NORTHWOOD STORMWATER TECHNOLOGIES

A Final Report to

The New Hampshire Estuaries Project

Submitted by:
The Water Resources Sub-Committee
Town of Northwood, NH

Prepared by:
TTG Environmental Consultants, LLC
Concord, NH

November 13, 2008

This project was funded in part by a grant from the New Hampshire Estuaries Project as authorized by the U.S. Environmental Protection Agency's National Estuary Program.

TABLE OF CONTENTS

CHAPTER

COVER LETTER

INTRODUCTION 1

NEED FOR STORMWATER MANAGEMENT 2

STORMWATER MANAGEMENT CONCEPTS 4

STORMWATER MANAGEMENT TECHNOLOGIES
APPROPRIATE FOR NORTHWOOD 6

QUANTITY CONTROLS
- Quantity Control Requirements in Northwood 8
- Detention Basins 9
- Subsurface Detention Facilities 10
- Infiltration Practices 12

QUALITY CONTROLS
- Stormwater Ponds 14
- Stormwater Wetlands 15
- Infiltration Practices 16
- Filtering Practices 17
  - Surface Sand Filter 17
  - Subsurface Wetland 19
  - Bioretention Systems 20
  - Tree Box Filter 22
  - Vegetated Buffers 23
  - Permeable Pavement 24
- Treatment Swales 26
- Manufactured Practices 27

LIST OF REFERENCES 28

APPENDIX: Summary of Review of Relevant Documents, July 2008

INTRODUCTION

TTG Environmental Consultants, LLC (TEC), under contract to the New Hampshire Estuaries Project and in conjunction with the Northwood Water Resources Sub-Committee, has prepared this report on stormwater technologies appropriate for the Town of Northwood, NH. This report is divided into two (2) main sections with a number of subsections. The first section describes the need for stormwater management, and the second section describes stormwater management technologies that are appropriate for Northwood.

Stormwater management has been evolving for many years, from a need to convey stormwater away from or through a developed site, to the realization that land development has a significant impact on the rate, volume, and quality of stormwater runoff, and that these impacts to the runoff leads to corresponding impacts on downstream properties and receiving water bodies. Much of this increased awareness has been growing since the 1970’s with the passage of the Federal Clean Water Act in 1972, and subsequent revisions. It is now understood that stormwater runoff is one of the leading causes of water quality violations in many of our water bodies.

The State of NH has had an evolving stormwater program for more than 25-years, the NH Department of Environmental Services, Alteration of Terrain program (AOT). The latest iteration of this evolution is evident in the proposed program rules. The revisions to the rules, expected to be implemented late this year (2008) will create a state-of-the-art stormwater management program and address many of the current issues associated with stormwater from land development. It should be noted that the AOT program only regulates larger developments.

In addition to the Alteration of Terrain program, the University of New Hampshire has a very active Stormwater Center at its Durham campus. The Center, funded by various grants, performs research and education on many of the various stormwater treatment technologies in use today. According to the Center’s 2005 report, the “Center… evaluates the effectiveness of different stormwater treatments in a side-by-side setting, under strictly controlled conditions. It is the only testing facility of its kind in the nation.”

The Town of Northwood Water Resources Sub-Committee, understanding the importance of adequate stormwater management, and wishing to address these issues on a local level, has instituted this report. This report will attempt to explain the need for proactively dealing with stormwater issues, and describe the various technologies currently available to address these needs. One of the major thrusts of this report is to identify stormwater management practices suitable for a rural/suburban community such as Northwood.

NEED FOR STORMWATER MANAGEMENT

Land development has a number of impacts upon stormwater runoff. These impacts are well documented, and it is not the purpose of this report to detail them. However, a brief overview is presented as an introduction to the subject of stormwater technologies. These impacts can be divided into two (2) broad categories; hydrologic impacts and water quality impacts.

Hydrologic Impacts

A typical development removes much of the natural vegetation from a site and replaces it with buildings, pavement and landscaped areas. These changes tend to create a site that is substantially less pervious and hydrologically more efficient than the undeveloped site, which is to say that the site sheds water more quickly and retains less. This decrease in pervious surfaces and increase in hydrological efficiency increases both the rate and volume of runoff, resulting in a number of impacts including:

- Reduced infiltration of stormwater.
- Decrease in time to peak runoff rate.
- Reduced groundwater recharge.
- Reduced stream base flow (Dry weather flow).
- Increase in stream channel size.
- Increase in downstream flooding.

The U.S. Environmental Protection Agency publication "Low Impact Development Hydrologic Analysis" states:

> *Changes in Existing Hydrologic Balance. Both the annual and seasonal water balance can change dramatically as a result of development practices. These changes include increases in surface runoff volume and decrease in evapotranspiration and groundwater recharge. For example, eastern hardwood forests typically have an annual water balance comprised of 40% evapotranspiration, 50% subsurface flows and less than 10% surface runoff volume. Development, depending on its size and location in a watershed, alters the existing hydrologic balance by increasing surface flow volumes up to 43%, reducing subsurface flows to 32%, and reducing evapotranspiration rates to 25%. All this results in major changes to the local hydrology."*

These impacts manifest themselves in a number of ways:

a. Decreased groundwater recharge due to reduced infiltration of stormwater.
b. Reduced stormwater infiltration results in decreased water volume available to streams during dry periods.
c. To accommodate higher rates of runoff, stream channels increase their capacity by becoming larger through erosion.
d. Higher rates of runoff will increase both the frequency and size of flooding events.

As a result of b. and c. above, perennial streams in areas without proper stormwater management have been known to become seasonal streams, dry for portions of the year even as their channels become larger.

Water Quality Impacts

Runoff from snowmelt, rainfall and other sources such as irrigation has the potential to pick up and carry away whatever is on the surface of the landscape. This is not a significant concern in natural areas, as the overland runoff flow rates and velocities are much lower than in developed areas. The runoff from natural areas is more diffuse and for many storms, infiltrates prior to reaching surface waters. In addition, the amount of pollutants present on the ground surface available for transport to surface waters in natural areas is much less than in developed areas. Developed areas tend to have a significant percentage of impervious area, which is much more hydrologically efficient, allowing the runoff to pick up and transport surface pollutants. Developed surfaces have much higher pollutant loads on them because of human activity. These pollutants may include trash, sediments, oils and grease, pet droppings, pesticides, fertilizers, and anything else that can be deposited by human and animal activity. Runoff will flush many of these pollutants to other, often undesirable locations. Some of the documented impacts of unmanaged runoff to surface waters include:

- Bacteriological contamination.
- Toxicity impacts from ammonia, metals, organic compounds, pesticides and other contaminants.
- Nuisance algal growth from nutrients.
- Reduced dissolved oxygen levels due to the presence of oxygen-demanding substances in runoff.
- Increased temperature from runoff passing over surfaces with elevated temperature levels, such as parking lots.
- Contamination from runoff exposed to chemicals, such as road salt.

STORMWATER MANAGEMENT CONCEPTS

Stormwater management has been a concern of human society for thousands of years. However, it is only in recent decades that attempts have been made to mitigate the impacts to surface water from stormwater runoff. As the technology has progressed over recent decades, stormwater management has progressed from heavily engineered practices to more natural practices that attempt to mimic pre-development drainage patterns and strategies, although the engineered practices are often the only viable option in many circumstances. An overview of how the natural systems manage stormwater runoff is useful in understanding how the built environment should also address these issues.

ITEM	NATURAL SYSTEM RESPONSE
Runoff Rate	Runoff travel time tends to be longer than over developed areas because runoff velocity is lower as a result of surface roughness, surface storage and longer runoff paths.
Runoff Volume	Runoff volume is reduced by infiltration, diffuse and concentrated surface storage, and evapo-transpiration.
Pollutant Loading	There is a limited potential for surface loading of many pollutants common in developed areas; many nutrients that are present are reduced or eliminated by cycling through natural systems, including uptake and incorporation into the plant biomass, and being tied up in the soil matrix.

The state of the art practice in stormwater management is to apply a natural response to the extent practical in the built environment. Accomplishing this leads to more diffuse stormwater management, i.e., managing the stormwater closer to its source verses at the end of the pipe. The creation of Low Impact Development (LID) strategies in recent years is a direct result of attempting to implement natural stormwater management solutions and replicate natural outcomes. The Unified Facilities Criteria, Design of Low Impact Development Manual, US Department of Defense provides the following excellent definition of LID:

> *LID is a stormwater management strategy concerned with maintaining or restoring the natural hydrologic functions of a site to achieve natural resource protection objectives and fulfill environmental regulatory requirements. LID employs a variety of natural and built features that reduce the rate of runoff, filter out its pollutants, and facilitate the infiltration of water into the ground. By reducing water pollution and increasing groundwater recharge, LID helps to improve the quality of receiving surface waters and stabilize the flow rates of nearby streams.*
>
> *LID incorporates a set of overall site design strategies as well as highly localized small-scale, decentralized source control techniques know as Integrated Management Practices (IMPs). IMPs may be integrated into buildings, infrastructure, or landscape design. Rather than collecting runoff in piped or channelized networks and controlling the flow*

downstream in a large stormwater management facility, LID takes a decentralized approach that disperses flows and manages runoff closer to where it originates.

Two of the main concepts at the core of LID stormwater management are disconnected impervious areas and diffuse stormwater management. Traditional stormwater management practices include all the impervious areas, such as roofs and pavement, in the central stormwater collection system. This creates high peak flows and limits the ability of the stormwater to infiltrate on site. The LID approach disconnects the impervious areas, which allows runoff from impervious areas to flow over pervious areas. LID design can take many forms, such as directing roof runoff over lawn or landscaped areas or into infiltration drip zones, and allowing parking areas to flow onto perimeter landscape areas. LID design aims to maintain existing drainage features and patterns where possible.

The most cost effective and often ignored method of addressing stormwater quality concerns is pollution prevention. Pollution prevention can be addressed though a number of means such as good housekeeping (litter disposal), limiting the use of fertilizers, public education, street sweeping, etc. These methods are usually overlooked, but offer very cost effective solutions as it is easier to prevent pollution than it is to treat it. LID concepts will be emphasized in this report, but more heavily engineered practices will also be discussed.

STORMWATER MANAGEMENT TECHNOLOGIES APPROPRIATE FOR NORTHWOOD

While it is impossible to know every future circumstance that will require stormwater management, it is expected that most future development will be similar to past types. This assumption will allow for the selection of typical stormwater treatment practices suitable for Northwood. This report considers two (2) broad categories: that of a typical residential development with relatively low density and that of a commercial/industrial site, with a significant percentage of impervious areas. Secondary criteria will be the restrictions imposed by the site itself, such as slope, existing wetlands, soils and receiving water.

The low-density development is ideal for LID practices. There is typically sufficient land available to site diffuse practices, disconnected impervious areas, and open stormwater conveyance measures. Detention facilities can be small and spread throughout the development. Curb and gutter closed drainage systems should be avoided. This type of design will create a complete stormwater management system, which will diffuse throughout the site and attempt to replicate the natural system.

The higher density sites present additional challenges, but are by no means unsuitable for LID practices. Diffuse stormwater management is possible in landscaped areas, within parking lot aisles, around the pavement perimeter, at grassed panels between pavement and walks, and in many other pervious areas. In addition, infiltration can be accomplished in subsurface detention systems to reduce the outflow to surface water. Even in soils not conducive to large amounts of infiltration, a significant amount of groundwater recharge can be achieved on an annual basis with properly designed subsurface detention systems.

