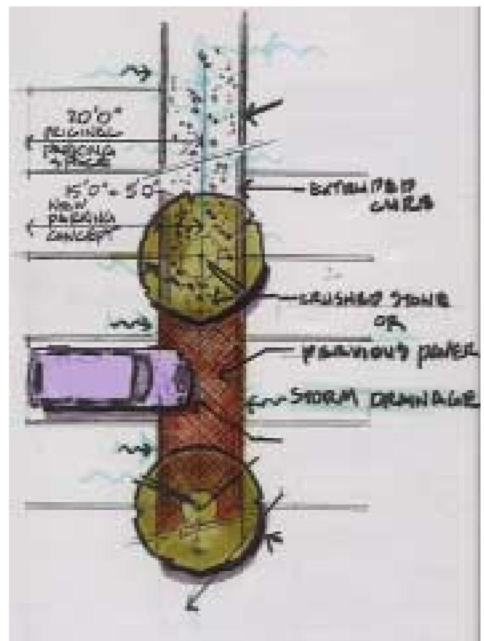
Stormwater Manual

CITY OF NASHUA, NEW HAMPSHIRE ALTERNATIVE STORMWATER MANAGEMENT METHODS

PART 1 – PLANNING & GUIDANCE



FINAL REPORT – MARCH 2003

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Table of Contents

PART 1 – PLANNING & GUIDANCE

Table of Contents

Tables

Figures

PART 2 – DESIGNS & SPECIFICATIONS

Section **Title** **Page No.**

Table of Contents

Tables

Appendix

Addendum to City of Nashua, New Hampshire Alternative Stormwater Management Methods, Part 1 – Planning & Guidance

In Section 6.0 Sample Redesign of Parking Lot using RPMs, a site bordering Salmon Brook was described and a theoretical redesign was completed. As with the other sites, the designs were done as theoretical conceptual designs and the landowners were not involved nor did the designs go through any Planning Board approval. As noted in the report, the designs would also require site specific engineering information for completion and actual use.

At the Globe Plaza site, actual parking lot renovation was just starting simultaneously with the theoretical conceptual designs produced for this report. The report states on page 6-1 that the redevelopment project that was carried out was not required to improve the drainage situation, and that all drainage currently exits the site via two catch basins in the lot which discharges it untreated to Salmon Brook. It has been brought to CEI’s attention that this is not correct, and that the redevelopment did require improvements in drainage and two proprietary units were added before the discharge point. Because the site was already under construction, there was no way to incorporate any of the additional improvements from the CEI design at that time.

There has also been concern raised about the fill underneath this parking lot in that it may contain solid waste other than construction rubble and fill. This is not known, and again, site specific engineering information in the form of borings would be required in order to do any infiltration beneath this lot. If the site was used for landfill, then it would not be appropriate to assume that any infiltration occurs over time. As it was, the design did not include any exfiltration in the calculations and it assumed that the two-year storm volume was stored by using wider and shallower trenches.

As noted in the report, all designs would require site specific engineering information for use and would probably need some adjustments based on this information. The purpose in developing these conceptuals was to identify possibilities for difficult sites that might have wide application at these and other less challenging sites.

1.0 Overview

1.1 Project Background

This report is the result of a project initiated in 2001 by the City of Nashua Department of Public Works, Pennichuck Water Works and the New Hampshire Department of Environmental Services (DES). The purpose of the project was to develop updates to the street and drainage specifications for the City of Nashua to address stormwater quality and quantity issues. These stormwater issues are closely related to transportation functions including roadways and parking lots and the idea was to develop a more environmentally friendly engineering and planning specification for use in the City. The project was to be a model for other Pennichuck watershed communities (Amherst, Hollis, Merrimack and Milford), and the rest of the state.

Stormwater was identified as a significant issue whose increasing volumes and velocity were damaging Nashua's natural resources, particularly water supply. The need for addressing transportation related stormwater was identified in the 1998 report entitled "Pennichuck Watershed Management Plan" by Comprehensive Environmental Inc. (CEI).

