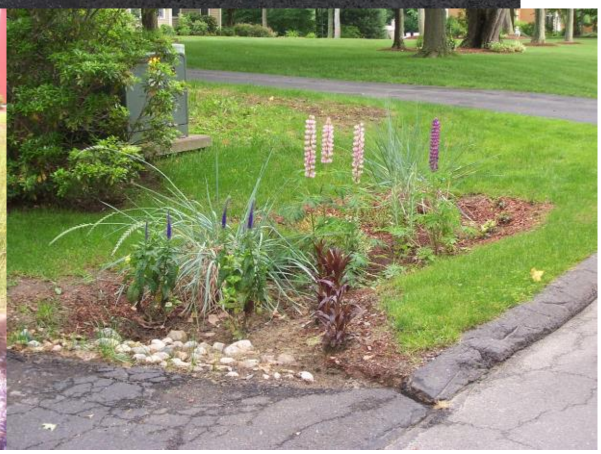
Effective Date:  January 1, 2018

# MORRIS

## Low Impact Sustainable Development and Stormwater Management Design Manual



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Northwest Conservation District

NHCOG
— Northwest Hills —
Council of Governments

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Connecticut Institute for Resilience and Climate Adaptation

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## LIST OF ACRONYMS

| | |
|---|---|
| ASCE | American Society of Civil Engineers |
| BOD | Biological Oxygen Demand |
| COD | Chemical Oxygen Demand |
| BMP | Best Management Practice |
| CFS | Cubic Feet per Second |
| CPFR | Channel Protection Flow Rate |
| CT DEP | Connecticut Department of Environmental Protection |

| | |
|---|---|
| CT DEEP | Connecticut Department of Energy and Environmental Protection |
| CT DOT | Connecticut Department of Transportation |
| DIN | Dissolved Inorganic Nitrogen |
| ESD | Environmental Site Design |
| EWRI | Environmental Water Resource Institute |
| FP | Flood Protection |
| GRV | Groundwater Recharge Volume |
| LISD | Low Impact Sustainable Development |
| MLSS | Minimum Leaching System Spread |
| NCSU | North Carolina State University |
| NRCS | Natural Resource and Conservation Service |
| O/M | Operations and Maintenance |
| PICP | Permeable Interlocking Concrete Pavers |
| PPB | Parts per Billion |
| RCN | Runoff Curve Number |
| RI DEM | Rhode Island Department of Environmental Management |
| SWQM | Storm Water Quality Manual |
| Tc | Time of Concentration |
| TN | Total Nitrogen |
| TP | Total Phosphorous |
| TPH | Total Petroleum Hydrocarbons |
| TSS | Total Suspended Solids |
| Zn | Zinc (Indicator Metal) |
| UNHSC | University of New Hampshire Stormwater Center |
| WQF | Water Quality Flow |
| WQV | Water Quality Volume |

# Section 1.0
# Overview of Water Resources in the Town of Morris

The Town of Morris is in the south-central portion of Litchfield County. The town contains 18.7 square miles, including wetlands and watercourses. Of this amount, approximately 8.2% is water with the primary aquatic resource being Bantam Lake, which is in the north-central portion of the town and extends into the Town of Litchfield. Bantam Lake is approximately 1,200 acres in size and is the largest natural lake in Connecticut. This is a critical aquatic resource for the town from an economic standpoint. There are many homes located along the shores of Bantam Lake which contribute to the tax base of the town. Additionally, the lake is used for recreation, including fishing, boating, and swimming. The northeast shoreline of Mount Tom is also located in the Town of Morris.

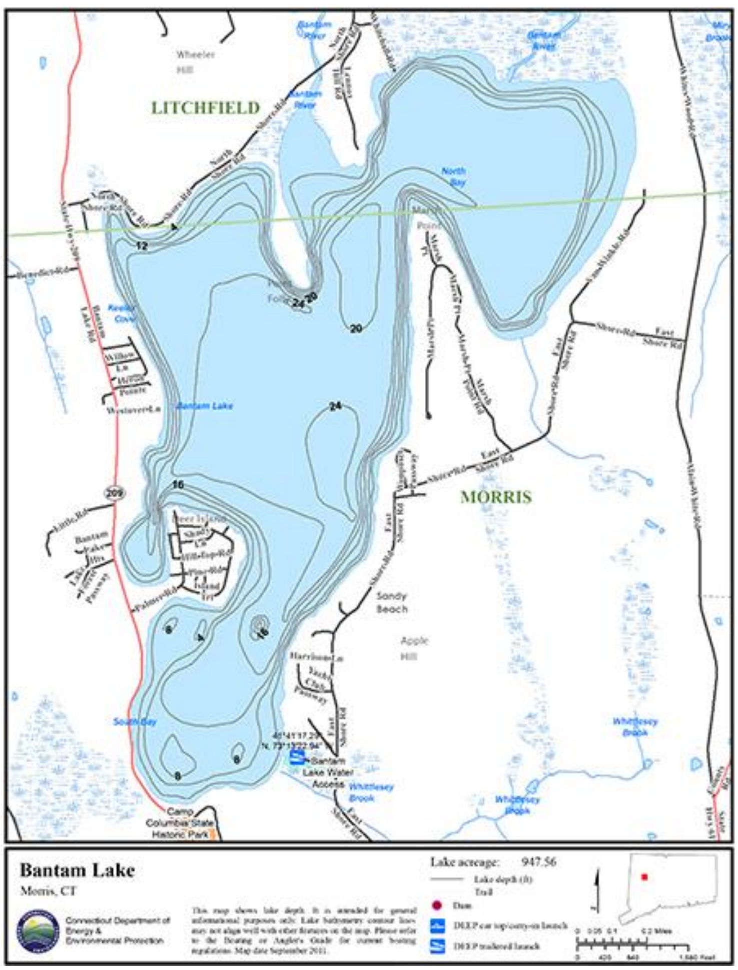



**Figure 1.0.1: Bantam Lake**

Deer Island is a densely developed island in Bantam Lake connected by a causeway to the western shoreline of the lake. Figure 1.0.2, taken from Google Earth shows the scale of development on Deer Island. There are significant impervious areas, consisting of paved roads, driveways, building roofs and accessory structures throughout the island. The extent and connectedness of the impervious areas on parcels within 700’ of the perimeter of Bantam Lake is also a concern, as up to 40% of the annual nutrient load from non-point source runoff comes as atmospheric deposition onto impervious surfaces throughout the year.

Bantam Lake currently suffers from frequent and significant algae blooms during the warm months of the year. The primary cause of the algae blooms is the increased nutrient loads being discharged into the lake. The primary nutrient of concern is phosphorous, with the source being fertilizers from residential lawns that front on Bantam Lake. A typical residential development on the shoreline of Bantam Lake is shown in Figure 1.0.3.


**Figure 1.0.2: Aerial view of Deer Island**

Yearly monitoring of phosphorous levels in Bantam Lake has been done by Northeast Aquatics. Phosphorous concentrations, as measured in parts per billion (ppb), have increased since monitoring began in 2007 and continued through 2016. Average phosphorous values in 2007 were 14 ppb as measured within a meter of the water surface. In 2016, the average value of phosphorous increased to 42 ppb, a 200% increase over 10 years. More troublesome, the peak phosphorous levels at the bottom of the lake increased from approximately 180 ppb to almost 500 ppb. As the water in the lake “turns over”, the higher phosphorous levels in the bottom of the lake are then brought to the surface of the lake, when, in conjunction with shallower and warmer waters, will lead to increased growth of invasive plants as well as algae blooms. As can be seen in Figures 1.0.2 and 1.0.3, the well-maintained lawn extends right up to the edge of the lake. There is no vegetative buffer between the edge of the lake and the limit of the lawn that would act as a filter strip to trap nutrients from the lawn. In addition to the development on Deer Island, the western shore of Bantam Lake north of Deer Island has a similar development pattern up to the Litchfield town line to the north.

White Memorial Conservation Center is partially located in the Town of Morris and extends into the Town of Litchfield. Under the stewardship of the center are over 4,000 acres of forest, meadows, and wetlands in both communities. Within the conservation area are 10 ponds as well as over six (6) miles of the Bantam River. The center also owns almost 60% of the shoreline of Bantam Lake and manages several seasonal residential structures, which are leased. This ownership has had the incredibly positive effect of limiting the scale of residential development along the portion of the Bantam Lake shoreline under the center's control. Many of the residential properties along the shoreline of Bantam Lake but under the control of the White Memorial Conservation Center have limited lawn areas as well as natural vegetated buffers along the edge of the lake, but other parcels along the eastern shoreline of Bantam Lake on Marsh Point Road, as shown in Figure 1.0.4, have the same development patterns as found on Deer Island with similar water quality impacts.

On the right side of the land in Figure 1.0.4, residential development is less intense, with extremely limited lawn areas. However, that is in contrast with those homes located on the left side of the land, which show larger residential footprints as well as larger lawn areas like those found on Deer Island.

**Figure 1.0.3: Typical residential use along Bantam Lake shore**


**Figure 1.0.4: Residential use on White Memorial property**

There is limited commercial development in the Town of Morris, which located along Route 109 consists of small retail businesses and restaurants. Agriculture is the dominant land use in the community and is spread throughout the community. The primary agricultural use is the growing of crops.

Surface water quality in the Town of Morris is rated Class AA by the CT DEEP on a map dated November 2015. However, the draft Water Quality Monitoring System (WQMS) Plan has downgraded the quality of water in Bantam Lake due to the impacts of stormwater. The groundwater classification for most of the town is GAA. The GAA water quality classification means that the groundwater is or can be used for a public drinking 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.

Stormwater management on state roads under the jurisdiction of the Connecticut Department of Transportation within the town consist of standard catch basins and pipes with the discharges being directed to wetland and/or watercourse systems. There is only minimal treatment of the runoff by the sumps in catch basins, which may trap an exceedingly small percentage of coarse-grained sediments. While there are some catch basins on town-owned roads that are handled in the same manner as the state roads, most of the roads allow the runoff to simply flow along the edge of the road until it reaches a low point or a ditch and is directed away from the road. In these situations, there is minimal, if any, treatment of the runoff from roadways.

The water quality in Bantam Lake is currently being adversely affected by increased nutrient loads, as discussed above, so a primary goal of the implementation of the LISD strategies is to stop, to the maximum extent possible, the discharge of nutrients to the lake and allow the water quality to improve in Bantam Lake. Elsewhere in the Town of Morris, the implementation of LISD will reduce or eliminate the adverse impacts of increased stormwater runoff volumes, and reduce the pollutant loads found in the runoff, which are ultimately directed to the aquatic resources in the Town of Morris.

# Section 2.0
# Purpose of the LISD Manual

Stormwater discharges to wetland and watercourse systems from the roadways, both local and state, have clearly caused pollution and adverse impacts on the aquatic and natural environment. The impacts associated with road runoff are increased runoff volumes that cause adverse physical impacts to receiving streams, by causing the erosion of channel banks and the downstream deposition of the eroded material. The channel erosion will also receive phosphorus in the soil, which can increase the growth of algae and non-native aquatic plants in ponds and lakes. Metals and hydrocarbons from the movement of vehicles on the roadways are also discharged to the receiving aquatic systems. Both metals and hydrocarbons are toxic to many aquatic organisms at exceptionally low concentrations.

Residential development on the shoreline of Bantam Lake is also causing adverse water quality impacts on the lake itself. The impacts associated with residential and light commercial development within 700' of the shoreline of Bantam Lake are the discharge of increased nutrients, such as nitrogen and phosphorus from fertilizers used on the lakeside lawns, and the potential discharge of bacteria and viruses from poorly maintained or leaking sewage disposal systems near the lake.

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 by the application of Low Impact Sustainable Development (LISD) 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 Morris.

# Section 2.1
# Applicability of the Manual
# Town-Wide

The standards and processes stated in this manual shall apply to all development projects proposed in the Town of Morris, including those initiated by the town itself. Specific performance standards have been developed for new development, as well as commercial redevelopment and residential improvements that 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 Morris.

## Requirements for Bantam Lake

As Bantam Lake is experiencing significant water quality issues associated with non-point source runoff into the lake, a higher standard for the implementation shall be applied to an area encompassing the lake itself and all land that is within 700' of the shoreline of Bantam Lake. The 700' was determined by the evaluation of existing land use patterns that surround Bantam Lake, particularly on the west side of the lake, which drain to Bantam Lake. Without the implementation of these approaches, the water quality in Bantam Lake will continue to worsen due to increased phosphorous loads associated with the presence of lawns and fertilizer applications within the defined 700' zone around the lake as well as the pollutant loads associated with the impervious cover on these parcels. These higher standards are set forth below:

1. A stormwater management plan conforming to the requirement of Section 4.0 and 4.1 of this Manual shall be required when any structure with a footprint of 200 square feet or larger is removed and either replaced in kind or enlarged or simply the renovation of an existing structure whose impervious footprint is 200 square feet or larger.
2. A stormwater management plan conforming to the requirements of Section 4.0 and 4.1 of this Manual shall be required when an area of woods/brush/meadow is to be removed and replaced with grass that is greater than 0.1 acre (4,350 square feet).
3. It is strongly encouraged that the extent of lawn for new residential construction is not located within twenty-five (25) feet of the shoreline of Bantam Lake.
4. It is strongly encouraged that residents remove lawn areas within fifteen (15) feet of the shoreline of Bantam Lake and plant this area with native perennials or shrubs to provide a Vegetated Filter Strip along the shoreline to filter runoff from the adjacent lawn area. Vegetated Filter Strips shall be designed in accordance with the specifications found in Section 7.18 of this Manual.
5. It is strongly encouraged that existing trees within fifty (50) feet of the shoreline remain in place and not be permitted to be cleared. To achieve views of Bantam Lake without the clearing of the trees, the lower branches associated with the crown of the tree can be removed by a licensed arborist, which will provide a view of the lake and maintain the health of the tree.

While it cannot be required, it is strongly recommended that all the LISD stormwater management practices outlined in this manual be applied to the maximum extent practicable on existing residential and commercial developments within the Town of Morris to treat the runoff from the impervious areas to improve the water quality of this runoff.

Additionally, while agricultural land uses are exempt from Federal stormwater management requirements, these land uses have the potential to cause significant adverse water quality impacts to wetlands and watercourses that are adjacent to agricultural uses. It is strongly suggested that existing and potentially new agricultural uses in the Town of Morris apply specific LISD best management practices to address water quality issues as discussed in Section 2.5 of this Manual.

The specifications found in this manual shall be implemented by individuals who are licensed professional engineers in the State of Connecticut. The manual should also be read by non-technical individuals who are interested in the stormwater management and LISD fields. All the required analyses and design of LISD stormwater practices must be prepared by a licensed professional engineer in the State of Connecticut.

All designers must adhere to all 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 situation. Final design plans for any type of treatment or storage system must include all relevant design specifications for that system.

It is important that the homeowners and individuals who will have LISD treatment systems on their property understand the adverse impacts of stormwater on our environment and how the LISD systems can mitigate these impacts. LISD 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 Morris.

## Section 2.2
## How to Apply This Manual

Low Impact Sustainable Development is the next generation of Low Impact Development (LID) and represents a paradigm shift of the current processes that drive the development process. It is imperative that the professionals who will use this Manual understand the concepts that created LID in the first place. 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 LISD can only be realized by the application of the processes outlined in this Manual. LISD is the site component of creating sustainable designs for residential and commercial projects.

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 Sustainable Development strategies.

## Section 2.3
## Understanding the Hydrologic Cycle

Before we can apply LISD concepts, all users of this Manual must understand the natural hydrologic cycle and how development affects the hydrologic cycle and causes adverse impacts to our environment. There is a finite amount of freshwater on the Earth, and only through the recognition of this fact and realization that we must conserve and protect this limited resource will there be clean water for this and future generations.

The natural hydrologic cycle shows how water travels through our environment in the many forms that provide myriad 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. 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 loses 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 that 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 does not infiltrate the soil flows on the surface as runoff.

D. Runoff is the amount of rainfall that 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 and 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)

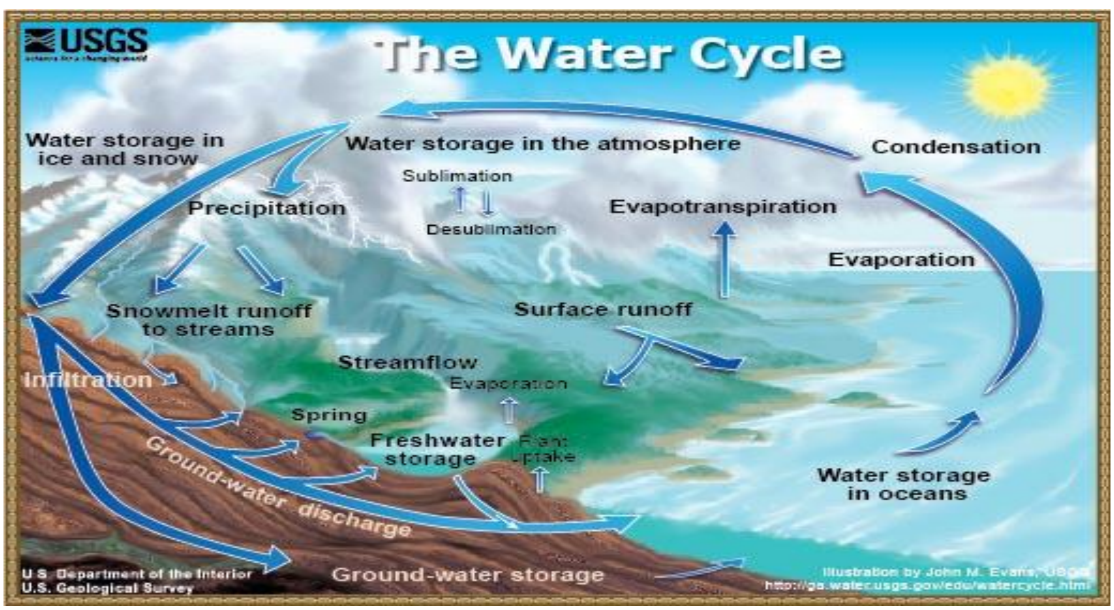



**Figure 2.3.1: The Hydrologic Cycle**

# Impacts of Development on the Hydrologic Cycle

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

The 2004 Connecticut Stormwater Quality Manual (SWQM) prepared by the Connecticut Department of Environmental Protection (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 extraordinarily 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 2.3.2.

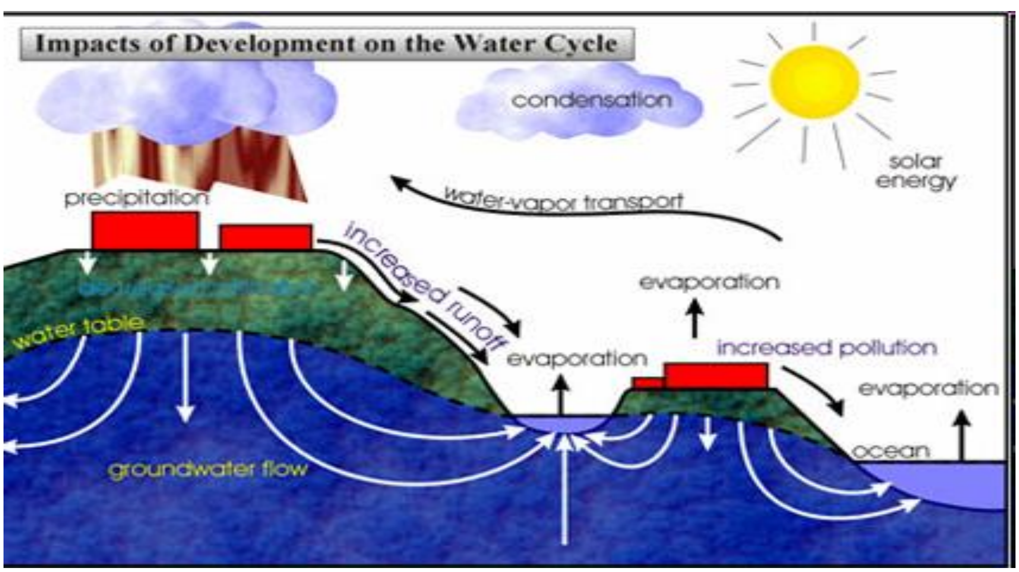



**Figure 2.3.2: Changes to the Hydrologic Cycle because of development**

It can be seen from Figure 2.3.2 that as impervious cover increases, there is less base flow into the ground, less evapotranspiration as the vegetated cover has been eliminated and there are increased rates and volumes of runoff from the impervious areas as well as increased pollutant loads associated with typical development patterns.

# Section 2.4
# Impacts of Residential, Commercial & Industrial Development on the Natural Landform

Land development has the potential to create many adverse impacts on the environment both during the construction period and after construction has been completed. Natural areas, both meadows and woodlands, provide a range of environmental benefits from a stormwater perspective. Native vegetation will intercept rainfall and thus prevent it from directly impacting the ground surface. This intercepted rainfall is often absorbed by the green vegetated matter and used in photosynthesis. Rainfall that is not absorbed by the vegetation will run down the stem or trunk to the ground surface. The deep root systems of meadow grasses and trees provide conduits deep down into the soils that can increase infiltrative capacity even in soils with high silt and clay content. Once on the ground surface, the rainfall slowly and easily infiltrates into the native soils.

Natural vegetation provides an additional benefit: the uptake of carbon dioxide from the atmosphere. Carbon dioxide is taken in by the vegetation to use in photosynthesis, with oxygen being released to the atmosphere. Carbon is sequestered in growing vegetation as well as in the undisturbed soils, so native woodlands and meadows are large carbon sinks.

When land is cleared, the positive benefits of the native vegetation stated above are lost. When the natural organic layer on top of the soil is removed, there is no longer the ability to store carbon in the soil. As the native soils are cut and filled to fit the desired development plan, the natural ability of the soil to infiltrate runoff is lost as the natural porosity is significantly reduced or eliminated, thus more runoff is created, which in turn increases the likelihood of erosion of the soil. Additionally, with no infiltration occurring, there is no replenishment of the shallow groundwater table.

After construction has been completed, the large, often interconnected impervious area prevents rainfall from infiltrating into the ground. Because of this, the natural water balance is adversely affected as more of the rainfall is converted to runoff, which is demonstrated in Figure 2.4.1.

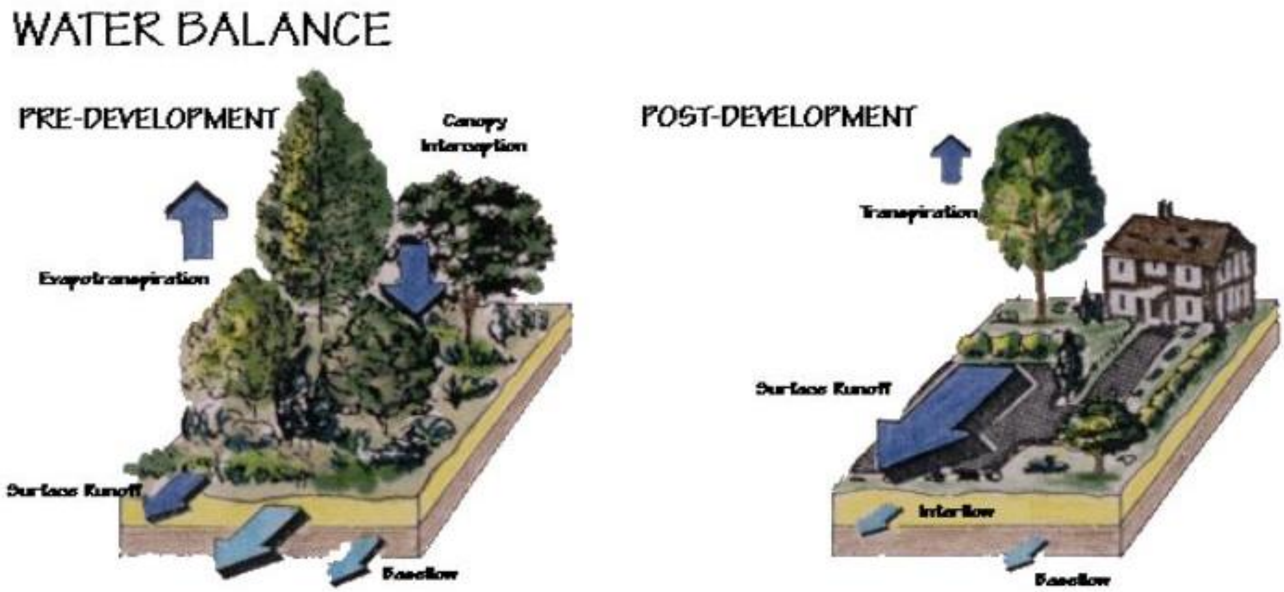



**Figure 2.4.1: Effects of Impervious Cover on Water Balance**

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. When the total impervious cover in a watershed is greater than 10%, the water quality of natural aquatic environments will be adversely affected. Once the impervious coverage exceeds 25% in a watershed, the adverse impacts to the aquatic ecological systems are often irreversible.

While it was initially thought that a watershed impervious coverage of 10% or less did not adversely affect water quality, research by the University of Connecticut (UCONN) has shown that the extent of directly connected impervious surfaces is a more significant measure of potential water quality impacts. The research showed that a watershed with only 5% of directly connected impervious area will experience adverse water quality impacts more commonly associated with impervious coverage of 10% in the watershed. It is noted in the 2010 Rhode Island Department of Environmental Management (RI DEM) Stormwater Manual that adverse water quality impacts can occur with total impervious cover being between 5 – 7%.

The following table highlights the typical percentages of impervious cover for various land uses. It is important to note that these values often underestimate the actual impervious coverage for residential uses, as accessory structures, such as pools, pool houses, sheds, and walkways, are often not considered in these values.

**Table 2.4.1 – 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)**

# Impacts of Residential, Commercial & Industrial Development on Stormwater

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 base flow
- Increased frequency of bank full and overbank floods
- Increase flow velocity during storms
- Increase frequency and duration of high stream flows

**Figure 2.4.2 - Stream Channel Impact from increased runoff volumes (S. Hayden photo)**

Stream Channel and Floodplain Impacts:

- Channel scour, widening and down cutting
- 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 2.4.3 - Stream Channel Impacts (R.Claytor file photo)**

**Figure 2.4.4 - Deposition of sediment in a wetland (S. Hayden photo)**

Water Quality Impacts:

- Excess Nutrients (Nitrogen and soluble phosphorus)
- Sediments
- Pathogens

- Organic Materials
- Hydrocarbons
- Metals
- Synthetic Organic Compounds
- Deicing Constituents
- Trash and Debris
- Thermal Impacts
- Freshwater discharge to estuarine systems


**Figure 2.4.5 - 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 Hydro modification 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 Phosphorus (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.

Litter

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)

Total Suspended Solids are fine soil particles, such as silts and clay which are 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. Turbidity is measured as NTU. A range of turbidity levels are shown in Figure 2.4.5 below.

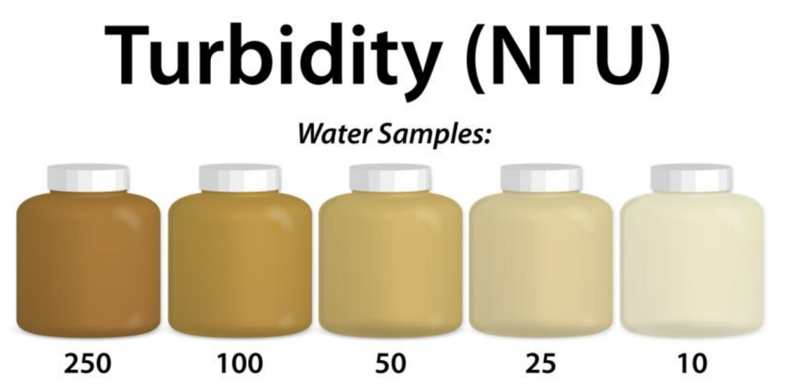



**Figure 2.4.6 - Range of Turbidity in water samples**

Nutrients

Phosphorus and nitrogen are commonly found in non-point runoff with the primary source being lawn fertilizers. Excessive levels of phosphorus in freshwater systems are a concern as this nutrient cause's excess growth of non-native aquatic plants and algae in lakes. As a result of increased nutrient loads, toxic algae blooms are becoming more prevalent in lakes in Connecticut, including Bantam Lake. These toxic algae blooms have resulted in beach closures as exposure to the algae blooms can cause adverse health issues in humans. A further problem occurs, when the algae die off, the decomposition process of organic matter removes oxygen from the water column, thus reducing oxygen levels in the water. The reduced oxygen levels in the waterbody can result in fish kills. 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.

Sources of nutrients are organic and inorganic fertilizers, animal manure, bio solids and failing sewage disposal systems.

**Figure 2.4.7 - Phosphorus impacts on a freshwater pond**

<u>Metals</u>

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 bio accumulate 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. Zinc, Copper, and Cadmium found in non-point source runoff result from the movement and wear and tear of automobiles on our roadways.

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 zinc or copper concentrations in stormwater.


**Figure 2.4.8 - Primary source of zinc (automobile brake pads)**

Hydrocarbons

Total Petroleum Hydrocarbons (TPH) are highly toxic in the aquatic environment, especially to aquatic invertebrates. The primary sources of petroleum hydrocarbons are oil, grease drops from an automobile, gas spills, and vehicle exhaust. Polycyclic Aromatic Hydrocarbons (PAHs) are also toxic to aquatic life. PAHs can be discharged into the environment using coal tar asphalt sealants, commonly used by homeowners on residential driveways. The movement of vehicles or people walking over the sealed driveway can release dust particles containing PAH, which can then be washed off with the next rainfall into the stormwater management system. PAHs are also generated by the burning of fossil fuels and the airborne particles are then deposited by atmospheric deposition on an impervious surface, especially large flat roof areas. When it rains, the accumulations of PAHs due to atmospheric deposition are carried off in the stormwater.

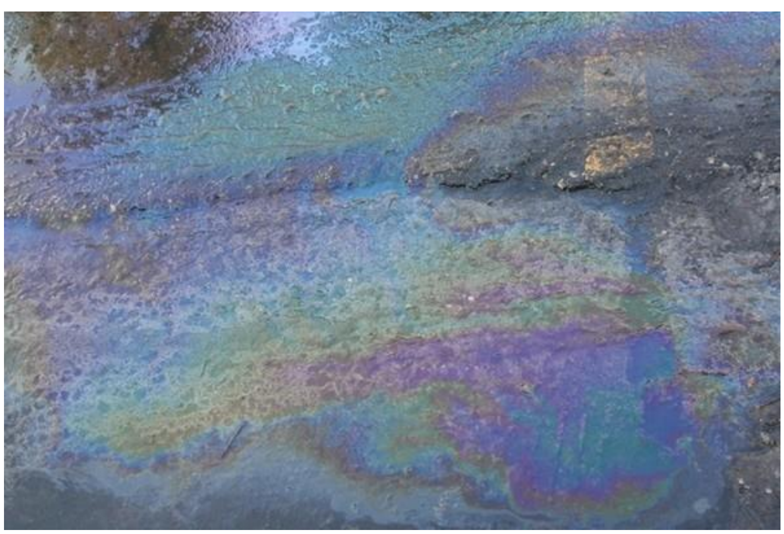


**Figure 2.4.9 - Petroleum Hydrocarbons in Stormwater**

Thermal Impacts

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


**Figure 2.4.10 - Fish kills due to increased thermal levels**

Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD)

Biochemical oxygen demand (BOD) is the amount of dissolved oxygen needed by aerobic biological organisms to break down organic material present in each water sample at certain temperature over a specific time. The BOD value is most expressed in milligrams of oxygen consumed per liter of sample during 5 days of incubation at 20 °C and is often used as a surrogate of the degree of organic pollution of water. Dissolved oxygen depletion is most likely to become evident during the initial aquatic microbial population explosion in response to a large amount of organic material. If the microbial population deoxygenates the water, however, that lack of oxygen imposes a limit on population growth of aerobic aquatic microbial organisms resulting in a longer-term food surplus and oxygen deficit.

Chemical oxygen demand (COD) is the total measurement of all chemicals in the water that can be oxidized. Total Organic Carbon (TOC) is the measurement of organic carbons. The chemical oxygen demand test procedure is based on the chemical decomposition of organic and inorganic contaminants, dissolved, or suspended in water. The result of a chemical oxygen demand test indicates the amount of water-dissolved oxygen (expressed as parts per million or milligrams per liter of water) consumed by the contaminants, during two hours of decomposition from a solution of boiling potassium dichromate. The higher the chemical oxygen demand, the higher the amount of pollution in the test sample.

Both BOD and COD are surrogates for the direct measures of specific pollutants found in non-point source runoff.

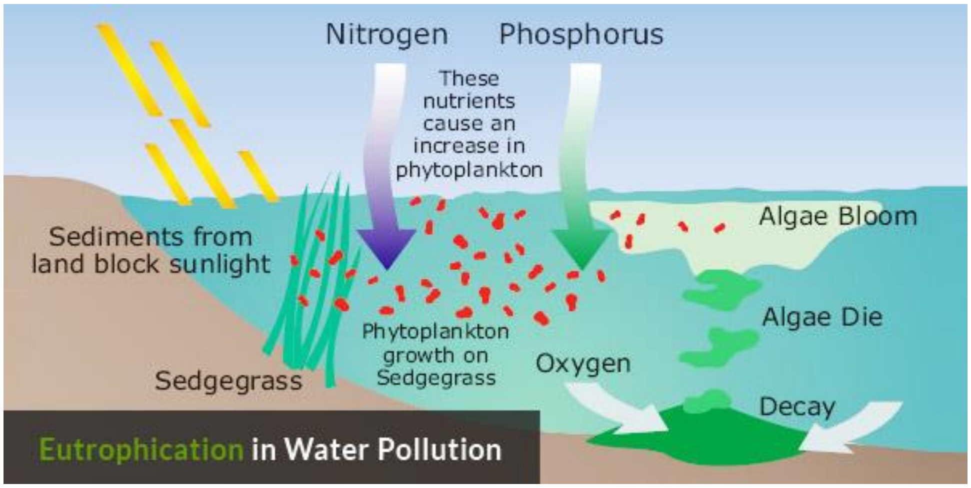



**Figure 2.4.11 - Impacts of Nitrogen and phosphorus on aquatic systems**

<u>Pathogens</u>

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 which is not applicable to the Town of Morris. In communities such as Morris, the primary source of pathogens in stormwater is pet waste which is not picked up along roadways. Dog poop which washes into a storm drain are the common source of both fecal coliform and enterococci bacteria which 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.

**Figure 2.4.12 - Primary source of pathogens in stormwater**

# Section 2.5
# Water Quality Issues associated with agricultural land use

In the Town of Morris, there are two predominant types of agricultural land use. The first is the keeping of livestock, primarily cows which graze on native grass areas. Potential impacts include overgrazing of grass areas, which lead to the soil surface being directly exposed to rainfall, which increases the potential of erosion of the soil surface as well as allowing livestock to enter wetland and watercourse areas, where animal waste can result in bacteria discharges to natural aquatic systems.

1. Allowing livestock to graze and congregate in or immediately adjacent to undisturbed wetlands and watercourses. This significantly increases the potential of animal waste being discharged to wetland and watercourse systems. When animal waste reaches receiving streams and bodies of water, it can result in high to excessive levels of fecal coliform bacteria which can prevent the waterbody from being used for recreational uses, such as swimming and boating,
2. Cutting and removal of native trees adjacent to natural stream systems, removes any shading of the streams, and increase thermal impacts on the natural stream. Additionally, this activity removes the native vegetative buffer along the stream which provides filtering of runoff from upgradient upland grazing areas for livestock and/or the cultivation of crops,
3. Allow over grazing of grass fields by livestock which exposes soil surface to the erosive impacts of rainfall, where erosion can potentially occur which is then discharged to a wetland or watercourse. Phosphorous which is commonly held within a soil profile can become unbound from the soil particles and be discharged in runoff from the disturbed soil surface,
4. Creating crop patterns which increase the potential for erosion of the disturbed soil surface,
5. The planting of the same crop year after year which has the effect of removing the natural nutrients from the soil which then increases the need for the application of fertilizers to maintain or improve the yield of the crop,
6. Not maintaining a densely vegetative buffer between the edge of the active farming area and a wetland/watercourse system. While a buffer consisting of tall trees which shade the stream are extremely helpful in minimizing thermal impacts of agricultural runoff, because there is a significant lack of ground level vegetative cover, these buffers do not the ability to filter runoff and trap pollutants.

The second type of agricultural is the growing of crops on upland areas above wetland and watercourse systems. In many instances, there are only narrow, less than 50’ foot wide and consist of mature deciduous trees or poorly vegetated areas. The deciduous tree buffers generally do have a vegetated understory, consisting of herbaceous plants and shrubs. This type of buffer does is often not able to provide an effective system for trapping non-point source pollutants, such as sediments and nutrients from agricultural runoff.


**Figure 2.5.1 - Common agricultural grass buffer strip**

**Figure 2.5.2 - Typical wooded & grass agricultural buffer strips**

Figures 2.5.1 and 2.5.2 above show typical vegetated agricultural buffer strips, these types of buffer strips are very ineffective at trapping sediments and filtering of nutrients found in agricultural runoff due to the lack of width and the density of the vegetation at the ground surface. Solutions to these stormwater issues will be addressed in Section 4.6.

# Section 3.0
# What is Low Impact Sustainable Development (LISD)?

Low Impact Sustainable Development (LISD) 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. In addition to minimizing the impacts on the land, water and air, the ultimate success of the implementation of LISD is the creation of sustainable projects which are embraced by the owners and the public. For residential developments, LISD designs result in projects which protect and enhance sensitive environmental areas while creating development patterns which foster a greater sense of community character for the residents residing in these types of development.

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

1. Encourage Conservation Development Measures,
2. Reduce Impervious Areas,
3. Slow runoff by using landscape features,
4. Use multiple measures to reduce and cleanse runoff,
5. Pollution prevention.

Each LISD tool is enumerated below:

1. **Encourage Conservation Development Measures**
    a. Implement Open Space or Cluster Development Regulations to preserve large tracts of the site while reducing the size of the residential lots,
    b. Implement “Site Fingerprinting” to minimize land clearing & soil disturbance yet provide flexibility for the location of single-family residences and other improvements. Site fingerprinting is the establishment of clearing limits and/or site disturbance which are defined by the establishment of a percentage limit on a parcel. The site fingerprinting line is adjustable, so it allows flexibility in the final site design while ensuring that a certain percentage of the parcel remains in its natural state,
    c. Minimize soil compaction and/or amend previously disturbed soils to increase infiltrative capacity,
    d. Provide low maintenance landscaping & plant native species which will minimize the use of fertilizers and pesticides,
    e. Use Source Erosion Control measures.

2. **Reduce Impervious Areas**
    a. Disconnect impervious coverage to the maximum extent practical to encourage overland flow conditions across natural or restored vegetated surfaces,
    b. Reduce pavement widths for local roads, private lanes & common driveways when feasible without compromising public safety and movement of emergency vehicles,
    c. Use Permeable Pavement, Porous Concrete, and Open Course Pavers for parking areas and other low traffic areas where appropriate soil conditions are present,

d. Use Porous Concrete for sidewalks where appropriate soil conditions are present.

3. **Slow runoff by using landscape features**
    a. Maintain Pre-Development Time of Concentration (Tc) flow paths on vegetated Surfaces to the Maximum Extent Practical,
    b. Minimize the length of flow on impervious surfaces, particularly on grades more than 6%,
    c. Consider the use of riprap or grass lined swales with check dams for the conveyance of stormwater instead of curb/gutter or catch basins/pipes systems,
    d. Maintain and encourage overland flow conditions across vegetated areas for at least 75', where feasible,
    e. Maintain pre-development infiltration rates by preserving those soils with moderate to high infiltrative capacities to the Maximum Extent Practical,
    f. Maintain existing vegetation to Maximum Extent Practical,

4. **Use multiple measures to reduce and cleanse runoff**
    a. Allow runoff from impervious surfaces to discharge as overland flow onto lawn areas and then into undisturbed woodlands or meadows. This will remove pollutants from runoff by flow thru vegetated systems and allow for natural infiltration to occur,
    b. Direct roof runoff to a rain barrel for use as irrigation water of landscape beds or lawns. Direct overflow from rain barrel to small Bioretention system for infiltration into the ground,
    c. Use rain barrels or cisterns to collect runoff for reuse for washing of vehicles and/or side-walks.

5. **Pollution prevention**
    a. Minimize applications of sand and salt on roads, driveways, parking areas, and sidewalks, without reducing public safety on these surfaces during the winter months,
    b. Use "Source Controls" such as weekly sweeping of large impervious areas, such as parking lots during winter operations if sand is used,
    c. Minimize application of fertilizers on turf areas, particularly those which drain onto an impervious surface.

# Section 3.1
# Measures to Evaluate the Effectiveness of LISD

A primary objective of Low Impact Sustainable Development is to mimic the pre-development hydrologic conditions on a site for the 95% rainfall event. The 95% rainfall event is 1.3" of rain or less within a 24-hour period as measured from mid-night to mid-night. Based upon 10 years of weather records, annual rainfall amounts in Connecticut vary between 49"and 52". However, we are experiencing more short duration rainfall events with higher rainfall intensities, so by using the 1.3"design storm, we can capture and infiltrate more rainfall which will reduce surface water runoff which is the primary driver of flooding. 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 95% rainfall event. The second metric is to match or closely 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 run-off 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”.

Lastly, pollutant loads found in the non-point source runoff will be reduced by LISD strategies and will minimize discharges into receiving wetlands and watercourses.

# Section 3.2
# Goals and Benefits of LISD

The overriding goal of LISD 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 desired outcomes for the implementation of LISD strategies are listed below:

1. Preservation of environmentally sensitive areas, such as wetlands/watercourses, steep slopes, well drained soils, unique vegetative communities, and other natural resources to reduce changes to the hydrology of the watershed,
2. Focus on maintaining natural drainage patterns as a key goal in the design/development plans of the site,
3. Prevent direct adverse impacts to wetlands, watercourses (both perennial & intermittent), to the maximum extent practical,
4. Minimize the extent of impervious cover and thus reduce the increases in runoff volume particularly for the 95% rainfall event,
5. Implement source controls for water quantity and water quality, while minimizing the extent of structural drainage systems,
6. Create a landscape environment that is multi-functional for all users.

A primary benefit of LISD 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 Sustainable Development strategies for all 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 LISD for each stakeholder group are stated below.

**Environmental Benefits:**

1. Preserve the biological and ecological integrity of natural systems through the preservation of large extents of contiguous land,
2. Protect the water quality by reducing sediment, nutrient and toxic loads to the wetland/watercourse aquatic environments and terrestrial plants and animals,

3. Reduce runoff volumes in receiving streams for the 95% rainfall event thus preventing changes to the physical stream channel morphology.

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

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

# Section 3.3
# Environmental Site Design Strategies

A key aspect for the successful implementation of LISD 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 Sustainable Development. The ESD process focuses on the natural landform 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 be 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. If the Natural Resource Conservation Service (NRCS) Websoil survey ( https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm ) is used for the upland soil boundaries, these boundaries need to be reviewed by the soil scientist and confirmed to be representative of the conditions on the site. These boundaries are typically sketched on a preliminary map of the site.
2. Obtain an inspection of the site by the soil scientist, if qualified or 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 with a Diameter at Breast Height (DBH) greater than 24" in the field by a qualified individual, such as the soil scientist, environmental consultant, land surveyor, or professional engineer.
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 the above information shall be prepared so all the resources can be fully evaluated.

1. 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.
2. Determine and delineate the existing sub watershed boundaries on the site.
3. Determine the generalized vegetative types on the site, whether they are deciduous, coniferous, a combination of both, and meadow areas.
4. 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.
5. 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 LISD 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.

# Section 3.4
# LISD Site Design Strategies

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

**Road Design:**

1. Road alignments shall follow the existing contours to the maximum extent practical to minimize excessive cuts and fills,
2. 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,
3. Utilize LISD treatment strategies to treat runoff at the source and not at the end of the pipe,
4. Utilize multiple LISD treatment systems in a series to increase the effectiveness of the pollutant removal from the stormwater.

**Driveway Layouts:**

a. Use a common driveway wherever feasible to minimize the extent of impervious cover on the site,
b. Use impervious area disconnection strategies to intercept and infiltrate driveway runoff prior to the runoff reaching the road,

c. Allow runoff from driveways to travel across vegetated areas for a minimum of 75' to facilitate infiltration.

**Lot Layout & Design:**

1. 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,
2. 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,
3. 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,
4. Do not randomly disturb areas of the site that are not necessary, this will preserve the infiltrative capacity of native soils,
5. 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,
6. Consider the use of meadow filter strips at the downhill limits of development to filter runoff prior to leaving the lot.

# Section 3.5
# Applying LISD Strategies to land development projects

The analyses and calculations required in Section 4.0 are the second part of the LISD equation. The first part of the LISD equation involves the evaluation of the natural landform and systems to identify the environmentally sensitive resources on the site. An evaluation using a sample process for application of LISD stormwater strategies for residential and commercial / Industrial applications is provided below. These requirements do not apply to existing approved single-family lots that have not been built on as of the effective date of this manual.

**Residential Applications:**

1. After the site analyses and processes required under Section 3.0 have been applied to a site. A Conceptual Development Plan shall be done including a preliminary plan for conveyance and treatment of stormwater,
2. Road alignments shall follow existing grades to the maximum extent practical to minimize regrading for the road. If road grades are less than 5%, a road cross section with a cross slope and not a crown should be considered to direct runoff to a swale system along one side of the road. The cross section of the road would have a uniform cross slope of 2-3%. If a cross slope would not be considered by the regulatory authorities, then the primary process would be to eliminate curbing on both sides of the road and utilize vegetated swales (dry or wet) along both sides of the road. The swales can convey water to an appropriate LISD treatment system. A grass filter strip could be utilized to convey flow to the swale,
3. 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", ideal length = 36") at 50' in-

tervals for grades up to 5% and 30' intervals for grades over 5% to convey runoff to a LISD treatment system along the road, such as a Bioretention system or wet swale,

4. 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 LISD treatment system(s) opposite the catch basin. This is a form of "source control" and moves away from the "end of the pipe" treatment of stormwater,
5. Runoff from residential roofs can be handled in one of two ways: Rooftop disconnection which directs runoff onto a stabilized surface and then 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; the connection of roof drains to a rain barrel for reuse as non-potable water, such as watering the lawn or landscaped area, or the connection of roof drains to Bioretention facility,
6. For those driveways which are located below the grade at the edge of the road, grade the driveway surface to direct runoff onto a vegetated surface which provides a minimum of 75' of overland flow. If the vegetated surface is lawn, the grade of this surface should be less than 8%. If the flow is directed to an undisturbed wooded area, the average grade can be increased to 15%,
7. For those driveways which drain toward to the road, the surface shall be graded to direct runoff off the impervious surface prior to reaching the road edge. It can be directed to a Bioretention facility or onto a vegetated filter strip.

**Commercial / Industrial Applications:**

1. Commercial / Industrial designs shall utilize LISD site strategies, such as respecting the natural landform 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 when Class A or Class B soils are present on the site. For industrial sites, any type of LISD 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 when Class A or Class B soils are present on the site. For industrial sites, any type of LISD 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, such as the Christmas shopping period, thus allowing for a significant reduction of imperious surfaces,
6. The gravel storage layer under permeable pavement or porous concrete surfaces located in Class A or Class B soils can be increased in depth to increase the storage volume for the runoff from adjacent impervious areas or building roofs. Pretreatment of runoff from large commercial / Industrial uses must be provided by a LISD vegetated system,
7. Impervious area disconnection can be utilized if there is sufficient space on the parcel.

# Section 3.6
# LISD Systems for Water Quality Retrofits for Commercial Sites

In the Town of Morris there may be some opportunities to apply stormwater retrofits in the central commercial areas of the town utilizing LISD concepts to provide some reduction of non-point source pollutants and reduce runoff volumes where the soils are suitable. The retrofits can be incorporated within the existing infrastructure in the commercial districts. Building planter systems, Bioretention systems, rainwater harvesting systems and swales are acceptable LISD systems for commercial retrofits. These systems are simply adaptations of proven LISD 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 3.6.1 – LISD Street Bioretention system**

**Figure 3.6.2 – LISD Curb Extension Bioretention System (City of Portland, OR)**

**Figure 3.6.3 - Painted Rain Barrels**

**Figure 3.6.4 - Rain Barrel with Planter on top**

# Section 4.0
# Overview of LISD Strategies

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

These requirements shall apply to all new land development projects in the Town of Morris after the Effective Date of this LISD Manual. These projects shall include new lots created by the "first division" of property, residential subdivisions, and commercial projects.

## Section 4.0.1 – Requirement #1
## Application of LISD strategies to minimize impact on the natural environment

A key aspect for the implementation of Low Impact Sustainable Development is to work with the natural resources which exist on a site. All new residential and commercial projects must utilize the Environmental Site Design Strategies as provided in **Section 3.0** 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 LISD design strategies is to provide a framework by which LISD 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 3 acres and to commercial sites greater than 1 acre.

Requirements #2, and #3 shall be provided for all new development projects where there is either new construction proposed which changes or increases impervious area on a site. Requirements #4, #5, and #6 shall be provided for all new development projects as may be applicable depending upon the development plan.

## Section 4.0.2 - Requirement #2
## Groundwater Recharge Volume

To maintain pre-development hydrology, post-development stormwater must be infiltrated to maintain the appropriate pre-development infiltration rate for the soil conditions on the site. The required Groundwater Recharge Volume is defined as a function of the annual pre-development recharge rate for site-specific soil conditions, the 95% rainfall event (1.3" of rain/24 hrs.), and the extent of impervious cover proposed on a site.

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 the 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 stormwaters must pass through a pre-treatment facility under this requirement. The technical requirement for the Groundwater Recharge and appropriate equations are found in **Section 4.1.1**.

**General Description of Hydrologic Soil Groups (Natural Resource Conservation Service):**

**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 terribly 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 clay pan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a terribly slow rate of water transmission.

## Section 4.0.3 - Requirement #3
## Water Quality Volume

Stormwater runoff from a site must be adequately treated reduce non-point source pollutants prior to discharge to a receiving wetland or watercourse. Non-structural LISD systems shall be the primary type of stormwater treatment system to be utilized for projects. Structural systems may be considered for pre-treatment of runoff only where the device will reduce Total Suspended Solids by a minimum of 25%.

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 1.3" per 24 hours. This is known as the water quality storm. All stormwater must pass through a pre-treatment facility under this requirement. The technical requirements for the Water Quality Volume, and necessary calculations are provided in **Section 4.1.2.** The required pollutant removal efficiencies that are to be achieved are specified in **Section 4.1.3**.

## Section 4.0.4 - 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 rates for the 95% rainfall event can reduce major adverse impacts to stream channel morphology, however, the other major adverse impact; increases in the flow duration from standard detention ponds which provide zero increases in the peak rate of runoff must be addressed. When a standard detention basin is proposed, it is basically a large bathtub with a small drain out of it. While the runoff is metered out to match the pre-development peak rate, there is a much larger volume of runoff in the basin, so the duration of flow out of the basin is significantly extended past the end of the actual rainfall event.

All-natural streams have a nominal flow depth and flow duration for all rainfall events within the stable section of the stream channel. The outflow from the basin causes the stream to flow at the nominal depth for an extended period, resulting in erosion of the channel banks and the uneven widening of the channel. The eroded material is washed downstream and ultimately settles out which then changes the morphology of stream by creating sandbars and filling of pools within the channel.

The Channel Protection Flow requirement addresses these increases in flow duration associated with zero peak rate designs and the adverse impacts on the hydro morphology of the stream channel which result from the increased flow durations. The standard for the Channel Protection Flow requirement is found in **Section 4.1.4**.

The goal of this requirement is to maintain the structural integrity of the stream channel by the reducing the depth of flow for the peak rate of runoff to compensate for the increased flow duration of the runoff. This results in the flow depth being kept in the most stable section of the channel, thus eliminating the erosion of the channel banks associated with increased flow durations. 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.

## Section 4.0.5 - Requirement #5
## Flood Protection/Peak Rate Attenuation

Storm events more than the 2-year, 24-hour storm can cause flood damage depending upon the total amount of impervious area on a site as well as the extent of the connectedness of the impervious area. Flooding impacts can be mitigated by the wide scale implementation of LISD infiltration systems on a site as these systems can infiltrate more runoff than associated with the 95% rainfall event, thus reducing the amount of surface runoff.

However, there will be situations where the detention of runoff is necessary to prevent adverse downstream impacts of runoff for larger rainfall events. The objective of this requirement is to prevent the magnitude and frequency of overbank flooding and to protect downstream structures from flooding. The requirements for Flood Protection are specified in the **Section 4.1.6**.

Flood protection shall be provided by the attenuation of the 10-year, 24-hour and/or 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 following are a series of design standards and requirements which shall apply to the actual location, design, and/or hydrologic modeling of LISD systems.

## Section 4.0.6 - Standard #1
## Stormwater Conveyance Systems

Open LISD systems, such as dry, wet and riprap swales or enclosed piped 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.

## Section 4.0.7 - Standard #2
## Commercial / Industrial Redevelopment Projects

Many existing developed sites, particularly those containing commercial or industrial uses lack adequate stormwater treatment measures to remove pollutants from stormwater. The purpose of this section is to provide a set of standards which will apply to these sites. The standards in this section shall only apply to those redevelopment projects which will cause 10,000 square feet of the current site area to be modified. This requirement will apply to commercial and industrial projects. If an industrial redevelopment project is to consist of a use with a high pollutant load, then the requirements found in standard #3 shall apply.

To apply the stormwater requirements on the site, the extent of the existing impervious area must be determined. All the existing impervious areas (paved/gravel roads, parking areas, sidewalks, and buildings) shall be calculated from an existing survey of the site conforming to Class A-2 standards. The site area shall be defined as all that area upon which the current development is located. It may include multiple lots or parcels. Wetlands, watercourses, open water bodies, and lands protected by easement from development shall be excluded from the lot area for the calculation of percent impervious coverage.

1. Provide full compliance with groundwater recharge volume,
2. Provide full compliance with water quality requirements,
3. Provide full compliance with Channel Protection Flow.

A waiver of this requirement may be requested from the Planning and Zoning Commission in accordance with **Section 4.7** of this manual.

## Section 4.0.8 - Standard #3
## 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 stated below 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 from these sites, the following requirements shall be met:

1. Groundwater Recharge Volume is not required to be calculated as infiltration is not permitted on High Pollutant Load sites.
2. The Water Quality Volume must be fully provided and adequately treated. Infiltration of runoff from all impervious paved surfaces from these types of land use shall not be permitted. All on-grade LISD treatment systems shall be lined with an impermeable liner, consisting of a 3 mil geosynthetic liner or a layer of 6” of compacted clay under and on the sidewalls of a treatment system.
3. Channel Protection Flow Rate shall be provided if the runoff is to be discharged to an open watercourse within 100’ of the development site.
4. Flood Protection requirement shall be provided, as necessary.

**Land Uses with High Pollutant Loads**

1. Industrial Sites (Any use as defined under Section **35** of the Town of Morris Aquifer Area Protection Regulations with an Effective Date of October 14, 2008),
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, contractor yards, logging, or mulch operations,
5. Exterior vehicle maintenance and service facilities, & equipment storage areas.

# Section 4.0.9 - Standard #4
# Provisions to address Increases of Imperviousness in Residential Zones

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 met by one or more of an appropriate LISD system 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 projects which will increase the impervious area on their property by more than 300 square feet.

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

| | |
|---|---|
| **Bioretention*** | 20 sq.ft. of surface area per 200 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 a Bioretention system or rain barrel is not able to be installed on a property, the following are alternative methods to address the increase of imperviousness on a property.

1. For properties which are greater than 0.5 acres, the runoff from increases of impervious cover shall be directed to flow across a minimum of 75' of vegetated surface (lawn, meadow or woods) prior to reaching a conventional drainage system or a downgradient property line.
2. For Building additions without gutters, the installation a gravel drip bed around the foundation to infiltrate runoff from the roof. Design specifications for a gravel drip bed are provided in Section 7.25 of the manual.

# Section 4.1
# Hydrologic Performance Requirements for Stormwater

## 4.1.1 - Groundwater Recharge Volume (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 = 1.3" (95% rainfall event)
D = Recharge Factor, see Table 4.1.1
I = Impervious area (acres)

**Table 4.1.1 Recharge Factors Based on Hydrologic Soil Group (HSG)**

| Hydrologic Soil Group (HSG) | Recharge Factor (D) |
|---|---|
| A | 0.80 |
| B | 0.60 |
| C | 0.40 |
| D | 0.10 |

The hydrologic soil group must be verified by field data in the vicinity of the proposed recharge infiltration 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.

## 4.1.2 - Water Quality Volume (WQV)

When it rains, the initial runoff generated by rainfall event contains the highest pollutant loads of the typical non-point source pollutants discussed earlier in this manual. The WQV is equal to runoff (1" of runoff) generated by 1.3" of rainfall on an impervious surface. The Water Quality volume is the amount of runoff generated by a rainfall event which must be treated to reduce the pollutant loads found in the runoff. The WQV contains the highest pollutant load from each rainfall event on an annual basis. The Water Quality volume is defined as follows:

WQV = (P) (Rv) (A)/12

Where:

Rv = 0.05 + 0.009(I)
WQV = Water Quality Volume (acre-feet)
P = 1.3" (95% rainfall event)
A = Total Drainage Area to design point (acres)
Rv = Runoff Coefficient
I = Impervious area (percent)

To convert the WQV to cubic feet, multiply the calculated WQV by 43,560.

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 drainage area) is required.

Minimum WQV = (0.2") (A)/12

Where:

A = Total Drainage Area to design point (acres)

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:

1. 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 an impermeable base)
2. Any off-site area which would be tributary to a proposed treatment facility must be bypassed around the proposed treatment system. If the off-site flows cannot be diverted safely around the treatment system, then the size of the treatment system must include the off-site drainage area for the sizing of that specific practice.
3. 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.

## 4.1.3 - Pollutant Removal Performance Standards

**Table 4.1.2 Required Minimum Pollutant Removal Efficiencies**

| Pollutant Type | Minimum Pollutant Removal Rate |
|---|---|
| **Total Suspended Solids (TSS)** | 90% |
| **Total Nitrogen (TN)** | 40% |
| **Total Phosphorus (TP)** | 60% |
| **Zinc (Zn)** | 75% |
| **Total Petroleum Hydrocarbons (TPH)** | 80% |
| **Dissolved Inorganic Nitrogen (DIN)** | 40% |

## 4.1.4 - Channel Protection Flow Rate (CPFR)

Control the 2-year, 24-hour post-development peak flow rate to 50% of the 2-year, 24-hour pre-development level at each point at which runoff is directed to a receiving stream or wetland system.

## 4.1.5 - 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 for structural water quality treatment systems, such as Hydrodynamic Separators, Filterra Tree Box Systems, and Modular Wetland Systems. Only the WQF is directed to one of these practices by using a splitter manhole. Flows greater than the WQF are directed around the practice to either an additional treatment system or detention system.

