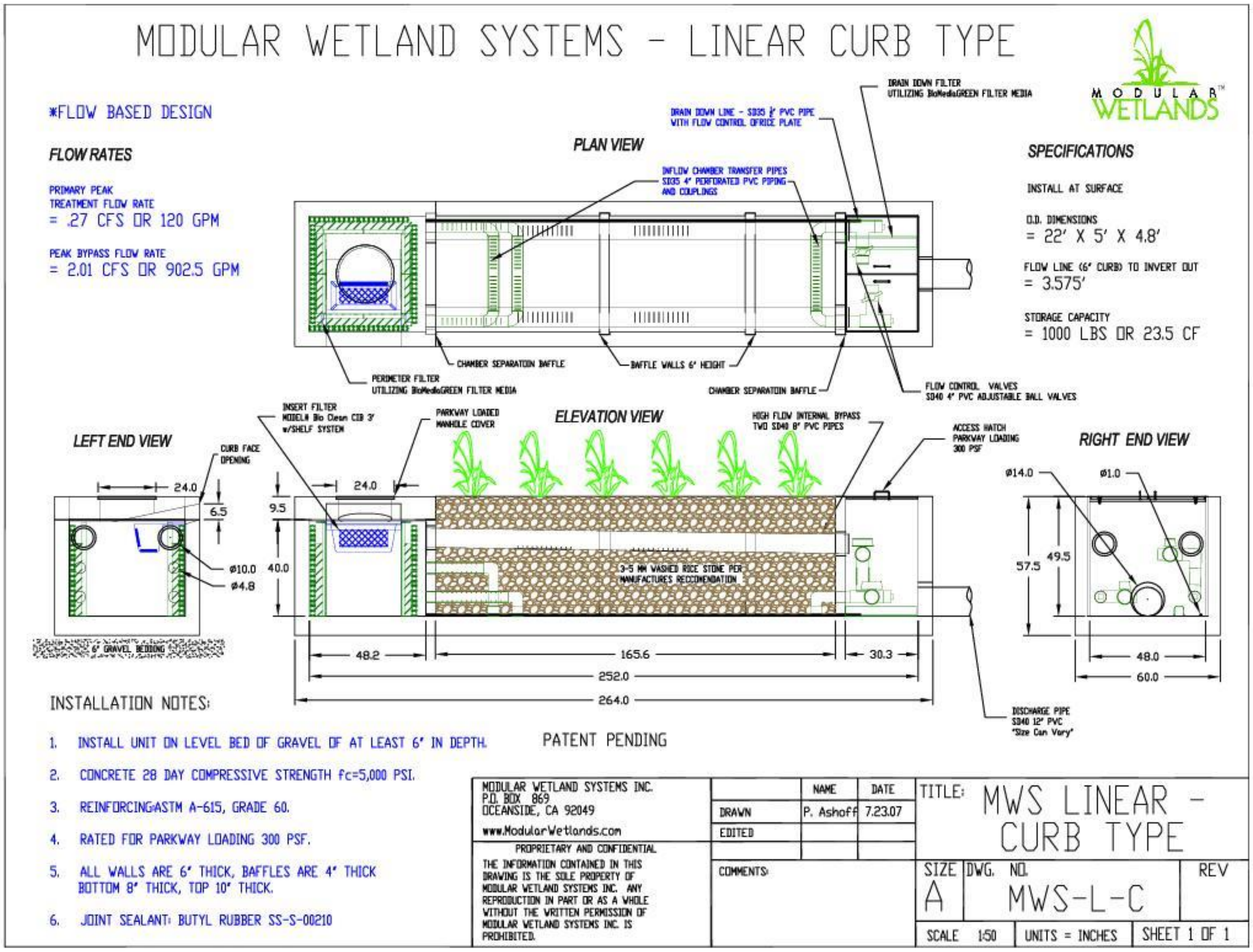


Figure 7.22.a – Modular Wetland System (Modularwetlands.com)

Required Design Elements for Modular Wetland

FEASIBILITY:

- Must be installed on slopes < 5%.
- Must not conflict with existing underground utility lines.
- Outlet pipe shall connect to existing stormwater conveyance system in the stream
- The maximum drainage area shall be 2 acres, unless sizing calculations will demonstrate that the system can handle a larger area.

CONVEYANCE:

- Conveyance to the system is by a field inlet structure that is an integral part of the treatment structure.

PRETREATMENT:

- Pretreatment is provided in the inlet structure of the modular wetland system.

SIZING CRITERIA:

- The Modular Wetland system may be sized for either the Water Quality Flow or the Water Quality Volume.
- Sizing calculators are available online at www.modularwetlands.com for this purpose.

TREATMENT:

- The Modular Wetlands provides filtration, sedimentation and biological uptake to remove pollutants from storm-water.

CONSTRUCTION AND MAINTENANCE REQUIREMENTS:

- The Modular Wetland System must be installed in accordance with all the specifications provided by the manufacturer. (www.modularwetlands.com)
- Clean screening filter device a minimum of twice a year (15 minute service time).
- Clean separation (sediment) chamber once a year (30 minute service time).
- Evaluate primary filtration media on an annual basis and replace primary filtration media (BioMediaGREEN blocks) as needed.
- Evaluate condition of wetland media on annual basis. Replacement of media may need to occur once every 5 to 20 years depending upon pollutant loads.
- Replace drain down filter media (BioMediaGREEN blocks) once a year (5 minute service time).
- Trim vegetation as needed (15 minute service time).

7.23 FILTERRA BIORETENTION SYSTEM (Commercial Retrofit)

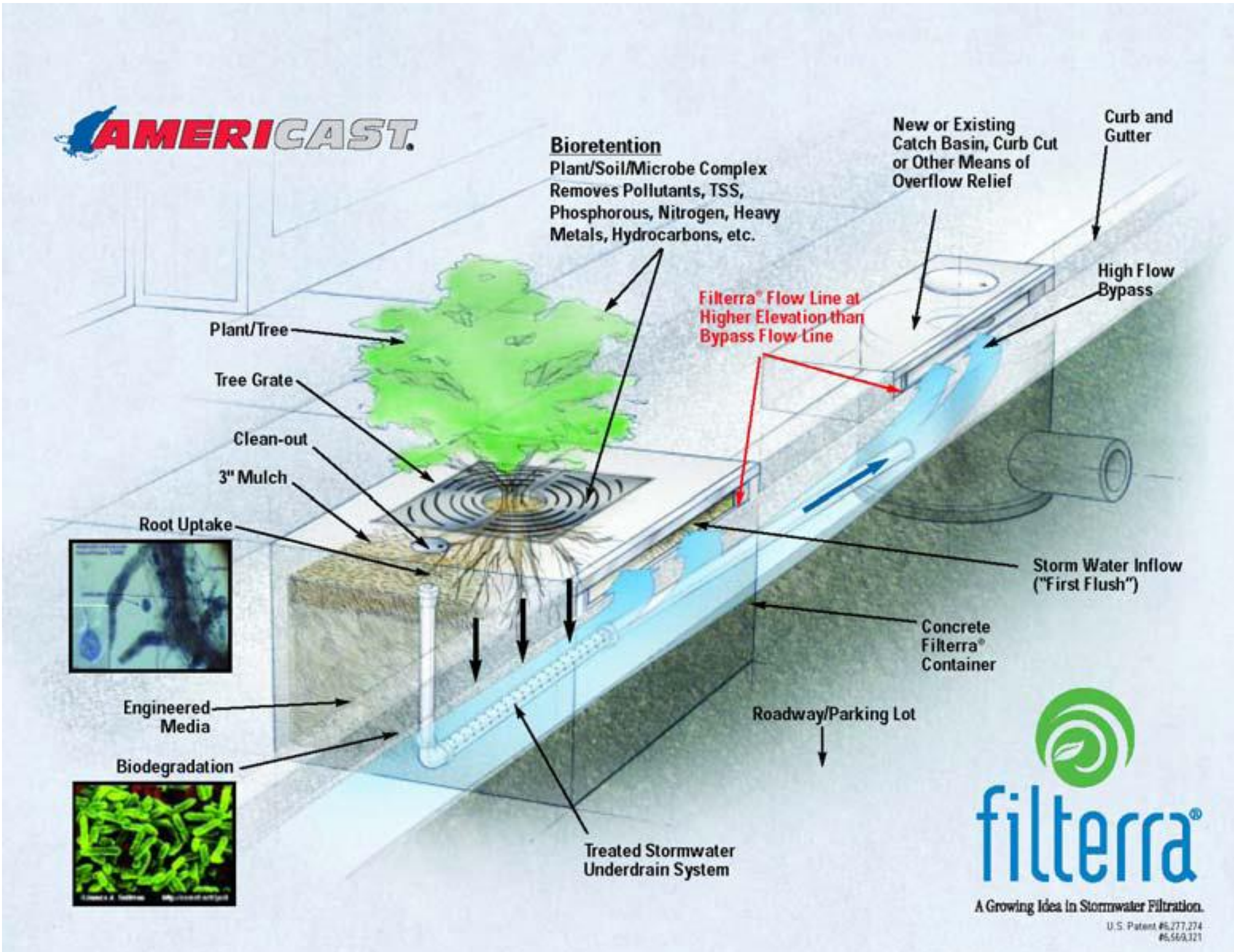


Figure 7.23.a – Filterra Bioretention (Filterra.com)

Required Design Elements for Filterra Bioretention System

FEASIBILITY:

- Must be installed on slopes < 5%.
- Must not conflict with existing underground utility lines.
- Outlet pipe shall connect to existing stormwater conveyance system in the stream
- The maximum drainage area shall be 1 acre, unless sizing calculations will demonstrate that the system can handle a larger area.

CONVEYANCE:

- Conveyance to the system is by a field inlet structure that is an integral part of the treatment structure.

PRETREATMENT:

- Pretreatment is provided in the inlet structure of the modular wetland system.

SIZING CRITERIA:

- The Filterra Bioretention system may be sized for either the Water Quality Flow.
- Sizing calculators are available online at www.filterra.com for this purpose.

TREATMENT:

- The Filterra Bioretention system provides filtration, sedimentation and biological uptake to remove pollutants from stormwater.

CONSTRUCTION AND MAINTENANCE REQUIREMENTS:

- The Filterra Bioretention System must be installed in accordance with all the specifications provided by the manufacturer. (www.filterra.com).
- Inspection of Filterra and surrounding area shall be done twice a year.
- At time of inspection, remove tree grate and erosion control stones to access media surface.
- Remove trash, debris and mulch layer.
- Replace mulch on top of Bioretention media.
- Replace erosion control stones and clean area around Filterra.
- Complete written maintenance report and submit copy to municipality.

7.24 RAIN BARREL

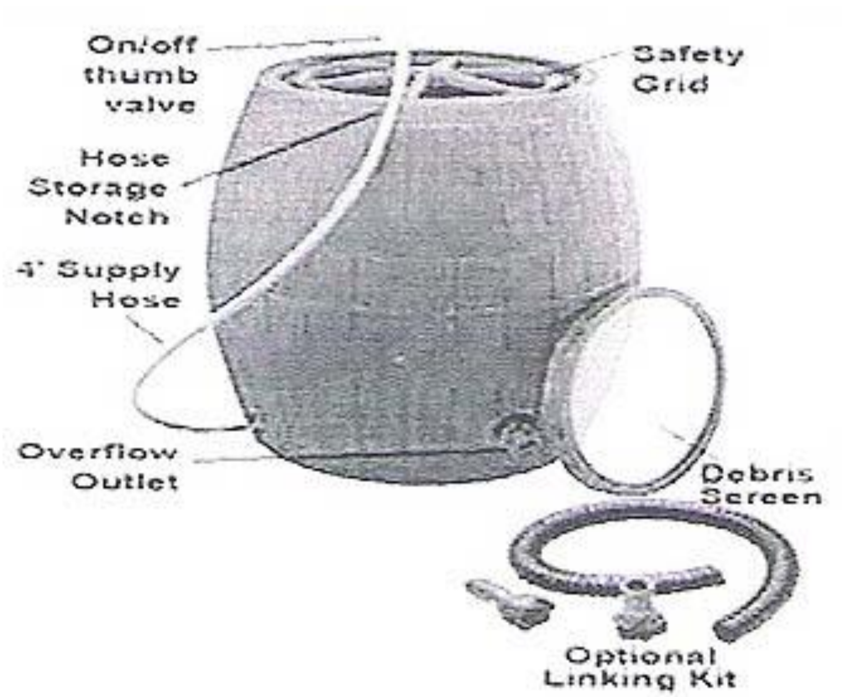


Figure 7.24.a – Rain Barrel

Required Design Elements for Rain Barrel

FEASIBILITY:

- Any residential roof with existing or proposed downspouts.

CONVEYANCE:

- Gutter downspout shall direct runoff to rain barrel, an overflow pipe shall be provided to by-pass rain barrel for large storm events or when rain barrel is full,
- Overflow pipe shall be located a minimum of 10’ away from building foundation and direct runoff across a vegetated surface.

PRE-TREATMENT:

- No pre-treatment is required.

SIZING CRITERIA:

- Rain barrel shall have a minimum capacity of 55 gallons per 100 square feet of contributing roof area.

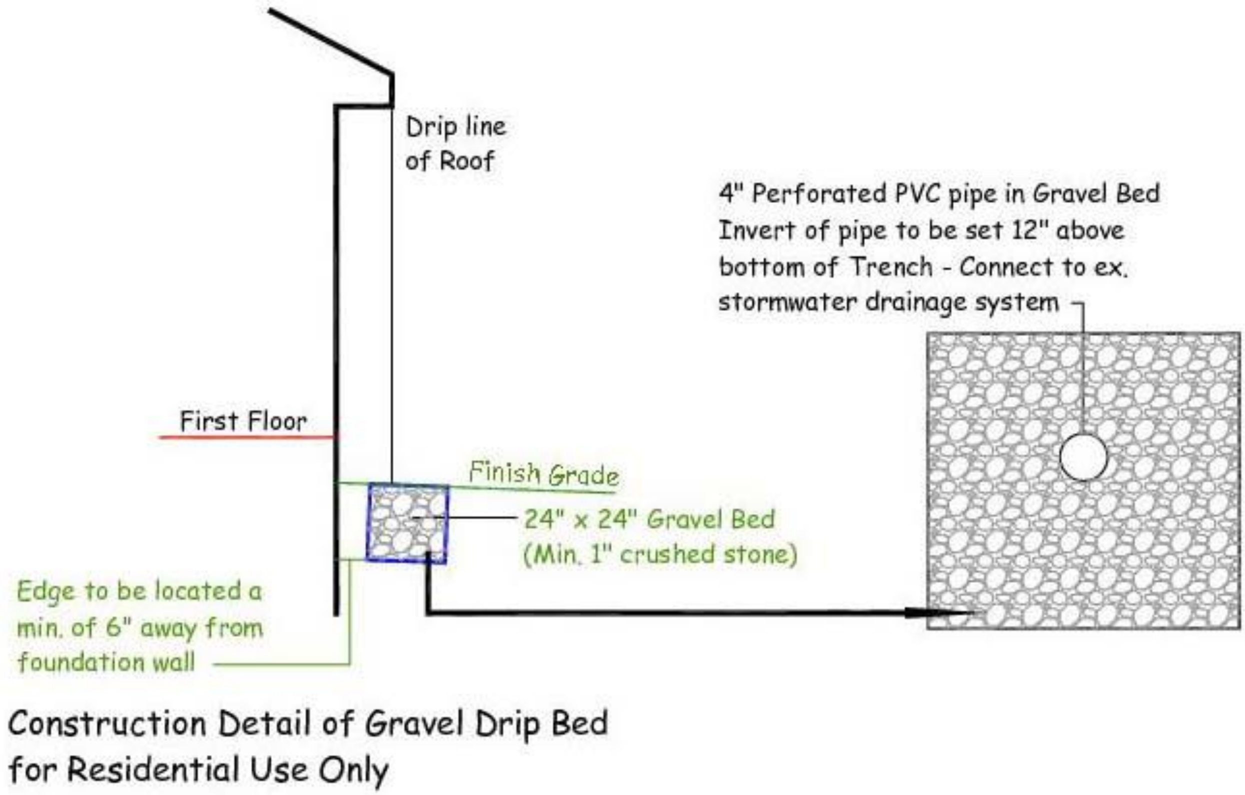
TREATMENT:

- This is a water reuse system, no treatment of runoff is required.

CONSTRUCTION AND MAINTENANCE:

- Rain barrel shall be drained each fall to prevent freezing of water in the barrel.
- An inline filter, if utilized on downspout shall be inspected twice a year and any debris promptly removed from the filter.
- The discharge line from the downspout to the rain barrel shall be disconnected during the winter months to prevent the accumulation of water in the barrel during freezing weather.

7.25 GRAVEL DRIP BED



Gravel Drip Bed: A gravel drip bed is a system consists of crushed stone installed below the drip line of a residential roof without gutters to collect and infiltrate runoff from the roof into the ground.

Figure 7.25.a – Gravel Drip Bed (Trinkaus Engineering)

Required Design Elements for Gravel Drip Bed

FEASIBILITY:
- Any Single Family Residential House without gutters and downspouts
- Shall be located in Class A or B soils. It is not suitable for use in Class C or D soils.
- Edge of gravel shall be located a minimum of 6” away from foundation wall

CONVEYANCE:
- Not Applicable

PRETREATMENT:
- No pretreatment required

SIZING CRITERIA:
- Not Applicable

TREATMENT:
- Not Applicable

CONSTRUCTION AND MAINTENANCE REQUIREMENTS:
- The finish grade must pitch away from the foundation wall at 2% for a minimum of ten (10) feet.
- When the trench is excavated for the gravel, the sides and bottom of the excavation shall be scarified by hand raking prior to the placement of the gravel.
- The gravel must be a minimum of 1” in size, but shall not exceed 2.5”. It shall consist of washed native bank run stone or quarried rock, no stone dust shall be permitted.

8.0 Environmental Site Design Strategies

8.1 Environmental Site Design Strategies

A key aspect for the successful implementation of LID is to utilize Environmental Site Design Strategies. The strategies of Environmental Site Design (ESD) are the base building blocks for the application of Low Impact Development. The ESD process focuses on the natural land form and the natural environmental systems. There are many environmental systems on a parcel of land, including wetlands, watercourses, vernal pools, flood plains, steep slopes (>25%), significant individual trees, unusual vegetative communities and soils with moderate to high infiltrative capacities. The ESD process requires that these natural environmental systems are fully evaluated prior to the creation of a development concept for residential projects. The ESD process is enumerated below and must be applied and documented by the appropriate design professional as part of a subdivision application.