The following table shows the suitability of particular practices for various land uses and lot constraints. Following sections of this report provide more information specific to each practice. However, this report is not intended to be a design manual, and the reader is referred to other sources, such as those in the reference section, for more information.

PRACTICE	LID Y/N	Suitable Low Density Residential Y/N	Suitable High Density Comm/Ind Y/N	Preferred Soil Type NRCS/HSG See Note 7	Suitable High Groundwater	Suitable Steep Slopes
QUANTITY CONTROL						
Detention Basin	[1]	Y	Y	All[8]	Y[8]	N
Subsurface Detention	[1]	N[4]	Y	All[8]	Y[8]	N
Infiltration	Y	Y[5]	Y	A, B & C	N	Y[10]
QUALITY CONTROL						
Stormwater Ponds	[1]	Y[6]	Y	B, C, & D[9]	Y[9]	N
Stormwater Wetlands	[1]	Y[6]	Y	B, C, & D[9]	Y[9]	N
Infiltration	Y	Y[5]	Y	A, B, & C	N	Y[10]
Surface Sand Filter	Y	N[4]	Y	A, B, & C	N	Y[10]
Subsurface Wetland	Y	N[4]	Y	All	Y[9]	N
Bioretention	Y	Y	Y	All	Y	Y
Tree Box Filter	Y	Y	Y	All	Y	Y
Vegetated Buffers	Y	Y	Y	All	Y	Y
Permeable Pavement	Y	Y[6]	Y	All	N	N
Treatment Swales	[2]	Y	Y	A, B, & C	Y	Y
Manufactured Products	[3]	N	Y	All	Y	Y

NOTES:

1. Not normally a LID practice but frequently used with LID practices as part of an overall stormwater management system.
2. Not a LID practice but frequently used as part of LID design for water conveyance and pre-treatment.
3. Pre-treatment practice only, particularly for subsurface systems or treatment system in retrofit of existing sites.
4. Not generally suitable for low-density residential developments due to cost and maintenance responsibilities.
5. Infiltration in low-density residential should be limited to those practices that achieve it as part of overall functionality. Infiltration practices require maintenance not normally available in these types of developments.
6. These practices not normally cost effective except in large developments.
7. Development on Group D soils should be limited.
8. These practices in high groundwater soils may have continuous discharge during portions of the year.
9. These practices require base flow of water typically from groundwater.
10. Slope will limit size and surface breakout of water must be considered during design.

QUANTITY CONTROL

Quantity Control Requirements in Northwood

The Northwood Site Plan Review Regulations contain extensive requirements for the control of both the volume and rate of stormwater runoff. These regulations require as a minimum the following:

> The two-year, 24-hour post-development peak flow rate shall be (a) less than or equal to 50 percent of the two-year, 24-hour pre-development peak flow rate and (b) less than or equal to the one-year, 24-hour pre-development peak flow rate.
>
> The post-development total runoff volume shall be equal to 90 to 110 percent of the pre-development total runoff volume (based on two-year, 10-year and 25-year, 24-hour storms).
>
> Except where prohibited, stormwater management designs shall demonstrate that the annual average recharge volume for the major hydrologic soil groups found on-site are maintained.

These regulations require the designer to consider the use of infiltration practices as well as other measures, such as limiting impervious surfaces, utilizing porous pavements, disconnected impervious areas, and other measures to properly manage stormwater. Stormwater detention facilities may be incorporated into an overall stormwater management system, but typically not the sole method of managing stormwater quantity control.

Detention Basins

Detention basins are one of the most common stormwater management measures in use today. The basic detention basin is storage pond designed for either one particular storm, or a series of storm events with sufficient volume to reduce the rate of runoff to some predetermined outlet rate. Detention basins reduce the rate of runoff, but are not typically capable of reducing the volume of runoff. An extended detention basin is a variation of the standard detention basin designed to detain runoff for longer periods of time, typically 24-hours or more. This longer detention time allows time for settling of a portion of the suspended solids.

Advantages	Disadvantages
• Least costly practice to address both quality and quantity issues. • When designed as Extended Detention with sediment forebays can remove significant amounts of sediment and the absorbed pollutants. • Less hazard potential as compared with practices that have a permanent pool.	• Minimal runoff volume reduction. • Minimal removals of soluble pollutants. • Requires relatively large land area. • Potential warming of stormwater. • Resuspension of sediments during large storm events has been reported. • Potential for insect vector problem if basin creates a pool of standing water.

Detention ponds are one of the most common stormwater management measures, and are appropriate under many circumstances for use in Northwood. They are not a LID practice and should be used where LID practices are not feasible or to augment LID practices.

Small Detention Pond at an Industrial Facility

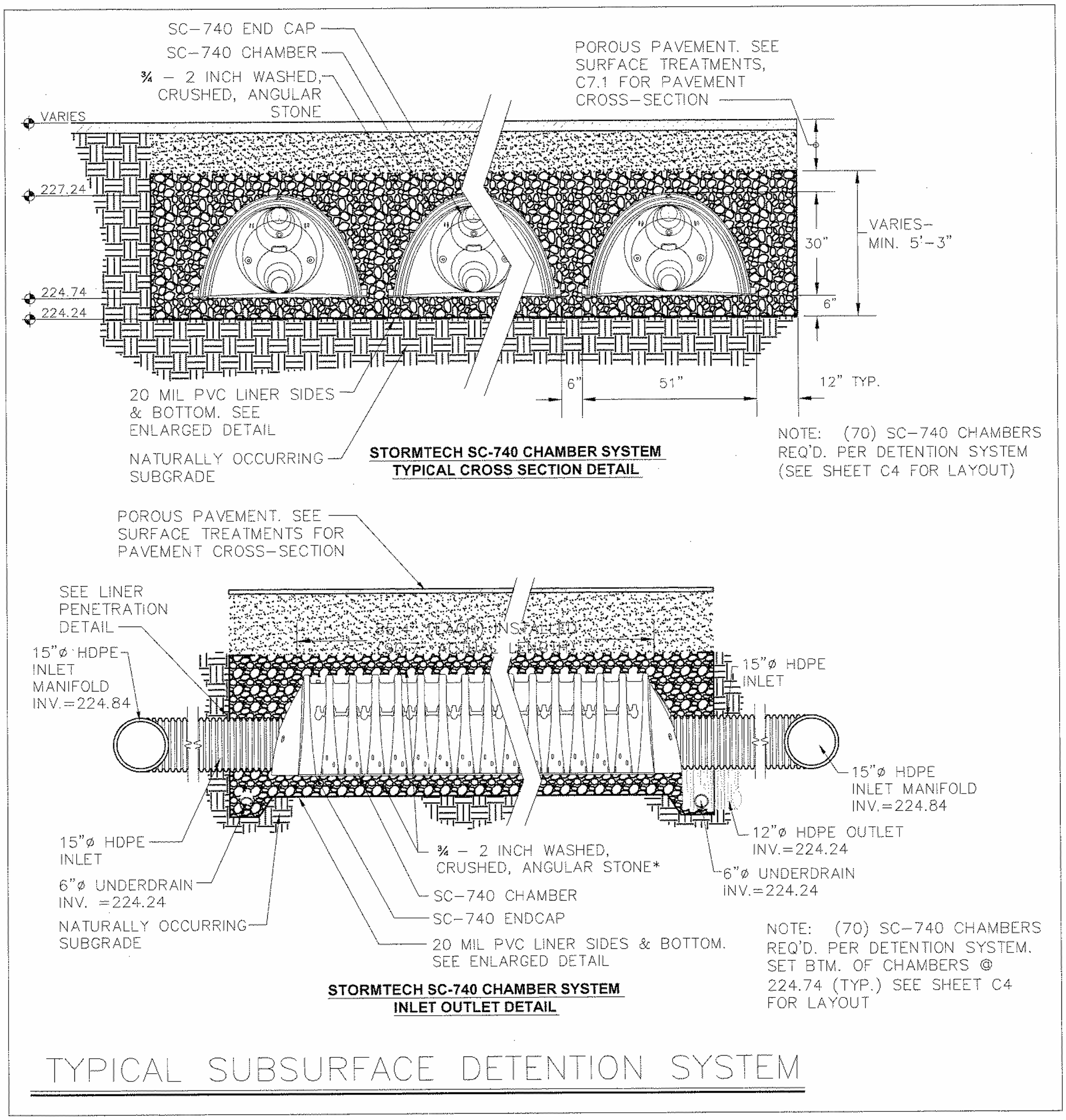
Subsurface Detention Facilities

With usable land becoming increasingly valuable, detention of stormwater in subsurface facilities is a common practice. These systems are commonly constructed under parking lots or other areas of the site outside of the building footprint. A typical subsurface detention facility is constructed by excavating an area to the required depth; lining with a geotextile fabric to prevent the surrounding soil from migrating into the system; installing perforated pipes or chambers; and backfilling with crushed stone. The crushed stone portion of the system has between 30 and 40% open volume available for storage of stormwater, in addition to that available in the pipes or chambers. There are several proprietary products that are designed to replace the pipe and stone and provide over 90% available storage in the total system. Unless these systems are designed as infiltration systems, no treatment of runoff is assumed to occur in the system.

Pretreatment of runoff is critical for these systems to prevent sediment from accumulating within. Depending on the surrounding soils, infiltration of a portion or all of the runoff may be possible (see Infiltration Practices). In areas where the groundwater may be contaminated, or where contamination from inflow into the system may be a concern, the system can be lined with an impervious liner.

Advantages	Disadvantages
• Makes maximum use of available land area. • No unsightly pond requiring screening and fencing. • Will not warm runoff as a surface detention pond can. • Will not create insect vector problem.	• High construction cost. • Minimal runoff volume reduction, unless also constructed as a subsurface infiltration system. • Difficult to maintain; in fact if not properly maintained it may have to be excavated to remove accumulated sediment.

Subsurface detention facilities are appropriate for use in commercial and industrial sites in Northwood; these practices are not LID practices. Refer to the following page for a typical example of a subsurface detention system.


SC-740 END CAP
SC-740 CHAMBER
¾ - 2 INCH WASHED, CRUSHED, ANGULAR STONE
POROUS PAVEMENT. SEE SURFACE TREATMENTS, C7.1 FOR PAVEMENT CROSS-SECTION
VARIES
227.24
224.74
224.24
30"
6"
VARIES- MIN. 5'-3"
6"
51"
12" TYP.
20 MIL PVC LINER SIDES & BOTTOM. SEE ENLARGED DETAIL
NATURALLY OCCURRING SUBGRADE
STORMTECH SC-740 CHAMBER SYSTEM
TYPICAL CROSS SECTION DETAIL
NOTE: (70) SC-740 CHAMBERS REQ'D. PER DETENTION SYSTEM (SEE SHEET C4 FOR LAYOUT)
POROUS PAVEMENT. SEE SURFACE TREATMENTS FOR PAVEMENT CROSS-SECTION
SEE LINER PENETRATION DETAIL
15"ø HDPE INLET MANIFOLD INV.=224.84
15"ø HDPE INLET
15"ø HDPE INLET MANIFOLD INV.=224.84
12"ø HDPE OUTLET INV.=224.24
6"ø UNDERDRAIN INV.=224.24
15"ø HDPE INLET
6"ø UNDERDRAIN INV. =224.24
NATURALLY OCCURRING SUBGRADE
¾ - 2 INCH WASHED, CRUSHED, ANGULAR STONE*
SC-740 CHAMBER
SC-740 ENDCAP
20 MIL PVC LINER SIDES & BOTTOM. SEE ENLARGED DETAIL
NOTE: (70) SC-740 CHAMBERS REQ'D. PER DETENTION SYSTEM. SET BTM. OF CHAMBERS @ 224.74 (TYP.) SEE SHEET C4 FOR LAYOUT
STORMTECH SC-740 CHAMBER SYSTEM
INLET OUTLET DETAIL
TYPICAL SUBSURFACE DETENTION SYSTEM

Infiltration Practices

Infiltration practices refer to any one of several measures designed to store and infiltrate a portion or all of a runoff event. The two broad categories of infiltration practices are infiltration trenches and infiltration basins.