Steps to calculate the Water Quality Flow:

1. Calculate the Water Quality Volume in inches using the following equation:
   **$Q_{wv} = (P) * R_v$ , Where P = 1.3", Rv = 0.05 + 0.009 (I)**

2. Compute the NRCS Curve Number (CN) using the following equation:

   **$CN = 1000/[10 + 5P + 10Q_{wv} – 10((Q_{wv})^2 + 1.25*Q_{wv}*P)^{0.5}]$**

   Where:
   CN = Curve Number
   P = Rainfall Depth (1.3")
   Q = runoff depth (in watershed inches) [calculation directly below]
   $Q_{wv}$ = Water Quality Volume in inches

3. Calculate the Maximum Potential Abstraction (S):
   **S = 1000/CN – 10**
   Where:
   S = Maximum Potential Abstraction
   CN = Curve Number

4. Calculate the Initial Abstraction (Ia) or use data from Table 4-1:
   **Ia = 0.2 * S**
   Where:
   Ia = Initial Abstraction
   S = Maximum Potential Abstraction

5. Calculate Ia/P:
   **Ia/P**
   Where:
   Ia = Initial Abstraction
   P = Rainfall Depth (1.3")

6. Use Exhibit 4-III to estimate the unit peak discharge ($q_u$) using Ia/P and the Time of Concentration. Compute the time of concentration (Tc) based upon the methods described in Chapter 3 of the Manual for TR-55. A minimum Tc value of 0.1 hours (6 minutes) shall be used. For Sheet flow, the flow path shall not be longer than 100 feet.
7. After obtaining the unit peak discharge ($q_u$), you then calculate the water quality flow rate using the following equation:

   **$Q_{wq} = q_u * A * Q_{wv}$**
   Where:
   $Q_{wq}$ = Water Quality Flow rate (cfs)
   A = Area in Square Miles

$Q_{wv}$ = Water Quality Volume in inches

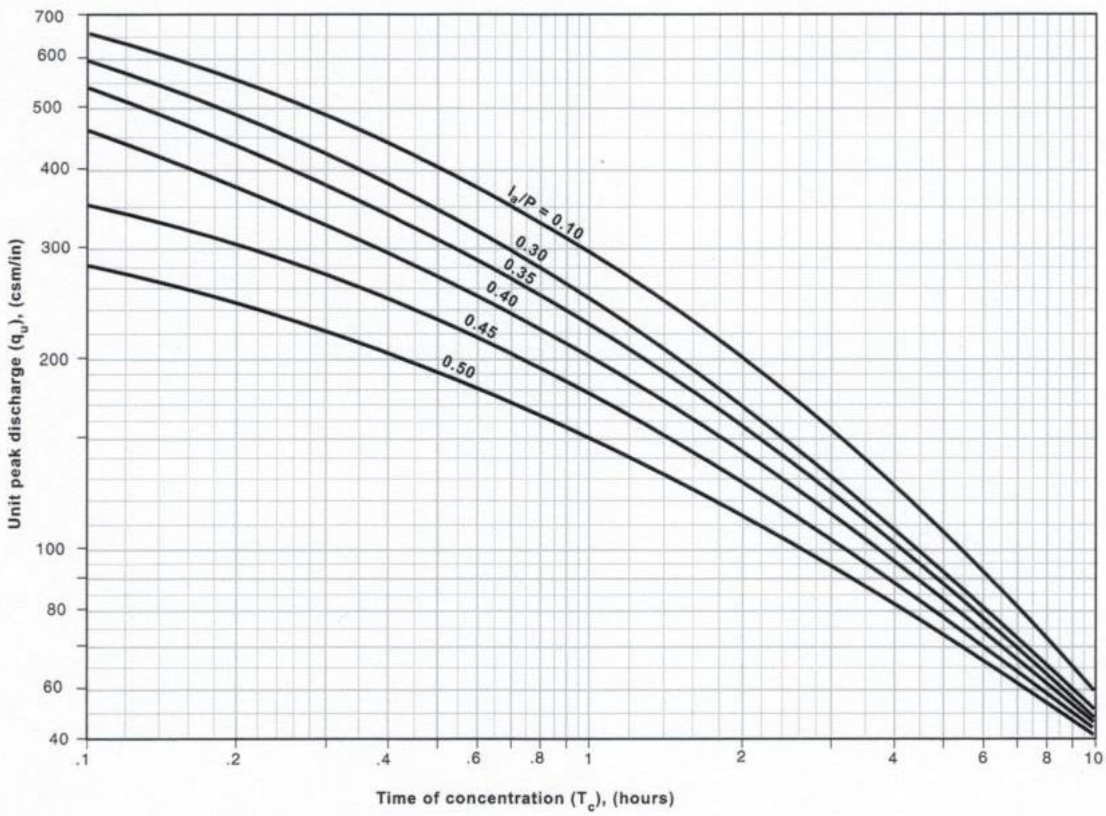
**Table 4-1 from Chapter 4 of TR-55:**

| RCN | $I_a$ | RCN | $I_a$ |
|---|---|---|---|
| 40 | 3.000 | 41 | 2.878 |
| 42 | 2.762 | 43 | 2.651 |
| 44 | 2.545 | 45 | 2.444 |
| 46 | 2.348 | 47 | 2.255 |
| 48 | 2.167 | 49 | 2.082 |
| 50 | 2.000 | 51 | 1.922 |
| 52 | 1.846 | 53 | 1.774 |
| 54 | 1.704 | 55 | 1.636 |
| 56 | 1.571 | 57 | 1.509 |
| 58 | 1.448 | 59 | 1.390 |
| 60 | 1.333 | 61 | 1.279 |
| 62 | 1.226 | 63 | 1.175 |
| 64 | 1.125 | 65 | 1.077 |
| 66 | 1.030 | 67 | 0.985 |
| 68 | 0.941 | 69 | 0.899 |
| 70 | 0.857 | 71 | 0.817 |
| 72 | 0.778 | 73 | 0.740 |
| 74 | 0.703 | 75 | 0.667 |
| 76 | 0.632 | 77 | 0.597 |
| 78 | 0.564 | 79 | 0.532 |
| 80 | 0.500 | 81 | 0.469 |
| 82 | 0.439 | 83 | 0.410 |
| 84 | 0.381 | 85 | 0.353 |
| 86 | 0.326 | 87 | 0.299 |
| 88 | 0.273 | 89 | 0.247 |
| 90 | 0.222 | 91 | 0.198 |
| 92 | 0.174 | 93 | 0.151 |
| 94 | 0.128 | 95 | 0.105 |
| 96 | 0.083 | 97 | 0.062 |
| 98 | 0.041 | | |

Exhibit 4-III of TR-55:



**Exhibit 4-III** Unit peal discharge ($q_u$) for NRCS (SCS) type III rainfall distribution




## 4.1.6 - Flood Protection (FP)

The matching of the pre-development infiltration rate is an important metric measuring the effectiveness of a LISD 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 sub watershed area. The total area of the sub watershed 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 impervious area directed to an infiltration LISD systems 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 or become closer to the RCN for pre-development conditions. If the post-development calculation still shows an increase in the peak rate of runoff from the sub watershed 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.

1. For those sites no greater than 10 acres, and having no more than 30% total impervious coverage, the 10-year, 24-hour storm shall be used to design the facility.
2. For a 10-acre site with more than 30% impervious coverage, or a site greater than 10 acres, both the 10-year, 24-hour, and 100-year, 24-hour storm event shall be accommodated.

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 large storms, protect the integrity of the stormwater management practice as well as maintain the existing boundaries of the pre-development flood plain.

# Section 4.2
# Pollutant Renovation Analysis

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. To achieve the pollutant removal efficiencies stated in **Section 4.1.3** for a particular practice, the practice must be designed and constructed in accordance with all the required parameters as found in **Section 7.0**.

# Section 4.3
# Pollutant Concentrations per Land Use Type

Concentrations of common non-point source pollutants are provided for common land uses in Table 4.3.1. All concentrations are in mg/l.

**Table 4.3.1 – 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 | 0.8 | 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 |

| Land Use | Pollutant Concentration (mg/l) TSS | TP | TN | Zn | TPH | DIN |
|---|---|---|---|---|---|---|
| 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 |

# Section 4.4
# 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 University of New Hampshire Stormwater Center, and the EWRI/ASCE BMP Database. The Pollutant Removal Efficiencies shown in Table 4.4.1 are for standalone treatment systems only. If two or more treatment systems are in series, the published removal efficiency of the second and subsequent systems in series must be reduced by the percentages which follow:

For the Second treatment system in series, only 75% of the stated pollutant removal percentage found in Table 4.4.1 shall be used. If the standalone removal efficiency for a system is 56%, then this value would be reduced by 75% to result in a removal efficiency of 42.0%.

For the Third treatment system is series, only 35% of the stated pollutant removal percentage found in Table 4.4.1 shall be used. Using the example above the stated 56% would be reduced to 19.6%.

If a fourth treatment system was used in series, then only 15% of the stated pollutant removal percentage would be used. The stated 56% would be reduced to 8.4%.

The justification for the reduction of the pollutant removal percentages for a treatment train approach to reducing the pollutant loads found in non-point source runoff is quite simple. As a particular pollutant load is removed from the runoff in the first treatment system, the runoff entering the second and subsequent treatment systems contains a lower load of that pollutant which is more difficult to remove by the subsequent treatment system, so the efficiency of the second, third or fourth treatment system is not as high as the values stated in Table 4.4.1.

**Table 4.4.1 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 | 45 | 45 | 35 |
| Subsurface Gravel Wetland | 98 | 55 | 57 | 82 | 99 | 75 |
| Pond/Wetland System | 71 | 29 | 16 | 56 | 42 | 40 |
| Wet Extended Detention Pond | 80 | 35 | 16 | 69 | 41 | 63 |
| Wet Pond/Pocket Pond | 80 | 35 | 15 | 65 | 45 | 33 |
| Micropool Extended Detention Pond | 78 | 23 | 16 | 55 | 55 | 22 |
| Shallow Wetlands | 73 | 24 | 10 | 45 | 45 | 24 |
| Multiple Pond | 75 | 31 | 14 | 42 | 47 | 28 |
| Dry Detention Pond | 80 | 40 | 10 | 50 | 74 | 25 |
| Infiltration Basin | 90 | 21 | 35 | 88 | 90 | 24 |
| Infiltration Trenches/Chambers | 75 | 19 | 33 | 86 | 90 | 24 |
| ADS Infiltration Water Quality Unit** | 99 | 0 | 81 | 99 | 99 | 0 |
| Bioretention | 82 | 36 | 25 | 65 | 65 | 41 |
| Tree Filter | 88 | 10 | 20 | 86 | 65 | 8 |
| Surface Sand Filter | 51 | 0 | 33 | 77 | 98 | 0 |
| Dry Swale w/filter berms | 56 | 10 | 22 | 40 | 82 | 0 |
| Wet Swale | 75 | 55 | 7 | 55 | 65 | 20 |
| Vegetated Filter Strip | 68 | 0 | 29 | 45 | 45 | 0 |
| Permeable Asphalt Pavement*** | 99 | 45 | 58 | 75 | 99 | 0 |
| Porous Concrete Pavement*** | 85 | 38 | 58 | 75 | 51 | 42 |
| Permeable Interlocking Pavers**** | 99 | 45 | 58 | 75 | 99 | 0 |
| Deep Sump Catch Basins (48") | 9 | 0 | 0 | 0 | 14 | 0 |
| On-line Hydrodynamic Separators | 29 | 0 | 0 | 26 | 42 | 0 |
| Off-line Hydrodynamic Separators | 75 | 0 | 0 | 21 | 64 | 0 |
| LISD Urban Planter | 63 | 22 | 34 | 65 | 65 | 25 |
| LISD Curb Extension | 63 | 22 | 34 | 65 | 62 | 25 |

** Off-line system with bypass
*** With filter course and elevated underdrain or no underdrain
**** With elevated underdrain

# Section 4.5
# Equation and Process

In 1987, Tom Schueler developed the Simple Method 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 sub watershed 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 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

** For the determination of Annual Pollutant Loads, P = 51" (average annual rainfall for the Town of Morris). For the determination of Pollutant Loads for the Water Quality Rainfall event, P = 1.3".

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 base flow volumes. For large acreage sites with low density residential developments (1 unit per 5 acres or greater), where I < 5% of the lot area, up to 75% of the annual runoff volume may be comprised of base flow, the annual nutrient load associated with the base flow 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 Morris. The following process shall be followed for the calculation of the pollutant loads and the effectiveness of the stormwater treatment systems.

## 4.5.1 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, generally Mixed Forest would be acceptable),

4. Use P=51" to calculate loads on annual basis or P=1" for the water quality storm,
5. Use the Simple Method to calculate the pollutants loads for the pre-development conditions.

Post-Development Conditions:

1. 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 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(s), 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 treatment(s) 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 especially 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 by technical analysis and calculations that the required pollutant removal efficiencies are achieved for the entire site.

**Pollutant Removal Calculation Procedure for three system treatment train**

Load removed by first system (removal #1):

Removal #1 = total load * pollutant removal rate
Remaining #1 = total load – removal #1

Load removed by second system (removal #2):

Removal #2 = Remaining #1 * (pollutant removal rate*0.75)
Remaining #2 = Remaining #1 – Removal #2

Load removed by third system (removal #3):
Removal #3 = Remaining #2 * (pollutant removal rate*0.35)
Remaining #3 = Remaining #2 – Removal #3

Total load removed = Removal #1 + Removal #2 + Removal #3
Percent load removal = total load removed/total load * 100

**Numerical Example for TSS removal only:**

Treatment system #1: Deep sump catch basin = 9%
Treatment system #2: Dry swale with filter berms = 56%
Treatment system #3: Detention pond = 79%
Initial TSS load = 350 lbs.

Load removed by first system (removal #1):
Removal #1 = 350 * 0.09 = 31.5 lbs.
Remaining #1 = 350 – 31.5 = 318.5 lbs.

Load removed by second system (removal #2):
Removal #2 = 318.5 * (0.56*0.75) = 133.77 lbs.
Remaining #2 = 318.5 – 133.77 = 184.73 lbs.

Load removed by third system (removal #3):
Removal #3 = 184.73 * (0.79*0.35) = 51.1 lbs.
Remaining #3 = 184.73 – 51.1 = 133.23 lbs.

Total load removed = 31.5 + 133.77 + 51.1 = 216.37
Percent load removal = 216.37/350 * 100 = 61.8%

# Section 4.6
# Measures to address agricultural runoff

As noted in **Section 2.5** of this manual, runoff from agricultural use can have significant adverse water quality impacts on receiving streams. As agricultural land uses are exempt from Federal stormwater quality regulations under the NDPES permit, it cannot be mandated that existing or proposed agricultural uses in the Town of Morris follow these recommendations. It is highly encouraged that the following strategies are implemented by agricultural operations to improve the water quality which is discharged from their properties.

Strategy #1: Allow regeneration of natural plants in wetland and watercourse systems

(Before the project) Pasture and stream before fence was constructed at Westphall's.

(Post Project) Fence was installed to separate pasture from riparian area. Native trees and shrubs were planted.

**Figure 4.6.1 - Installation of fence to protect wet swale**

A simple strategy to protect sensitive wetland and watercourse systems is the installation of a fence to prevent livestock from entering the wetland area. This allows for the native vegetation to grow denser which provide a higher filtering level for any runoff from the agricultural field. The fence can be installed a few feet outside the limit of the agricultural field to provide working area for the operation.

Strategy #2: Vegetated buffers along perennial streams

**Figure 4.6.2 – Un-mowed vegetated buffers along perennial streams**

This strategy involves allowing natural vegetative areas adjacent to a perennial stream to grow naturally and before thicker and denser. By allowing the density of the vegetation to increase, the trapping and filtering ability of the vegetated area greatly increases. A dense vegetative area will trap more sediment and nutrients than one than is frequently mowed. Creating flatter vegetative slopes on both sides of a perennial stream will provide a significant improvement to the water quality which reaches the stream. There is no defined buffer width for this type of improvement, but the wider the better, but should not require excessive earthwork to accomplish this improvement.

Strategy #3: Vegetated Filter Strips between agricultural fields and stream

**Figure 4.6.3 - Vegetated Filter Strip between field and stream**

The installation of well planted vegetated filter strip between an agricultural field and a stream system provides a significant improvement in the water quality which reaches the stream. The dense, low grass cover on a mild slope slows the runoff from the agricultural fields, allow the vegetation to absorb soluble nutrients found in the runoff and trap fine sediments which are found in the runoff. As the filter strip gets closer to the watercourse, the vegetation can be allowed to grow taller which increases the effectiveness of the system. This type of buffer strip should be 20 – 25' in width and be planted with native grasses.

Strategy #4: The installation of Dry Swales within the agricultural area

**Figure 4.6.4 - Dry swales in agricultural fields**

The creation of wide, shallow, and densely vegetated (with grass) swales at low points within existing agricultural fields provide a safe conveyance system for runoff from agricultural fields while providing a high level of treatment as runoff moves through the dense vegetated matrix. Dry swales in this application should have a bottom width of 8-10' and a shallow depth of 6-12" and simply be graded on the existing landscape. Swale side slopes should be 5:1 or flatter to allow for the movement of vehicles across them as well as periodic mowing (once a year). No special soil media is needed.

Strategy #5: Enhanced vegetated buffers along perennial streams

**Figure 4.6.5 - Enhanced Vegetative Buffer along perennial stream**

Where there is an existing wooded buffer along a stream, a densely planted vegetated buffer can be added between the wooded buffer and the agricultural field. This type of enhanced buffer should be 15-25’ in width and be planted with native grasses.

# Section 4.7
# Waiver of LISD Requirements

An applicant may apply for a waiver of any of the nine requirements and/or standards found in **Section 4.0** of this manual from the Planning and Zoning Commission “Commission” for a development or redevelopment application. A waiver may also be granted for residential lots of 10,000 square feet or less that were in existence prior to the adoption of the manual that have not be built on. The applicant’s consultant shall provide the necessary material to support his waiver request. The Commission shall obtain the professional opinion from the town engineer regarding the waiver request. The Commission may take one of the following actions:

1. The Commission may grant the waiver,
2. Deny the waiver,
3. Offer the applicant the option of obtaining a third-party review, subject to the provisions below with no guarantee that the waiver will be granted.

The third-party review shall be provided by an independent professional engineer licensed in the State of Connecticut with significant expertise in Low Impact Sustainable Development. The retaining of this independent engineer is subject to the following provisions:

1. Such engineer is hired by the Commission, and
2. The fee for such consulting engineer is paid for by the applicant.

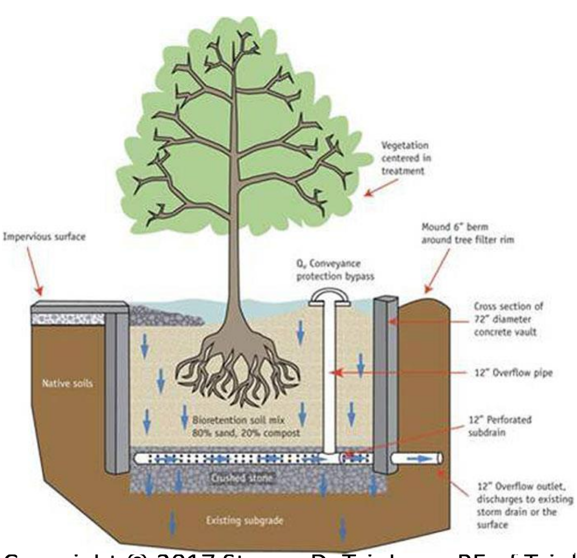
# Section 5.0
# LISD and Conventional Stormwater Practices to Meet Groundwater Recharge, Water Quality, and Water Quantity Control Requirements

There are many types of LISD stormwater management practices which can be utilized depending upon the performance requirement to be met the physical parameters as well on a site. Many of the LISD systems can address more than one of the hydrologic parameters stated above. The following sections provide pictures of typical LISD systems and a brief description of them. Detailed design information for all the system area provided in **Section 7.0** of this manual.

## Section 5.0.1
## List of BMPS for Groundwater Recharge and Water Quality Treatment

### FILTERING AND INFILTRATION SYSTEMS

**Bioretention (filtering and Infiltration):** A shallow depression with vegetation that treats stormwater as it filters through a specific soil mixture. To be utilized for groundwater recharge, the bottom of the system must be unlined to infiltrate stormwater into the underlying soils.
**Figure 5.01.1 – Bioretention System**




**Tree Box Filter (Filtering and Infiltration):** Tree box filters are mini Bioretention systems installed with a singular tree that can be highly effective at controlling runoff, especially when distributed throughout the site.
**Figure 5.01.2 – Tree Filter Section (UNHSC)**

**Surface Sand Filter (Filtering and Infiltration):** This system treats stormwater by the removal of coarse sediments in a sediment chamber or forebay, which is easily maintained prior to the stormwater filtering through a surface sand matrix. To be utilized for groundwater recharge, the bottom of the system must be unlined to infiltrate stormwater into the underlying soils.
**Figure 5.01.3 – Surface Sand Filter (UNHSC)**

**Dry Swale (Filtering and Infiltration):** 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. To be utilized for groundwater recharge, the bottom of the system must be unlined to infiltrate stormwater into the underlying soils.
**Figure 5.01.4 – Dry Swale (UCONN NEMO)**

**Infiltration Trenches (Infiltration):** These are infiltration practices that store water volume in open 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 (<3,000 sq.). For commercial/Industrial roofs, pre-treatment via one of the filtering systems list above must be provided prior to discharge into this type of infiltration system.
**5.01.5 – Infiltration Trench (www.washco-md.net)**

**Infiltration Chambers (Infiltration):** These are infiltration practices that store water volume in open spaces both within the chamber and the void spaces in the crushed stone. These practices are permissible for runoff from residential roofs (<3,000 sq.ft.). For commercial/Industrial roofs, pre-treatment via one of the filtering systems list above must be provided prior to discharge into this type of infiltration system.

**Figure 5.01.6 – Infiltration Chamber (www.tritonsws.com/Images/case-studies)**

**Infiltration Basin (Filtering and Infiltration):** This is an infiltration practice that temporarily stores stormwater above a flat, vegetated surface depression prior to infiltrating into the underlying soils. To be most effective, it needs to be designed as an off-line system with a bypass for rainfall events greater than the 95% storm.

**Figure 5.01.7 – Infiltration Basin – (www.wash-md.net)**

**Porous Asphalt (Filtering and Infiltration):** This is a filtering and infiltration practices which must be located on Class A or B soils. Filtering occurring within a layer of bank-run sand and gravel prior to entering the native soils below.

**Figure 5.01.8 – Porous Asphalt (www.stormwaterenvironments.com)**

**Porous Concrete (Filtration and Infiltration):** This is a filtering and infiltration system like porous asphalt. It is stronger than porous asphalt and is more suitable for travel lanes in addition to parking spaces. Water quality treatment is provided in a sand and gravel layer prior to infiltration into the underlying Class A or B soils.

**Figure 5.01.9 – Porous Concrete (www.perviouspavement.org)**

**Permeable Interlocking Concrete Pavers (PICP): (Infiltration):** PICP systems come in many different types of surface shapes. They are installed on permeable gravel base with an elevated underdrain to drive infiltration into the underlying native soils. The infiltrative surface consists of the openings between the paver stones and need to be filled with a coarse, fine gravel to be effective.

**Figure 5.01.10 – Permeable Interlocking Concrete Pavers** (www.hemengineering.com)

## Section 5.0.2
## List of Wetland and Pond BMPs for Water Quality Treatment

**Extended Detention Shallow Wetland (Treatment, CPFR, and Flood Protection:** 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 5.02.1 – Extended Detention Shallow Wetlands (www.wetlands.com.au)**

**Subsurface Gravel Wetlands (Treatment, CPFR, Flood Protection):** 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 5.02.2 – Subsurface Gravel Wetlands (UNHSC)**

**Pond / Wetland System (Treatment, CPFR, Flood Protection):** A treatment system which combines the shallow, vegetated aspects of a marsh with at least one pond component.

**Figure 5.02.3 – Pond/Wetland System (www.starenvironmentalinc.com)**

**Wet Swale (Treatment, Conveyance):** 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 5.02.4 – Wet Swale (Dr. Bill Hunt, NCSU)**

## Section 5.0.3
## List of Wetland and Pond BMPs for Water Quantity Control

**Wet Extended Detention Pond (CPFR and Flood Protection):** 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 in areas of seasonally high groundwater.
**Figure 5.03.1 – Wet Extended Detention Pond (NCSU)**

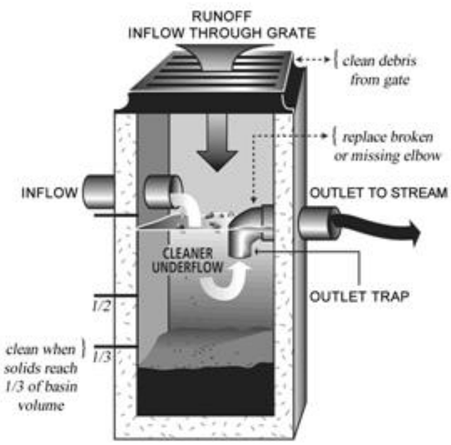
**Dry Detention Pond (CPFR and Flood Protection):** This practice has a dry bottom and is also designed to address changes in stormwater quantity only.
**Figure 5.03.2 – Dry Detention Pond (www.dhn.iihr.uiova.edu)**

## Section 5.0.4
## List of BMPs for Pretreatment for Water Quality Systems

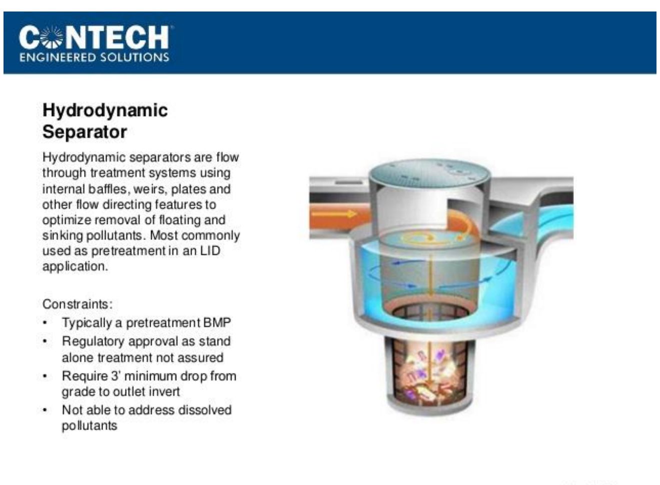
**Filter Strips:** These vegetated systems that are designed to treat stormwater from adjacent impervious area which occurs as overland flow. These systems function by slowing flow velocities, which allows the removal of sediments and other pollutants.
**5.04.1 – Filter Strip (www.trinkausengineering.com)**

**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 5.04.2 – 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.
**Figure 5.04.3 – Deep Sump Catch Basin with Hooded Outlet** ([www.stormwater.pca.state.minnesota](www.stormwater.pca.state.minnesota))




**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.   To use a proprietary treatment device, independent research documentation must be provided to justify the pollutant removal efficiency.
**Figure 5.04.4 – Hydrodynamic Separator** ([www.contech.com](www.contech.com))

# Section 5.0.5
# List of LISD BMPs for Commercial Water Quality Retrofits


**LISD Planter (Filtering):** These systems provide a "greening" of the urban streetscape while providing pollutant attenuation and potential reductions of runoff volume. These systems are modifications of a standard Bioretention design.

**Figure 5.05.1 – LISD Urban Planter (City of Portland, OR)**

**LISD Curb Extension (Filtering and Infiltration):** These systems are used to reduce run-off volumes by infiltration as well as filtering the pollutants in the runoff. They provide a "greening" benefit to any green in addition to a traffic calming device

**Figure 5.05.2 – LISD Curb Extensions (City of Portland, OR) ([www.portlandoregon.gov/bes/34598](www.portlandoregon.gov/bes/34598))**

## Section 5.0.6
## List of Alternative BMPs for Increases of Imperviousness on 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 such as irrigation of landscaped areas or the washing of vehicles.

**Figure 5.06.1 – Rain Barrel (http://www.cbtrust.org/site/c.miJPKXPCJnH/b.5458173/k.8975/Rain_Barrels.htm)**

**Gravel Drip Bed (Infiltration):** 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 5.06.2 – Gravel Drip Bed** (www.pinterest.com)

## Section 5.2
## Determining the appropriate LISD system

The long-term effectiveness of any LISD systems depends on many parameters with the most important ones being the suitability of the soils for a particular LISD system. LISD infiltration systems are most effective when installed at the source of the runoff versus the end of the pipe. The following design matrices evaluate the each of the possible LISD treatment systems for these design parameters:

a. Contributing Drainage Area,
b. Percent Impervious Area in Contributing Drainage Area,
c. Hydrologic Soil Group,
d. Depth to Seasonal High Groundwater,
e. Depth to Bedrock,
f. Land Slope.

The matrices are color coded in accordance with the Legend shown below. In the category of "Suitable with No Restrictions", there are notations for design modifications which are required to be implemented depending upon certain conditions in the field. As an example, for Surface Sand Filters, forebays area required when the Contributing Drainage Area exceeds 10,000 square feet. The required capacity of the forebay is information found in Figure 5.2.5 below.

In the category of "Suitable with Design Modifications", there are notations which address the design modification required to design a LISD system under this category. In the category "Not Suitable", the rationale for not recommending the installation of a LISD system is provided.

| **LISD COLOR CODE LEGEND** | |
|---|---|
| SUITABLE WITH NO RESTRICTIONS | (green) |
| SUITABLE WITH DESIGN MODIFICATIONS | (yellow) |
| NOT SUITABLE | (red) |

There are four LISD matrices on the following pages:

Figure 6.0.a – Contributing Drainage Area (CDA)
Figure 6.0.b – Percent Impervious Area in CDA and Hydrologic Soil Group (HSG)
Figure 6.0.c – Depth to Seasonal High Groundwater and Depth to Bedrock
Figure 6.0.d – Land Slope

Figure 5.2.5 states what the specific design modifications are required for a particular LISD treatment system for a particular site parameter found in the prior figures.

**LOW IMPACT SUSTAINABLE DEVELOPMENT**
**STORMWATER MANAGEMENT SYSTEMS**
**DECISION MATRIX**

| | **CONTRIBUTING DRAINAGE AREA (CDA)** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **TYPE OF LID TREATMENT PRACTICE** | CDA < 5,000 SQ.FT. | CDA < 10,00 SQ.FT. | CDA < 20,00 SQ.FT. | CDA < 1 ACRE | CDA 1-5 ACRE | CDA 5-10 ACRE | CDA 10-20 ACRE | CDA > 20 ACRE |
| BIORETENTION | | FB - 1 | FB - 2 | FB - 3 | FB - 3 | WATERSHED TOO LARGE | | |
| TREE FILTER | | | | | WATERSHED TOO LARGE | | | |
| SURFACE SAND FILTER | | FB - 1 | FB - 1 | FB - 2 | FB - 3 | FB - 3 | WATERSHED TOO LARGE | |
| ORGANIC FILTER | | FB - 1 | FB - 1 | FB - 2 | FB - 3 | FB - 3 | WATERSHED TOO LARGE | |
| INFILTRATION BASIN | | FB - 1 | FB - 1 | FB - 2 | FB - 3 | FB - 3 | WATERSHED TOO LARGE | |
| INFILTRATION TRENCH | | FB - 1 | FB - 1 | FB - 2 | FB - 2 | FB - 2 | WATERSHED TOO LARGE | |
| INFILTRATION CHAMBERS | | | | | FB - 2 | FB - 2 | WATERSHED TOO LARGE | |
| PERMEABLE ASPHALT PAVEMENT | NOT COST EFFECTIVE | | | | | | | |
| POROUS CONCRETE PAVEMENT | NOT COST EFFECTIVE | | | | | | | |
| PERMEABLE INTERLOCKING CONCRETE PAVERS | | | | | | | | |
| GRASS FILTER STRIPS (MOWED) | 1-M | 2-M | 3-M | 4-M | WATERSHED AREA TOO LARGE | | | |
| VEGETATED FILTER STRIPS (UNMOWED) | 1-UM | 2-UM | 3-UM | 4-UM | WATERSHED AREA TOO LARGE | | | |
| DRY SWALES (OVERLAND FLOW) | | | | | WATERSHED AREA TOO LARGE | | | |
| DRY SWALES (END OF PIPE) | FB - 1 | FB - 1 | FB - 1 | FB - 1 | FB - 2 | FB - 3 | SAME AS DRY SWALES | |
| WET SWALES (OVERLAND FLOW) | | | | | WATERSHED AREA TOO LARGE | | | |
| WET SWALES (END OF PIPE) | | | | FB - 1 | FB - 2 | FB - 2 | SAME AS WET SWALES | |
| SUBSURFACE GRAVEL WETLANDS | INSUFFICIENT WATERSHED AREA | | | FB | FB | FB | FB | FB |
| EXTENDED DETENTION SHALLOW WETLANDS | INSUFFICIENT WATERSHED AREA | | | | FB | FB | FB | FB |
| WET POND | INSUFFICIENT WATERSHED AREA | | | | | FB | FB | FB |
| MULTIPLE POND SYSTEM | INSUFFICIENT WATERSHED AREA | | | | | | FB | FB |
| SHALLOW WETLANDS | INSUFFICENT WATERSHED AREA | | | | FB | FB | FB | FB |
| WET EXTENDED DETENTION POND | INSUFFICIENT WATERSHED AREA | | | | | FB | FB | FB |
| POND/WETLAND SYSTEM | INSUFFICIENT WATERSHED AREA | | | | FB | FB | FB | FB |
| POCKET POND SYSTEM | INSUFFICIENT WATERSHED AREA | | | | FB | FB | FB | FB |
| MICRO-POOL EXTENDED DETENTION POND | INSUFFICIENT WATERSHED AREA | | | | | | FB | FB |
| DRY DETENTION POND | MAY NOT BE COST EFFECTIVE | | | | FB | FB | FB | FB |
| RAIN BARRELS ( < 100 GALLONS) | | WATERSHED AREA TOO LARGE | | | | | | |
| CISTERNS ( > 100 GALLONS) | | | | | WATERSHED AREA TOO LARGE | | | |

**Figure 5.2.1 - Contributing Drainage Area (CDA)**

**LOW IMPACT SUSTAINABLE DEVELOPMENT**
**STORMWATER MANAGEMENT SYSTEMS**
**DECISION MATRIX**

| | PERCENTAGE OF IMP. AREA IN CDA | | | | HYDROLOGIC SOIL GROUP (HSG) | | | |
|---|---|---|---|---|---|---|---|---|
| **TYPE OF LID TREATMENT PRACTICE** | < 30% | < 60% | < 90% | < 100% | HSG A | HSG B | HSG C | HSG D |
| BIORETENTION | | | | | | | Slow Inf. | No Inf. |
| TREE FILTER | | | | | | | Slow Inf. | No Inf. |
| SURFACE SAND FILTER | | | | | | | No Inf. | No Inf. |
| ORGANIC FILTER | | | | | | | No Inf. | No Inf. |
| INFILTRATION BASIN | | | | | | | No Inf. | No Inf. |
| INFILTRATION TRENCH | | | | | | | No Inf. | No Inf. |
| INFILTRATION CHAMBERS | | | | | | | No Inf. | No Inf. |
| PERMEABLE ASPHALT PAVEMENT | | | | | | | No Inf. | No Inf. |
| POROUS CONCRETE PAVEMENT | | | | | | | No Inf. | No Inf. |
| PERMEABLE INTERLOCKING CONCRETE PAVERS | | | | | | | No Inf. | No Inf. |
| GRASS FILTER STRIPS (MOWED) | | | | | | | Slow Inf. | No Inf. |
| VEGETATED FILTER STRIPS (UNMOWED) | | | | | | | Slow Inf. | No Inf. |
| DRY SWALES (OVERLAND FLOW) | | | | | | | Slow Inf. | No Inf. |
| DRY SWALES (END OF PIPE) | | | | | | | Slow Inf. | No Inf. |
| WET SWALES (OVERLAND FLOW) | | | | | REQUIRE LINER | | | |
| WET SWALES (END OF PIPE) | | | | | REQUIRE LINER | | | |
| SUBSURFACE GRAVEL WETLANDS | | | | | REQUIRE LINER | | | |
| EXTENDED DETENTION SHALLOW WETLANDS | | | | | REQUIRE LINER | | | |
| WET POND | | | | | REQUIRE LINER | | | |
| MULTIPLE POND SYSTEM | | | | | REQUIRE LINER | | | |
| SHALLOW WETLANDS | | | | | REQUIRE LINER | | | |
| WET EXTENDED DETENTION POND | | | | | REQUIRE LINER | | | |
| POND/WETLAND SYSTEM | | | | | REQUIRE LINER | | | |
| POCKET POND SYSTEM | | | | | REQUIRE LINER | | | |
| MICRO-POOL EXTENDED DETENTION POND | | | | | REQUIRE LINER | | | |
| DRY DETENTION POND | | | | | | | REQUIRE LINER | |
| RAIN BARRELS ( < 100 GALLONS) | | | | | NOT APPLICABLE | | | |
| CISTERNS ( > 100 GALLONS) | | | | | NOT APPLICABLE | | | |

**Figure 5.2.2 - Percent Impervious Area in CDA, Hydrologic Soil Group**

| LOW IMPACT SUSTAINABLE DEVELOPMENT STORMWATER MANAGEMENT SYSTEMS DECISION MATRIX | DEPTH TO SEASONAL HIGH GROUNDWATER (FEET) | | | | | DEPTH TO BEDROCK (FEET) | | | |
|---|---|---|---|---|---|---|---|---|---|
| **TYPE OF LID TREATMENT PRACTICE** | < 1.5 | 1.5 < 2 | 2 < 3 | 3 < 4 | > 4 | < 3 | 3 < 5 | 5 < 7 | > 7 |
| BIORETENTION | GW-1 | GW-1 | | | | LTS | | | |
| TREE FILTER | GW-1 | GW-1 | | | | LTS | LTS-1 | | |
| SURFACE SAND FILTER | GW-2 | GW-2 | GW-1 | | | LTS | LTS-1 | | |
| ORGANIC FILTER | GW-2 | GW-2 | GW-1 | | | LTS | LTS-1 | | |
| INFILTRATION BASIN | GW-2 | GW-2 | GW-1 | | | LTS | LTS-1 | | |
| INFILTRATION TRENCH | GW-2 | GW-2 | GW-1 | | | LTS | LTS-1 | | |
| INFILTRATION CHAMBERS | GW-2 | GW-2 | GW-1 | | | LTS | LTS | | |
| PERMEABLE ASPHALT PAVEMENT | GW-2 | GW-2 | GW-1 | | | LTS | LTS-1 | | |
| POROUS CONCRETE PAVEMENT | GW-2 | GW-2 | GW-1 | | | LTS | LTS-1 | | |
| PERMEABLE INTERLOCKING CONCRETE PAVERS | GW-2 | GW-2 | | | | LTS | LTS-1 | | |
| GRASS FILTER STRIPS (MOWED) | | | | | | | | | |
| VEGETATED FILTER STRIPS (UNMOWED) | | | | | | | | | |
| DRY SWALES (OVERLAND FLOW) | GW-1S | GW-1S | | | | LTS-1 | | | |
| DRY SWALES (END OF PIPE) | GW-1S | GW-1S | | | | LTS-1 | | | |
| WET SWALES (OVERLAND FLOW) | | | REQUIRE LINER | | | LTS-1 | | | |
| WET SWALES (END OF PIPE) | | | REQUIRE LINER | | | LTS-1 | | | |
| SUBSURFACE GRAVEL WETLANDS | | | REQUIRE LINER | | | LTS-1 | LTS-1 | | |
| EXTENDED DETENTION SHALLOW WETLANDS | | | REQUIRE LINER | | | LTS-1 | LTS-1 | | |
| WET POND | | | REQUIRE LINER | | | LTS-1 | LTS-1 | | |
| MULTIPLE POND SYSTEM | | | REQUIRE LINER | | | LTS-1 | LTS-1 | | |
| SHALLOW WETLANDS | | | REQUIRE LINER | | | LTS-1 | LTS-1 | | |
| WET EXTENDED DETENTION POND | | | REQUIRE LINER | | | LTS-1 | LTS-1 | | |
| POND/WETLAND SYSTEM | | | REQUIRE LINER | | | LTS-1 | LTS-1 | | |
| POCKET POND SYSTEM | | | REQUIRE LINER | | | LTS-1 | LTS-1 | | |
| MICRO-POOL EXTENDED DETENTION POND | | | REQUIRE LINER | | | LTS-1 | LTS-1 | | |
| DRY DETENTION POND | REQUIRE LINER | | | | | LTS-1 | | | |
| RAIN BARRELS ( < 100 GALLONS) | NOT APPLICABLE | | | | | NOT APPLICABLE | | | |
| CISTERNS ( > 100 GALLONS) | NOT APPLICABLE | | | | | NOT APPLICABLE | | | |

**Figure 5.2.3 - Depth to Seasonal High Groundwater, Depth to Bedrock**

**LOW IMPACT SUSTAINABLE DEVELOPMENT**
**STORMWATER MANAGEMENT SYSTEMS**
**DECISION MATRIX**

| | **LAND SLOPE (PERCENT)** | | | | |
|---|---|---|---|---|---|
| **TYPE OF LID TREATMENT PRACTICE** | < 6 | 6 < 10 | 10 < 15 | 15 < 20 | > 20 |
| BIORETENTION | | | S-1 | S-2 | S-2 |
| TREE FILTER | | | | S-2 | S-2 |
| SURFACE SAND FILTER | | | S-2 | S-2 | S-2 |
| ORGANIC FILTER | | | S-2 | S-2 | S-2 |
| INFILTRATION BASIN | | | S-2 | S-2 | S-2 |
| INFILTRATION TRENCH | | | | S-2 | S-2 |
| INFILTRATION CHAMBERS | | | | S-2 | S-2 |
| PERMEABLE ASPHALT PAVEMENT | | | S-2 | S-2 | S-2 |
| POROUS CONCRETE PAVEMENT | | | S-2 | S-2 | S-2 |
| PERMEABLE INTERLOCKING CONCRETE PAVERS | | | S-2 | S-2 | S-2 |
| GRASS FILTER STRIPS (MOWED) | | | | | |
| VEGETATED FILTER STRIPS (UNMOWED) | | | | | |
| DRY SWALES (OVERLAND FLOW) | | CD | CD | S-2 | S-2 |
| DRY SWALES (END OF PIPE) | | CD | CD | S-2 | S-2 |
| WET SWALES (OVERLAND FLOW) | | RLCD | S-2 | S-2 | S-2 |
| WET SWALES (END OF PIPE) | | RLCD | S-2 | S-2 | S-2 |
| SUBSURFACE GRAVEL WETLANDS | | | S-2 | S-2 | S-2 |
| EXTENDED DETENTION SHALLOW WETLANDS | | | S-2 | S-2 | S-2 |
| WET POND | | | S-2 | S-2 | S-2 |
| MULTIPLE POND SYSTEM | | | S-2 | S-2 | S-2 |
| SHALLOW WETLANDS | | | S-2 | S-2 | S-2 |
| WET EXTENDED DETENTION POND | | | S-2 | S-2 | S-2 |
| POND/WETLAND SYSTEM | | | S-2 | S-2 | S-2 |
| POCKET POND SYSTEM | | | S-2 | S-2 | S-2 |
| MICRO-POOL EXTENDED DETENTION POND | | | S-2 | S-2 | S-2 |
| DRY DETENTION POND | | | S-2 | S-2 | S-2 |
| RAIN BARRELS ( < 100 GALLONS) | **NOT APPLICABLE** | | | | |
| CISTERNS ( > 100 GALLONS) | **NOT APPLICABLE** | | | | |

Figure 5.2.4 - Land Slope

| | |
|---|---|
| **CONTRIBUTING DRAINAGE AREA MODIFICATIONS** | |
| **FOREBAY** | |
| **FB** | Requires Forebay providing 10% (minimum) of Calculated Water Quality Volume |
| **FB - 1** | Requires Forebay providing 25% of Calculated Water Quality Volume |
| **FB - 2** | Requires Forebay providing 50% of Calculated Water Quality Volume |
| **FB - 3** | Requires Forebay providing 100% of Calculated Water Quality Volume |
| | Forebay must be designed in full compliance with specifications stated in LISD Manual |
| | |
| **FILTER STRIP LENGTH** | |
| **1-M** | Minimum Length of Filter Strip perpendicular to flow shall be 20' |
| **2-M** | Minimum Length of Filter Strip perpendicular to flow shall be 25' |
| **3-M** | Minimum Length of Filter Strip perpendicular to flow shall be 30' |
| **4-M** | Minimum Length of Filter Strip perpendicular to flow shall be 50' |
| | |
| **1-UM** | Minimum Length of Filter Strip perpendicular to flow shall be 10' |
| **2-UM** | Minimum Length of Filter Strip perpendicular to flow shall be 15' |
| **3-UM** | Minimum Length of Filter Strip perpendicular to flow shall be 25' |
| **4-UM** | Minimum Length of Filter Strip perpendicular to flow shall be 35' |
| | |
| **HYDROLOGIC SOIL GROUP MODIFICATIONS** | |
| **Slow Inf.** | Slow/Marginal Infiltration |
| **No Inf.** | No Infiltration |
| | |
| | |
| **DEPTH TO SEASONAL HIGH GROUNDWATER MODIFICATIONS** | |
| **GW-1** | Design requires shallow ponding depth and larger surface area |
| **GW-1S** | Design requires shallow ponding depth and larger surface area |
| **GW-2** | Groundwater too shallow for system |
| **REQ. LINER** | 30 mil. (min) thick impermeable liner required |
| | |
| **DEPTH TO BEDROCK** | |
| **LTS** | Ledge too shallow to provide required adequate vertical separation |
| **LTS-1** | Depth of ledge may be too shallow to provide required vertical separation |
| | |
| **LAND SLOPE** | |
| **S-1** | System must be narrow and long parallel to slope |
| **S-2** | Slope too steep for LISD system |
| **CD** | Requires check dams |
| **RLCD** | Require 30 mil. (min) thick impermeable liner and check dams |

**Figure 5.2.5 - List of Design Modifications**

# Section 7.0
# Design Requirements for Stormwater Systems

All LISD and conventional stormwater management practices have specific design, construction, and maintenance requirements to provide the desired water quality or quantity control benefits. The six categories are feasibility, conveyance, pretreatment, sizing criteria, treatment, and maintenance. The following pages provide detailed design parameters for each type of LISD treatment system to be used to address stormwater issues in the Town of Morris.


| System Type | | Page Number |
|---|---|---|
| 7.1 | Bioretention | 73 |
| 7.2 | Tree Filter | 80 |
| 7.3 | Surface Sand Filter | 84 |
| 7.4 | Dry Swales | 89 |
| 7.5 | Infiltration Trench | 97 |
| 7.6 | Infiltration Chamber | 102 |
| 7.7 | Infiltration Basin | 107 |
| 7.8 | Permeable Paving Surfaces | 112 |
| 7.9 | Extended Detention Shallow Wetland | 119 |
| 7.10 | Subsurface Gravel Wetlands | 123 |
| 7.11 | Pond / Wetland System | 129 |
| 7.12 | Micropool Extended Detention Pond | 133 |
| 7.13 | Wet Pond/Pocket Pond | 137 |
| 7.14 | Shallow Wetland System | 142 |
| 7.15 | Wet Extended Detention Pond | 146 |
| 7.16 | Multiple Pond | 150 |
| 7.17 | Wet Swale | 154 |
| 7.18 | Filter Strip | 159 |
| 7.19 | Sediment Forebay | 164 |
| 7.20 | Deep Sump Catch Basin | 166 |
| 7.21 | Proprietary Treatment Device | 168 |
| 7.22 | Dry Detention Pond | 170 |
| 7.23 | LISD Planter | 174 |
| 7.24 | LISD Curb Extension | 179 |
| 7.25 | Rain Barrel | 184 |
| 7.26 | Gravel Drip Bed | 185 |


As the LISD approach to stormwater management focuses on treating runoff at its source, which will be on private property, maintenance of these systems is especially important. Legally binding maintenance agreements for these LISD and/or conventional systems must be prepared and filed in the Office of the Town Clerk for the Town of Morris. Each maintenance agreement must include the maintenance requirements as specified for each system.

Table 7.0.1 and 7.0.2 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 4.1** of this manual.

**Table 7.0.1 – Stormwater System Matrix**

## Stormwater Treatment Device Selection Matrix

| Stormwater Treatment Systems | GRV | WQV | PT | CPFR | FP |
|---|---|---|---|---|---|
| **FILTERING/INFILTRATION SYSTEMS** | | | | | |
| Bioretention (page 69) | YES | YES | | | |
| Tree Filter (page 76) | YES | YES | | | |
| Surface Sand Filter (page 80) | YES | YES | | | |
| Dry Swales (page 85) | YES | YES | | | |
| **INFILTRATION SYSTEMS** | | | | | |
| Infiltration Trenches (page 93) | YES | YES | | | |
| Infiltration Chambers (page 98) | YES | YES | | | |
| Infiltration Basins (page 103) | YES | YES | | | |
| Permeable Paving Surface (page 108) | YES | YES | | | |
| **WET VEGETATED TREATMENT SYSTEMS** | | | | | |
| Extended Detention Shallow Wetlands (page 115) | | YES | | YES | YES |
| Subsurface Gravel Wetlands (page 119) | | YES | | YES | |
| Pond / Wetland System (page 125) | | YES | | YES | YES |
| Micropool Extended Detention Pond (page 129) | | YES | | YES | YES |
| Wet Pond/Pocket Pond (page 133) | | YES | | YES | YES |
| Shallow Wetland System (page 138) | | YES | | | |
| Wet Extended Detention Pond (page 142) | | | | YES | YES |
| Multiple Pond (page 146) | | YES | | YES | YES |
| Wet Swales (page 150) | | YES | | | |
| **DRY DETENTION SYSTEM** | | | | | |
| Dry Detention Pond (page 167) | | | | YES | YES |
| **PRE-TREATMENT SYSTEMS** | | | | | |
| Filter Strip (page 156) | | | YES | | |
| Sediment Forebay (page 161) | | | YES | | |
| Deep Sump Catch Basins (page 163) | | | YES | | |
| Proprietary Treatment Devices (page 165) | | | YES | | |
| **COMMERCIAL LISD RETROFITS** | | | | | |
| LISD Planter (page 171) | YES | YES | | | |
| LISD Curb Extension (page 176) | YES | YES | | | |
| **RAINFALL REUSE** | | | | | |
| Rain Barrel (page 181) | | YES | | | |
| Gravel Drip Bed (page 182) | YES | | | | |

GRV: Groundwater Recharge Volume
WQV: Water Quality Volume
PT: Pretreatment
CPFR: Channel Protection Flow Rate
FP: Flood Protection

**Table 7.0.2 – Treatment System Matrix**

| POLLUTANT REMOVAL RATING | Excellent | Very Good | Good | Fair | Marginal |
|---|---|---|---|---|---|
| Pollutant Removal Efficiency | 80% – 95% | 70% - 80% | 55% - 70% | 40% - 55% | < 40% |
| Letter Coded System | E | VG | G | F | M |

## Stormwater Treatment System Pollutant Removal Selection Matrix

| Stormwater Treatment Systems | TSS | TN | TP | Zn | TPH | DIN |
|---|---|---|---|---|---|---|
| **FILTERING/INFILTRATION SYSTEMS** | | | | | | |
| Bioretention (page 69) | E | M | M | G | G | M |
| Tree Filter (page 76) | E | M | M | E | G | M |
| Surface Sand Filter (page 80) | F | M | M | VG | E | M |
| Dry Swales (page 85) | G | M | M | F | E | M |
| **INFILTRATION SYSTEMS** | | | | | | |
| Infiltration Trenches (page 93) | VG | M | M | E | E | M |
| Infiltration Chambers (page 98) | VG | M | M | E | E | M |
| Infiltration Basins (page 103) | E | M | M | E | E | M |
| Permeable Paving Surface (page 108) | E | F | G | VG | VG | M |
| **WET VEGETATED TREATMENT SYSTEMS** | | | | | | |
| Extended Detention Shallow Wetlands (page 115) | G | G | M | F | F | M |
| Subsurface Gravel Wetlands (page 119) | E | G | G | E | E | VG |
| Pond / Wetland System (page 125) | VG | M | M | G | F | F |
| Micropool Extended Detention Pond (page 129) | VG | M | M | G | G | M |
| Wet Pond/Pocket Pond (page 133) | VG | M | M | G | F | M |
| Shallow Wetland System (page 138) | VG | M | M | F | F | M |
| Wet Extended Detention Pond (page 142) | VG | M | M | G | F | G |
| Multiple Pond (page 146) | VG | M | M | F | F | M |
| Wet Swales (page 150) | VG | G | M | G | G | M |
| **DRY DETENTION SYSTEM** | | | | | | |
| Dry Detention Pond (page 167) | VG | M | M | F | VG | M |
| **PRE-TREATMENT SYSTEMS** | | | | | | |
| Filter Strip (page 156) | VG | M | M | F | F | M |
| Sediment Forebay as part of other BMP (page 161) | VG | M | M | G | G | M |
| Deep Sump Catch Basins (page 163) | M | M | M | M | M | M |
| Proprietary Treatment Devices – off-line (page 165) | VG | M | M | M | G | M |
| Proprietary Treatment Devices – on-line (page 165) | M | M | M | M | F | M |
| **COMMERCIAL LISD RETROFITS** | | | | | | |
| LISD Planter (page 171) | G | M | M | G | G | M |
| LISD Curb Extension (page 176) | G | M | M | G | G | M |

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

**Table 7.0.3 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** | 25’ | 25’ |
| **Top of 15%+ Slopes** | 50’ | 50’ |
| **Buildings (up-gradient)** | 10’ | 10’ |
| **Buildings (down-gradient)** | 10’ | 50’ |
| **On-site Subsurface Sewage Disposal Systems** | 50’[1] | 75’[2] |

**Note: These setback requirements shall apply to Bioretention, Surface Sand Filters, Tree Filters, Infiltration Trenches, Infiltration Chambers, Infiltration Basins, and Dry Swales**

1. Distance shall be reduced to 25 feet to a leaching system if MLSS is not applicable or the storm water system is not up-gradient or down-gradient of the leaching system. Distances may be further reduced to 10 feet for Bioretention, Surface Sand Filters, Tree Filters, Infiltration Trenches, Infiltration Chambers, Infiltration Basins, and Dry Swales with the approval from the local director of health if the design professional has demonstrated by hydrologic modeling that the infiltration of runoff will not increase the seasonal groundwater level under the leaching system.
2. Distance shall be reduced to 50 feet to leaching system if MLSS is not applicable or the storm water system is not up-gradient or down-gradient, or with the approval from the local director of health if the design professional has demonstrated by hydrologic modeling that the infiltration of runoff will not increase the seasonal groundwater level under the leaching system.

## 7.1 – BIORETENTION (GRV & WQV)

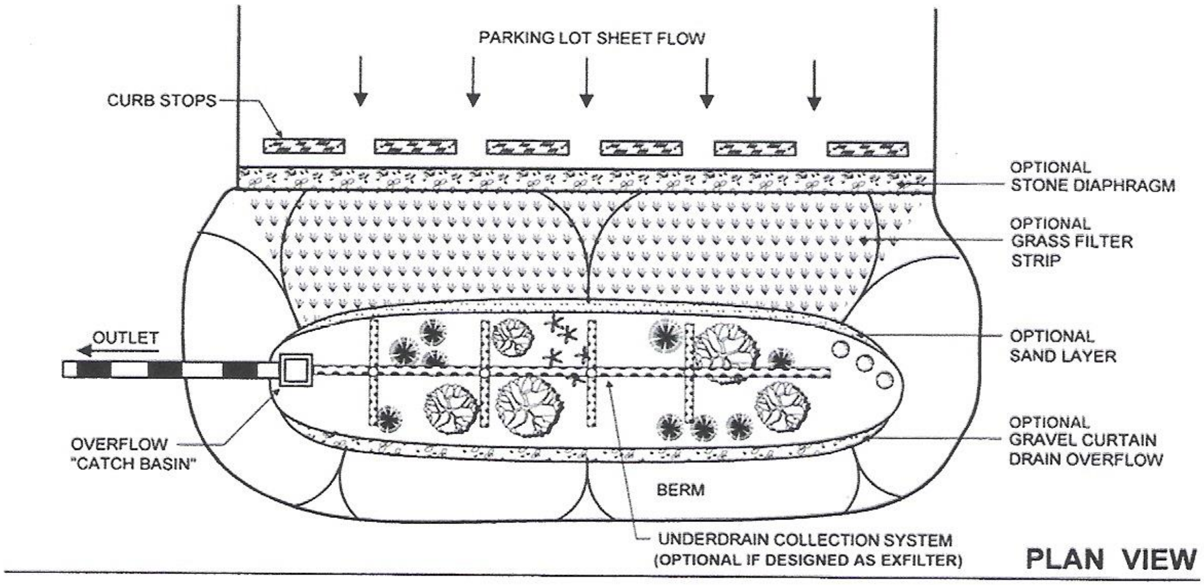



**Figure 7.1.1 – Typical Bioretention (RI DEM, 2010)**

**Bioretention Design Parameters**

Bioretention systems are simply depressed landscaped beds which are designed to accept runoff from impervious areas. The runoff temporarily ponds above the soil surface, filters through the soil media which causes non-point source pollutants to be reduced through physical, chemical, and biological processes with the soil and plant community. After passing through the soil media, the runoff infiltrates into the underlying natural soils thus recharging shallow groundwater levels while at the same time reducing runoff being discharged onto the ground surface.

The primary function of a Bioretention system is the filtering and infiltration of runoff. In some situations, an underdrain pipe may be required to be installed below the soil media such as to create an Internal Water Storage Zone to enhance the removal of nitrogen in the runoff or to discharge runoff if the system is constructed with an impermeable liner to prevent infiltration such as when used for industrial land uses. The typical overhead view of a Bioretention system is shown in Figure 7.1.1. A typical cross section of a Bioretention system is shown in Figure 7.1.2.

**Site Investigation:**

1. A deep test pit shall be excavated within 20’ of the proposed location of a Bioretention system to a depth three (3) feet below the anticipated bottom of the soil media or gravel storage of the Bioretention system.
2. An Infiltration test using a Double Ring Infiltrometer shall be done within five (5) feet of the proposed location of a Bioretention system. The infiltration test must be done at a depth which is equal to or below the lowest elevation of the soil media or gravel storage layer. The Infiltration test shall be done in accordance with the specifications found in Appendix “E” at the end of this manual.

**Design Requirements:**

1. Depth of Soil Media shall be 12" for residential applications and 18" for commercial applications.
2. Minimum Vertical Separation to Seasonal High Groundwater Level from either bottom of soil media or bottom of gravel layer:
    a. Residential roof or driveway = 12" for Class A Soils; 9" for Class B Soils; and 6" for Class C Soils,
    b. Commercial roof or driveway = 18" for Class A Soils; 12" for Class B Soils; and 9" for Class C Soils.
3. Minimum Vertical Separation to Bedrock from the bottom of the soil media shall be twenty-four (24) inches.
4. Maximum Allowable Ponding Depth (D) of full Water Quality Volume above soil surface. As the allowable ponding depth becomes shallower, the surface area of the soil media surface increases:
    a. Class A Soils = 18"
    b. Class B Soils = 12" (where restrictive layer is greater than 36" deep)
    c. Class B Soils = 9" (where restrictive layer is less than 36" deep)
    d. Class C Soils = 6" (where restrictive layer is greater than 24" deep)
    e. Class C Soils = 3" (where restrictive layer is less than 24" deep)
5. Sizing of the surface area of the Bioretention system:

    SA = (WQV)/D where:

    SA = Surface area of filter bed (square feet)
    WQV = Calculated water quality volume (cubic feet) directed to system
    D = Depth of ponding above soil surface in feet (use values above per soil class)
6. Allowable Contributing Drainage Area (CDA) directed to Bioretention system and required (pre-treatment):
    a. CDA < 5,000 square feet: (Outlet protection at end of pipe or overland flow across vegetated filter strip, a minimum of 25' in width),
    b. 5,000 square feet ≤ CDA ≤ 10,000 square feet: (Forebay containing 25% of the calculated WQV designed in accord with the specifications found in this manual),
    c. 10,000 square feet ≤ CDA ≤ 20,000 square feet: (Forebay containing 50% of the calculated WQV designed in accord with the specifications found in this manual),
    d. 20,000 square feet ≤ CDA ≤ 1 acre: (Forebay containing 100% of the calculated WQV designed in accord with the specifications found in this manual),
    e. 1 acre ≤ CDA ≤ 5 acres: (Forebay containing 100% of the calculated WQV designed in accord with the specifications found in this manual.
7. Natural Land Slope: There are no design modification necessary for a Bioretention system on slopes up to 10% other than meeting the other requirements found in this section. For slopes between 10% and 15%, the Bioretention system shall have a narrow width and a long length following the natural contours while meeting the other requirements found in this section.
8. Underdrains: For all underdrain configurations, two layers of gravel shall be installed below the soil media layer. The first gravel layer shall consist of 3" of 3/8" washed gravel (pea gravel). The lower gravel layer consists of 6" – 12" of ¾" washed gravel. Specific information on the gravel layers is shown in the details cited below. There are three underdrain configurations which can be used in a Bioretention system.

   a. The underdrain pipe can be installed as an overflow pipe to by-pass larger storm events while allowing infiltration into the underlying natural soils to be the primary discharge system. In this case the underdrain, typically consisting of 4" perforated PVC pipe is set at the top of a stone layer below the soil media. This configuration is shown in Figure 7.1.3 below.
   b. For Bioretention systems which are lined with an impermeable barrier to prevent infiltration, the underdrain pipe (4" PVC) is located at the bottom of the gravel layer to provide a discharge point to daylight or to another stormwater management practice. This configuration is shown in Figure 7.1.4 below.
   c. The last underdrain configuration is used to provide for enhanced removal of Nitrogen by the creation of an Internal Water Storage zone within the bottom of the system. In this case the underdrain (4" PVC) is set at the top of the stone layer and the outlet consists of a "goose neck" pipe to create a saturated zone in the bottom of the soil media. This configuration is shown in Figure 7.1.5 below.
9. Soil Media Specification for Bioretention systems is designed to filter the runoff as well as provide sufficient organic material for the initial establishment of plants in the Bioretention system. The material shall be mixed on a hard clean surface prior to being placed in the Bioretention system. The soil media shall consist of the following material containing the specified percentage by volume:
   a. Washed Concrete Sand – 80% (ASTM C33)
   b. Well decomposed wood chip or leaf compost – 15%
   c. Sandy loam or sandy topsoil – 5% (no more than 2% clay content)
10. Overflow provisions from a Bioretention system can be done in one of several ways:
   a. A vertical Solid PVC pipe with the top of the pipe set at the allowable ponding depth for the water quality volume. A slotted end cap shall be used on the top of the pipe to prevent organic debris from entering the overflow pipe.
   b. A small spillway lined with 3" or larger native field stones can be placed in the berm of the Bioretention system. The minimum width of the spillway should be 24". The field stone should extend to the bottom of the Bioretention system as well as the existing ground on the outside of the Bioretention system.
   c. A catch basin with outlet pipe can be placed in the Bioretention system. The top of the grate shall be set at the allowable ponding depth for the water quality volume.
11. Internal Water Storage (Enhanced Nitrogen Removal):
   a. Only used when system is in Class "C" soils.
   b. Native soils to have infiltration rate between 0.25"/hr. to 0.5"/hr.
   c. Only bottom six (6) inches of soil media is to be saturated by Internal Water Storage.