Evaluation of the Natural Resources:

1) Obtain field delineation of inland wetlands and watercourses on the site by a Certified Soil Scientist. In Connecticut, wetlands are solely determined by soil evaluation criteria established by the CT DEP. The criteria used to determine inland wetlands should always reflect local requirements. The soil scientist should also approximate the boundaries and types of upland soil types on the site. These boundaries are typically sketched on a preliminary map of the site.
2) Obtain an inspection of the site by an environmental consultant to determine the presence of vernal pools or other high quality wetland areas.
3) Identify and locate all significant or unusual tree species in the field by a qualified individual.
4) Identify large ledge (600 square feet or larger) outcrops in the field.
5) Obtain a topographic base map of the property based upon current aerial photographs which will provide existing contours at a 2' interval.
6) Investigate the presence of 100-year flood boundary limits on the site from the available mapping by the Federal Emergency Management Agency (FEMA).
7) Obtain a boundary survey of the site along with the field location of all delineated inland wetlands and watercourses, significant trees, ledge outcrops and natural stone walls.

Creation of Base Map:

A base map incorporating all of the above information shall be prepared so all the resources can be fully evaluated.

a) Boundaries of upland soil types shall be added to the plan. Determine the potential infiltrative capacity of the soils by using data available from the Natural Resources and Conservation Service (www.websoilsurvey.nrcs/usda.gov/app/). Highlight the extent of these soils on the plan.
b) Determine and delineate the existing sub watershed boundaries on the site.
c) Determine the generalized vegetative types on the site, whether they are deciduous, coniferous, a combination of both, or meadow areas.
d) Determine which of the significant trees located in the field warrant protection from development. This could be a 200 year old Oak Tree in the middle of a field.

e) Delineate extent of 25% slopes on the parcel. The 25% slopes shall be defined as those areas where there is a 10’ change in grade across 40’ in horizontal distance.

Determination of Developable Area:

The Developable area results from the removal of the wetlands, watercourses, vernal pools and steep slopes from the site area. In addition, a portion of the upland area adjacent to wetland/watercourse systems shall be removed to provide a biological connectivity to the wetland resources. The width of the upland area to be preserved shall be based upon a scientific evaluation by an environmental consultant and documented in writing. This report shall be submitted as part of the subdivision application.

The designer shall then develop plans for the site utilizing the following LID strategies:

Avoidance of Impacts:

1. Protect as much undisturbed land as possible to maintain pre-development hydrology and allow rainfall to infiltrate into the ground,
2. Protection of the natural drainage systems, such as wetlands, watercourses, ponds, vernal pools to the maximum extent possible,
3. Minimize the disturbance of the land necessary for clearing and grading,
4. Implement techniques to prevent the compaction of natural soils

Reduction of Impacts:

1. Utilize low maintenance landscapes that will encourage the retention and planting of native types of vegetation, and minimize the extent of lawn areas, which will reduce the potential application of fertilizers and pesticides,
2. Minimize the extent of impervious areas on the site, particularly the directly connected impervious areas,
3. Increase the “Time of Concentration” for post-development conditions to match the “Time of Concentration” for pre-development conditions, where the “Time of Concentration” is defined as the time it takes for runoff to travel from the hydrologically most distant point of the watershed or sub-watershed area to the design point.

Management of Impacts:

1. Use vegetated conveyance and treatment source controls to infiltrate runoff as close as possible to the point rainfall reaches the ground surface,
2. Disconnect impervious areas to the maximum extent possible to reduce runoff over the impervious surface,
3. Implement procedures to prevent or minimize the use of compounds which are responsible for the pollutants found in non-point source runoff,
4. Utilize source controls to minimize or prevent the discharge of pollutants to receiving wetlands or watercourse systems.

8.2 LID Site Design Strategies

These LID strategies are applied as follows during each stage of the design process as described below.

8.2.1 Road Design:

- Road alignments shall follow the existing contours to the maximum extent practical to minimize excessive cuts and fills,
- Minimize the extent of directly connected impervious area to the maximum extent practical. This can be achieved by the minimization of drainage structures on the road, such as catch basins and connecting pipe and the use of vegetated swales along the road in appropriate locations,
- Utilize LID treatment strategies to treat runoff at the source and not at the end of the pipe,
- Utilize multiple LID treatment systems in a series to increase the effectiveness of the pollutant removal from the stormwater.

8.2.2 Driveway Layouts:

- Use a common driveway wherever feasible to minimize the extent of impervious cover on the site,
- Use impervious area disconnection strategies to intercept and infiltrate driveway runoff prior to the runoff reaching the road,
- Allow runoff from driveways to travel across vegetated areas for a minimum of 75’ to facilitate infiltration.

8.2.3 Lot Designs:

- Layout lots in such a manner as to minimize site clearing by the implementation of “site fingerprinting”. Site fingerprinting is delineating the smallest possible area for clearing and site disturbance where roads, structures and other improvements are to be constructed,
- Layout house, driveway and on-site sewage disposal systems in such a manner as to minimize the extent of soil disturbance and grading on the lot,
- Utilize the natural topography when siting the proposed house to minimize site disturbance. An example of this is to create a walkout basement for a house on a natural 15-20% slope,
- Don’t randomly disturb areas of the site that aren’t necessary, this will preserve the infiltrative capacity of native soils,
- Use “source” controls such as rain barrels for roof runoff to collect and reuse runoff; rain gardens for roof runoff to infiltrate runoff into the ground; impervious area disconnection to allow runoff to occur as overland flow across a vegetated surface,
- Consider the use of meadow filter strips at the downhill limits of development to filter runoff prior to leaving the lot.

9.0 Design Standards for Conventional Stormwater Systems

If structural stormwater systems are necessary to be constructed on roads or commercial sites, the following Town of Plainville standards shall apply to these systems.

9.1 Storm Drainage Planning:

All structural stormwater management systems in the Town of Plainville shall comply with these standards.

a. to take into account any land which would normally drain across the subdivision and the effect upon downstream drainage systems,
b. to provide for adequate drainage of property within the development and other areas upgradient,
c. to protect locations necessary for on-site sewage disposal and water supply facilities and driveways and building sites,
d. to minimize any adverse effects on adjacent property and upon downstream watercourses, property or improvements,
e. in compliance with all governmental codes and regulations and in accordance with the ordinances of the Town of Plainville and the standards set forth in these regulations, and
f. in a manner capable of acceptance for public use and maintenance by the Town of Plainville although no such obligation shall be placed on the Town of Plainville as a result of this requirement.

9.2 Design of in-road stormwater management systems:

g. The design of storm drainage facilities shall be designed under the "Rational Formula" whereby Q=CIA, where:
    Q = Peak Rate of Runoff (cubic feet per second)
    C = Runoff Coefficient
    I = Rainfall Intensity
    A = Watershed Area
h. Runoff Coefficients as shown in Table 9.1:
i. Design flood frequency shall be:
    1. Pipe drainage systems; 10 year flood,
    2. Channels and trunk lines; 25 year flood,
    3. Culverts; 25 year flood, and
    4. Channels and encroachment lines along streams; 50 year flood.

9.3 Construction Standards:

Catch basins, manholes, drop inlets, end walls, and other appurtenances to the storm drainage system shall be constructed in accordance with Section 5.07 and Article M.08.02 of the latest revision of the Connecticut Department of Transportation's "Standard Specifications for Roads, Bridges, and Incidental Construction as amended."

9.4 Drainage Facilities:

Drainage facilities shall be located in perpetual unobstructed easements where feasible, or within the street right of way, where necessary.

9.5 Standards for Drainage Pipes:

All drainage pipes shall conform to the following specifications:

a) The pipe system should flow full for the calculated total flow.

b) The system should operate under pressure with a free outfall.

c) The HGL (Hydraulic Grade Line) should not rise to within two (2) feet of any manhole cover or top of any inlet at the design discharge.

d) The HGL should not rise to a level that would flood any subdrain outfalling into the storm drain system.

e) Minimum slope of all pipes shall be 0.4%.

f) Energy dissipaters, stilling basins, or other approved devices must be incorporated when design slopes exceed 4.0%.

g) The minimum cover over the top of the pipe shall be two (2) feet.

h) Manholes shall be provided at all deflection points and/or the junction of two or more lines.

i) Catch basins should be spaced to the following standards:
   j. 300 feet on a tangent, or closer as required for intersections,
   k. 200-250 feet on the inside of superelevated curves,
   l. 250 feet on highway grades over 6.0%,
   m. on the up hill side of intersections,
   n. 250 feet from roadway high points, and
   o. center of cul-de-sacs.

9.6 Underdrains:

At the base of uphill shoulder embankments and as elsewhere required by the Town Engineer, a minimum 6 inch diameter perforated pipe continuous underdrain shall be installed behind the curbing in accordance with Section 7.51 of the latest Connecticut Department of Transportation specifications, except that the aggregate shall be limited to Broken Stone or Screened Gravel conforming to Article M.01.01 for 3/8 inch stone.

9.7 Discharge:

The discharge of all stormwater that has been collected or otherwise artificially channeled shall be directed to suitable streams or into Town or State drainage systems with adequate capacity to carry the discharge. There shall be no discharge onto or over private property within or adjoining the development unless (a) proper easements and discharge rights have been secured by the applicant, (b) such easements and rights are transferable to the Town in the event that the discharge includes stormwater from any street, and (c) proper provisions are made to safeguard against soil erosion and flood danger. No stormwater shall be diverted from one watershed to another. Discharge shall be made in a manner that protects streams, ponds and swamps from pollution.

9.8 Drainage Construction:

a. Pipe Materials: Corrugated Metal Pipe (CMP) or Corrugated Polyethylene Pipe (HDPE – Type S – smooth interior surface only) or Reinforced Concrete Pipe (RCP), joint sealants and bedding material shall conform to Article M.08.01 of the latest revision of the Connecticut Department of Transportation's "Standard Specifications for Roads, Bridges, and Incidental Construction."

b. Methods: Excavation and backfill shall conform to Section 2.05 of the latest Connecticut Department of Transportation specifications. Corrugated Metal Pipe (CMP), Corrugated Polyethylene Pipe (HDPE – Type S – smooth interior surface only) or Reinforced Concrete Pipe (RCP), joint sealants and bedding installation shall conform to Section 6.51 of the latest revision of the Connecticut Department of Transportation's "Standard Specification's for Roads, Bridges, and Incidental Construction."

c. Appurtenances: Catch basins, manholes, drop inlets, end walls, and other appurtenances to the storm drainage system shall be construction in accordance with Section 5.07 and Article M.08.02 of the latest revision of the Connecticut Department of Transportation's "Standard Specification's for Roads, Bridges, and Incidental Construction."

d. Special Structures: Bridges, box culverts, and other special structures shall be designed and constructed in accordance with sound engineering practice and the latest revision of the Connecticut Department of Transportation's "Standard Specification's for Roads, Bridges, and Incidental Construction." Bridges shall be designed in accordance with the latest revision of the Standard Specifications for Highway Bridges as adopted by the American Association of State Highway and Transportation Officials (AASHTO).

Table 9.8.a – Rational Method Runoff Coefficients

Land Use	Runoff Coefficient
Business, Downtown	0.70 – 0.95
Business, Neighborhood	0.50 – 0.70
Residential:	
Single Family	0.30 – 0.50
Multi – detached	0.40 – 0.60
Multi – attached	0.60 – 0.75
Suburban	0.25 – 0.40
Industrial	
Light use	0.50 – 0.80
Heavy use	0.60 – 0.90
Parks	0.10 – 0.25
Land Use	Runoff Coefficient
Playgrounds	0.20 – 0.35
Streets/sidewalks	0.95
Driveways, gravel	0.75 – 0.85
Roofs	0.95
Lawns:	
Sandy soils, 2% slope`	0.10
Sandy soils, 7% slope	0.20
Sandy soils, >7% slope	0.22
Heavy soils, 2% slope	0.35
Heavy soils, 7% slope	0.40
Heavy soils, >7% slope	0.60
Agricultural Land:	
Bare packed soil	0.20 – 0.60
Cultivated rows	0.15 – 0.45
Crop land	0.10 – 0.20
Pasture, heavy soil	0.15 – 0.45
Pasture, sandy soil	0.05 – 0.25
Woodlands	0.05 – 0.25

10.0 Computational and Design Examples

10.1 Groundwater Recharge Volume and Water Quality Volume

Sample Site: A 25 acre site shall be developed as single family residential units. The total impervious cover shall be 9 acres; 5 acres on HSG “A”, 3 acres on HSG “B” and 1 acre on HSG “C”. The Groundwater Recharge Volume is calculated as follows:

GRv = (1”)(D)(I)/12

GRv for HSG A: (1”)(0.60)(5)/12 = 0.25 acre-feet
GRv for HSG B: (1”)(0.40)(3)/12 = 0.10 acre-feet
GRv for HSG C: (1”)(0.25)(1)/12 = 0.02 acre-feet

On the same site, the post-development conditions will divide the site into two subwatershed areas. One area contains 13 acres with 6 acres of the impervious cover, the second contains 12 acres with 3 acres of impervious coverage. The Water Quality Volume will be calculated for each area.

WQv = (1”)(I)/12

WQv for Area 1: (1”)(6)/12 = 0.50 acre-feet
WQv for Area 2: (1”)(3)/12 = 0.25 acre-feet

10.2 Application of Environmental Site Design Strategies

Sample Site: A 104 acre site, located in Winchester, CT to be developed as single family residential units. Site is mostly wooded with hardwoods being the dominant species. Some meadow areas exist from past farming operations.

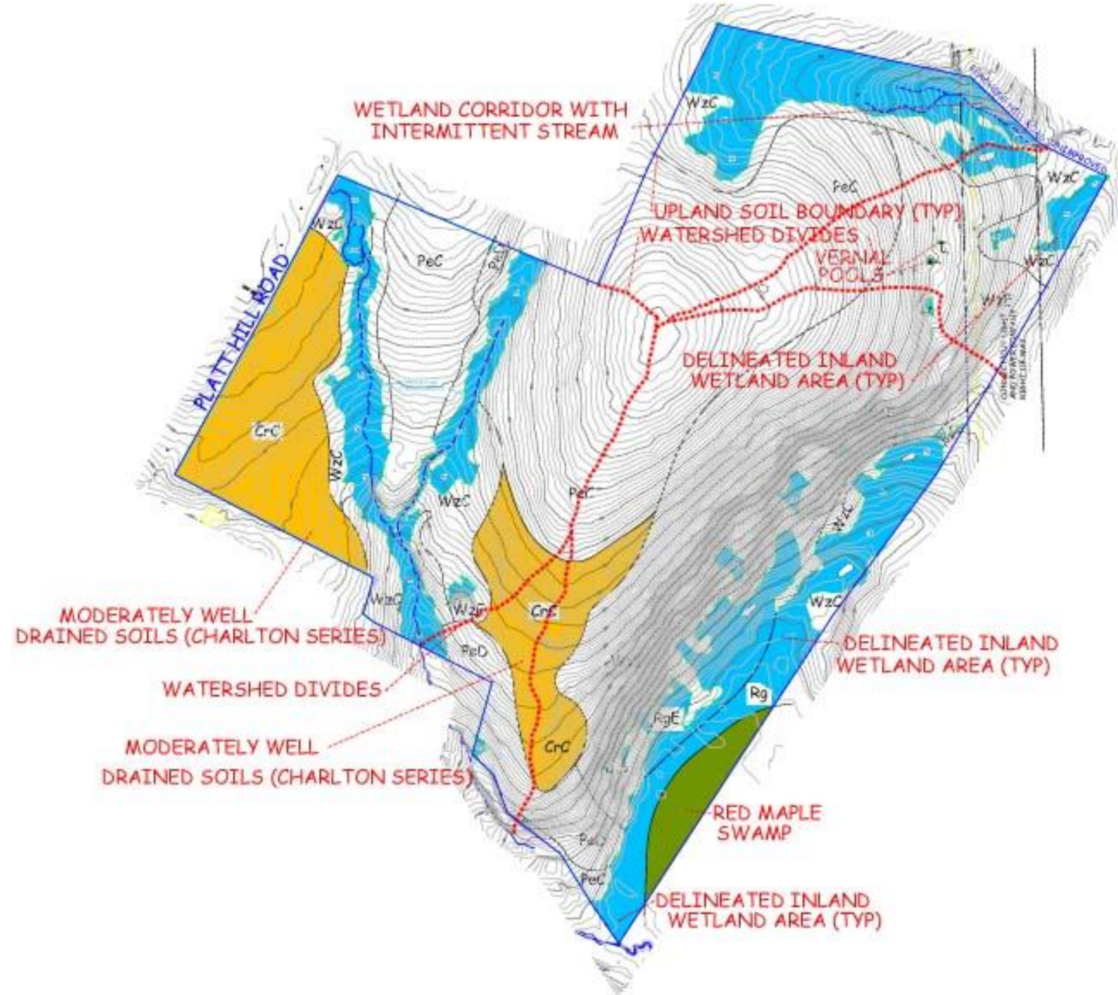


Figure 10.2.a - Wetlands/Watercourses/Soils/Drainage Divides

Figure 10.2.a shows the results of the initial assessment of the natural resources on the site. The wetlands, watercourses, red maple swamp and vernal pools have been highlighted on the plan. In addition, those soils with good to moderate infiltrative capacities have been determined by the soil scientist and verified by soil testing. The existing sub-watersheds on the site have been delineated.