Infiltration trenches, as the name implies, are trenches excavated into the ground with an available volume to store runoff for a sufficient period of time to allow its infiltration into the underlying soil. An infiltration trench is constructed and functions much like the subsurface detention system previously discussed. These systems are typically constructed with perforated pipe or chambers surrounded by crushed stone. Both the pipes and the void space in the stone provide storage of the runoff. The infiltration occurs at the interface between the crushed stone and soil surface. Pretreatment of runoff and maintenance of the pretreatment devices is critical to prevent clogging of the infiltrative soil surface.

Infiltration basins are similar to detention basins but are designed to store and infiltrate a portion of the runoff. Infiltration basins are generally excavated into natural soils with favorable permeability to infiltrate the stormwater over a predetermined period of time. Infiltration basins may be equipped with an outlet to discharge any runoff exceeding the infiltration design storm event.

Advantages	Disadvantages
• Significant reduction in runoff volume. • Provides groundwater recharge.	• Infiltration trench systems can be expensive to construct. • Requires pretreatment and regular maintenance to prevent clogging of infiltrative surface. • Potential for groundwater contamination. • Infiltration basins have potential to experience soil freezing problems.

Infiltration practices are appropriate for use in Northwood and their use should be encouraged. The proposed AOT rules in most circumstances require infiltration of a portion of the stormwater runoff. Infiltration practices are a LID practice and can serve as both quantity and quality controls of stormwater. A number of practices will be discussed in the Quality Controls sections which rely entirely or partially on infiltration for their function. Refer to the following page for an example of a subsurface detention system.

Large subsurface infiltration system under construction.

QUALITY CONTROLS

Stormwater Ponds
(Wet Ponds)

Stormwater ponds have a permanent pool of water to provide treatment of runoff. Stormwater ponds can also have storage above the permanent pool elevation to provide detention of stormwater. The pool creates an environment for the settling of sediments and provides some removal of soluble pollutants. The proposed AOT rules require a sediment forebay and a permanent pool at least equal to the water quality volume.

Advantages	Disadvantages
• Capable of removing sediment and soluble pollutants from runoff. • Capable of providing both quality and quantity control of runoff. • If properly designed and landscaped can be aesthetically pleasing.	• Requires a dependable base flow of water. • Potential to warm runoff. • Can require significant land area. • Will not normally provide significant reduction in runoff volume. • Safety and insect vector concerns.

The use of stormwater ponds in Northwood is only marginally appropriate, and it is not expected that they will be proposed, except in rare circumstances. Not normally considered a LID practice, it can, however, be incorporated in a site utilizing LID practices for additional volume reduction.

Photograph showing stormwater Pond City of Austin, Texas.

Stormwater Wetlands

Stormwater wetlands are wetlands constructed in upland areas that utilize natural wetland functions to remove pollutants by settling, filtering, and plant uptake. The term "Stormwater Wetlands" refers to a number of practices. The Massachusetts Stormwater Handbook lists the following five (5) basic types: shallow marsh systems, basin/wetland systems, extended detention wetlands, pocket wetlands, and gravel wetlands. For the purposes of this report, gravel wetlands will be discussed in a later section. The proposed AOT rules require that a stormwater wetland have a sediment forebay and a permanent pool similar to that of a stormwater pond.

Advantages	Disadvantages
• Capable of removing sediment and soluble pollutants from runoff. • Capable of providing both quality and quantity control of runoff. • If properly designed and landscaped can be aesthetically pleasing.	• Requires large land area. • Costly to construct. • Potential to warm runoff. • Requires a dependable base flow. • Will not normally provide significant reduction in runoff volume. • Safety and insect vector concerns.

The use of stormwater wetlands in Northwood, with the exception of gravel wetlands, although appropriate under many circumstances, are not generally cost effective. With the exception of gravel wetlands, stormwater wetlands are not generally considered a LID practice, although as with other practices, can be used in conjunction with LID practices.

.

Infiltration Practices

As previously discussed, infiltration practices are both a quantity and a quality control practice, having many benefits under both categories. In addition to the practices discussed under this section, many of the other practices have an infiltration component. The general construction requirements of infiltration practices have already been discussed and will not be repeated. It will be difficult to meet the treatment standard in the proposed AOT rules without some infiltration component to stormwater management.

Advantages	Disadvantages
• Significant reduction or elimination of discharge to surface waters. • Excellent pollutant removal. • Will not increase water temperature. • Provides groundwater recharge. • Provides water for stream base flow.	• Infiltration trench systems can be expensive to construct. • Requires regular maintenance to prevent clogging of infiltrative surface. • Potential for groundwater contamination, including chloride contamination from deicing salts. • Infiltration basins have potential for soil freezing issues.

As is the case for quantity control, infiltration practices are appropriate for use in Northwood for quality control. Infiltration practices are critical in meeting the requirements of the proposed AOT rules. Infiltration practices are a LID practice.

Photograph of large infiltration practice which serves as both quantity and quality practice.

Filtering Practices

Filtering practices consist of a number of measures, all of which are LID practices, and should be considered for all developments.

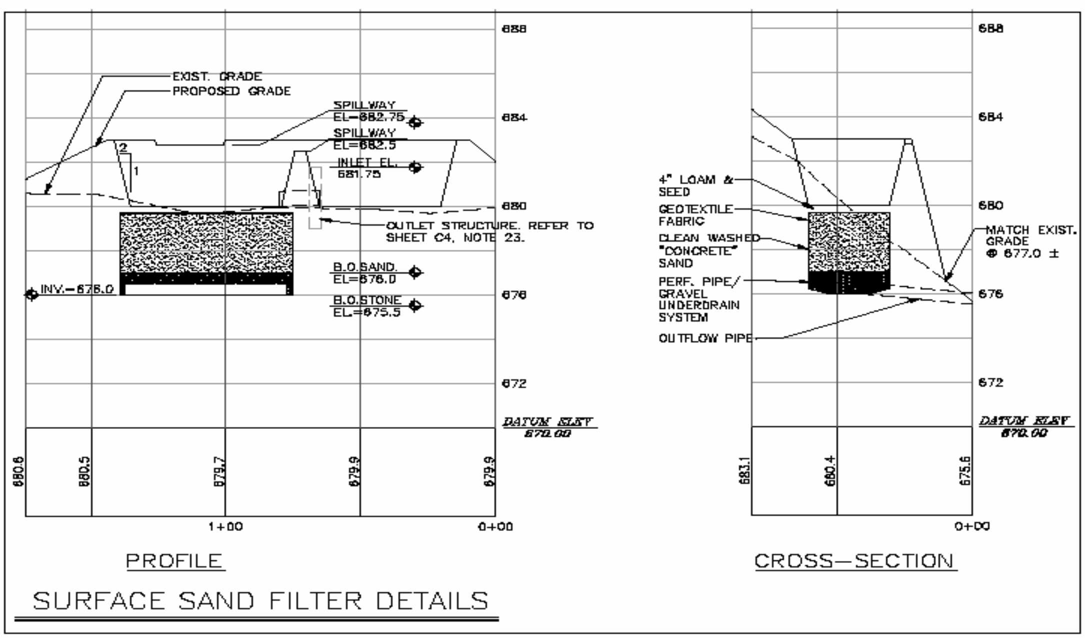
Surface Sand Filter

A surface sand filter is a basin with an underdrained sand bed. Water is introduced onto the surface of the sand bed and allowed to filter through the sand, where it is collected in the underdrain system. Sand filters improve water quality by settling pollutants on top of the filter surface and straining pollutants through the filter media. Sand filters can achieve good removal efficiencies. Sand filters should be preceded by pretreatment measures to prevent sediments from clogging the sand media. If the filter is not lined and the underdrains are set above the bottom of the bed, these practices can also achieve a measure of infiltration depending upon the permeability of the natural soils.

Advantages	Disadvantages
• Can be used in small drainage areas. • Has few site constraints. • Can be used in highly developed sites. • Can be used in areas with low soil permeability.	• Require care until site is stabilized to prevent clogging of sand media with construction related sediments. • Low peak flow reduction, unless incorporated into a detention basin. • May be considered unsightly. • Potential soil freezing issues.

Surface sand filters are appropriate for Northwood and are a LID practice. They can be of any size and placed at various locations within a site. This allows for a diffuse stormwater management system, and although not a quantity practice, a diffuse system will extend the time of concentration of runoff, thereby decreasing its rate.

Surface Sand Filter Under Construction.
Note Detention Pond in Background.



Detail of Surface Sand Filter in Photograph.

Subsurface Wetland

A subsurface wetland is a wetland constructed in a bed or channel which contains an engineered media. The media supports the growth of common wetland plants, such as cattails. The flow is introduced below-grade through a distribution system at the upstream end of the wetland. It flows through the media to a collection system at the downstream end. These systems are typically designed to allow the flow to pass through it below the ground surface. Treatment is accomplished in two ways: through filtration to surrounding soil as the flow passes through the media, and also through absorption as the plant roots uptake some of the water and pollutants. These systems require a nearly continuous supply of water to keep the plants alive, and may not be suitable for dry, well drained sites.

Advantages	Disadvantages
• Can be used in small or large drainage areas. • Provides effective treatment. • Can be used in highly developed sites. • Can be used in areas with low soil permeability. • Insect vectors are not a problem.	• Require care until site is stabilized to prevent clogging of media with construction related sediments. • May be considered unsightly. • Potential soil freezing issues. • Potential anoxic discharge. • Requires continuous water base flow to sustain vegetation.

Subsurface wetlands are appropriate for Northwood, but may have limited application. Subsurface wetlands are a LID practice.