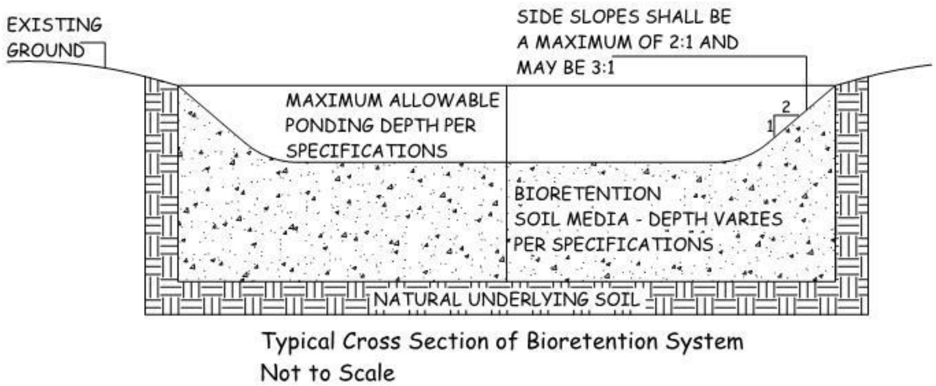



**Figure 7.1.2 - Typical Bioretention System (Trinkaus Engineering, LLC – 2017)**

**Hydrologic Modeling:**

As part of the design of a Bioretention system, it shall be demonstrated by hydrologic modeling using a program such as HydroCAD that the system will fully infiltrate at a minimum the water quality storm event. The modeling shall be done in a conservative fashion to ensure that the system will function as intended. To perform this approach, the following parameters shall be adhered to:

1. The slowest observed infiltration rate shall be reduced by at least 50% to be used as the exfiltration rate in the model,
2. Only the storage volume above the soil media surface shall be used,
3. Storage in the media and/or the gravel layers shall not be considered in the model.

**Construction Requirements:**

The design engineer shall develop a detailed, site specific construction sequence for the Bioretention system. The design engineer shall also inspect the installation of the Bioretention system during the installation process. Bioretention systems shall be constructed early on during the overall construction process, so that they are fully vegetated and stabilized prior to the introduction of stormwater to them.

A typical construction sequence will follow these generalized steps:

1. The area of the Bioretention system shall be fenced off with orange poly construction fence after the clearing of trees to prevent the movement of construction vehicles over the area of the Bioretention system,
2. A stable benchmark shall be set by the design engineer or land surveyor for use by the contractor,
3. The outline of the Bioretention system shall be staked in the field by the design engineer or contractor,
4. The Bioretention system shall be excavated to the required design depth (bottom of soil media or gravel layer as applicable) by hydraulic excavator located outside the limit of the facility. No excavation equipment is permitted in the actual Bioretention system,
5. After the rough excavation has occurred, the side walls shall be raked with a metal garden rake to remove any soil smearing,
6. The bottom of the facility shall also be scarified by the teeth on the excavated and be made as level as possible. Loose soil from the scarification shall be removed by the excavator,

7. Grade stakes shall be set as necessary to ensure the proper placement of soil media and/or gravel, if applicable,
8. Placement of the gravel, if applicable shall be done by hydraulic excavator from outside the Bioretention limits and then hand raked to the required design elevation,
9. The soil media shall be placed by the hydraulic excavator in the same fashion as the gravel and then hand raked level. It is imperative that the top of the soil media be as level as possible to ensure that runoff will spread out across the entire of the Bioretention system,
10. The soil media shall be lightly tamped by walking on it or spraying the surface with water,
11. Plants or grass shall be installed in the Bioretention system. It is acceptable to place a small amount of wood mulch around the plant stems, but the entire bottom of the Bioretention system shall **NOT** be covered with mulch,
12. Plants shall be watered as necessary to ensure their establishment.

**Inspection Requirements:**

The design engineer shall oversee the entire installation of the Bioretention system at these specific steps:

1. After the excavation and scarification of the Bioretention system has been done,
2. After placement of gravel layer, if part of the design,
3. Inspection of the soil media prior to placement in the Bioretention system,
4. After placement and leveling of the Bioretention soil media,
5. After installation of overflow provisions as may be applicable,
6. After plants have been installed.

The design engineer shall prepare an as-built plan of the completed Bioretention system and provide a written statement which addresses the following items:

1. Excavation and scarification of the natural soils,
2. Approval of soil media,
3. Approval of overflow provisions, if applicable,
4. Approval of plant installation,
5. Approval of completed system.

**Maintenance Requirements:**

1. Annual inspection of the Bioretention system,
2. Removal of organic debris (sticks and leaves) in the Spring and Fall,
3. Weeding as necessary to prevent undesirable plants from colonizing the Bioretention system,
4. Removal of accumulated sediment by hand rake or shovel from the top of the soil surface if the Bioretention system receives runoff from a driveway or road where sand is applied. In general, only the top ¼" or so of accumulated sediment needs to be removed. After the material is removed, lightly rake the bottom of the Bioretention system,
5. Replace of dead or dying plants as needed.

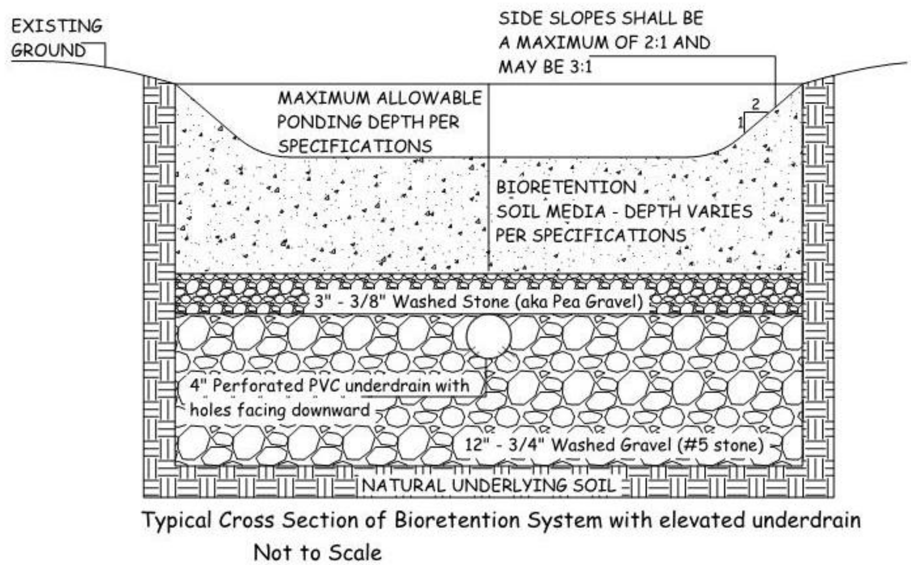



**Figure 7.1.3 - Bioretention with Elevated Underdrain (Trinkaus Engineering, LLC – 2017)**

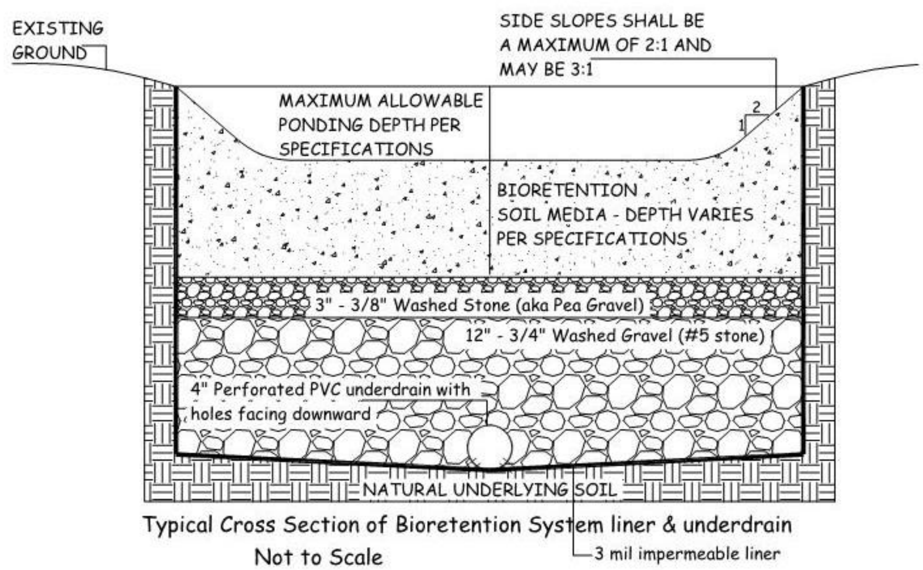



**Figure 7.1.4 - Bioretention with liner & Underdrain (Trinkaus Engineering, LLC – 2017)**

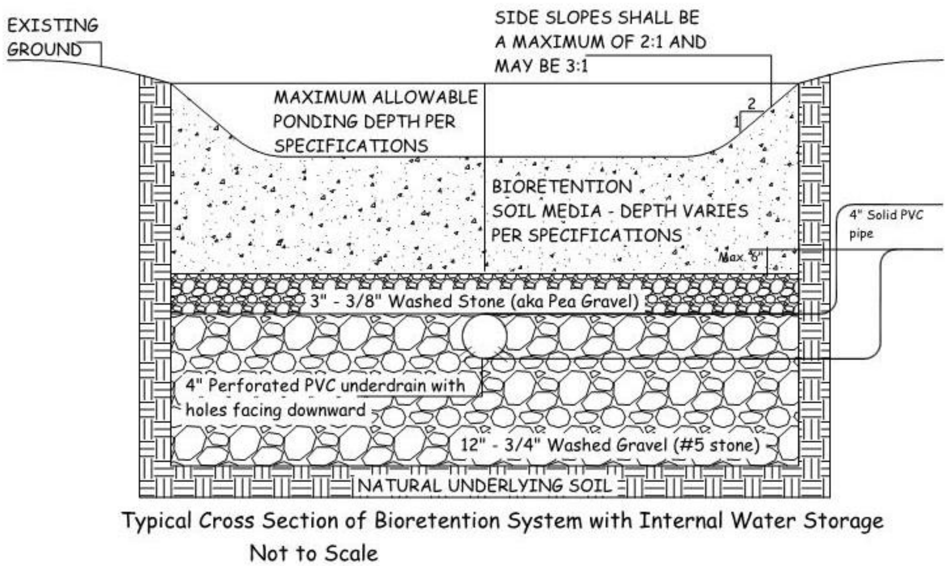



**Figure 7.1.5 - Bioretention with Internal Water Storage (Trinkaus Engineering, LLC – 2017)**

# 7.2 – TREE FILTER (GRV & WQV)

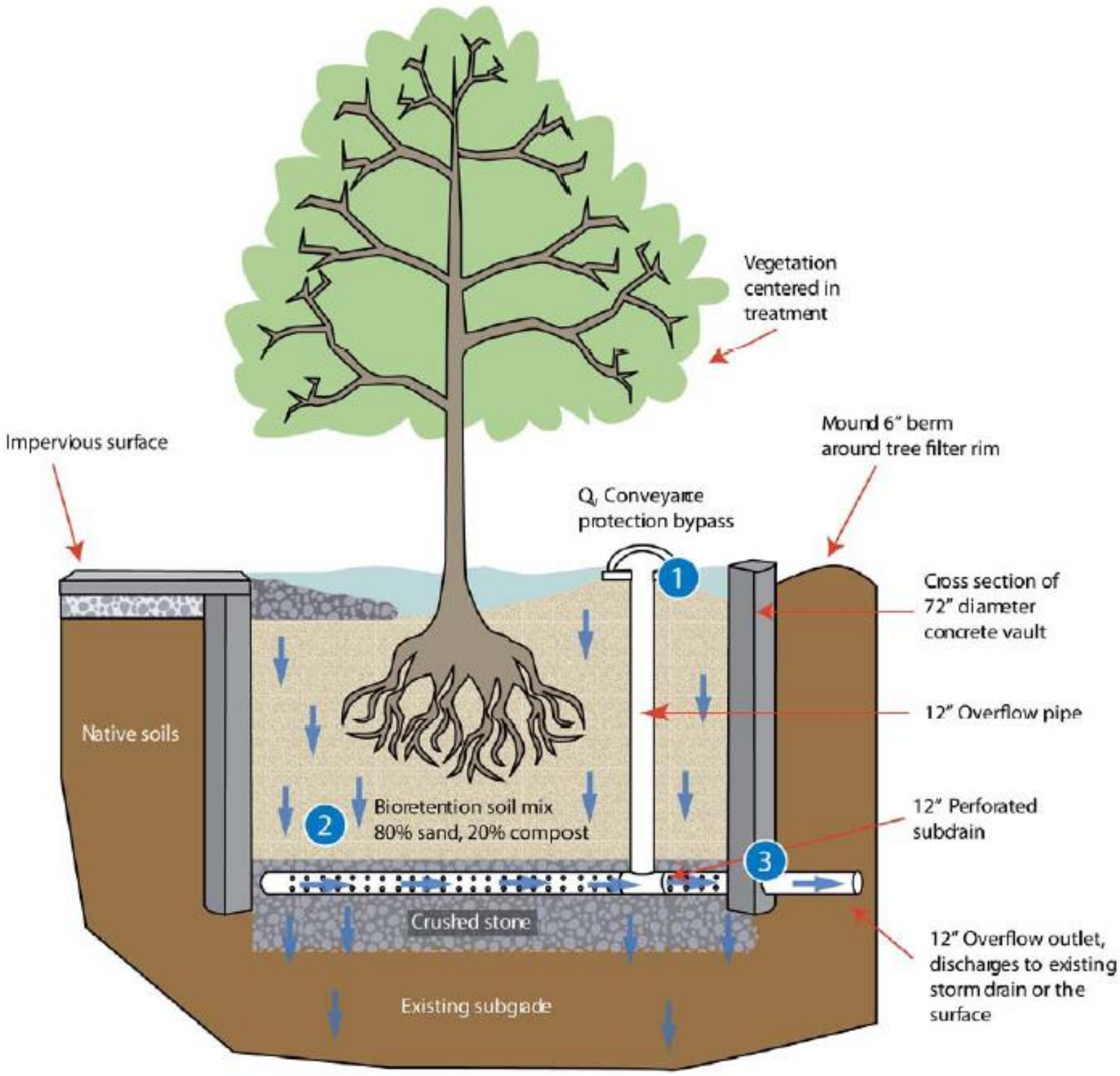



**Figure 7.2.1 – Generalized Detail of Tree Filter (UNHSC)**

**Site Investigation:**

1. A deep test pit shall be excavated within 20' of the proposed location of Tree Filter to a depth three (3) feet below the anticipated bottom of the soil media or gravel storage of the Bioretention system.
2. An Infiltration test using a Double Ring Infiltrometer shall be done within five (5) feet of the proposed location of a Tree Filter. The infiltration test must be done at a depth which is equal to or below the lowest elevation of the soil media or gravel storage layer. The Infiltration test shall be done in accordance with the specifications found in Appendix "E" at the end of this manual.

**Design Requirements:**

1. Depth of Soil Media shall be 48” for residential and commercial applications.
2. Minimum Vertical Separation to Seasonal High Groundwater Level from the bottom of soil media:
    a. Residential/Commercial roof or driveway = 12”
3. Minimum Vertical Separation to Bedrock from the bottom of the soil media shall be twelve (12) inches.
4. Maximum Allowable Ponding Depth (D) of full Water Quality Volume above soil surface. As the allowable ponding depth becomes shallower, the surface area of the soil media surface increases:
    a. Class A Soils = 12”
    b. Class B Soils = 12”
5. Sizing of the surface area of the Tree Filter:
    a. The minimum surface area of a tree filter is 36 square feet (6’ x 6’),
    b. The Tree Filter shall contain the required WQV at the maximum allowable ponding depth of 12”.
6. Allowable Contributing Drainage Area (CDA) directed to a singular Tree Filter
    a. CDA $\leq$ 5,000 square feet
7. Natural Land Slope: There are no design modifications necessary for a Tree Filter on slopes up to 15% other than meeting the other requirements found in this section.
8. Underdrains: An underdrain can be installed in a Tree Filter like a Bioretention system: two layers of gravel shall be installed below the soil media layer. The first gravel layer shall consist of 3” of 3/8” washed gravel (pea gravel). The lower gravel layer consists of 6” – 12” of ¾” washed gravel. Specific information on the gravel layers is shown in the details cited below. There are three underdrain configurations which can be used in a Bioretention system.
    a. The underdrain pipe can be installed as an overflow pipe to by-pass larger storm events while allowing infiltration into the underlying natural soils to be the primary discharge system. In this case the underdrain, typically consisting of 4” perforated PVC pipe is set at the top of a stone layer below the soil media. This configuration is shown in Figure 7.2.3.
9. Soil Media Specification for Tree Filters is designed to filter the runoff as well as provide sufficient organic material for the initial establishment of the tree in the Tree Filter. The material shall be mixed on a hard clean surface prior to being placed in the Tree Filter. The soil media shall consist of the following material containing the specified percentage by volume:
    a. Washed Concrete Sand – 80% (ASTM C33)
    b. Well decomposed wood chip or leaf compost – 15%
    c. Sandy loam or sandy topsoil – 5% (no more than 2% clay content)
10. Overflow provisions from a Tree Filter shall be done in the following manner:
    a. A vertical Solid PVC pipe with the top of the pipe set at the allowable ponding depth for the water quality volume. A slotted end cap shall be used on the top of the pipe to prevent organic debris from entering the overflow pipe.

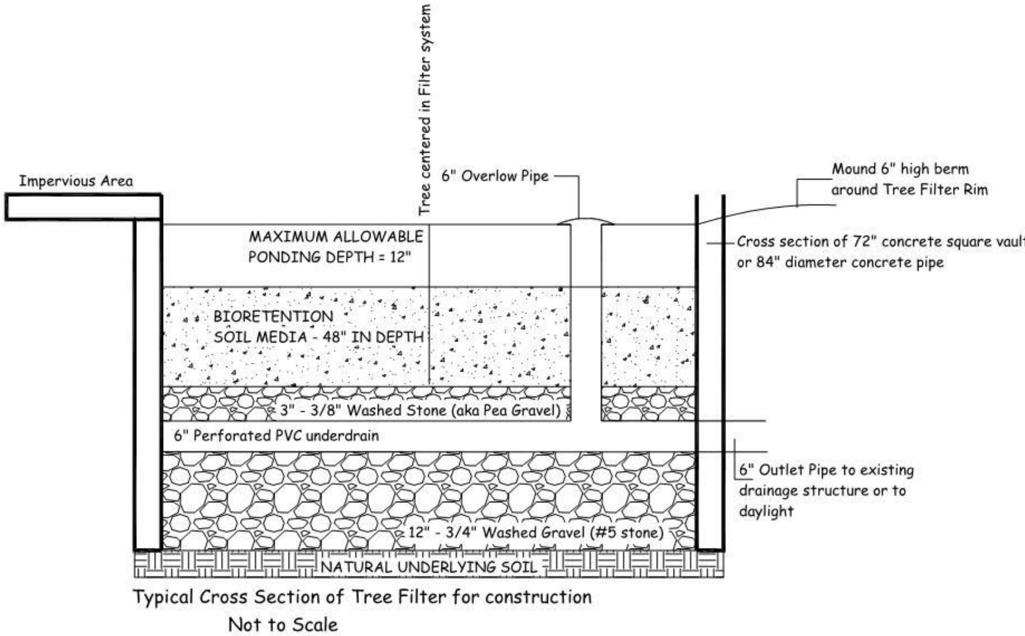



**Figure 7.2.2 - Tree Filter (Trinkaus Engineering, LLC – 2017)**

**Hydrologic Modeling:**

As part of the design of a Tree Filter, it shall be demonstrated by hydrologic modeling using a program such as HydroCAD that the system will fully infiltrate at a minimum the water quality storm event. The modeling shall be done in a conservative fashion to ensure that the system will function as intended. To perform this approach, the following parameters shall be adhered to:

1. The slowest observed infiltration rate shall be reduced by at least 50% to be used as the exfiltration rate in the model,
2. Only the storage volume above the soil media surface shall be used,
3. Storage in the media and/or the gravel layers shall not be considered in the model.

**Construction Requirements:**

The design engineer shall develop a detailed, site specific construction sequence for the Tree Filter. The design engineer shall also inspect the installation of the Tree Filter during the installation process. Tree Filters shall be constructed early on during the overall construction process, so that they are fully vegetated and stabilized prior to the introduction of stormwater to them.

A typical construction sequence will follow these generalized steps:

1. The area of the Tree Filter shall be fenced off with orange poly construction fence after the clearing of trees to prevent the movement of construction vehicles over the area of the Tree Filter,
2. A stable benchmark shall be set by the design engineer or land surveyor for use by the contractor,
3. The outline of the Tree Filter shall be staked in the field by the design engineer or contractor,

4. The Tree Filter shall be excavated to the required design depth (bottom of gravel layer) by hydraulic excavator located outside the limit of the facility. No excavation equipment is permitted in the actual Tree Filter,
5. After the rough excavation has occurred, concrete vault with no bottom shall be installed,
6. The soil bottom area within the bottom of the concrete box shall be scarified by hand be made as level as possible. Loose soil from the scarification shall be removed by hand,
7. Placement of the gravel shall be done by hydraulic excavator from outside the Tree Filter limits and then hand raked to the required design elevation. The underdrain, outlet pipe and vertical overflow pipes shall also be installed at this time,
8. The soil media shall be placed at this time. It is imperative that the top of the soil media be as level as possible to ensure that runoff will spread out across the entire top of the Tree Filter,
9. The soil media shall be lightly tamped by walking on it or spraying the surface with water,
10. Install deciduous tree in the center of the Tree Filter.
11. The tree shall be watered as necessary to ensure its establishment.

**Inspection Requirements:**

The design engineer shall oversee the entire installation of the Tree Filter at these specific steps:

1. After the excavation and the installation of concrete vault has been done,
2. After placement of gravel layer, and drainage pipes,
3. Inspection of the soil media prior to placement in the Tree Filter,
4. After placement and leveling of the Tree Filter soil media,
5. After the tree has been installed.

The design engineer shall prepare an as-built plan of the completed Tree Filter and provide a written statement which addresses the following items:

1. Excavation and scarification of the natural soils,
2. Approval of soil media,
3. Approval of overflow provisions,
4. Approval of tree installation,
5. Approval of completed system.

**Maintenance Requirements:**

1. Annual inspection of the Tree Filter,
2. Removal of organic debris (sticks and leaves) in the Spring and Fall,
3. Weeding as necessary to prevent undesirable plants from colonizing the Tree Filter,
4. Removal of accumulated sediment by hand rake or shovel from the top of the soil surface if the Bioretention system receives runoff from a driveway or road where sand is applied. In general, only the top ¼" or so of accumulated sediment needs to be removed. After the material is removed, lightly rake the bottom of the Bioretention system,
5. Replace of dead or dying plants as needed.

# 7.3 - SURFACE SAND FILTER (GRV & WQV)

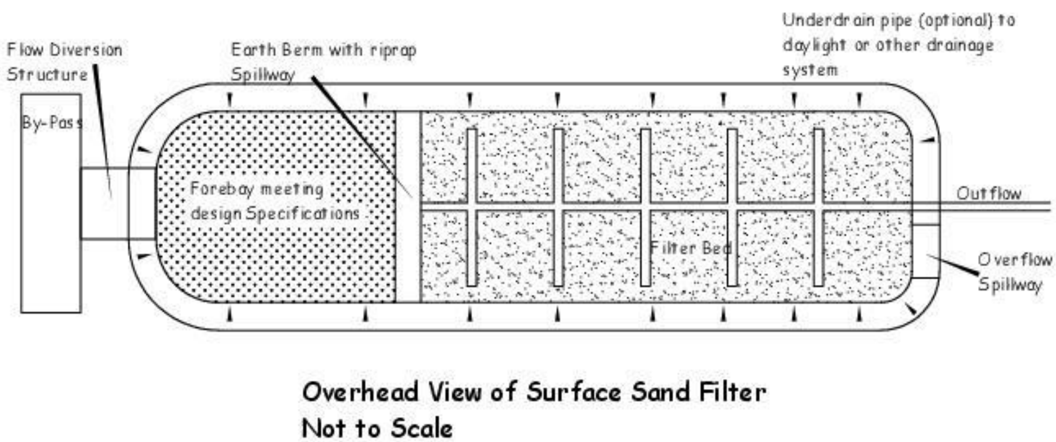



**Figure 7.3.1 - Surface Sand Filter (Trinkaus Engineering, LLC - 2017)**

**Site Investigation:**

1. A deep test pit shall be excavated within 20' of the proposed location of a Surface Sand Filter to a depth three (3) feet below the anticipated bottom of the filter media or gravel storage of the Surface Sand Filter. One (1) deep test pit shall be done for each 2,000 square feet of the filter bed of the Surface Sand Filter.
2. An Infiltration test using a Double Ring Infiltrometer shall be done within five (5) feet of the proposed location of a Surface Sand Filter. The infiltration test must be done at a depth which is equal to or below the lowest elevation of the soil media. One infiltration test shall be done for each 1,000 square feet of the filter bed of the Surface Sand Filter. The Infiltration test shall be done in accordance with the specifications found in Appendix "E" at the end of this manual.

**Design Requirements:**

1. Surface Sand Filters are designed to be off-line systems with the Water Quality Volume directed to the Sand Filter, but larger runoff events are bypassed to a quantity control system. If runoff is to be delivered by a curb/gutter system or pipe, then an appropriate bypass structure must be incorporated into the design by the engineer of record.
2. Depth of Filter Media shall be 18" for residential applications and 24" for commercial applications.
3. Minimum Vertical Separation to Seasonal High Groundwater Level from bottom of Filter Media:
    a. Residential roof or driveway = 24" for Class A Soils; 18" for Class B Soils; and 12" for Class C Soils,
    b. Commercial roof or driveway = 30" for Class A Soils; 24" for Class B Soils; and 18" for Class C Soils.
4. Minimum Vertical Separation to Bedrock from the bottom of the soil media shall be twenty-four (24) inches.

5. Maximum Allowable Ponding Depth (D) of full Water Quality Volume above surface of the Sand Filter. As the allowable ponding depth becomes shallower, the surface area of the soil media surface increases:
    a. Class A Soils = 18”
    b. Class B Soils = 12” (where restrictive layer is greater than 36” deep)
    c. Class B Soils = 9” (where restrictive layer is less than 36” deep)
    d. Class C Soils = 6” (where restrictive layer is greater than 24” deep)
    e. Class C Soils = 3” (where restrictive layer is less than 24” deep)
6. Sizing of the surface area of the Surface Sand Filter:

    SA = (WQV)*(df)/ [(k)*(hr + df)*(tf)] where:

    SA = Surface area of filter bed of the Sand Filter (square feet)
    WQV = Calculated water quality volume (cubic feet) directed to system
    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
7. Allowable Contributing Drainage Area (CDA) directed to Surface Sand Filter and required (pre-treatment). Only Water Quality Volume from contributing area is directed to Surface Sand Filter, all other flows must bypass the Surface Sand Filter:
    a. CDA < 5,000 square feet: (Outlet protection at end of pipe or overland flow across vegetated filter strip, a minimum of 25’ in width),
    b. 5,000 square feet ≤ CDA ≤ 10,000 square feet: (Forebay containing 25% of the calculated WQV designed in accord with the specifications found in this manual),
    c. 10,000 square feet ≤ CDA ≤ 20,000 square feet: (Forebay containing 25% of the calculated WQV designed in accord with the specifications found in this manual),
    d. 20,000 square feet ≤ CDA ≤ 1 acre: (Forebay containing 50% of the calculated WQV designed in accord with the specifications found in this manual),
    e. 1 acre ≤ CDA ≤ 5 acres: (Forebay containing 100% of the calculated WQV designed in accord with the specifications found in this manual
    f. 5 acres < CDA < 10 acres: (Forebay containing 100% of the calculated WQV designed in accord with the specification found in this manual.
8. Natural Land Slope: There are no design modifications necessary for a Surface Sand Filter on slopes up to 10% other than meeting the other requirements found in this section.
9. Underdrains: For all underdrain configurations, two layers of gravel shall be installed below the soil media layer. The first gravel layer shall consist of 3” of 3/8” washed gravel (pea gravel). The lower gravel layer consists of 12” of ¾” washed gravel (#5 Stone). Specific information on the gravel layers is shown in the details cited below. There is only one underdrain configuration for a Surface Sand Filter.
    a. The underdrain pipe is installed as an overflow pipe while allowing infiltration into the underlying natural soils to be the primary discharge system. In this case the underdrain, typically consisting of 4” perforated PVC pipe is set at the top of the #5 stone layer below the soil media. This configuration is shown in Figure 7.3.1.
10. Filter Media for Surface Sand Filter is designed to filter the runoff and allow for infiltration into the underlying native soils. The Filter Media shall consist of the following material:

   a. Washed Concrete Sand – 100% (ASTM C33)
11. Overflow provisions from a Surface Sand Filter can be done in one of several ways:
   a. A vertical Solid PVC pipe with the top of the pipe set at the allowable ponding depth for the water quality volume. A slotted end cap shall be used on the top of the pipe to prevent organic debris from entering the overflow pipe.
   b. A small spillway lined with 3" or larger native field stones can be placed in the berm of the Surface Sand Filter. The minimum width of the spillway should be 24". The field stone should extend to the bottom of the Surface Sand Filter as well as the existing ground on the outside of the Surface Sand Filter.
   c. A catch basin with outlet pipe can be placed in the Surface Sand Filter. The top of the grate shall be set at the allowable ponding depth for the water quality volume.

**Hydrologic Modeling:**

As part of the design of a Surface Sand Filter, it shall be demonstrated by hydrologic modeling using a program such as HydroCAD that the system will fully infiltrate at a minimum the water quality storm event. The modeling shall be done in a conservative fashion to ensure that the system will function as intended. To perform this approach, the following parameters shall be adhered to:

1. The slowest observed infiltration rate shall be reduced by at least 50% to be used as the exfiltration rate in the model,
2. Only the storage volume above the soil media surface shall be used,
3. Storage in the media and/or the gravel layers shall not be considered in the model.

**Construction Requirements:**

The design engineer shall develop a detailed, site specific construction sequence for a Surface Sand Filter. The design engineer shall also inspect the installation of the Surface Sand Filter during the installation process. Surface Sand Filters shall be constructed early on during the overall construction process, so that they are fully vegetated and stabilized prior to the introduction of stormwater to them.

A typical construction sequence will follow these generalized steps:

1. The area of the Surface Sand Filter shall be fenced off with orange poly construction fence after the clearing of trees to prevent the movement of construction vehicles over the area of the Surface Sand Filter,
2. A stable benchmark shall be set by the design engineer or land surveyor for use by the contractor,
3. The outline of the Surface Sand Filter shall be staked in the field by the design engineer or contractor,
4. The Surface Sand Filter shall be excavated to the required design depth (bottom of gravel layer) by hydraulic excavator located outside the limit of the facility. No excavation equipment is permitted in the actual Surface Sand Filter,
5. After the excavation of the Surface Sand Filter has been completed, the soil bottom area within the bottom of the Surface Sand Filter shall be scarified by hand be made as level as possible. Loose soil from the scarification shall be removed by hand,
6. Placement of the gravel shall be done by hydraulic excavator from outside the Surface Sand Filter limits and then hand raked to the required design elevation. The underdrain, outlet pipe and vertical overflow pipes shall also be installed at this time,

7. The soil media shall be placed at this time. It is imperative that the top of the soil media be as level as possible to ensure that runoff will spread out across the entire top of the Surface Sand Filter,
8. The soil media shall be lightly tamped by walking on it or spraying the surface with water,
9. The surface of the Sand Filter shall be placed with a drought tolerant grass,
10. The grass shall be watered as necessary to ensure its establishment.

**Inspection Requirements:**

The design engineer shall oversee the entire installation of the Surface Sand Filter at these specific steps:

1. After the excavation has been done to the bottom of the Surface Sand Filter,
2. After placement of gravel layer, and drainage pipes,
3. Inspection of the soil media prior to placement in the Surface Sand Filter,
4. After placement and leveling of the Surface Sand Filter soil media,
5. After the grass has been installed.
6. The design engineer shall prepare an as-built plan of the completed Surface Sand Filter and provide a written statement which addresses the following items:
    a. Excavation and scarification of the natural soils,
    b. Approval of soil media,
    c. Approval of overflow provisions,
    d. Approval of grass installation,
    e. Approval of completed system.

**Maintenance Requirements:**

1. Twice a year inspections of the Sediment Forebay,
2. Removal of accumulated sediment in the Forebay when the depth is greater than 24”,
3. Annual inspection of the Surface Sand Filter,
4. Removal of organic debris (sticks and leaves) in the Spring and Fall,
5. Grass shall be maintained at a height of 6 – 8” by mowing,
6. Weeding as necessary to prevent undesirable plants from colonizing the Surface Sand Filter,
7. If ponding on the soil surface exceeds 24 hours after a rainfall event, the soil media has become clogged. To eliminate the clogging, the top 2” of discolored soil media shall be removed and replaced with C33 Sand. If this is necessary, the area shall be reseeded with a drought tolerant grass. Reseed the soil media surface as necessary to maintain grass cover over a minimum of 75% of the soil media surface.

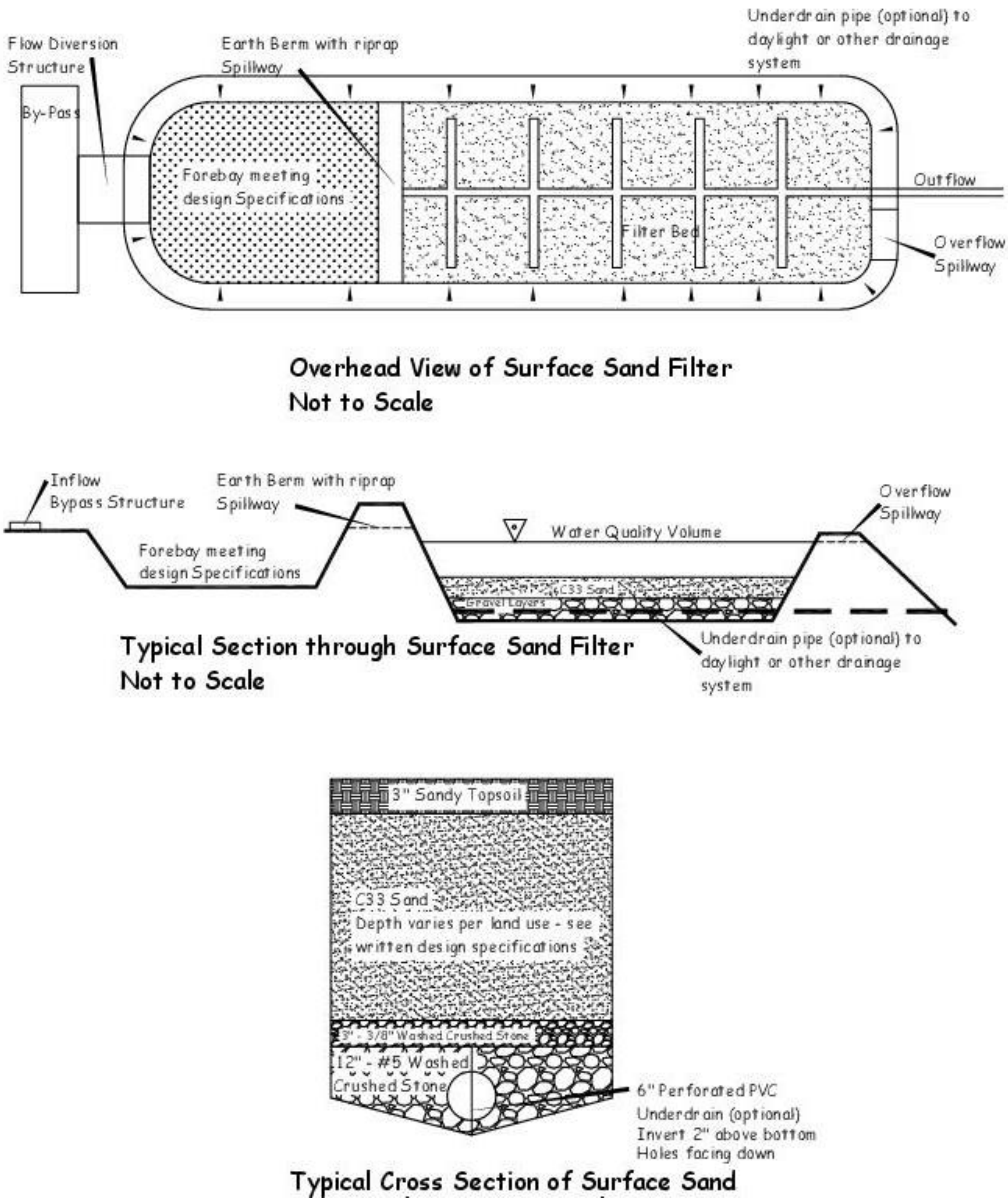



**Figure 7.3.2 - Surface Sand Filter (Trinkaus Engineering, LLC - 2017)**

# 7.4 – DRY SWALE (GRV & WQV)

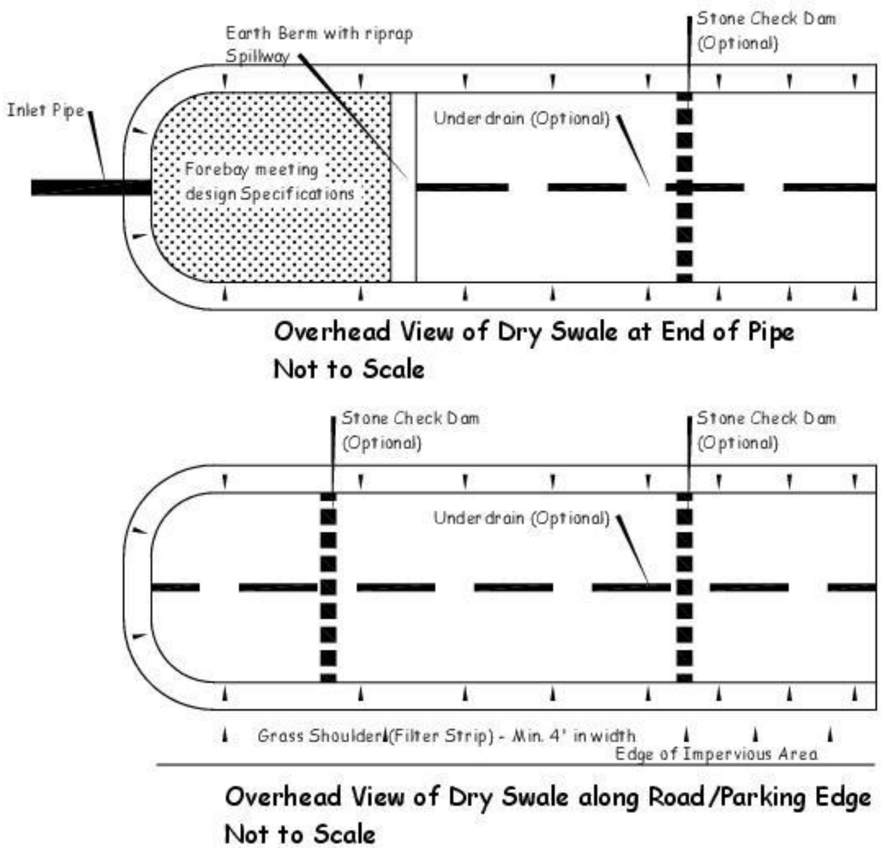



**Figure 7.4.1 - Dry Swale (Trinkaus Engineering, LLC - 2017)**

**Site Investigation:**

1. A deep test pit shall be excavated for every 100 linear feet along the proposed location of a Dry Swale to a depth three (3) feet below the anticipated bottom of the filter media or gravel storage of the Dry Swale.
2. An Infiltration test using a Double Ring Infiltrometer shall be done within five (5) feet of the proposed location of a Dry Swale. The infiltration test must be done at a depth which is equal to or below the lowest elevation of the soil media. One infiltration test shall be done for every 200 linear feet of the length of the Dry Swale. The Infiltration test shall be done in accordance with the specifications found in Appendix "E" at the end of this manual.

**Design Requirements:**

1. Dry Swales can be designed as online systems, where runoff is directed to the Dry Swale via a structural drainage system or as an offline system, where runoff enters the Dry Swale as overland flow from an impervious area, such as a parking lot or edge of road. If runoff is to be delivered

by a drainage pipe, then a forebay, meeting the requirements of this manual shall be installed at the end of the pipe.

2. Depth of Filter Media shall be 12" for residential and commercial applications.
3. Minimum Vertical Separation to Seasonal High Groundwater Level from bottom of Filter Media:
   a. 12" for Class A Soils,
   b. 9" for Class B Soils,
   c. 6" for Class C Soils,
4. Minimum Vertical Separation to Bedrock from the bottom of the soil media shall be twenty-four (24) inches.
5. Sizing of the surface area of the Dry Swale:

   SA = (WQV)*(df)/ [(k)*(hr + df)*(tf)] where:

   SA = Surface area of filter bed of the Dry Swale (square feet)
   WQV = Calculated water quality volume (cubic feet) directed to system
   df = Filter bed depth (Bioretention Soil Media) (feet)
   k = Coefficient of Bioretention Soil Media, use k=1.0 ft/day
   hf = Average height of water above dry swale surface (feet)
   tf = Design filter bed drain time (days), use tf = 2.0 for dry swale
6. Allowable Contributing Drainage Area (CDA) directed to Dry Swale when located at end of pipe and required (pre-treatment). Runoff from all storm events is directed to Dry Swale:
   a. CDA < 5,000 square feet: (Forebay containing 25% of the calculated WQV designed in accord with the specifications found in this manual),
   b. 5,000 square feet ≤ CDA ≤ 10,000 square feet: (Forebay containing 25% of the calculated WQV designed in accord with the specifications found in this manual),
   c. 10,000 square feet ≤ CDA ≤ 20,000 square feet: (Forebay containing 25% of the calculated WQV designed in accord with the specifications found in this manual),
   d. 20,000 square feet ≤ CDA ≤ 1 acre: (Forebay containing 25% of the calculated WQV designed in accord with the specifications found in this manual),
   e. 1 acre ≤ CDA ≤ 5 acres: (Forebay containing 50% of the calculated WQV designed in accord with the specifications found in this manual),
   f. 5 acres < CDA < 10 acres: (Forebay containing 100% of the calculated WQV designed in accord with the specification found in this manual).
7. Allowable Contributing Drainage Area (CDA) directed to Dry Swale when receiving overland flow directly from an impervious surface. Runoff from all storm events is directed to Dry Swale:
   a. CDA < 5,000 square feet,
   b. 5,000 square feet ≤ CDA ≤ 10,000 square feet,
   c. 10,000 square feet ≤ CDA ≤ 20,000 square feet,
   d. 20,000 square feet ≤ CDA ≤ 1 acre,
   e. 1 acre ≤ CDA ≤ 5 acres: Not permitted as contributing drainage area is too large,
   f. 5 acres < CDA < 10 acres: Not permitted as contributing drainage area is too large.
8. Slope of Dry Swale:
   a. 6.0% of less no restriction or design modifications are required,
   b. For slopes between 6.0% and 10.0%, then gravel check dams are required,
   c. Dry Swales are not permitted on slopes greater than 10.0%.

9. Underdrains: For all underdrain configurations, two layers of gravel shall be installed below the soil media layer. The first gravel layer shall consist of 3” of 3/8” washed gravel (pea gravel). The lower gravel layer consists of 8” of ¾” washed gravel (#5 Stone). Specific information on the gravel layers is shown in the details cited below. There is only one underdrain configuration for a Dry Swale.
    a. The underdrain pipe is installed lengthwise in the Dry Swale with the top of the 4” perforated PVC pipe being set at the bottom of the pea gravel layer.
10. Soil Media Specification for a Dry Swale is designed to filter the runoff as well as provide sufficient organic material for the initial establishment of plants in the Dry Swale. The material shall be mixed on a hard clean surface prior to being placed in the Dry Swale. The soil media shall consist of the following material containing the specified percentage by volume:
    a. Washed Concrete Sand – 80% (ASTM C33)
    b. Well decomposed wood chip or leaf compost – 15%
    c. Sandy loam or sandy topsoil – 5% (no more than 2% clay content)
11. Overflow provisions from a Dry Swale:
    a. A Dry Swale shall either convey runoff to another water quality/quantity stormwater management practice or,
    b. Discharge onto an upland vegetated area which is a minimum of fifty (50) feet from a delineated inland wetland or watercourse. In this scenario, the end of the swale shall be flared out to ensure that overland flow will occur. A pad of native field stones shall be placed on the flared-out section and pressed into the ground surface by a hydraulic excavator so that no more than 50% of the stone is above the ground surface.

**Hydrologic Modeling:**

As part of the design of a Dry Swale, it shall be demonstrated by hydrologic modeling using a program such as HydroCAD that the system will fully convey both the peak rates for both the 2-year and 10-year rainfall events. Non-erosive velocities must be less than 3 fps for the 2-year event.

**Construction Requirements:**

The design engineer shall develop a detailed, site specific construction sequence for a Dry Swale. The design engineer shall also inspect the installation of the Dry Swale during the installation process. Dry Swales shall be constructed early on during the overall construction process, so that they are fully vegetated and stabilized prior to the introduction of stormwater to them.

A typical construction sequence will follow these generalized steps:

1. The area of the Dry Swale shall be fenced off with orange poly construction fence after the clearing of trees to prevent the movement of construction vehicles over the area of the Dry Swale,
2. A stable benchmark shall be set by the design engineer or land surveyor for use by the contractor,
3. The centerline of the Dry Swale shall be staked in the field by the design engineer or contractor,
4. The Dry Swale shall be excavated to the required design depth (bottom of soil media or gravel layer) by hydraulic excavator located outside the limit of the facility. No excavation equipment is permitted in the actual Dry Swale,

5. After the excavation of the Dry Swale has been completed, the soil bottom area within the bottom of the Dry Swale shall be scarified by hand to remove any smeared soil. Loose soil from the scarification shall be removed by hand,
6. Placement of the gravel shall be done by hydraulic excavator from outside the Dry Swale and then hand raked to the required design elevation. The underdrain, outlet pipe and vertical overflow pipes shall also be installed at this time,
7. The soil media shall be placed at this time. It is imperative that the top of the soil media be as level across the width of the Dry Swale as much as possible to ensure that runoff will spread out across the entire with of the Dry Swale,
8. The soil media shall be lightly tamped by walking on it or spraying the surface with water,
9. The surface of the Dry Swale shall be planted with an appropriate perennial grass mixture,
10. The grass shall be watered as necessary to ensure its establishment.

**Inspection Requirements:**

The design engineer shall oversee the entire installation of the Dry Swale at these specific steps:

1. After the excavation has been done to the bottom of the Dry Swale,
2. After placement of gravel layer, and drainage pipes (if applicable),
3. Inspection of the soil media prior to placement in the Dry Swale,
4. After placement and leveling of the Dry Swale soil media,
5. After the grass has been installed.
6. The design engineer shall prepare an as-built plan of the completed Dry Swale and provide a written statement which addresses the following items:
    f. Excavation and scarification of the natural soils,
    g. Approval of soil media,
    h. Approval of overflow provisions,
    i. Approval of grass installation,
    j. Approval of completed system.

**Maintenance Requirements:**

1. Twice a year inspections of the Sediment Forebay (if applicable),
2. Removal of accumulated sediment in the Forebay when the depth is greater than 24”,
3. Annual inspection of the Dry Swale,
4. Removal of organic debris (sticks and leaves) in the Spring and Fall,
5. Grass shall be maintained at a height of 3 - 4” by mowing,
6. Removal of leaves in the fall by raking or leaf blowing as necessary,
7. Weeding as necessary to prevent undesirable plants from colonizing the Dry Swale,
8. If ponding on the soil surface exceeds 24 hours after a rainfall event, the soil media is becoming clogged. To prevent clogging, cut the grass to 1.5 – 2” height, then rake the bottom of the gravel to remove grass clipping, leaves from the bottom of the Dry Swale. Lightly rake the soil surface with a leaf rake to loosen the top of the soil surface without affecting the health of the vegetation.

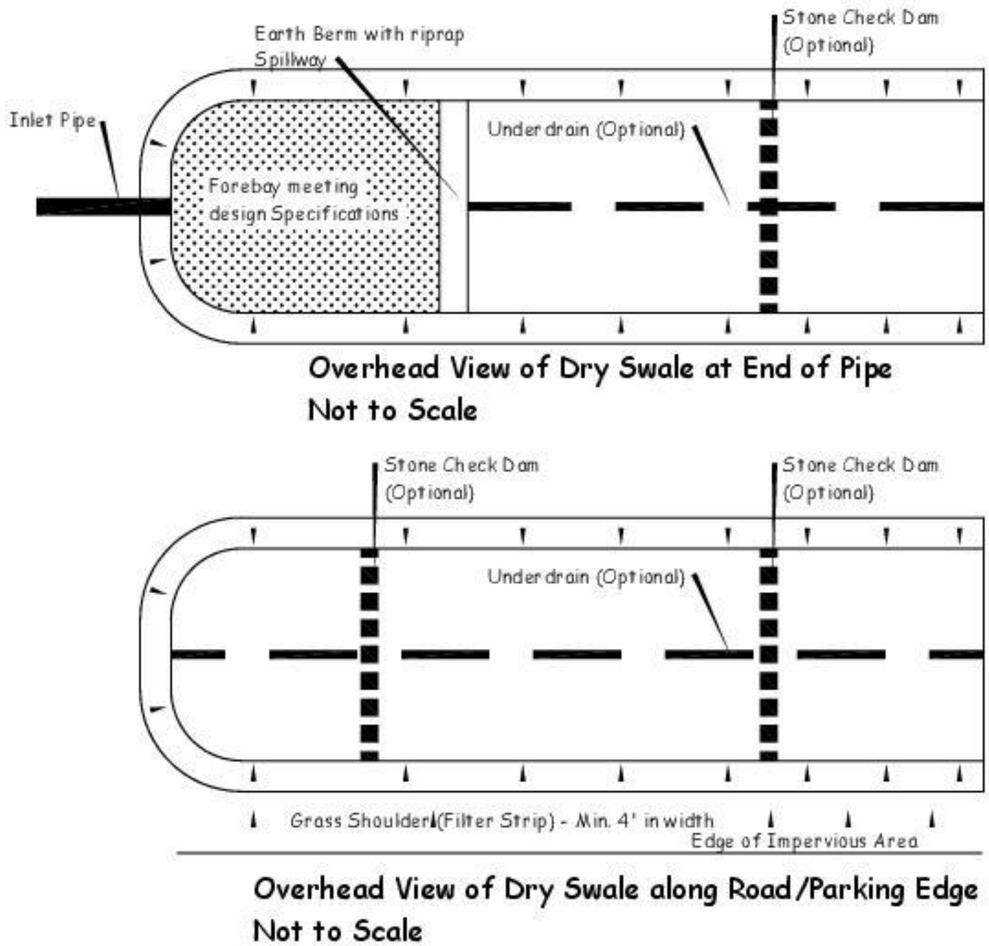
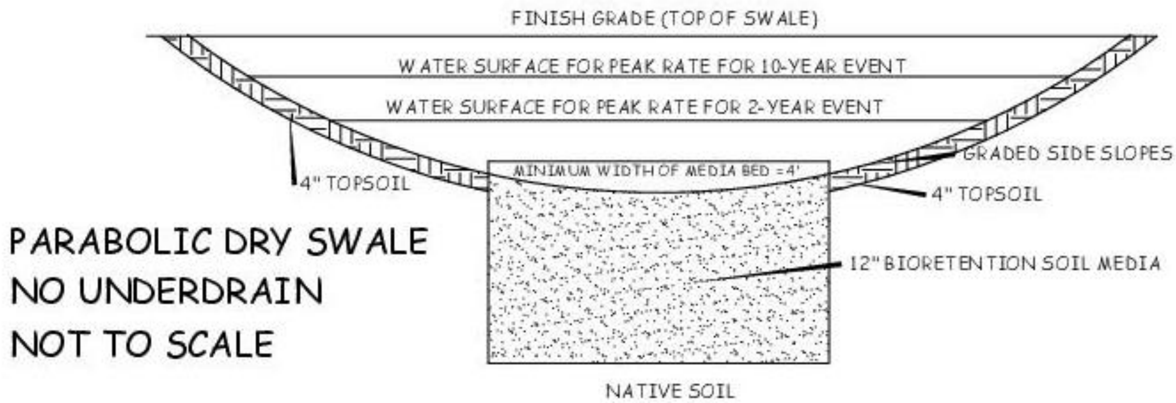



**Figure 7.4.2 - Overhead View of Dry Swales (Trinkaus Engineering, LLC – 2017)**



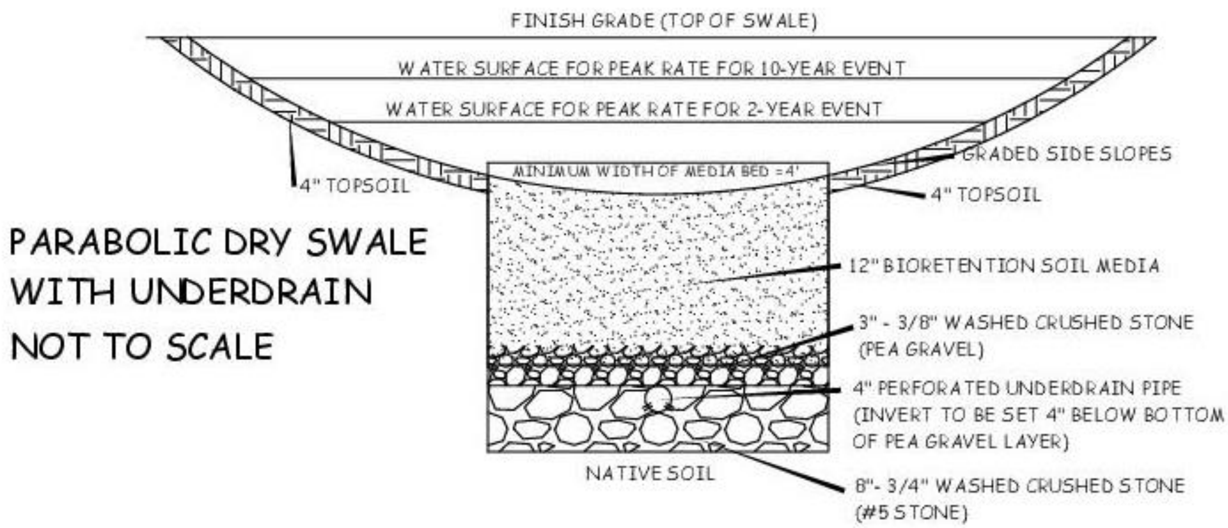
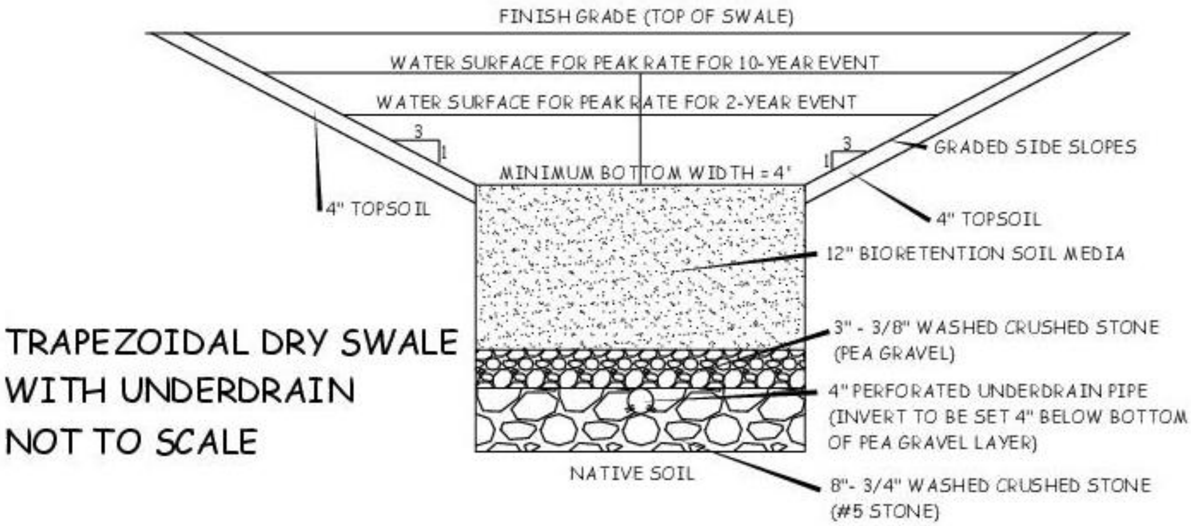




**Figure 7.4.3 - Parabolic Dry Swales (Trinkaus Engineering, LLC – 2017)**



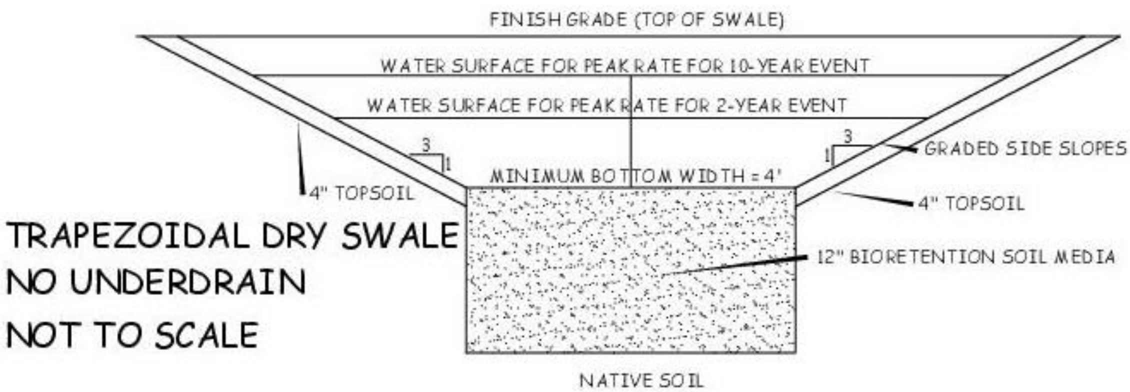




**Figure 7.4.4 - Trapezoidal Dry Swales (Trinkaus Engineering, LLC – 2017)**

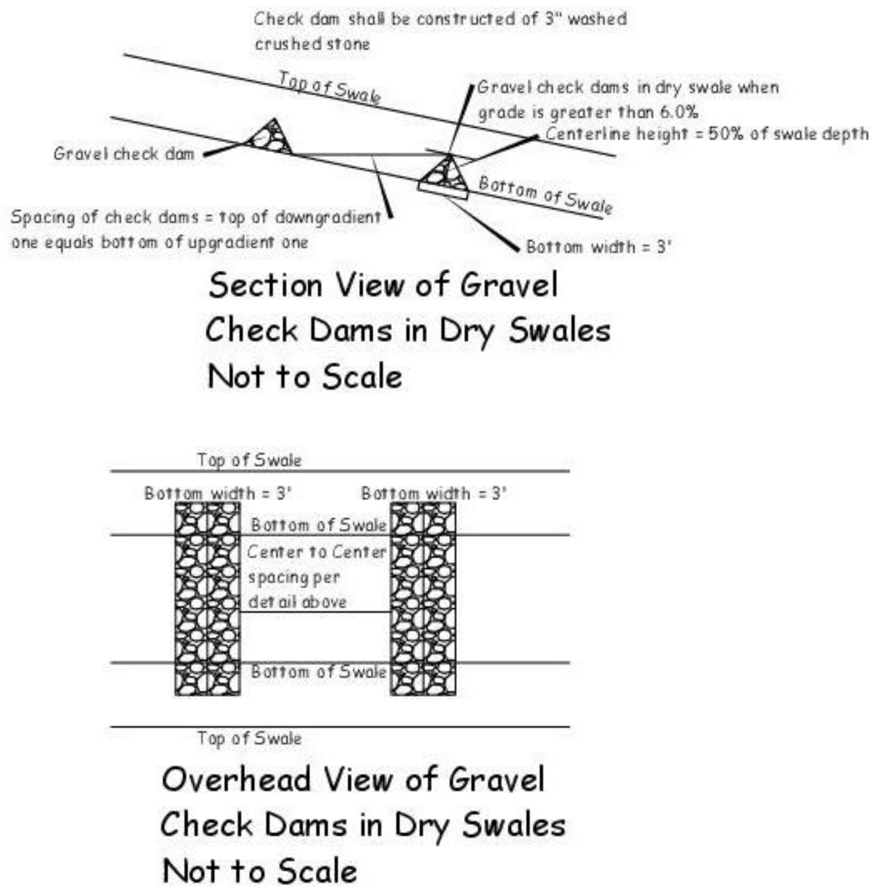



**Figure 7.4.5 - Gravel Check Dams in Dry Swales (Trinkaus Engineering, LLC – 2017)**

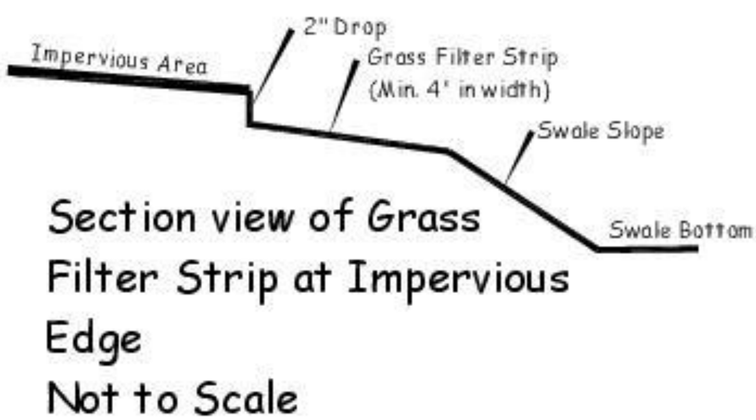



**Figure 7.4.6 - Overland Flow to Dry Swale (Trinkaus Engineering, LLC – 2017)**

# 7.5 - INFILTRATION TRENCH (GRV & WQV)

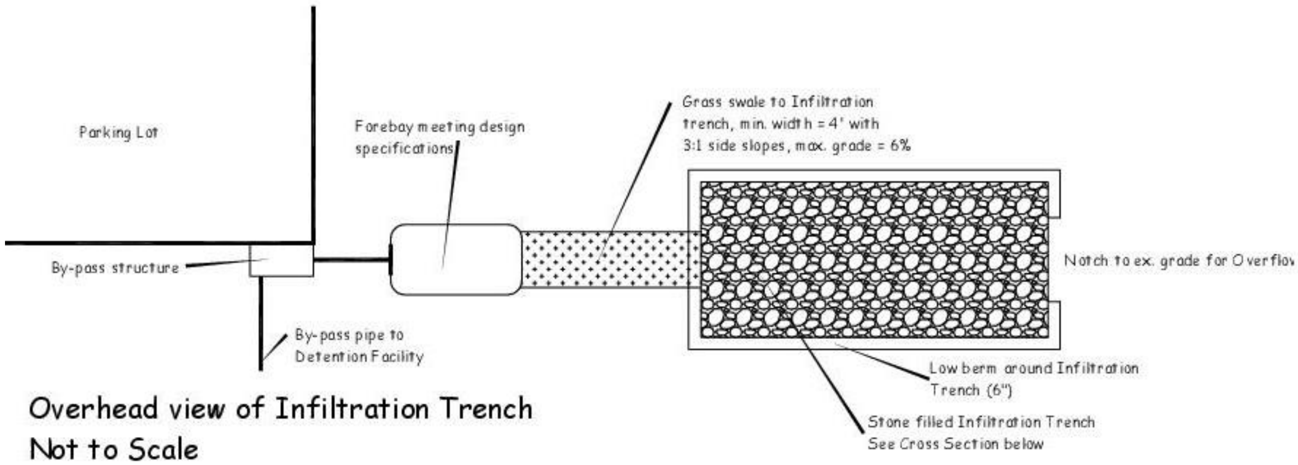



**Figure 7.5.1 - Infiltration Trench (Trinkaus Engineering, LLC - 2017)**

**Site Investigation:**

1. A deep test pit shall be excavated within 20' of the proposed location of an Infiltration Trench to a depth three (3) feet below the anticipated bottom of the gravel storage layer of the Infiltration Trench.  One (1) deep test pit shall be done for each 1,000 square feet of the filter bed of the Infiltration Trench.
2. An Infiltration test using a Double Ring Infiltrometer shall be done within five (5) feet of the proposed location of an Infiltration Trench.   The infiltration test must be done at a depth which is equal to or below the lowest elevation of the soil media.   One infiltration test shall be done for each 1,000 square feet of the Infiltration Trench.  The Infiltration test shall be done in accordance with the specifications found in Appendix "E" at the end of this manual.