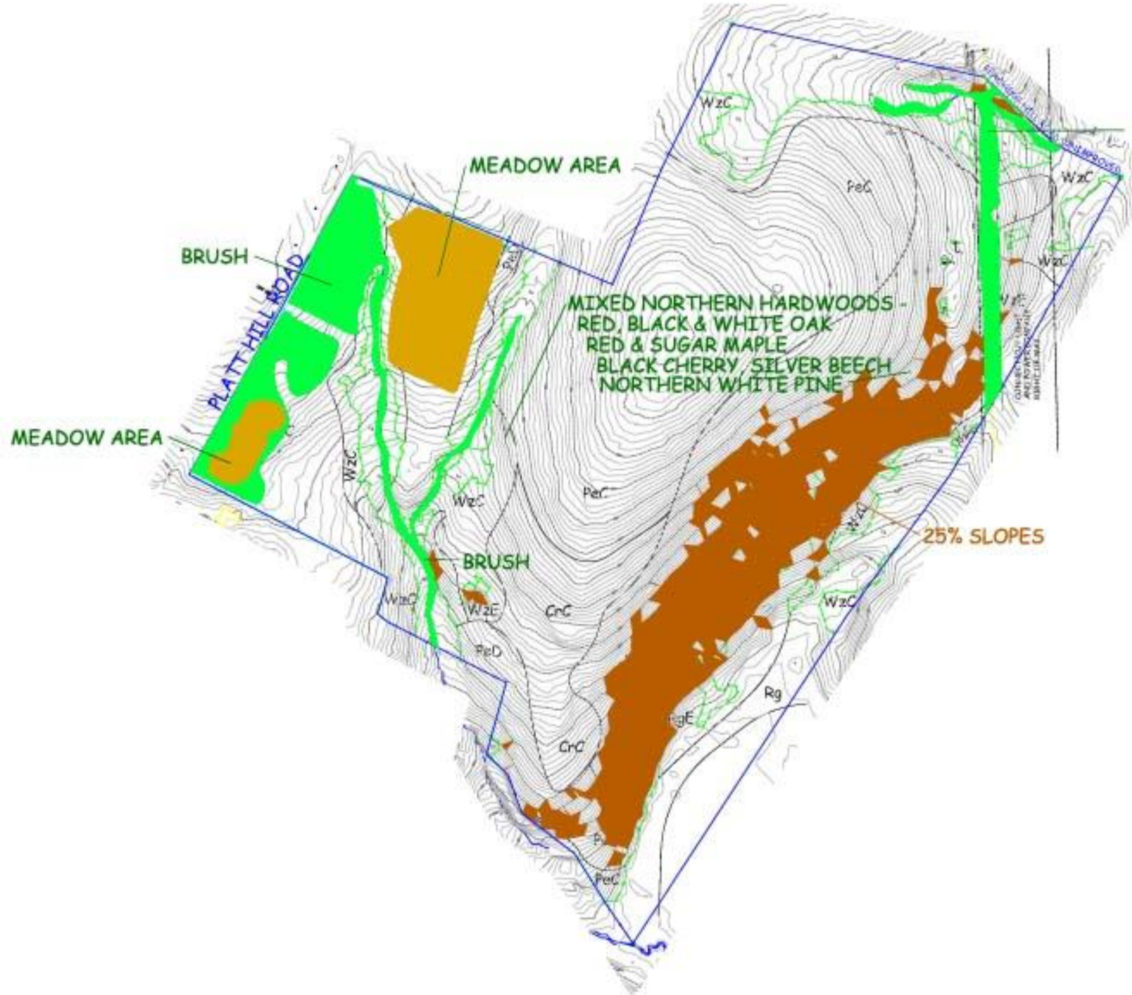


Figure 10.2.b - 25% Slopes/Vegetation Types

Figure 10.2.b shows the extent of 25% slopes on the site, along with the generalized vegetative communities.

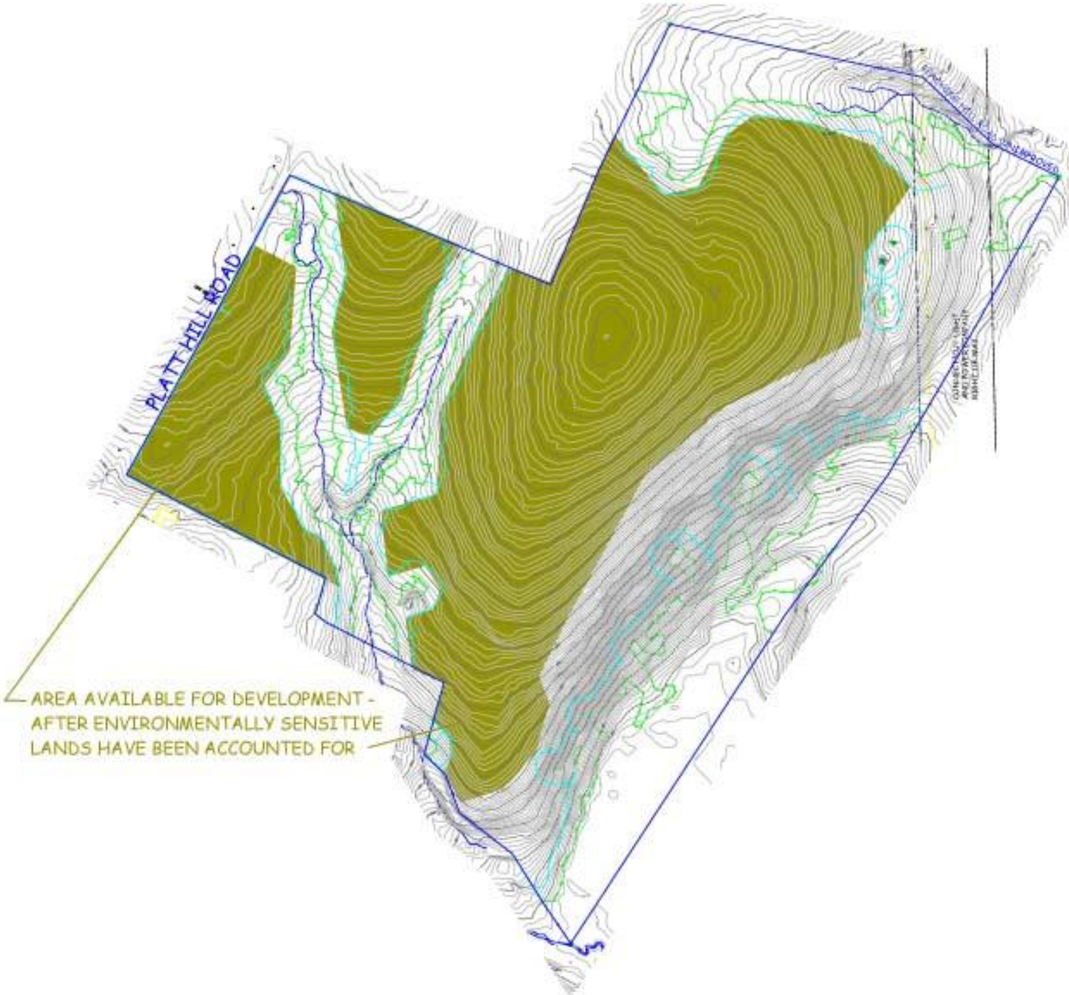


Figure 10.2.c - Developable Area

Figure 10.2.c shows the land remaining after the environmentally sensitive areas have been removed from development consideration. At this point, the good infiltrative soils and the ridge top are included as part of the developable area.

The designer can then evaluate the previously performed soil test results to determine the best locations on the site to support on-site sewage disposal systems. Once ideal conceptual locations are determined for on-site sewage disposal systems, potential home locations shall be determined. The goals of LID, such as working with the land, minimizing site clearing and site disturbance, and addressing stormwater at its source will also be considered during this time. As the designer begins to formulate the development concept for the property, it is important to balance potential unavoidable direct impacts on wetlands and watercourses with the LID strategies. At this point the strategies discussed in Section 8.2 for the layout of roads, driveways and lots shall be applied to the site.

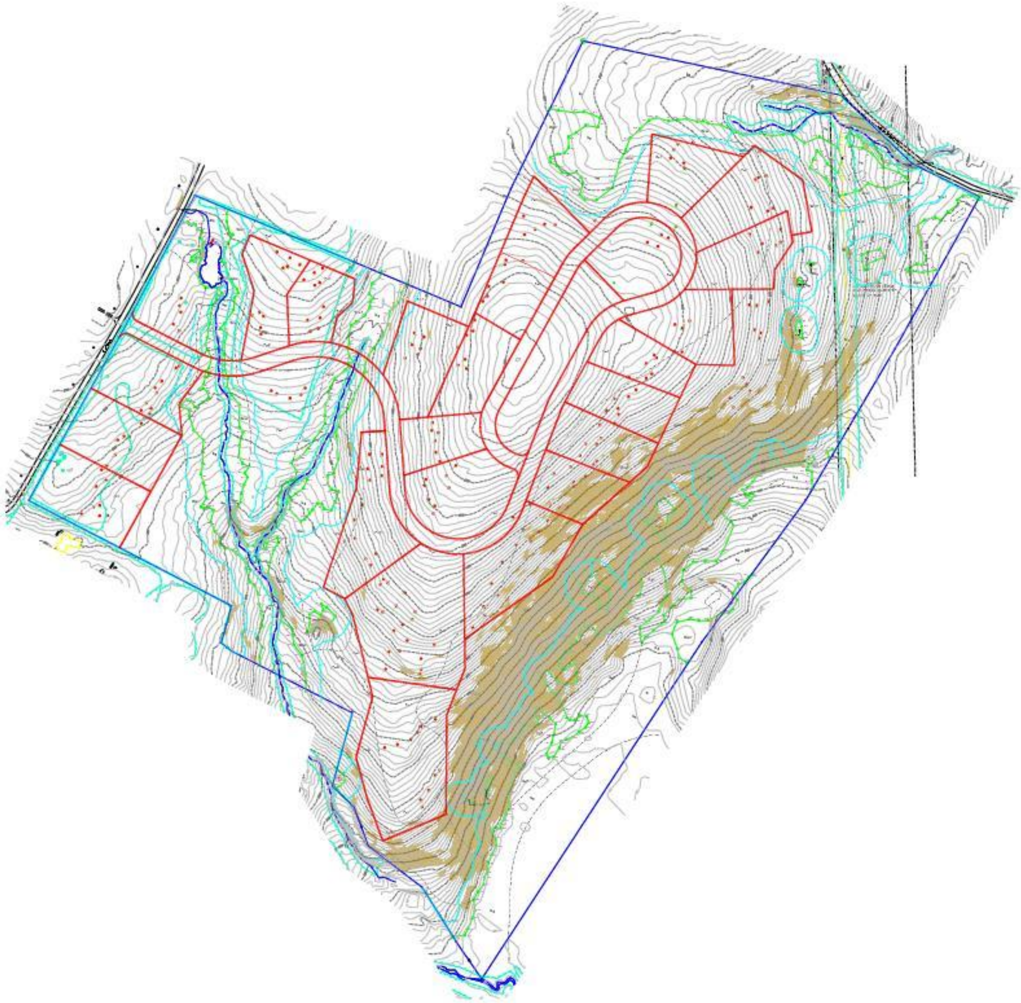


Figure 10.2.d – Road & Lot Layout

In Figure 10.2.d, roads have been laid out to follow the existing contours to the maximum extent possible. This will minimize clearing limits as well as grading requirements. Lots are laid out in the area defined as developable area. Most of the density is concentrated on lands having Class C soils, while the density is less on those soils with high to moderate infiltration rates.

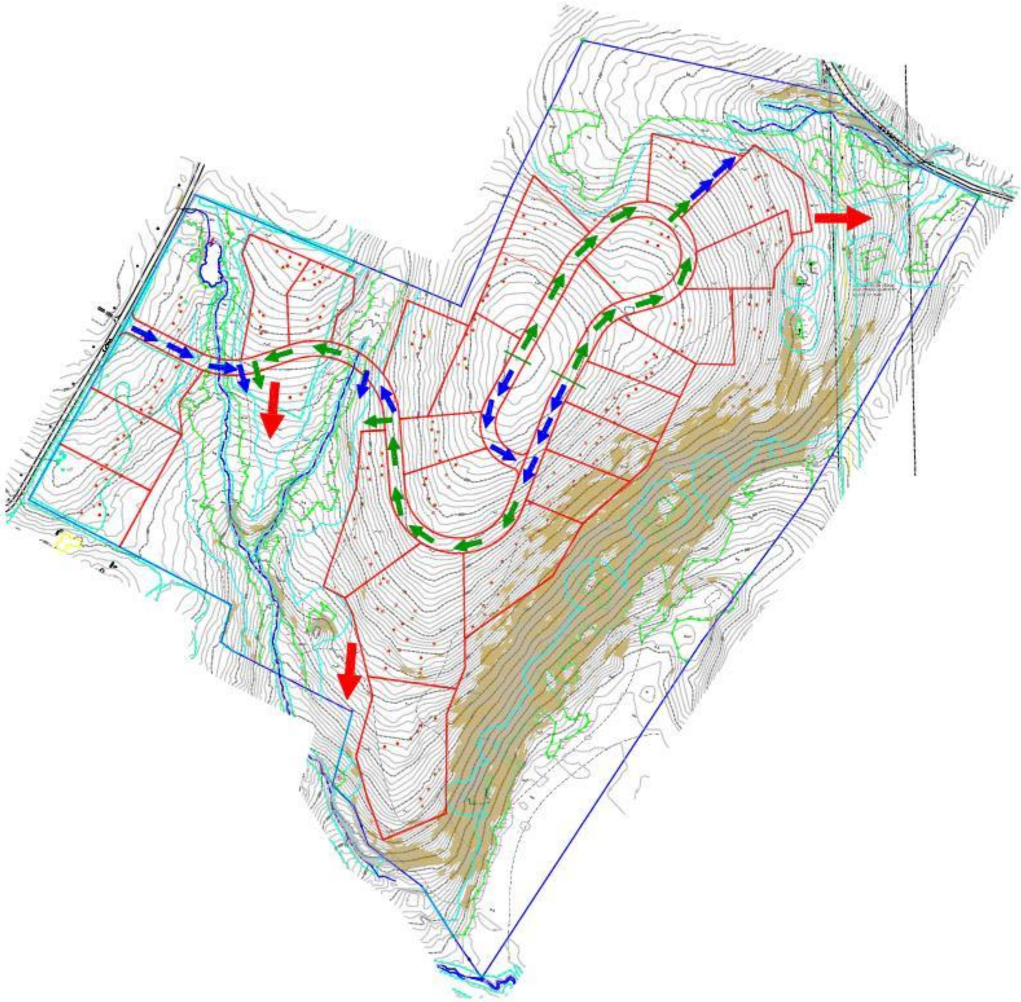


Figure 10.2.e – Preliminary stormwater layout

Figure 10.2.e demonstrates the conceptual layout of the stormwater conveyance system. The Red arrows connote discharge locations for post-development stormwater which will maintain pre-development watershed boundaries. Green arrows show locations where vegetated conveyance systems can be utilized due to topographic conditions. Blue arrows show the extent of conveyance drainage systems (catch basin & pipe).

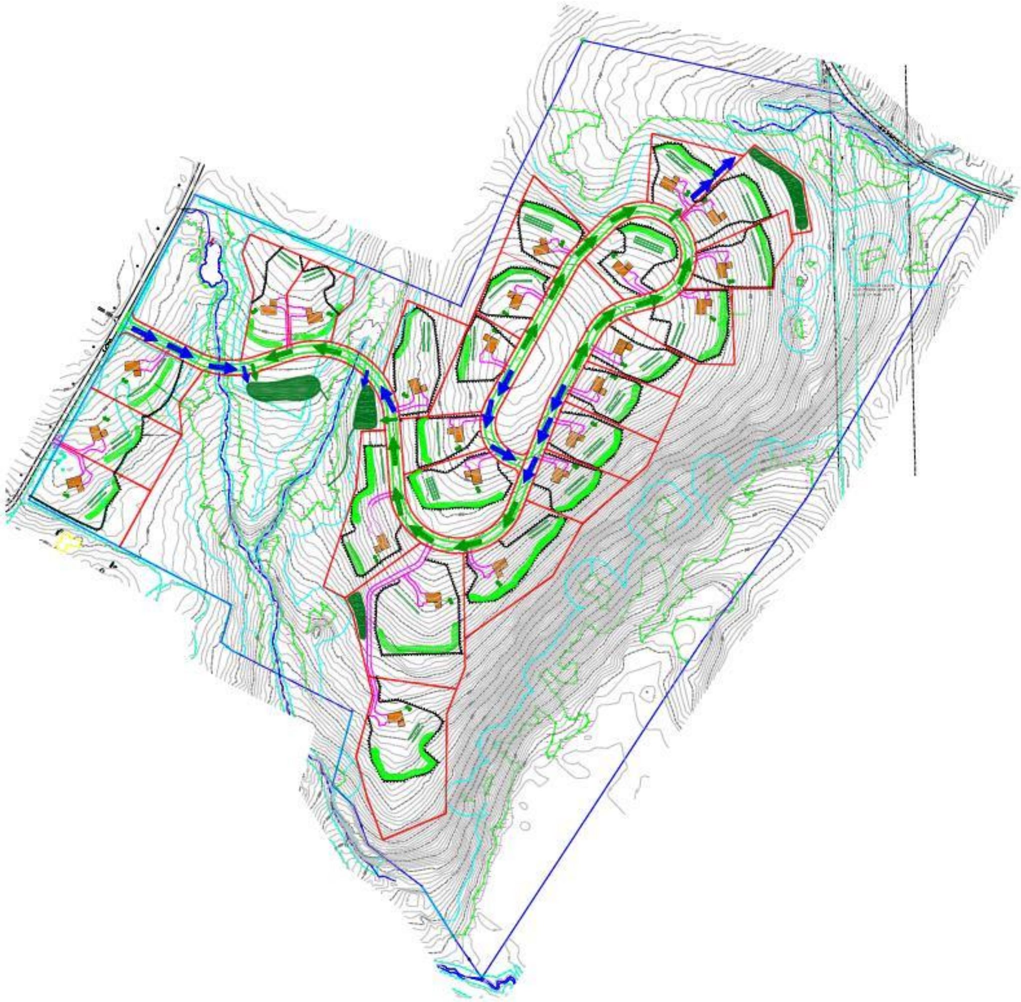


Figure 10.2.f – Implementation of LID Concepts

Figure 10.2.f demonstrates how several LID strategies can be applied to the site. Site fingering is utilized to define clearing limits of each lot. Rain gardens are utilized for the runoff from roof areas. Impervious area disconnection to encourage flow across vegetated surfaces is used for driveways down-gradient of the road. Meadow filter strips are installed at the downhill edge of all lawn areas to filter runoff prior to entering undisturbed woodlands.

Figure 10.2.g – Final Site Design

Figure 10.2.g clearly demonstrates how the use of Open Space Subdivision Concepts results in the preservation of 60% of the site area. Stormwater from the connected impervious areas are directed to either a Subsurface Gravel Wetland, Constructed Wetland, grass swale with filter berms, linear vegetated level spreader, or infiltration trenches for both groundwater recharge and water quality.

By the implementation of these LID strategies and treatment system, both metrics for LID were achieved. Pre-development groundwater recharge rates were met as well as matching the pre-development Runoff Curve Number after development.

As a key goal of LID is meeting of the pre-development hydrologic conditions, the design will likely go through several iterations to reach the desired result. This particular project went through three design iterations before the LID goals were achieved. The paradigm shift from “end of the pipe” to “source control” for handling stormwater will become second nature for the designer with time.