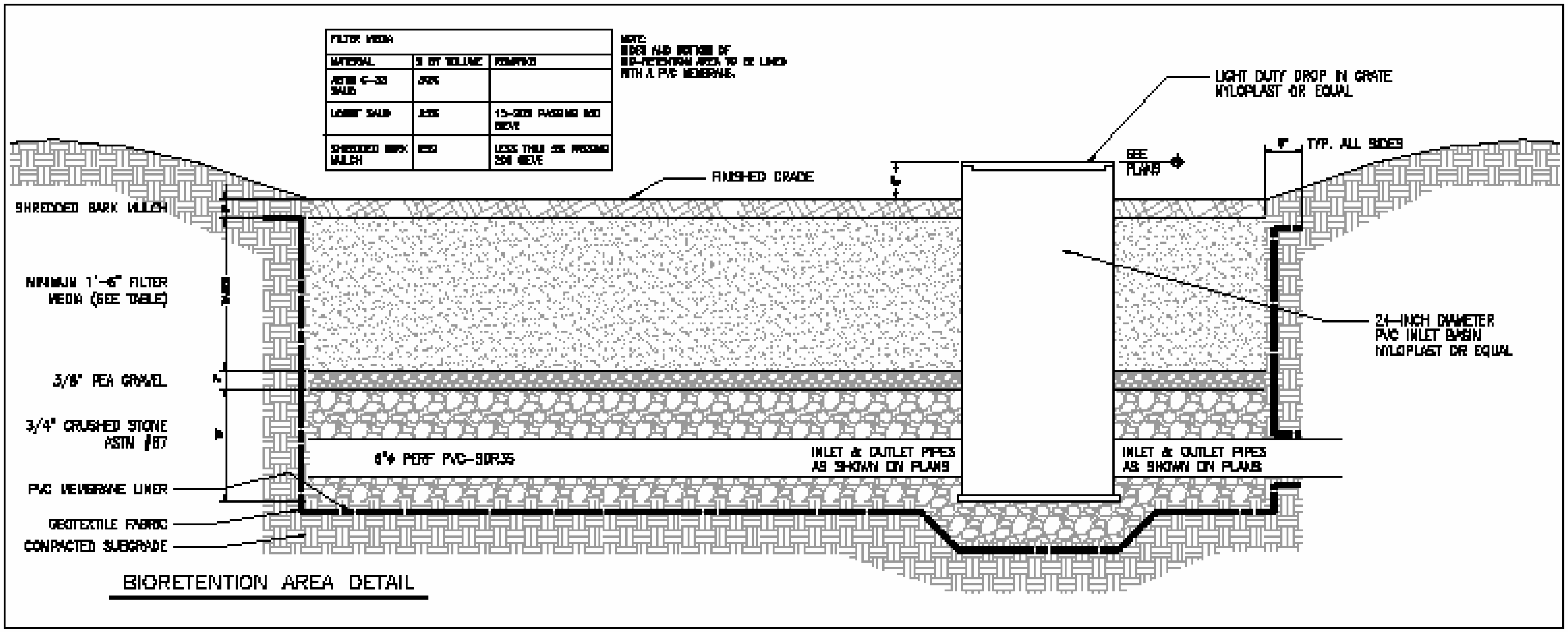
<u>Bioretention Systems</u>

Bioretention systems are the most common LID practice. They can function as a filtering practice or as a filtering and infiltration practice, depending on their construction and the natural soils. Bioretention systems consist of vegetated basins with a filtering media and an underdrain system. The filtering media can be sand or a media containing sand and organic material for better pollutant removal. Bioretention systems can and should be scattered throughout the site. Doing so allows them to be used in smaller areas such as landscape islands, and as with surface sand, filters helps create a diffuse stormwater management system.

<u>Advantages</u>	<u>Disadvantages</u>
• High pollutant removal ability. • Can be used in large or small drainage areas. • With proper sitting and landscaping will blend into the site. • Have few site constraints. • Can be used in highly developed sites. • Can be used in areas with low soil permeability. • Potential for peak flow reduction.	• Require care until site is stabilized to prevent clogging of filter media with construction related sediments. • Potential soil freezing issues.

Bioretention areas are appropriate for Northwood and are a LID practice. They can be of any size and placed at various locations within a site. This allows for a diffuse stormwater management system, and although not a quantity practice, a diffuse system will extend the time of concentration of runoff, thereby decreasing its rate.

Bioretention Area Within a Parking Lot.



Cross-section through Bioretention Area

Tree Box Filter

A tree box filter is a small, specialty bioretention system. It typically consists of a concrete vault with an underdrained, bioretention soil mix, and planted with vegetation, which can consist of shrubs or a small tree. The tree box filter is constructed immediately behind the curb with a break or inlet in the curb to allow the runoff to flow into the tree box filter. They also serve as catch basins. Tree box filters make maximum use of landscape spaces particularly on highly developed sites with a high percentage of imperviousness. Pollutant removal efficiencies are similar to bioretention areas.

Tree box filters should be designed to treat the water quality volume with an overflow bypass for larger runoff events.

Advantages	Disadvantages
• High pollutant removal ability. • Can be used in very small drainage areas. • Can replace catch basins. • With proper planning will complement the landscaping. • Have few site constraints. • Can be used in highly developed sites. • Can be used in areas with low soil permeability. • Serve as part of the stormwater collection system.	• Require care until site is stabilized to prevent clogging of filter media with construction related sediments. • Potential soil freezing issues. • Plantings will require periodic maintenance and long term may require replacement.

Tree box filters are appropriate for Northwood and are a LID practice. They can be placed at various locations outside of the curbing within a site.

Vegetated Buffers

Vegetated buffers are, as the name implies, vegetated areas between a developed site and the resource that is being protected. A vegetated buffer is typically a vegetated area, either planted or left natural, between a small parking area and a wetland or watercourse. Vegetated buffers should be designed to receive sheet runoff only. Vegetated buffers remove sediment and nutrients from runoff through sedimentation, filtration and infiltration. Important design considerations are slope and length. The proposed AOT Rules contain sizing criteria that vary the required buffer length depending on slope, soil type, and type of vegetated cover. The rules also state that the use of vegetated buffers should be limited to low-density residential development, developed areas with less than 10% imperviousness, and small impervious areas.

Advantages	Disadvantages
• Modest pollutant removal. • Can be aesthetically pleasing. • If maintained as a natural area can provide wildlife habitat. • Can be used as a pretreatment measure for other treatment practices.	• Does not provide significant flow rate control. • Can only function under conditions of sheet runoff. • Require significant land area.

Vegetated buffers are appropriate for Northwood and are a LID practice. They can be placed at various locations around the perimeter of a site or as a pretreatment measure for other practices.

Buffer and Grass Treatment Swale.

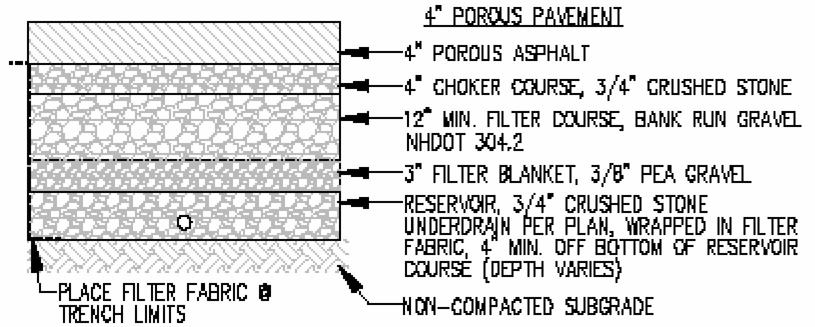
Permeable Pavements

Permeable pavements can consist either of asphalt - typically referred to as porous asphalt, or Portland cement concrete - typically referred to as pervious concrete. In each case the pavement is manufactured with an open-graded aggregate that permits substantial amounts of water to pass through the pavement and into a subbase intended to provide storage and facilitate infiltration. With a properly designed and constructed subbase, pavement manufactured in this manner will have little to no runoff during most storm events. A typical application will have the following cross section or layers:

- Permeable pavement layer.
- Crushed stone layer to provide structural support and remove the water from the immediate subgrade.
- Sand/gravel filter layer; this is the treatment layer.
- A storage/infiltration layer; this layer will vary in size and provides detention storage until the stormwater infiltrates into the surrounding natural ground or is released to the underdrain drainage system in a controlled manner. This layer is typically constructed of crushed stone with or without chambers or pipes to provide enhanced void space.

Advantages	Disadvantages
• Do not increase development footprint, i.e., they use the same land area already being used for an impervious surface. • Provide both quantity and quality management functions. • If used as a detention practice with discharge to surface water will not increase water temperature. • Tests have shown that permeable pavements require less winter maintenance.	• Requires routine vacuuming of surface to maintain effectiveness. • Concerns have been expressed regarding spills of hazardous material on the surface infiltrating through the system and contaminating the groundwater. • Future owners/managers of the site may not be aware of the need to maintain the surface and may perform seal coating, not realizing the negative impact to the system.

Permeable pavements are appropriate for Northwood and are a LID practice.



TYPICAL POROUS PAVEMENT DETAIL

Treatment Swales

The grass treatment swale has long been a widely used stormwater treatment practice in New Hampshire and nearly every other state. The original designs used in New Hampshire were based upon studies performed at the University of New Hampshire and elsewhere. In recent years, this method has been shown to be less effective than other available methods. The proposed AOT rules classify vegetated swales as pretreatment devices. Treatment swales of and by themselves cannot be considered a LID practice due to their low performance. However, they can be used in an overall LID design.

Advantages	Disadvantages
• Require a limited area. • Can function as a stormwater conveyance features. • Relatively inexpensive. • Widely accepted.	• Limited pollutant removal. • Pollutants removed during small storms may washout during large storms.

Treatment swales are appropriate for Northwood and although not a LID practice, they can be utilized as both runoff conveyance and pretreatment in an overall LID design.

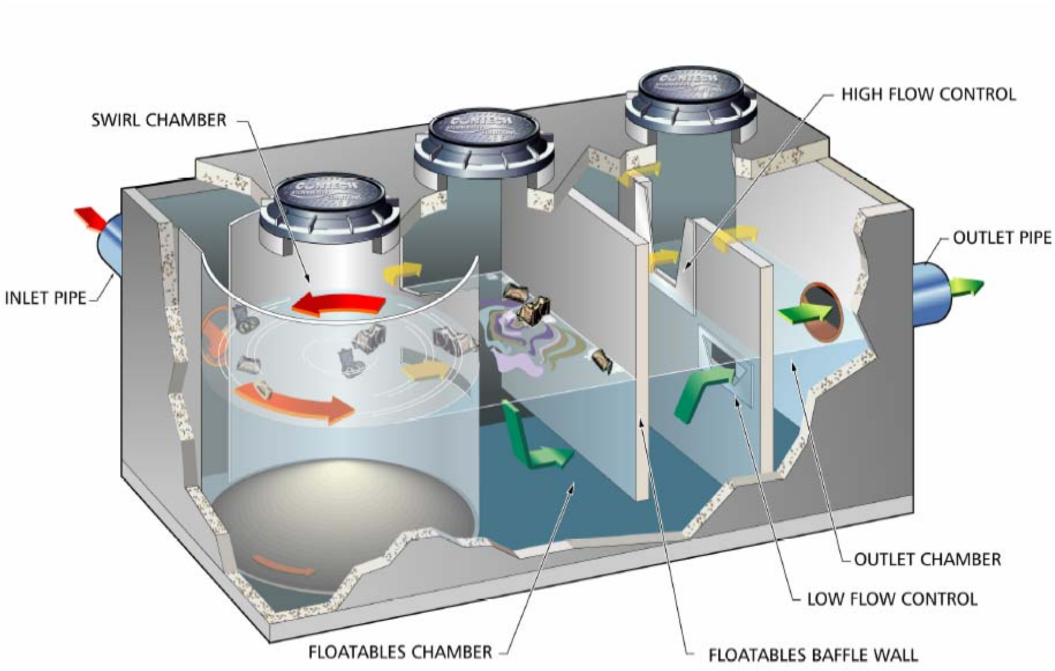
Grass Treatment Swale at Edge of Parking Area.

Manufactured Practices

The market place contains scores of factory-manufactured devices for the treatment of stormwater. A number of these devices have been subject to independent performance testing, but many more have not. These devices tend to be flow-through devices and do not offer flow rate reduction benefits. Common devices include hydrodynamic separators, filter devices with manufactured filter media, and water quality units. Currently these devices are only accepted as pretreatment devices to remove larger particles when implemented with other practices.

Manufactured practices are not LID practices.

Advantages	Disadvantages
• Requires limited land area. • Can be installed under paved areas. • Can be retrofitted into existing drainage system.	• Limited pollutant removals. • Not generally approvable as stand-alone treatment.