**Design Requirements:**

1. Infiltration Trenches can be designed to accept runoff from a conventional drainage system or as overland flow.
    a. If the Infiltration Trench is located at the end of drainage pipe from a road, driveway, or parking area, then a forebay shall be provided prior to the Infiltration Trench.   Additionally, a bypass system directing the flow associated with the Water Quality Volume to the Infiltration Trench and larger events to a different stormwater management practice.
    b. When runoff from the contributing area will enter the Infiltration Trench as overland flow, the runoff must pass over a grassed filter strip having a minimum width of 25'.
2. Minimum Vertical Separation to Seasonal High Groundwater Level from bottom of Gravel Layer:
    a. Class A Soils = 24",

   b. Class B Soils = 12”.
3. Minimum Vertical Separation to Bedrock from the bottom of the Gravel Layer shall be thirty-six (36”) inches.
4. The Gravel Layer shall be sized to fully contain the full Water Quality Volume and the bottom surface area of the Infiltration Trench shall be sized using the following formula:

   Ap = V / (n*dt = fc*t/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) (50% of the slowest observed field infiltration rate)
   t = Time to fill trench (hours), assume t = 2.0
5. Allowable Contributing Drainage Area (CDA) directed to Infiltration Trench and required (pretreatment). Only Water Quality Volume from contributing area is directed to Infiltration Trench, all other flows must bypass the Infiltration Trench:
   a. CDA < 5,000 square feet: (Outlet protection at end of pipe or overland flow across vegetated filter strip, a minimum of 25’ in width),
   b. 5,000 square feet $\leq$ CDA $\leq$ 10,000 square feet: (Forebay containing 25% of the calculated WQV designed in accord with the specifications found in this manual),
   c. 10,000 square feet $\leq$ CDA $\leq$ 20,000 square feet: (Forebay containing 25% of the calculated WQV designed in accord with the specifications found in this manual),
   d. 20,000 square feet $\leq$ CDA $\leq$ 1 acre: (Forebay containing 50% of the calculated WQV designed in accord with the specifications found in this manual),
   e. 1 acre $\leq$ CDA $\leq$ 5 acres: (Forebay containing 100% of the calculated WQV designed in accord with the specifications found in this manual
   f. 5 acres < CDA < 10 acres: (Forebay containing 100% of the calculated WQV designed in accord with the specification found in this manual.
6. Natural Land Slope: There are no design modifications necessary for an Infiltration Trench on slopes up to 15% other than meeting the other requirements found in this section. Infiltration Trenches are not permitted on slopes greater than 15%.
7. No Underdrains in Infiltration Trenches.
8. Gravel layers for Infiltration Trench shall consist of 1-1/4” to 2” washed crushed stone.
9. Overflow provisions from an Infiltration Trench shall be done in the following manner:
   a. A low earth berm (6”) higher than the top of the stone surface shall surround almost all of the Infiltration Trench (Figure 7.5.1). The minimum opening shall be four (4) feet.

**Hydrologic Modeling:**

As part of the design of an Infiltration Trench, it shall be demonstrated by hydrologic modeling using a program such as HydroCAD that the system will fully infiltrate at a minimum the water quality storm event. The modeling shall be done in a conservative fashion to ensure that the system will function as intended. To perform this approach, the following parameters shall be adhered to:

1. The slowest observed infiltration rate shall be reduced by at least 50% to be used as the exfiltration rate in the model,

2. The available void space volume in the infiltration trench shall be 40% of the total volume of the infiltration trench.

**Construction Requirements:**

The design engineer shall develop a detailed, site specific construction sequence for an Infiltration Trench. The design engineer shall also inspect the installation of the Infiltration Trench during the installation process. Infiltration Trenches may be installed at any point during the overall construction period for the project with the following provision. All the disturbed area outside the limits of the Infiltration Trench must be fully stabilized with vegetation cover for twenty-five (25) feet. This will prevent the introduction of silt to the Infiltration Trench which can cause clogging of the system. Infiltration Trenches shall not be installed when the native soils have high moisture content because of rainfall or snowmelt. The design engineer shall make this determination in the field.

A typical construction sequence will follow these generalized steps:

1. The area of the Infiltration Trench shall be fenced off with orange poly construction fence after the clearing of trees to prevent the movement of construction vehicles over the area of the Infiltration Trench.
2. A stable benchmark shall be set by the design engineer or land surveyor for use by the contractor,
3. The outline of the Infiltration Trench shall be staked in the field by the design engineer or contractor,
4. The Infiltration Trench shall be excavated to the required design depth (bottom of gravel layer) by hydraulic excavator located outside the limit of the facility. No excavation equipment is permitted in the actual Infiltration Trench,
5. After the excavation of the Infiltration Trench has been completed, the soil bottom area within the bottom and side walls of the Infiltration Trench shall be scarified by using a metal garden rake to remove any smeared or lightly compacted soils,
6. Placement of the gravel shall be done by hydraulic excavator from outside the Infiltration Trench. The filter fabric on the side walls of the Infiltration Trench as the gravel is being placed.
7. Once the gravel has been installed to the ground surface, an appropriate erosion control barrier (siltation fence or wattle) shall be installed around the perimeter of the Infiltration Trench to prevent the movement of silt into the Infiltration Trench. Once the adjacent area has been stabilized and vegetated, this erosion control measures shall be removed. A minimum of 85% of the disturbed area outside and adjacent to the Infiltration Trench shall be covered with vegetation prior to the removal of the erosion control measures.
8. The grass around the Infiltration Trench shall be watered as necessary to ensure its viability.

**Inspection Requirements:**

The design engineer shall oversee the entire installation of the Infiltration Trench at these specific steps:

1. After the excavation has been done to the bottom of the Infiltration Trench,
2. After the scarification of the bottom and sidewalls have been done and the excess earth material removed,
3. During the placement of filter fabric on the sidewalls of the Infiltration Trench and the placement of gravel and observation well,

4. After all gravel has been placed in Infiltration Trench,
5. After all disturbed areas within 25’of the Infiltration Trench have been fully vegetated,
6. The design engineer shall prepare an as-built plan of the completed Infiltration Trench and provide a written statement which addresses the following items:
    k. Excavation and scarification of the natural soils,
    l. Approval of the crushed stone used,
    m. Approval of overflow provisions,
    n. Approval of site stabilization,
    o. Approval of completed system.

**Maintenance Requirements:**

1. Twice a year inspections of the Sediment Forebay,
2. Removal of accumulated sediment in the Forebay when the depth is greater than 24”,
3. Annual inspection of the Infiltration Trench,
4. Removal of organic debris (sticks and leaves) in the Spring and Fall,
5. Grass within 25’of the Infiltration Trench shall be maintained at a height of 3” by mowing, as necessary.

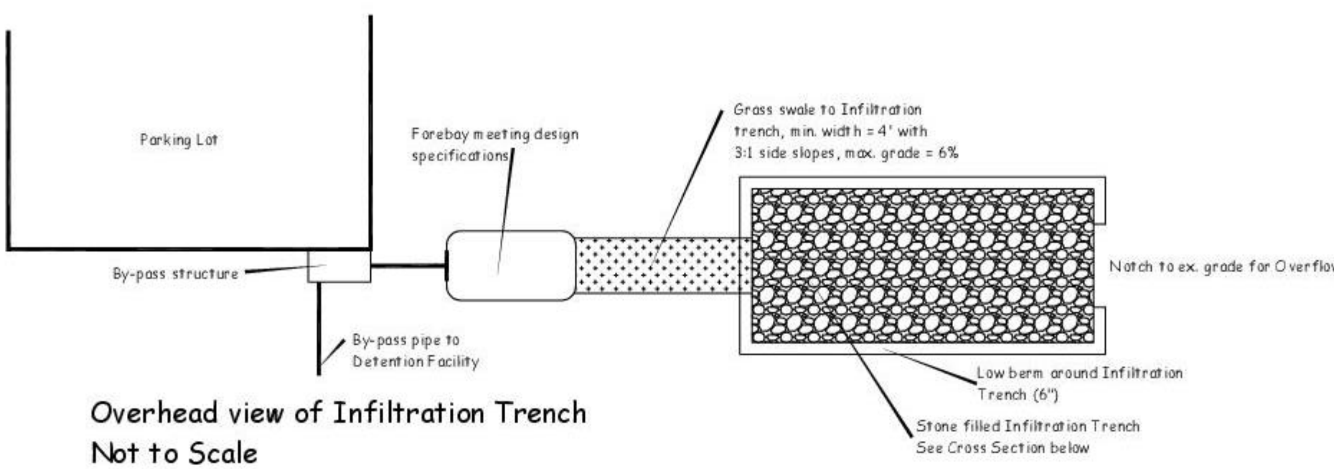



**Figure 7.5.2 - Overhead View of Infiltration Trench (Trinkaus Engineering, LLC - 2017)**

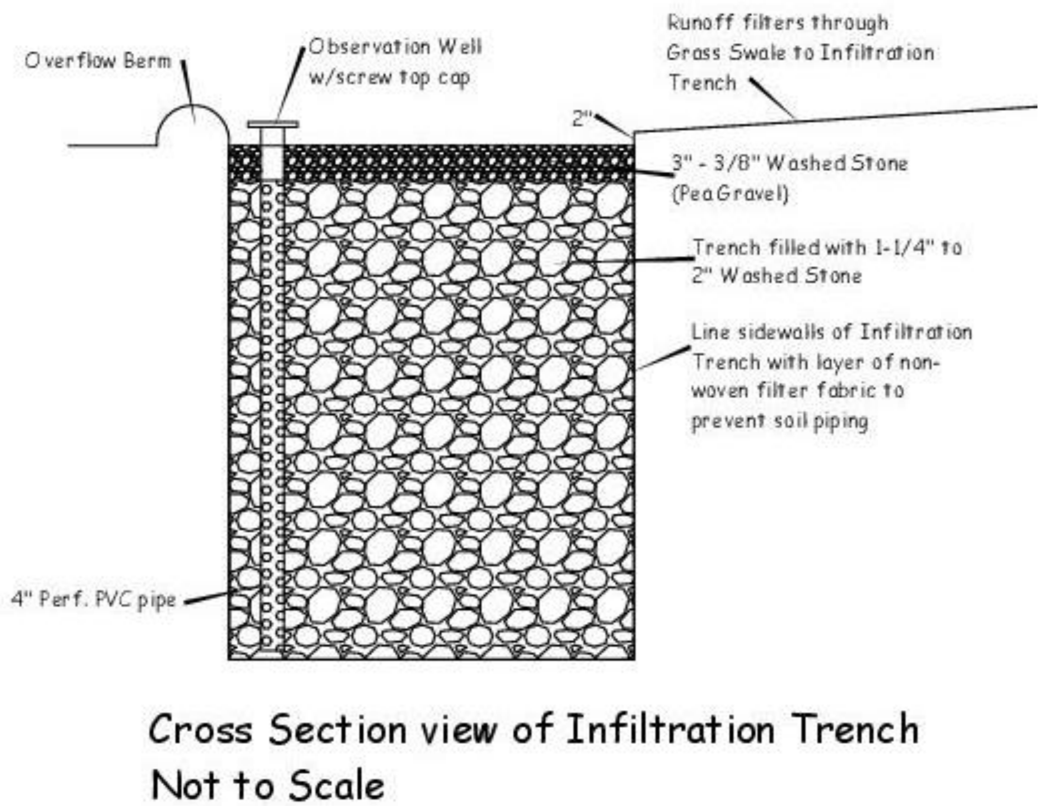



**Figure 7.5.3 - Cross Section of Infiltration Trench (Trinkaus Engineering, LLC - 2017)**

# 7.6 – INFILTRATION CHAMBERS (GRV & WQV)

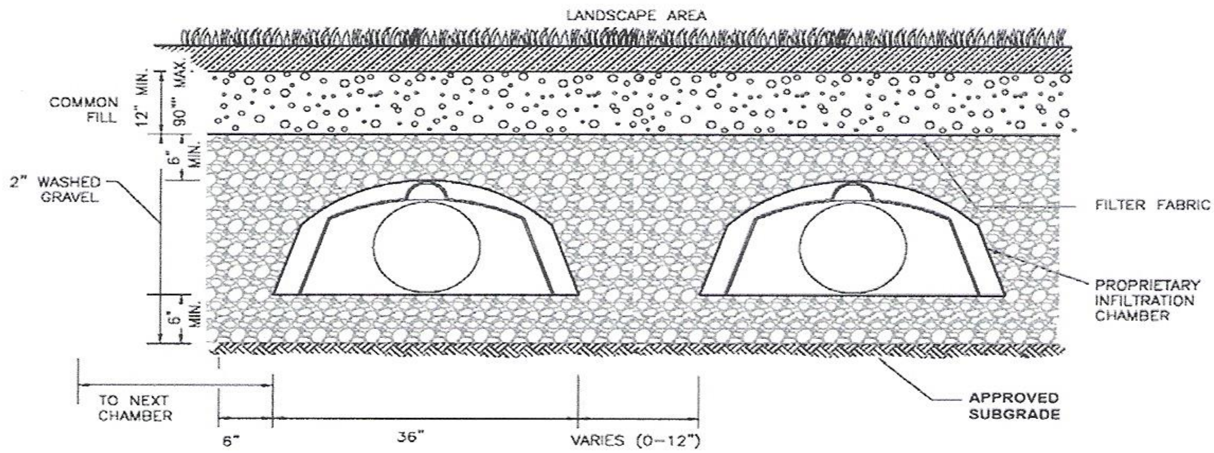



**Figure 7.6.1 - Underground Infiltration Chamber (RI DEM - 2010)**

**Types of Infiltration Chambers:**

There are many types of underground infiltration chambers. They range from precast concrete galleries, units made from corrugated HDPE such as Cultec, Contech and others as well as large diameter CMP and HDPE perforated pipe, which are often wrapped in non-woven geotextile fabric. The requirements of this section are applicable to all types of underground infiltration chambers.

**Site Investigation:**

1. A deep test pit shall be excavated within 20' of the proposed location of an Infiltration Chamber to a depth three (3) feet below the anticipated bottom of the gravel storage layer of the Infiltration Chamber. One (1) deep test pit shall be done for each 1,000 square feet of the filter bed of the Infiltration Trench.
2. An Infiltration test using a Double Ring Infiltrometer shall be done within five (5) feet of the proposed location of an Infiltration Trench. The infiltration test must be done at a depth which is equal to or below the lowest elevation of the soil media. One infiltration test shall be done for each 1,000 square feet of the Infiltration Chamber system. The native soils must have a minimum infiltration rate of 1.0"/hr. The Infiltration test shall be done in accordance with the specifications found in Appendix "E" at the end of this manual.

**Design Requirements:**

1. Infiltration Chambers most designed to handle runoff from a roof or surface impervious area via a conventional drainage system.
   a. If the Infiltration Chamber is located at the end of drainage pipe from a road, driveway, or parking area, then a pre-treatment system, typically a forebay shall be provided prior to the Infiltration Chamber. Additionally, a bypass system directing the flow associated

with the Water Quality Volume to the Infiltration Chamber and larger events to a different stormwater management practice.
   b. If the runoff is from a residential roof, a yard drain with a minimum 24" deep sump shall be installed prior to the Infiltration Chambers to trap debris and organic matter.

2. Minimum Vertical Separation to Seasonal High Groundwater Level from bottom of Gravel Layer:
   a. Class A Soils = 24",
   b. Class B Soils = 24".
3. Minimum Vertical Separation to Bedrock from the bottom of the Gravel Layer shall be thirty-six (36") inches.
4. The Infiltration Chambers shall be sized to fully contain the calculated water quality volume within the units and crushed stone as a static volume. No credit is taken for infiltration into the native soils.
5. Allowable Contributing Drainage Area (CDA) directed to Infiltration Chamber and required (pretreatment). Only Water Quality Volume from contributing area is directed to Infiltration Chamber, all other flows must bypass the Infiltration Chamber:
   a. CDA < 5,000 square feet: (Yard drain with minimum 24" deep sump),
   b. 5,000 square feet ≤ CDA ≤ 10,000 square feet: (Yard drain with minimum 24" deep sump),
   c. 10,000 square feet ≤ CDA ≤ 20,000 square feet: (Forebay containing 10% of the calculated WQV designed in accord with the specifications found in this manual),
   d. 20,000 square feet ≤ CDA ≤ 1 acre: (Forebay containing 10% of the calculated WQV designed in accord with the specifications found in this manual),
   e. 1 acre ≤ CDA ≤ 5 acres: (Forebay containing 50% of the calculated WQV designed in accord with the specifications found in this manual
   f. 5 acres < CDA < 10 acres: (Forebay containing 50% of the calculated WQV designed in accord with the specification found in this manual.
6. Natural Land Slope: There are no design modifications necessary for an Infiltration Chamber on slopes up to 15% other than meeting the other requirements found in this section. Infiltration Chambers are not permitted on slopes greater than 15%.
7. No Underdrains are used in Infiltration Chambers.
8. Gravel used Infiltration Chamber shall consist of 1-1/4" to 2" washed crushed stone.
9. Overflow provisions from an Infiltration Chamber shall be done in the following manner:
   a. A vertical solid PVC riser pipe from the top of the Infiltration Chamber to finish grade. A slotted cap shall be place on the top of the PVC pipe. The PVC pipe shall have a minimum diameter of 4" and there may be multiple risers to finish grade as required by the design engineer.

**Hydrologic Modeling:**

As part of the design of an Infiltration Chamber, it shall be demonstrated by hydrologic modeling using a program such as HydroCAD that the system will fully infiltrate at a minimum the water quality storm event as well as larger storm events when used for a roof system. The modeling shall be done in a conservative fashion to ensure that the system will function as intended. To perform this approach, the following parameters shall be adhered to:

1. The slowest observed infiltration rate shall be reduced by at least 50% to be used as the exfiltration rate in the model,
2. The available void space volume in the stone used around an infiltration chamber shall be 40% of the total volume of the actual volume of the stone.

**Construction Requirements:**

The design engineer shall develop a detailed, site specific construction sequence for an Infiltration chamber. The design engineer shall also inspect the installation of the Infiltration chamber during the installation process. Infiltration chambers may be installed at any point during the overall construction period for the project with the following provision. All the disturbed area outside the limits of the Infiltration chamber must be fully stabilized with vegetation cover for twenty-five (25) feet. This will prevent the introduction of silt to the Infiltration chamber which can cause clogging of the system. Infiltration chambers shall not be installed when the native soils have high moisture content because of rainfall or snowmelt. The design engineer shall make this determination in the field.

A typical construction sequence will follow these generalized steps:

1. The area of the Infiltration chambers shall be fenced off with orange poly construction fence after the clearing of trees to prevent the movement of construction vehicles over the area of the Infiltration chambers.
2. A stable benchmark shall be set by the design engineer or land surveyor for use by the contractor,
3. The outline of the Infiltration chamber system shall be staked in the field by the design engineer or contractor,
4. The area of the Infiltration chambers shall be excavated to the required design depth (bottom of gravel layer) by hydraulic excavator located outside the limit of the facility. No excavation equipment is permitted within the area of the Infiltration chambers,
5. After the excavation of the area for the Infiltration chambers has been completed, the soil bottom area within the bottom and side walls of the excavation shall be scarified by using a metal garden rake to remove any smeared or lightly compacted soils,
6. Placement of the gravel shall be done by hydraulic excavator from outside the area of the Infiltration chambers. Filter fabric on the side walls of the excavation, if required by the design engineer shall be installed as the gravel is being placed,
7. Installation of yard drain or forebay as may be applicable in advance of the Infiltration chamber system,
8. Once the gravel has been installed below the infiltration chambers, the chambers shall be set per the design. After the infiltration chambers have been set, washed crushed stone per the design shall be installed. A layer of non-woven filter fabric shall be placed over the top of the Infiltration chambers to prevent the introduction of silt into the crushed stone. The Infiltration chamber system shall be backfilled with the required amount of topsoil, seeded and mulched.
9. The grass over the Infiltration chamber system shall be watered as necessary to ensure its viability.

**Inspection Requirements:**

The design engineer shall oversee the entire installation of the Infiltration chamber system at these specific steps:

1. After the excavation has been done to the bottom of the Infiltration chamber system as well as the scarification of the bottom and sidewalls of the excavation,
2. After the placement of gravel under the Infiltration chamber system, the Infiltration chambers, and the gravel on top of the chambers,
3. After the Infiltration chamber system has been installed and backfilled,
4. The design engineer shall prepare an as-built plan of the completed Infiltration chamber system and provide a written statement which addresses the following items:
    a. Excavation and scarification of the natural soils,
    b. Approval of the crushed stone used,
    c. Approval of the installation of the Infiltration chambers and crushed stone,
    d. Approval of overflow provisions,
    e. Approval of completed system.

**Maintenance Requirements:**

1. Twice a year inspections of the Sediment Forebay, if applicable,
2. Removal of accumulated sediment in the Forebay when the depth is greater than 24",
3. Twice a year inspections of the yard drain and removable of any accumulated sediment or organic debris,
4. Annual inspection of overflow systems and removal of any organic debris which could clog them.

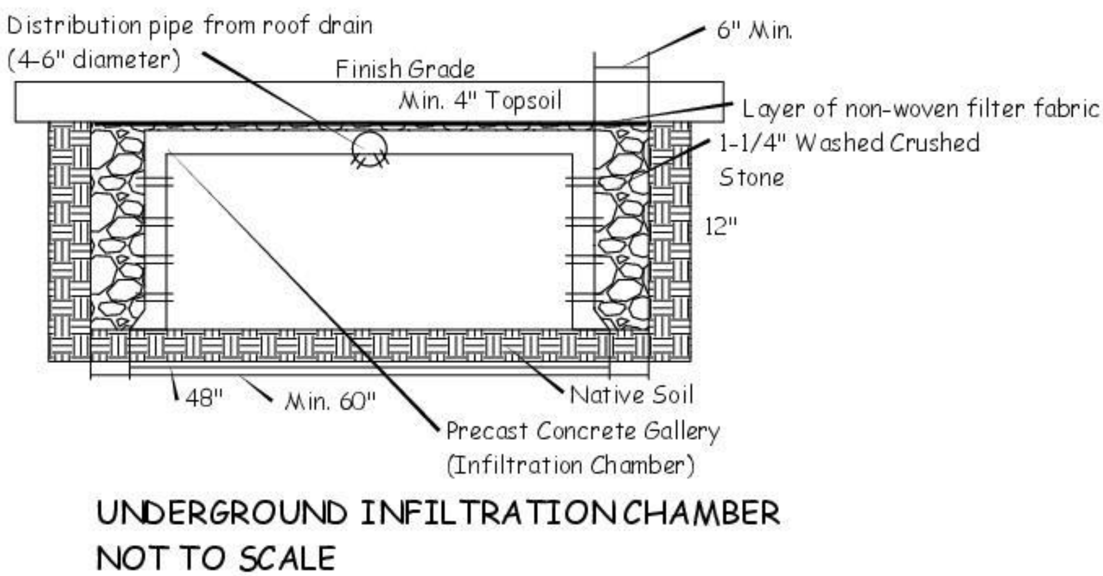



**Figure 7.6.2 - Typical Underground Chamber - (Trinkaus Engineering, LLC - 2017)**

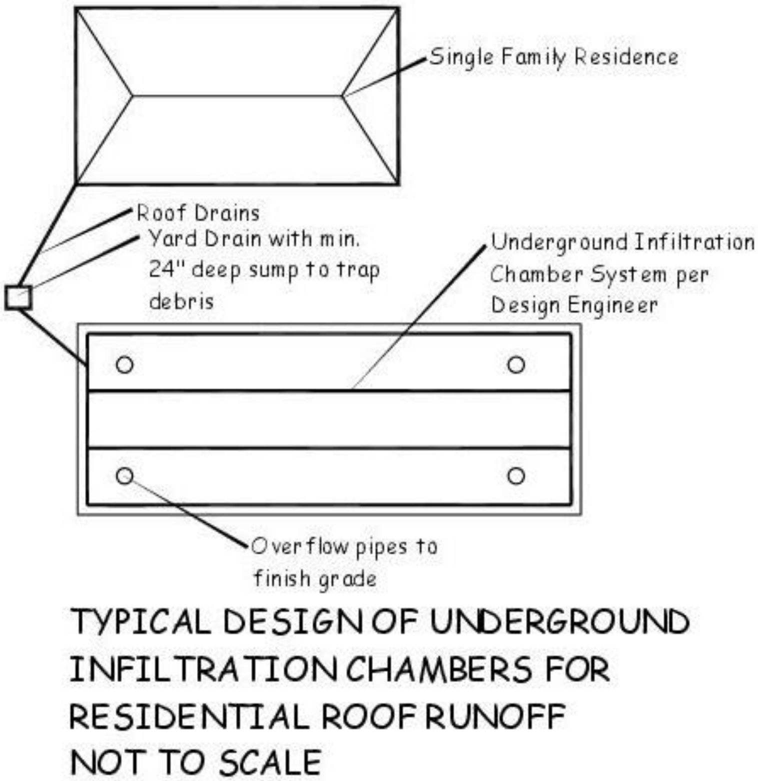



**Figure 7.6.3 - Configuration for roof runoff - (Trinkaus Engineering, LLC - 2017)**

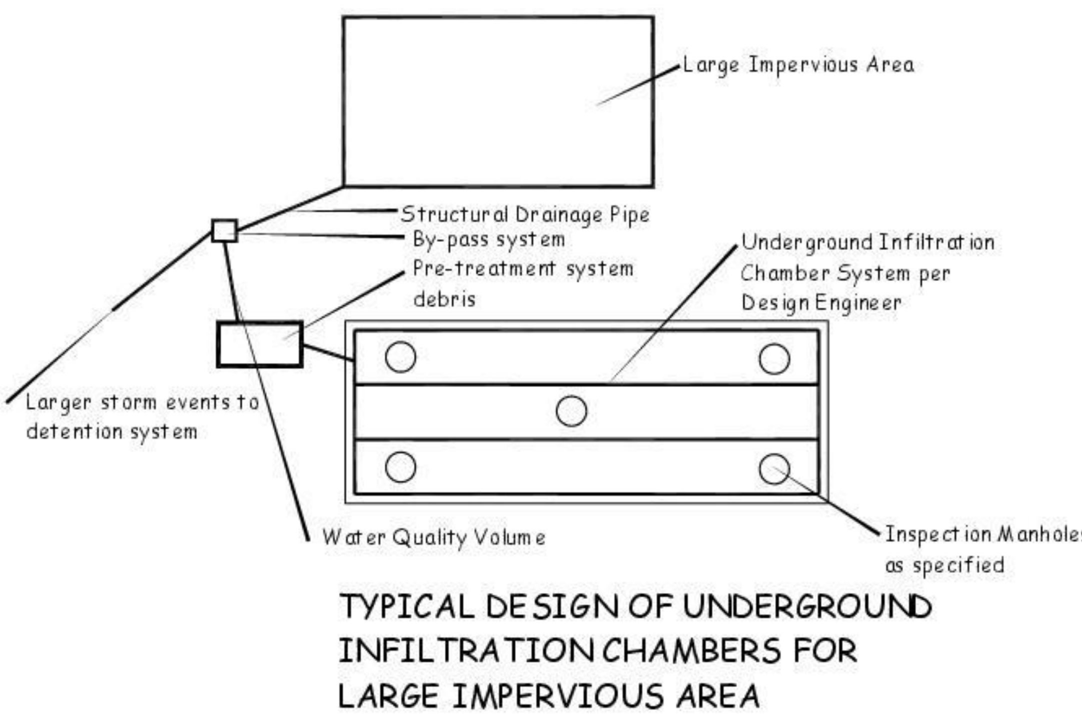



**Figure 7.6.4 - Parking lot configuration - (Trinkaus Engineering, LLC - 2017)**

# 7.7 – INFILTRATION BASIN (GRV & WQV)

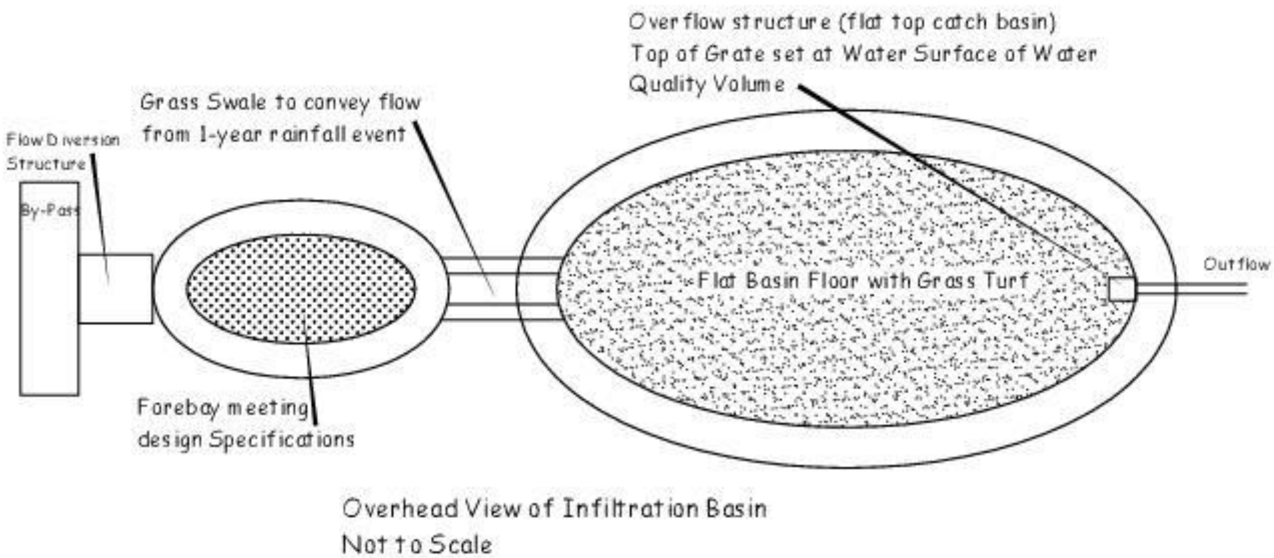



**Figure 7.7.1 - Infiltration Basin (Trinkaus Engineering, LLC – 2017)**

**Site Investigation:**

1. A deep test pit shall be excavated within 20' of the proposed location of an Infiltration Basin to a depth three (3) feet below the anticipated bottom of the filter media or gravel storage of the Infiltration Basin. One (1) deep test pit shall be done for each 2,000 square feet of the filter bed of the Surface Sand Filter.
2. An Infiltration test using a Double Ring Infiltrometer shall be done within five (5) feet of the proposed location of an Infiltration Basin. The infiltration test must be done at a depth which is equal to or below the lowest elevation of the soil media. One infiltration test shall be done for each 1,000 square feet of the filter bed of an Infiltration Basin. The native soils must have a minimum infiltration rate of 0.5"/hr. The Infiltration test shall be done in accordance with the specifications found in Appendix "E" at the end of this manual.

**Design Requirements:**

1. An Infiltration Basin is designed to be an off-line system with the Water Quality Volume directed to the Infiltration Basin, but larger runoff events are bypassed to a stormwater quantity control system. If runoff is to be delivered by a curb/gutter system or pipe, then an appropriate bypass structure must be incorporated into the design by the engineer of record.
2. Depth of Filter Media shall be 18" for residential applications and commercial applications.
3. Minimum Vertical Separation to Seasonal High Groundwater Level from bottom of Filter Media:
    a. Residential roof or driveway = 24" for Class A Soils; 18" for Class B Soils,
    b. Commercial roof or driveway = 30" for Class A Soils; 24" for Class B Soils.
4. Minimum Vertical Separation to Bedrock from the bottom of the soil media shall be twenty-four (24) inches.

5. Maximum Allowable Ponding Depth (D) of full Water Quality Volume above surface of an Infiltration Basin shall be determined by the following equation:
    a. D = f * T, where
        i. D = Maximum allowable basin depth (feet)
        ii. f = Design infiltration rate (in/hr) [50% of the slowest observed infiltration rate]
        iii. T = Maximum allowable drain time (48 hours)
6. Sizing of the surface area of an Infiltration Basin:

    SA = (WQV)/ (f) (T), where

    SA = Minimum basin bottom surface area (square feet)
    WQV = Calculated water quality volume (cubic feet) directed to system
    f = Design infiltration rate (in/hr)
    T = Maximum allowable drain time (48 hours)
7. Allowable Contributing Drainage Area (CDA) directed to an Infiltration Basin and required (pretreatment). Only Water Quality Volume from contributing area is directed to an Infiltration Basin, all other flows must bypass an Infiltration Basin:
    a. CDA < 5,000 square feet: (Outlet protection at end of pipe or overland flow across vegetated filter strip, a minimum of 25' in width),
    b. 5,000 square feet ≤ CDA ≤ 10,000 square feet: (Forebay containing 25% of the calculated WQV designed in accord with the specifications found in this manual),
    c. 10,000 square feet ≤ CDA ≤ 20,000 square feet: (Forebay containing 25% of the calculated WQV designed in accord with the specifications found in this manual),
    d. 20,000 square feet ≤ CDA ≤ 1 acre: (Forebay containing 50% of the calculated WQV designed in accord with the specifications found in this manual),
    e. 1 acre ≤ CDA ≤ 5 acres: (Forebay containing 100% of the calculated WQV designed in accord with the specifications found in this manual
    f. 5 acres < CDA < 10 acres: (Forebay containing 100% of the calculated WQV designed in accord with the specification found in this manual.
8. Natural Land Slope: There are no design modifications necessary for an Infiltration Basin on slopes up to 10% other than meeting the other requirements found in this section. Infiltration basins are not suitable on slopes greater than 10% because of the substantial earthwork which would be involved.
9. Underdrains: For all underdrain configurations, two layers of gravel shall be installed below the soil media layer. The first gravel layer shall consist of 3" of 3/8" washed gravel (pea gravel). The lower gravel layer consists of 12" of ¾" washed gravel (#5 Stone). Specific information on the gravel layers is shown in the detail cited below. There is only one underdrain configuration for an Infiltration Basin.
    a. The underdrain pipe is installed as an overflow pipe while allowing infiltration into the underlying natural soils to be the primary discharge system. In this case the underdrain, typically consisting of 4" perforated PVC pipe is set at the top of the #5 stone layer below the soil media. This configuration is shown in Figure 7.7.a.
10. Filter Media for an Infiltration Basin is designed to filter the runoff and allow for infiltration into the underlying native soils. The Filter Media shall consist of the following material:
    a. Washed Concrete Sand – 100% (ASTM C33)
11. Overflow provisions from an Infiltration Basin can be done in one of several ways:

a. A vertical Solid PVC pipe with the top of the pipe set at the allowable ponding depth for the water quality volume. A slotted end cap shall be used on the top of the pipe to prevent organic debris from entering the overflow pipe.
b. A catch basin with outlet pipe can be placed in an Infiltration Basin. The top of the grate shall be set at the allowable ponding depth for the water quality volume.

**Hydrologic Modeling:**

As part of the design of an Infiltration Basin, it shall be demonstrated by hydrologic modeling using a program such as HydroCAD that the system will fully infiltrate at a minimum the water quality storm event. The modeling shall be done in a conservative fashion to ensure that the system will function as intended. To perform this approach, the following parameters shall be adhered to:

1. The slowest observed infiltration rate shall be reduced by at least 50% to be used as the exfiltration rate in the model,
2. Only the storage volume above the soil media surface shall be used,
3. Storage in the media and/or the gravel layers shall not be considered in the model.

**Construction Requirements:**

The design engineer shall develop a detailed, site specific construction sequence for an Infiltration Basin. The design engineer shall also inspect the installation of the Infiltration Basin during the installation process. An Infiltration Basin shall be constructed early on during the overall construction process, so that the surface is stabilized with a drought tolerant grass prior to the introduction of stormwater to them.

A typical construction sequence will follow these generalized steps:

1. The area of an Infiltration Basin shall be fenced off with orange poly construction fence after the clearing of trees to prevent the movement of construction vehicles over the area of an Infiltration Basin,
2. A stable benchmark shall be set by the design engineer or land surveyor for use by the contractor,
3. The outline of an Infiltration Basin shall be staked in the field by the design engineer or contractor,
4. The Infiltration Basin shall be excavated to the required design depth (bottom of sand media or gravel layer depending upon the design) by hydraulic excavator located outside the limit of the facility. No excavation equipment is permitted in the actual an Infiltration Basin,
5. After the excavation of an Infiltration Basin has been completed, the soil bottom area within the bottom of an Infiltration Basin shall be scarified by hand be made as level as possible. Loose soil from the scarification shall be removed by hand,
6. Placement of the gravel (if applicable) shall be done by hydraulic excavator from outside an Infiltration Basin limits and then hand raked to the required design elevation. The underdrain, outlet pipe and vertical overflow pipes shall also be installed at this time (if applicable),
7. The sand media shall be placed at this time. It is imperative that the top of the sand media be as level as possible to ensure that runoff will spread out across the entire top of an Infiltration Basin,
8. The sand media shall be lightly tamped by walking on it or spraying the surface with water,
9. The surface of an Infiltration Basin shall be placed with a drought tolerant grass,

10. The grass shall be watered as necessary to ensure its establishment.

**Inspection Requirements:**

The design engineer shall oversee the entire installation of an Infiltration Basin at these specific steps:

1. After the excavation has been done to the bottom of an Infiltration Basin,
2. After placement of gravel layer, and drainage pipes (if applicable),
3. Inspection of the sand media prior to placement in an Infiltration Basin,
4. After placement and leveling of an Infiltration Basin sand media,
5. After the grass has been installed.
6. The design engineer shall prepare an as-built plan of the completed an Infiltration Basin and provide a written statement which addresses the following items:
    a. Excavation and scarification of the natural soils,
    b. Approval of sand media,
    c. Approval of overflow provisions,
    d. Approval of grass installation,
    e. Approval of completed system.

**Maintenance Requirements:**

1. Twice a year inspections of the Sediment Forebay,
2. Removal of accumulated sediment in the Forebay when the depth is greater than 24”,
3. Annual inspection of an Infiltration Basin,
4. Removal of organic debris (sticks and leaves) in the Spring and Fall,
5. Grass shall be maintained at a height of 6 – 8” by mowing,
6. Weeding as necessary to prevent undesirable plants from colonizing an Infiltration Basin,
7. If ponding on the soil surface exceeds 24 hours after a rainfall event, the soil media has become clogged. To eliminate the clogging, the top 2” of discolored soil media shall be removed and replaced with C33 Sand. If this is necessary, the area shall be reseeded with a drought tolerant grass. Reseed the soil media surface as necessary to maintain grass cover over a minimum of 75% of the soil media surface.

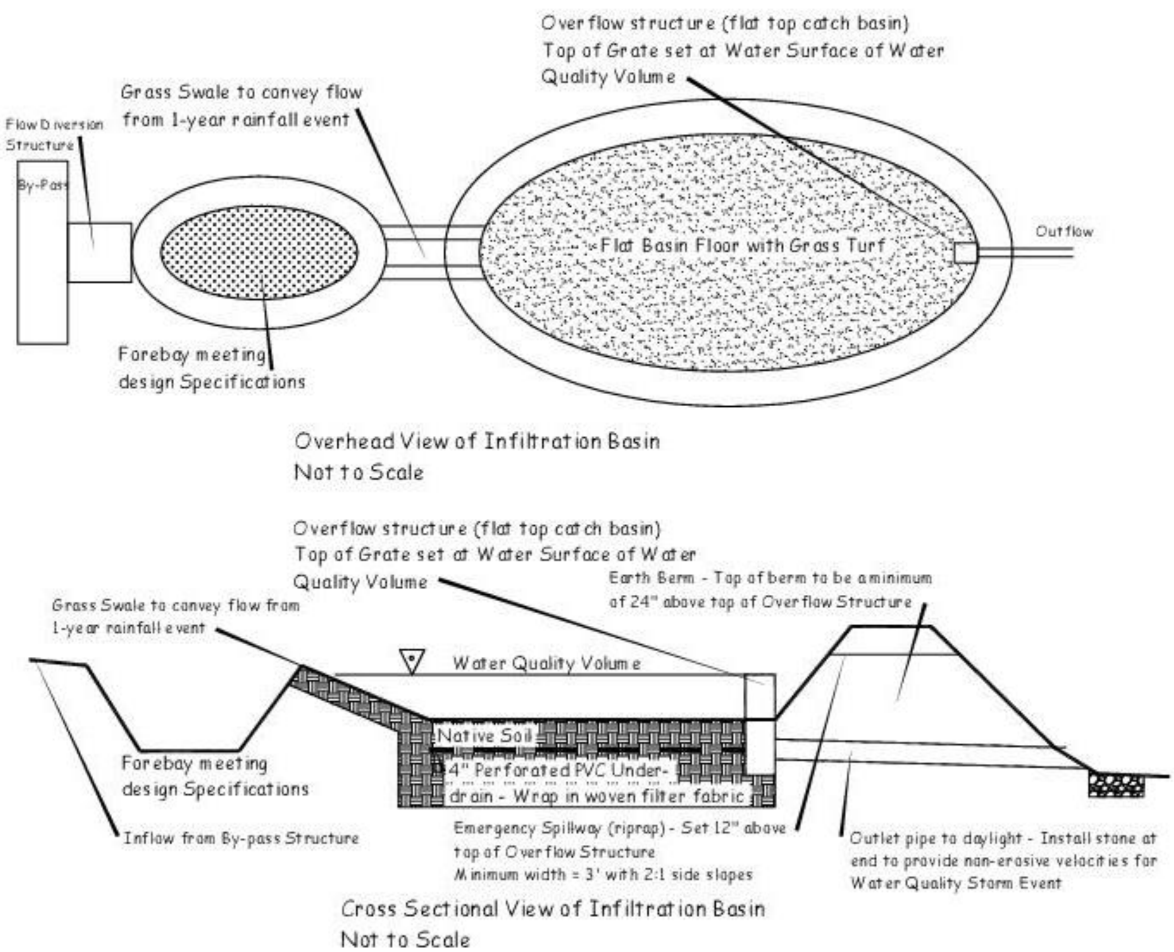



**Figure 7.7.1 - Infiltration Basin (Trinkaus Engineering, LLC - 2017)**

# 7.8 – PERMEABLE PAVING SURFACES (GRV & WQV)

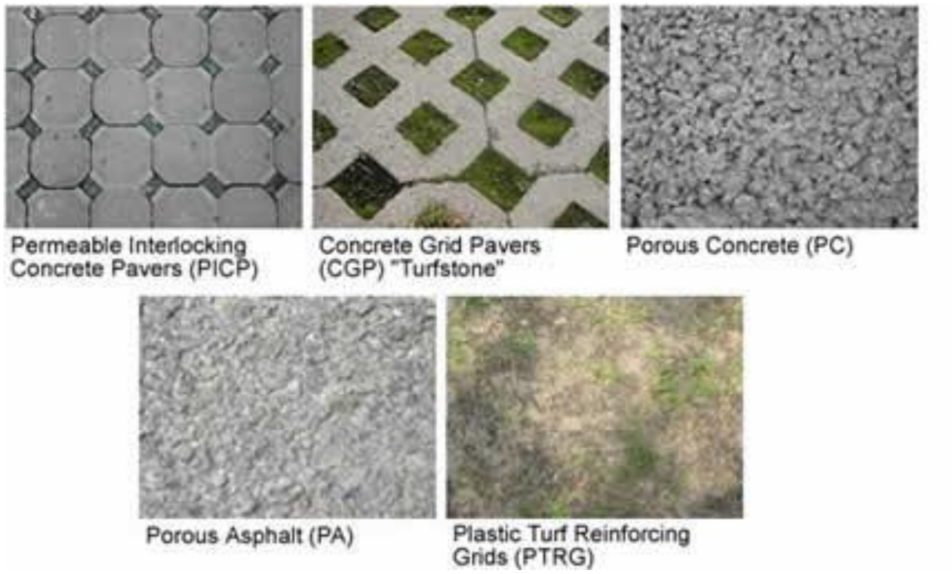



**Figure 7.8.1 - Types of Permeable Pavement Surfaces**

There are numerous types of commonly used permeable pavement systems. These systems are Permeable Asphalt, Porous Concrete and Permeable Interlocking Concrete Pavers. All three systems function in a similar fashion, rainfall, or runoff from an adjacent impervious area infiltrates through the surface material, goes through a filter course in the case of Permeable Asphalt and Porous Concrete, through an aggregate layer and then infiltrates in the native soils. Additionally, there are other systems such as open cell pavers, where the open cells can be filled with pea gravel or with topsoil and then seeded with grass. For both systems, the aggregate base is the same as that for Permeable Interlocking Concrete Pavers.

If the topsoil/grass system is utilized, it is imperative that the top of the topsoil be a minimum of ½" below the top of the open cell paver, so that where vehicles drive over the surface, the tires only touch the top of the paver cells and not on the topsoil. This will allow the grass roots to become well established and will result in a full grass over the open cell pavers.

All these systems require that an appropriate site investigation be done to evaluate the soils as specified below.

**Site Investigation:**

1. A deep test pit shall be excavated within the area of the proposed location of a Permeable Pavement system to a depth three (3) feet below the anticipated bottom of the gravel storage of the Permeable Pavement system. At least one (1) deep test pit shall be done for each 2,000 square feet of the permeable pavement system,
2. An Infiltration test using a Double Ring Infiltrometer shall be done within the area of the proposed location of a permeable pavement system. The infiltration test must be done at a depth which is equal to or below the lowest elevation of the lowest gravel layer. One infiltration test shall be done for each 1,000 square feet of the proposed permeable pavement system. The na-

tive soils must have a minimum infiltration rate of 0.5"/hr. The Infiltration test shall be done in accordance with the specifications found in Appendix "E" at the end of this manual.

**Design Requirements for all types of Permeable Pavement systems:**

1. Permeable pavement systems are primarily designed to infiltrate the runoff which funs on them. They can also be designed to not only handle the rainfall which falls on them but also runoff from adjacent impervious areas,
2. The depths of the aggregate and filter course layers depend upon the application of the permeable pavement system, see the cross sections at the end of this section for specific design information,
3. Permeable pavement systems can only be installed in Class A or Class B soil types. They are not permitted to be installed in Class C or Class D soils,
4. Minimum Vertical Separation to Seasonal High Groundwater Level from bottom of gravel layer shall be 24" for all applications,
5. Minimum Vertical Separation to Bedrock from the bottom of the soil media shall be thirty-six (36) inches for all applications,
6. To address water quality, the surface area of a permeable pavement system shall be determined by the following equation:
    a. Ap = WQV/ (n8dt + fct/12) Where:

        Ap = Surface area (square feet)
        WQV = Water Quality Volume (cubic feet)
        n = Porosity of gravel (assume 0.33)
        dt = Depth of gravel base (feet)
        fc = Design infiltration rate (in/hr) [50% of slowest observed infiltration rate]
        t = Time to fill (hours) (use t=2 hours for design purposes)
7. Allowable Contributing Drainage Area (CDA) directed to either a permeable asphalt or porous concrete system should be greater than 0.5 acres as these surface types are not cost effective from an installation perspective. There is no area limitation for Permeable Interlocking Concrete Pavers,
8. Natural Land Slope: All permeable paver systems can be installed on slopes up to 10% as a maximum. For a finish slope greater than 5.0%, a design modification must be added to the reservoir layer to force runoff to infiltrate and not follow the slope to the bottom,
9. Underdrains: As permeable pavement systems are designed to infiltrate runoff, underdrains can be used to by-pass larger runoff events,
    a. For permeable asphalt and porous concrete, the underdrain shall be located at the top of the reservoir layer with the perforations facing down,
    b. For Permeable Interlocking Concrete Pavers, the underdrain is located at the bottom of the reservoir layer, but the perforations are facing up.
10. Specifications for the Filter Course and aggregate layers are found on the details at the end of this section,
11. Overflows from a permeable pavement system can be done in one of two ways:
    a. The underdrain pipe as discussed in #9 above,

b. Allowing the full depth of the system to become saturated with surface ponding then being directed to a standard conventional drainage structure located on the top of the surface.

**Hydrologic Modeling:**

As all permeable pavement systems do infiltrate the rainfall which falls on them, under zoning regulations, they are considered a hardscape surface and there is a Runoff Curve Number (RCN) associated with all these systems which is dependent upon the soil type and depth of the reservoir layer. Table 7.8.1 below shows the RCN value to be used in a modeling analysis for a permeable pavement system.

**Table 7.8.1 – Curve Numbers for Infiltrating Permeable Pavement Surfaces (MDE, 2009)**

| Reservoir Depth | Hydrologic Soil Group | |
|---|---|---|
| (Inches) | A | B |
| 6 | 76 | 84 |
| 12 | 62 | 65 |
| >12 | 40 | 55 |

As part of the design of a permeable pavement system, it shall be demonstrated by hydrologic modeling using a program such as HydroCAD that the system will fully infiltrate at a minimum the water quality storm event and potentially other larger rainfall events. Using the RCN values above the permeable pavement system can be modeled to show how it will infiltrate all the required storm events. The modeling shall be done in a conservative fashion to ensure that the system will function as intended. To perform this approach, the following parameters shall be adhered to:

1. The slowest observed infiltration rate shall be reduced by at least 50% to be used as the exfiltration rate in the model,
2. Only storage in the bottom reservoir layer shall be counted. The available storage volume in the aggregate shall be 40%.

**Construction Requirements:**

All types of paver systems shall be installed at the end of the project so that no heavy construction vehicles will be driving over the surface, particularly for permeable asphalt and porous concrete. For permeable asphalt, the University of New Hampshire Stormwater Center specification, and requirements for the installation of permeable asphalt shall be followed. This document is found at the following link: http://www.unh.edu/unhsc/sites/default/files/media/unhsc_pa_spec_-_feb-2014_-rev_9-16.pdf.

For porous concrete, Specification 522R-10, prepared by the American Concrete Institute contains the specifications and installation procedures for this material. This document can be found at this link: https://www.concrete.org/store/productdetail.aspx?ItemID=52210&Format=PROTECTED_PDF.

Permeable Interlocking Concrete Pavers shall be installed in accordance with the specific requirements of each manufacturer. The aggregate base shall be installed in accordance with the details found in this section.

The design engineer shall develop a detailed, site specific construction sequence for a permeable pavement system. The design engineer shall also inspect the installation of the permeable pavement system during the installation process.

A typical construction sequence will follow these generalized steps:

1. Only rough grade the area of the permeable pavement system for access during the early stages of project construction,
2. When all major site work and work on the building are complete which eliminate the necessary of using heavy construction vehicles, then the area of the permeable pavement system can be prepared,
3. A stable benchmark shall be set by the design engineer or land surveyor for use by the contractor,
4. The outline of the permeable pavement system shall be staked in the field by the project land surveyor if necessary,
5. The area shall be excavated to the required design depth for the bottom of the aggregate layer. The bottom and side walls of the excavation shall be scarified to remove any soil smearing. Soil dislodged during this operation shall be removed from the area,
6. The base aggregate layer shall be installed along with any underdrain, if applicable. The aggregate shall be rolled with a one-ton roller,
7. The second layer of aggregate shall be installed and lightly compacted as noted in #6 above,
8. The Filter Course shall be installed and lightly compacted as noted in #6 above,
9. The Choker Course shall be installed at this time and lightly compacted as noted in #6 above,
10. Permeable asphalt or porous concrete shall be placed in accordance with the applicable installation requirements from the University of New Hampshire Stormwater Center or the American Concrete Institute,
11. Permeable interlocking concrete pavers shall be installed by the contractor and the gaps between the stones filled with 3/8" pea gravel,

**Inspection Requirements:**

The design engineer shall oversee the entire installation of a permeable pavement system at these specific steps:

1. After the excavation has been done to the bottom of the proposed aggregate layer,
2. After placement of each gravel layer, and drainage pipes (if applicable),
3. Inspection of the gravel surface prior to the placement of the permeable asphalt, porous concrete, or permeable interlocking concrete pavers,
4. For Permeable asphalt:
    a. On site entire time, asphalt is being placed,
    b. Measure temperature of material when transferred from truck to paving machine to verify in compliance with required temperature range,
    c. After all pavements has been installed,
    d. Material testing company also required to measure compaction ratio during the installation process,
5. For Porous concrete:
    a. On site entire time, concrete is being placed,
    b. Visit site on daily basis to inspection curing process of concrete per specifications,

   c. Material testing company also required to measure compaction ratio during the installation process,
   d. After curing period.
6. For Permeable Interlocking Concrete Pavers:
   a. After installation of pavers,
   b. After installation of gravel infill between the pavers.
7. The design engineer shall prepare an as-built plan of the completed permeable pavement system and provide a written statement which address the following items:
   a. Excavation and scarification of the natural soils,
   b. Approval the installation of the gravel and filter layers,
   c. Approval of permeable asphalt, porous concrete, permeable interlocking concrete pavers,
   d. Approval of completed system.

**Maintenance Requirements:**

**Permeable Asphalt:**
1. No application of sand during winter operations,
2. Quarterly sweeping or cleaning of surface with leaf blower to remove organic debris and fine sediments,
3. Reduced application of deicing agents,
4. Do not permit landscape contractors to place mulch, soil, or plant material on permeable pavement surface directly, a tarp must be placed over the surface prior to the placement of any organic material by a contractor.

**Porous Concrete:**
1. No application of deicing agents during the first winter season,
2. Only apply sand to porous concrete surface for first winter season for pedestrian safety. Monthly sweeping of surface to remove sand during the first winter season,
3. Reduced application of deicing agents starting in the second winter season,
4. Do not permit landscape contractors to place mulch, soil, or plant material on permeable pavement surface directly, a tarp must be placed over the surface prior to the placement of any organic material by a contractor.

**Permeable Interlocking Concrete Pavers:**

1. No application of sand during winter operations,
2. Quarterly sweeping or cleaning of surface with leaf blower to remove organic debris and fine sediments,
3. Reduced application of deicing agents,
4. Do not permit landscape contractors to place mulch, soil, or plant material on permeable pavement surface directly, a tarp must be placed over the surface prior to the placement of any organic material by a contractor.