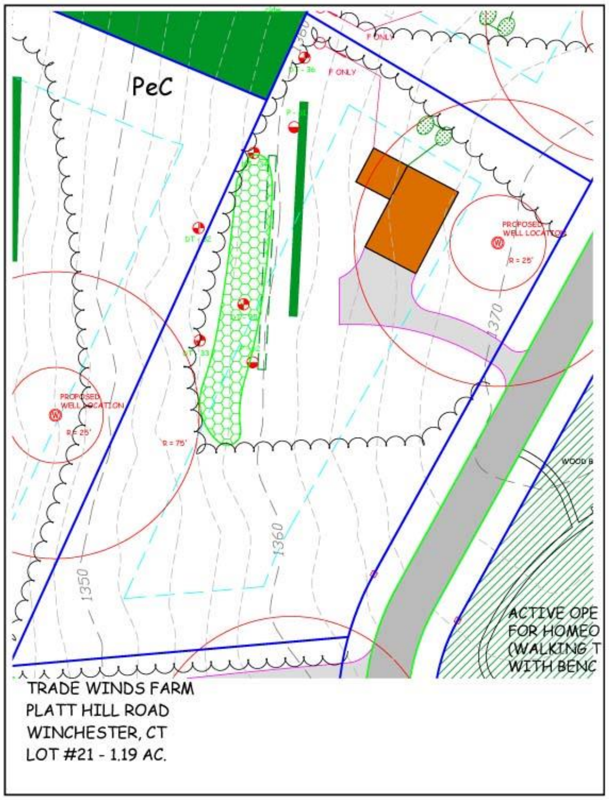


Figure 10.2.h – Individual Lot Design

This figure demonstrates the application of the following LID strategies: Site fingerprinting to define percentage clearing limit on lot, rain gardens for roof drains, meadow filter strip at downhill limit of lawn area, and impervious area disconnection as runoff from driveway will occur as overland flow across rear yard.

11.0 Definitions

Adverse Impact: Any deleterious effect on waters or wetlands, including their quality, quantity, surface area, species composition, aesthetics or usefulness for human or natural uses which are or may potentially be harmful or injurious to human health, welfare, safety or property, to biological productivity, diversity, or stability or which unreasonably interfere with the enjoyment of life or property, including outdoor recreation.

Bank full Discharge: Stream discharge that fills the channel to the top of the banks and just begins to spread onto the floodplain. Bank full discharges occur on average every 1 to 1.5 years in undisturbed watersheds and are primarily responsible for controlling the shape and form of natural channels.

Biological Oxygen Demand: A measurement of the oxygen demand of organic material which, when breaking down in water, consumes oxygen in the water column.

Bioretention: On-lot retention of storm water through the use of vegetated depressions engineered to collect, store, filter and infiltrate runoff.

Best Management Practice (BMP): The practice or combination of practices that are the most effective and practical means of reducing or eliminating the discharge of pollutants to surface waters from point or non-point source discharges, including storm water.

Buffer: A vegetated zone adjacent to a stream, wetland, or shoreline where development is restricted or controlled to minimize the effects of development.

Channel Protection Flow (CPf): Control the 2-yr, 24 hour post-development peak flow rate to 50 percent of the 2-yr, 24 hour pre-development level or to the 1-yr, 24 hour pre-development level.

Clear Cutting: The removal of all of the trees from a given land area.

Clearing: The removal of trees and brush from the land, but shall not include the ordinary mowing of grass.

Cluster (Open Space) Development: A development concept by which lots or buildings are concentrated in specific areas to preserve large, contiguous area of the natural environment while minimizing infrastructure and development costs. The preservation of large, contiguous areas of the natural environment allow for passive recreation, common open space, and preservation of environmentally sensitive features.

Commission: Planning and Zoning Commission.

Conveyance Protection: Design the conveyance system leaching to, from, and through storm water management facilities based upon the 10-year, 24 hour storm event.

Curbs: Concrete or bituminous concrete barriers on the edge of streets used to direct storm water run-off to an inlet or storm drain and to protect lawns and sidewalks from vehicles.

Denitrification: Reduction of nitrate (commonly by bacteria) to nitrogen gas in an anaerobic environment.

Design Storm: A rainfall event of specific size, intensity, and return frequency that is used to calculate runoff volume and peak rate discharge.

Detention: The temporary storage of storm water to control discharge rates, allow for infiltration, and improve water quality.

Dry Detention Basin: A permanent structure for the temporary storage of runoff, which is designed so as not to create a permanent pool of water.

Dry Well: Hollow concrete or plastic structure, surrounded by crushed stone placed in the ground to control and infiltrate roof top runoff.

Easement: A grant or reservation by the owner of land for the use of such land by others for a specific purpose or purposes.

Erosion: The process of soil detachment and movement by forces of wind and water.

Environmental Site Design (ESD): The process of assessing and evaluating the natural resources on a site prior to the creation of development plans and the application of LID strategies to minimize the impact on the environment.

Evapotranspiration: Collective term for the processes of water returning to the atmosphere via interception and evaporation from plant surfaces and transpiration through plant leaves.

Exfiltration: Movement of water from an infiltration management practice into the surrounding soil layers.

Flow Attenuation: Prolonging the flow time of runoff to reduce the peak rate of discharge.

Grading: The act by which soil is cleared, stripped, stockpiled, excavated, scarified, and filled or any combination thereof.

Groundwater Recharge Volume (GRv): Maintain pre-development annual groundwater recharge volume to the maximum extent practicable through the use of infiltration measures.

Hydrologically Functional Landscape: Term used to describe a design approach for the built environment that attempts to more closely mimic the overland and subsurface flow, infiltration, storage, evapotranspiration, and time of concentration characteristic of the native landscape of the area.

Hydrologic Transparency: The use of LID design strategies and storm water treatment systems for a development scenario which yields hydrologic conditions matching or in extremely close proximity to the hydrologic conditions of the natural site prior to development.

Hydromodification: The alteration of a natural drainage system through a change in the system's flow characteristics.

Impervious Area: A hard surface that prevents or severely retards the entry of water into the soil, thus causing water to run off the surface in greater amounts and at an increased rate of flow when compared to natural conditions. The surfaces include, but are not limited to, conventional asphalt or concrete roads, parking areas, sidewalks, alleys and roof tops.

Infiltration: The downward movement of water from the land surface down into the soil.

Integrated Management Practices: The application of multiple storm water treatment systems to address increased runoff volumes from development. IMP offers several techniques including storm water harvest (to reduce the amount of water that can cause flooding), infiltration (to restore the natural recharge of groundwater), biofiltration or Bioretention (e.g., rain gardens) to store and treat runoff and release it at a controlled rate to reduce impact on streams and wetland treatments (to store and control runoff rates and provide habitat in urban areas).

Low Impact Development: The integration of site ecological and environmental goals and requirements into all phases of urban planning and design from the individual lot level to the entire watershed.

Nitrification: Process in which ammonium is converted to nitrite and then nitrate by specialized bacteria.

Non-point Source Pollutants: Pollutants in water caused by rainfall or snowmelt moving both over and through the ground and carrying with it a variety of pollutants associated with human land uses. A non-point source is any source of water pollution that does not meet the legal definition of point source in Section 502(14) of the Federal Clean Water Act.

NPDES: National Pollutant Discharge Elimination System is a regulatory program in the Federal Clean Water Act that prohibits the discharge of pollutants into the surface waters of the United States without a permit.

Open Space: Land set aside for public or private use within a development that is not built upon and is legally preserved in its natural state for perpetuity.

Phosphorous (P)-Index: The measure of the amount of phosphorous a soil contains. A low P-Index means a soil can absorb more phosphorous from the stormwater.

Peak Runoff Attenuation: Control the post-development peak discharge rates from the 10-yr, and 100-yr 24 hour storm events to the corresponding pre-development peak discharge rate, as required by the local regulatory authority.

Permeable: Soil or other material that allows for the infiltration or passage of water.

Recharge Zone: A land area in which surface water infiltrates the soil and reaches the zone of saturation or shallow groundwater table.

Retention Basin: A permanent structure that provides for the storage of runoff by means of a permanent pool of water.

Retrofitting: The construction of a BMP (both structural and non-structural) in a previously developed area, the modification of an existing BMP (both structural and non-structural), to improve the water quality over current conditions.

Runoff: Water from rain, snow melt or irrigation that flows over the land surface.

Runoff Curve Number (RCN): The runoff curve number is an empirical parameter used in hydrology for predicting direct runoff or infiltration from rainfall excess. The curve number method was developed by the USDA Natural Resources Conservation Service, which was formerly called the *Soil Conservation Service* or *SCS* — the number is still popularly known as a "SCS runoff curve number" in the literature. The runoff curve number was developed from an empirical analysis of runoff from small catchments and hillslope plots monitored by the USDA. It is widely used and is an efficient method for determining the approximate amount of direct runoff from a rainfall event in a particular area.

Sediment: Soils or other surfical materials transported or deposited by the action of wind, water, ice, or gravity as a product of erosion.

Site fingerprinting: The delineation of the smallest possible area for clearing and site disturbance where roads, structures and other improvements are to be constructed.

Stabilization: The prevention of soil movement by any of various vegetative and/or structural means.

Storm water Management Plan: A set of drawings or other documents submitted by a person(s) as a prerequisite to obtain a storm water management approval, which contains all of the information and specifications pertaining to storm water management and conforms to the standards found in the Design Manual.

Swale (generic): An open channel designed to convey storm water.

Time of Concentration: The time that it takes surface runoff to reach the outlet of a sub-basin or watershed from the most hydraulically distant point in that watershed.

Vegetated Swale: An open channel which is planted with grasses (primarily) convey runoff.

Water Quality Volume (WQv): The volume needed to capture and treat the runoff from the 90 percent of the average annual rainfall at a development site. Methods for calculating the water quality volume are specified in the Design Manual.

Watercourse: Any natural or artificial stream, river, creek, ditch, channel, canal, conduit, culvert, drain, waterway, gully, ravine, or wash in and including any adjacent area that is subject to inundation from overflow or flood water.

Watershed: The topographic boundary within which water drains to a particular stream, river, wetland or other body of water.

Water Quality Flow (WCf): Peak flow associated with the water quality volume calculated using the NRCS Graphical Peak Discharge Method.

Water Quality Storm: A rainfall event of 1.2” of rain in 24-hours which results in 1” of runoff from an impervious surface.

Wet Swale: A vegetated conveyance system also used to remove pollutants from storm water runoff.

12.0 References

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L. National Stormwater Quality Database, Version 1.1 – A compilation and Analysis of NPDES Stormwater Monitoring Information; Alex Maestre and Robert Pitt, Department of Civil Engineering, University of Alabama, Center for Watershed Protection, September 4, 2005

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13.0 APPENDIX A - STORMWATER MANAGEMENT PLAN CHECKLIST

Stormwater Management Plan Checklist for Projects

A.1 General Information

☐ Applicant’s name, mailing address, telephone number, email

☐ Name, address, phone and email of licensed professional engineer responsible for the preparation of the stormwater management plan

☐ Street address of project site

☐ Vicinity map at a scale of 1” = 1000’ or larger

☐ Current zoning and land use

☐ Proposed use of property

A.2 Mapping Requirements for Existing Natural Resources

☐ Overall plan at a scale not to exceed 1” = 100’

☐ North arrow

☐ Existing topography (2’ contours based upon aerial or field mapping)

☐ Location of all man-made features on or adjacent to the site, such as roads, drainage systems, utilities, and buildings

☐ Location of inland wetlands and watercourses as defined by Certified Soil Scientist in the field and flags located by a licensed land surveyor

☐ Location of vernal pools, swamps, or bogs by qualified environmental consultant

☐ Location of 100-year flood plans, if applicable from current FEMA mapping

☐ Mapping of upland soil types by either soil scientist or NRCS mapping

☐ Extent and type of different vegetative communities on the site

☐ Delineation of existing watershed boundaries on the site

☐ Delineation of 25% slopes on the site

A.3 Mapping Requirements for Proposed Project

- ☐ Location & results of soil test pits performed on the site
- ☐ Delineation of proposed watershed boundaries on the site
- ☐ Location of proposed roads, lot lines, buildings, driveways and other improvements to the site
- ☐ Location of all proposed stormwater management conveyance and LID treatment systems

A.4 **Compliance with Section 4.2 Stormwater Management Requirements**

Requirement #1

- ☐ Identification of environmentally sensitive resources on the site
- ☐ Maintain existing drainage patterns on the site to the maximum extent practical
- ☐ Maintain as much of the site in the natural condition to maintain pre-development hydrology
- ☐ Protection of natural drainage systems, such as wetlands, watercourses, ponds, vernal pools to maximum extent practical
- ☐ Minimize the extent of land disturbance for clearing and grading
- ☐ Demonstrate that soil compaction has been minimized or will be remediated on the site
- ☐ Layout of roads, lots, driveways, buildings, etc to minimize the extent of impervious coverage on the site
- ☐ Utilize LID stormwater strategies to adjust the post-development time of concentration to match or closely approximate the pre-development time of concentration in each subwatershed area
- ☐ Application of source controls to collect, convey and treatment stormwater runoff at its source
- ☐ Demonstrate that impervious areas have been disconnected to the maximum extent practical
- ☐ Demonstrate that the application of pollutant causing substances have been minimized on the site
- ☐ Demonstrate that flow velocities are reduced to non-erosive levels

Requirement #2

- ☐ Provide amount and type of impervious cover in each subwatershed area
- ☐ Provide calculations of Groundwater Recharge Volume for each post-development subwatershed area and for each soil type within the area
- ☐ Provide the amount of volume required to meet the Groundwater Recharge Volume

Requirement #3

- ☐ Provide amount and type of impervious cover in each subwatershed area
- ☐ Provide calculations for the Water Quality Volume for each subwatershed area
- ☐ Provide the amount of volume required to meet the Water Quality Volume
- ☐ Provide pollutant loading analysis to demonstrate that all Water Quality Goals will be achieved by the proposed stormwater treatment systems

Requirement #4

- ☐ Calculate the Channel Protection Flow for each discharge point of the stormwater management system as applicable
- ☐ Demonstrate how the reductions in peak rate for the 2-year post-development storm will be reduced to comply with this requirement
- ☐ Provide time of concentration calculations for each area for pre- and post-development conditions
- ☐ Provide Runoff Curve Numbers for each area for pre- and post-development conditions
- ☐ Provide routing analyses for stormwater management system being used to meet this requirement

Requirement #5

- ☐ Provide drainage area, time of concentration, and peak rate of runoff for each conveyance system
- ☐ Provide calculations to demonstrate that any open or enclosed drainage conveyance systems have been sized in accordance with this requirement

Requirement #6

- ☐ Calculate the peak rate of runoff for the 10-year, 24-hour storm event and the 100-year, 24-hour storm event, if necessary for each watershed area as applicable
- ☐ Provide time of concentration calculations for each area for pre- and post-development conditions

- ☐ Provide Runoff Curve Numbers for each area for pre- and post-development conditions
- ☐ Provide routing analyses for stormwater management system being used to meet this requirement

Requirement #7

- ☐ Provide a written statement describing how pollution prevention will occur on the site both during construction and the post-construction period
- ☐ Describe maintenance requirements for the pollution prevention plan and who will be responsible for compliance with these requirements.

Requirement #8

- ☐ Demonstrate that the requirements for Groundwater Recharge Volume and Water Quality Volume have been met for a redevelopment project

Requirement #9

- ☐ Identify the specific land use which will be present on the site
- ☐ Provide survey showing the proposed increase of impervious area proposed
- ☐ Provide calculations for Groundwater Recharge Volume for building roof and Water Quality Volume for all impervious areas as required
- ☐ Demonstrate how these requirements will be addressed on the site

14.0 APPENDIX B - PLANT LIST FOR LID TREATMENT SYSTEMS

Plant List for LID Treatment Systems

There are six distinct hydrological planting zones for Low Impact Development Treatment Systems. Table B defines the hydrological characteristics of each planting zone.

Table B – Hydrologic Planting Zones

Zone #	Hydrologic Condition	Zone Description
1	1-6 deep permanent pool	Deep Water Pool
2	6 inches to 1 foot deep	Shallow Water Bench
3	Regularly inundated	High & Low Marsh
4	Periodically inundated	Riparian Fringe, Aquatic Bench
5	Infrequently inundated	Upland terraces within pond/wetland system
6	Rarely inundated	Upland slopes

ZONE 1 – Deep Water Pool

Trees and shrubs: not recommended for this zone

Herbaceous Plants:

Coontail	Submergent
Duckweed	Submergent/Emergent
Pond Weed	Submergent
Waterweed	Submergent
Wild Celery	Submergent

ZONE 2 – Shallow Water Bench

Trees and shrubs:

Buttonbush	Deciduous shrub

Herbaceous Plants:

Arrow arum	Emergent
Arrowhead, Duck Potato	Emergent
Blue Flag Iris	Emergent
Blue Joint	Emergent
Broomsedge	Perimeter
Bushy Beardgrass	Emergent
Cattail	Emergent
Duckweed	Submergent/Emergent
Hardstem Bulrush	Emergent
Long-leaved Pond Weed	Rooted Submerged Aquatic

Pickerelweed	Emergent
Sedges	Emergent
Soft-stem Bulrush	Emergent
Smartweed	Emergent
Herbaceous Plants:	
Soft Rush	Emergent
Switchgrass	Perimeter
Sweet Flag	Herbaceous
Wild Rice	Emergent
Wool Grass	Emergent

ZONE 3 – High & Low Marsh

Trees and shrubs:

Arrowwood Viburrium	Deciduous shrub
Bald Cypress	Deciduous tree
Black Ash	Deciduous tree
Black Willow	Deciduous tree
Buttonbush	Deciduous shrub
Elderberry	Deciduous shrub
Larch	Coniferous tree
Pin Oak	Deciduous tree
Red Maple	Deciduous tree
River Birch	Deciduous tree
Silky Dogwood	Deciduous tree
Smooth Alder	Deciduous tree
Swamp White Oak	Deciduous tree
Winterberry	Deciduous shrub

Herbaceous Plants:

Arrow arum	Emergent
Arrowhead, Duck Potato	Emergent
Blue Flag Iris	Emergent
Blue Joint	Emergent
Broomsedge	Perimeter
Bushy Beardgrass	Emergent
Cattail	Emergent
Duckweed	Submergent/Emergent
Flat-top Aster	Emergent
Hardstem Bulrush	Emergent
Long-leaved Pond Weed	Rooted Submerged Aquatic
Pickerelweed	Emergent
Redtop	Perimeter
Sedges	Emergent
Soft-stem Bulrush	Emergent
Smartweed	Emergent

Soft Rush	Emergent
Switchgrass	Perimeter
Sweet Flag	Herbaceous
Herbaceous Plants:	
Wild Rice	Emergent
Wool Grass	Emergent

ZONE 4 – Riparian Fringe, Aquatic Bench

Trees and shrubs:

American Elm	Deciduous tree
Arrowwood Viburrium	Deciduous shrub
Bald Cypress	Deciduous tree
Black Ash	Deciduous tree
Black Gum	Deciduous tree
Black Willow	Deciduous tree
Buttonbush	Deciduous shrub
Eastern Cottonwood	Deciduous tree
Elderberry	Deciduous shrub
Larch	Coniferous tree
Pin Oak	Deciduous tree
Red Maple	Deciduous tree
River Birch	Deciduous tree
Shadowbush	Deciduous shrub
Silky Dogwood	Deciduous tree
Slippery Elm	Deciduous tree
Smooth Alder	Deciduous tree
Swamp White Oak	Deciduous tree
Sweetgum	Deciduous tree
Winterberry	Deciduous shrub
Witch Hazel	Deciduous shrub