Vortechs System graphic courtesy of Contech Construction Products.

LIST OF REFERENCES

1. Alteration of Terrain Rules, Initial Proposal, April 9, 2008, NH Department of Environmental Services.
2. Contech Construction Products, Marketing information.
3. Low Impact Development Center, Beltsville, Maryland, various fact sheets.
4. Massachusetts Stormwater Handbook, Volume 2, February 2008.
5. National Association of Home Builders, Research Center, various fact sheets.
6. NH Stormwater Management Manual DRAFT Copy, May 2007, NH Department of Environmental Services.
7. Northwood Development Ordinance, as amended through March 11, 2008.
8. Northwood Site Plan Review Regulations, as modified 2008.
9. Northwood Subdivision Regulations, revised July 2004.
10. Roseen, et al, Storm Water Low-Impact Development, Conventional Structural and Manufactured Treatment Strategies for Parking Lot Runoff, 2005, UNH Stormwater Center.
11. Stone Environmental, Review of Northwood's Stormwater Management Regulations, Draft Copy, July 12, 2007.
12. TTG Environmental Consultants, various project related information.
13. University of New Hampshire Stormwater Center, numerous publications and fact sheets.
14. US Department of Defense, Unified Facilities Criteria, Design: Low Impact Development Manual, 25 October 2004.
15. US EPA Low-Impact Development Hydrologic Analysis, January 2000.
16. US EPA, Low-Impact Development Design Strategies an Integrated Design Approach, January 2000.
17. US EPA, Wastewater Technology Fact Sheet, Wetlands: Subsurface Flow, September 2000.
18. Vermont Stormwater Management Manual Volume I, Stormwater Treatment Standards, April 2002.

APPENDIX

Summary of Review of Relevant Documents

Note: Publication/revision dates of documents reviewed noted, more recent documents may exist.

Summary of Review of Relevant Documents

July 2008

This review was undertaken as the first item of the project Scope of Work for the Northwood Stormwater Technologies report. This report is being prepared by TTG Environmental Consultants, LLC (TEC) on behalf of the Town of Northwood under contract to the NH Estuaries Project.

The first section of the project scope required the review of relevant Northwood documents, as well as those of the NH DES and the UNH Stormwater Center. In addition, a review of representative documents in the library of TTG Environmental Consultants, LLC (TEC) was performed.

The following documents were reviewed:

I. Northwood Subdivision Regulations, Revised July 2004.
II. Northwood Development Ordinance, Amended March 11, 2008.
III. Northwood Site Plan Review Regulations (2008 Edition).
IV. Draft copy of review of "Northwood's Stormwater Management Regulations," by Stone Environmental, dated July 12, 2007.
V. NH Department of Environmental Services, April 9, 2008, Initial Proposal, Alteration of Terrain (AOT) Rules.
VI. Draft copy of "NH Stormwater Management Manual – Stormwater Management Techniques to Achieve Pollutant Load Reductions for New or Retrofit Development Activities," NH DES May 29, 2007.
VII. University of New Hampshire, Stormwater Center's website.
VIII. Vermont Stormwater Management Manual, Volume I – Stormwater Treatment Standards, Vermont Agency of Natural Resources, April 2002, 5th Printing.
IX. US Department of Defense, Unified Facilities Criteria (UFC), Design: Low Impact Development Manual, 25 October 2004.

There are a seemingly unlimited number of readily available documents on the subject of stormwater management. In addition to the traditional stormwater management practices, Low Impact Development (LID) practices are well represented in the literature. "Low Impact Development (LID) is a stormwater management strategy … LID employs a variety of natural and built features that reduce the rate of runoff, filter out its pollutants, and facilitate the infiltration of water into the ground." LID is the preferred method of the proposed AOT rules of the NH DES, as well as the stormwater programs in a number of other states.

As a result of the review by TEC, the following recommendations for developing appropriate stormwater technologies for Northwood have been developed:

1. Northwood stormwater technologies should parallel or complement those contained in the AOT rules.
2. Small stormwater events should be evaluated for stormwater treatment and stream channel protection.
3. Larger storm events should be evaluated for flooding impacts both on site and below the project site.
4. LID practices should be emphasized, particularly for smaller developments which will only be regulated at the local level.
5. Appropriateness of stormwater practices for a particular project will depend on such features as:
   a. Proposed land use.
   b. Proposed development density.
   c. Position of proposed development on the overall landscape.
   d. Soils.
   e. Sensitivity of adjacent natural resources.
6. Maintenance of stormwater practices should be addressed.

Following review by the Water Resources Subcommittee, TEC will be able to focus on the types of stormwater technologies appropriate for Northwood.

Summary of Documents Reviewed

I. Northwood Subdivision Regulations Revised July 2004

3.04 DRAINAGE

- Provisions for retention and gradual release of storm water. … shall not drain onto adjacent … in an amount which exceeds pre-development.

- Design by PE required.

- Design for 25-year storm. No standing water shall be permitted in ditches, culverts or catch basins.

- Details for drainage facilities at 1"=20".

II. Northwood Development Ordinance Amended March 11, 2008

This is the zoning ordinance for the Town of Northwood, and although it does not contain specific items which can be considered BMPs, it in fact incorporates features that positively impact storm water runoff, as listed below:

Section 5.01 Wetlands Conservation Overlay District

(E) Setbacks

(1) "Where the Wetland Conservation Overlay District and the Conservation Area Overlay District overlap, or where there exists a prime wetland, a 100-foot setback area shall be maintained. …"

Section 5.05 Steep Slope Protection Overlay District

Regulates development on slopes between 20 and 25% for construction related erosion and sediment control and post-construction storm drainage.

Section 6.00 Open Space Design

Provides for smaller lots allowing for a more compact design and reduction in impervious area.

III. <u>Northwood Site Plan Review Regulations (2008 edition)</u>

Section IX Design Standards and Required Improvements

D. Storm Water Drainage

(1) General Requirements

(a) All developments shall make adequate provisions for storm water disposal facilities

P.E. stamp required.
Limits increase in flow off-site.

(b) Prohibit increase, modification or alteration of off-site drainage, erosion or sedimentation.

Provide and maintain means that eliminate detrimental downstream effects.

Shall not increase amount of erosion and sediment in surface waters.

(c) Drainage analysis and Storm Water Management Plan for any site development disturbing 20,000 sf or more, constructing of a road and/or disturbing environmentally critical areas.

(2) Design Standards

(a) Design for 25-year storm event.

Design prepared in conformance with the Green Book.

Drainage facilities in road ROW or 25 ft wide easement.

(b) Pre- and Post-Development Flow

[1] Provide pre- and post-development peak flow rates.

Any site wooded in past five years must be considered undisturbed woods for calculating pre-development flow rates.

[2] 2-year post –development peak flow rate shall be (a) less than or equal to 50% of 2-year, 24-hour pre-development peak flow rate and (b) less than or equal to the one-year, 24 hour pre-development peak flow rate.

[3] 10-year, 24-hour post-development peak flow rate shall not exceed the predevelopment peak flow rate for all flows off-site.

[4] Peak flow rates shall be measured at the drainage system discharge location or down-gradient property boundary.

[5] Design point off property allowed with board approval.

Evaluation of downstream facilities such as culverts.

[6] Post-development total runoff volume shall be equal to 90 to 110 % of pre-development total runoff volume, based on a 2-year, 10-year and 25-year storms.

(c) Groundwater Recharge – Stormwater management shall provide that the annual average recharge volume for the major HSG are maintained.

[1] For all areas covered by low permeability surfaces total volume of recharge that must be maintained shall be calculated as follows:

$$\text{REQUIRED RECHARGE VOLUME (ft}^3\text{)} = \frac{\text{(Soil Recharge Factor) X (Area)}}{12}$$

Soil Recharge Factor expressed as follows:

USDA/NRCS HSG	Soil Recharge Factor (inches)
A	0.40
B	0.25
C	0.10.
D	Not required

Area = area in square footage on low permeability surfaces

[2] Pre-treatment requirements

1) Pretreatment prior to groundwater recharge device.

2) Designed to capture anticipated pollutants and easily maintained.

[3] Sizing and design of infiltration (recharge) BMPs

1) Drain within 72 hours from end of storm.

2) At least 3-feet above seasonal high groundwater and bedrock.

3) Soils under BMP to be scarified or tilled to improve infiltration.

4) Infiltration BMPs not located in areas with materials or soils containing regulated or hazardous materials or areas of contaminated groundwater.

[4] Infiltration prohibited or subject to additional pre-treatment under the following:

1) Well-head protection or water supply intake protection area.

2) Area in an area where groundwater reclassified to GAA, GA1 or GA2.

3) Stormwater from "high-load area," as described in Section (e).

(d) Water Quality: If more than 35% site disturbance or 25% low permeability cover:

[1] Remove 80% of the average annual load of TSS, floatables, greases, and oils and/or;

[2] Remove 40% of phosphorus.

(e) Land uses with Higher Potential Pollutant Loads

[1] The following are considered high load and must comply with subsections 1, 2, and 3 below:

1) Areas where regulated substances are exposed to rainfall or runoff; or

2) Areas that generate higher concentrations or hydrocarbons, metals or suspended solids (Followed by a list of 13 facilities).

[2] In addition to BMPs provide a SWPPP describing methods for source reduction and methods of pretreatment.

[3] Infiltration of stormwater from high-load areas is prohibited. Except on parking areas and other areas of the site not involved in high-load uses with pretreatment.

[4] For high-load areas filtering and infiltration practices shall be sealed or lined.

(f) Natural Watercourses – Development transverse by natural watercourse, drainage way, channel, or stream an easement shall be provided.

(g) Accommodation of Upstream Drainage Area.

(h) Flood Plain Areas – Comply with Special Flood Hazard Areas of the regulations.

(i) Areas of poor Drainage – PB may restrict.

(3) Maintenance

(a) O & M

(b) Recording site plan at registry of deeds

(c) Ownership

(4) Reclamation, Redevelopment and Reuse – Previously developed land shall meet the stormwater management standards to the maximum extent technically feasible.