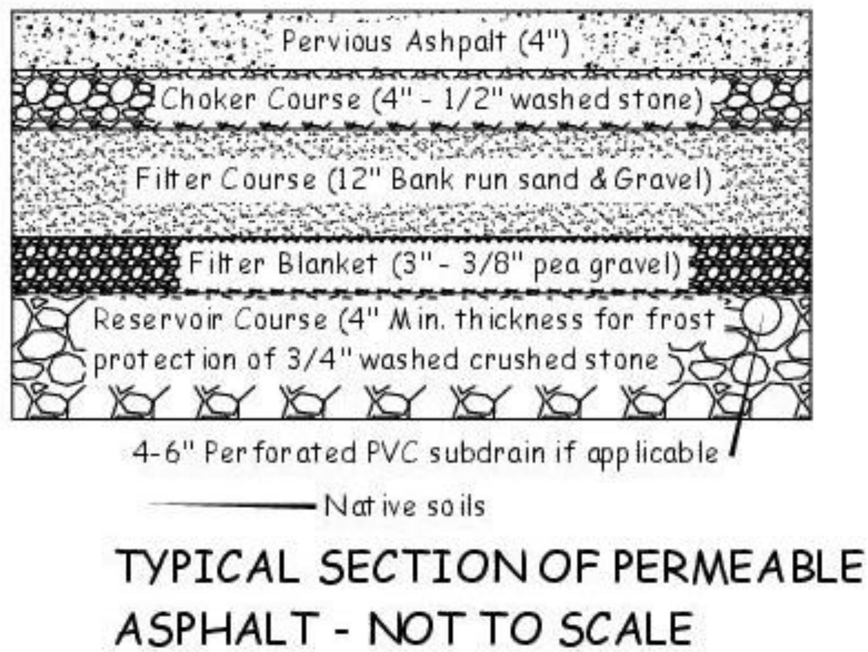



**Figure 7.8.2 - Permeable Asphalt Section - (Trinkaus Engineering, LLC - 2017)**

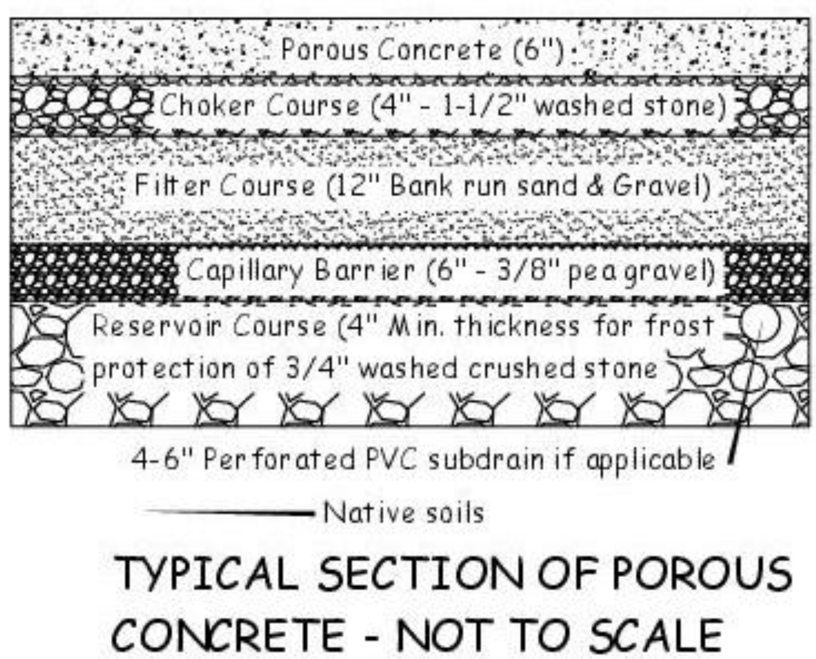



**Figure 7.8.3 - Porous Concrete Section - (Trinkaus Engineering, LLC - 2017)**

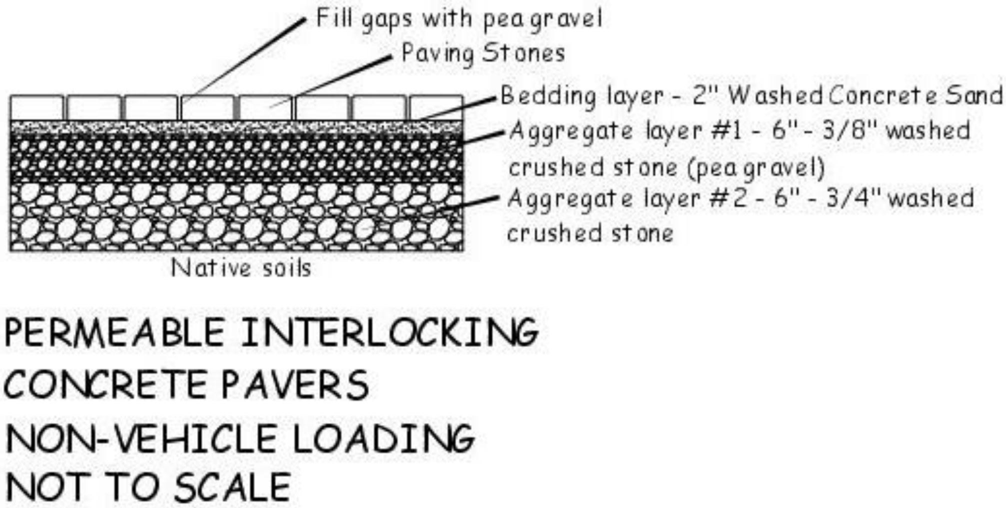



**Figure 7.8.4 - PICP - Typical Section - Non-vehicle Loading - (Trinkaus Engineering, LLC - 2017)**

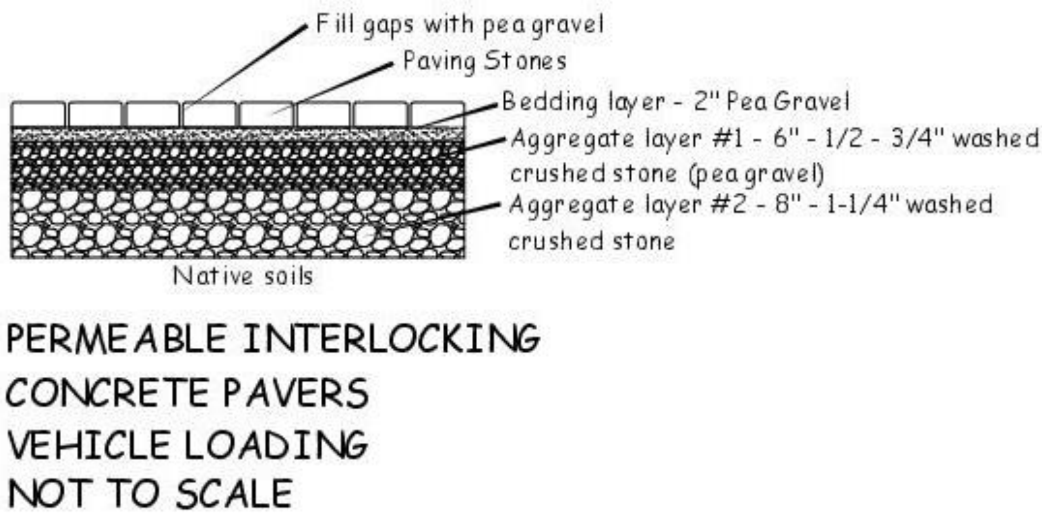



**Figure 7.8.5 - PICP Typical Section - Vehicle Loading - (Trinkaus Engineering, LLC - 2017)**

# 7.9 – EXTENDED DETENTION SHALLOW WETLANDS (WQ, CPF, & FP)

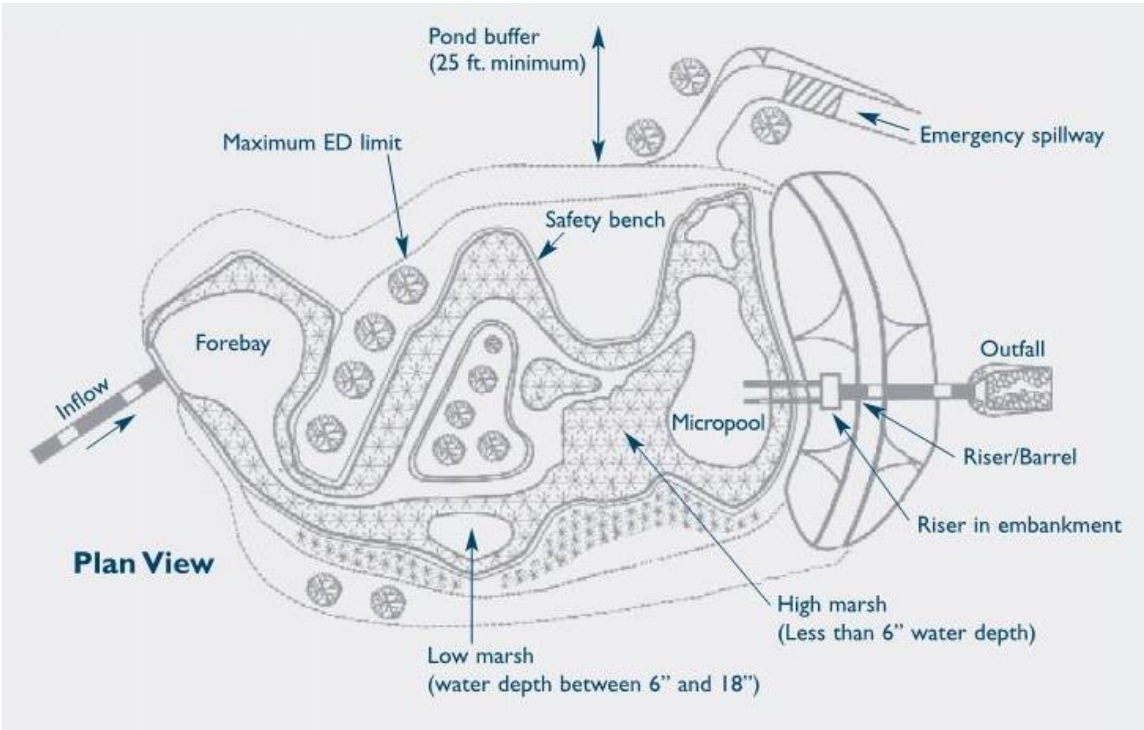



**Figure 7.9.1 - Extended Detention Shallow Wetlands (CT DEP 2004)**

**Site Investigation:**

1. Extended Detention Shallow Wetland systems will have a permanent water surface in them, so it is required that that the bottom of the basin be located below the seasonal high groundwater level. A deep test pit shall be excavated within the area of the proposed location of an Extended Detention Shallow Wetland system to a depth three (3) feet below the anticipated bottom of the system. One (1) deep test pit shall be done for each 2,000 square feet of the area of an Extended Detention Shallow Wetland System.

**Design Requirements:**

1. Extended Detention Shallow Wetland System are designed to handle both the runoff from the Water Quality Storm as well as larger rainfall events. Runoff can be delivered to an Extended Detention Shallow Wetland by either a pipe or swale,
2. A forebay designed in accordance with the specifications found in this manual must be located at the end of the pipe where runoff will enter the system. The forebay must contain a minimum of 10% of the required Water Quality Volume,
3. The elevation of the top of the permanent pool must be set at the seasonal high groundwater table,

4. The micro-pool must contain 25% of the required Water Quality Volume below the elevation of the permanent pool. The micro-pool shall be a minimum of 48" in depth and shall not exceed 96",
5. The full Water Quality Volume must be contained as a fixed storage volume below the lowest outlet control orifice or weir,
6. Low marsh areas (water depth between 6" – 18") shall comprise a minimum of 25% of the bottom area of the system,
7. High march areas (water depth < 6") shall comprise a minimum of 50% of the bottom area of the system. High marsh areas can consist of low graded berms which create a long flow path within the bottom of the basin as shown in Figure 7.9.1,
8. The shape of an Extended Detention Shallow Wetland shall be curvilinear in shape with a minimum length to width ratio of 3:1 from the inlet to the outlet,
9. The minimum surface area of an Extended Detention Shallow Wetland shall be 1.0% to 1.5% of the contributing drainage area,
10. Minimum Vertical Separation to Bedrock from the bottom of the soil media shall be twenty-four (24) inches to the naturally occurring elevation of the bedrock. Blasting and removal of shallow ledge is not permitted as fissures in the rock on the side walls will be exposed to non-point source pollutants found in the runoff,
11. The berm around the Extended Detention Shallow Wetlands shall be 48" or less above existing grade. If the berm is higher than 48" it shall be designed as a dam to CT DEEP requirements,
12. Allowable Contributing Drainage Area (CDA) directed to Extended Detention Shallow Wetland System and required (pre-treatment). All runoff flows can be directed to an Extended Detention Shallow Wetland system.
    a. CDA < 5,000 square feet: Not permitted as there is insufficient drainage area to maintain water surface in system,
    b. 5,000 square feet $\leq$ CDA $\leq$ 10,000 square feet: Not permitted as there is insufficient drainage area to maintain water surface in system,
    c. 10,000 square feet $\leq$ CDA $\leq$ 20,000 square feet: Not permitted as there is insufficient drainage area to maintain water surface in system,
    d. 20,000 square feet $\leq$ CDA $\leq$ 1 acre: (Forebay containing 10% of the calculated WQV designed in accord with the specifications found in this manual),
    e. 1 acre $\leq$ CDA $\leq$ 5 acres: (Forebay containing 10% of the calculated WQV designed in accord with the specifications found in this manual
    f. 5 acres < CDA < 20 acres: (Forebay containing 10% of the calculated WQV designed in accord with the specification found in this manual.
13. Natural Land Slope: There are no design modifications necessary for an Extended Detention Shallow Wetland System on slopes up to 10% other than meeting the other requirements found in this section.
14. Outflow provisions from an Extended Detention Shallow Wetland System can be done in one of several ways:
    a. An outlet control structure shall have either weirs or orifices to control peak rate discharges with the top of the structure acting as an overflow provision for storm events up to the 100-year event.

b. An emergency spillway can be provided through the berm of the system. The spillway shall be sufficient to convey flows more than the 100-year event and be lined with an appropriate size of riprap.
c. All discharge pipes must direct flows to an existing stable watercourse system which is downgradient from the basin.
d. Discharges from the primary outlet system shall not be permitted on upland slope areas.

**Hydrologic Modeling:**

As part of the design of an Extended Detention Shallow Wetland System, it shall be demonstrated by hydrologic modeling using a program such as HydroCAD that the system will provide the required Channel Protection Flow Rate as well as peak rate attenuation as may be required. Volume computations must be provided to demonstrate storage capacity in Pond/Wetland system for Water Quality Volume and compliance with the specifications found in this manual.

**Construction Requirements:**

The design engineer shall develop a detailed, site specific construction sequence for an Extended Detention Shallow Wetland System. The design engineer shall also inspect the installation of an Extended Detention Shallow Wetland System during the installation process. Extended Detention Shallow Wetland System shall be constructed early on during the overall construction process, so that they are fully vegetated and stabilized prior to the introduction of stormwater to them.

A typical construction sequence will follow these generalized steps:

1. The area of the Extended Detention Shallow Wetland System shall be fenced off with orange poly construction fence after the clearing of trees to prevent the movement of construction vehicles over the area of the Extended Detention Shallow Wetland System,
2. A stable benchmark shall be set by the design engineer or land surveyor for use by the contractor,
3. The outline of the Extended Detention Shallow Wetland System shall be staked in the field by the design engineer or contractor,
4. The Extended Detention Shallow Wetland System shall be excavated to the required design depth by hydraulic excavator,
5. The forebay and micro-pool shall be excavated as well as shaping the high and low marsh areas within the bottom of the system. These areas shall be over excavated by 6" to allow for the placement of 6" of wetland soil or topsoil to provide a growth media for the wetland plants,
6. The berm, outlet structure and piping as well as the emergency spillway shall be installed per the design,
7. The bottom and side slopes of the Extended Detention Shallow Wetland shall be placed with appropriate plans for the hydrologic conditions. Wetland plugs shall be used for the marsh areas,
8. The side slopes above the permanent pool shall be planted with both wetland and upland species which can survive with moist soil conditions as well as temporary inundated conditions,
9. The plants above the seasonal groundwater table shall be watered as necessary to ensure their establishment.

**Inspection Requirements:**

The design engineer shall oversee the entire installation of the Extended Detention Shallow Wetland System at these specific steps:

1. After the excavation has been done to the bottom of the system,
2. After installation of outlet structure, piping, berm, etc.,
3. After planting of the basin and stabilization of adjacent upland areas
4. The design engineer shall prepare an as-built plan of the completed Extended Detention Shallow Wetland and provide a written statement which addresses the following items:
    a. Excavation and grading of the Extended Detention Shallow Wetland,
    b. Approval of outlet hydrologic control structures,
    c. Approval of plantings,
    d. Approval of completed system.

**Maintenance Requirements:**

1. Twice a year inspections of the Sediment Forebay,
2. Removal of accumulated sediment in the Forebay when the depth is greater than 24",
3. Annual inspection of the Extended Detention Shallow Wetland,
4. Removal of invasive vegetation within wetland areas as necessary,
5. Annual inspection of outlet control structures.

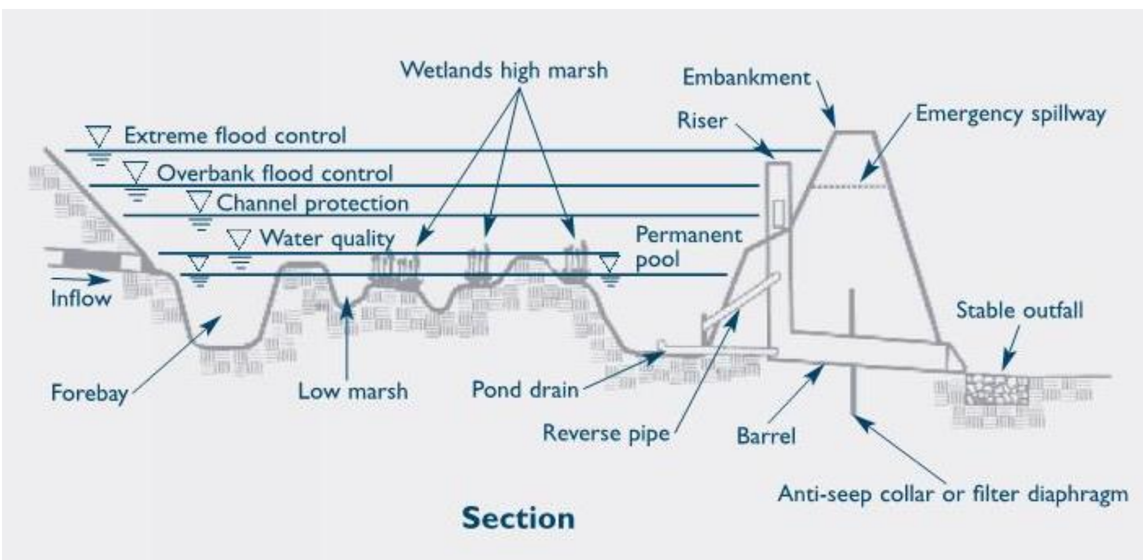



**Figure 7.9.2 – Section of Extended Detention Shallow Wetland (CT DEEP, 2004)**

Design modifications shown in Figure 7.9.2 which shall not be part of the design:

1. No pond drain valve,
2. No reverse pipe.

# 7.10 - SUBSURFACE FLOW GRAVEL WETLANDS (WQ, & CFP)

Subsurface Flow Gravel Wetlands are a great system to be installed as a retrofit at the end of an existing conventional drainage system. They provide tremendous reductions of nitrogen in the runoff as well as a significant increase in the time of concentration due to the flow through the gravel layers.

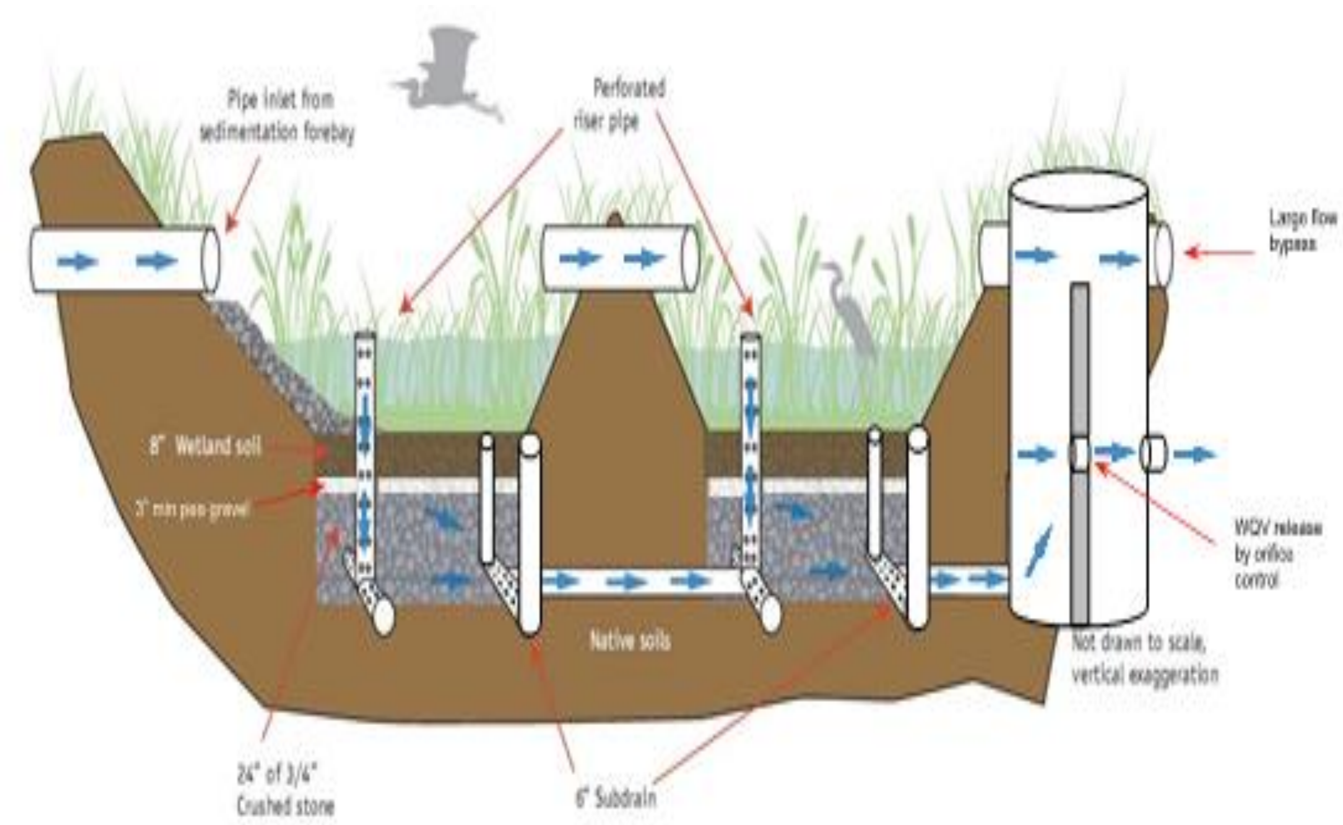



**Figure 7.10.1 – Subsurface Flow Gravel Wetland (UNHSC)**

**Site Investigation:**

1. Subsurface Flow Gravel Wetlands systems need to have a soil test pit performed to observe the generalized soil type and depth to bedrock under the system,
2. A deep test pit shall be excavated within the area of the proposed location of a Subsurface Flow Gravel Wetlands system to a depth three (3) feet below the anticipated bottom of the system. One (1) deep test pit shall be done for each 2,000 square feet of the area of a Subsurface Flow Gravel Wetlands.

**Design Requirements:**

1. Subsurface Flow Gravel Wetlands System is designed to handle both the runoff from the Water Quality Storm as well as meeting the Channel Protection Flow requirement. Runoff can be de-livered to a Subsurface Flow Gravel Wetlands by either a pipe or swale,

2. Shall be 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,
3. A forebay designed in accordance with the specifications found in this manual must be located at the end of the pipe where runoff will enter the system. The forebay must contain a minimum of 10% of the required Water Quality Volume. Computations must be provided to demonstrate this is being provided. For a Subsurface Flow Gravel Wetlands, the forebay shall have an underdrain to dewater the forebay within 48 hours after a rainfall event to maintain aerobic conditions in the forebay. Aerobic conditions in the forebay are necessary to allow denitrification to occur within the Subsurface Flow Gravel Wetlands,
4. After the forebay, there are two cells which comprise the Subsurface Flow Gravel Wetlands. Each cell shall have a minimum flow length of 15' (longer is better),
5. Each cell of the Subsurface Flow Gravel Wetland shall contain 45% of the required Water Quality Volume. The top of the perforated PVC riser pipes shall be set at the water surface associated with the Water Quality Volume. Ideally each treatment cell will be large enough to contain 45% of the required Water Quality Volume at a depth less than 18". If the water depth will exceed 18", then instead of wetland plants, wetland shrubs shall be planted in each treatment cell as they can better tolerate the increased water depth,
6. The Subsurface Flow Gravel Wetlands must be rectangular in shape,
7. Minimum Vertical Separation to Bedrock from the bottom of the soil media shall be twenty-four (24) inches,
8. The berm around the Subsurface Flow Gravel Wetlands shall be 48" or less above existing grade. If the berm is higher than 48" it shall be designed as a dam to CT DEEP requirements,
9. Allowable Contributing Drainage Area (CDA) directed to Subsurface Flow Gravel Wetlands System and required (pre-treatment). All runoff flows can be directed to an Extended Detention Shallow Wetland system.
    a. CDA < 5,000 square feet: Not recommended as the drainage area is too small to generate sufficient runoff to the system,
    b. 5,000 square feet ≤ CDA ≤ 10,000 square feet: Not recommended as the drainage area is too small to generate sufficient runoff to the system,
    c. 10,000 square feet ≤ CDA ≤ 20,000 square feet: Not recommended as the drainage area is too small to generate sufficient runoff to the system,
    d. 20,000 square feet ≤ CDA ≤ 1 acre: (Forebay containing 10% of the calculated WQV designed in accord with the specifications found in this manual),
    e. 1 acre ≤ CDA ≤ 5 acres: (Forebay containing 10% of the calculated WQV designed in accord with the specifications found in this manual
    f. 5 acres < CDA < 10 acres: (Forebay containing 10% of the calculated WQV designed in accord with the specification found in this manual.
10. Natural Land Slope: There are no design modifications necessary for a Subsurface Flow Gravel Wetlands System on slopes up to 10% other than meeting the other requirements found in this section. It is likely however that more substantial earthwork will be necessary on slopes greater than 5.0%.
11. Outflow provisions from a Subsurface Flow Gravel Wetlands System can be done in one of several ways:

g. An outlet control structure shall have a minimum 4" diameter orifice. The invert of the orifice shall be set 4" below the top of the soil surface in the two treatment cells to ensure that saturated conditions are maintained in the gravel layer,
h. Additional orifices or weirs can be implemented above the soil surface to provide detention of the Channel Protection Volume,
i. An emergency pipe or spillway can be provided through the berm of the system. The spillway shall be sufficient to convey flows more than the 100-year event and be lined with an appropriate size of riprap,
j. All discharge pipes must direct flows to an existing stable watercourse system which is downgradient from the basin.
k. Discharges from the primary outlet system shall not be permitted on upland slope areas.

**Hydrologic Modeling:**

As part of the design of a Subsurface Flow Gravel Wetlands, it shall be demonstrated by hydrologic modeling using a program such as HydroCAD that the system will provide the required Channel Protection Flow Rate. Only the storage volume above the water surface of the Water Quality Volume can be used for the Channel Protection Flow Rate. Volume computations must be provided to demonstrate storage capacity in Pond/Wetland system for Water Quality Volume and compliance with the specifications found in this manual.

**Construction Requirements:**

The design engineer shall develop a detailed, site specific construction sequence for a Subsurface Flow Gravel Wetlands System. The design engineer shall also inspect the installation of a Subsurface Flow Gravel Wetlands System during the installation process. Subsurface Flow Gravel Wetlands System shall be constructed early on during the overall construction process, so that they are fully vegetated and stabilized prior to the introduction of stormwater to them.

A typical construction sequence will follow these generalized steps:

1. The area of the Subsurface Flow Gravel Wetlands System shall be fenced off with orange poly construction fence after the clearing of trees to prevent the movement of construction vehicles over the area of the Subsurface Flow Gravel Wetlands System,
2. A stable benchmark shall be set by the design engineer or land surveyor for use by the contractor,
3. The outline of the Subsurface Flow Gravel Wetlands System shall be staked in the field by the design engineer or contractor,
4. The Subsurface Flow Gravel Wetland, including the forebay shall be excavated to the required design depth by hydraulic excavator,
5. The treatment cells and forebay shall be properly shaped per the design specifications. The underdrain shall be installed in the forebay with the outlet pipe being directed to a riprap pad on the inlet side of the first treatment cell,
6. The berm, outlet structure and piping as well as the emergency spillway shall be installed per the design,
7. The gravel layers with appropriate piping shall be installed at this time in accordance with the design,

8. After the gravel layers have been installed, the wetland soil shall be placed on top of the pea gravel layer and graded level. The inlet pipes above the wetland soil shall be perforated.
9. Appropriate wetland plants for the depth of the Water Quality Volume shall be planted in the two treatment cells,
10. The side slopes of the Subsurface Flow Gravel Wetlands and the forebay shall be seeded with an appropriate seed mixture,
11. The plants above the seasonal groundwater table shall be watered as necessary to ensure their establishment.

**Inspection Requirements:**

The design engineer shall oversee the entire installation of the Subsurface Flow Gravel Wetlands System at these specific steps:

1. After the excavation has been done to the bottom of the system,
2. After installation of outlet structure, piping, berm, etc.,
3. After the installation of gravel layers and associated piping,
4. After placement of wetland soil and installation of appropriate wetland plants,
5. After planting of the basin and stabilization of adjacent upland areas
6. The design engineer shall prepare an as-built plan of the completed Subsurface Flow Gravel Wetlands System and provide a written statement which addresses the following items:
    a. Excavation and grading of the Subsurface Flow Gravel Wetlands System,
    b. Approval of outlet hydrologic control structures,
    c. Approval of plantings,
    d. Approval of completed system.

**Maintenance Requirements:**

1. Twice a year inspections of the Sediment Forebay,
2. Removal of accumulated sediment in the Forebay when the depth is greater than 24",
3. Annual inspection of the Subsurface Flow Gravel Wetlands System,
4. Removal of invasive vegetation within wetland areas as necessary,
5. Cutting back of vegetation in the fall and removal of the clipping from the Subsurface Flow Gravel Wetlands and disposal of the clippings in an upland area away from the treatment system,
6. Annual inspection of perforated inlet pipes and outlet control structures, removal of any debris which could clog the inlet pipes.

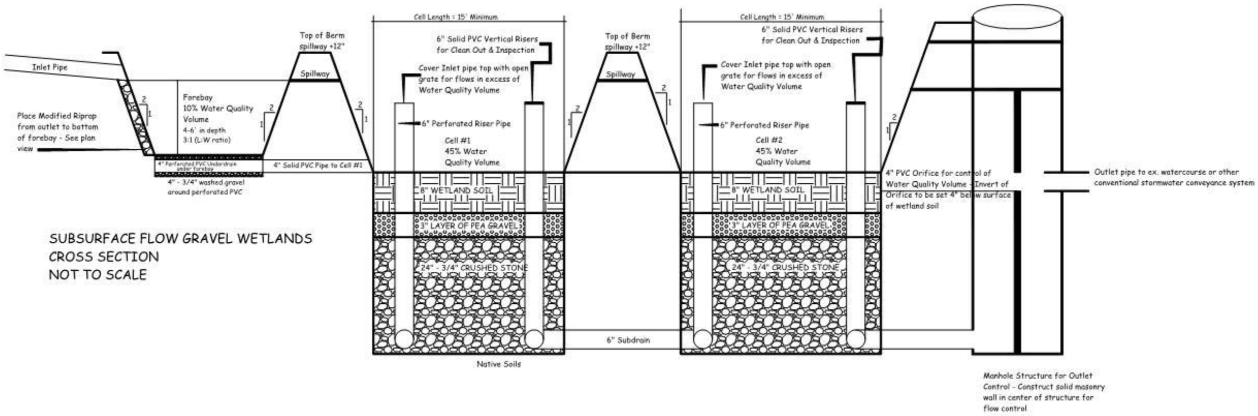



**Figure 7.10.2 - Full Section through Subsurface Flow Gravel Wetland (Trinkaus Engineering, LLC - 2017)**
(See Enlargements in Figure 7.10.3 and 7.10.4)

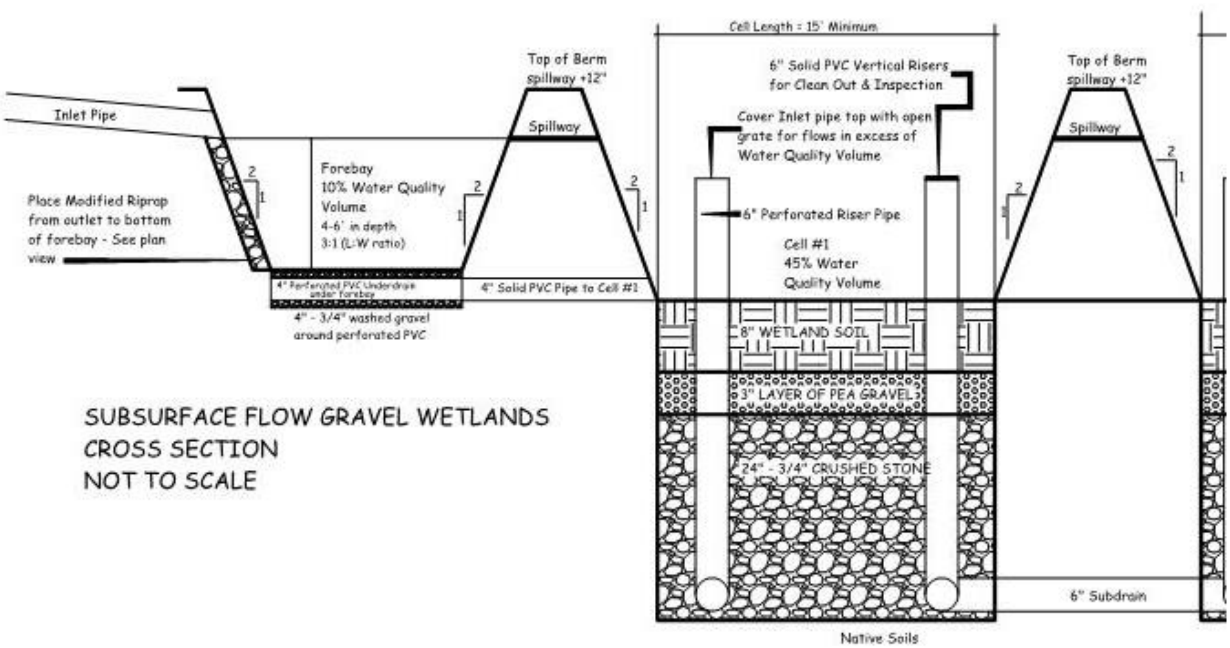



**Figure 7.10.3 - Partial Cross Section of Subsurface Flow Gravel Wetland (Trinkaus Engineering, LLC - 2017)**

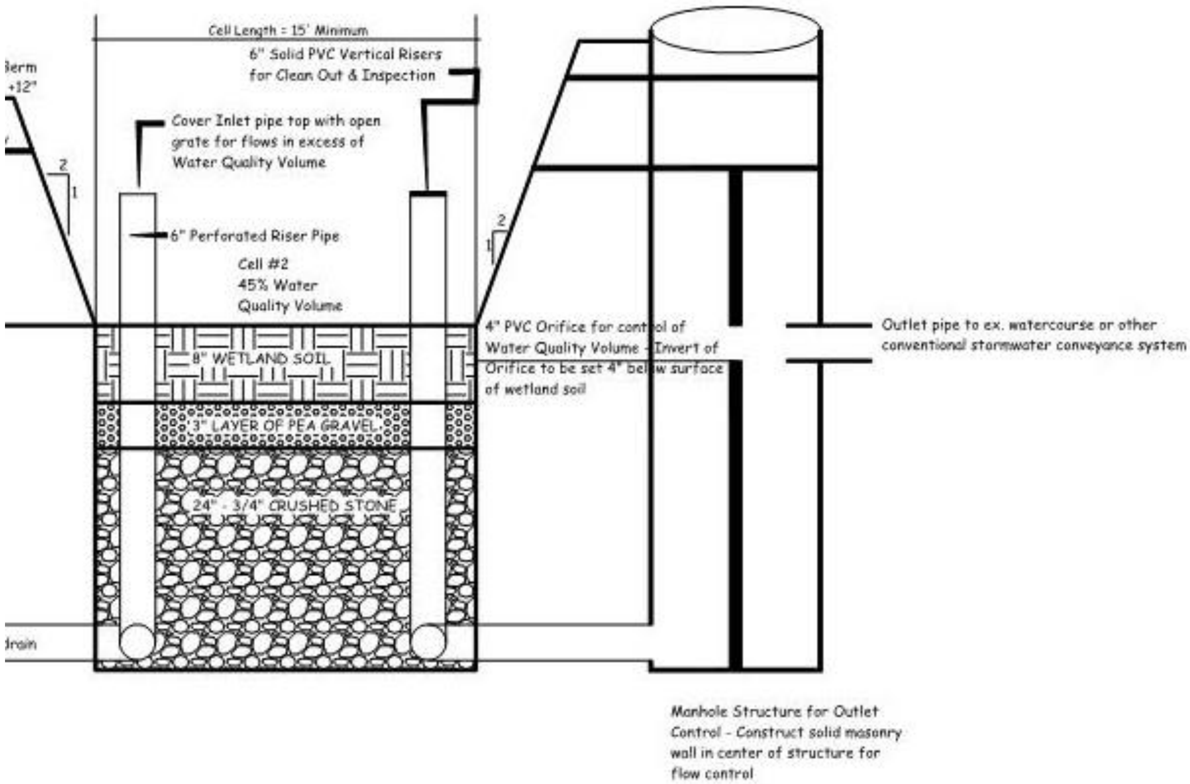



**Figure 7.10.4 - Partial Cross Section of Subsurface Flow Gravel Wetlands (Trinkaus Engineering, LLC - 2017)**

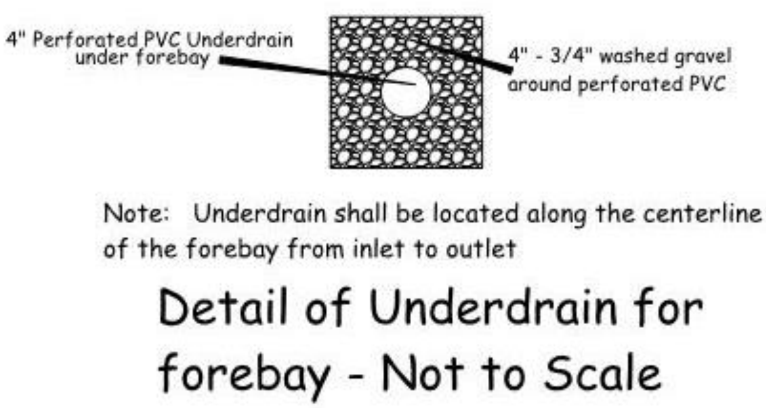



**Figure 7.10.5 - Cross Section of Forebay Underdrain (Trinkaus Engineering, LLC - 2017)**

# 7.11 – POND / WETLAND SYSTEM (WQ, CPF, & FP)

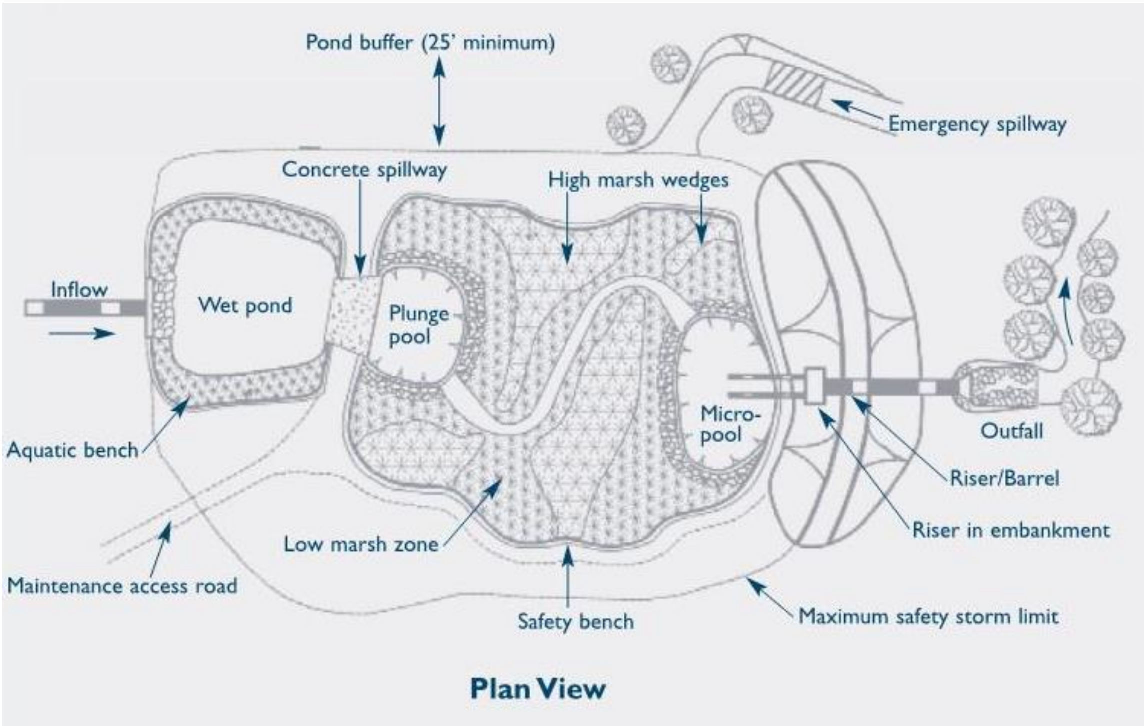



**Figure 7.11.1 – Plan View of Pond/Wetland System (CT DEEP, 2004)**

**Site Investigation:**

1. A Pond/Wetland system will have a permanent water surface in them, so it is required that that the bottom of the basin be located below the seasonal high groundwater level. A deep test pit shall be excavated within the area of the proposed location of an Extended Detention Shallow Wetland system to a depth three (3) feet below the anticipated bottom of the system. One (1) deep test pit shall be done for each 2,000 square feet of the area of an Extended Detention Shallow Wetland System.

**Design Requirements:**

1. A Pond/Wetland system is designed to handle both the runoff from the Water Quality Storm as well as larger rainfall events. Runoff can be delivered to an Extended Detention Shallow Wetland by either a pipe or swale,
2. A forebay designed in accordance with the specifications found in this manual must be located at the end of the pipe where runoff will enter the system. The forebay must contain a minimum of 10% of the required Water Quality Volume. Computations must be provided to demonstrate this is being provided,
3. The elevation of the top of the permanent pool must be set at the seasonal high groundwater table,

4. The micro-pool must contain 25% of the required Water Quality Volume below the elevation of the permanent pool. The micro-pool shall be a minimum of 48" in depth and no more than 72",
5. The full Water Quality Volume must be contained as a fixed storage volume below the lowest outlet control orifice or weir,
6. Low marsh areas (water depth between 6" – 18") shall comprise a minimum of 55% of the bottom area of the system,
7. High march areas (water depth < 6") shall comprise a minimum of 30% of the bottom area of the system. High marsh areas can consist of low graded berms which create a long flow path within the bottom of the basin as shown in Figure 7.11.2,
8. The shape of a Pond/Wetland system shall be curvilinear in shape with a minimum length to width ratio of 3:1 from the inlet to the outlet,
9. The minimum surface area of a Pond/Wetland system shall be 1.0% to 1.5% of the contributing drainage area,
10. Minimum Vertical Separation to Bedrock from the bottom of the soil media shall be twenty-four (24) inches to the naturally occurring elevation of the bedrock. Blasting and removal of shallow ledge is not permitted as fissures in the rock on the side walls will be exposed to non-point source pollutants found in the runoff,
11. The berm around the Pond/Wetland system shall be 48" or less above existing grade. If the berm is higher than 48" it shall be designed as a dam to CT DEEP requirements,
12. Allowable Contributing Drainage Area (CDA) directed to Pond/Wetland system and required (pre-treatment). All runoff flows can be directed to a Pond/Wetland system.
    a. CDA < 5,000 square feet: Not permitted as there is insufficient drainage area to maintain water surface in system,
    b. 5,000 square feet ≤ CDA ≤ 10,000 square feet: Not permitted as there is insufficient drainage area to maintain water surface in system,
    c. 10,000 square feet ≤ CDA ≤ 20,000 square feet: Not permitted as there is insufficient drainage area to maintain water surface in system,
    d. 20,000 square feet ≤ CDA ≤ 1 acre: Not permitted as there is insufficient drainage area to maintain water surface in system,
    e. 1 acre ≤ CDA ≤ 5 acres: (Forebay containing 10% of the calculated WQV designed in accord with the specifications found in this manual
    f. 5 acres < CDA < 20 acres: (Forebay containing 10% of the calculated WQV designed in accord with the specification found in this manual.
13. Natural Land Slope: There are no design modifications necessary for a Pond/Wetland System on slopes up to 10% other than meeting the other requirements found in this section. It is likely however that more substantial earthwork will be necessary on slopes greater than 5.0%.
14. Outflow provisions from a Pond/Wetland System can be done in one of several ways:
    a. An outlet control structure shall have either weirs or orifices to control peak rate discharges with the top of the structure acting as an overflow provision for storm events up to the 100-year event.
    b. An emergency spillway can be provided through the berm of the system. The spillway shall be sufficient to convey flows more than the 100-year event and be lined with an appropriate size of riprap.

c. All discharge pipes must direct flows to an existing stable watercourse system which is downgradient from the basin.
d. Discharges from the primary outlet system shall not be permitted on upland slope areas.

**Hydrologic Modeling:**

As part of the design of a Pond/Wetland System, it shall be demonstrated by hydrologic modeling using a program such as HydroCAD that the system will provide the required Channel Protection Flow Rate as well as peak rate attenuation as may be required. Volume computations must be provided to demonstrate storage capacity in Pond/Wetland system for Water Quality Volume and compliance with the specifications found in this manual.

**Construction Requirements:**

The design engineer shall develop a detailed, site specific construction sequence for a Pond/Wetland System. The design engineer shall also inspect the installation of a Pond/Wetland System during the installation process. A Pond/Wetland System shall be constructed early on during the overall construction process, so that they are fully vegetated and stabilized prior to the introduction of stormwater to them.

A typical construction sequence will follow these generalized steps:

1. The area of a Pond/Wetland System shall be fenced off with orange poly construction fence after the clearing of trees to prevent the movement of construction vehicles over the area of a Pond/Wetland System
2. A stable benchmark shall be set by the design engineer or land surveyor for use by the contractor,
3. The outline of a Pond/Wetland System shall be staked in the field by the design engineer or contractor,
4. A Pond/Wetland System shall be excavated to the required design depth by hydraulic excavator,
5. The forebay and micro-pool shall be excavated as well as shaping the high and low marsh areas within the bottom of the system. These areas shall be over excavated by 6” to allow for the placement of 6” of wetland soil or topsoil to provide a growth media for the wetland plants,
6. The berm, outlet structure and piping as well as the emergency spillway shall be installed per the design,
7. The bottom and side slopes of the Pond/Wetland System shall be placed with appropriate plans for the hydrologic conditions. Wetland plugs shall be used for the marsh areas,
8. The side slopes above the permanent pool shall be planted with both wetland and upland species which can survive with moist soil conditions as well as temporary inundated conditions,
9. The plants above the seasonal groundwater table shall be watered as necessary to ensure their establishment.

**Inspection Requirements:**

The design engineer shall oversee the entire installation of the Pond/Wetland System at these specific steps:

1. After the excavation has been done to the bottom of the system,
2. After installation of outlet structure, piping, berm, etc.,
3. After planting of the basin and stabilization of adjacent upland areas

4. The design engineer shall prepare an as-built plan of the completed Pond/Wetland System and provide a written statement which addresses the following items:
    a. Excavation and grading of the Pond/Wetland System,
    b. Approval of outlet hydrologic control structures,
    c. Approval of plantings,
    d. Approval of completed system.

**Maintenance Requirements:**
1. Twice a year inspections of the Sediment Forebay,
2. Removal of accumulated sediment in the Forebay when the depth is greater than 24",
3. Annual inspection of the Pond/Wetland System,
4. Removal of invasive vegetation within wetland areas as necessary,
5. Annual inspection of outlet control structures.

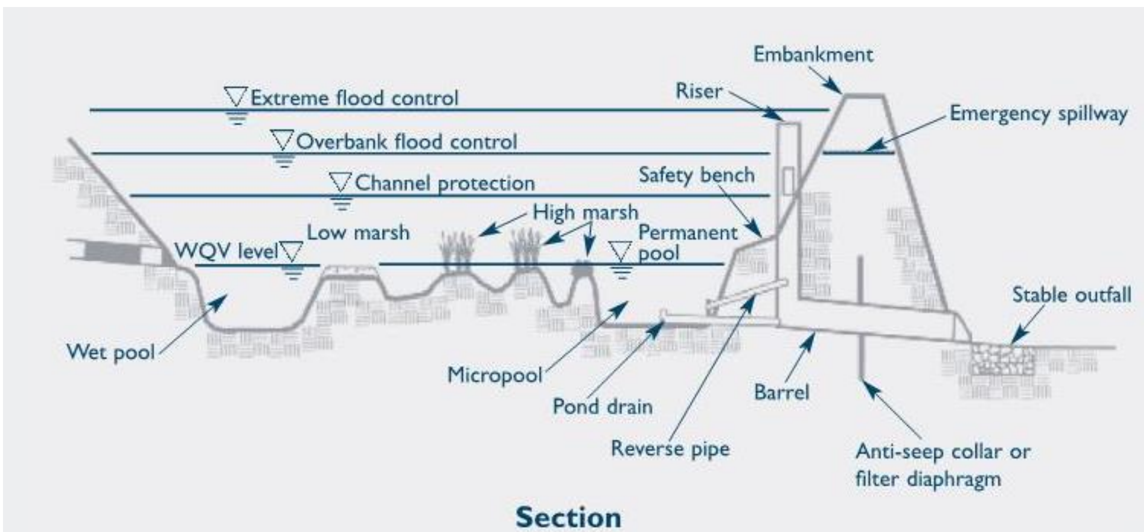



**Figure 7.11.2 – Cross Section of Pond/Wetland system (RI DEM 2010)**

Design modifications shown in Figure 7.11.2 which shall not be part of the design:
1. No pond drain valve,
2. No reverse pipe.

# 7.12 – MICROPOOL EXTENDED DETENTION POND (WQ, CPF, & FP)

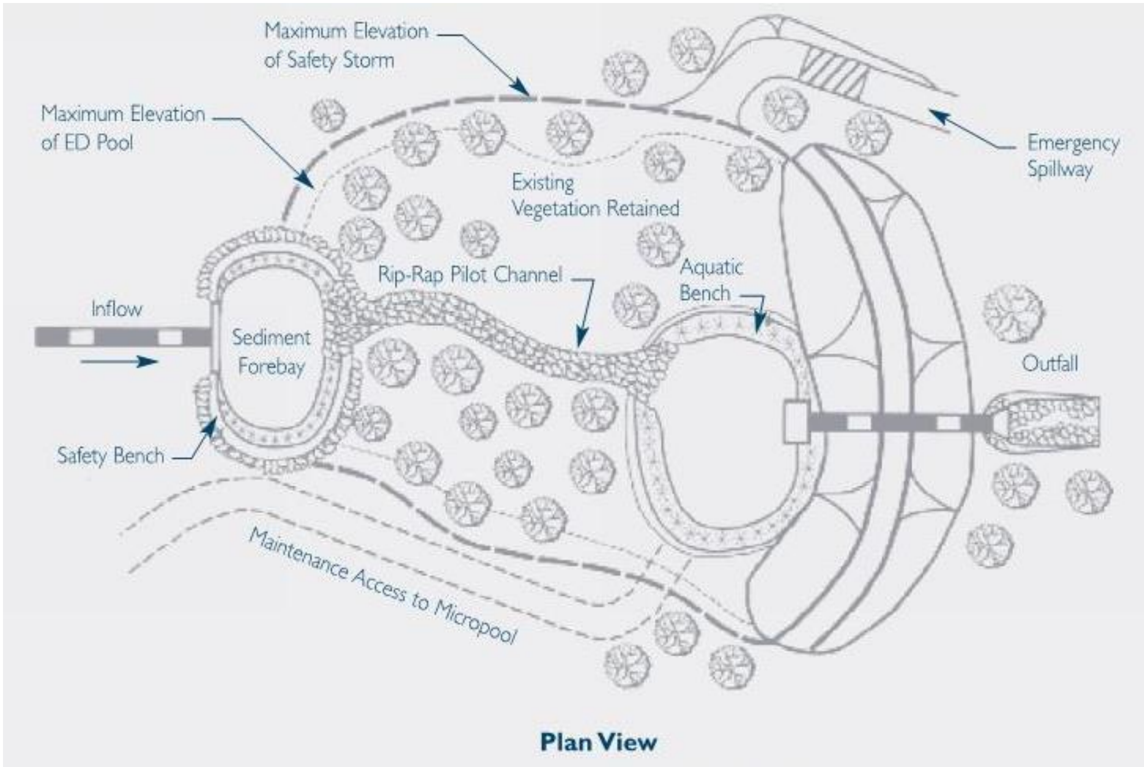



**Figure 7.12.1 – Plan View of Micropool Extended Detention Pond (CT DEEP, 2004)**

**Site Investigation:**

1. A Micropool Extended Detention Pond will have a permanent water surface in them, so it is required that that the bottom of the basin be located below the seasonal high groundwater level. A deep test pit shall be excavated within the area of the proposed location of a Micropool Extended Detention Pond to a depth three (3) feet below the anticipated bottom of the system. One (1) deep test pit shall be done for each 2,000 square feet of the area of a Micropool Extended Detention Pond.

**Design Requirements:**

1. A Micropool Extended Detention Pond is designed to provide the Channel Protection Flow Rate as well as Peak Rate Attenuation. They are not as efficient as Wet Ponds for reducing pollutant loads found in the Water Quality Storm. Runoff can be delivered to a Micropool Extended Detention Pond by either a pipe or swale,
2. A forebay designed in accordance with the specifications found in this manual must be located at the end of the pipe where runoff will enter the system. The forebay must contain a minimum of 10% of the required Water Quality Volume,
3. The elevation of the top of the permanent pool must be set at the seasonal high groundwater table,

4. The micro-pool must contain 20% of the required Water Quality Volume below the elevation of the permanent pool. The micro-pool shall be a minimum of 48” in depth and no more than 72”,
5. A hooded low flow orifice be set at the water surface of the permanent pool which will cause the full Water Quality Volume must be contained above the elevation of the permanent pool for a minimum of 48 hours after a rainfall event,
6. A low flow channel consisting of field stones or riprap shall convey runoff from the forebay to the micropool. The low flow channel shall have a minimum bottom width of 3’ and a centerline depth of 6”. The channel section shall be trapezoidal to ensure a shallow flow depth and non-erosive velocities,
7. The areas on either side of the low flow channel shall consist of wetland soils and be planted with native wetland species which can survive the inundation associated with all rainfall events,
8. The shape of a Micropool Extended Detention Pond shall be curvilinear in shape with a minimum length to width ratio of 3:1 from the inlet to the outlet,
9. The minimum surface area of a Micropool Extended Detention Pond shall be 1.0% to 1.5% of the contributing drainage area,
10. Minimum Vertical Separation to Bedrock from the bottom of the soil media shall be twenty-four (24) inches to the naturally occurring elevation of the bedrock. Blasting and removal of shallow ledge is not permitted as fissures in the rock on the side walls will be exposed to non-point source pollutants found in the runoff.
11. The berm around the Micropool Extended Detention Pond shall be 48” or less above existing grade. If the berm is higher than 48” it shall be designed as a dam to CT DEEP requirements,
12. Allowable Contributing Drainage Area (CDA) directed to a Micropool Extended Detention Pond and required (pre-treatment). All runoff flows can be directed to a Micropool Extended Detention Pond.
    a. CDA < 5,000 square feet: Not permitted as there is insufficient drainage area to maintain water surface in system,
    b. 5,000 square feet ≤ CDA ≤ 10,000 square feet: Not permitted as there is insufficient drainage area to maintain water surface in system,
    c. 10,000 square feet ≤ CDA ≤ 20,000 square feet: Not permitted as there is insufficient drainage area to maintain water surface in system,
    d. 20,000 square feet ≤ CDA ≤ 1 acre: Not permitted as there is insufficient drainage area to maintain water surface in system,
    e. 1 acre ≤ CDA ≤ 5 acres: Not permitted as there is insufficient drainage area to maintain water surface in system,
    f. 5 acres < CDA < 10 acres: Not permitted as there is insufficient drainage area to maintain water surface in system,
    g. 10 acres < CDA < 25 acres: Forebay containing a minimum of 10% of the required Water Quality Volume designed in accord with the specification found in this manual.
13. Natural Land Slope: There are no design modifications necessary for a Micropool Extended Detention Pond on slopes up to 10% other than meeting the other requirements found in this section. It is likely however that more substantial earthwork will be necessary on slopes greater than 5.0%.
14. Outflow provisions from a Micropool Extended Detention Pond can be done in one of several ways:

a. An outlet control structure shall have either weirs or orifices to control peak rate discharges with the top of the structure acting as an overflow provision for storm events up to the 100-year event.
b. An emergency spillway can be provided through the berm of the system. The spillway shall be sufficient to convey flows more than the 100-year event and be lined with an appropriate size of riprap.
c. All discharge pipes must direct flows to an existing stable watercourse system which is downgradient from the basin.
d. Discharges from the primary outlet system shall not be permitted on upland slope areas.

**Hydrologic Modeling:**

As part of the design of a Micropool Extended Detention Pond, it shall be demonstrated by hydrologic modeling using a program such as HydroCAD that the system will provide the required Channel Protection Flow Rate as well as peak rate attenuation as may be required. Volume computations must be provided to demonstrate storage capacity in Micropool Extended Detention Pond for Water Quality Volume and compliance with the specifications found in this manual.

**Construction Requirements:**

The design engineer shall develop a detailed, site specific construction sequence for a Micropool Extended Detention Pond. The design engineer shall also inspect the installation of a Micropool Extended Detention Pond during the installation process. A Micropool Extended Detention Pond shall be constructed early on during the overall construction process, so that they are fully vegetated and stabilized prior to the introduction of stormwater to them.

A typical construction sequence will follow these generalized steps:

1. The area of a Micropool Extended Detention Pond shall be fenced off with orange poly construction fence after the clearing of trees to prevent the movement of construction vehicles over the area of a Micropool Extended Detention Pond,
2. A stable benchmark shall be set by the design engineer or land surveyor for use by the contractor,
3. The outline of a Micropool Extended Detention Pond shall be staked in the field by the design engineer or contractor,
4. A Micropool Extended Detention Pond shall be excavated to the required design depth by hydraulic excavator,
5. The forebay and micro-pool shall be excavated as well as shaping the bottom of the basin for the low flow channel and adjacent wetland areas. These areas shall be over excavated by 6” to allow for the placement of 6” of wetland soil or topsoil to provide a growth media for the wetland plants,
6. The berm, outlet structure and piping as well as the emergency spillway shall be installed per the design,
7. The bottom and side slopes of the Micropool Extended Detention Pond shall be placed with appropriate plans for the hydrologic conditions. Wetland plugs shall be used for the marsh areas,
8. The side slopes above the permanent pool shall be planted with both wetland and upland species which can survive with moist soil conditions as well as temporary inundated conditions,

9. The plants above the seasonal groundwater table shall be watered as necessary to ensure their establishment.

**Inspection Requirements:**

The design engineer shall oversee the entire installation of the Micropool Extended Detention Pond at these specific steps:

1. After the excavation has been done to the bottom of the system,
2. After installation of outlet structure, piping, berm, etc.,
3. After planting of the basin and stabilization of adjacent upland areas
4. The design engineer shall prepare an as-built plan of the completed Micropool Extended Detention Pond and provide a written statement which addresses the following items:
    a. Excavation and grading of the Micropool Extended Detention Pond,
    b. Approval of outlet hydrologic control structures,
    c. Approval of plantings,
    d. Approval of completed system.

**Maintenance Requirements:**

1. Twice a year inspections of the Sediment Forebay,
2. Removal of accumulated sediment in the Forebay when the depth is greater than 24”,
3. Annual inspection of the Micropool Extended Detention Pond,
4. Removal of invasive vegetation within wetland areas as necessary,
5. Annual inspection of outlet control structures.