Herbaceous Plants:

Big Bluestem	Perimeter
Birdfoot deervetch	Perimeter
Blue Joint	Emergent
Broomsedge	Perimeter
Cardinal Flower	Perimeter
Fowl Bluegrass	Emergent
Green Bulrush	Emergent
Redtop	Perimeter
Tufted Hairgrass	Perimeter
Smartweed	Emergent
Soft Rush	Emergent
Swamp Aster	Emergent
Water Plantain	Emergent

ZONE 5 – Upland Terraces within Pond / Wetland Systems

Trees and shrubs:

American Elm	Deciduous tree
Bayberry	Deciduous shrub
Black Ash	Deciduous tree
Black Cherry	Deciduous tree
Black Gum	Deciduous tree
Black Willow	Deciduous tree
Buttonbush	Deciduous shrub
Eastern Cottonwood	Deciduous tree
Eastern Hemlock	Coniferous tree
Elderberry	Deciduous shrub
Green ash	Deciduous tree
Pin Oak	Deciduous tree
Red Maple	Deciduous tree
River Birch	Deciduous tree
Shadowbush	Deciduous shrub
Silky Dogwood	Deciduous tree
Slippery Elm	Deciduous tree
Smooth Alder	Deciduous tree
Swamp White Oak	Deciduous tree
Sweetgum	Deciduous tree
Winterberry	Deciduous shrub
Witch Hazel	Deciduous shrub

Herbaceous Plants:

Annual Ryegrass	Perimeter
Big Bluestem	Perimeter
Cardinal Flower	Perimeter
Creeping Red Fescue	Perimeter
Redtop	Perimeter
Switchgrass	Perimeter

ZONE 6 – Upland Slopes

Trees and shrubs:

American Elm	Deciduous tree
Bayberry	Deciduous shrub
Black Cherry	Deciduous tree
Eastern Hemlock	Coniferous tree
Eastern Red Cedar	Coniferous tree
Elderberry	Deciduous shrub
Pin Oak	Deciduous tree
Red Maple	Deciduous tree

Shadowbush	Deciduous shrub
Trees and shrubs:	
Sweetgum	Deciduous tree
White Ash	Deciduous tree

Herbaceous Plants:

Birdfoot deervetch	Perimeter
Cardinal Flower	Perimeter
Switchgrass	Perimeter

15.0 APPENDIX C - LOW IMPACT DEVELOPMENT RE-SOURCES

Low Impact Development Resources

A. Low Impact Development Center http://www.lowimpactdevelopment.org/

B. University of New Hampshire Stormwater Center http://www.unh.edu/erg/cstev/

C. Wisconsin Department of Natural Resources http://dnr.wi.gov/

D. Low Impact Development (LID) Urban Design Tools http://www.lid-stormwater.net/index.html

E. The Sustainable Site Initiative http://www.sustainablesites.org/

F. Environmental Protection Agency http://www.epa.gov/nps/lid/

G. Puget Sound Action Team http://www.psp.wa.gov/

H. Center for Watershed Protection http://www.cwp.org/

I. North Carolina State University Stormwater Engineering Group

http://www.bae.ncsu.edu/stormwater/

J. Chesapeake Stormwater Network http://www.chesapeakestormwater.net

16.0 APPENDIX D – UNH STORMWATER DESIGN SPECIFICATIONS

16.1 SUBSURFACE GRAVEL WETLANDS

UNIVERSITY OF NEW HAMPSHIRE
STORMWATER CENTER

UNHSC

Subsurface Gravel Wetland

Design Specifications

University of New Hampshire Stormwater Center (UNHSC)
Gregg Hall ● 35 Colovos Road ● Durham, New Hampshire 03824-3534 ● http://www.unh.edu/erg/cstev

UNHSC SUBSURFACE GRAVEL WETLAND DESIGN SPECIFICATIONS JUNE 2009

NOTICE

The specifications listed herein were developed by the UNHSC for UNHSC related projects and represent the author's best professional judgment. No assurances are given for projects other than the intended application. The design specifications provided herein are not a substitute for licensed, qualified engineering oversight and should be reviewed, and adapted as necessary and on full recognition of site specific conditions.

ACKNOWLEDGEMENTS

These specifications were developed at the University of New Hampshire Stormwater Center (UNHSC), of Durham, New Hampshire. The principal UNH authors are Robert M. Roseen, PE, Ph.D., and Thomas P. Ballestero, PE, Ph.D., PH, CGWP, PG. The contractor who constructed the original system in 2004 at the University of New Hampshire field site was Mike Alesse of East Coast Excavating. Other contributions to the project were made by James Houle, UNHSC Program Manager. Special recognition goes to Mr. Richard Claytor of the Horsley Witten Group (and formerly the Center for Watershed Protection) for his immense influence on improved stormwater management and for largely starting the use of gravel wetlands for stormwater applications.

The UNH Stormwater Center is housed within the Environmental Research Group (ERG) at the University of New Hampshire (UNH) in Durham, New Hampshire. Funding for the program was and continues to be provided by the Cooperative Institute for Coastal and Estuarine Environmental Technology (CICEET) and the National Oceanic and Atmospheric Administration (NOAA).

Robert M. Roseen, PE., PhD.
Director, UNHSC
Phone: 603-862-4024
robert.roseen@unh.edu

Thomas P. Ballestero, PE, PhD
Senior Scientist, Principal Investigator
Phone: 603-862-4024
tom.ballestero@unh.edu

James J. Houle, CPSWQ
Program Manager, Outreach Coordinator
Phone: 603-767-7091
james.houle@unh.edu

University of New Hampshire Stormwater Center (UNHSC)
Gregg Hall ● 35 Colovos Road ● Durham, New Hampshire 03824-3534 ● http://www.unh.edu/erg/cstev

UNH STORMWATER CENTER
SUBSURFACE GRAVEL WETLAND
JUNE 2009

DESIGN SUMMARY

Category Type: Filtration system and stormwater wetland

Layout Description

The subsurface gravel wetland (SGW) is designed as a series of horizontal flow-through treatment cells, preceded by a sedimentation basin (forebay) (Figure 1). The device is designed to retain and filter the entire Water Quality Volume (WQV): 10% in the forebay, and 45% in each of the respective treatment cells. For small, frequent storms, each treatment cell filters 100% of the WQV. The SGW is designed as flow through treatment, where the stormwater passes through a gravel substrate that is a microbe rich environment. The device can be designed with a multi-staged outlet control to detain the Channel Protection Volume (CPV) and allow overflow for larger storms. By design, the WQV is contained and filtered then drains to stormwater conveyance or receiving waters. All surface basin (and forebay) side slopes are 3:1 or flatter for maintenance. Standing water of significant depth is not expected other than during large rainfall events. The wetlands cell soils are to be continuously saturated below a depth of four inches (10 cm) from the ground surface in order to both promote water quality treatment conditions and support wetland vegetation. To force this near-surface ground water condition, the system primary outlet has an invert four inches (10 cm) below the wetland ground surface (see Figure 1). Vertical perforated or slotted risers deliver the forebay outflow to the gravel below. Within the gravel layer, horizontal subdrains distribute the incoming flow, which then passes through the gravel substrate to subdrains on the downstream end. These subdrains collect the flow and deliver it into the next cell. ***Hydraulic control of the system occurs at the primary outlet. For large precipitation events, this hydraulic control throttles the flow through the system and forces stormwater inflow to be temporarily stored above the wetland surfaces***. , By design, the ponded water slowly drains down into the gravel layer below and is filtered through this layer prior to leaving the system. Precipitation events larger than the WQV will have some portion that overflows to receiving waters through an emergency spillway. At a minimum this "spilled" water will have received minor treatment much as in a traditional detention pond/wetland system.

System Functionality

System functionality has multiple components. From a unit process perspective, sedimentation, filtration, physical and chemical sorption, microbially mediated transformation, and uptake and storage predominate. There is pre-treatment by a sedimentation forebay. This is followed by treatment above the wetland cells by sedimentation akin to a dry pond. In addition, there is water quality treatment during the flow through the wetland plants as well as the minor infiltration through the wetland soil to the gravel below. Finally and predominantly, within the gravel layer there is treatment involving filtration, sorption, uptake and storage, and microbially mediated transformation. The conversion and removal of nitrogen is dependent on two conditions: an aerobic sedimentation forebay followed by subsurface anaerobic treatment cells. Aerobic conditions exist in the forebay when it is designed *and maintained* as a dry area with temporary ponding conditions during storm events. The anaerobic condition in the treatment cells is created by maintaining the high water table within the system as well as the slow flow through the gravel layer. This saturated condition drives the dissolved oxygen level down and creates conditions in which nitrate conversion to nitrogen gas occurs.

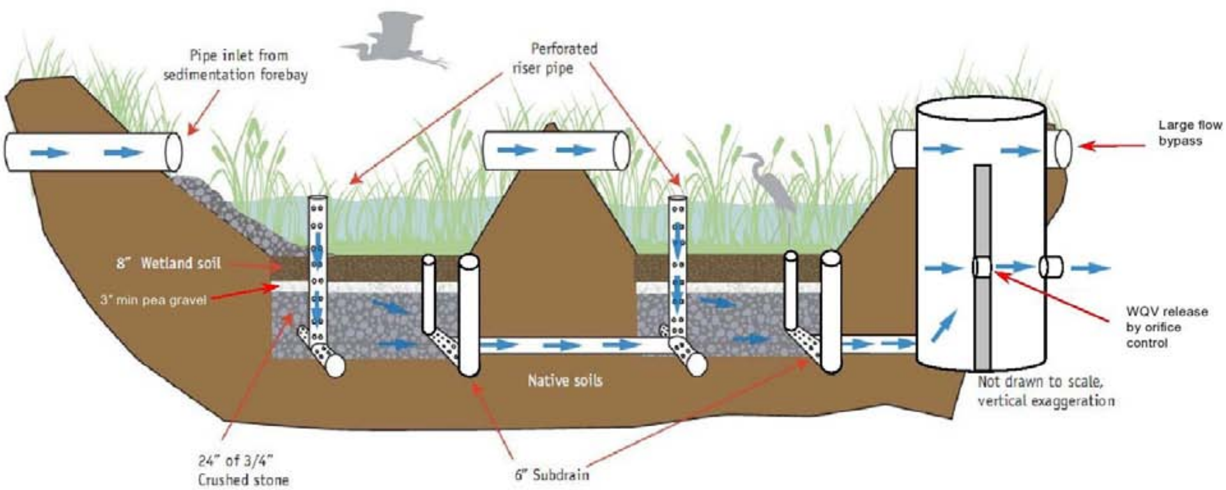
Retrofit Options

SGWs are well suited for retrofits within stormwater pond systems. These SGW systems are well suited because: 1) there is a limited hydraulic head requirement, 2) the SGW can be lined and does not require separation from groundwater, and 3) there is a straightforward placement of the system within the footprint of existing stormwater ponds. Hydraulic head requirements for gravel wetlands are approximately four inches (10 cm), whereas underdrained filtration systems may require as much as three feet (one meter) or more. Because the SGW is a horizontal porous media flow system it does require a hydraulic head to drive the water through the system. At a minimum, the driving head is the difference between the vertical distance from the ponded water level above the wetland surface and the invert of the primary outlet. To maintain the system in its saturated condition, it must be situated in low hydraulic conductivity soils or lined below the gravel layer. Because infiltration is not designed to occur, separation from groundwater is not required and the SGWs are sited much like stormwater ponds. While SGWs have a relatively large footprint for a stormwater quality treatment technology, they easily fit within the footprint of existing stormwater ponds that were sized for flood control. When retrofitting a SGW system into a stormwater pond, it is located towards the outlet of the pond. The area within the pond preceding the SGW is used for pretreatment. A wet pond retrofit would require a conversion to a dry pond by the elimination of the permanent pool.

SPECIFICATIONS SUMMARY

- May be preceded by pre-treatment: hydrodynamic separator, swale, forebay. Pre-treatment should normally be capable of holding 10% of the WQV.
- Two treatment cells.
- A subsurface water level is maintained through the design of the outlet invert elevation (invert just below the wetland soil surface).
- Retain and filter the entire Water Quality Volume (WQV), 10% in the forebay, and 45% above each of the respective treatment cells.
- Option to retain the Channel Protection Volume (CPV) for 24-48 hrs.
- No-geotextile or geofabric layers are used within this system, but may be used to line walls.
- If a native low hydraulic conductivity soil is not present below the desired location of the SGW, a low permeability liner or soil (hydraulic conductivity less than 10^{-5} cm/s = 0.03 ft/day) below the gravel layer should be used to minimize infiltration, preserve horizontal flow in the gravel, and maintain the wetland plants (Figure 2).
- Gravel length to width ratio of 0.5 (L:W) or greater is needed for each treatment cell with a minimum flow path (L) within the gravel substrate of 15 feet (4.6 m).
- 8 in. (20 cm) minimum thickness of a wetland soil as the top layer. (See description in Surface Infiltration Rates section for details (Figure 2)). This layer is leveled (constructed with a surface slope of zero).

Figure 1: Gravel Wetland—Concept Design



- 3 in. (8 cm) minimum thickness of an intermediate layer of a graded aggregate filter is needed to prevent the wetland soil from moving down into the gravel sub-layer. Material compatibility between layers needs to be evaluated.
- 24 in. (0.6 m) minimum thickness of ¾-in (2 cm) crushed-stone (gravel) sub-layer. This is the active zone where treatment occurs (Figure 2).
- The primary outlet invert shall be located 4" (10 cm) below the elevation of the wetland soil surface to control groundwater elevation. Care should be taken to not design a siphon that would drain the wetland: the primary outlet location must be open or vented. In contrast to Figure 1, the primary outlet can be a simple pipe.
- An optional high capacity outlet at equal elevation or lower to the primary outlet may be installed for maintenance. Thus outlet would need to be plugged during regular operation. This optional outlet allows for flushing of the treatment cells at higher flow rates. If it is located lower, it can be used to drain the system for maintenance or repairs.
- The Bypass outlet (emergency spillway, or secondary spillway) is sized to pass designs flows (10-year, 25-year, etc.). This outlet is sized by using conventional routing calculations of the inflow hydrograph through the surface storage provided by the subsurface gravel wetland system. Local criteria for peak flow reductions are then employed to size this outlet to meet those criteria.
- The primary outlet structure and its hydraulic rating curve are based on a calculated release rate by orifice control to drain the WQV in 24-48 hrs. For orifice diameter calculations refer to the NY Stormwater Manual (2001) or HDS 5 (FHWA, 2005) for details.
- The minimum spacing between the subsurface perforated distribution line and the subsurface perforated collection drain (see Figure 1) at either end of the gravel in each treatment cell is 15 ft (4.6 m): there should be a minimum horizontal travel distance of 15 ft (4.6 m) within the gravel layer in each cell.
- Vertical perforated or slotted riser pipes deliver water from the surface down to the subsurface, perforated or slotted distribution lines. These risers shall have a maximum spacing of 15 feet (4.6 m) (Figure 1). Oversizing of the perforated or slotted vertical risers is useful to allow a margin of safety against clogging with a minimum recommended diameter of 12" (30 cm) for the central riser and 6" (15 cm) for end risers. The vertical risers shall not be capped, but rather covered with an inlet grate to allow for an overflow when the water level exceeds the WQV.
- Vertical cleanouts connected to the distribution and collection subdrains, at each end, shall be perforated or slotted only within the gravel layer, and solid within the wetland soil and storage area above. This is important to prevent short-circuiting and soil piping.
- Berms and weirs separating the forebay and treatment cells should be constructed with clay, or non-conductive soils, and/or a fine geotextile, or some combination thereof, to avoid water seepage and soil piping through these earthen dividers.
- The system should be planted to achieve a rigorous root mat with grasses, forbs, and shrubs with obligate and facultative wetland species. In northern climates refer to the NY Stormwater Manual (http://www.dec.state.ny.us/website/dow/toolbox/swmanual/) or approved equivalent local guidance for details on local wetland plantings.
- Standard design approach for stormwater ponds should be followed as per the NY Stormwater Manual (2001) or approved equal with regards to forebay, spillways, bypass,

side slopes, erosion control, use of rip rap for stabilized regions at outlets and other locations of concentrated flow. etc.

SURFACE INFILTRATION RATES AND HYDROGEOLOGIC MATERIALS

Wetland Soil

The surface infiltration rates of the gravel wetland soil should be similar to a low hydraulic conductivity wetland soil (0.1-0.01 ft/day = 3.5 x 10^{-5} cm/sec to 3.5 x 10^{-6} cm/sec)). 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.

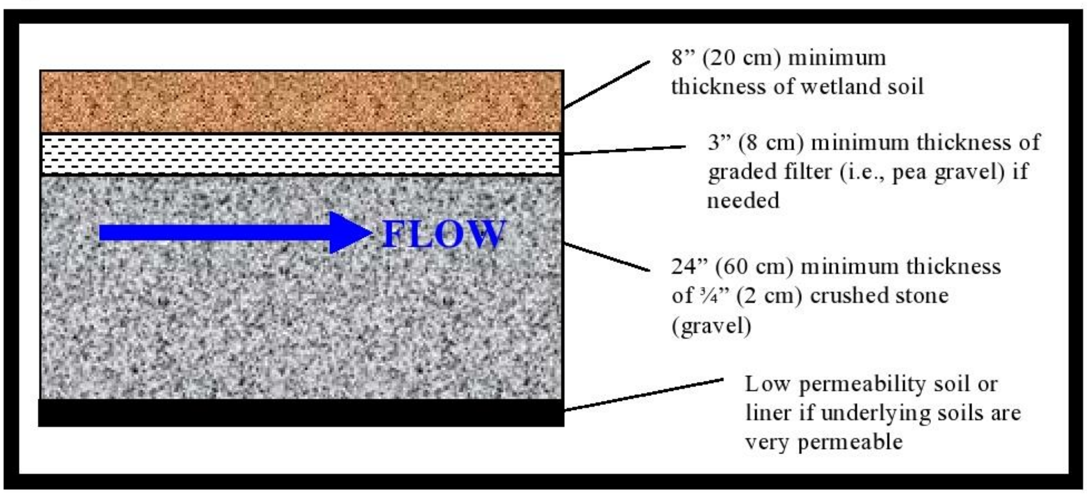
An intermediate layer of a graded aggregate filter (i.e., pea gravel) is needed to prevent the wetland soil from migrating down into the crushed-stone (gravel) sub-layer. This is to prevent migration of the finer setting bed (wetland soil) into the coarse sublayer. Material compatibility should be evaluated using FHWA criteria (see Ferguson, 2005):

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

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

Below the wetland soil and pea gravel is a crushed stone (gravel) sublayer with a 24 in. (0.6 m) minimum thickness. Angular crushed stone 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.