IV. Draft "Review of Northwood's Stormwater Management Regulations" By Stone Environmental, July 12, 2007

Section 4 Comparison of Northwood's Existing Development Rules with Center for Watershed Protection's (CWP)

CWP Principal	CWP Brief Description	Northwood
1 - Street Width	Design residential streets for the minimum required pavement width	Minimum 22-feet w/4 ft gravel shoulders
2 - Street Length	Reduce total length of residential streets.	150-ft or 125-ft minimum frontage per lot
3 - Right-of-Ways	Minimize width of ROW	50-ft required
4 - Cul-de-Sacs	Minimize number of residential cul-de-sacs and incorporate landscape areas to reduce their impervious cover	Not addressed
5 - Vegetated Open Channels	Where applicable vegetated open channels should be use to convey stormwater	Not addressed
6 - Parking Ratios	Curb excess parking space construction	Minimum per use, maximum not specified
7 – Parking Codes	Revise parking codes where mass transit is available or shared parking arrangements are made	Not addressed
8. Parking Lots	Reduce overall imperviousness- compact spaces, reduce stall dimensions, efficient parking lanes, and pervious spillover parking areas	9-ft by 18-ft spaces required, common for NH. Compact spaces not addressed, pervious surfaces not addressed
9 - Structured Parking	Encourage structured and shared parking	No considered important in Northwood
10 – Parking Lot Runoff	Provide stormwater treatment to parking areas using bioretention, filter strips and other practices integrated into the landscaping.	Not specified
11 – Open Space Design	Environmentally-sensitive practices to minimize total impervious area	Allowed under the Development Ordinance
12 – Setbacks and Frontages	Reduce setbacks to reduce total road and driveway lengths	Setback requirements for conventional and open space are identical
13 – Sidewalks	Locate sidewalks on only one side of street, grade to pervious areas	Required on both sides of the street
14 – Driveways	Promote alternate driveway surfaces and shared driveways	Shared driveways between a two lots allowed. Alternate surfaces not addressed
15 – Open Space Management	Clearly specify how open space is to be managed	Not addressed
16 – Rooftop Runoff	Direct roof runoff to pervious areas	Not addressed

17 – Buffer Systems	Create natural vegetated buffers along streams, critical environmental areas, floodplains, steep slopes, wetlands	Buffers required along wetlands
18 – Clearing and Grading	Limit clearing and grading to that required for buildings, access and fire protection	25% of area to remain natural or be landscaped
19- Land Conservation Incentives	Provide incentives in the form of density compensation, buffer averaging, tax reduction, stormwater credits, and by right open space development to promote conservation of stream buffers, forests, meadows etc	Not specified
20 – Stormwater Management	New stormwater outfalls should not discharge untreated or unmanaged stormwater into jurisdictional wetlands, sole-source aquifers and other water bodies	Not specified.

V. <u>NH Department of Environmental Services</u>
<u>April 9, 2008, Initial Proposal</u>
<u>Alteration of Terrain (AoT) Rules</u>

Water Quality Volume (WQV) based upon 1-inch of rainfall – Varies with the percent impervious of the site.

Water Quality Flow (WQF) equals the WQV times the unit peak hydrograph (WQV X q_u).

Ground Water Recharge Volume (GRV) equals volume of runoff that must be captured and infiltrated.

<u>Required (GRV) is based upon hydrologic soil group</u>

Hydrologic Soil Group (HSG)	"R_d" Groundwater Recharge Depth Inches
A	0.4
B	0.25
C	0.10
D	Not Required

GRV = Impervious Area X R_d

QUALITY PRACTICE

<u>Stormwater Ponds</u>

Env-Wq 1508.03 Stormwater Ponds include micropool extended detention ponds, wet ponds, multiple pond systems and pocket ponds.

<u>Stormwater Wetland</u>

Env-Wq 1508.04 Stormwater Wetlands include shallow wetlands, extended detention wetlands, pond/wetland systems, and gravel wetlands.

<u>Infiltration</u>

Env-Wq 1508.05 Infiltration Practices include infiltration trenches, infiltration basins, dry wells, and drip edges.

Filtering Practices

- Pretreatment
- Underground Sand Filter
- Bio Retention
- Pervious Asphalt Pavement
- Pervious Concrete Pavement

Env-Wq 1508.06 Filtering Practices include surface sand filters, underground sand filters, tree box filters, bioretention systems, pervious asphalt, and pervious concrete.

Flow Through Treatment Swale

Env-Wq 1508.07 Flow Through Treatment Swales

Vegetated Buffers

Env-Wq 1508.08 Vegetated Buffers include residential or small pervious area buffers, developed area buffers, roadway buffers, and ditch turn-out buffers.

Env-Wq 1508.10 Pretreatment Practice – Sediment Forebay Used ahead of other practice.

Env-Wq 1508-11 Pretreatment Practice – Vegetated Filter Strips.

Env-Wq 1508.12 Pretreatment Practice – Vegetated Swale.

Env-Wq 1508.13 Pretreatment Practice – Flow-Through Device.

Env-Wq 1508.14 Pretreatment Practice – Deep Sump Catch Basin.

QUANTITY

Channel Protection Requirements (Page 53)

A minimum of one of the following must be met

2-year, 24-hour Post-development volume =/< Predevelopment Volume	2-year, 24-hour post-development rate =/< 2-year, 24-hour predevelopment volume
	2-year, 24-hour post-development peak flow shall be </= 50% of the 2-year, 24-hour predevelopment peak flow rate.
	2-year, 24-hour post-development peak flow rate shall be </= 1-year, 24-hour pre-development peak flow.

Peak Runoff Control Requirements (Page 53)

1. 10-year, 24-hour post-development peak flow rate shall not exceed the 10-year 24-hour pre-development flow rate for all flows leaving the site

2. The 50-year, 24-hour post-development peak flow rate shall not exceed the 50-year, 24-hour pre-development peak flow rate for all flows leaving the site.

   Note: Exemption if no increase downstream peak

VI. Draft – NH Stormwater Management Manual – Stormwater Management Techniques to Achieve Pollutant Load Reductions for New or Retrofit Development Activities, NH DES May 29, 2007

Potential Water Quality Impacts

Changes to Stream flow

- Increase runoff volumes.
- Increase peak runoff discharges.
- Increase runoff velocities.
- Shorter times of concentration.
- Increase frequency of bank-full and near bank-full events.
- Increase flooding.
- Lower baseflows (dry weather flows).

Changes to Stream Geomorphology

- Stream widening and bank erosion.
- High flow velocities.
- Loss of riparian vegetation and canopy.
- Changes in stream bed due to sedimentation.
- Increase floodplain elevation.

Changes to Aquatic Habitat

- Degradation of habitat structure – channel scour, streambank erosion, riparian vegetation loss, sediment deposition.
- Loss of pool-riffle structure.
- Reduced baseflows.
- Increase stream temperatures.
- Decline in abundance and biodiversity of fish and benthic organisms.

Table 6-4a. BMP Removal Efficiencies

BMP	Ref 1,2	BOD	COD	TSS	Pb	Cu	Zn	TN	TP	Cd
Bioretention	2			0.72-0.99	0.7-0.95		0.64-0.95	0.49	0.51-0.91	
Vegetated filter strip	A&B	0.505	0.4	0.73	0.45		0.6	0.4	0.4525	
Grass Swale	A,B&C	0.3	0.25	0.65	0.7	0.5	0.6	0.1	0.25	0.5
Infiltration device	A	0.83		0.94					0.83	
Extended wet detention	A&B	0.72		0.86	0.4		0.2	0.55	0.685	
Stormwater wetland	A&B	0.63	0.5	0.78	0.65		0.35	0.2	0.44	
Dry detention	A&B	0.27	0.2	0.58	0.5		0.2	0.3	0.26	
Settling basin	A	0.56		0.82					0.515	
Sand filter	A	0.4		0.83					0.375	
WQ Inlets	A&B	0.13	0.05	0.37	0.15		0.05	0.02	0.09	
Weekly street sweeping	A	0.06		0.16					0.06	
Infiltration basin	B&D		0.65	0.75	0.65		0.65	0.6	0.65	
Infiltration trench	B&D		0.65	0.75	0.65		0.65	0.55	0.6	
Porous pavement	B		0.8	0.9	1		1	0.85	0.65	
Concrete grid pavement	B		0.9	0.9	0.9		0.9	0.9	0.9	
Sand filter	B		0.55	0.8	0.6		0.65	0.35	0.5	
WQ inlet w/sand filter	B		0.55	0.8	0.8		0.65	0.35		
Hydrodynamic separator	B		0.05	0.15	0.15		0.05	0.05	0.05	
Wet pond	B		0.4	0.6	0.75		0.6	0.35	0.45	
Agriculture filter strip	C								0.5325	0.6125

Sources as referenced in NH DES draft manual.

1. USEPA Region 5
    - A. Appendix D. Model Best Management Practice Selection Methodology & Lake County Decision Making Framework, NIPC. July 1994
    - B. www.epa.gov/owowwtrl/NPS/MMGI/Chapter4/table407.gif
    - C. http://ohiolineag.ohio-state.edu/aex-fact/0467.html; took middle value of ranges of confliction results
    - D. Athaqde 1983
2. Sources: US EPA. 2000; Prince George's County Maryland, 2000; US EPA 2006 (compiled)

Table 6-4b. Pollutant Removal Efficiencies by BMP Type

BMP	TSS	TP	TN	Metals[1]	Bacteria
Wet pond	0.80	0.50 (0.51)	0.35(0.33)	0.60(0.62)	0.70
Stormwater wetlands	0.80[2](0.76)	0.50(0.49)	0.30	0.40(0.42)	0.80(0.78)
Filtering practices	0.85(0.86)	0.60(0.59)	0.40(0.38)	0.70(0.69)	0.35(0.37)
Infiltration practices	0.90[3](0.95)	70	0.50(0.51)	0.90[3](0.99)	0.90[4]
Water quality swales	0.85(0.84)	0.40(0.39)	0.50[5](0.84)	0.70	0.0(-0.25)

1. Average zinc and copper. Only zinc for filtration.
2. Many wetland practices in the database were poorly designed; consequently, the sediment removal was adjusted upward.
3. It is assumed that no practice in greater than 90% efficient.
4. Data inferred from sediment removal.
5. Actual data is based on only tow highly performing practices.
6. Assume 0 rather than a negative removal.

Pollutant Removal Database – Revised Edition (winter, 2000).

Source: Adapted from Horsely Witten Group Appendix A: Model Stormwater Regulations Duxbury, Marshfield, and Plymouth, MA, December 31, 2004.

Chapter 7 – Non-Structural Site Design Techniques

7-1 Site Design Techniques

- Minimize Disturbed Area
- Minimize Impervious Cover
- Disconnect Impervious Cover
- Minimize Soil Compaction
- Use Alternative Pavement

7-2 Impervious Surface Disconnection Methods. These are non-structural stormwater management practices that are focused on infiltrating runoff.

- Disconnection of Rooftop Runoff
- Disconnection of Non-Rooftop Runoff
- Stream Buffers
- Grass Channels
- Conservation of Natural Areas
- Environmentally Sensitive Development

Chapter 8 – Selection Criteria for Best Management Practices

8-1 Land Use Criteria

1. Rural: The primary pollutants of concern in rural areas are most often sediment and nutrients. Because of this most stormwater BMPs are appropriate in rural areas, even those that require a large amount of land area. Rural areas also provide an increased opportunity to use non-structural site design techniques, such as maintaining stream buffers and disconnecting impervious surfaces.
2. Roads and Highways: Typical pollutants associated with road and highway runoff include sediments, chlorides, hydrocarbons, metals, and even nitrogen and bacteria. Because of this multiple treatment practices may be needed to address the variety of pollutants. Roads can have a narrow right-of-way that limits space and configuration of BMPs.
3. Commercial Development: Commonly, the majority of the land is consumed by the structure and parking area. Alternative pavements and bioretention areas, for example may be used to promote infiltration and reduce the amount of impervious cover.
4. High Load Areas: Activities include the need for storage of regulated substances that may be exposed to rainfall or runoff. Like commercial development the majority of the available land may be consumed by the building structure of parking lot, the added challenge is that infiltration should be discouraged in order to protect groundwater supplies.