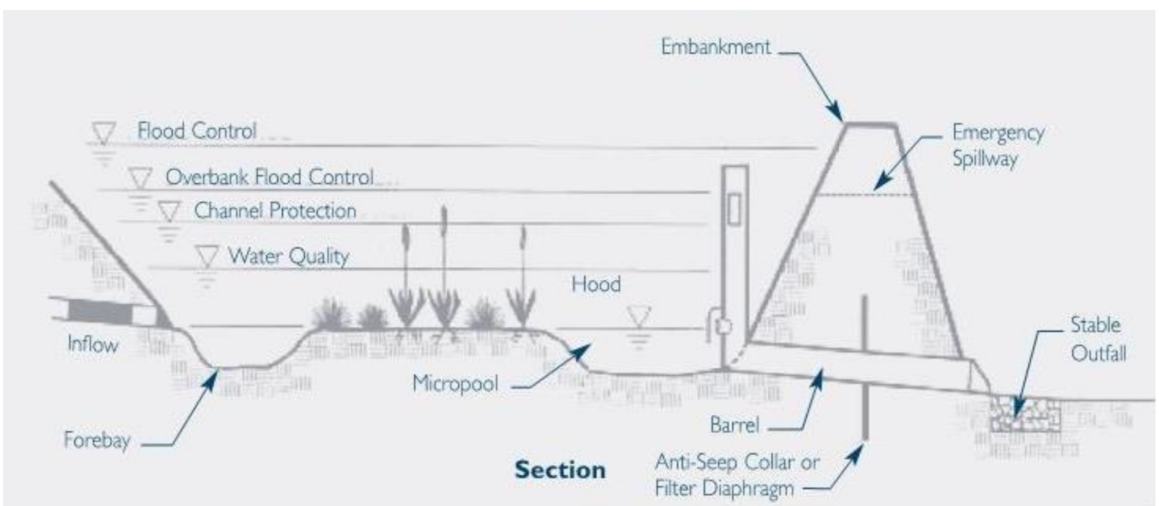



**Figure 7.12.2 – Cross Section of Micropool Extended Detention Pond (CT DEEP, 2004)**

# 7.13 WET POND/POCKET POND (WQ, CPF, & FP)

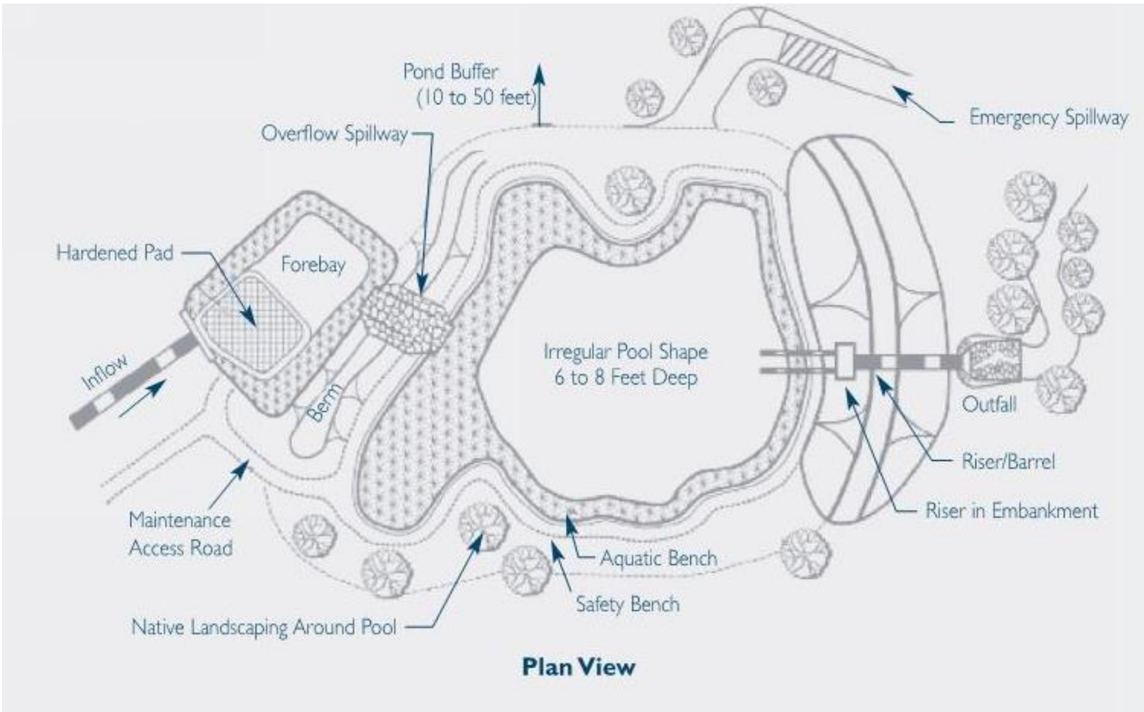



**Figure 7.13.1 – Plan View of Wet Pond (CT DEEP, 2004)**

**Site Investigation:**

1. A Wet Pond will have a permanent water surface in them, so it is required that that the bottom of the basin be located below the seasonal high groundwater level. A deep test pit shall be excavated within the area of the proposed location of a Wet Pond to a depth three (3) feet below the anticipated bottom of the system. One (1) deep test pit shall be done for each 2,000 square feet of the area of a Wet Pond.

**Design Requirements:**

1. A Wet Pond is designed to provide the Water Quality Volume, Channel Protection Flow Rate as well as Peak Rate Attenuation. Runoff can be delivered to a Wet Pond by either a pipe or swale,
2. A forebay designed in accordance with the specifications found in this manual must be located at the end of the pipe where runoff will enter the system. The forebay must contain a minimum of 10% of the required Water Quality Volume,
3. The deep pool of the Wet Pond shall be 6' – 8' in depth and the pool shall have an irregular shape,
4. An aquatic shelf shall be located outside and around the deep pool, the aquatic bench shall be 4' – 6' in width and the maximum elevation drop in the shelf shall not exceed 12",
5. The elevation of the top of the permanent pool must be set at the seasonal high groundwater table,
6. The full Water Quality Volume shall be held below the water surface of the permanent pool. The lowest outlet control weir or orifice shall be set at the top of the permanent pool.

7. The shape of a Wet Pond shall be curvilinear in shape with a minimum length to width ratio of 3:1 from the inlet to the outlet,
8. The minimum surface area of a Wet Pond shall be 1.0% to 1.5% of the contributing drainage area,
9. Minimum Vertical Separation to Bedrock from the bottom of the soil media shall be twenty-four (24) inches to the naturally occurring elevation of the bedrock. Blasting and removal of shallow ledge is not permitted as fissures in the rock on the side walls will be exposed to non-point source pollutants found in the runoff.
10. The berm around the Wet Pond shall be 48" or less above existing grade. If the berm is higher than 48" it shall be designed as a dam to CT DEEP requirements,
11. Allowable Contributing Drainage Area (CDA) directed to a Wet Pond and required (pre-treatment). All runoff flows can be directed to a Wet Pond.
    a. CDA < 5,000 square feet: Not permitted as there is insufficient drainage area to maintain water surface in system,
    b. 5,000 square feet ≤ CDA ≤ 10,000 square feet: Not permitted as there is insufficient drainage area to maintain water surface in system,
    c. 10,000 square feet ≤ CDA ≤ 20,000 square feet: Not permitted as there is insufficient drainage area to maintain water surface in system,
    d. 20,000 square feet ≤ CDA ≤ 1 acre: Not permitted as there is insufficient drainage area to maintain water surface in system,
    e. 1 acre ≤ CDA ≤ 5 acres: Not permitted as there is insufficient drainage area to maintain water surface in system,
    f. 5 acres < CDA < 10 acres: Forebay containing a minimum of 10% of the required Water Quality Volume designed in accord with the specification found in this manual,
    g. 10 acres < CDA < 25 acres: Forebay containing a minimum of 10% of the required Water Quality Volume designed in accord with the specification found in this manual.
12. Natural Land Slope: There are no design modifications necessary for a Wet Pond on slopes up to 10% other than meeting the other requirements found in this section. It is likely however that more substantial earthwork will be necessary on slopes greater than 5.0%.
13. Outflow provisions from a Wet Pond can be done in one of several ways:
    a. An outlet control structure shall have either weirs or orifices to control peak rate discharges with the top of the structure acting as an overflow provision for storm events up to the 100-year event.
    b. An emergency spillway can be provided through the berm of the system. The spillway shall be sufficient to convey flows more than the 100-year event and be lined with an appropriate size of riprap.
    c. All discharge pipes must direct flows to an existing stable watercourse system which is downgradient from the basin.
    d. Discharges from the primary outlet system shall not be permitted on upland slope areas.

**Hydrologic Modeling:**

As part of the design of a Wet Pond, it shall be demonstrated by hydrologic modeling using a program such as HydroCAD that the system will provide the required Channel Protection Flow Rate as well as peak rate attenuation as may be required. Volume computations must be provided to demonstrate storage capacity Wet Pond for Water Quality Volume and compliance with the specifications found in this manual.

**Construction Requirements:**

The design engineer shall develop a detailed, site specific construction sequence for a Wet Pond. The design engineer shall also inspect the installation of a Wet Pond during the installation process. A Wet Pond shall be constructed early on during the overall construction process, so that they are fully vegetated and stabilized prior to the introduction of stormwater to them.

A typical construction sequence will follow these generalized steps:

1. The area of a Wet Pond shall be fenced off with orange poly construction fence after the clearing of trees to prevent the movement of construction vehicles over the area of a Wet Pond,
2. A stable benchmark shall be set by the design engineer or land surveyor for use by the contractor,
3. The outline of a Wet Pond shall be staked in the field by the design engineer or contractor,
4. The forebay and permanent pool of a Wet Pond shall be excavated to the required design depth by hydraulic excavator,
5. The aquatic shelf shall be shaped at this time. The shelf shall be over excavated by 6" to allow for the placement of 6" of wetland soil or topsoil to provide a growth media for the wetland plants,
6. The berm, outlet structure and piping as well as the emergency spillway shall be installed per the design,
7. The bottom and side slopes of the Wet Pond shall be placed with appropriate plans for the hydrologic conditions. Wetland plugs shall be used for the marsh areas,
8. The side slopes above the permanent pool shall be planted with both wetland and upland species which can survive with moist soil conditions as well as temporary inundated conditions,
9. The plants above the seasonal groundwater table shall be watered as necessary to ensure their establishment.

**Inspection Requirements:**

The design engineer shall oversee the entire installation of the Wet Pond at these specific steps:

1. After the excavation has been done to the bottom of the system,
2. After installation of outlet structure, piping, berm, etc.,
3. After planting of the basin and stabilization of adjacent upland areas
4. The design engineer shall prepare an as-built plan of the completed Wet Pond and provide a written statement which addresses the following items:
    a. Excavation and grading of the Wet Pond,
    b. Approval of outlet hydrologic control structures,
    c. Approval of plantings,
    d. Approval of completed system.

**Maintenance Requirements:**

1. Twice a year inspections of the Sediment Forebay,
2. Removal of accumulated sediment in the Forebay when the depth is greater than 24",
3. Annual inspection of the Wet Pond,

4. Removal of invasive vegetation within wetland areas as necessary,
5. Annual inspection of outlet control structures.

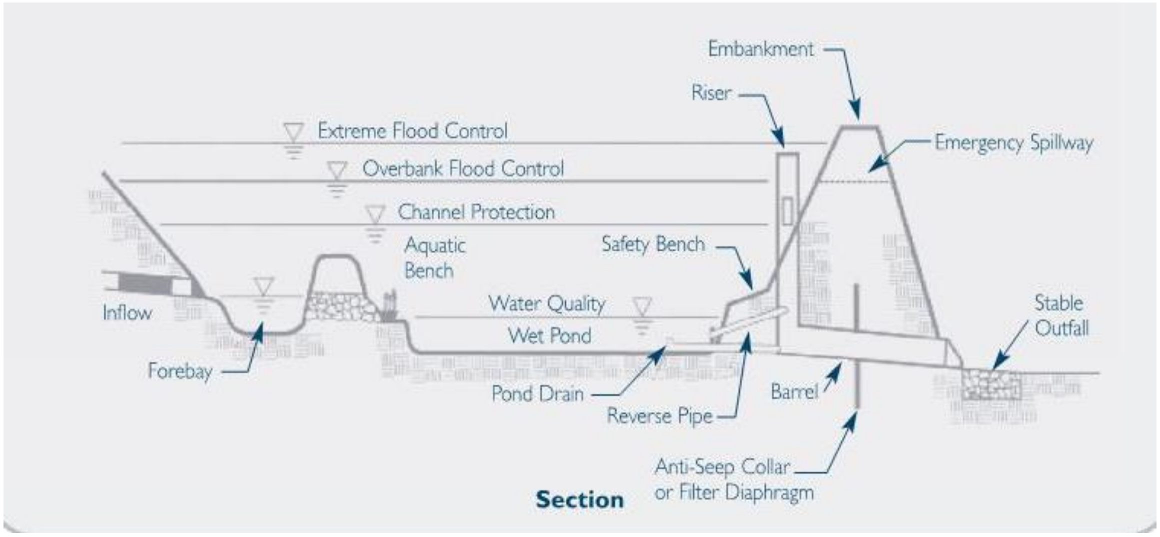



**Figure 7.13.2 – Cross Section of Wet Pond (CT DEEP, 2004)**

Design modifications shown in Figure 7.13.2 which shall not be part of the design:

1. No pond drain valve,
2. No reverse pipe.

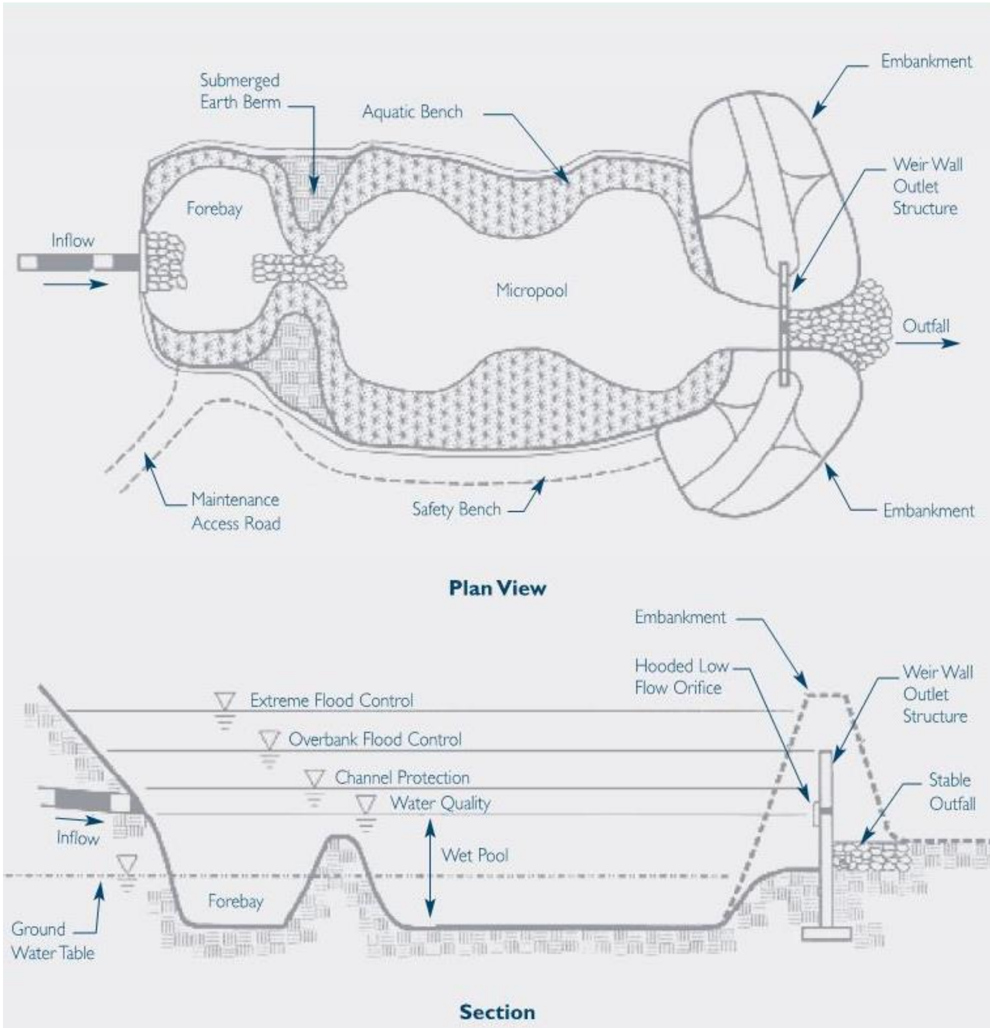



**Figure 7.13.3 - Plan & Cross Section of Pocket Pond (CT DEEP, 2004)**

# 7.14 SHALLOW WETLAND SYSTEM (WQ)

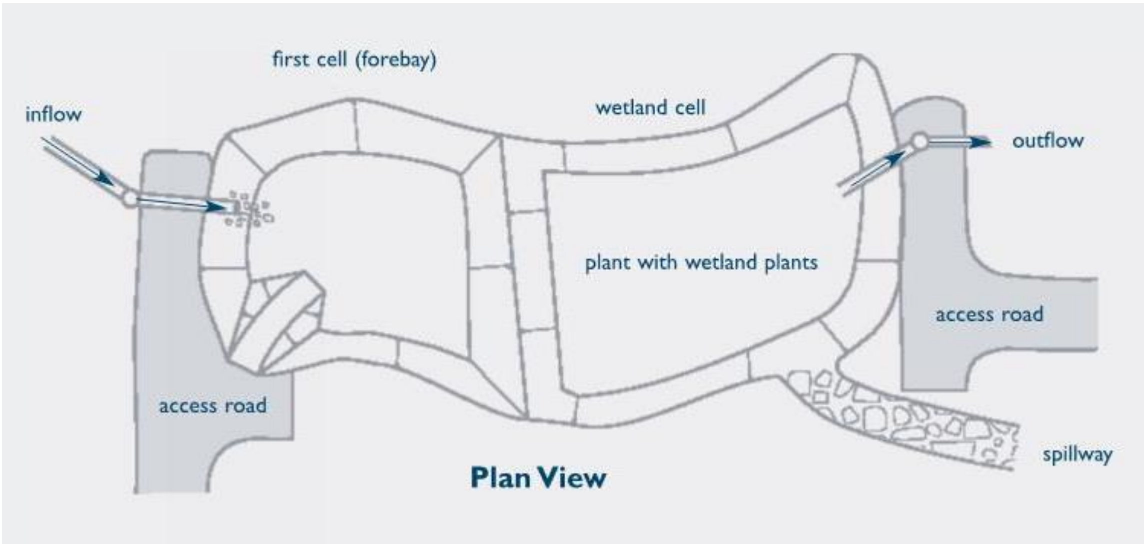



**Figure 7.14.1 - Plan View of Shallow Wetland System (CT DEEP, 2004)**

**Site Investigation:**

1. A Shallow Wetland will have a permanent water surface in them, so it is required that that the bottom of the basin be located below the seasonal high groundwater level. A deep test pit shall be excavated within the area of the proposed location of a Shallow Wetland to a depth three (3) feet below the anticipated bottom of the system. One (1) deep test pit shall be done for each 2,000 square feet of the area of a Shallow Wetland.

**Design Requirements:**

1. A Shallow Wetland is designed to address water quality only. Runoff can be delivered to a Shallow Wetland by either a pipe or swale, with a bypass for all rainfall events greater than the water quality storm,
2. A forebay (shown as first cell in Figure 7.14.1) designed in accordance with the specifications found in this manual must be located at the end of the pipe where runoff will enter the system. The forebay must contain a minimum of 10% of the required Water Quality Volume,
3. The wetland cell shall contain the full Water Quality Volume below the lowest outlet control weir or orifice,
4. There can be more than one wetland cell for water quality treatment,
5. The depth of the wetland cell shall vary from 6” to 18”, but shall not exceed 18”,
6. The elevation of the top of the permanent pool associated with the Water Quality Volume must be set at the seasonal high groundwater table,
7. The full Water Quality Volume shall be held below the water surface of the permanent pool. The lowest outlet control weir or orifice shall be set at the top of the permanent pool.
8. The shape of a Shallow Wetland shall be curvilinear in shape with a minimum length to width ratio of 3:1 from the inlet to the outlet,

9. Minimum Vertical Separation to Bedrock from the bottom of the soil media shall be twenty-four (24) inches to the naturally occurring elevation of the bedrock. Blasting and removal of shallow ledge is not permitted as fissures in the rock on the side walls will be exposed to non-point source pollutants found in the runoff.
10. The berm around the Wet Pond shall be 48" or less above existing grade. If the berm is higher than 48" it shall be designed as a dam to CT DEEP requirements,
11. Allowable Contributing Drainage Area (CDA) directed to a Shallow Wetland and required (pre-treatment). Only the flows associated with the water quality storm are to be directed to a Shallow Wetland.
    a. CDA < 5,000 square feet: Not permitted as there is insufficient drainage area to maintain water surface in system,
    b. 5,000 square feet $\leq$ CDA $\leq$ 10,000 square feet: Not permitted as there is insufficient drainage area to maintain water surface in system,
    c. 10,000 square feet $\leq$ CDA $\leq$ 20,000 square feet: Not permitted as there is insufficient drainage area to maintain water surface in system,
    d. 20,000 square feet $\leq$ CDA $\leq$ 1 acre: Not permitted as there is insufficient drainage area to maintain water surface in system,
    e. 1 acre $\leq$ CDA $\leq$ 5 acres: Forebay containing a minimum of 10% of the required Water Quality Volume designed in accord with the specification found in this manual,
    f. 5 acres < CDA < 10 acres: Forebay containing a minimum of 10% of the required Water Quality Volume designed in accord with the specification found in this manual,
    g. 10 acres < CDA < 25 acres: Forebay containing a minimum of 10% of the required Water Quality Volume designed in accord with the specification found in this manual.
12. Natural Land Slope: There are no design modifications necessary for a Shallow Wetland on slopes up to 10% other than meeting the other requirements found in this section. It is likely however that more substantial earthwork will be necessary on slopes greater than 5.0%.
13. Outflow provisions from a Shallow Wetland can be done in one of several ways:
    a. An outlet control structure shall have either weirs or orifices to water surface associated with the water quality storm,
    b. An emergency spillway shall also be provided through the berm of the system. The spillway shall be sufficient to convey flows in the event, the primary outlet structure gets clogged,
    c. All discharge pipes must direct flows to an existing stable watercourse system which is downgradient from the basin. ,
    d. Discharges from the primary outlet system shall not be permitted on upland slope areas.

**Hydrologic Modeling:**

As part of the design of a Shallow Wetland, it shall be demonstrated by hydrologic modeling using a program such as HydroCAD that the system will fully contain the required Water Quality Volume and bypass larger rainfall events. Volume computations must be provided to demonstrate storage capacity Shallow Wetland for Water Quality Volume and compliance with the specifications found in this manual.

**Construction Requirements:**

The design engineer shall develop a detailed, site specific construction sequence for a Shallow Wetland. The design engineer shall also inspect the installation of a Shallow Wetland during the installation process. A Shallow Wetland shall be constructed early on during the overall construction process, so that they are fully vegetated and stabilized prior to the introduction of stormwater to them.

A typical construction sequence will follow these generalized steps:

1. The area of a Shallow Wetland shall be fenced off with orange poly construction fence after the clearing of trees to prevent the movement of construction vehicles over the area of a Shallow Wetland,
2. A stable benchmark shall be set by the design engineer or land surveyor for use by the contractor,
3. The outline of a Shallow Wetland shall be staked in the field by the design engineer or contractor,
4. The forebay and one or more cells in a Shallow Wetland shall be excavated to the required design depth by hydraulic excavator,
5. The wetland cells shall be graded per the design. The cell(s) shall be over excavated by 6” to allow for the placement of 6” of wetland soil or topsoil to provide a growth media for the wetland plants,
6. The berm, outlet structure and piping as well as the emergency spillway shall be installed per the design,
7. The bottom and side slopes of the Shallow Wetland shall be placed with appropriate plans for the hydrologic conditions. Wetland plugs shall be used for the marsh areas,
8. The side slopes above the permanent pool shall be planted with both wetland and upland species which can survive with moist soil conditions as well as temporary inundated conditions,
9. The plants above the seasonal groundwater table shall be watered as necessary to ensure their establishment.

**Inspection Requirements:**

The design engineer shall oversee the entire installation of the Shallow Wetland at these specific steps:

1. After the excavation has been done to the bottom of the system,
2. After installation of outlet structure, piping, berm, etc.,
3. After planting of the basin and stabilization of adjacent upland areas
4. The design engineer shall prepare an as-built plan of the completed Wet Pond and provide a written statement which addresses the following items:
    a. Excavation and grading of the Shallow Wetland,
    b. Approval of outlet hydrologic control structures,
    c. Approval of plantings,
    d. Approval of completed system.

**Maintenance Requirements:**

1. Twice a year inspections of the Sediment Forebay,
2. Removal of accumulated sediment in the Forebay when the depth is greater than 24”,
3. Annual inspection of the Shallow Wetland,

4. Removal of invasive vegetation within wetland areas as necessary,
5. Annual inspection of outlet control structures.

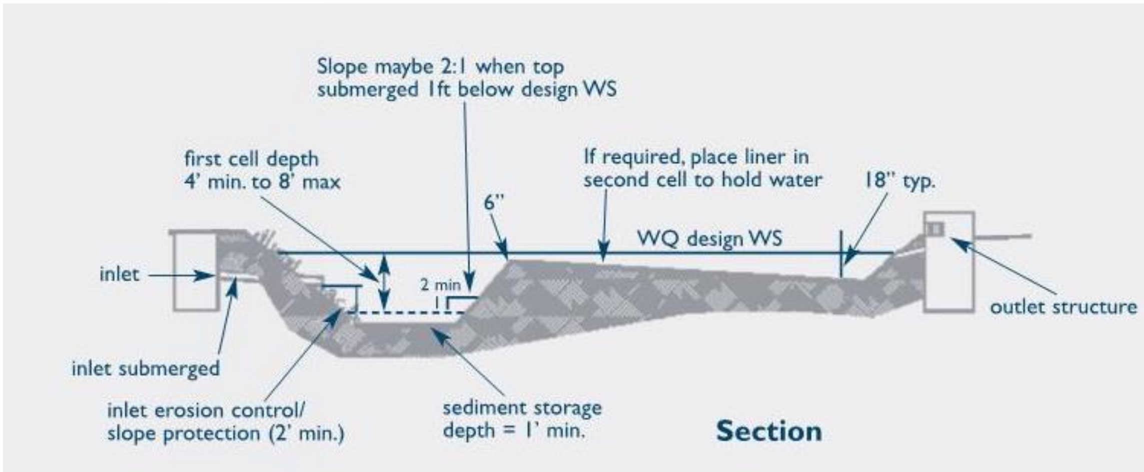



**Figure 7.14.2 - Cross Section of Shallow Wetland System (CT DEEP, 2004)**

# 7.15 WET EXTENDED DETENTION POND (CPF, & FP)

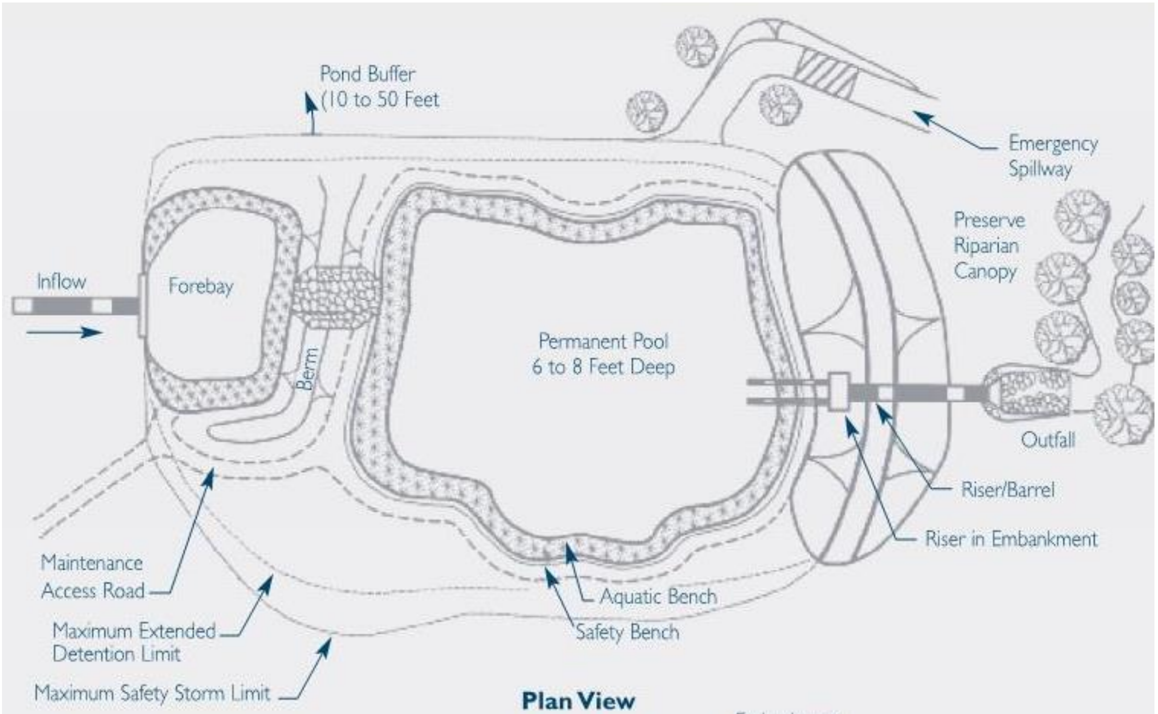



**Figure 7.15.1 - Plan View of Wet Extended Detention Pond (CT DEEP, 2004)**

**Site Investigation:**

1. A Wet Extended Detention Pond is like Wet Ponds in that the primary function of this system is peak rate attenuation and not water quality improvement. A Wet Extended Detention Pond will have a permanent water surface in them, so it is required that that the bottom of the basin be located below the seasonal high groundwater level. A deep test pit shall be excavated within the area of the proposed location of a Wet Pond to a depth three (3) feet below the anticipated bottom of the system. One (1) deep test pit shall be done for each 2,000 square feet of the area of a Wet Extended Detention Pond.

**Design Requirements:**

1. While the primary function of a Wet Extended Detention Pond is designed to provide the Channel Protection Flow as well as Peak Rate Attenuation, the permanent pool must contain 50% of the required Water Quality Volume with the extended detention storage providing the other 50% of the required Water Quality Volume. Runoff can be delivered to a Wet Extended Detention Pond by either a pipe or swale,
2. A forebay designed in accordance with the specifications found in this manual must be located at the end of the pipe where runoff will enter the system. The forebay must contain a minimum of 10% of the required Water Quality Volume,
3. The permanent pool of the Wet Extended Detention Pond shall be 6' – 8' in depth and the pool shall have an irregular shape,
4. An aquatic shelf shall be located outside and around the deep pool, the aquatic bench shall be 4' – 6' in width and the maximum elevation drop in the shelf shall not exceed 12",

5. The elevation of the top of the permanent pool must be set at the seasonal high groundwater table,
6. The lowest outlet control weir or orifice shall be set at the top of the permanent pool.
7. The shape of a Wet Extended Detention Pond shall be curvilinear in shape with a minimum length to width ratio of 3:1 from the inlet to the outlet,
8. The minimum surface area of a Wet Extended Detention Pond shall be 1.0% to 1.5% of the contributing drainage area,
9. Minimum Vertical Separation to Bedrock from the bottom of the soil media shall be twenty-four (24) inches to the naturally occurring elevation of the bedrock. Blasting and removal of shallow ledge is not permitted as fissures in the rock on the side walls will be exposed to non-point source pollutants found in the runoff.
10. The berm around the Wet Extended Detention Pond shall be 48" or less above existing grade. If the berm is higher than 48" it shall be designed as a dam to CT DEEP requirements,
11. Allowable Contributing Drainage Area (CDA) directed to a Wet Extended Detention Pond and required (pre-treatment). All runoff flows can be directed to a Wet Extended Detention Pond.
    a. CDA < 5,000 square feet: Not permitted as there is insufficient drainage area to maintain water surface in system,
    b. 5,000 square feet ≤ CDA ≤ 10,000 square feet: Not permitted as there is insufficient drainage area to maintain water surface in system,
    c. 10,000 square feet ≤ CDA ≤ 20,000 square feet: Not permitted as there is insufficient drainage area to maintain water surface in system,
    d. 20,000 square feet ≤ CDA ≤ 1 acre: Not permitted as there is insufficient drainage area to maintain water surface in system,
    e. 1 acre ≤ CDA ≤ 5 acres: Not permitted as there is insufficient drainage area to maintain water surface in system,
    f. 5 acres < CDA < 10 acres: Forebay containing a minimum of 10% of the required Water Quality Volume designed in accord with the specification found in this manual,
    g. 10 acres < CDA < 25 acres: Forebay containing a minimum of 10% of the required Water Quality Volume designed in accord with the specification found in this manual.
12. Natural Land Slope: There are no design modifications necessary for a Wet Extended Detention Pond on slopes up to 10% other than meeting the other requirements found in this section. It is likely however that more substantial earthwork will be necessary on slopes greater than 5.0%.
13. Outflow provisions from a Wet Extended Detention Pond can be done in one of several ways:
    a. An outlet control structure shall have either weirs or orifices to control peak rate discharges with the top of the structure acting as an overflow provision for storm events up to the 100-year event.
    b. An emergency spillway can be provided through the berm of the system. The spillway shall be sufficient to convey flows more than the 100-year event and be lined with an appropriate size of riprap.
    c. All discharge pipes must direct flows to an existing stable watercourse system which is downgradient from the basin.
    d. Discharges from the primary outlet system shall not be permitted on upland slope areas.

**Hydrologic Modeling:**

As part of the design of a Wet Extended Detention Pond, it shall be demonstrated by hydrologic modeling using a program such as HydroCAD that the system will provide the required Channel Protection Flow Rate as well as peak rate attenuation as may be required. Volume computations must be provided to demonstrate storage capacity Wet Extended Detention Pond for Water Quality Volume and compliance with the specifications found in this manual.

**Construction Requirements:**

The design engineer shall develop a detailed, site specific construction sequence for a Wet Extended Detention Pond. The design engineer shall also inspect the installation of a Wet Extended Detention Pond during the installation process. A Wet Extended Detention Pond shall be constructed early on during the overall construction process, so that they are fully vegetated and stabilized prior to the introduction of stormwater to them.

A typical construction sequence will follow these generalized steps:

1. The area of a Wet Extended Detention Pond shall be fenced off with orange poly construction fence after the clearing of trees to prevent the movement of construction vehicles over the area of a Wet Pond,
2. A stable benchmark shall be set by the design engineer or land surveyor for use by the contractor,
3. The outline of a Wet Extended Detention Pond shall be staked in the field by the design engineer or contractor,
4. The forebay and permanent pool of a Wet Extended Detention Pond shall be excavated to the required design depth by hydraulic excavator,
5. The aquatic shelf shall be shaped at this time. The shelf shall be over excavated by 6” to allow for the placement of 6” of wetland soil or topsoil to provide a growth media for the wetland plants,
6. The berm, outlet structure and piping as well as the emergency spillway shall be installed per the design,
7. The bottom and side slopes of the Wet Extended Detention Pond shall be placed with appropriate plans for the hydrologic conditions. Wetland plugs shall be used for the marsh areas,
8. The side slopes above the permanent pool shall be planted with both wetland and upland species which can survive with moist soil conditions as well as temporary inundated conditions,
9. The plants above the seasonal groundwater table shall be watered as necessary to ensure their establishment.

**Inspection Requirements:**

The design engineer shall oversee the entire installation of the Wet Extended Detention Pond at these specific steps:

1. After the excavation has been done to the bottom of the system,
2. After installation of outlet structure, piping, berm, etc.,
3. After planting of the basin and stabilization of adjacent upland areas
4. The design engineer shall prepare an as-built plan of the completed Wet Extended Detention Pond and provide a written statement which addresses the following items:
    a. Excavation and grading of the Wet Extended Detention Pond,

b. Approval of outlet hydrologic control structures,
c. Approval of plantings,
d. Approval of completed system.

**Maintenance Requirements:**

1. Twice a year inspections of the Sediment Forebay,
2. Removal of accumulated sediment in the Forebay when the depth is greater than 24”,
3. Annual inspection of the Wet Extended Detention Pond,
4. Removal of invasive vegetation within wetland areas as necessary,
5. Annual inspection of outlet control structures.

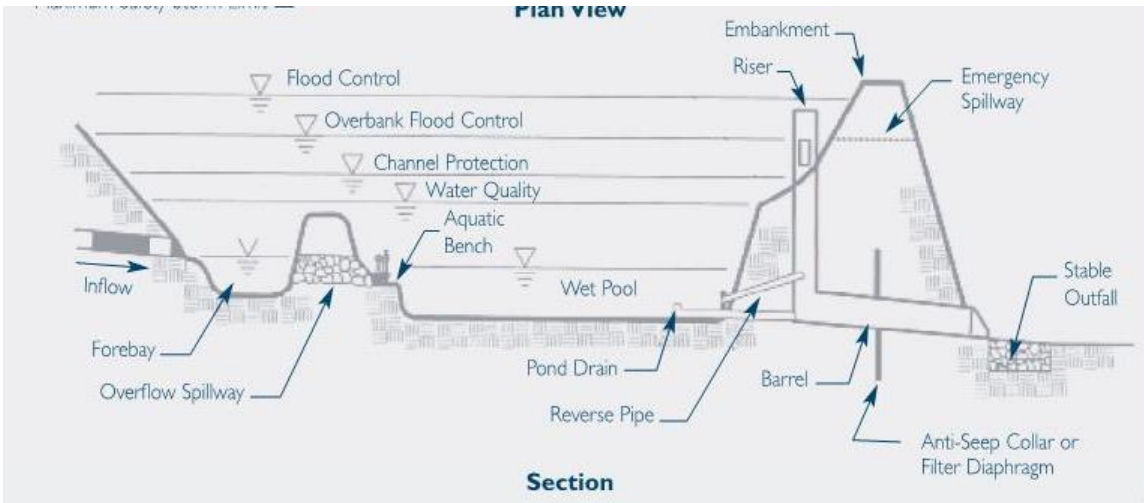



**Figure 7.15.2 - Cross Section of Wet Extended Detention Pond (CT DEEP, 2004)**

Design modifications shown in Figure 7.15.2 which shall not be part of the design:

1. No pond drain valve,
2. No reverse pipe.

# 7.16 MULTIPLE POND SYSTEM (WQ, CPF, & FP)

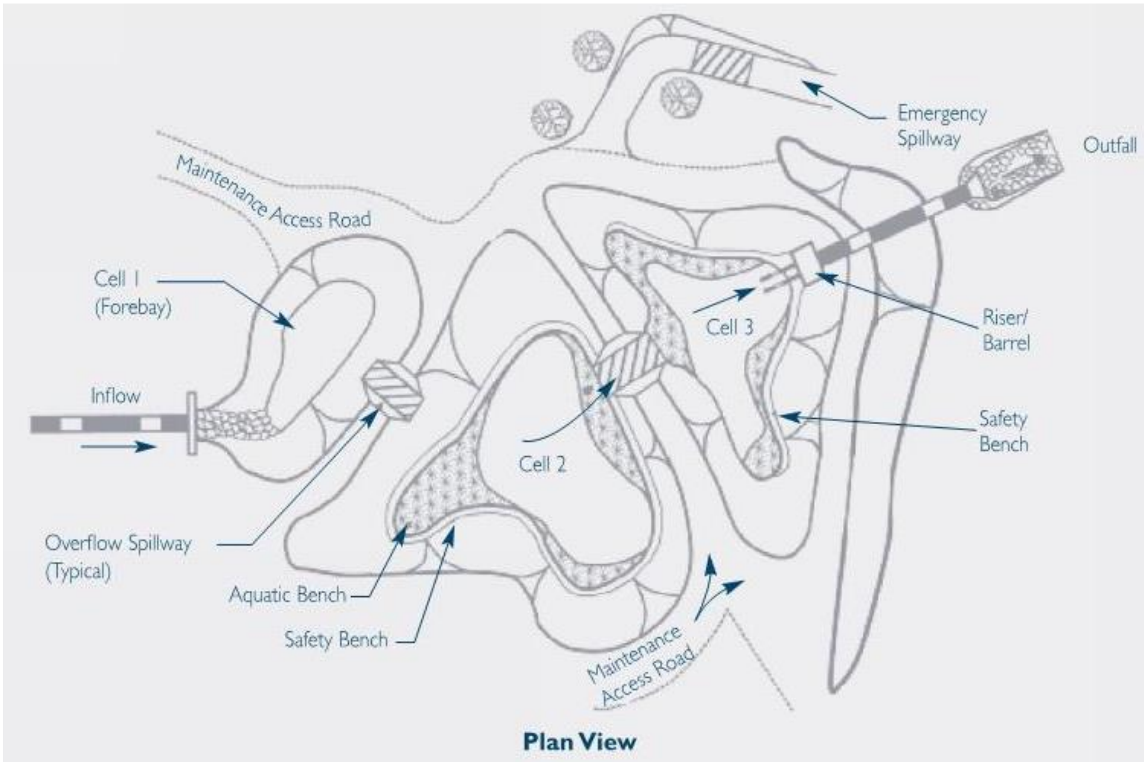



**Figure 7.16.1 - Plan View of Multiple Pond System (CT DEEP, 2004)**

**Site Investigation:**

1. A Multiple Pond System consists of is like Wet Ponds in that the primary function of this system is peak rate attenuation and not water quality improvement. A Multiple Pond System will have three cells, the first of which is a forebay. There are two other cells. All three of the cells will have a permanent water surface in them, so it is required that that the bottom of the basin be located below the seasonal high groundwater level. A deep test pit shall be excavated within the area of the proposed location of a Wet Pond to a depth three (3) feet below the anticipated bottom of the system. One (1) deep test pit shall be done for each 2,000 square feet of the area of a Multiple Pond System.

**Design Requirements:**

1. While the primary function of a Multiple Pond System is designed to provide the Channel Protection Flow as well as Peak Rate Attenuation, the two cells after the forebay must each contain 50% of the required Water Quality Volume. The two cells will each step down from the forebay as shown in Figure 7.16.2. Runoff can be delivered to a Multiple Pond System by either a pipe or swale,
2. A forebay designed in accordance with the specifications found in this manual must be located at the end of the pipe where runoff will enter the system. The forebay must contain a minimum of 10% of the required Water Quality Volume,

3. The permanent pool of each cell of a Multiple Pond System shall be 2'- 3' in depth and the pool shall have an irregular shape,
4. An aquatic shelf shall be located outside and around the deep pool, the aquatic bench shall be 2'-4' in width and the maximum elevation drop in the shelf shall not exceed 12",
5. The elevation of the top of the permanent pool must be set at the seasonal high groundwater table,
6. The lowest outlet control weir or orifice shall be set at the top of the permanent pool of the last cell.
7. The shape of a Multiple Pond System shall be curvilinear in shape with a minimum length to width ratio of 3:1 from the inlet to the outlet,
8. Riprap swales shall connect the forebay to the first cell and then to the second cell. The swales shall have a minimum bottom width of 3'and shall have a centerline depth of 12"with 2:1 side slope,
9. The minimum surface area of a Multiple Pond System shall be 1.0% to 1.5% of the contributing drainage area,
10. Minimum Vertical Separation to Bedrock from the bottom of the soil media shall be twenty-four (24) inches to the naturally occurring elevation of the bedrock. Blasting and removal of shallow ledge is not permitted as fissures in the rock on the side walls will be exposed to non-point source pollutants found in the runoff.
11. The berm around the Multiple Pond System shall be 48" or less above existing grade. If the berm is higher than 48" it shall be designed as a dam to CT DEEP requirements,
12. Allowable Contributing Drainage Area (CDA) directed to a Multiple Pond System and required (pre-treatment). All runoff flows can be directed to a Multiple Pond System.
    a. CDA < 5,000 square feet: Not permitted as there is insufficient drainage area to maintain water surface in system,
    b. 5,000 square feet ≤ CDA ≤ 10,000 square feet: Not permitted as there is insufficient drainage area to maintain water surface in system,
    c. 10,000 square feet ≤ CDA ≤ 20,000 square feet: Not permitted as there is insufficient drainage area to maintain water surface in system,
    d. 20,000 square feet ≤ CDA ≤ 1 acre: Not permitted as there is insufficient drainage area to maintain water surface in system,
    e. 1 acre ≤ CDA ≤ 5 acres: Not permitted as there is insufficient drainage area to maintain water surface in system,
    f. 5 acres < CDA < 10 acres: Forebay containing a minimum of 10% of the required Water Quality Volume designed in accord with the specification found in this manual,
    g. 10 acres < CDA < 25 acres: Forebay containing a minimum of 10% of the required Water Quality Volume designed in accord with the specification found in this manual.
13. Natural Land Slope: There are no design modifications necessary for a Multiple Pond System on slopes up to 10% other than meeting the other requirements found in this section. It is likely however that more substantial earthwork will be necessary on slopes greater than 5.0%.
14. Outflow provisions from a Multiple Pond System can be done in one of several ways:
    a. An outlet control structure shall have either weirs or orifices to control peak rate discharges with the top of the structure acting as an overflow provision for storm events up to the 100-year event.

b. An emergency spillway can be provided through the berm of the system. The spillway shall be sufficient to convey flows more than the 100-year event and be lined with an appropriate size of riprap.
c. All discharge pipes must direct flows to an existing stable watercourse system which is downgradient from the basin.
d. Discharges from the primary outlet system shall not be permitted on upland slope areas.

**Hydrologic Modeling:**

As part of the design of a Multiple Pond System, it shall be demonstrated by hydrologic modeling using a program such as HydroCAD that the system will provide the required Channel Protection Flow Rate as well as peak rate attenuation as may be required. Volume computations must be provided to demonstrate storage capacity Multiple Pond System for Water Quality Volume and compliance with the specifications found in this manual.

**Construction Requirements:**

The design engineer shall develop a detailed, site specific construction sequence for a Multiple Pond System. The design engineer shall also inspect the installation of a Wet Extended Detention Pond during the installation process. A Multiple Pond System shall be constructed early on during the overall construction process, so that they are fully vegetated and stabilized prior to the introduction of stormwater to them.

A typical construction sequence will follow these generalized steps:

1. The area of a Multiple Pond System shall be fenced off with orange poly construction fence after the clearing of trees to prevent the movement of construction vehicles over the area of a Multiple Pond System,
2. A stable benchmark shall be set by the design engineer or land surveyor for use by the contractor,
3. The outline of a Multiple Pond System shall be staked in the field by the design engineer or contractor,
4. The forebay and permanent cells of a Multiple Pond System shall be excavated to the required design depth by hydraulic excavator,
5. The aquatic shelf shall be shaped at this time. The shelf shall be over excavated by 6" to allow for the placement of 6" of wetland soil or topsoil to provide a growth media for the wetland plants,
6. The berm, outlet structure and piping as well as the emergency spillway shall be installed per the design,
7. The bottom and side slopes of the Multiple Pond System shall be placed with appropriate plans for the hydrologic conditions. Wetland plugs shall be used for the marsh areas,
8. The side slopes above the permanent pool shall be planted with both wetland and upland species which can survive with moist soil conditions as well as temporary inundated conditions,
9. The plants above the seasonal groundwater table shall be watered as necessary to ensure their establishment.

**Inspection Requirements:**

The design engineer shall oversee the entire installation of the Multiple Pond System at these specific steps:

1. After the excavation has been done to the bottom of the system,
2. After installation of outlet structure, piping, berm, etc.,
3. After planting of the basin and stabilization of adjacent upland areas
4. The design engineer shall prepare an as-built plan of the completed Multiple Pond System and provide a written statement which addresses the following items:
    a. Excavation and grading of the Multiple Pond System,
    b. Approval of outlet hydrologic control structures,
    c. Approval of plantings,
    d. Approval of completed system.

**Maintenance Requirements:**

1. Twice a year inspections of the Sediment Forebay,
2. Removal of accumulated sediment in the Forebay when the depth is greater than 24",
3. Annual inspection of the Multiple Pond System,
4. Removal of invasive vegetation within wetland areas as necessary,
5. Annual inspection of outlet control structures.

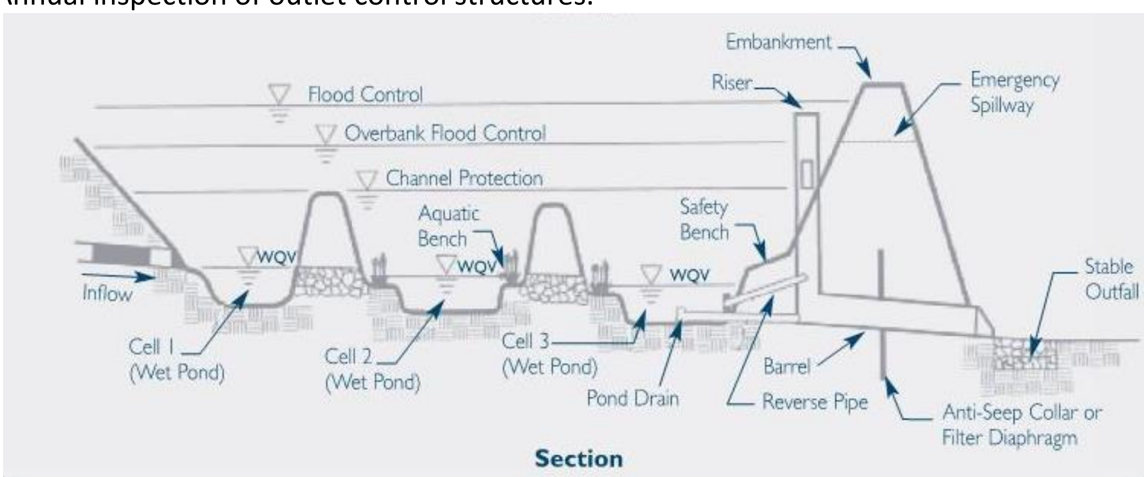



**Figure 7.16.2 - Cross Section of Multiple Pond System**

Design modifications shown in Figure 7.15.2 which shall not be part of the design:

1. No pond drain valve,
2. No reverse pipe.

# 7.17 WET SWALE (WQ TREATMENT)

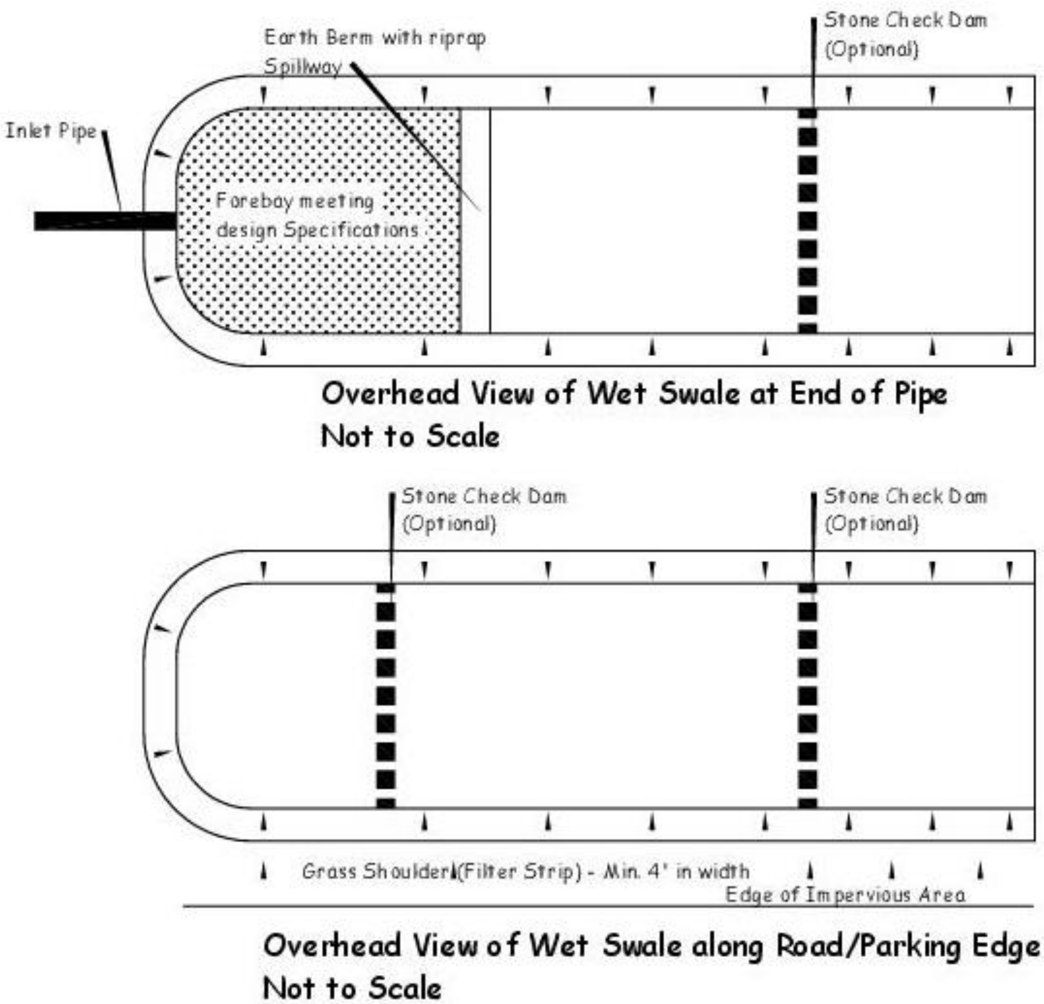



**Figure 7.17.1 - Overhead view of Wet Swale (Trinkaus Engineering, LLC - 2017)**

**Site Investigation:**

1. A deep test pit shall be excavated for every 100 linear feet along the proposed location of a wet Swale to a depth three (3) feet below the anticipated bottom of the Wet Swale to verify the depth of seasonal high groundwater in the Wet Swale location.

**Design Requirements:**

1. Wet Swales can be designed as online systems, where runoff is directed to the Wet Swale via a structural drainage system or as an offline system, where runoff enters the Wet Swale as overland flow from an impervious area, such as a parking lot or edge of road. If runoff is to be delivered by a drainage pipe, then a forebay, meeting the requirements of this manual shall be installed at the end of the pipe.

2. Depth of wetland soil media shall be 12" for residential and commercial applications.
3. Surface of Wet Swale to be set at or below the observed seasonal high groundwater level.
4. Minimum Vertical Separation to Bedrock from the bottom of the wetland soil shall be twenty-four (24) inches.
5. Sizing of the surface area of the Wet Swale:
   Minimum Bottom Width = 3'
   Maximum Bottom Width = 8'
   Minimum Side Slopes = 3:1
   Must convey runoff from both 2-year and 10-year rainfall event with a minimum of 6" of freeboard to top of swale
6. Allowable Contributing Drainage Area (CDA) directed to Wet Swale when located at end of pipe and required (pre-treatment). Runoff from all storm events is directed to Wet Swale:
   a. CDA < 5,000 square feet: (Riprap pad at end of pipe to reduce flow velocities to 3 fps),
   b. 5,000 square feet ≤ CDA ≤ 10,000 square feet: (Riprap pad at end of pipe to reduce flow velocities to 3 fps),
   c. 10,000 square feet ≤ CDA ≤ 20,000 square feet: (Riprap pad at end of pipe to reduce flow velocities to 3 fps),
   d. 20,000 square feet ≤ CDA ≤ 1 acre: (Forebay containing 25% of the calculated WQV designed in accord with the specifications found in this manual),
   e. 1 acre ≤ CDA ≤ 5 acres: (Forebay containing 50% of the calculated WQV designed in accord with the specifications found in this manual),
   f. 5 acres < CDA < 10 acres: (Forebay containing 50% of the calculated WQV designed in accord with the specification found in this manual).
7. Allowable Contributing Drainage Area (CDA) directed to Wet Swale when receiving overland flow directly from an impervious surface. Runoff from all storm events is directed to Wet Swale:
   a. CDA < 5,000 square feet,
   b. 5,000 square feet ≤ CDA ≤ 10,000 square feet,
   c. 10,000 square feet ≤ CDA ≤ 20,000 square feet,
   d. 20,000 square feet ≤ CDA ≤ 1 acre,
   e. 1 acre ≤ CDA ≤ 5 acres: Not permitted as contributing drainage area is too large,
   f. 5 acres < CDA < 10 acres: Not permitted as contributing drainage area is too large.
8. Slope of Wet Swale:
   a. 6.0% of less no restriction or design modifications are required,
   b. For slopes between 6.0% and 10.0%, then gravel check dams are required,
   c. Wet Swales are not permitted on slopes greater than 10.0%.
9. Soil Media Specification for a Wet Swale is designed to create a saturated wetland environment.
   a. Clayey, high organic content topsoil – 100%
10. Overflow provisions from a Wet Swale:
    a. A Wet Swale shall either convey runoff to another water quality/quantity stormwater management practice or,
    b. Discharge onto a native wetland vegetated area. In this scenario, the end of the swale shall be flared out to ensure that overland flow will occur. A pad of native field stones shall be placed on the flared-out section and pressed into the ground surface by a hydraulic excavator so that no more than 50% of the stone is above the ground surface.

**Hydrologic Modeling:**

As part of the design of a Wet Swale, it shall be demonstrated by hydrologic modeling using a program such as HydroCAD that the system will fully convey both the peak rates for both the 2-year and 10-year rainfall events. Non-erosive velocities must be less than 3 fps for the 2-year event.

**Construction Requirements:**

The design engineer shall develop a detailed, site specific construction sequence for a Wet Swale. The design engineer shall also inspect the installation of the Wet Swale during the installation process. Wet Swales shall be constructed early on during the overall construction process, so that they are fully vegetated and stabilized prior to the introduction of stormwater to them.

A typical construction sequence will follow these generalized steps:

1. The area of the Wet Swale shall be fenced off with orange poly construction fence after the clearing of trees to prevent the movement of construction vehicles over the area of the Wet Swale,
2. A stable benchmark shall be set by the design engineer or land surveyor for use by the contractor,
3. The centerline of the Wet Swale shall be staked in the field by the design engineer or contractor,
4. The Wet Swale shall be excavated to the required design depth (bottom of wetland soil layer) by hydraulic excavator.
5. After the excavation of the Wet Swale has been completed, the wetland soil media shall be done by hydraulic excavator from outside the Wet Swale and then hand raked to the required design elevation.
6. The soil media shall be lightly tamped by walking on it, or using the excavation bucket to lightly compact the soil surface,
7. The surface of the Wet Swale shall be planted with an appropriate wetland seed mixture or wetland plant plugs,
8. The grass shall be watered as necessary to ensure its establishment.

**Inspection Requirements:**

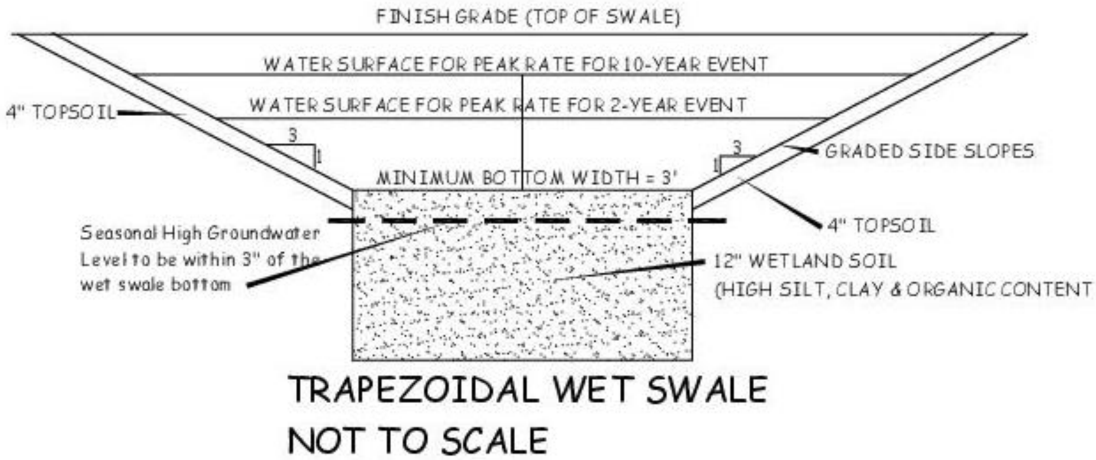
The design engineer shall oversee the entire installation of the Wet Swale at these specific steps:

1. After the excavation has been done to the bottom of the Wet Swale,
2. After placement, leveling and light compaction of the wetland soil media,
3. After the wetland seed mixture or wetland plant plugs have been installed.
4. The design engineer shall prepare an as-built plan of the completed Wet Swale and provide a written statement which addresses the following items:
    a. Excavation of the natural soils,
    b. Approval of soil media,
    c. Approval of overflow provisions,
    d. Approval of plant or seed installation,
    e. Approval of completed system.