Figure 2: Gravel Wetland Materials Cross -Section



Native Materials and Liner
If native 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 wetland plants. If geotechnical tests confirm the need for a liner, acceptable options include: (a) 6 to 12 inches (15 – 30 cm) of clay soil (minimum 15% passing the #200 sieve and a minimum permeability of 1×10^{-5} cm/sec), (b) a 30 ml HDPE liner, (c) bentonite, (d) use of chemical additives (see NRCS Agricultural Handbook No. 386, dated 1961, or Engineering Field Manual), or (e) a design prepared by a Professional Engineer.

DESIGN SOURCES
The primary design sources for the development of the subsurface gravel wetland are listed below, in the order of use.

- University of New Hampshire Stormwater Center 2002, http://www.unh.edu/erg/cstev//
- Claytor, R. A., and Schueler, T. R. (1996). Design of Stormwater Filtering Systems, Center for Watershed Protection, Silver Spring, MD.
- Georgia Stormwater Management Manual, Volume 2: Technical Handbook, August 2001, prepared by AMEC Earth and Environmental, Center for Watershed Protection, Debo and Associates, Jordan Jones and Goulding, Atlanta Regional Commission.
- New York State Stormwater Management Design Manual, October 2001, prepared by Center for Watershed Protection, 8391 Main Street, Ellicott City, MD 21043, for New York State, Department of Environmental Conservation, 625 Broadway, Albany, NY 12233.

MAINTENANCE
Maintenance and Inspection Recommendations are largely adapted from CTDEP (2004) Stormwater Quality Manual for filtration systems. Inspection schedules have two periods: i) 1st Year Post-Construction, ii) Post-Construction Routine Monitoring. Maintenance is critical for the proper operation of subsurface gravel wetland systems. 1st Year Post-Construction monitoring differs primarily by its increased frequency to assure proper vegetative establishment and system functioning. Post-Construction Routine Monitoring is based on USEPA requirements for Good Housekeeping practices.

Unlike other filtration systems, a subsurface gravel wetland is a subsurface, horizontal filtration system and does not rely upon the surface soils for treatment. As such, surface infiltration rates are expected to be low and are not used for the criteria for cleaning/maintenance. Rather, stormwater access to the subsurface gravel layer is the critical hydraulic performance measure.

Inspection and Maintenance

❍ ***1st Year Post-Construction:*** Inspection frequency should be after every major storm in the first year following construction.

- ❑ Inspect to be certain system drains within 24-72 hrs (within the design period, but also not so quickly as to minimize stormwater treatment)).
- ❑ Watering plants as necessary during the first growing season
- ❑ Re-vegetating poorly established areas as necessary
- ❑ Treating diseased vegetation as necessary
- ❑ Quarterly inspection of soil and repairing eroded areas, especially on slopes
- ❑ Checking inlets, outlets, and overflow spillway for blockage, structural integrity, and evidence of erosion.

❍ ***Post-Construction:*** Inspection frequency should be at least every 6 months thereafter, as per USEPA Good House-Keeping Requirements. Inspection frequency can be reduced to annual following 2 years of monitoring that indicates the rate of sediment accumulation is less than the cleaning criteria listed below. Inspections should focus on:

- ❑ Checking the filter surface for dense, complete, root mat establishment across the wetland surface. Thorough revegetation with grasses, forbs, and shrubs is necessary. Unlike bioretention, where mulch is commonly used, complete surface coverage with vegetation is needed.
- ❑ Checking the gravel wetland surface for standing water or other evidence of riser clogging, such as discolored or accumulated sediments.
- ❑ Checking the sedimentation chamber or forebay for sediment accumulation, trash, and debris.
- ❑ Inspect to be certain the sedimentation forebay drains within 24 to 72 hrs.
- ❑ Checking inlets, outlets, and overflow spillway for blockage, structural integrity, and evidence of erosion.
- ❑ Removal of decaying vegetation, litter, and debris.

❍ ***Cleaning Criteria for Sedimentation Forebay***: Sediment should be removed from the sedimentation chamber (forebay) when it accumulates to a depth of more than 12 inches (30 cm) or 10 percent of the pretreatment volume. The sedimentation forebay should be cleaned of vegetation if persistent standing water and wetland vegetation becomes dominant. The cleaning interval is approximately every 4 years. A dry sedimentation forebay is the optimal condition while in practice this condition is rarely achieved. The sedimentation chamber, forebay, and treatment cell outlet devices should be cleaned when drawdown times exceed 60 to 72 hours. Materials can be removed with heavy construction equipment; however this equipment should not track on the wetland surface. Revegetation of disturbed areas as necessary. Removed sediments should be dewatered (if necessary) and disposed of in an acceptable manner.

❍ ***Cleaning Criteria for Gravel Wetland Treatment Cells***: Sediment should be removed from the gravel wetland surface when it accumulates to a depth of several inches (>10 cm) across the wetland surface. Materials should be removed with rakes rather than heavy construction equipment to avoid compaction of the gravel wetland surface. Heavy equipment could be used if the system is designed with dimensions that allow equipment to be located outside the gravel wetland, while a backhoe shovel reaches inside the gravel wetland to remove sediment. Removed sediments should be dewatered (if necessary) and disposed of in an acceptable manner.

❍ ***Draining and Flushing Gravel Wetland Treatment Cells***: For maintenance it may be necessary to drain or flush the treatment cells. The optional drains will permit simpler maintenance of the system if needed. The drains need to be closed during standard operation. Flushing of the risers and horizontal subdrains is most effective with the entire system drained. Flushed water and sediment should be collected and properly disposed.

REFERENCES

- Center for Watershed Protection (CWP). 2001. The Vermont Stormwater Management Manual – Public Review Draft. Prepared For Vermont Agency of Natural Resources.
- CTDEP (2004). Connecticut Stormwater Quality Manual. Hartford, CT.
- Ferguson, B. K. (2005). *Porous Pavements*, CRC Press.
- FHWA. (2005). "Hydraulic Design of Highway Culverts (HDS-5)." *NHI-01-020*, Federal Highway Administration.
- Hepting, G. H., 1971, Diseases of Forest and Shade Trees of the United States, USDA Agricultural Handbook No. 386, USDA, Washington, DC
- New York State Stormwater Management Design Manual, October 2001, prepared by Center for Watershed Protection, 8391 Main Street, Ellicott City, MD 21043, for New York State, Department of Environmental Conservation, 625 Broadway, Albany, NY 12233.
- UNHSC, Roseen, R., T. Ballestero, and Houle, J. (2007). "UNH Stormwater Center 2007 Annual Report." University of New Hampshire, Cooperative Institute for Coastal and Estuarine Environmental Technology, Durham, NH.
- USDA, 1979, Engineering field manual for conservation practices, U.S. Dept. of Agriculture, Soil Conservation Service, Washington, D.C.

16.2 PERMEABLE PAVEMENT

UNIVERSITY OF NEW HAMPSHIRE
STORMWATER CENTER

UNHSC Design Specifications for Porous Asphalt Pavement and Infiltration Beds

Rev. October 2009

University of New Hampshire Stormwater Center (UNHSC)
Gregg Hall ● 35 Colovos Road ● Durham, New Hampshire 03824-3534 ● http://www.unh.edu/erg/cstev

UNHSC DESIGN SPECIFICATIONS FOR POROUS ASPHALT PAVEMENT AND INFILTRATION BEDS

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NOTICE

The specifications listed herein were developed by the UNHSC for UNHSC related projects and represent the author's best professional judgment. No assurances are given for projects other than the intended application. These design specifications are not a substitute for licensed, qualified engineering oversight and should be reviewed, and adapted as necessary.

ACKNOWLEDGEMENTS

The original 2007 specifications were completed by collaboration between the University of New Hampshire, of Durham, New Hampshire, and Pike Industries Inc., of Belmont, New Hampshire. The principal UNH authors were Joshua F. Briggs, Robert M. Roseen, PE, PhD, and Thomas P. Ballestero, PE, PhD, PH, CGWP, PG. The principal author from Pike Industries was the Corporate Quality Control Manager, Jeff Pochily. Other contributions to the project were made by Grant Swenson, also of Pike Industries. The revised specifications (2009) were prepared by the UNHSC after a round table discussion with New Hampshire Asphalt Manufacturers (Rick Charbonneau, Mark Charbonneau, and Keith Dane of Continental Paving, Jeff Lewis of Brox Industries, and Mary Wescott, Dave Duncan, and Jeff Pochily of Pike Industries) and a round table discussion with design engineers. The 2009 specifications were also reviewed and revised by Antonio P. Ballestero, Jr., PE.

The UNH Stormwater Center is housed within the Environmental Research Group (ERG) at the University of New Hampshire (UNH) in Durham, New Hampshire. Funding for the program was and continues to be provided by the Cooperative Institute for Coastal and Estuarine Environmental Technology (CICEET) and the National Oceanic and Atmospheric Administration (NOAA).

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Gregg Hall ● 35 Colovos Road ● Durham, New Hampshire 03824-3534 ● http://www.unh.edu/erg/cstev

PART 1 GENERAL

1.1 DESCRIPTION

A. This specification is intended to be used for porous asphalt pavement in parking lot applications. Stormwater management functions of porous asphalt installations include water quality treatment, peak flow reduction, storm volume reduction via groundwater recharge, and increased hydrograph time lag. This specification is intended for a cold climate application based upon the field experience at the UNHSC porous asphalt parking lot located in Durham, New Hampshire, however the specification can be adapted to projects elsewhere provided that selection of materials and system design reflects local conditions, constraints, and objectives.

B. The work of this Section includes subgrade preparation, installation of the underlying porous media beds, and porous asphalt mix (mix) design, production, and installation. Porous media beds refer to the material layers underlying the porous asphalt pavement. Porous asphalt pavement refers to the compacted mix of modified asphalt, aggregate, and additives.

C. The porous asphalt pavement specified herein is modified after the National Asphalt Pavement Association (NAPA) specification outlined in *Design, Construction, and Maintenance Guide for Porous Asphalt Pavements, Information Series 131* (2003) and *Design, Construction, and Maintenance of Open-Graded Friction Courses, Information Series 115* (2002).

D. Alternative specifications for mix, such as Open Graded Friction Courses (OGFC) from Federal Agencies or state Departments of Transportation (DOT), may be used if approved by the Engineer. The primary requirements for the specifications of the mix are performance grade (PG) asphalt binder, binder content, binder draindown, aggregate gradation, air void content, retained tensile strength (TSR).

1.2 SUBMITTALS

A. Submit a list of materials proposed for work under this Section including the name and address of the materials producers and the locations from which the materials are to be obtained.

B. Submit certificates, signed by the materials producers and the relevant subcontractors, stating that materials meet or exceed the specified requirements, for review and approval by the Engineer.

C. Submit samples of materials for review and approval by the Engineer. For mix materials, samples may be submitted only to the QA inspector with the Engineer's approval.

D. Submittal requirements for samples and certificates are summarized in 1.3 QC/*QA*

A. Use adequate numbers of skilled workers who are thoroughly trained and experienced in the necessary crafts and who are completely familiar with the specified requirements and the methods needed for proper performance of the work in this section.

B. Codes and Standards - All materials, methods of construction and workmanship shall conform to applicable requirements of AASHTO ASTM Standards, NHDOT Standard Specifications for

Road and Bridge Construction, latest revised (including supplements and updates), or other standards as specified.

C. QC/QA requirements for production of mix are discussed in the Materials section, and for construction of the porous media beds and paving in the Execution section.

E. Table 1 and discussed in further detail in the Materials section.

1.3 QC/QA

D. Use adequate numbers of skilled workers who are thoroughly trained and experienced in the necessary crafts and who are completely familiar with the specified requirements and the methods needed for proper performance of the work in this section.

E. Codes and Standards - All materials, methods of construction and workmanship shall conform to applicable requirements of AASHTO ASTM Standards, NHDOT Standard Specifications for Road and Bridge Construction, latest revised (including supplements and updates), or other standards as specified.

F. QC/QA requirements for production of mix are discussed in the Materials section, and for construction of the porous media beds and paving in the Execution section.

Table 1. Submittal requirements.

Material or Pavement Course*	Properties to be reported on Certificate**
choker course, reservoir course	gradation, max. wash loss, min. durability index, max. abrasion loss, air voids (reservoir course)
filter course	gradation, permeability/ sat. hydraulic conductivity
filter blanket	gradation
geotextile filter fabric	manufacturer's certification, AOS/EOS, tensile strength
striping paint	certificate
binder	PGAB certification
coarse aggregate	gradation, wear, fracture faces (fractured and elongated)
fine aggregate	gradation,
silicone	manufacturer's certification
Fibers (optional)	manufacturer's certification
mineral filler (optional)	manufacturer's certification
fatty amines (optional anti-strip)	manufacturer's certification
hydrated lime (optional anti-strip)	manufacturer's certification

* Samples of each material shall be submitted to the Engineer (or QA inspector for mix). These samples must be in sufficient volume to perform the standardized tests for each material.
** At a minimum, more material properties may be required (refer to Materials Section).

1.4 PROJECT CONDITIONS

A. <u>Site Assessment</u> should be performed per the steps outlined in *IS 131* (NAPA, 2003).

B. Construction Phasing should be performed as outlined in IS 131 (NAPA, 2003).

C. Protection of Existing Improvements
   1. Protect adjacent work from the unintended dispersal/splashing of pavement materials. Remove all stains from exposed surfaces of pavement, structures, and grounds. Remove all waste and spillage. If necessary, limit access to adjacent work/structures with appropriate signage and/or barriers.
   2. Proper erosion and sediment control practices shall be provided in accordance with existing regulations. Do not damage or disturb existing improvements or vegetation. Provide suitable protection where required before starting work and maintain protection throughout the course of the work. This includes the regular, appropriate inspection and maintenance of the erosion and sediment control measures.
   3. Restore damaged areas, including existing pavement on or adjacent to the site that has been damaged as a result of construction work, to their original condition or repair as directed to the satisfaction of the Engineer at no additional cost.

D. Safety and Traffic Control
   1. Notify and cooperate with local authorities and other organizations having jurisdiction when construction work will interfere with existing roads and traffic.
   2. Provide temporary barriers, signs, warning lights, flaggers, and other protections as required to assure the safety of persons and vehicles around and within the construction area and to organize the smooth flow of traffic.

E. Weather Limitations
   1. Porous asphalt, Open graded friction course, or dense-mixed asphalt shall not be placed between November 15 and March 15, or when the ambient air temperature at the pavement site in the shade away from artificial heat is below 16 °C (60 °F) or when the actual ground temperature is below 10 °C (50 °F). Only the Engineer may adjust the air temperature requirement or extend the dates of the pavement season.
   2. The Contractor shall not pave on days when rain is forecast for the day, unless a change in the weather results in favorable conditions as determined by the Engineer.

1.5 REFERENCES

A. *General Porous Asphalt Bituminous Paving and Groundwater Infiltration Beds,* specification by UNH Stormwater Center, February, 2005.

B. *Design, Construction, and Maintenance Guide for Porous Asphalt Pavements, Information Series 131*, National Asphalt Pavement Association (NAPA), 2003.

C. *Design, Construction, and Maintenance of Open-Graded Friction Courses, Information Series 115*, NAPA, 2002.

D. *Annual Book of ASTM Standards*, American Society for Testing and Materials, Philadelphia, PA, 1997 or latest edition.

E. *Standards of the American Association of State Highway and Transportation Officials* (AASHTO), 1998 or latest edition.

F. *Section 401- Plant Mix Pavements – General*, in *Standard Specifications for Road and Bridge Construction – State of New Hampshire Department of Transportation*, 2006.

G. *Section 02725 - General Porous Pavement and Groundwater Infiltration Beds*, specification from NAPA Porous Asphalt Seminar handout, Cahill Associates, Inc., 2004.

H. *Correlations of Permeability and Grain Size*, Russell G. Shepherd, Groundwater 27 (5), 1989.

I. *Groundwater*, R. Allan Freeze and John A. Cherry, 1979.

PART 2 PRODUCTS

2.1 MATERIALS

A. Porous Media Infiltration Beds

Below the porous asphalt itself are located the porous media infiltration beds (Figure 1), from top to bottom: a 4" – 8 "(10 - 20 cm) (minimum) thick layer of choker course of crushed stone (8" is preferable to alleviate compaction issues with the porous asphalt); an 8" to 12" (20 cm to 30 cm) minimum thickness layer of filter course of poorly graded sand (a.k.a. bankrun gravel or modified 304.1); 3" (8 cm) minimum thickness filter blanket that is an intermediate setting bed (pea gravel); and a reservoir course of crushed stone, thickness dependant 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, perforated or slotted drain pipe is located in the stone reservoir course for drainage. This drain pipe can be daylighted to receiving waters or connected into other stormwater management infrastructure (wetland, storm sewer, etc.). The fine gradation of the filter course is for enhanced filtration and delayed infiltration. The high air void content of the uniformly graded crushed stone reservoir course: maximizes storage of infiltrated water thereby allowing more time for water to infiltrate between storms; and creates a capillary barrier that arrests vertical water movement and in doing so prevents winter freeze-thaw and heaving. The filter blanket is placed to prevent downward migration of filter course material into the reservoir course. The optional underdrain in the reservoir course is for hydraulic relief (typically raised off of the bottom of the reservoir stone layer for enhanced groundwater recharge). Nonwoven geotextile filter fabric (geotextile) is used only for stabilizing the sloping sides of the porous asphalt system excavation and not to be used on the bottom of the system unless needed for structural reasons.

1. Choker Course

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

Maximum Wash Loss of 0.5%
Minimum Durability Index of 35
Maximum Abrasion Loss of 10% for 100 revolutions, and maximum of 50% for 500 revolutions.

Material for the choker course and reservoir course shall have the AASHTO No. 57 and AASHTO No. 3 gradations, respectively, as specified in

Table 2. If the AASHTO No. 3 gradation cannot be met, AASHTO No. 5 is acceptable with approval of the Engineer. AASHTO no. 3 is also suitable for the choker course.

2. 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 commonly referred to as a bankrun gravel (modified NHDOT 304.1). 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 Estimation of Saturated Hydraulic Conductivity* (Freeze and Cherry, 1979). The hydraulic conductivity should be determined by ASTM D2434 and reported to the Engineer.

3. Filter blanket material

Filter blanket 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.