Table 8-1 Land Use Selection Criteria

Category	Practice	Rural	Residential	Roads and Highways	Commercial	High-load Areas[3]
Stormwater Pond	Wet Pond	A	C	A	A[2]	C
	Micropool Extended Detention Pond	A	B	A	A[2]	C
	Wet extended detention pond	A	B	A	A[2]	C
	Multiple pond system	A	C	B	A[2]	C
Stormwater Wetland	Shallow wetland	A	C	A	A[2]	C
	Extended detention wetland	A	C	A	A[2]	C
	Pond/wetland system	A	B	B	B[2]	C
Infiltration Practices	Infiltration trench	B	B	B	B	C
	Infiltration basin	A	B	A	A	C
Filtering Practice	Surface sand filter	B	A	A	A[1]	C
	Underground sand filter	C	B	A	A	A
	Perimeter sand filter	C	C	C	B	B
	Bioretention	B	B	A	A[1]	B
Water Quality Swales	Dry swale	A	A	A	B[1]	C
	Wet swale	A	B	A	B	C

NOTES: A appropriate
B somewhat appropriate
C least appropriate

[1] If not designed to infiltrate.
[2] May require pond liner.
[3] Secondary treatment practices and stormwater treatment trains are typically more appropriate for High-Load areas.
Source: Adapted from CT DEP 2004

8-2 Physical Feasibility Factors

1. Infiltration Capacity – Effectiveness of infiltration practices; easier to mimic natural hydrology of a site if impervious surfaces are located over areas that naturally have low infiltration capacity.
2. Water Table
3. Drainage Area
4. Slope
5. Required Head

Table 8-2 Physical Feasibility Criteria

Category	Practice	Soil Infiltration Capacity	SHWT	Drainage Area (Acres)	Slope	Required Head
Stormwater Pond	Micropool Extended Detention Pond	USDA HSG A and B soils may require pond liner unless groundwater intercepted	Construct below water table Use liner for sites with higher potential pollutant loads or water supply aquifers	10 Min[1]	15% Max	4 to 8 ft
	Wet Pond			25 Min[1]		
	Wet extended detention pond					
	Multiple pond system			1-5 Max[2] (Pocket Pond)		
Stormwater Wetland	Shallow wetland	USDA HSG A and B soils may require pond liner unless groundwater intercepted	Construct below water table Use liner for sites with higher potential pollutant loads or water supply aquifers	10 Min	8% max	2 to 5 ft
	Extended detention wetland			5 max[2] (pocket pond)		
	Pond/wetland system					
Infiltration Practices	Infiltration trench	Min field measured infiltration rate 0.3 in/hr Max infiltration rate 5.0 in/hr Pre-treatment required over 3.0 in/hr	Bottom of facility 3 feet above SHWT	2 max[2]	15% max	1 ft
	Infiltration basin			10 max[2]		3 ft
Filtering Practice	Surface sand filter	Unrestricted	Underdrain for unlined system 2 ft above SHWT	25 max[2]	6% max	5 ft
	Underground sand filter			10 max[2]		5 to 7 ft
	Perimeter sand filter			2 max[2]		2 to 3 ft
	Bioretention			5 max[2]		3 to 5 ft
Water Quality Swales	Dry swale	Unrestricted	Swale bottom 2 -4 ft above SHWT	5 max[2]	5% max	3 to 5 ft
	Wet swale		At or below SHWT			< 1 ft

Notes: [1] Unless adequate water balance
[2] Drainage area can be larger if appropriately sized and designed

Table 8-5 BMP Capability Criteria

Category	Practice	Pollutant Reduction						Groundwater recharge vol reduction	Stream channel Protection	Peak Flow Control
		Sediment	Total P	Total N	Metals	Hydro Carbons	Bacteria			
Stormwater Pond	Micropool Extended Detention Pond	A	A	A	A	A	B	C	A	A
	Wet Pond							B	A	A
	Wet extended detention pond							B	A	A
	Multiple pond system							C	A	A
Stormwater Wetland	Shallow wetland	A	A	A	B	A	A	C	A	B
	Extended detention wetland							C	A	A
	Pond/wetland system							C	A	A
Infiltration Practices	Infiltration trench	A	A	A	A	B	A	A	B	C
	Infiltration basin							A	A	B
Filtering Practice	Surface sand filter	A	A	A	A	A	B	B[1]	B	C
	Underground sand filter							C	C	C
	Perimeter sand filter							C	C	C
	Bioretention							B[1]	B	C
Water Quality Swales	Dry swale	A	B	B	A	B	C	B[1]	C	C
	Wet swale							C	C	C

NOTES: A Effective; B Somewhat effective; C Least effective

[1] If designed as exfilter

Source NH DES adopted from CT DEP 2004

Table 8-6 Maintenance Criteria

Category	Practice	Maintenance Sensitivity	Inspections	Sediment Removal	Other
Stormwater Pond	Micropool Extended Detention Pond	C	C	B	Aging ponds become ineffective and may become pollutant source in some cases; more frequent dredging may be required in watersheds with significant sediment loads
	Wet Pond	C	C	B	
	Wet extended detention pond	C	C	B	
	Multiple pond system	C	C	B	
Stormwater Wetland	Shallow wetland	B	B	A	Requires periodic harvesting to maximize nutrient and metals removal
	Extended detention wetland	C	C	A	
	Pond/wetland system	C	C	A	
Infiltration Practices	Infiltration trench	A	A	A	Frequent sediment/debris removal required to maintain performance
	Infiltration basin	A	A	A	
Filtering Practice	Surface sand filter	A	A	A	Periodic removal and replacement of media is required
	Underground sand filter	A	A	A	
	Perimeter sand filter	A	A	A	
	Bioretention	A	A	A	
Water Quality Swales	Dry swale	C	C	C	Sediment removal may damage swale
	Wet swale	C	C	C	

NOTES: A Significant; B Moderate; C Least
Source: NH DES adapted from CT DEP

Table 8-7 Community and Environmental Criteria

Category	Practice	Maintenance Requirements	Community Acceptance	Affordability	Safety	Habitat
Stormwater Pond	Micropool Extended Detention Pond	B	B	A	A	B
	Wet Pond	A	A	A	C	A
	Wet extended detention pond	A	A	A	C	A
	Multiple pond system	A	A	B	C	A
Stormwater Wetland	Shallow wetland	B	A	B	A	A
	Extended detention wetland	B	B	B	B	A
	Pond/wetland system	A	A	B	C	A
Infiltration Practices	Infiltration trench	C	A	B	A	C
	Infiltration basin	C	C	B	A	C
Filtering Practice	Surface sand filter	B	B	C	B	C
	Underground sand filter	C	A	C	A	C
	Perimeter sand filter	C	A	C	A	C
	Bioretention	B	B	B	A	B
Water Quality Swales	Dry swale	A	A	B	A	C
	Wet swale	A	B	A	A	B

NOTES: A High; B Moderate; C Low

Source: NH DES adapted from NY DEC 2003

VII. <u>University of New Hampshire, Stormwater Center's Web Site</u>

The Center is evaluating both conventional and LID measures.

Conventional Measures

Vegetated and Rock Line Swales

Vegetated dry, wet, or stone-lined stormwater swales are open, channel-like structures that are used to convey stormwater runoff. Trapezoidal channel with minimum slope. Its ability to remove pollutants is modest at best, venerable to large high-velocity storm flows its effectiveness will likely decline with age. Vegetated swales are the most commonly employed stormwater management system.

UNH reports large seasonal variations in performance for TSS, total petroleum hydrocarbons and Zn.

Retention Pond

Retention ponds or "wet ponds" are among the most common stormwater treatment systems. Retention ponds retain a resident pool of standing water, which improves water quality treatment between storms. Retention ponds demonstrate a reasonable strong water quality treatment, particularly in comparison to dry pond systems.

The UNH Stormwater Center reported reasonably effective removals during the first year of operation; however the Center reports a reduction in performance during the second year of operation.

Approximate removal efficiencies:

TSS	70%
Total petroleum hydrocarbons	80%
Dissolved inorganic nitrogen	40%
Zn	90%
Total phosphorus	20%

Hydrodynamic Separators (HDS)

These are manufactured, flow through devices that remove sediment, trap debris, and separate floating oils from runoff. The Center evaluated four (4) different designs. The results indicated that they are most effective when used as pretreatment devices to remove sediment particles greater than 100 microns in diameter.

A typical HDS consists of a chamber configured to create tangential flow, meaning that the stormwater enters the device through an angled inlet that creates a swirl action to enhance particle settling. Many also contain a flow partition to minimize sediment re-suspension. Typically, they are equipped with a baffle to remove floating debris.

Water quality performance was moderate to poor. The ability of HDS devices to remove sediments was significantly impacted during cold weather months. This is due to the increased viscosity of stormwater runoff and high concentrations of chloride, both of which combine to reduce particle-settling velocity.

Approximate removal efficiencies:

TSS	30%
Total petroleum hydrocarbons	40%
Dissolved inorganic nitrogen	0%
Zn	20%
Total phosphorus	>5%

Low Impact Development (LID) Measures

Bio Retention System

Bio retention systems are landscaped depressions where runoff flows to and collects. The systems are constructed with an engineered soils media and under drain system which filters the runoff allow a portion to infiltrate and collecting the remainder. Bioretention systems area among the most common low impact development stormwater measures.

The Center reports that its bioretention system has proven effective in removing nearly all of the pollutants commonly associated with stormwater treatment performance assessments.

Approximate removal efficiencies:

TSS	95%+
Total petroleum hydrocarbons	55%
Dissolved inorganic nitrogen	30%
Zn	100%
Total phosphorus	5%

Tree Box Filet

Tree box filters are mini bioretention systems that combine the versatility of manufactured devices with the water quality treatment of vegetated systems. The tree box filter's basic design is a concrete vault filled with a bioretention soil mix, planted with vegetation, and underlain with a sub drain. They typically are constructed at the edge of a paved area or in a sidewalk, and in addition to the water quality function, they are integrated into the overall site landscape design.

Approximate removal efficiencies:

TSS	95%+
Total petroleum hydrocarbons	90%
Dissolved inorganic nitrogen	40%
Zn	95%+
Total phosphorus	0%

Subsurface Gravel Wetland

A created wetland with subsurface flow media, it approximates the look and function of a natural wetland, effectively removing sediments and other pollutants commonly found in runoff. It demonstrates a tremendous capacity to reduce peak flow and improve water quality.

The gravel wetland does an exceptional job of removing nearly all of the pollutants commonly associated with stormwater treatment performance assessment. It consistently exceeds EPA's recommended level of removal for TSS and meets regional ambient water quality criteria for nutrients, heavy metals, and petroleum hydrocarbons.

Approximate removal efficiencies:

TSS	95%+
Total petroleum hydrocarbons	95%+
Dissolved inorganic nitrogen	95%+
Zn	95%+
Total phosphorus	55%

Surface Sand Filter

The surface sand filter tested at the Stormwater Center consists of a sediment forebay and a surface sand filtration basin. The filtration basin is composed of a 30-inch deep course to medium grained sand. To achieve maximum reduction of peak flow and stormwater runoff it is important to locate them in soils that accommodate infiltration and to minimize ponding depth. In the right soils they, they provide infiltration similar to undeveloped areas.

The surface sand filter at the Stormwater Center performed only moderately well at removing most pollutants commonly associated with stormwater treatment performance assessment.

Approximate removal efficiencies:

TSS	50%
Total petroleum hydrocarbons	95%+
Dissolved inorganic nitrogen	0%+
Zn	80%
Total phosphorus	30%

Porous Pavement

The porous asphalt pavement system utilized at the Stormwater Center consists of four (4) basic layers:

- The top is a four-inch layer of porous asphalt pavement with 18 to 20 percent void space.
- The second layer is a four-inch choker course consisting of ¾-inch crushed stone.
- The third layer consists of 24-inches of poorly graded sand or bank run gravel.
- The fourth layer is 21-inches of crushed stone with a six-inch elevated sub drain.