**Maintenance Requirements:**

1. Twice a year inspections of the Sediment Forebay (if applicable),
2. Annual inspection of the Wet Swale,

3. Removal of organic debris (sticks and leaves) in the Spring and Fall,
4. Inspection for and removal of invasive plant species if present in Wet Swale



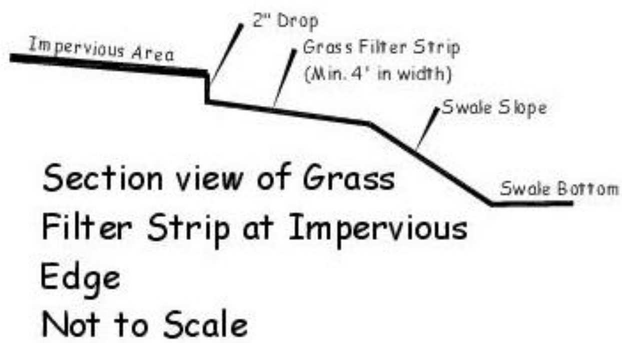
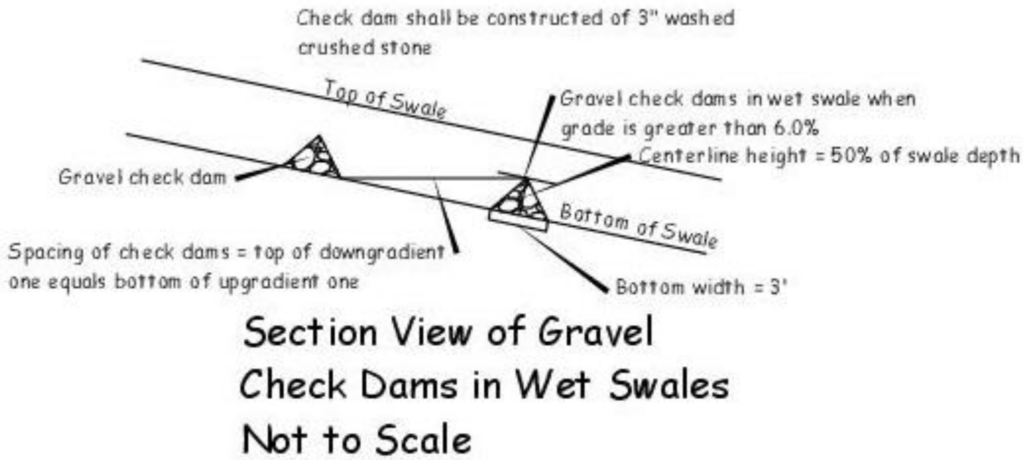




**Figure 7.17.2 - Cross Section of Trapezoidal Wet Swale (Trinkaus Engineering, LLC - 2017)**



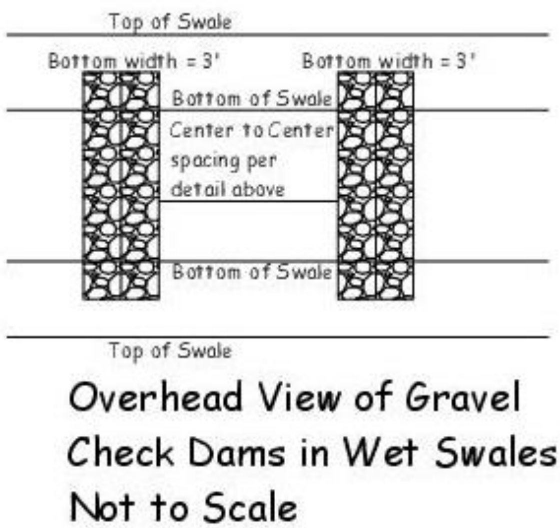




**Figure 7.17.3 - Check Dams in Wet Swale (Trinkaus Engineering, LLC - 2017)**

# 7.18 – FILTER STRIPS (Pretreatment)

**Figure 7.18.1 - Grass Filter Strip (Trinkaus Engineering, LLC - 2000)**

**Site Investigation:**

1. A deep test pit shall be excavated for every 100 linear feet along the proposed location of a Vegetated Filter Strip to a depth three (3) feet below the proposed finish grade to verify that there is no mottling or bedrock within this depth.
2. An Infiltration test using a Double Ring Infiltrometer shall be done within five (5) feet of the proposed location of a Vegetated Filter Strip. The infiltration test must be done at a depth which is 12" – 18" below the proposed elevation of the finish grade. One infiltration test shall be done for every 200 linear feet of the length of the Vegetated Filter Strip. The Infiltration test shall be done in accordance with the specifications found in Appendix "E" at the end of this manual.

**Design Requirements:**

1. Vegetated Filter Strip are primarily used to accept overland flow from an impervious surface. Concentrated flow from an impervious surface on to the Vegetated Filter Strip is prohibited.
2. Depth of sandy topsoil shall be 12" for residential and commercial applications.
3. Minimum Vertical Separation to Seasonal High Groundwater Level finish grade of the Vegetated Filter Strip shall be 18",
4. Minimum Vertical Separation to Bedrock from the bottom of the soil media shall be twenty-four (24) inches.
5. Allowable Contributing Drainage Area (CDA) directed to a mowed Vegetated Filter Strip as overland flow:
   a. CDA < 5,000 square feet: Permitted, minimum length shall be 20',
   b. 5,000 square feet $\leq$ CDA $\leq$ 10,000 square feet: Permitted, minimum length shall be 25',

   c. 10,000 square feet ≤ CDA ≤ 20,000 square feet: Permitted, minimum length shall be 30’,
   d. 20,000 square feet ≤ CDA ≤ 1 acre: Permitted, minimum length shall be 50’,
   e. 1 acre ≤ CDA ≤ 5 acres: Not Permitted as watershed area is too large for overland flow on to the Filter Strip,
   f. 5 acre < CDA < 10 acres: Not Permitted as watershed area is too large for overland flow on to the Filter Strip,
   g. 10 acres < CDA < 20 acres: Not Permitted as watershed area is too large for overland flow on to the Filter Strip,
6. Allowable Contributing Drainage Area (CDA) directed to an unmowed Vegetated Filter Strip as overland flow:
   a. CDA < 5,000 square feet: Permitted, minimum length shall be 10’,
   b. 5,000 square feet ≤ CDA ≤ 10,000 square feet: Permitted, minimum length shall be 15’,
   c. 10,000 square feet ≤ CDA ≤ 20,000 square feet: Permitted, minimum length shall be 25’,
   d. 20,000 square feet ≤ CDA ≤ 1 acre: Permitted, minimum length shall be 35’,
   e. 1 acre ≤ CDA ≤ 5 acres: Not Permitted as watershed area is too large for overland flow on to the Filter Strip,
   f. 5 acre < CDA < 10 acres: Not Permitted as watershed area is too large for overland flow on to the Filter Strip,
   g. 10 acres < CDA < 20 acres: Not Permitted as watershed area is too large for overland flow on to the Filter Strip,
7. Maximum permitted slope of Vegetated Filter Strip shall be 6.0%,
8. Vegetated Filter Strips shall be located on undisturbed soils to the maximum extent practicable,
9. Soil Media Specification for a Vegetated Filter Strip shall be either a Sandy topsoil or the filter media used for a Bioretention system as specified below:
   a. Washed Concrete Sand – 80% (ASTM C33)
   b. Well decomposed wood chip or leaf compost – 15%
   c. Sandy loam or sandy topsoil – 5% (no more than 2% clay content)

**Hydrologic Modeling:**

No modeling is required for Vegetated Filter Strip.

**Construction Requirements:**

The design engineer shall develop a detailed, site specific construction sequence for a Vegetated Filter Strip. The design engineer shall also inspect the installation of the Vegetated Filter Strip during the installation process. Vegetated Filter Strip shall be constructed early on during the overall construction process, so that they are fully vegetated and stabilized prior to the introduction of stormwater to them.

A typical construction sequence will follow these generalized steps:

1. The area of the Vegetated Filter Strip shall be fenced off with orange poly construction fence after the clearing of trees to prevent the movement of construction vehicles over the area of the Vegetated Filter Strip,
2. A stable benchmark shall be set by the design engineer or land surveyor for use by the contractor,
3. The Vegetated Filter Strip graded as necessary to achieve the maximum grade of 6.0%. If the existing soil has a high content of silt of clay, it shall be removed and replaced with sandy topsoil.

The top of the topsoil at the edge of pavement shall be a minimum of 2" below the elevation of the edge of pavement. This is shown in Figure 7.18.3. The underlying soil shall be scarified by the excavated to a depth of 3" – 4",

4. If the Vegetated Filter Strip is to be mowed, it shall be seeded with an appropriate grass mix or sod can be placed,
5. If the Vegetated Filter Strip is to remain unmowed, it shall be seeded with a Conservation Seed Mixture from New England Wetland Plants (www.newp.com),
6. The grass shall be watered as necessary to ensure its establishment.

**Inspection Requirements:**

The design engineer shall oversee the entire installation of the Vegetated Filter Strip at these specific steps:

1. After grading of the area for the Vegetated Filter Strip has been done,
2. After the Vegetated Filter Strip has been seeded,
3. The design engineer shall prepare an as-built plan of the completed Vegetated Filter Strip and provide a written statement which addresses the following items:
    a. Grading and scarification of the natural soils,
    b. Approval of sandy topsoil or Bioretention media as applicable,
    c. Approval of grass installation,
    d. Approval of completed system.

**Maintenance Requirements:**

1. For a Vegetated Filter Strip which is mowed:
    a. Mow grass as necessary to maintain average height of 3",
    b. Water as necessary,
    c. Reseed bare spots as necessary,
    d. Remove leaves from the Vegetated Filter Strip in the Fall and Spring as necessary,
    e. Inspect pavement edge once a year to ensure that organic debris has not built up along the drop edge. If organic debris has built up, remove with rake, and then reseed.
2. For a Vegetated Filter Strip which is unmowed:
    a. Mow vegetation down in Fall (late October) and remove cut vegetation from the area and dispose in an upland area or compost,
    b. Water as necessary,
    c. Reseed bare spots as necessary,
    d. Remove leaves from the Vegetated Filter Strip in the Fall and Spring as necessary,
    e. Inspect pavement edge once a year to ensure that organic debris has not built up along the drop edge. If organic debris has built up, remove with rake, and then reseed.

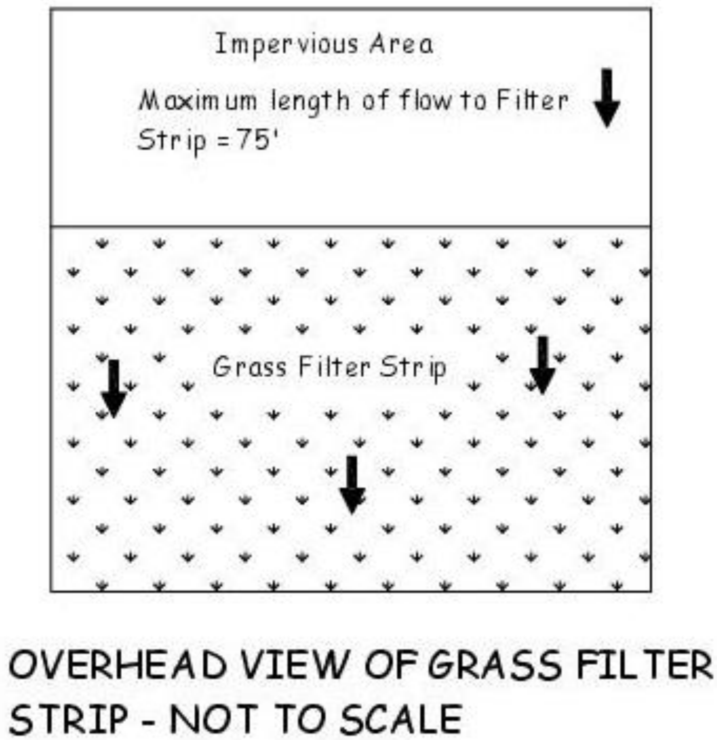



**Figure 7.18.2 - Overhead view of Grass Filter Strip (Trinkaus Engineering, LLC - 2017)**

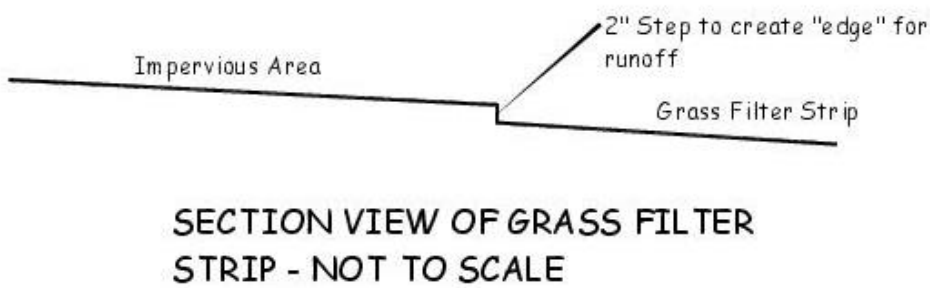



**Figure 7.18.3 - Edge Treatment for Filter Strip (Trinkaus Engineering, LLC - 2017)**

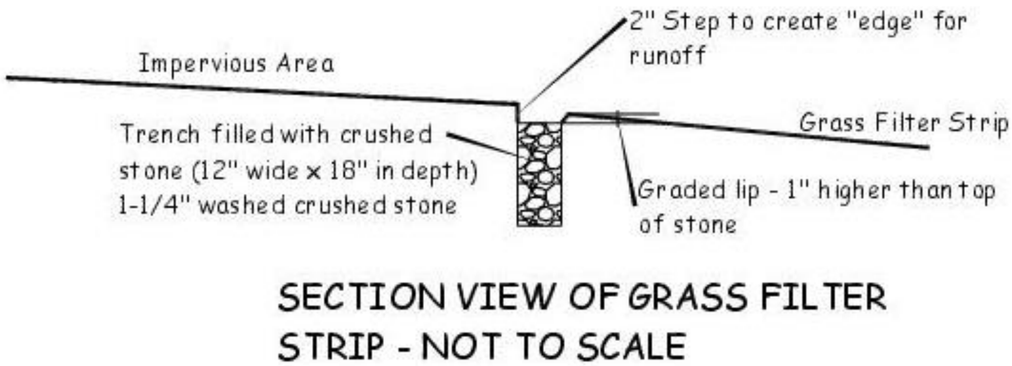



**Figure 7.18.4 - Alternative Edge Treatment for Filter Strip (Trinkaus Engineering, LLC - 2017)**

# 7.19 – SEDIMENT FOREBAYS (Pretreatment)

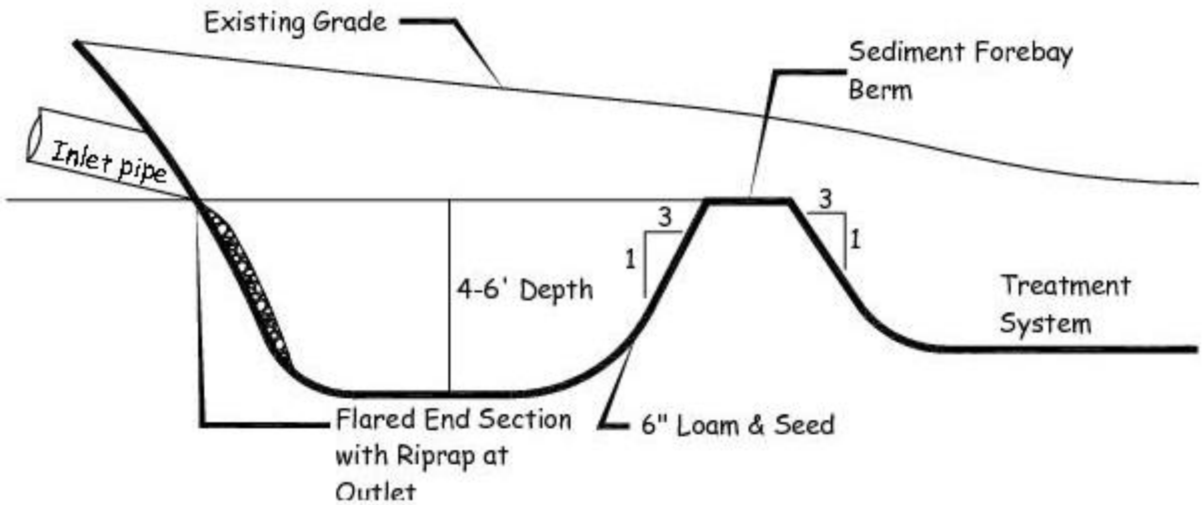



**Figure 7.19.1 - Forebay (Trinkaus Engineering, LLC – 2017)**

**Site Investigation:**

1. A deep test pit shall be excavated in the forebay to determine if ledge is located within eight (8) feet of the ground surface.

**Design Requirements:**

1. Sediment forebays are extremely important features for infiltration BMPs as well as wetland/pond systems. They trap coarse to medium sediments and can also allow finer sediments to settle out of the water column and prevent these fine particles from entering the treatment component of the BMP,
2. The forebay must be 4' – 6' in depth and be separated from the treatment BMP by an earth berm. A riprap berm is not an accepted separation system,
3. The forebay must have a minimum length to width ratio of 3:1 (inlet pipe to outlet spillway). The dimensions shall be taken along the centerline of the forebay from the inlet to the outlet and then a perpendicular line at the center of the flow line,
4. The forebay must contain a minimum of 10% of the required Water Quality Volume which is directed to the BMP. This requirement will be greater for some systems as specified in other sections of this manual,
5. The invert of the inlet pipe shall be set at the top of the water surface associated with the Water Quality Volume,

6. The slope from the end of the pipe to the bottom of the forebay shall be lined with an appropriately sized riprap to reduce flow velocities,
7. The forebay shall NOT be lined with riprap as it makes it increases the maintenance costs to remove accumulated sediment from the riprap,

**Hydrologic Modeling:**

In the hydrologic model of the BMP, no credit for storage in the forebay shall be considered as it will have a permanent pool. Volume computations of the forebay shall be provided in the stormwater report to demonstrate the compliance with the storage volume requirements found in this Manual.

**Construction Requirements:**

The forebay is incorporated in the design of all the wetland/pond BMPs as well as some of the Infiltration systems and dry swales. The forebay shall be constructed at the same time as the BMP so it is stabilized prior to the introduction of stormwater. The construction narrative by the design professional shall include specific provisions for the installation of the forebay.

**Inspection Requirements:**

The design engineer shall oversee the entire installation of the stormwater BMP including the forebay as applicable.

1. After excavation and shaping of the forebay has been done,
2. After installation of berm, inlet pipe and riprap,
3. After completion of the stormwater BMP.
4. The as built of the BMP shall include the forebay and a written statement of compliance with the design.

**Maintenance Requirements:**

1. Annual inspection and measurement of accumulated sediment in the forebay,
2. Removal of accumulated sediment when the sediment depth exceeds 24".

# 7.20 – DEEP SUMP CATCH BASIN (Pretreatment)

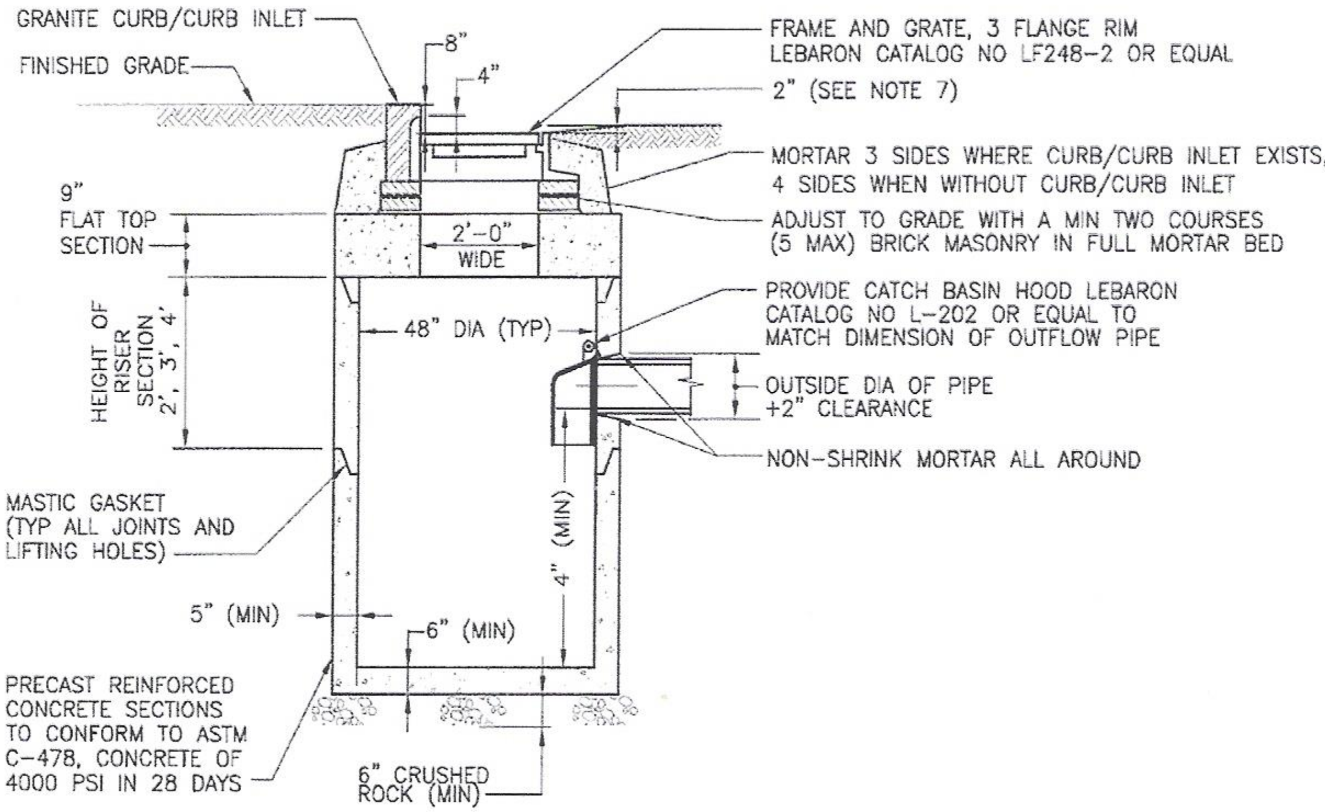



**Figure 7.20.1 - Deep Sump Catch Basin (RI DEM, 2010)**

**Site Investigation:**

No site inspection is required for the installation of a deep sump catch basin.

**Design Requirements:**

1. Maximum drainage area to a singular deep sump catch basins is 0.5 acres,
2. The depth of the sump below the invert of the outlet pipe shall be 48”,
3. A PVC hood shall be installed on the outlet pipe to prevent the discharge of lighter than water emulsions (gas, oil, grease, etc.) from being discharged. The bottom opening of the hood shall be a minimum of 6” below the invert of the outlet pipe,

**Construction Requirements:**

Construction specifications as well as a construction sequence shall be provided by the design professional for the installation of a deep sump catch basin. If the basin is installed when additional site work is being done, the grate shall be protected by the installation of a ring of siltation fence barrier, or a silt sack shall be installed under the grate to prevent the introduction of silt into the system.

**Inspection Requirements:**

The deep sump catch basin shall be inspected by the design engineer after installation to verify the following requirements:

1. The sump below the invert of the outlet pipe measures a minimum of 48”,
2. The PVC hood has been professionally installed,
3. Any sediment has been removed from the bottom of the basin,
4. The location of the deep sump catch basin shall be shown on an as-built survey with rim, invert elevations of all pipes as well as all applicable pipe sizes.

**Maintenance Requirements:**

1. Inspections of a deep sump catch basin shall be made twice a year (one in the late Fall and then in late Spring after snow melt),
2. Removal and disposal of any accumulated hydrocarbons on top of the water surface,
3. Removal of accumulated sediment in the deep sump when the sediment depth exceeds 24”.

# 7.21 – PROPRIETARY TREATMENT DEVICES (Pretreatment)

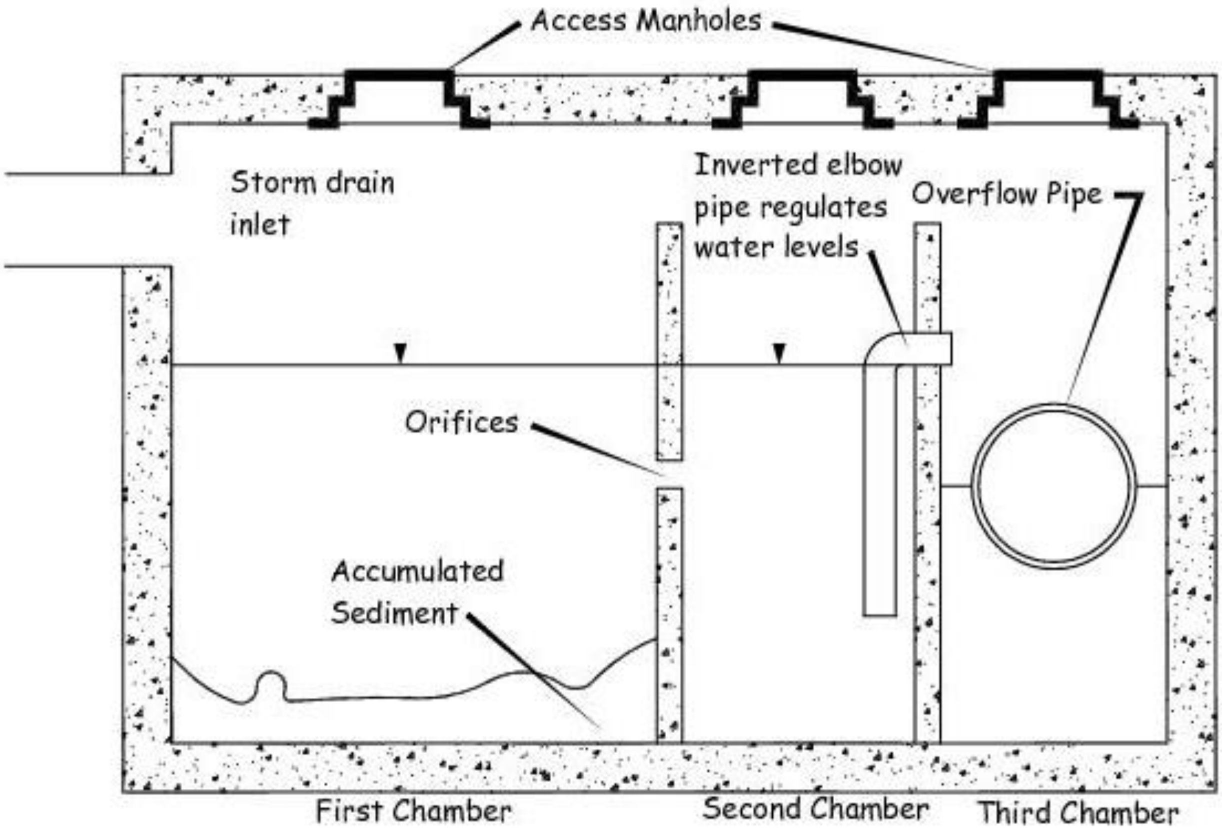



**Figure 7.21.1 - Oil Grit Separator (Trinkaus Engineering, LLC – 2017)**

**Site Investigation:**

No site inspection is required for the installation of an Oil Grit Separator.

**Design Requirements:**

1. The Oil Grit Separator shall be designed as an off-line system with only the water quality flow being directed to the separator,
2. A bypass for larger storm events shall be designed,
3. Calculations of the Water Quality Flow shall be provided. The Water Quality Flow is the flow rate associated with the Water Quality Volume for the contributing watershed. The maximum allowable flow rate to an oil/grit separator shall be 5.0 cfs,
4. Maximum drainage area to a singular Oil Grit Separator shall be 2.0 acres,
5. Minimum capacity of an oil/grit separator shall be 1500 gallons. First chamber 1000 gallons, second chamber 250 gallons, third chamber 250 gallons.

6. The inverted PVC pipe in the second chamber shall be a minimum of 4" in diameter.
7. The outlet pipe from the oil/grit separator shall be capable of handling the maximum allowable flow rate of 5.0 cfs and shall be a minimum of 12" in diameter.

**Construction Requirements:**

Construction specifications as well as a construction sequence shall be provided by the design professional for the installation of an oil/grit separator. If a two-section concrete tank is used, the joint between the sections must be made watertight.

**Inspection Requirements:**

An oil/girt separator shall be inspected by the design engineer after installation to verify the following requirements:

1. The unit is sealed and watertight. This shall be verified prior to backfilling of the unit,
2. After all piping has been installed and manhole bypass systems have been installed

**Maintenance Requirements:**

1. Inspections of an oil/grit separator shall be made twice a year (one in the late Fall and then in late Spring after snow melt),
2. Removal and disposal of any accumulated hydrocarbons on top of the water surface,
3. Removal of accumulated sediment in the deep sump when the sediment depth exceeds 24".

# 7.22 – DRY DETENTION POND (CPFR, FP)

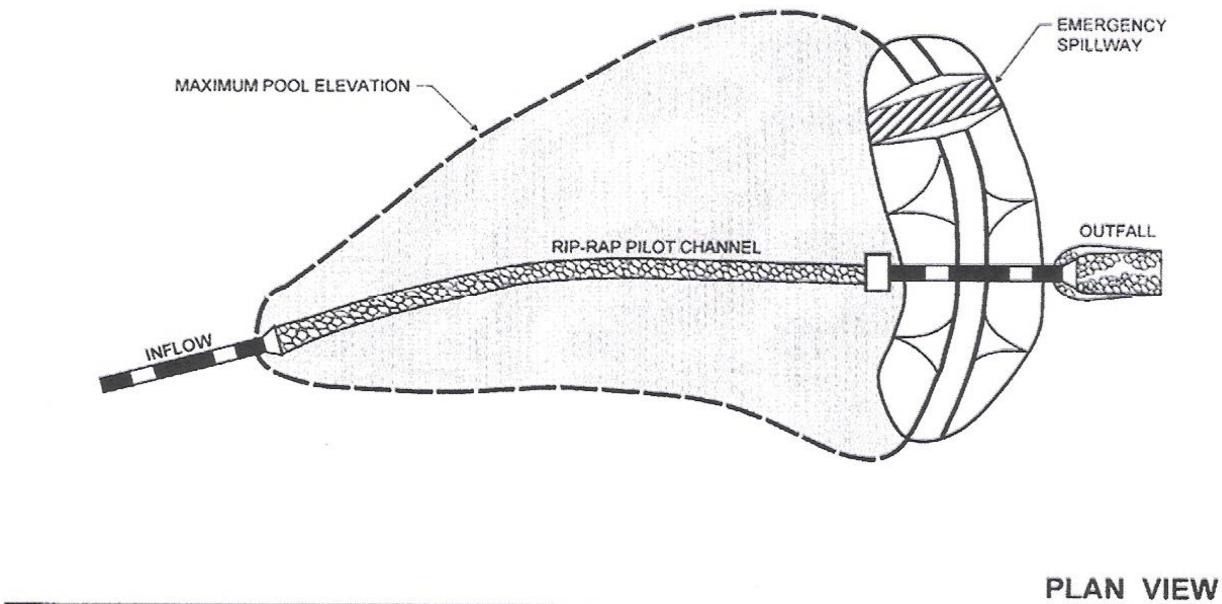



**Figure 7.22.1 - Dry Detention Pond (RI DEM, 2010)**

**Site Investigation:**

1. A Dry Detention Pond is for water quantity control only. A deep test pipe shall be excavated for every 1,000 square feet of the bottom of the Dry Detention Pond to verify the depth of seasonal high groundwater as well as bedrock. Dry ponds shall only be used as a BMP after other LISD infiltration practices have been implemented to address water quality and volume reduction.

**Design Requirements:**

1. While the primary function of a Dry Detention Pond is designed to provide the Channel Protection Flow as well as Peak Rate Attenuation, the addition of a forebay can allow the Dry Detention Pond to perform some water quality treatment.
2. A forebay designed in accordance with the specifications found in this manual shall be located at the end of the pipe where runoff will enter the system if the designer wants to include any water quality benefit from a Dry Detention Pond. The forebay must contain a minimum of 10% of the required Water Quality Volume,
3. There is no permanent pool or wet bottom in a Dry Detention Pond,
4. The bottom of the Dry Detention Pond shall be a minimum of 18" above the seasonal high groundwater level,
5. The bottom of the Dry Detention Pond shall be sloped from the inlet to the outlet. The minimum pitch shall be 1.0%,
6. A low flow channel consisting of modified riprap shall be installed from the inlet to the outlet structure,

7. The lowest outlet control weir or orifice shall be set at the lowest elevation of the bottom of the Dry Detention Pond,
8. Multiple orifices or weirs shall be used in the outlet control structure to provide the Channel Protection Flow Rate as well peak rate attenuation for the required design storms (10-year and 100-year) events.
9. The berm around the Multiple Pond System shall be 48" or less above existing grade. If the berm is higher than 48" it shall be designed as a dam to CT DEEP requirements,
10. Allowable Contributing Drainage Area (CDA) directed to a Multiple Pond System and required (pre-treatment). All runoff flows can be directed to a Multiple Pond System.
    a. CDA < 5,000 square feet: Not permitted as there is insufficient drainage area to maintain water surface in system,
    b. 5,000 square feet ≤ CDA ≤ 10,000 square feet: Not permitted as there is insufficient drainage area to maintain water surface in system,
    c. 10,000 square feet ≤ CDA ≤ 20,000 square feet: Not permitted as there is insufficient drainage area to maintain water surface in system,
    d. 20,000 square feet ≤ CDA ≤ 1 acre: Permitted, forebay is optional,
    e. 1 acre ≤ CDA ≤ 5 acres: Forebay containing a minimum of 10% of the required Water Quality Volume designed in accord with the specification found in this manual,
    f. 5 acres < CDA < 10 acres: Forebay containing a minimum of 10% of the required Water Quality Volume designed in accord with the specification found in this manual,
    g. 10 acres < CDA < 25 acres: Forebay containing a minimum of 10% of the required Water Quality Volume designed in accord with the specification found in this manual.
11. Natural Land Slope: There are no design modifications necessary for a Dry Detention Pond on slopes up to 10% other than meeting the other requirements found in this section. It is likely however that more substantial earthwork will be necessary on slopes greater than 5.0%,
12. If a Dry Detention Pond is located on Class C or Class D soils, it must be lined with an impermeable liner to prevent the intrusion of shallow groundwater,
13. If a Dry Detention Pond is located where the seasonal high groundwater is less than 3' below the existing ground surface, it shall be lined with an impermeable barrier to prevent the intrusion of shallow groundwater,
14. Outflow provisions from a Multiple Pond System can be done in one of several ways:
    a. An outlet control structure shall have either weirs or orifices to control peak rate discharges with the top of the structure acting as an overflow provision for storm events from the 10-year and 100-year event, in addition to providing the Channel Protection Flow,
    b. An emergency spillway can be provided through the berm of the system. The spillway shall be sufficient to convey flows more than the 100-year event and be lined with an appropriate size of riprap.
    c. All discharge pipes must direct flows to an existing stable watercourse system which is downgradient from the basin.
    d. Discharges from the primary outlet system shall not be permitted on upland slope areas.

**Hydrologic Modeling:**

As part of the design of a Dry Detention Pond, it shall be demonstrated by hydrologic modeling using a program such as HydroCAD that the system will provide the required Channel Protection Flow Rate as well as peak rate attenuation as may be required.

**Construction Requirements:**

The design engineer shall develop a detailed, site specific construction sequence for a Dry Detention Pond. The design engineer shall also inspect the installation of a Dry Detention Pond during the installation process. A Dry Detention Pond shall be constructed early on during the overall construction process, so that they are fully vegetated and stabilized prior to the introduction of stormwater to them.

A typical construction sequence will follow these generalized steps:

1. The area of a Dry Detention Pond shall be fenced off with orange poly construction fence after the clearing of trees to prevent the movement of construction vehicles over the area of a Multiple Pond System,
2. A stable benchmark shall be set by the design engineer or land surveyor for use by the contractor,
3. The outline of a Dry Detention Pond shall be staked in the field by the design engineer or contractor,
4. The forebay and shape of the Dry Detention Pond shall be excavated to the required design depth by hydraulic excavator,
5. The berm, outlet structure and piping as well as the emergency spillway shall be installed per the design,
6. The bottom and side slopes of the Dry Detention Pond shall be seeded with a grass seed mixture that can tolerate periodic ponding up to 4' in depth and a duration of 24 – 48 hours,
7. The grass above the seasonal groundwater table shall be watered as necessary to ensure their establishment.

**Inspection Requirements:**

The design engineer shall oversee the entire installation of the Dry Detention Pond at these specific steps:

1. After the excavation has been done to the bottom of the system,
2. After installation of outlet structure, piping, berm, etc.,
3. After seeding of the basin and stabilization of adjacent upland areas
4. The design engineer shall prepare an as-built plan of the completed Dry Detention Pond and provide a written statement which addresses the following items:
    a. Excavation and grading of the Dry Detention Pond,
    b. Approval of outlet hydrologic control structures,
    c. Approval of seeding,
    d. Approval of completed system.

**Maintenance Requirements:**

1. Twice a year inspections of the Sediment Forebay,
2. Removal of accumulated sediment in the Forebay when the depth is greater than 24",
3. Annual inspection of the Dry Detention Pond,

4. Removal of invasive vegetation the Dry Detention Pond as necessary,
5. Annual inspection of outlet control structures.

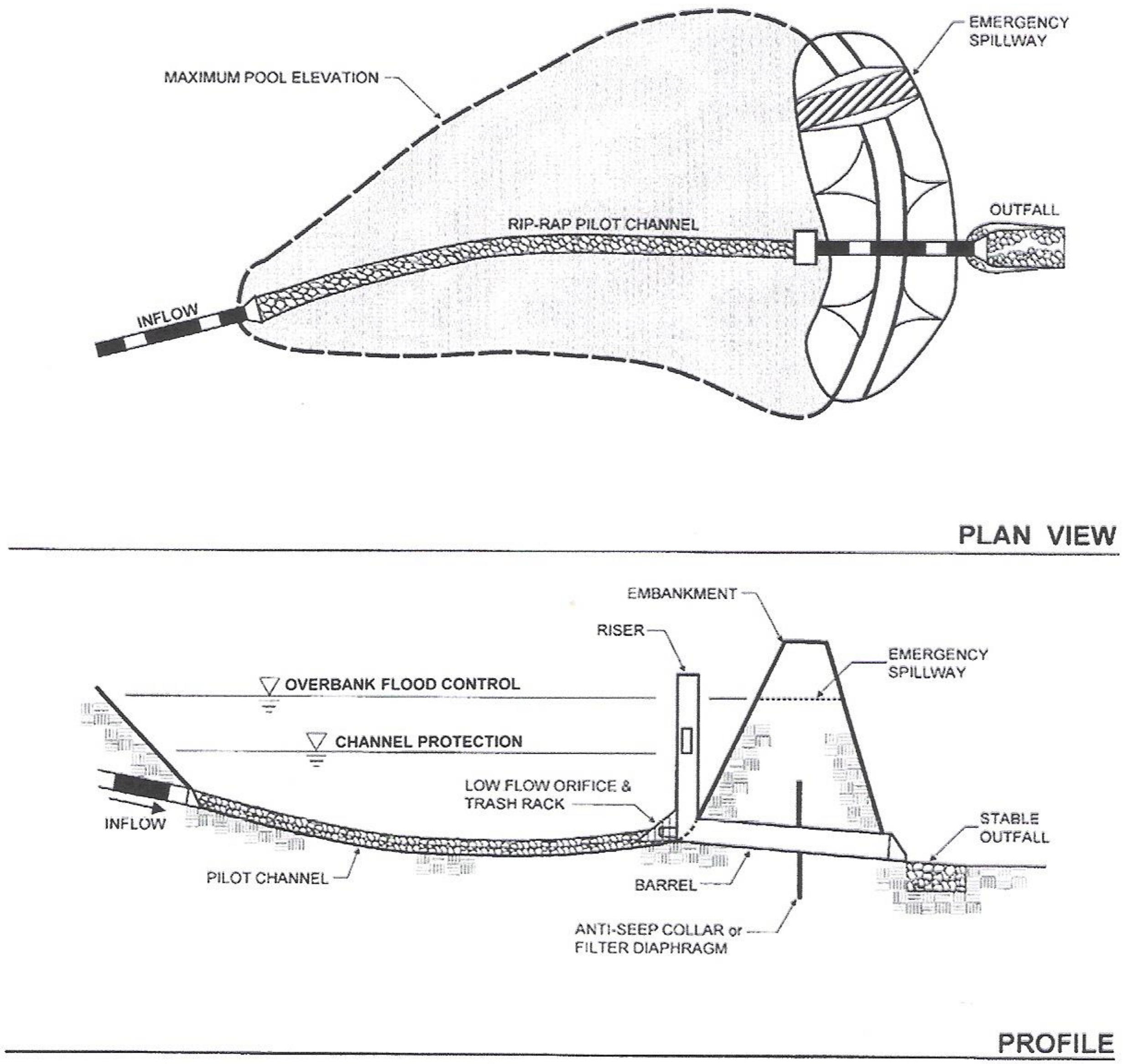



**Figure 7.22.2 - Plan and Section view of Dry Detention Pond (RIDEM-2010)**

# 7.23 – LISD PLANTER (Water Quality)


**Figure 7.23.1 – LISD Planter**

**Site Investigation:**

1. A LISD Planter is for water quality treatment and to a lesser extent, volume reduction. As these are linear systems along an existing roadway, deep test pits shall be done every 100' for this type of system,
2. An Infiltration test using a Double Ring Infiltrometer shall be done within five (5) feet of the proposed location of an Urban Planter. The infiltration test must be done at a depth which is equal to or below the lowest elevation of the soil media or gravel storage layer. One infiltration test shall be done for every 50 lf of LISD Planters to be installed. The Infiltration test shall be done in accordance with the specifications found in Appendix "E" at the end of this manual.

**Design Requirements:**

1. The water quality volume of the contributing drainage area shall be calculated,
2. The storage volume above the soil media surface shall contain the water quality volume if sufficient room exists. If the full water quality volume cannot be provided, then at least 50% of the water quality volume shall be provided as the fixed storage volume,
3. Depth of Soil Media shall be 18" for all applications,
4. Minimum Vertical Separation to Seasonal High Groundwater Level from either bottom of soil media or bottom of gravel layer shall be 12",
5. Maximum Allowable Ponding Depth (D) of full Water Quality Volume above soil surface shall be 12",

6. Sizing of the surface area of a LISD Planter system:
   SA = (WQV)/D where:
   SA = Surface area of filter bed (square feet)
   WQV = Calculated water quality volume (cubic feet) directed to system
   D = Depth of ponding above soil surface in feet (use values above per soil class)
7. Maximum allowable Contributing Drainage Area (CDA) directed to a LISD Planter shall be 5,000 square feet with a stone pad at inlet to system to reduce flow velocities,
8. Natural Land Slope: A LISD Planter should be installed on slopes less than 6.0%. If the slope of the road is greater than 6.0% and less than 10.0%, then small gravel berms shall be placed within the LISD Planter perpendicular to the flow direction to maintain low flow velocities,
9. Underdrains: A LISD Planter will likely need and underdrain as soils under or along roadways are often cut and filled and may not have adequate infiltrative capacities.
10. For all underdrain configurations, two layers of gravel shall be installed below the soil media layer. The first gravel layer shall consist of 3" of 3/8" washed gravel (pea gravel). The lower gravel layer consists of 6" – 12" of ¾" washed gravel. Specific information on the gravel layers is shown in the details cited below. There are three underdrain configurations which can be used in a LISD Planter system:
    a. The underdrain pipe can be installed as an overflow pipe to by-pass larger storm events while allowing infiltration into the underlying natural soils to be the primary discharge system. In this case the underdrain, typically consisting of 4" perforated PVC pipe is set at the top of a stone layer below the pea gravel layer.
    b. For LISD Planter systems which are lined with an impermeable barrier to prevent infiltration, the underdrain pipe (4" PVC) is located at the bottom of the gravel layer to provide a discharge point to daylight or to another stormwater management practice.
11. Soil Media Specification for a LISD Planter systems is designed to filter the runoff as well as provide sufficient organic material for the initial establishment of plants in the LISD Planter system. The material shall be mixed on a hard clean surface prior to being placed in the LISD Planter system. The soil media shall consist of the following material containing the specified percentage by volume:
    a. Washed Concrete Sand – 80% (ASTM C33)
    b. Well decomposed wood chip or leaf compost – 15%
    c. Sandy loam or sandy topsoil – 5% (no more than 2% clay content)
12. Overflow provisions from a LISD Planter system can be done in one of several ways:
    a. For LISD Planters which are level, a vertical Solid PVC pipe with the top of the pipe set at the allowable ponding depth for the water quality volume. A slotted end cap shall be used on the top of the pipe to prevent organic debris from entering the overflow pipe.
    b. For LISD Planters which are on a slope, a notch shall be installed at the downhill end of the planter to allow excess flows to follow an existing curb line to a field inlet.
13. The bottom of the Dry Detention Pond shall be a minimum of 18" above the seasonal high groundwater level,
14. The bottom of the Dry Detention Pond shall be sloped from the inlet to the outlet. The minimum pitch shall be 1.0%,
15. A low flow channel consisting of modified riprap shall be installed from the inlet to the outlet structure.

**Hydrologic Modeling:**

As part of the design of a LISD Planter, it shall be demonstrated that the system has the capacity to pass the peak rate of runoff associated with the 1-year storm with flow velocities less than 3.0 fps.

**Construction Requirements:**

The design engineer shall develop a detailed, site specific construction sequence for a LISD Planter. The design engineer shall also inspect the installation of a LISD Planter during the installation process. A LISD Planter shall be constructed early on during the overall construction process, so that they are fully vegetated and stabilized prior to the introduction of stormwater to them.

A typical construction sequence will follow these generalized steps:

1. The area of a LISD Planter shall be fenced off with orange poly construction fence after the clearing of trees to prevent the movement of construction vehicles over the area of a LISD Planter,
2. A stable benchmark shall be set by the design engineer or land surveyor for use by the contractor,
3. The outline of a LISD Planter shall be staked in the field by the design engineer or contractor,
4. The LISD Planter shall be excavated to the required design depth by hydraulic excavator,
5. The bottom and side walls of the excavation shall be scarified by using a garden rake to loosen any smeared soil,
6. This soil shall be removed from the Planter area by hand shovel,
7. Underdrains, gravel layer and filter media shall be installed per the design,
8. Notches to the curb line or other inlet configurations shall be constructed,
9. The soil media shall be planted with native species,
10. The grass above the seasonal groundwater table shall be watered as necessary to ensure their establishment.

**Inspection Requirements:**

The design engineer shall oversee the entire installation of the LISD Planter at these specific steps:

1. After the excavation has been done to the bottom of the system,
2. After installation of gravel, underdrain, and soil media,
3. After planting of the system,
4. The design engineer shall prepare an as-built plan of the completed LISD Planter and provide a written statement which addresses the following items:
    a. Excavation and grading of the LISD Planter,
    b. Approval of gravel, underdrain system and soil media,
    c. Approval of planting,
    d. Approval of completed system.

**Maintenance Requirements:**

1. Twice a year inspection of the LISD Planter,
2. Removal of accumulated sediment annually from the initial stone pad,
3. Removal of invasive vegetation the LISD Planter as necessary,

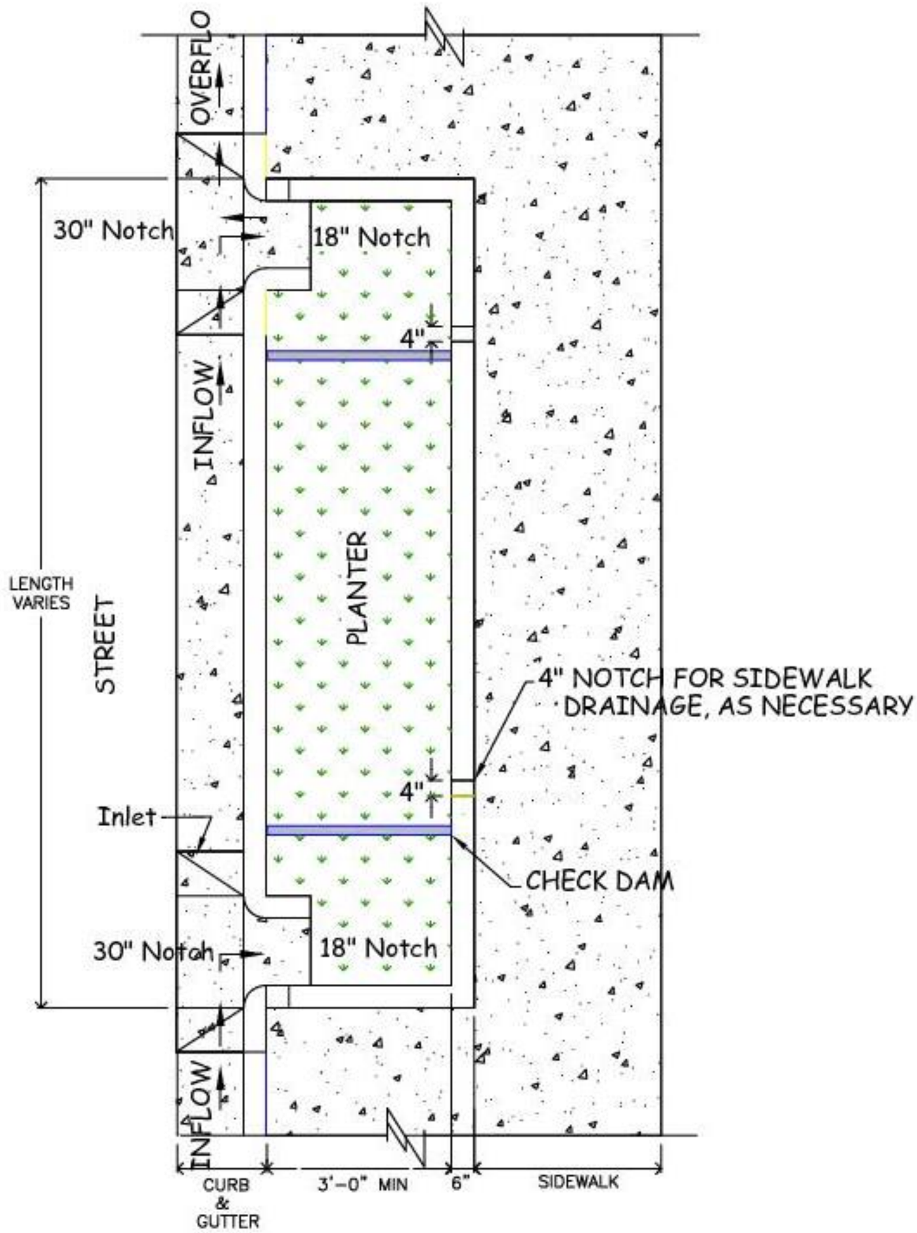
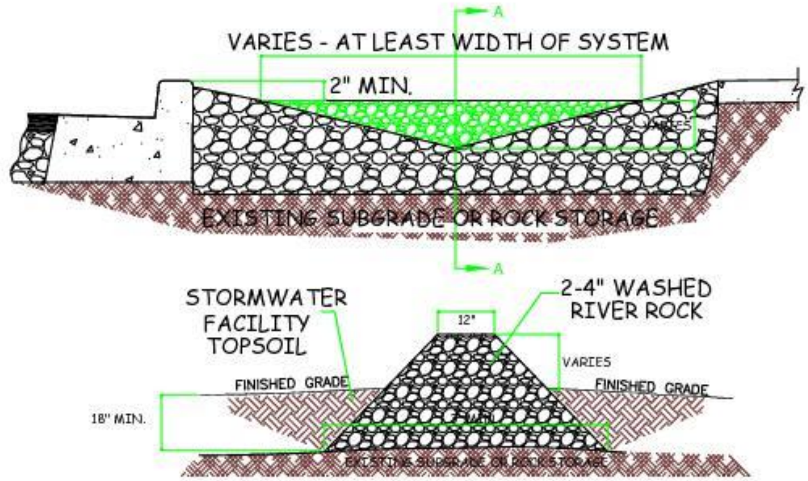



**Figure 7.23.2 - Plan view of LISD Planter System (Trinkaus Engineering, LLC - 2017)**
**(Modified from Portland, OR Planter Detail)**




STONE CHECK DAM TYPICAL DETAIL

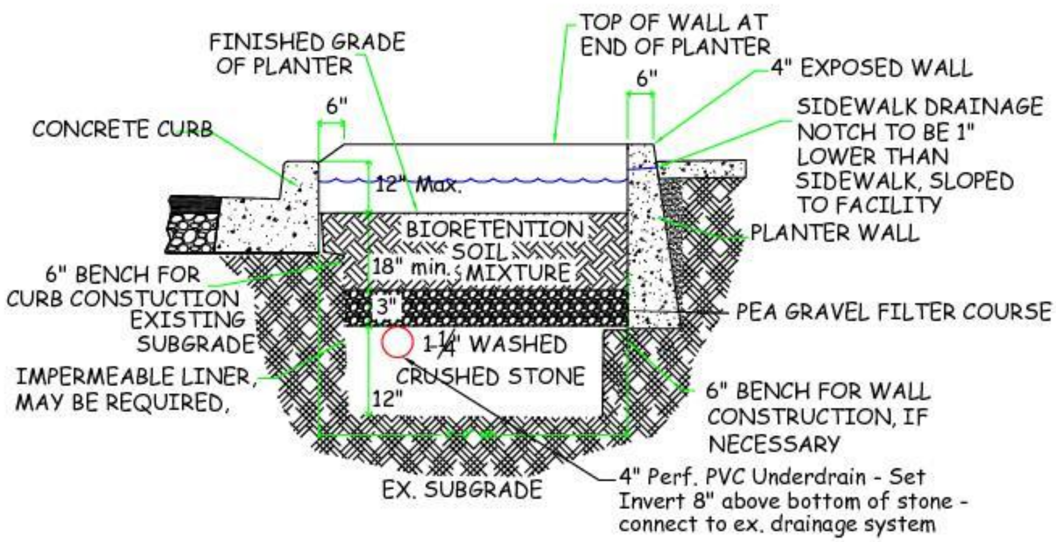



**Figure 7.23.3 - Cross Sectional view of LISD Planter systems (Trinkaus Engineering, LLC - 2017)**
**(Modified from Portland, OR Planter Detail)**

# 7.24 – LISD CURB EXTENSION (Water Quality)

**Figure 7.24.1 – LISD Curb Extension (City of Portland, OR)**

**Site Investigation:**

1. A LISD Curb Extension is for water quality treatment and to a lesser extent, volume reduction. As these are linear systems along an existing roadway, deep test pits shall be done every 100' for this type of system,
2. An Infiltration test using a Double Ring Infiltrometer shall be done within five (5) feet of the proposed location of a LISD Curb Extension. The infiltration test must be done at a depth which is equal to or below the lowest elevation of the soil media or gravel storage layer. One infiltration test shall be done for every 50 lf of LISD Curb Extension to be installed. The Infiltration test shall be done in accordance with the specifications found in Appendix "E" at the end of this manual.

**Design Requirements:**

1. The water quality volume of the contributing drainage area shall be calculated,
2. The storage volume above the soil media surface shall contain the water quality volume if sufficient room exists. If the full water quality volume cannot be provided, then at least 50% of the water quality volume shall be provided as the fixed storage volume,
3. Depth of Soil Media shall be 18" for all applications,
4. Minimum Vertical Separation to Seasonal High Groundwater Level from either bottom of soil media or bottom of gravel layer shall be 12",
5. Maximum Allowable Ponding Depth (D) of full Water Quality Volume above soil surface shall be 12",
6. Sizing of the surface area of a LISD Curb Extension:

    SA = (WQV)/D where:

    SA = Surface area of filter bed (square feet)
    WQV = Calculated water quality volume (cubic feet) directed to system
    D = Depth of ponding above soil surface in feet (use values above per soil class)

7. Maximum allowable Contributing Drainage Area (CDA) directed to a LISD Curb Extension shall be 5,000 square feet with a stone pad at inlet to system to reduce flow velocities,
8. Natural Land Slope: A LISD Curb Extension should be installed on slopes less than 6.0%. If the slope of the road is greater than 6.0% and less than 10.0%, then small gravel berms shall be placed within the LISD Curb Extension perpendicular to the flow direction to maintain low flow velocities,
9. Underdrains: A LISD Curb Extension will likely need and underdrain as soils under or along roadways are often cut and filled and may not have adequate infiltrative capacities.
10. For all underdrain configurations, two layers of gravel shall be installed below the soil media layer. The first gravel layer shall consist of 3" of 3/8" washed gravel (pea gravel). The lower gravel layer consists of 6" – 12" of ¾" washed gravel. Specific information on the gravel layers is shown in the details cited below. There are three underdrain configurations which can be used in a LISD Curb Extension system:
    a. The underdrain pipe can be installed as an overflow pipe to by-pass larger storm events while allowing infiltration into the underlying natural soils to be the primary discharge system. In this case the underdrain, typically consisting of 4" perforated PVC pipe is set at the top of a stone layer below the pea gravel layer.
    b. For LISD Curb Extension systems which are lined with an impermeable barrier to prevent infiltration, the underdrain pipe (4" PVC) is located at the bottom of the gravel layer to provide a discharge point to daylight or to another stormwater management practice.
11. Soil Media Specification for a LISD Curb Extension systems is designed to filter the runoff as well as provide sufficient organic material for the initial establishment of plants in the LISD Curb Extension system. The material shall be mixed on a hard clean surface prior to being placed in the LISD Curb Extension system. The soil media shall consist of the following material containing the specified percentage by volume:
    a. Washed Concrete Sand – 80% (ASTM C33)
    b. Well decomposed wood chip or leaf compost – 15%
    c. Sandy loam or sandy topsoil – 5% (no more than 2% clay content)
12. Overflow provisions from a LISD Curb Extension system can be done in one of several ways:
    a. For LISD Curb Extension which are level, a vertical Solid PVC pipe with the top of the pipe set at the allowable ponding depth for the water quality volume. A slotted end cap shall be used on the top of the pipe to prevent organic debris from entering the overflow pipe.
    b. For LISD Curb Extension which are on a slope, a notch shall be installed at the downhill end of the planter to allow excess flows to follow an existing curb line to a field inlet.
13. The bottom of the LISD Curb Extension shall be a minimum of 18" above the seasonal high groundwater level,
14. The bottom of the LISD Curb Extension shall be sloped from the inlet to the outlet. The minimum pitch shall be 1.0%,
15. A low flow channel consisting of modified riprap shall be installed from the inlet to the outlet structure.

**Hydrologic Modeling:**

As part of the design of a LISD Curb Extension, it shall be demonstrated that the system has the capacity to pass the peak rate of runoff associated with the 1-year storm with flow velocities less than 3.0 fps.

**Construction Requirements:**

The design engineer shall develop a detailed, site specific construction sequence for a LISD Curb Extension. The design engineer shall also inspect the installation of a LISD Curb Extension during the installation process. A LISD Curb Extension shall be constructed early on during the overall construction process, so that they are fully vegetated and stabilized prior to the introduction of stormwater to them.

A typical construction sequence will follow these generalized steps:

1. The area of a LISD Curb Extension shall be fenced off with orange poly construction fence after the clearing of trees to prevent the movement of construction vehicles over the area of a LISD Curb Extension,
2. A stable benchmark shall be set by the design engineer or land surveyor for use by the contractor,
3. The outline of a LISD Curb Extension shall be staked in the field by the design engineer or contractor,
4. The LISD Curb Extension shall be excavated to the required design depth by hydraulic excavator,
5. The bottom and side walls of the excavation shall be scarified by using a garden rake to loosen any smeared soil,
6. This soil shall be removed from the Extension area by hand shovel,
7. Underdrains, gravel layer and filter media shall be installed per the design,
8. Notches to the curb line or other inlet configurations shall be constructed,
9. The soil media shall be planted with native species,
10. The grass above the seasonal groundwater table shall be watered as necessary to ensure their establishment.

**Inspection Requirements:**

The design engineer shall oversee the entire installation of the LISD Curb Extension at these specific steps:

1. After the excavation has been done to the bottom of the system,
2. After installation of gravel, underdrain, and soil media,
3. After planting of the system,
4. The design engineer shall prepare an as-built plan of the completed LISD Curb Extension and provide a written statement which addresses the following items:
    a. Excavation and grading of the LISD Curb Extension,
    b. Approval of gravel, underdrain system and soil media,
    c. Approval of planting,
    d. Approval of completed system.