4. Reservoir Coarse

Reservoir Coarse thickness is dependent upon the following criteria (that vary from site to site):

a. A 4" (10 cm) minimum thickness of reservoir course acts as a capillary barrier for frost heave protection. The reservoir course is located at the interface between subbase and native materials.

b. 4-in. (10 cm) minimum thickness if the underlying native materials are either well drained (Hydrologic Group A soils).

c. 8-in. (30 cm) minimum thickness if subdrains are installed. Subdrains insure that the subbase is well drained

d. Subdrains, if included, are elevated a minimum of 4" (10 cm) from the reservoir course bottom to provide storage and infiltration for the water quality volume. If the system is lined ,

e. Subbase thickness is determined from subbase materials having sufficient void space to store the design storm,

> **Example:** If the 25-year storm is 5.1" (13 cm) of rainfall depth, and the reservoir void space is 30%, then the minimum subbase thickness = 5.1"/0.3 = 17" (43.2 cm).

f. Pavement system and subbase thickness are ≥ 0.65 * design frost depth for area.

Example: Durham, New Hampshire, 48" (122 cm) = $D_{maximum\ frost}$, therefore the *minimum* depth to the bottom of the subbase = 0.65(48") = 32" (81 cm).

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:

a. 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.). In such cases, the systems can be lined to prevent infiltration yet still preserving water quality, hydrograph lag, and peak flow reduction benefits.

b. Refer to state or USEPA guidelines regarding the use of infiltration systems (USEPA, 1999, CalTrans, 2003, WI DNR, 2004, USEPA, 2004)

c. Suitable liners may include Hydrologic Group D soils, HDPE liners, or suitable equivalent. Refer to state or USEPA guidelines regarding selection of impermeable liners (USEPA, 2004).

d. 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.

e. 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.

Figure 1: Typical Parking Area Cross-Section for Pervious Pavement System

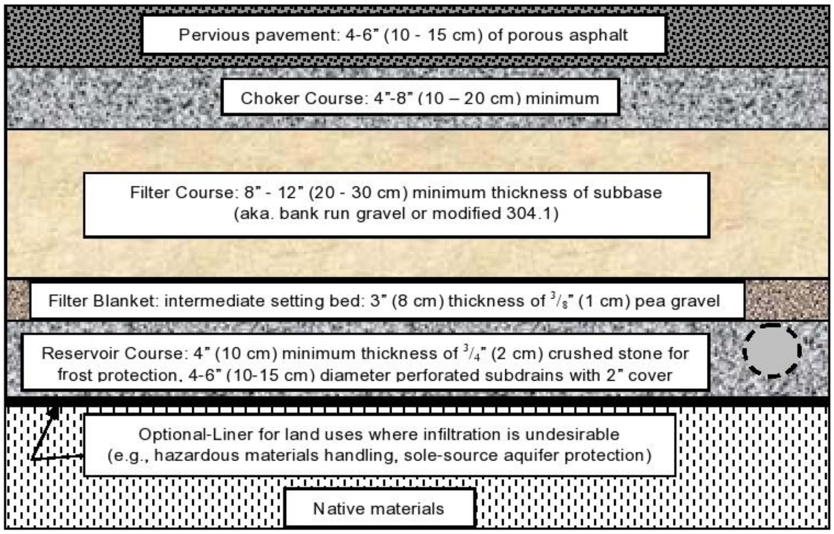
Pervious pavement: 4-6" (10 - 15 cm) of porous asphalt
Choker Course: 4"-8" (10 – 20 cm) minimum
Filter Course: 8" - 12" (20 - 30 cm) minimum thickness of subbase
(aka. bank run gravel or modified 304.1)
Filter Blanket: intermediate setting bed: 3" (8 cm) thickness of 3/8" (1 cm) pea gravel
Reservoir Course: 4" (10 cm) minimum thickness of 3/4" (2 cm) crushed stone for
frost protection, 4-6" (10-15 cm) diameter perforated subdrains with 2" cover
Optional-Liner for land uses where infiltration is undesirable
(e.g., hazardous materials handling, sole-source aquifer protection)
Native materials

Table 2. Gradations and compaction of choker, filter, and reservoir course materials.

US Standard Sieve Size Inches/mm	Percent Passing (%)			
	Choker Course (AASHTO No. 57)	Filter Course (Modified NHDOT 304.1)	Reservoir Course (AASHTO No. 3)	Reservoir Course Alternative* (AASHTO No. 5)
6/150	-	100	-	
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	-		-	0 - 5
#4/4.75	0 - 10	70-100	-	
#8/2.36	0 - 5		-	
#200/0.075		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

6. <u>Non-woven geotextile filter fabric</u>

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 3. 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.

7. <u>Alternative Applications and Residential Driveways</u>.
The recommendations above are based on a commercial parking application for both traffic and contaminant load. Alternative applications such as residential driveways and low use applications may justify the use of alternative subbase thicknesses for the porous media beds, filter blanket, and geotextiles. Residential driveway applications have been designed with a subbase limited to only an 8" compacted choker course. Variations should consider structural load requirements for material thickness, and contaminant load for filter course thickness. A reduced total system thickness (Section 2.1.3.f) will subject the pavement to greater freeze thaw susceptibility.

Table 3. Non-woven geotextile filter fabric 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

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)

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

B. Porous Asphalt Mix

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.

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 5

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:

a. PG 64-28 with 5 pounds of fibers per ton of asphalt mix. This mix is recommended for smaller projects with lower traffic counts or loading potential. This mix is manageable at common batch plants.
b. Pre-Blended PG 64-28 SBS with 5 pounds of fibers per ton of asphalt mix. This mix is recommended for large projects > 1acre where high durability pavements are needed. The SBS will be supplied by an approved PGAB supplier holding a Quality Control Plan approved by the state DOT. A Bill of Lading (BOL) will be delivered with each transport of PG 64-28 SBS. A copy of the BOL will be furnished to the QA inspector at the Plant.

c. Post-Blended PG 64-28 SBR with 5 pounds of fibers per ton of asphalt mix. This mix is recommended for projects where high durability pavements are needed. The SBR will be supplied by a HMA plant approved to perform in-line blending or blending by injection into the pugmill. A Post-Blended SBR Binder Quality Control Plan (Table 4) will be submitted to the Engineer for approval at least 10 working days prior to production.

d. Pre-Blended PG 76-22 modified with SBS and 5 pounds of fibers per ton of asphalt mix. 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 the state DOT. A Bill of Lading (BOL) will be delivered with each transport of PG 76-22 SBS. A copy of the BOL will be furnished to the QA inspector at the Plant.

e. Post-Blended PG 76-22 modified with SBR and 5 pounds of fibers per ton of asphalt mix. This mix is recommended for large sites anticipating high wheel load (H-20) and traffic counts for maximum durability. The SBR will be supplied by a HMA plant approved to perform in-line blending or blending by injection into the pugmill. A Post-Blended SBR Binder Quality Control Plan (Table 4) will be submitted to the Engineer for approval at least 10 working days prior to production.

f. Quality control plans may be altered at the discretion of the Engineer and based on feasible testing as suggested by the asphalt producer. Certain QC testing requirements during production may not be feasible for small projects in which limited asphalt is generated. Some testing methods cannot be completed during the time needed during small batch (less than approximately 50 tons of porous asphalt mix) production. The feasibility should be assessed with the Engineer and producer.

Table 4. Post-Blended SBR Binder QC Plan requirements.

The QC Plan will contain:
1. Company name and address
2. Plant location and address
3. Type of Facility
4. Contact information for the Quality Control Plan Administrator
5. QC Tests to be performed on each PGAB
6. Name(s) of QC Testing Lab to perform QC and Process Control testing.
7. Actions to be taken for PG Binders and SBR in Non compliance
8. List of mechanical controls (requirements below)
9. List of process controls and documentation (requirements below)
List of Mechanical Controls
1. Liquid SBR no-flow alert system with an "alert" located in the control room and automatic documentation of a no flow situation on the printout
2. Provide means of calibrating the liquid SBR metering system to a delivery tolerance of 1%.
3. A batching tolerance at the end of each day's production must be within 0.5% of the amount of SBR solids specified.
4. Mag-flow meter (other metering system may be considered)
5. Method of sampling liquid SBR
List of Process Controls and Documentation
1. Printouts of liquid SBR and PG binder quantities must be synchronized within one minute of each other
2. SBR supplier certification showing the percent of SBR solids in liquid SBR
3. Test results of a lab sample blended with the specified dosage of SBR. At a minimum, provide the name of the PGAB and liquid SBR suppliers, and PGAB information such as grade and lot number, and SBR product name used for the sample.
4. MSDS sheet for liquid SBR
5. Handling, storage, and usage requirements will be followed as required by the liquid SBR manufacturer
6. At a minimum, provide a table showing proposed rate of SBR liquid (L/min.) in relation to HMA production rate (tons per hour, TPH) for the % solids in liquid SBR, quantity of SBR specified for HMA production, and the specific gravity of the SBR.
7. QCT or QC Plan Administrator must be responsible for documenting quantities, ensuring actual use is within tolerance, etc. All printouts, calculations, supplier certifications etc. must be filed and retained as part of the QCTs daily diary/reports.
8. Method and Frequency of testing at the HMA plant, including initial testing and specification testing.

*This Plan shall be submitted to the Engineer 10 days before production.

3. Anti-Stripping Mix Additives.

The mix shall be tested for moisture susceptibility and asphalt stripping from the aggregate by AASHTO T283. 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/m3 (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 DOT specification and NAPA IS 115.

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 a not more than 8.0% of flat or elongated pieces (>3:1) as specified in ASTM D4791.

5. Fine Aggregate.

The fine aggregate shall be that part of the aggregate mixture passing the No. 8 sieve and 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.

6. Porous Asphalt Mix Design Criteria.

The Contractor shall submit a mix design at least 10 working days prior to the beginning of production. The Contractor shall make available samples of coarse aggregate, fine aggregate, mineral filler, fibers and a sample of the PGAB that will be used in the design of the mixture. A certificate of analysis (COA) of the PGAB will be submitted with the mix design. The COA will be certified by a laboratory meeting the requirements of AASHTO R18. The Laboratory will be certified by the state DOT, regional equivalent (e.g. NETTCP), and/or qualified under ASTM D3666. Technicians will be certified by the regional certification agency (e.g. NETTCP) in the discipline of HMA Plant Technician.

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 5.

Table 5: 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	5-10
No.200/0.075 (#200)	2-4
Binder Content (AASHTO T164)	6 - 6.5%
Fiber Content by Total Mixture Mass	0.3% cellulose or 0.4% mineral
Rubber Solids (SBR) Content by Weight of the Bitumen	1.5-3% or TBD
Air Void Content (ASTM D6752/AASHTO T275)	16.0-22.0%
Draindown (ASTM D6390)*	$\leq$ 0.3 %
Retained Tensile Strength (AASHTO 283)**	$\geq$ 80 %
Cantabro abrasion test on unaged samples (ASTM D7064-04)	$\leq$ 20%
Cantabro abrasion test on 7 day aged samples	$\leq$ 30%

*Cellulose or mineral 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 antistrip additive, such as hydrated lime (ASTM C977) or a fatty amine, to raise the TSR value above 80%.

C. Porous Asphalt Mix Production

1. Mixing Plants.
Mixing plants shall meet the requirements of hot mix asphalt plants as specified in the state DOT or regional equivalent unless otherwise approved by the Engineer (e.g. Section 401-Plant Mix Pavements – General for Quality Assurance specifications in the Standard Specifications for Road and Bridge Construction – State of New Hampshire DOT, 2006, or latest revised edition and including supplemental specifications and updates).

2. Preparation of Asphalt Binder.
The asphalt material shall be heated to the temperature specified in the state DOT specification (if using a DOT spec for the mix) in a manner that will avoid local overheating. A continuous supply of asphalt material shall be furnished to the mixer at a uniform temperature.

3. Preparation of Aggregates.
The aggregate for the mixture shall be dried and heated at the mixing plant before being placed in the mixer. Flames used for drying and heating shall be properly adjusted to avoid damaging the aggregate and depositing soot or unburned fuel on the aggregate.

4. Mineral filler
Mineral filler if required to meet the grading requirements, shall be added in a manner approved by the Engineer after the aggregates have passed through the dryer.

5. Mixing.
The above preparation of aggregates does not apply for drum-mix plants. The dried aggregate shall be combined in the mixer in the amount of each fraction of aggregate required to meet the job-mix formula and thoroughly mixed prior to adding the asphalt material.

The dried aggregates shall be combined with the asphalt material in such a manner as to produce a mixture that when discharged from the pugmill is at a target temperature in the range that corresponds to an asphalt binder viscosity of 700 to 900 centistokes and within a tolerance of ± 11 °C (± 20 °F).

The asphalt material shall be measured or gauged and introduced into the mixer in the quantity determined by the Engineer for the particular material being used and at the temperature specified in the relevant specification.

After the required quantity of aggregate and asphalt material has been introduced into the mixer, the materials shall be mixed until a complete and uniform coating of the particles and a thorough distribution of the asphalt material throughout the aggregate is secured. The mixing time will be regulated by the Engineer.

All plants shall have a positive means of eliminating oversized and foreign material from being incorporated into the mixer.

6. QC/QA During Production
The Contractor shall provide at Contractors' expense and the Engineer's approval a third-party QA Inspector to oversee and document mix production. All mix testing results during production should be submitted to the QA Inspector.

The QC plan may be altered at the discretion of the Engineer and based on feasible testing as suggested by the asphalt producer. Certain QC testing requirements during production may not be feasible for small projects in which limited asphalt is generated. Some testing methods cannot be completed during the time needed during small batch production. The feasibility should be assessed with the Engineer and producer.

The mixing plant shall employ a Quality Control Technician (QCT). The QCT will perform QC/QA testing and will be certified in the discipline of HMA Plant Technician by the relevant certifying agency (e.g. NETTCP in New England). The Contractor shall sample, test and evaluate the mix in accordance with the methods and minimum frequencies in Table 6 and the

Post-Blended SBR Binder Quality Control Plan (if applicable).

Table 6. QC/QA testing requirements during production.

Test	Min. Frequency	Test Method
Temperature in Truck at Plant	6 times per day	
Gradation	greater of either (a) 1 per 500 tons, (b) 2 per day, or (c) 3 per job	AASHTO T30
Binder Content	greater of either (a) 1 per 500 tons, (b) 2 per day, or (c) 3 per job	AASHTO T164
Air Void Content	greater of either (a) 1 per 500 tons, (b) 2 per day, or (c) 3 per job	ASTM D6752
Binder Draindown	greater of either (a) 1 per 500 tons, (b) 1 per day, or (c) 1 per job	ASTM D6390

If an analyzed sample is outside the testing tolerances immediate corrective action will be taken. After the corrective action has been taken the resulting mix will be sampled and tested. If the re-sampled mix test values are outside the tolerances the Engineer will be immediately informed. The Engineer may determine that it is in the best interest of project that production is ceased. The Contractor will be responsible for all mix produced for the project.

Testing Tolerances During Production. Testing of the air void content, binder draindown, and TSR shall be within the limits set in Table 6. The paving mixture produced should not vary from the design criteria for aggregate gradation and binder content by more than the tolerances in Table 7.

Table 7. QC/QA testing tolerances during production.

Sieve Size (inch/mm)	Percent Passing
0.75/19	-
0.50/12.5	±6.0
0.375/9.5	±6.0
No.4/4.75	±5.0
No.8/2.36	±4.0
No.200/0.075 (#200)	±2.0
%PGAB	+0.4, -0.2

Should the paving mixture produced vary from the designated grading and asphalt content by more than the above tolerances, the appropriate production modifications are to be made until the porous asphalt mix is within these tolerances.

Samples of the mixture, when tested in accordance with AASHTO T164 and T30, shall not vary from the grading proportions of the aggregate and binder content designated by the Engineer by more than the respective tolerances specified above and shall be within the limits specified for the design gradation.

7. Plant Shutdown and Rejection of Mix.

Should the porous asphalt mix not meet the tolerances specified in this section upon repeat testing, the Engineer may reject further loads of mix. Mix that is loaded into trucks during the time that the plant is changing operations to comply with a failed test shall not be accepted, and should be recycled at the plant.

8. Striping Paint

Striping paint shall be latex, water-base emulsion, ready-mixed, and complying with pavement marking specifications PS TT-P-1952.

PART 3 EXECUTION

3.1 INSTALLATION

A. **Porous Media Beds**

Protection of native materials from over compaction is important. Proper compaction of select subbase materials is essential. Improper compaction of subbase materials will result in either 1) low pavement durability from insufficient compaction, or 2) poor infiltration due to over-compaction of subbase. Care must be taken to assure proper compaction as detailed below.

1. Grade Control

a. Establish and maintain required lines and elevations. The Engineer shall be notified for review and approval of final stake lines for the work before construction work is to begin. Finished surfaces shall be true to grade and even, free of roller marks and free of puddle-forming low spots. All areas must drain freely. Excavation elevations should be within +/- 0.1 ft (+/- 3 cm).

b. If, in the opinion of the Engineer, based upon reports of the testing service and inspection, the quality of the work is below the standards which have been specified, additional work and testing will be required until satisfactory results are obtained.

c. The Engineer shall be notified at least 24 hours prior to all porous media bed and porous pavement work.

2. Subgrade Preparation

a. Native subgrade refers to materials beyond the limit of the excavation. The existing native subgrade material under all bed areas shall NOT be compacted or subject to excessive construction equipment traffic prior to geotextile and stone bed placement. Compaction is acceptable if an impermeable liner is used at the base of the porous asphalt system and infiltration is not desired.

b. Where erosion of the native material subgrade has caused accumulation of fine materials and/or surface ponding, this material shall be removed with light equipment and the underlying soils scarified to a minimum depth of 6 inches with a York rake or equivalent and light tractor.

c. Bring subgrade to line, grade, and elevations indicated. Fill and lightly regrade any areas damaged by erosion, ponding, or traffic compaction before the placing of the stone subbase.

d. All bed bottoms are as level as feasible to promote uniform infiltration. For pavements subbases constructed on grade, soil or fabric barriers should be constructed along equal elevation for every 6-12" of grade change to act as internal check dams. This will prevent erosion within the subbase on slope.