Porous asphalt pavements are an extremely effective approach to stormwater management; rainfall drains through the pavement and directly infiltrates the sub drainage. This significantly reduces runoff volume, decreases runoff temperature, improves water quality, and essentially eliminates impervious surface. The water quality treatment performance generally has been excellent. It consistently exceeds EPA's recommended level of removal of TSS and meets regional ambient water quality criteria for petroleum hydrocarbons and zinc.

The porous asphalt system's ability to manage runoff was exceptional. It has outperformed all systems tested at the Stormwater Center.

Approximate removal efficiencies:

TSS	95%+
Total petroleum hydrocarbons	95%+
Dissolved inorganic nitrogen	0%
Zn	95%+
Total phosphorus	40%

VIII. Vermont Stormwater Management Manual, Volume I – Stormwater Treatment Standards, Vermont Agency of Natural Resources, April 2002, 5th Printing

1.1 Treatment Standards

1.1.1 Water Quality Treatment Standards (WQTS)
Objective to capture 90% of the annual storm events, and remove 80% of the average annual post development TSS and 40% of the TP.

1.1.4 Overbank Flood Protection Treatment Standard
The post-development peak discharge rate shall not exceed the pre-development peak discharge rate for the 10-year, 24-hour storm event

1.1.5 Extreme Flood Protection Treatment Standard
The post-development peak discharge rate shall not exceed the pre-development peak discharge rate for the 100-year, 24-hour storm event.

1.3.2. Water Quality Peak Flow Calculation

$Q_{wq} = q_u * A * WQ_v$

Q_{wq} = peak discharge in cfs
q_u = peak discharge rate in cfs/mi^2/inch
A = drainage area in square miles
WQ_v = Water Quality Volume in watershed inches

2.1 Acceptable Stormwater Treatment Practices (STPs)

STPs to meet the following objectives:

- Water quality
- Water quantity
- Groundwater recharge

2.2 Water Quality STPs
Criteria:

1. Capture and treat the WQ_v
2. Remove 80% TSS and 40% TP
3. Acceptable performance and longevity in the field

From Table 2.1 Lists of Practices Acceptable for Water Quality Treatment

GROUP	PRACTICE	DESCRIPTION
Stormwater Ponds Combination of permanent pool and extended detention capable of treating the WQ_v	Micropool Extended Detention Pond	Pond treats the majority of the WQ_V through extended detention and incorporates a micropool at the outlet of the pond to prevent sediment resuspension
	Wet Pond	Pond that provides storage for the entire water quality volume in the permanent pool
	Wet Extended Detention Pond	Pond that treats a portion of the WQ_V by detaining storm flows above the permanent pool for a specified minimum detention time.
	Multiple Pond System	A group of ponds that collectively treat the WQ_V
	Pocket Pond	A pond design adapted for the treatment of runoff from small drainage area and which has little or no baseflow and relies on groundwater to maintain a permanent pool
Stormwater Wetlands Practices that include significant shallow marsh areas and may also incorporate small permanent pools	Shallow Marsh	A wetland that provides water quality treatment primarily in a wet shallow marsh
	Extended Detention Wetland	A wetland system that provides a portion of the water quality volume by detaining storm flows above the marsh surface
	Pond/Wetland System	A wetland system that provides a portion of the water quality volume in the permanent pool of a wet pond that precedes the shallow marsh wetland.
	Gravel Wetland	A wetland system composed of a wetland plant mat grown in a gravel or rock matrix
Infiltration Practices Capture and store WQ_V before infiltrating into ground	Infiltration Trench	An infiltration practice that stores the water quality volume in the void spaces of a gravel trench before it is infiltrated into the ground.
	Infiltration Basin	An infiltration practice that stores the water quality volume in a shallow surface depression, before it is infiltrated into the ground.
Filtering Practices Capture WQ_V and pass through sand bed, organic matter, soil or other media	Surface Sand filter	A filtering practice that treats stormwater by settling out larger particles in a sediment chamber, and then filtering stormwater through a sand matrix.
	Underground Sand Filter	A filtering practice that treats stormwater as it flows through underground settling and filtering chambers
	Perimeter Sand Filter	A filter that incorporates a shallow sediment chamber and filter bed as parallel vaults adjacent to a parking lot.
	Organic Filter	A filtering practice that uses an organic medium such compost in the filter or incorporates organic material in addition to sand (e.g., peat/sand mix)
	Bioretention	A shallow depression that treats stormwater as it flows through a soil matrix, and is returned to the storm drain system.
Open Channels Practices that capture and treat WQ_V within dry or wet cells formed by check dams or other means	Dry Swale	An open vegetated channel or depression explicitly designed to detain and promote the filtration of stormwater runoff into an underlying soil media.
	Wet Swale	An open vegetated channel or depression designed to retain water or intercept groundwater for water quality treatment.
	Grass Swale	An open channel or depression designed to convey and detain the WQ_V at a maximum velocity of 1fps with a minimum residence time of 10 minutes

2.3 Groundwater Recharge Stormwater Treatment Practices (STPs)

Type	Practice	Notes
Structural	Infiltration Trench	Practice explicitly designed for groundwater recharge
	Infiltration Basin	Practice explicitly designed for groundwater recharge
	Surface Sand Filter	Provides recharge only if designed as an exfilter system
	Organic Filter	Provides recharge only if designed as an exfilter system
	Bioretention	Provides recharge only if designed as an exfilter system
	Dry Swale	Provides recharge only if designed as an exfilter system
	Grass Channel	Refer to document
Nonstructural (Design Credits)	Disconnection of Rooftop Runoff	Vermont Rules allow credits for use of these devices
	Disconnection of non-rooftop runoff	
	Sheet flow runoff to stream buffer	
	Use of Open Vegetated Swales	
	Environmentally sensitive rural development	

2.6 Stormwater Hotspots

A stormwater hotspot is defined as a land use or activity that generates higher concentrations of hydrocarbons, trace metals or toxicants than are found in typical stormwater runoff. If a site or specific discharge point at a site is designated as a hotspot, … First and foremost, stormwater runoff from hotspot discharges cannot be allowed to infiltrate into groundwater unless an individual stormwater permit is obtained.

Table 2.3 Classification of Stormwater Hotspots

The following land uses and activities are deemed stormwater hotspots:

- Vehicle salvage yards and recycling facilities.
- Vehicle fueling stations.
- Vehicle service and maintenance facilities.
- Vehicle and equipment cleaning facilities.
- Fleet storage areas.
- Industrial sites.
- Marinas (service and maintenance).
- Outdoor liquid container storage.
- Outdoor loading/unloading facilities.
- Public works storage areas.
- Facilities that generate or store hazardous materials.
- Commercial container nursery.

IX. U.S. Department of Defense, Unified Facilities Criteria (UFC), Design: Low Impact Development Manual, 25 October 2004

Chapter 1 – Introduction to LID and Manual Overview

1-1 Definition of LID. Low Impact Development (LID) is a stormwater management strategy …LID employs a variety of natural and built features that reduce the rate of runoff, filter out its pollutants, and facilitate the infiltration of water into the ground.

From Figure 1-1

Key LID Elements:

- Directing Runoff to Natural Areas.
- Conservation – Preserves native trees, vegetation and soils. – Maintains natural drainage patterns.
- Small-Scale Controls – Mimics natural hydrology and processes.
- Customized Site Design – Ensures each site helps protect the entire watershed.
- Maintenance, Pollution Prevention and Education – Reduces pollutant loads and increases efficiency and longevity – Educates and involves the public.

1-4 LID Site Design Strategies

Some examples of LID site design strategies include:

- Grade to encourage sheet flow and lengthen flow paths.
- Maintain natural drainage divides to keep flow paths dispersed.
- Disconnect impervious areas such as pavement and roofs from the storm drain network, allowing runoff to be conveyed over pervious areas.
- Preserve the naturally vegetated areas and soil types that slow runoff, filter out pollutants, and facilitate infiltration.
- Direct runoff into or across vegetated areas to help filter runoff and encourage recharge.
- Provide small-scale distributed features and devices that help meet regulatory and resource objectives.
- Treat pollutant loads where they are generated, or prevent their generation.

1-5 Basic List of Integrated Management Practices (IMPs)

Bioretention: Vegetated depressions that collect runoff and facilitate its infiltration into the ground.

Dry Wells: Gravel- or stone-filled pits that are located to catch water from roof downspouts of paved areas.

Filter Strips: Bands of dense vegetation planted immediately downstream of a runoff source designed to filter runoff before entering a receiving structure or water body.

Grassed Swales: Shallow channels lined with grass and used to convey and store runoff.

Infiltration Trenches: Trenches filled with porous media such as bioretention material, sand, or aggregated that collect runoff and exfiltrate it into the ground.

Inlet Pollution Removal Devices: Small stormwater treatment systems that are installed below grade at the edge of paved areas and trap or filter pollutants in runoff before it enters the storm drain.

Permeable Pavement: Asphalt or concrete rendered porous by the aggregate structure.

Permeable Pavers: Manufactured paving stones containing spaces where water can penetrate into the porous media placed underneath.

Rain Barrels and Cisterns: Containers of various sizes that store the runoff delivered through building downspouts. Rain barrels are generally smaller structures located above ground. Cisterns are larger, often buried underground, and may connect to the building's plumbing or irrigation system.

Soil Amendments: Minerals or organic material added to soil to increase its capacity for absorbing moisture and sustaining vegetation.

Tree Box Filters: Curbside containers placed below-grade, covered with a grate, filled with filter media and planted with a tree in the center.

Vegetated buffers: Natural or man-made vegetated areas adjacent to a water body, providing erosion control, filtering capability, and habitat.

Vegetated Roofs: Impermeable roof membranes overlaid with a lightweight planting mix with a high infiltration rate and vegetated with plants tolerant of heat, drought, and periodic inundation.

Chapter 5 LID Design Goals and Objectives

5-3 Fundamental Site Planning Concepts – The goal of LID site planning is to allow for full development and function of the intended site activity while maintaining the site's essential natural or existing hydrologic function. The LID site design process is sequential and iterative, and embraces the following five concepts:

- Hydrology is the Integrating Framework for the Design
  - LID designs have the goal of mimicking the natural site drainage processes and functions.
- Distribute Controls Through Micromanagement
  - View the site as a series of interconnected small-scale design controls
- Stormwater is controlled at the Source
- Incorporate Non-Structural Systems Where Possible
  - LID designs recognize the potential of natural systems to intercept and filter pollutants.
- Utilize Multifunctional Landscape, Buildings and Infrastructures
  - The primary criterion in selecting LID practices is that the design component contributes to satisfying the design and regulatory objectives. Design features are often multifunctional and satisfy multiple objectives.

Table 6-1 Functions of LID Features

Feature	Effect or Function				
	Slower Runoff	Infiltration	Retention	Detention	Water Quality Control
Soil Amendments		**X**			
Bioretention		**X**	**X**	**X**	**X**
Dry Wells		**X**	**X**		**X**
Filter Strips	**X**				**X**
Vegetated Buffers	**X**				**X**
Grassed Swales	**X**				**X**
Infiltration Trenches		**X**			**X**
Inlet Devices					**X**
Rain Barrels			**X**		
Cisterns			**X**		
Tree Box Filters					**X**
Vegetated Roofs	**X**			**X**	**X**
Permeable Pavers		**X**			**X**

CORPORATE OFFICE:

27 Locke Road
Concord, NH 03301
Telephone: (603) 228-1122
Fax: (603) 228-1126
E-mail: info@hlturner.com
Web Page: www.hlturner.com/env.htm