**Maintenance Requirements:**

1. Twice a year inspection of the LISD Curb Extension,
2. Removal of accumulated sediment annually from the initial stone pad,

3. Removal of invasive vegetation the LISD Curb Extension, as necessary.

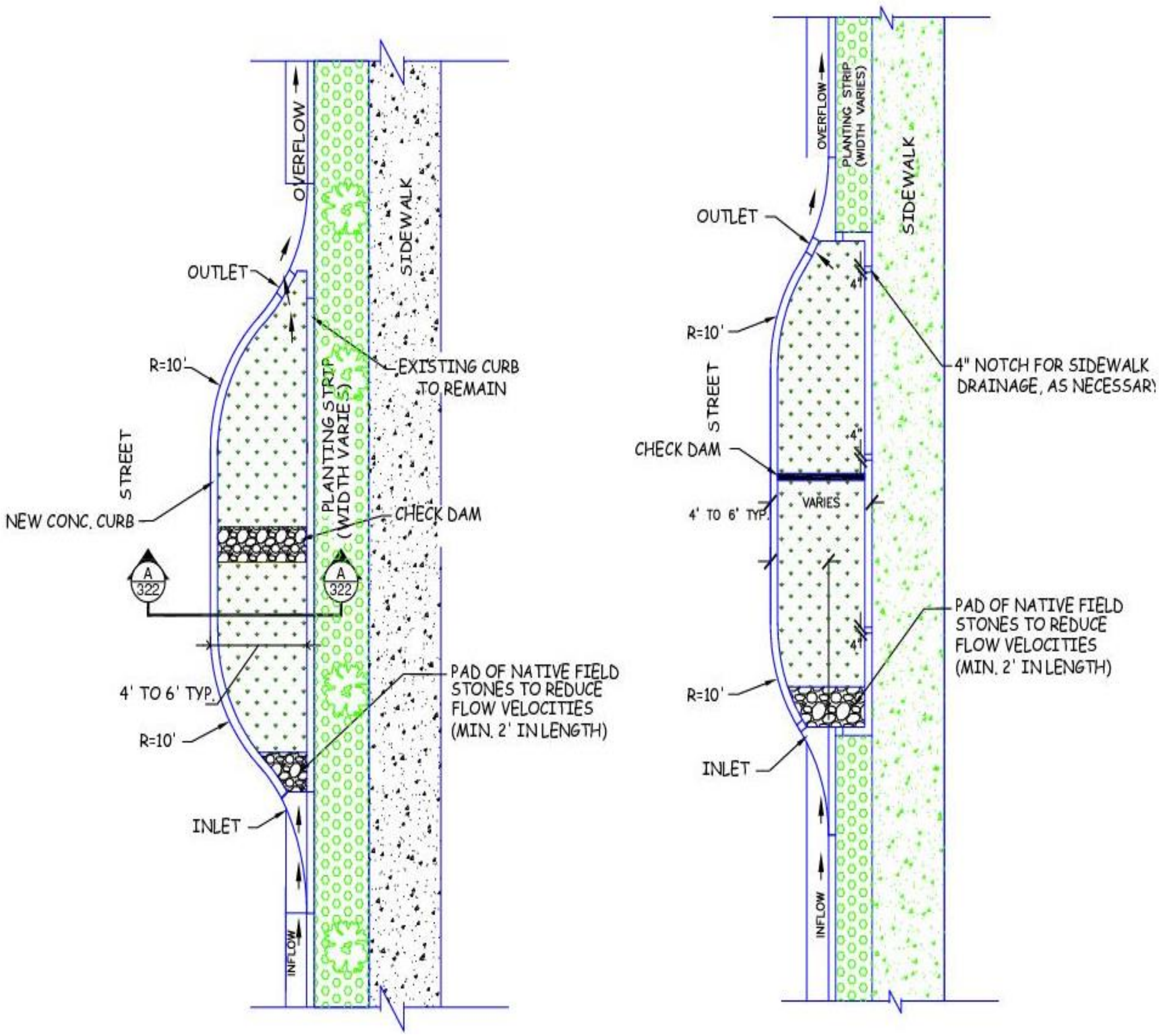
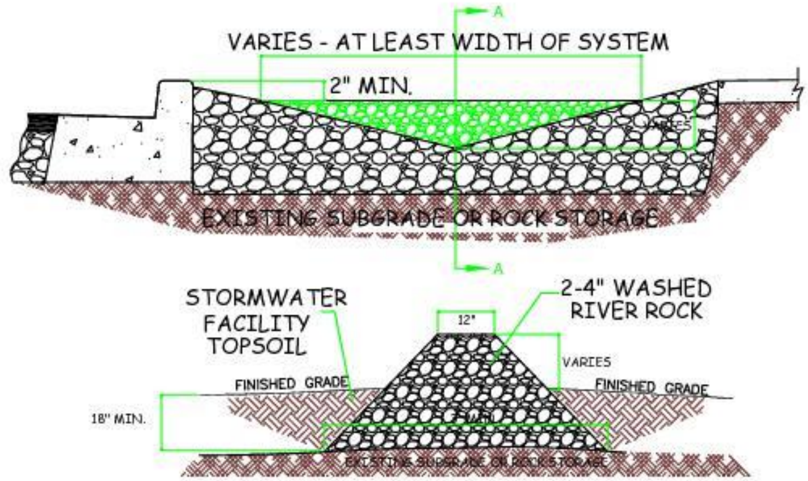



**Figure 7.24.2 - Plan view of LISD Curb Extension Systems (Trinkaus Engineering, LLC - 2017)**
**(Modified from Portland, OR Planter Detail)**




STONE CHECK DAM TYPICAL DETAIL

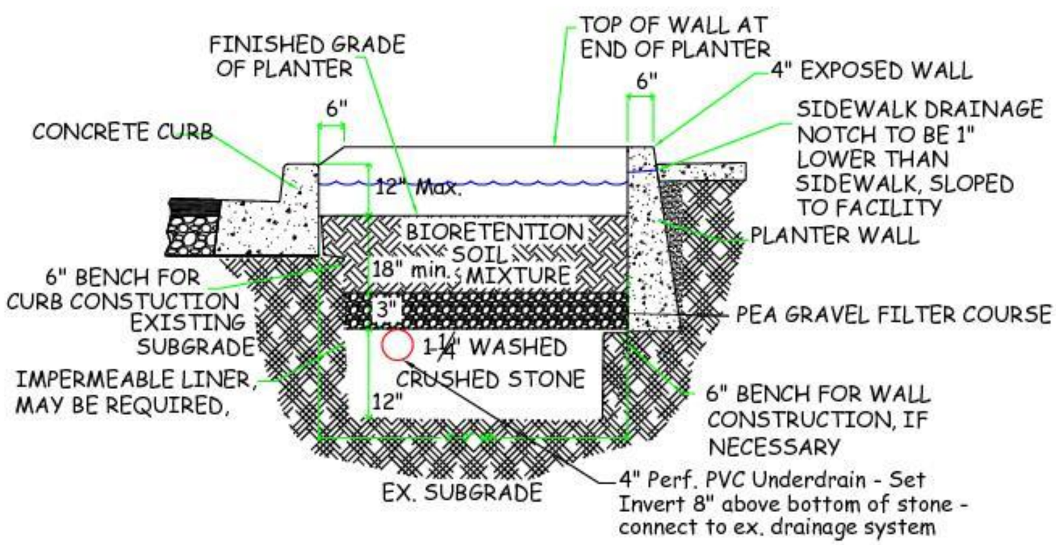



**Figure 7.24.3 – Cross Section of LISD Curb Extension (Trinkaus Engineering, LLC - 2017)**
**(Modified from Portland, OR Planter Detail)**

# 7.25 – RAIN BARREL (Water Reuse)

**Figure 7.25.1 – Rain Barrel**

**Site Investigation:**

1. No site investigation is necessary to install a rain barrel.

**Design Requirements:**

1. If collected runoff in the rain barrel is to be used infrequently, once a week or less, then only 100 square feet of roof area shall be directed to a singular 55-gallon rain barrel,
2. If the collected runoff in the rain barrel is to be used frequently, a minimum of three times a week, then 200 square feet of roof area shall be directed to a singular 55-gallon rain barrel,
3. The downspout from the gutter shall be connected to the top of the rain barrel. An overflow pipe shall be located so that once the rain barrel has been filled, excess runoff shall be directed to either a Bioretention system, or onto a vegetated surface which will allow the runoff to flow as overland flow across a minimum of 75'.

**Hydrologic Modeling:**

No hydrologic modeling is required for a rain barrel.

**Construction Requirements:**

A residential rain barrel shall be set on either a level crushed stone base or concrete slab to ensure it stays level.

**Inspection Requirements:**

The rain barrel shall be inspected after it has been installed to verify that the connection from the downspout is secure, there is an appropriate overflow pipe, and the rain barrel is set on a level base.

# 7.26 – GRAVEL DRIP BED (Impervious Area Disconnection)

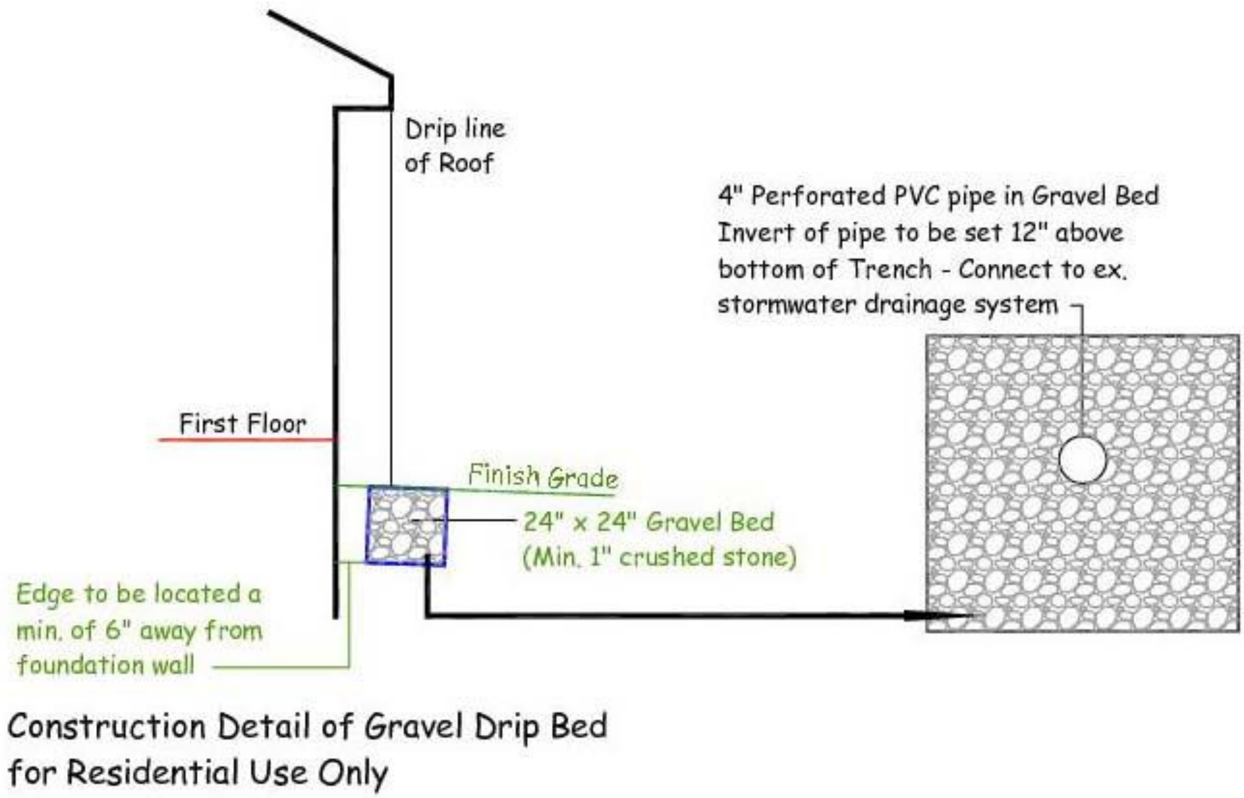



**Figure 7.26.1 – Gravel Drip Bed (Trinkaus Engineering, LLC - 2017)**

**Site Investigation:**

1. No site investigation is necessary to install a Gravel Drip Bed.

**Design Requirements:**

1. The finish grade around the foundation must slope away from the foundation wall at 2.0% for a minimum of ten (10) feet,
2. The gravel trench shall be centered on the drip line from the edge of the roof,
3. The gravel trench shall be 24" in width and a minimum of 12" in depth,
4. 1" or 1-1/4" washed crushed stone shall be used in the gravel trench,
5. A 4" Perforated PVC pipe shall be placed in the gravel trench. It can be placed at the bottom of the trench to minimize the infiltration of runoff near the foundation or elevated within the trench to allow infiltration to occur and the pipe will act as an overflow provision,
6. The PVC pipe shall either directed to daylight or connected to an existing drainage system which daylights on the property.

**Hydrologic Modeling:**

No hydrologic modeling is required for a Gravel Drip Bed.

**Construction Requirements:**

The bottom of the Gravel Drip Bed shall be level unless the PVC pipe is located at the bottom of the trench, if this is the case, the bottom of the trench shall have a minimum pitch of 1.0% from the high point to the discharge point.

**Inspection Requirements:**

The Gravel Drip Bed shall be inspected when excavated and during the placement of the gravel and PVC pipe.

# Section 8.0
# Design Standards for Conventional Stormwater Systems

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

1. **Storm Drainage Planning**:

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

a. to consider 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 Morris 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 Morris although no such obligation shall be placed on the Town of Morris because of this requirement.

2. **Design of in-road stormwater management systems:**

a. 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

b. Runoff Coefficients as shown in Table 9.1:

c. 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.

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."

4. **Drainage Facilities**:

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

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:
   a. 300 feet on a tangent, or closer as required for intersections,
   b. 200-250 feet on the inside of superelevated curves,
   c. 250 feet on highway grades over 6.0%,
   d. on the up-hill side of intersections,
   e. 250 feet from roadway high points, and
   f. Center of cul-de-sacs.

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.

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 if 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.

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 8.1.1 – 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 |

| Land Use | Runoff Coefficient |
|---|---|
| Parks | 0.10 – 0.25 |
| 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 |

# Section 9.0
# Computational and Design Examples

## 9.0.1 – 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: (1.3") (0.80) (5)/12 = 0.4333 acre-feet
GRV for HSG B: (1.3") (0.60) (3)/12 = 0.1950 acre-feet
GRV for HSG C: (1.3") (0.40) (1)/12 = 0.0433 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 = (1.3") (Rv) (A)/12

WQV for Area 1: Rv = 0.05 + 0.009(46.15) = 0.4654
WQV = (1.3") (13) (0.4654)/12 = 0.6554 acre-feet
WQV for Area 2: Rv = 0.05 + 0.009(25) = 0.2750
WQV = (1.3") (12) (0.2750)/12 = 0.3575 acre-feet

## 9.0.2 – Application of Environmental Site Design Strategies

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

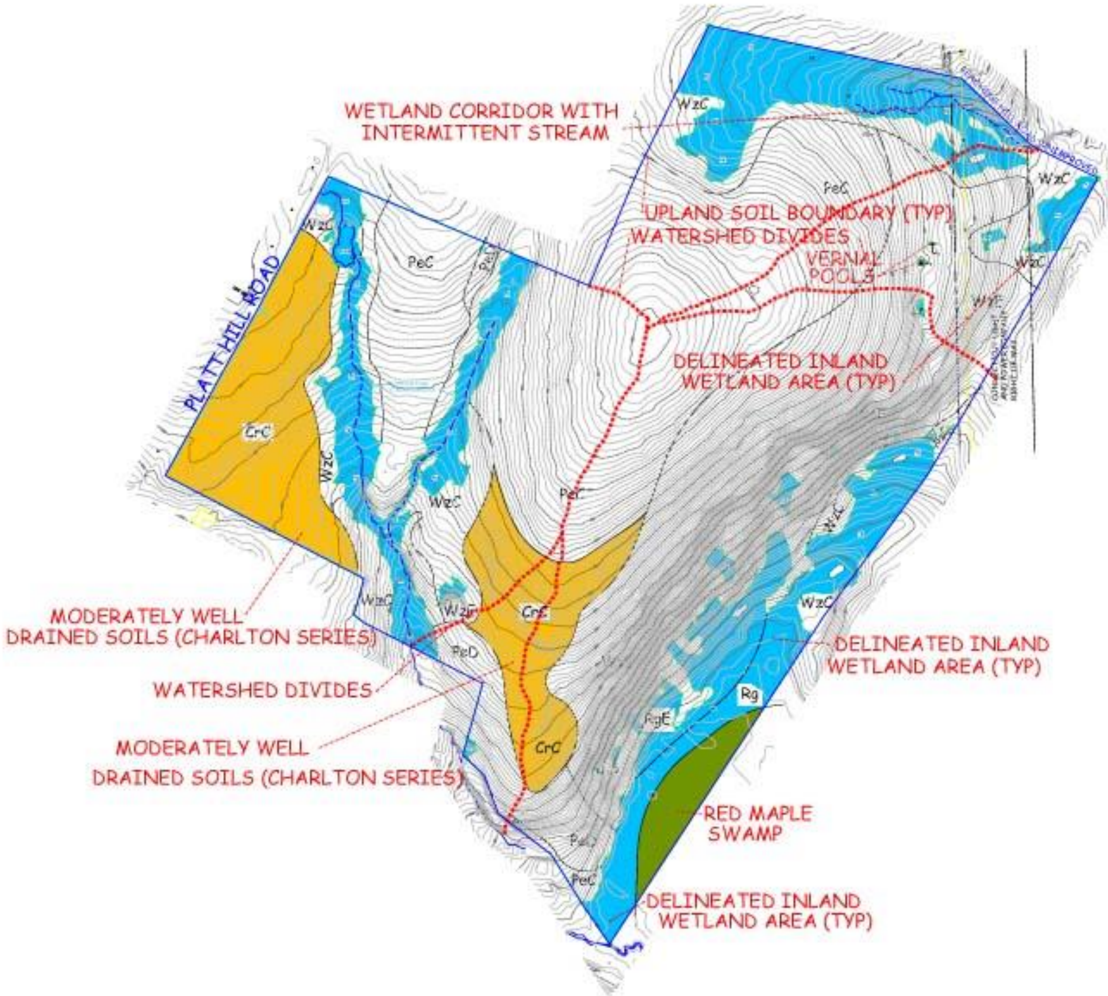



**Figure 9.2.1 - Wetlands/Watercourses/Soils/Drainage Divides**

Figure 9.2.1 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 subwatersheds on the site have been delineated.

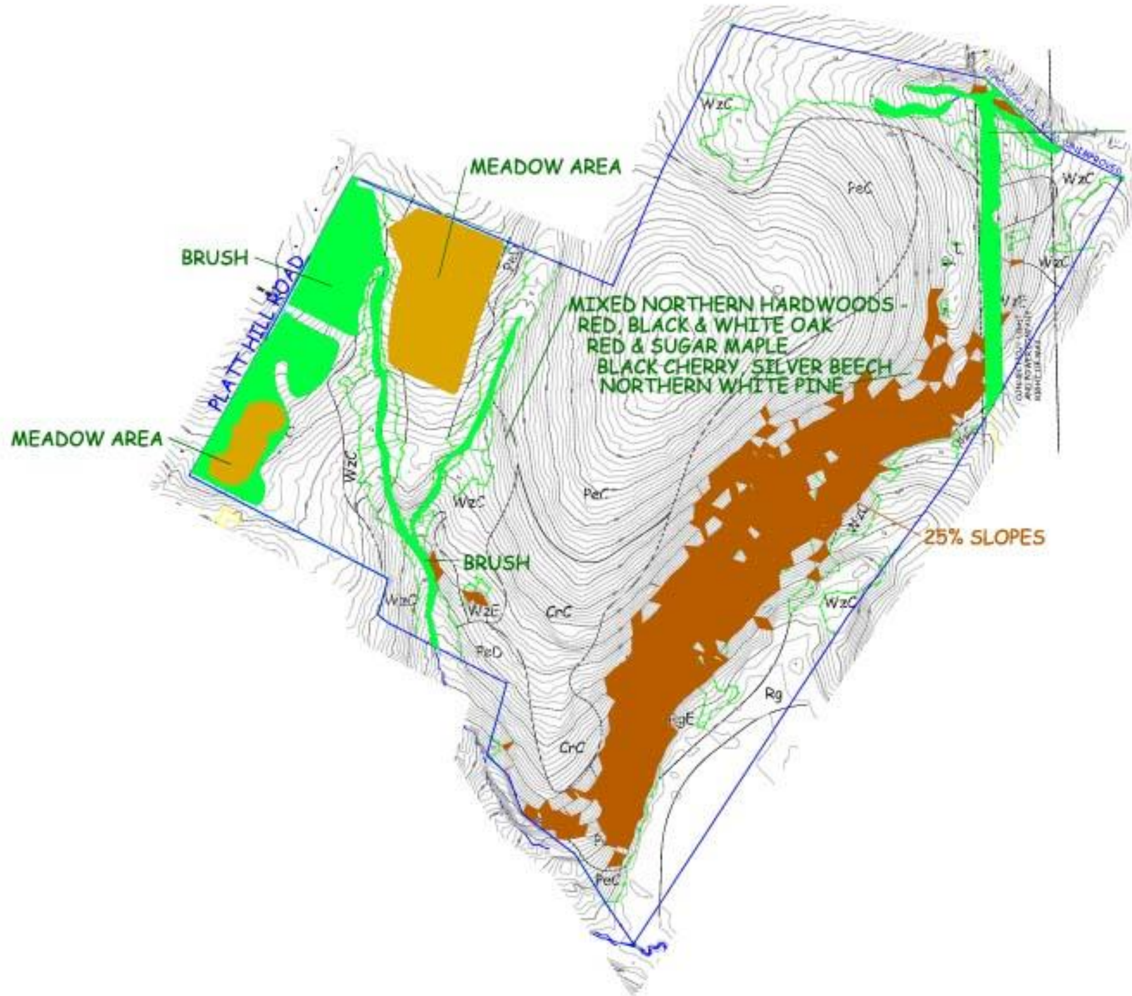



**Figure 9.2.2 - 25% Slopes/Vegetation Types**

Figure 9.2.2 shows the extent of 25% slopes on the site, along with the generalized vegetative communities.

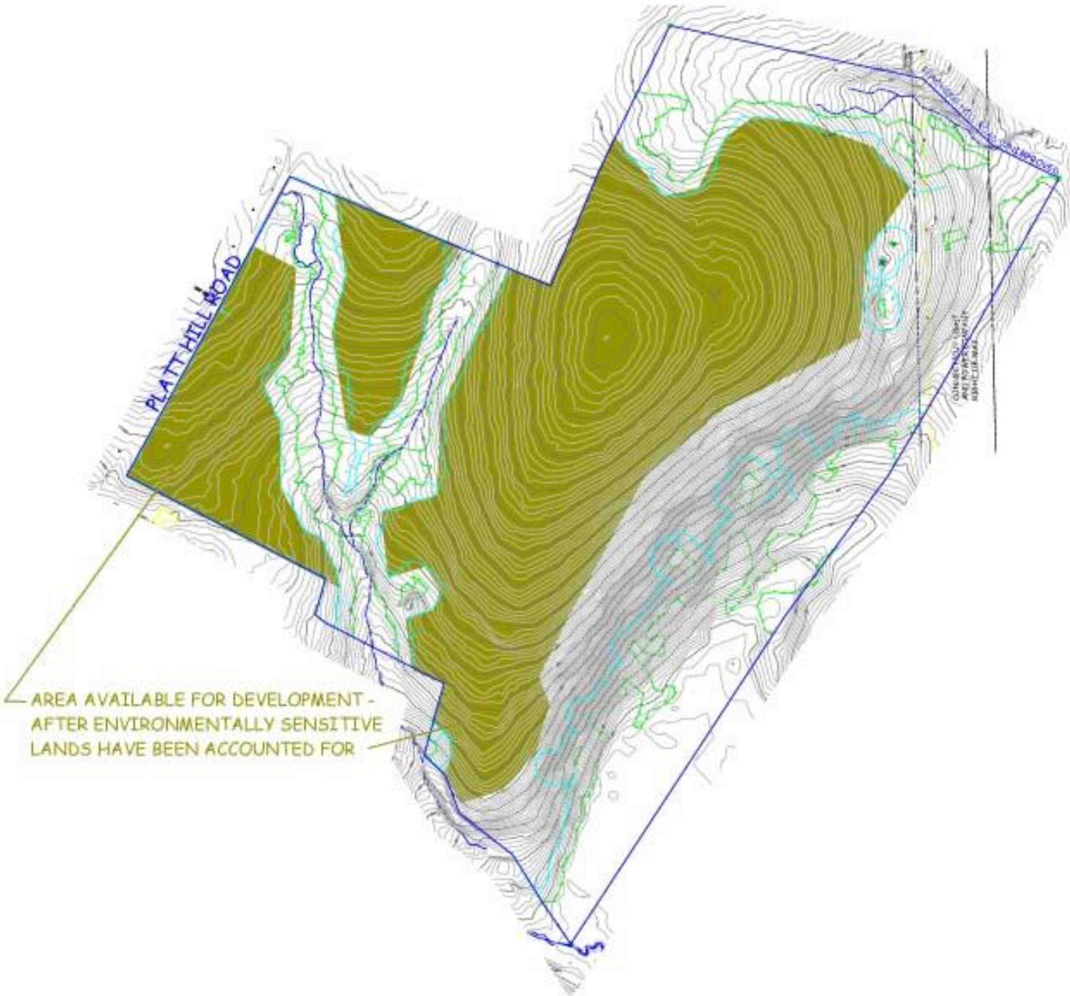



**Figure 9.2.3 - Developable Area**

Figure 9.2.3 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 LISD, 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 LISD strategies. At this point the strategies discussed in Section 3.4 for the layout of roads, driveways and lots shall be applied to the site.

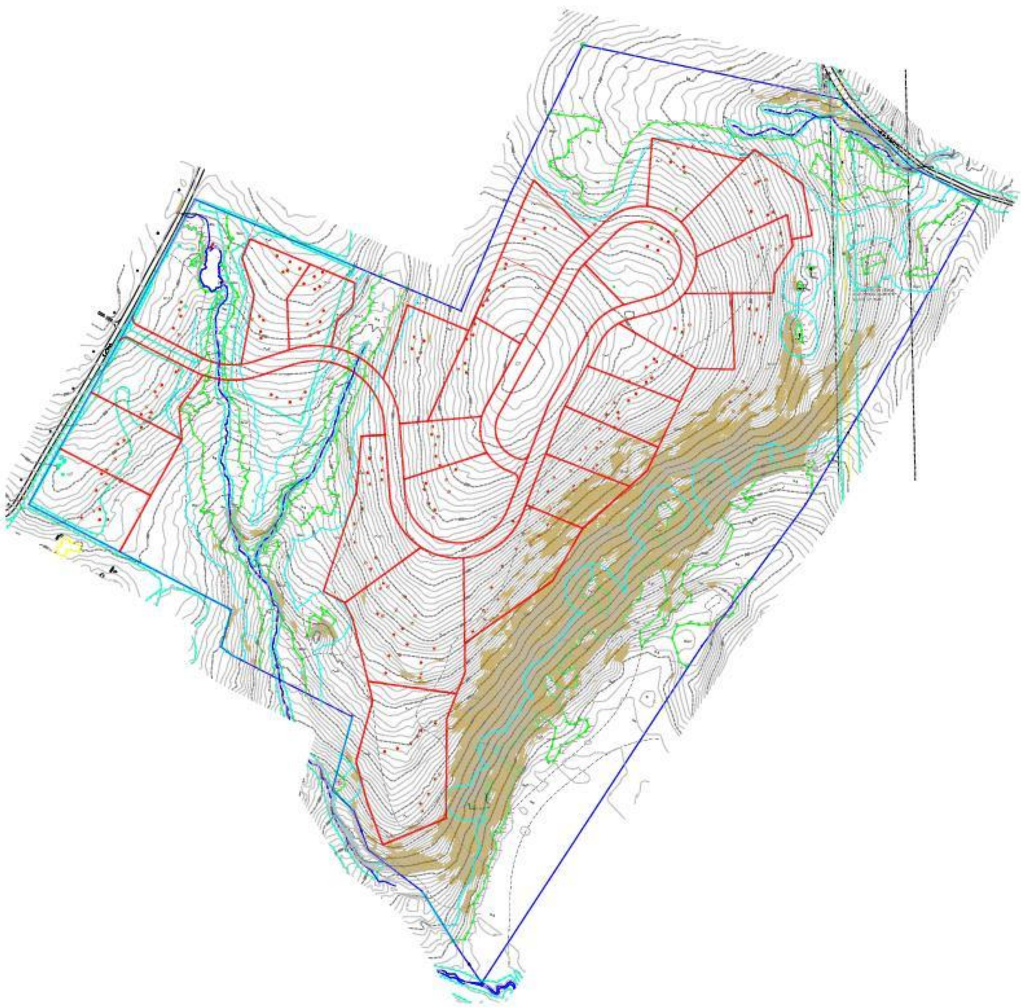


**Figure 9.2.4 – Road & Lot Layout**

In Figure 9.2.4, 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.

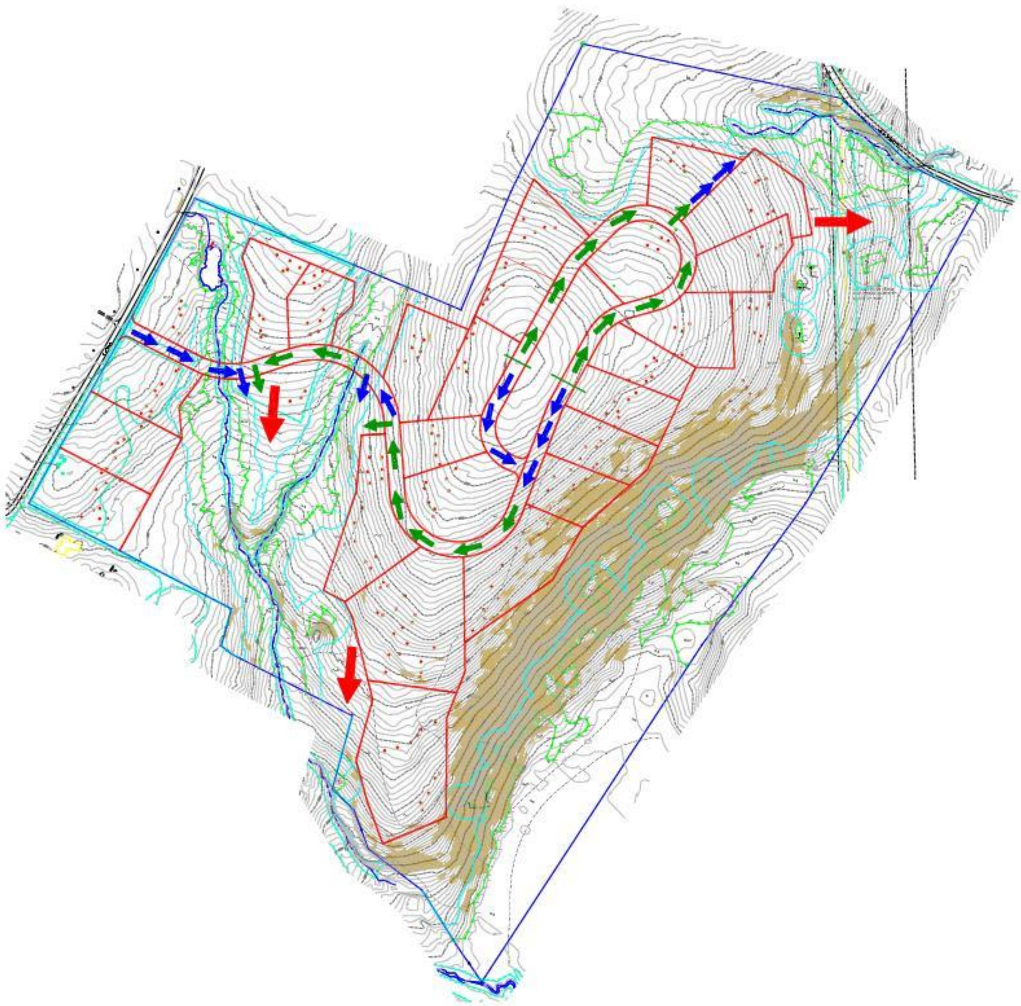


**Figure 9.2.5 – Preliminary stormwater layout**

Figure 9.2.5 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).

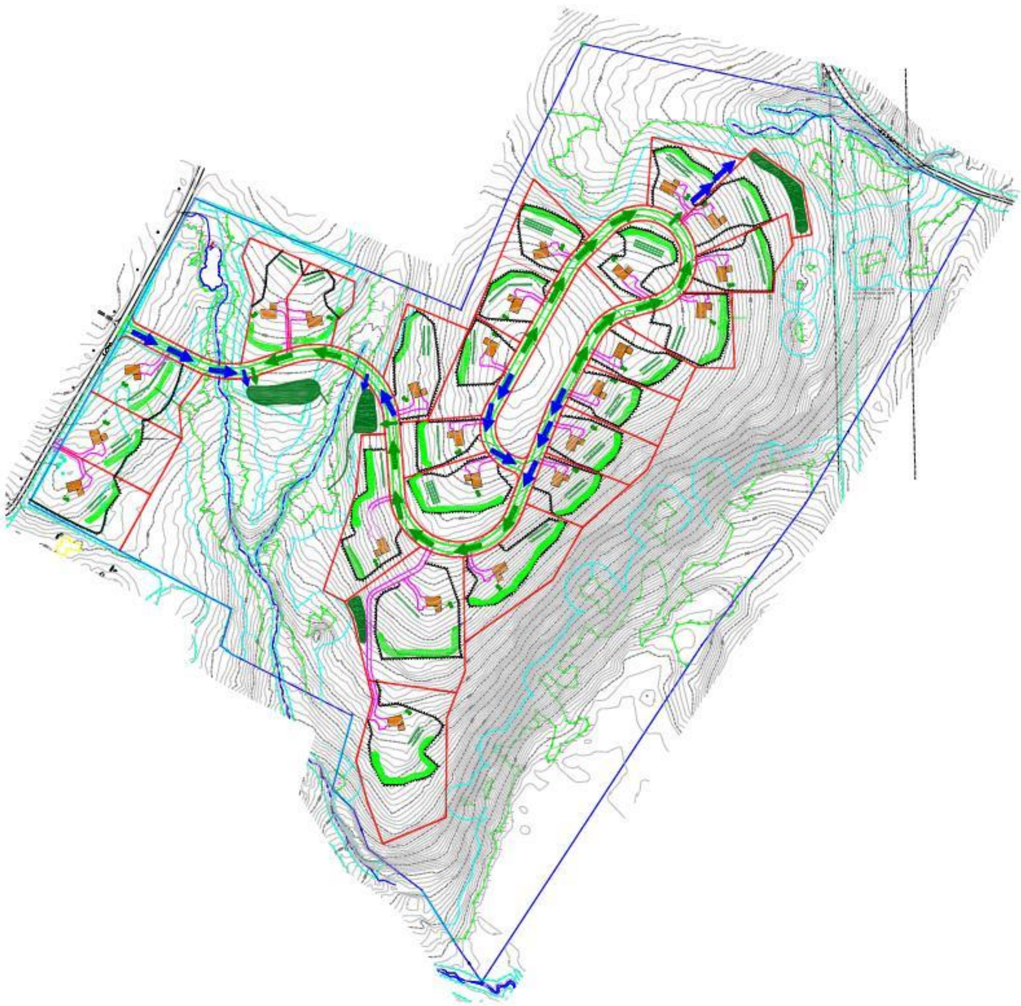


**Figure 9.2.6 – Implementation of LISD Concepts**

Figure 9.2.6 demonstrates how several LISD 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.

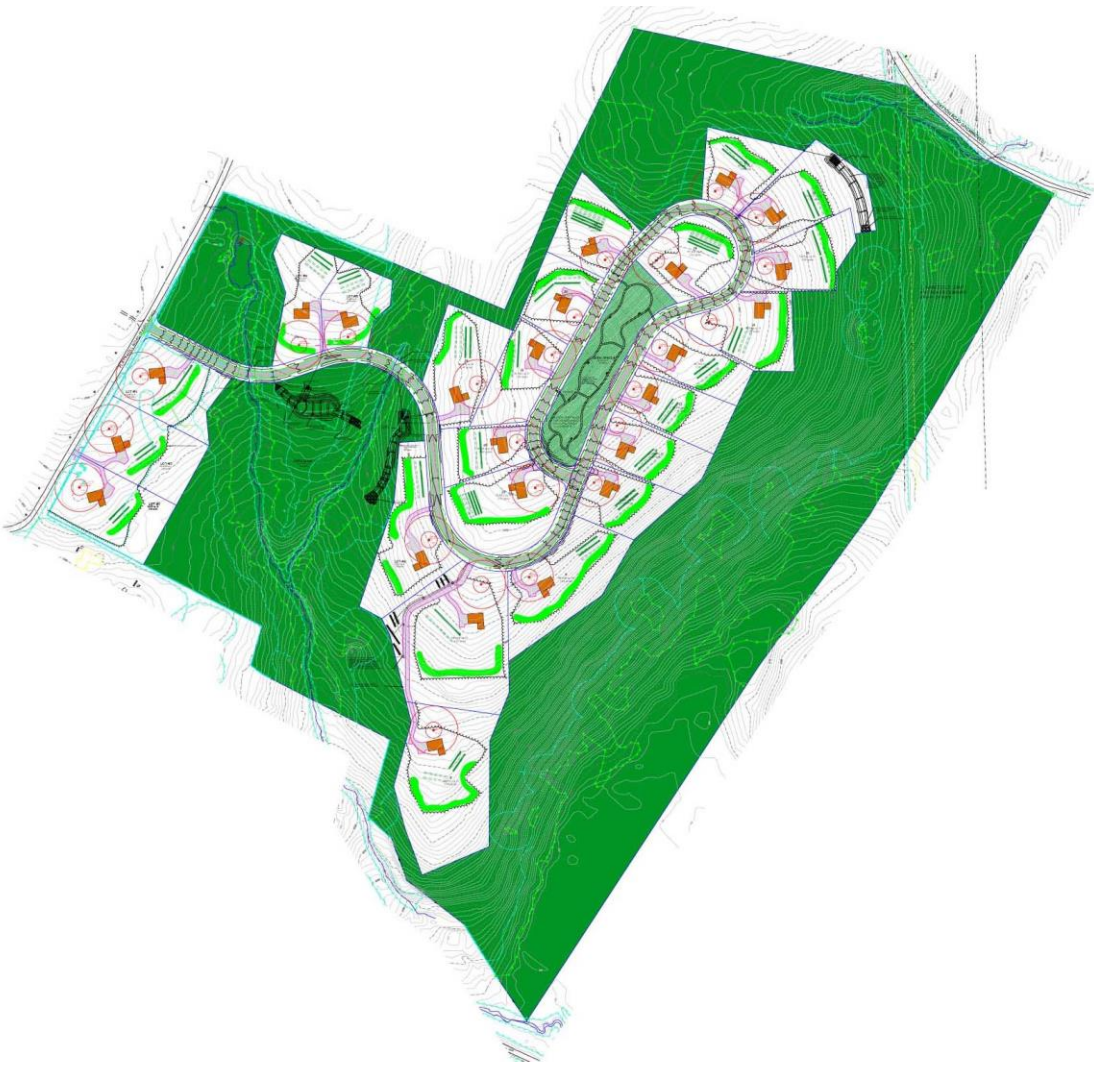


**Figure 9.2.7 – Final Site Design**

Figure 9.2.7 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 is 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 LISD strategies and treatment system, both metrics for LISD 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 LISD is meeting of the pre-development hydrologic conditions, the design will likely go through several iterations to reach the desired result. This project went through three design iterations before the LISD 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.

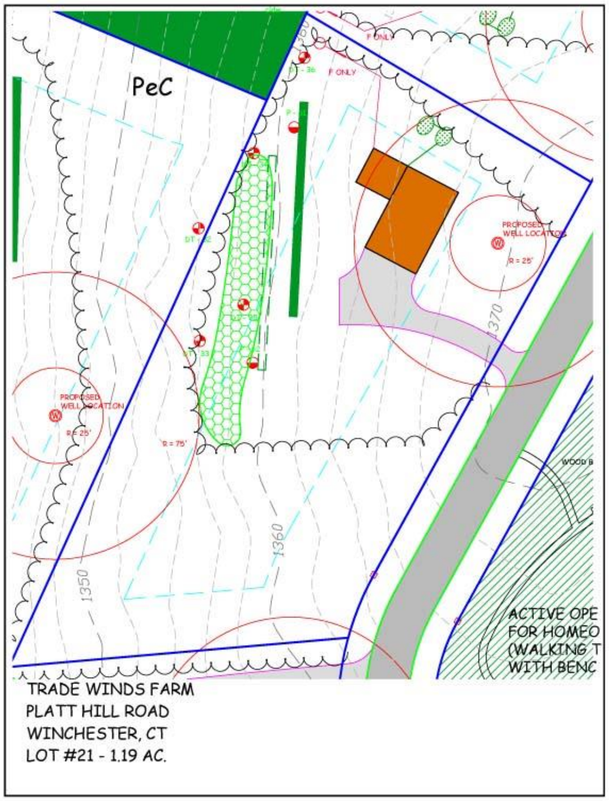



**Figure 9.2.8 – Individual Lot Design**

This figure demonstrates the application of the following LISD 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.

# Section 10.0
# 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 using 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 the trees from a given land area.

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 allows for passive recreation, common open space, and preservation of environmentally sensitive features.

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 runoff 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 Swale: A swale designed for water quality improvement by infiltrating runoff into the underlying soils as well as by flow through the vegetative cover. Can also be used for a conveyance system.

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

Effective Impervious Cover: That portion of the total impervious area on a site minus those impervious areas which are directed to one or more LISD Infiltrative Practices.

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 LISD 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): The amount of runoff from post-development conditions which must be infiltrated back into the ground to maintain pre-development infiltration rates by specific soil type.

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

Hydrologic Transparency: The use of LISD 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 roads, driveways, parking areas, sidewalks, alleys, tennis courts, pools, patios, roof tops, and concrete paver systems.

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

Integrated Management Practices (IMP): 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), Bioretention 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 Sustainable 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.

Phosphorus (P)-Index: The measure of the amount of phosphorus a soil contains. A low P-Index means a soil can absorb more phosphorus 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 this design manual.

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: A flexible delineation of the area to be cleared for residential or commercial development where the percent area to be cleared is defined and fixed, but the actual physical limit is flexible.

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 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.

Total Impervious Cover: The sum of all the impervious areas existing or proposed on a site.

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

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 1.3” of rain in 24-hours which results in 1” of runoff from an impervious surface.

Wet Swale: A vegetated conveyance system consisting of wetland soil and plants also used to reduce pollutants from storm water runoff.

# Section 11.0
# Low Impact Sustainable Development References


A. International Stormwater Best Management Practices Database by EWRI/ASCE
http://www.bmpdatabase.org/

B. Low Impact Sustainable Development – Technical Guidance Manual for Puget Sound, January 2005; Puget Sound Action Team – Washington State University Pierce County Extension
http://www.psp.wa.gov/

C. United States Environmental Protection Agency https://www.epa.gov/nps/urban-runoff-low-impact-development

D. National Stormwater Quality Database, Version 3.0 – 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
http://www.bmpdatabase.org/nsqd.html

E. New Hampshire Stormwater Manual,
https://www.des.nh.gov/organization/divisions/water/stormwater/manual.htm

F. Rhode Island Stormwater Design and Installation Standards Manual and Appendices, March 2015
http://www.dem.ri.gov/pubs/regs/regs/water/swmanual15.pdf

G. The Practice of Watershed Protection, http://www.cwp.org/

H. The Sustainable Sites Initiative http://www.sustainablesites.org/

I. University or New Hampshire Storm Water Center http://www.unh.edu/unhsc/

J. UNHSC Design Specifications for Porous Asphalt Pavement and Infiltration Beds, Revised to September 2016. University of New Hampshire, Cooperative Institute for Coastal and Estuarine Environmental Technology, Durham, NH
http://www.unh.edu/unhsc/sites/default/files/media/unhsc_pa_spec_-_feb-2014_-rev_9-16.pdf

K. UNHSC Subsurface Gravel Wetland Design Specifications, June 2016. University of New Hampshire, Cooperative Institute for Coastal and Estuarine Environmental Technology, Durham, NH
http://www.unh.edu/unhsc/sites/default/files/media/unhsc_gravel_wetland_spec_6-2016.pdf

L. Low Impact Development Center, http://www.lowimpactdevelopment.org/

M. Wisconsin Department of Natural Resources, http://dnr.wi.gov/topic/stormwater/

N. North Carolina State University Engineering Group, https://www.bae.ncsu.edu/stormwater/team.htm

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

# APPENDIX A
# STORMWATER MANAGEMENT PLAN CHECKLIST

**Stormwater Management Plan Checklist for Projects**

## A.1 General Information

- ☐ Appliant'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 Existing Conditions Mapping Requirements for LISD Site Plans

- ☐ Overall plan at a scale not to exceed 1" = 100'
- ☐ Detailed site plans are 1" = 40' or 1" = 20' depending upon size and scope of project
- ☐ North arrow
- ☐ Existing topography (2' contours based upon aerial or field mapping)
- ☐ 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 all man-made features on or adjacent to the site, such as roads, drainage systems, underground utilities, and buildings. Drainage and sanitary sewer systems shall have rim, inverts and pipe sizes shown on the plan and how the system is connected
- ☐ 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
- ☐ Existing watershed boundaries on the site
- ☐ Delineation of 25% slopes on the site
- ☐ Delineation of Developable area in accordance with Environmental Site Design requirements found in Section 2.4 of this manual

## A.3 Mapping Requirements for Proposed Project

- ☐ Site plans including all the following information shall be provided at a scale of 1" =20' or 1" = 40' depending upon size and scope of the project.
- ☐ Location & results of soil test pits performed on the site (deep test holes, infiltration tests)
- ☐ Location of proposed roads, lot lines, buildings, driveways, and other improvements to the site as may be applicable
- ☐ Location and general feasibility of on-site sewage disposal systems on the site, if applicable
- ☐ Defining of limits of "site fingerprinting" for proposed development to maintain as much of the site in the natural condition to maintain pre-development hydrology
- ☐ Location of all proposed stormwater management conveyance systems
- ☐ Layout of erosion and sedimentation control measures for entire project
- ☐ Construction narrative per CT DEP 2002 Guidelines for Soil Erosion & Sediment Control as amended, including inspection provisions during construction period and both short- & long-term maintenance provisions
- ☐ Delineation of proposed watershed boundaries on the site to each LISD BMP with the goal of maintaining existing drainage patterns to the maximum extent practicable
- ☐ Demonstrate that soil compaction has been minimized or will be remediated on the site
- ☐ Demonstrate how directly connected impervious area will be minimized on the site
- ☐ Calculation of the total impervious area on the site
- ☐ Calculation of the effective impervious area on the site
- ☐ Location and type of LISD BMPs at the source of the runoff
- ☐ All LISD and/or Conventional BMPs shall have rim, invert and contour elevations provided as applicable
- ☐ Construction details for all LISD systems
- ☐ Construction details for all Erosion/Sedimentation Control Measures
- ☐ Construction details for all other man-made improvements
- ☐ Calculations that demonstrate that flow velocities at the outlet pipes are reduced to non-erosive levels. Calculations shall follow CT DEP 2002 Guidelines for Soil Erosion and Sediment Control as amended

☐ If structural drainage systems are to be used, then the following information shall also be provided:

- Limits of each sub-watershed area to each structural drainage structure,
- Runoff Curve Number and Time of Concentration for each sub-watershed area
- Peak rate of runoff for the 10-year rainfall event
- Capacity of analysis of the pipe conveyance system to demonstrate that it safely conveys the peak rate associated with the 10-year rainfall event

## A.4 LISD Stormwater Management Report

☐ The LISD stormwater management report shall contain all the technical data required by this manual and all the design specifications found in the manual for LISD and/or Conventional stormwater treatment or conveyance systems. This data shall include, but it not limited to the following data

- **Written Narrative describing existing and proposed conditions,**
- **Tabular data showing the following:**
  - Pre-development peak rates and runoff volumes for water quality rainfall event and two-year rainfall event
  - Post-development peak rates and runoff volumes for water quality rainfall event and two-year rainfall event without treatment by a LISD system
  - Post-development peak rates and runoff volumes for water quality rainfall event and two-year rainfall event with treatment by a LISD system
  - Net change in the peak rate and runoff volume for water quality rainfall event and two-year rainfall event after treatment by a LISD system
- **Watershed maps for pre-development and post-development conditions**
- **Watershed maps shall also show sub-watershed areas directed to each LISD BMP**
- **Groundwater Recharge Volume (4.1.1)**
  - Provide amount and type of impervious cover in each sub watershed 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
- **Water Quality Volume (4.1.1)**
  - Provide amount and type of impervious cover in each sub watershed area
  - Provide calculations for the Water Quality Volume for each sub watershed area
  - Provide the amount of volume required to meet the Water Quality Volume
- **Pollutant Removal Renovation Analysis (4.2 to 4.5)**
  - Provide calculations of pollutant loads under pre-development conditions,
  - Provide calculations of pollutant loads for post-development conditions for each sub watershed area directed to a Best Management Practice,
  - Provide calculations to demonstrate that required pollutant load reductions will be achieved by the proposed LISD Best Management Practices
- **Channel Protection Flow Rate (4.1.4)**
  - 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
  - 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
- **Water Quality Flow (4.1.5)**
  - Calculation of Water Quality Flow if applicable for design of LISD BMP

- **Flood Protection (4.1.6)**
  - Calculations of the peak rate of runoff for pre-development and post-development conditions
  - Provide routing analyses to show how peak rate attenuation will be provided by LISD BMP
  - Analysis shall include Runoff Curve Number and Time of Concentration calculations (These calculations shall only be provided once for each sub-watershed area)
  - Watershed boundaries shall also be shown on the map

# APPENDIX B
# PLANT LIST FOR LISD TREATMENT SYSTEMS

## Plant List for LISD Treatment Systems

There are six distinct hydrological planting zones for Low Impact Sustainable 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 |

# APPENDIX C
# MAINTENANCE AGREEMENT FOR STORMWATER SYSTEMS

Note: The Stormwater Maintenance Agreement was reproduced from the New York State Stormwater Manual.

Stormwater Maintenance Agreement

Whereas the Municipality of Morris ("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 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 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 Morris 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 ______________________.

# APPENDIX D
# MODELING OF LISD INFILTRATION PRACTICES

All LISD infiltration practices must be hydrologic modeled to demonstrate that they will function property. This modeling can be done by using HydroCAD software or a similar program. For the modeling of Infiltration Best Management Practices, a maximum of 50% of the slowest observed field infiltration rate shall be used in the hydrologic model. The following is a sample analysis to model a Bioretention system:

1. PRE-DEVELOPMENT CONDITIONS:
    a. Define watershed boundaries and area for subject property to design point for pre-development conditions,
    b. Calculate the Runoff Curve Number (RCN) by land cover type and soil type pre-development watershed areas,
    c. Define and calculate the Time of Concentration (Tc) for pre-development watershed areas,
    d. Enter all data into HydroCAD or similar program to calculate peak rate of runoff and runoff volume for following storm events and rainfall intensities:
        i. Water Quality Storm, 1.3"/24 hour
        ii. Two-year Storm, 3.3"/24 hour
        iii. Ten-year Storm, 4.8"/24 hour
        iv. Twenty-five-year Storm, 5.5"/24 hour
        v. Fifty-year Storm, 6.2"/24 hour
        vi. One-hundred-year Storm, 7.0"/24 hour

2. POST-DEVELOPMENT CONDITIONS:
    a. Define watershed boundaries and area on subject property to each proposed LISD BMP for post-development conditions,
    b. Calculate the Runoff Curve Number (RCN) by land cover type and soil type for each post-development area directed to LISD BMP,
    c. Define and calculate the Time of Concentration (Tc) for each post-development area directed to LISD BMP,
    d. Enter all data into HydroCAD or similar program to calculate peak rate of runoff and runoff volume for following storm events and rainfall intensities for each post-development area directed to a LISD BMP or by-pass area (area which is not directed to BMP):
        i. Water Quality Storm, 1.3"/24 hour
        ii. Two-year Storm, 3.3"/24 hour
        iii. Ten-year Storm, 4.8"/24 hour
        iv. Twenty-five-year Storm, 5.5"/24 hour
        v. Fifty-year Storm, 6.2"/24 hour
        vi. One-hundred-year Storm, 7.0"/24 hour
    e. Calculate Groundwater Recharge Volume for the contributing drainage area to the LISD BMP,
    f. Calculate Water Quality Volume for contributing drainage area to the LISD BMP,
    g. Calculate the bottom area of the Bioretention Cell using the formula found in Section 7.1 of the Manual using the appropriate maximum allowable ponding depth based upon soil conditions,

h. Layout the size and shape of the Bioretention system. Measure the surface area of the bottom of the Bioretention cell as well as the top of the berm,
i. In HydroCAD, click on the 'Storage' Tab, use the Custom Stage Data option for a detention pond to enter the elevation and area of bottom and top contour of the Bioretention cell, click box to "Allow Exfiltration", embed Inside shall be set to 'nothing'; Storage Multiplier shall be set to 1.0; and voids shall be set to 100.0,
j. Click on the 'Outlets' Tab, for first outlet, choose "Exfiltration"; 'Routing' Tab to be set to "Discarded"; 'Constant Velocity' under the 'Type" Tab shall be highlighted; under 'Velocity' Tab, insert 50% of the slowest observed infiltration rate (observed rate = 6"/hr, so use 3"/hr); under 'Apply to Available' Tab, click "Surface Area"; under 'Allow Exfiltration' Tab, click "At all elevations"; the 'Discharge Multiplier' Tab shall be set to "1.0",
k. Create second outlet for the Bioretention cell, this is commonly an Orifice/Grate; choose this option on the menu; for vertical PVC riser pipes, insert the invert elevation for the top of the pipe above the soil surface; set the diameter of the outlet pipe in the 'Office Diameter' Tab; set number of outlet pipes in the 'Rows' Tab; click the "Horizontal Plane" under the 'Opening in' Tab; the discharge coefficient will automatically set to 0.6,
l. Once this information has been set, you can run the routing analysis for the LISD BMP.

3. The following are the HydroCAD reports for a sample analysis:

PRE-DEVELOPMENT CONDITIONS

**Summary for Subcatchment 9S: pre-development**

[45] Hint: Runoff=Zero

Runoff = 0.00 cfs @ 0.00 hrs, Volume= 0 cf, Depth= 0.00"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type III 24-hr WQ Storm Rainfall=1.30"

| Area (sf) | CN | Description |
|---|---|---|
| 32,595 | 60 | Woods, Fair, HSG B |
| 32,595 | | 100.00% Pervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 6.0 | | | | | **Direct Entry, ex** |

## POST-DEVELOPMENT CONDITIONS (NO DETENTION)

**Summary for Subcatchment 7S: post-development**

Runoff = 0.00 cfs @ 14.97 hrs, Volume= 69 cf, Depth> 0.03"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type III 24-hr WQ Storm Rainfall=1.30"

| Area (sf) | CN | Description |
|---|---|---|
| 2,400 | 98 | Paved parking, HSG B |
| 1,560 | 98 | Unconnected roofs, HSG B |
| 742 | 98 | Unconnected pavement, HSG B |
| 8,000 | 74 | >75% Grass cover, Good, HSG C |
| 19,893 | 60 | Woods, Fair, HSG B |
| 32,595 | 69 | Weighted Average, UI Adjusted CN = 68 |
| 27,893 | | 85.57% Pervious Area |
| 4,702 | | 14.43% Impervious Area |
| 2,302 | | 48.96% Unconnected |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 6.0 | | | | | **Direct Entry, roof runoff** |

## IMPERVIOUS AREA DIRECTED TO BIORETENTION SYSTEM

**Summary for Subcatchment 10S: Impervious**

Runoff = 0.13 cfs @ 12.09 hrs, Volume= 424 cf, Depth> 1.08"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type III 24-hr WQ Storm Rainfall=1.30"

| Area (sf) | CN | Description |
|---|---|---|
| 4,702 | 98 | Roofs, HSG B |
| 4,702 | | 100.00% Impervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 6.0 | | | | | **Direct Entry, post-dev** |

## ROUTING OF WATER QUALITY STORM THROUGH BIORETENTION SYSTEM

**Summary for Pond 8P: Bioretention**

| | | | |
|---|---|---|---|
| Inflow Area = | 4,702 sf,100.00% Impervious, Inflow Depth > 1.08" for WQ Storm event | | |
| Inflow = | 0.13 cfs @ 12.09 hrs, Volume= | 424 cf | |
| Outflow = | 0.07 cfs @ 12.21 hrs, Volume= | 424 cf, | Atten= 44%, Lag= 7.6 min |
| Discarded = | 0.07 cfs @ 12.21 hrs, Volume= | 424 cf | |
| Primary = | 0.00 cfs @ 0.00 hrs, Volume= | 0 cf | |

Routing by Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Peak Elev= 77.74' @ 12.21 hrs Surf.Area= 1,021 sf Storage= 37 cf

Plug-Flow detention time= 4.1 min calculated for 423 cf (100% of inflow)
Center-of-Mass det. time= 3.7 min ( 782.8 - 779.1 )

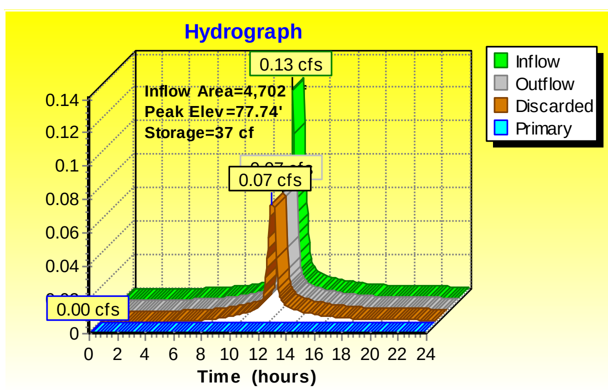
| Volume | Invert | Avail.Storage | Storage Description |
|---|---|---|---|
| #1 | 77.70' | 1,611 cf | **Custom Stage Data (Prismatic)** Listed below (Recalc) |

| Elevation (feet) | Surf.Area (sq-ft) | Inc.Store (cubic-feet) | Cum.Store (cubic-feet) |
|---|---|---|---|
| 77.70 | 1,001 | 0 | 0 |
| 78.00 | 1,161 | 324 | 324 |
| 79.00 | 1,413 | 1,287 | 1,611 |

| Device | Routing | Invert | Outlet Devices |
|---|---|---|---|
| #1 | Discarded | 77.70' | **3.000 in/hr Exfiltration over Surface area** |
| #2 | Primary | 78.45' | **4.0" Horiz. Orifice/Grate** X 2 rows C= 0.600<br>Limited to weir flow at low heads |

**Discarded OutFlow** Max=0.07 cfs @ 12.21 hrs HW=77.74' (Free Discharge)
↑**1=Exfiltration** (Exfiltration Controls 0.07 cfs)

**Primary OutFlow** Max=0.00 cfs @ 0.00 hrs HW=77.70' (Free Discharge)
↑**2=Orifice/Grate** ( Controls 0.00 cfs)




BY-PASS AREA NOT DIRECTED TO BIORETENTION SYSTEM

**Summary for Subcatchment PR1: post-bypass**

Runoff = 0.00 cfs @ 21.59 hrs, Volume= 12 cf, Depth> 0.01"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type III 24-hr WQ Storm Rainfall=1.30"

| Area (sf) | CN | Description |
|---|---|---|
| 8,000 | 74 | >75% Grass cover, Good, HSG C |
| 19,893 | 60 | Woods, Fair, HSG B |
| 27,893 | 64 | Weighted Average |
| 27,893 | | 100.00% Pervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 6.0 | | | | | **Direct Entry, post-dev** |

# APPENDIX E
# DOUBLE RING INFILTRATION TESTING PROTOCOL

All LISD Infiltrative systems defined in Section 7.0 of this manual must have infiltration tests performed in accordance with this section to determine the suitability of the soil for infiltration and for the modeling of an infiltration Best Management Practice.

It is highly recommended that the Turf-Tech Infiltrometer be used for the performing of infiltration tests for LISD systems.

Required Steps for Double Ring Infiltration Tests:

1. Test pit shall be excavated by a hydraulic excavator to a depth which is at or below the bottom of the soil media or gravel layer for a LISD Infiltrative system. The test pit shall be wide enough to allow for safe access for the design professional to work at the bottom of the test pit,
2. A three-prong garden rake shall be used to loosen the smeared and slightly compacted soil at the bottom of the test pit where the infiltration test is to be performed. Loosened soil shall be removed area of the test,
3. The Infiltrometer shall be pushed into the soil layer at the bottom of the test pit using the handles on the Infiltrometer until the bottom metal plate is flush to the soil surface,
4. Fill both the inner and outer rings of the infiltrometer with water to the top of the rings. Let the water drain into the soil. When the water has drained down to the soil surface, refill the rings and repeat. This procedure shall be repeated a minimum of three times before commencing the infiltration test,
5. Conduct the actual infiltration test:
   a. Confirm that timer is set to 0 minutes and 0 seconds,
   b. Refill outer ring and maintain the water surface to the top of outer ring throughout the test,
   c. Fill the inner ring to the top, so that the pointer on the float scale is set at the top of the vertical ruler. Push the start/stop button on the timer. Timer is set for automatically set for 15 minutes, when timer ends, observe measurement on scale. Write down drop in inches per 15 minutes. If you are doing the infiltration test in well drained soils, you will need to stop the timer before the point reaches the bottom of the ruler. Write down the drop in inches and the time duration,
   d. Repeat this test a minimum of three times. The rates should be consistent. If there is a wide range of results between the observations (> 1” per 15 minutes), run the additional times until the rates are within a range of 0.5” between the high and low readings,
   e. Convert the observed data to inches per hour, which is the standard for infiltration tests,
   f. The slowest observed infiltration rate shall be used in the design of LISD Infiltration treatment systems,
   g. Remove Infiltrometer from soil and clean the metal to remove any soil which has stuck onto the two rings.