3. Porous Media Bed Installation

a. Subbase refers to materials below pavement surface and above native subgrade. Upon completion of subgrade work, the Engineer shall be notified and shall inspect at his/her discretion before proceeding with the porous media bed installation.

b. Sideslope geotextile and porous media bed aggregate shall be placed immediately after approval of subgrade preparation. Any accumulation of debris or sediment which has taken place after approval of subgrade shall be removed prior to installation of geotextile at no extra cost to the Owner.

c. Place sideslope geotextile in accordance with manufacturer's standards and recommendations. Adjacent strips of geotextile shall overlap a minimum of sixteen inches (16"). Secure geotextile at least four feet (1.2 m) outside of the bed excavation and take any steps necessary to prevent any runoff or sediment from entering the storage bed.

d. Install filter course aggregate in 8-inch maximum lifts to a MAXIMUM of 95% standard proctor compaction (ASTM D698 / AASHTO T99). Install aggregate to grades indicated on the drawings.

e. Install choker, gravel, and stone base course aggregate to a MAXIMUM of 95% compaction standard proctor (ASTM D698 / AASHTO T99). Choker should be placed evenly over surface of filter course bed, sufficient to allow placement of pavement, and notify Engineer for approval. Choker base course thickness shall be sufficient to allow for even placement of the porous asphalt but no less than 4-inches (10 cm) in depth.

f. The density of subbase courses shall be determined by AASHTO T 191 (Sand-Cone Method), AASHTO T 204 (Drive Cylinder Method), or AASHTO T 238 (Nuclear Methods), or other approved methods at the discretion of the supervising engineer.

g. The infiltration rate of the compacted subbase shall be determined by ASTM D3385 or approved alternate at the discretion of the supervising engineer. The infiltration rate shall be no less 5-30 ft/day or 50% of the hydraulic conductivity (D2434) at 95% standard proctor compaction (refer to section 2.1.A.5).

h. Compaction of subbase course material shall be done with a method and adequate water to meet the requirements. Rolling and shaping shall continue until the required density is attained. Water shall be uniformly applied over the subbase course materials during compaction in the amount necessary for proper consolidation.

i. Rolling and shaping patterns shall begin on the lower side and progress to the higher side of the subbase course while lapping the roller passes parallel to the centerline. Rolling and shaping shall continue until each layer conforms to the required grade and cross-section and the surface is smooth and uniform.

j. Following placement of subbase aggregate, the sideslope geotextile shall be folded back along all bed edges to protect from sediment washout along bed edges. At least a four-foot edge strip shall be used to protect beds from adjacent bare soil. This edge strip shall remain in place until all bare soils contiguous to beds are stabilized and vegetated. In addition, take any other necessary steps to prevent sediment from washing into beds during site development. When the site is fully stabilized, temporary sediment control devices shall be removed.

4. <u>QC/QA requirements for Porous Media Bed Construction.</u>
QC/QA activities are summarized in **Table 8**.

B. **Porous Asphalt Pavement Installation**

1. <u>Mixing Plant</u>
The mixing plant, hauling and placing equipment, and construction methods shall be in conformance with NAPA IS 131 and applicable sections of the state DOT's specification for asphalt mixes. The use of surge bins shall not be permitted.

Table 8. QC/QA requirements for porous media bed construction.

Activity	Schedule
Contractor to notify Engineer for approval	24 hours in advance of start of work
Contractor to employ soil inspector acceptable to Engineer	NA
Contractor to employ staking and layout control inspector acceptable to Engineer	NA
Contractor to employ site grading inspector acceptable to Engineer	NA
Contractor to employ pavement work inspector acceptable to Engineer	NA
Contractor to notify Engineer for approval	after subgrade preparation, before construction of porous media bed
Contractor to notify Engineer for approval	after choker course placed, before placement of pavement

2. <u>Hauling Equipment.</u>
The open graded mix shall be transported in clean vehicles with tight, smooth dump beds that have been sprayed with a non-petroleum release agent or soap solution to prevent the mixture from adhering to the dump bodies. Mineral filler, fine aggregate, slag dust, etc.

shall not be used to dust truck beds. The open graded mix shall be covered during transportation with a suitable material of such size sufficient to protect the mix from the weather and also minimize mix cooling and the prevention of lumps. When necessary, to ensure the delivery of material at the specified temperature, truck bodies shall be insulated, and covers shall be securely fastened. Long hauls, particularly those in excess of 25 miles (40 km), may result in separation of the mix and its rejection.

3. Placing Equipment.
The paver shall be a self-propelled unit with an activated screed or strike-off assembly, capable of being heated if necessary, and capable of spreading and finishing the mixture without segregation for the widths and thicknesses required. In general, track pavers have proved superior for Porous Asphalt placement. The screed shall be adjustable to provide the desired cross-sectional shape. The finished surface shall be of uniform texture and evenness and shall not show any indication of tearing, shoving, or pulling of the mixture. The machine shall, at all times, be in good mechanical condition and shall be operated by competent personnel.

Pavers shall be equipped with the necessary attachments, designed to operate electronically, for controlling the grade of the finished surface.

The adjustments and attachments of the paver will be checked and approved by the Engineer before placement of asphalt material.

Pavers shall be equipped with a sloped plate to produce a tapered edge at longitudinal joints. The sloped plate shall be attached to the paver screed extension.

The sloped plate shall produce a tapered edge having a face slope of 1:3 (vertical: horizontal). The plate shall be so constructed as to accommodate compacted mat thickness from 35 to 100 mm (1 1/4 to 4 inches). The bottom of the sloped plate shall be mounted 10 to 15 mm (3/8 to 1/2 inch) above the existing pavement. The plate shall be interchangeable on either side of the screed.

Pavers shall also be equipped with a joint heater capable of heating the longitudinal edge of the previously placed mat to a surface temperature of 95 °C (200 °F), or higher if necessary, to achieve bonding of the newly placed mat with the previously placed mat. This shall be done without undue breaking or fracturing of aggregate at the interface. The surface temperature shall be measured immediately behind the joint heater. The joint heater shall be equipped with automated controls that shut off the burners when the pavement machine stops and reignite them with the forward movement of the paver. The joint heater shall heat the entire area of the previously placed wedge to the required temperature. Heating shall immediately precede placement of the asphalt material.

4. Rollers.
Rollers shall be in good mechanical condition, operated by competent personnel, capable of reversing without backlash, and operated at speeds slow enough to avoid displacement of the asphalt mixture. The mass (weight) of the rollers shall be sufficient to compact the mixture to the required density without crushing of the aggregate. Rollers shall be

equipped with tanks and sprinkling bars for wetting the rolls.

Rollers shall be two-axle tandem rollers with a gross mass (weight) of not less than 7 metric tons (8 tons) and not more than 10 metric tons (12 tons) and shall be capable of providing a minimum compactive effort of 44 kN/m (250 pounds per inch) of width of the drive roll. All rolls shall be at least 1 m (42 inches) in diameter.

A rubber tired roller will not be required on the open graded asphalt friction course surface.

5. Conditioning of Existing Surface.
Contact surfaces such as curbing, gutters, and manholes shall be painted with a thin, uniform coat of Type RS-1 emulsified asphalt immediately before the asphalt mixture is placed against them.

6. Temperature Requirements.
The temperature of the asphalt mixture, at the time of discharge from the haul vehicle and at the paver, shall be between 135-163°C (275 to 325°F), within 6 °C (10 °F) of the compaction temperature for the approved mix design.

7. Spreading and Finishing.
The Porous Asphalt shall be placed either in a single application at 4 inches (10 cm) thick or in two lifts. If more than one lift is used, great care must be taken to insure that the porous asphalt layer join completely. This means: keeping the time between layer placements minimal; keeping the first layer clear from dust and moisture, and minimizing traffic on the first layer.

The Contractor shall protect all exposed surfaces that are not to be treated from damage during all phases of the pavement operation.

The asphalt mixture shall be spread and finished with the specified equipment. The mixture shall be struck off in a uniform layer to the full width required and of such depth that each course, when compacted, has the required thickness and conforms to the grade and elevation specified. Pavers shall be used to distribute the mixture over the entire width or over such partial width as practical. On areas where irregularities or unavoidable obstacles make the use of mechanical spreading and finishing equipment impractical, the mixture shall be spread and raked by hand tools.

No material shall be produced so late in the day as to prohibit the completion of spreading and compaction of the mixture during daylight hours, unless night paving has been approved for the project.

No traffic will be permitted on material placed until the material has been thoroughly compacted and has been permitted to cool to below 38 °C (100 °F). The use of water to cool the pavement is not permitted. The Engineer reserves the right to require that all work adjacent to the pavement, such as guardrail, cleanup, and turf establishment, is completed prior to placing the wearing course when this work could cause damage to the pavement. On projects where traffic is to be maintained, the Contractor shall schedule daily pavement operations so that at the end of each working day all travel lanes of the roadway on which work is being performed are paved to the same limits. Suitable aprons to transition approaches, where required, shall be placed at side road intersections and driveways as directed by the Engineer.

8. Compaction.

Immediately after the asphalt mixture has been spread, struck off, and surface irregularities adjusted, it shall be thoroughly and uniformly compacted by rolling. The compaction objective is 16% - 19% in place void content (Corelock).

Breakdown rolling shall occur when the mix temperature is between 135-163°C (275 to 325°F).

Intermediate rolling shall occur when the mix temperature is between 93-135°C (200 to 275°F).

Finish rolling shall occur when the mix temperature is between 66-93°C (150 to 200°F).

The cessation temperature occurs at approximately 79°C (175°F), at which point the mix becomes resistant to compaction. If compaction has not been done at temperatures greater than the cessation temperature, the pavement will not achieve adequate durability.

The surface shall be rolled when the mixture is in the proper condition and when the rolling does not cause undue displacement, cracking, or shoving.

Rollers or oscillating vibratory rollers, ranging from 8-12 tons, shall be used for compaction. The number, mass (weight), and type of rollers furnished shall be sufficient to obtain the required compaction while the mixture is in a workable condition. Generally, one breakdown roller will be needed for each paver used in the spreading operation.

To prevent adhesion of the mixture to the rolls, rolls shall be kept moist with water or water mixed with very small quantities of detergent or other approved material. Excess liquid will not be permitted.

Along forms, curbs, headers, walls, and other places not accessible to the rollers, the mixture shall be thoroughly compacted with hot or lightly oiled hand tampers, smoothing irons or with mechanical tampers. On depressed areas, either a trench roller or cleated compression strips may be used under the roller to transmit compression to the depressed area.

Other combinations of rollers and/or methods of compacting may be used if approved in writing by the Engineer, provided the compaction requirements are met.

Unless otherwise specified, the longitudinal joints shall be rolled first. Next, the Contractor shall begin rolling at the low side of the pavement and shall proceed towards the center or high side with lapped rollings parallel to the centerline. The speed of the roller shall be slow and uniform to avoid displacement of the mixture, and the roller should be kept in as continuous operation as practical. Rolling shall continue until all roller marks and ridges have been eliminated.

Rollers will not be stopped or parked on the freshly placed mat.

It shall be the responsibility of the Contractor to conduct whatever process control the Contractor deems necessary. Acceptance testing will be conducted by the Engineer using cores provided by the Contractor.

Any mixture that becomes loose and broken, mixed with dirt, or is in any way defective shall be removed and replaced with fresh hot mixture. The mixture shall be compacted to conform to the surrounding area. Any area showing an excess or deficiency of binder shall be removed and replaced. These replacements shall be at the Contractor's expense.

If the Engineer determines that unsatisfactory compaction or surface distortion is being obtained or damage to highway components and/or adjacent property is occurring using vibratory compaction equipment, the Contractor shall immediately cease using this equipment and proceed with the work in accordance with the fifth paragraph of this subsection.

The Contractor assumes full responsibility for the cost of repairing all damages that may occur to roadway or parking lot components and adjacent property if vibratory compaction equipment is used. After final rolling, no vehicular traffic of any kind shall be permitted on the surface until cooling and hardening has taken place, and in no case within the first 48 hours. For small batch jobs, curing can be considered to have occurred after the surface temperature is less than 100 ºF (38 ºC). Curing time is preferably one week, or until the entire surface temperature cools below 100 ºF (38 ºC). Provide barriers as necessary at no extra cost to the Owner to prevent vehicular use; remove at the discretion of the Engineer.

9. Joints.

Joints between old and new pavements or between successive day's work shall be made to ensure a thorough and continuous bond between the old and new mixtures. Whenever the spreading process is interrupted long enough for the mixture to attain its initial stability, the paver shall be removed from the mat and a joint constructed.

Butt joints shall be formed by cutting the pavement in a vertical plane at right angles to the centerline, at locations approved by the Engineer. The Engineer will determine locations by using a straightedge at least 4.9 m (16 feet) long. The butt joint shall be thoroughly coated with Type RS-1 emulsified asphalt just prior to depositing the pavement mixture when pavement resumes.

Tapered joints shall be formed by tapering the last 450 to 600 mm (18 to 24 inches) of the course being laid to match the lower surface. Care shall be taken in raking out and discarding the coarser aggregate at the low end of the taper, and in rolling the taper. The taper area shall be thoroughly coated with Type RS-1 emulsified asphalt just prior to resuming pavement. As the paver places new mixture on the taper area, an evenly graduated deposit of mixture shall complement the previously made taper. Shovels may be used to add additional mixture if necessary. The joint shall be smoothed with a rake, coarse material discarded, and properly rolled.

Longitudinal joints that have become cold shall be coated with Type RS-1 emulsified asphalt before the adjacent mat is placed. If directed by the Engineer, joints shall be cut back to a clean vertical edge prior to applying the emulsion.

10. Surface Tolerances.
The surface will be tested by the Engineer using a straightedge at least 4.9 m (16 feet) in length at selected locations parallel with the centerline. Any variations exceeding 3 mm (1/8 inch) between any two contact points shall be satisfactorily eliminated. A straightedge at least 3 m (10 feet) in length may be used on a vertical curve. The straightedges shall be provided by the Contractor.

Work shall be done expertly throughout, without staining or injury to other work. Transition to adjacent impervious asphalt pavement shall be merged neatly with flush, clean line. Finished pavement shall be even, without pockets, and graded to elevations shown on drawing.

Porous pavement beds shall not be used for equipment or materials storage during construction, and under no circumstances shall vehicles be allowed to deposit soil on paved porous surfaces.

11. Repair of Damaged Pavement.
Any existing pavement on or adjacent to the site that has been damaged as a result of construction work shall be repaired to the satisfaction of the Engineer without additional cost to the Owner.

12. Striping Paint

Vacuum and clean surface to eliminate loose material and dust.

Paint 4 inch wide parking striping and traffic lane striping in accordance with layouts of plan. Apply paint with mechanical equipment to produce uniform straight edges. Apply in two coats at manufacturer's recommended rates. Provide clear, sharp lines using white traffic paint

Color for Handicapped Markings: Blue

C. **QC/QA for Paving Operations**

1. The full permeability of the pavement surface shall be tested by application of clean water at the rate of at least 5 gpm (23 lpm) over the surface, using a hose or other distribution devise. Water used for the test shall be clean, free of suspended solids and deleterious liquids and will

be provided at no extra cost to the Owner. All applied water shall infiltrate directly without large puddle formation or surface runoff, and shall be observed by the Engineer.

2. Testing and Inspection: Employ at Contractor's expense an inspection firm acceptable to the Engineer to perform soil inspection services, staking and layout control, and testing and inspection of site grading and pavement work. Inspection and list of tests shall be reviewed and approved in writing by the Engineer prior to starting construction. All test reports must be signed by a licensed Engineer.
3. Test in-place base and surface course for compliance with requirements for thickness and surface smoothness. Repair or remove and replace unacceptable work as directed by the Engineer.
4. Surface Smoothness: Test finished surface for smoothness using a 10 foot straightedge applied parallel with and at right angles to the centerline of the paved area. Surface will not be accepted if gaps or ridges exceed 3/16 of an inch.
5. QC/QA requirements during paving are summarized in **Error! Reference source not found.**.

Table 9. QC/QA requirements during paving.

Activity	Schedule/ Frequency	Tolerance
Inspect truck beds for pooling (draindown)	every truck	NA
Take surface temp. behind joint heater	each pull	6°C (10°F) of compaction temp
Consult with Engineer to determine locations of butt joints	as needed	NA
Test surface smoothness & positive drainage with a 10 ft straightedge	after compaction	4.5 mm (3/16")
Consult with Engineer to mark core locations for QA testing	after compaction	NA
Hose test with at least 5 gpm water	after compaction	immediate infiltation, no puddling

PART 4. 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, 2006, 2006 Standard Specifications for Construction Book, Division 700, Section 708, Montpelier, VT.

http://www.aot.state.vt.us/conadmin/2006StandardSpecs.htm

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

Reserved

17.0 APPENDIX E – STORMWATER MAINTENANCE AGREEMENT

note: The Stormwater Maintenance Agreement was reproduced from the New York State Stormwater Manual and is provided as a sample only.

Stormwater Maintenance Agreement

Whereas, the Municipality of Plainville ("Municipality") and the ____________________________ ("facility owner") want to enter into an agreement to provide for the long term maintenance and continuation of stormwater control/treatment measures approved by the Municipality for the below named project, and

Whereas, the Municipality and the facility owner desire that the stormwater control/treatment measures be built in accordance with the approved project plans and thereafter be maintained, cleaned, repaired, replaced, and continued in perpetuity in order to ensure optimum performance of the stormwater systems. Therefore, the Municipality and the facility owner agree as follows:

1. This agreement binds the Municipality and the facility owner, its successors and assigns, to the maintenance provisions depicted in the approved project plans which are attached as Schedule A of this agreement.

2. The facility owner shall maintain, clean, repair, replace and continue the stormwater control/treatment measures depicted in Schedule A as necessary to ensure optimum performance of the measures to design specifications. The stormwater control/treatment measures shall include, but shall not be limited to, the following: catch basins, mechanical treatment systems, Bioretention facilities, swales, sand or organic filters, infiltration systems, permeable pavement systems, subsurface gravel wetlands, constructed wetlands and ponds.

3. The facility owner shall be responsible for all expenses related to the maintenance of the stormwater control/treatment measures and shall establish a means for the collection and distribution of expenses among parties for any commonly owned facilities.

4. The facility owner shall provide for periodic inspection of the stormwater control/treatment measures on an annual basis, to determine the condition and integrity of the measures. Such inspection shall be performed by a Professional Engineer licensed by the State of Connecticut. The inspecting engineer shall prepare and submit to the Municipality within 30 days of the inspection, a written report of the findings including recommendations for those actions necessary for the continuation of the stormwater control/treatment measures.

5. The facility owner shall not authorize, undertake or permit alteration, abandonment, modification or discontinuation of the stormwater control/treatment measures except in accordance with written approval of the Municipality.

6. The facility owner shall undertake necessary repairs and replacement of the stornwater control/treatment measures at the direction of the Municipality or in accordance with the recommendation of the inspecting engineer.

7. The facility owner shall provide to the Municipality within 30 days of the date of this agreement, a security for the maintenance and continuation of the stormwater control/treatment measures in the form of (a Bond, letter of credit or escrow account).

8. This agreement shall be recorded in the Town Clerks Office, Town of Plainville together with Schedule A.

9. If ever the Municipality determines that the facility owner has failed to construct or maintain the stormwater control/treatment measures in accordance with the project plan or has failed to undertake corrective action specified by the Municipality or by the inspecting engineer, the Municipality is authorized to undertake such steps as reasonably necessary for the preservation, continuation, or maintenance of the stormwater control/treatment measures and affix the expenses thereof as a lien against the property.

10. This agreement is effective ______________________.