This project was funded by New Hampshire Department of Environmental Services, the City of Nashua Department of Public Works, Pennichuck Water Works Corporation and Comprehensive Environmental Inc. and was designed to address the stormwater issue by

Above photo shows some of the results of uncontrolled stormwater runoff and urban pollution on water quality.

going directly to the source of the problem of how development and redevelopment occur.

1.2 How This Manual Was Developed

The project included a year long series of meetings facilitated by CEI and attended by a diverse group of City of Nashua and State participants. A complete participant list may be found in Appendix A. During its initial stages, the project participants, called the Workgroup herein, focused on reviewing all available existing information and the latest techniques for addressing stormwater quality and quantity. After this review of nationally and internationally available information, the Workgroup moved on to address four types of development:

1. Commercial/industrial;
2. Urban downtown;
3. High density residential; and
4. Low density suburban residential.

In each of these four areas, CEI developed conceptual designs to handle drainage better than traditional techniques. The Workgroup would then review the conceptual designs to ask questions, raise concerns and suggest modifications or new ideas. From this process, this draft document was developed.

The manual has been divided into two parts for easier distribution:

- Part 1 – Planning & Guidance
- Part 2 – Designs & Specifications

The first part, *Planning & Guidance*, contains the following major sections:

1.0 Overview – introduction to the project.
2.0 Stormwater Impacts and Issues – this section provides an introductory text describing the environmental issues associated with stormwater and the concerns addressed by this project.
3.0 How Traditional Designs Fail – this section provides some details on what's wrong with today's stormwater management and handling practices in New Hampshire and elsewhere.
4.0 Innovative Designs – Runoff Prevention Methods (RPMs) – a description of the benefits of using new, more innovative designs and how they can be more effective at addressing the impacts and concerns with traditional designs.
5.0 Nashua Design Guidelines – this section is the meat of the document and provides the Workgroups' major recommendations.
6.0 Sample Redesign of a Parking Lot using RPMs – as it states, the design process and details for a parking lot site in Nashua are

described in this section to assist engineers and planners in understanding the issues and characteristics of more environmentally friendly stormwater design.

The second part, *Designs & Specifications*, contains the following major sections:

1.0 Planning & Engineering – this section contains a design selection matrix.
2.0 Alternative Designs – This section provides the design conceptual drawings.
3.0 Technical Specifications – the final section contains specifications for materials and construction practices to be used in RPM construction.

This guidebook should help planning officials show designers and engineers alternative methods of addressing drainage issues on new and redeveloped sites with far less environmental impacts. Although much of the material is generic by nature, it provides a number of new techniques and designs that have widespread applicability to the City of Nashua and other communities in New Hampshire and elsewhere.

This parking lot is both part of the cause and part of the result of greater stormwater volume. With urbanization and increased imperviousness come increased floodwaters due to an interruption of the natural hydrologic cycle.

Traditional drainage designs have served communities well to alleviate flooding conditions in some areas, but have unfortunately created new flooding problems and many environmental issues. Some of these environmental issues are so important that they require a change in the way business is done and development is constructed. Without changes such as those promoted in this guidebook, surface and groundwater resources, including our precious drinking water, are at significant risk. Widespread adoption of these techniques can make a significant impact on improving the situation. The problems addressed by this guidebook are described further in the next section.

2.0 Stormwater Impacts & Issues

2.1 Introduction

A recent nationwide Roper Survey noted that only 1/3 of respondents could correctly identify the definition of "watershed" in a list of multiple choice options.[1] This suggests that stormwater and its impacts may not be on the forefront of coffee table topics for most Americans. Yet the effects of yesterday's and today's stormwater management techniques clearly have an effect on all people who reside in developed areas. Some of the most important impacts are shown on Table 2-1 above.

Table 2-1. Impacts of Stormwater on New Hampshire Residents

More flooding	Floodplains are expanding due to more imperviousness and higher stormwater peaks
Beach closures	Stormwater contains high levels of pathogenic bacteria
Poor fishing	High temperatures and low dissolved oxygen prevent spawning and cause a loss of cold water species
Drinking water impacts	Less quantity and threats to quality
Loss of groundwater recharge	Declining groundwater levels/stream baseflow
Loss of species and habitat diversity	Poor water quality affects many areas of the environment
Higher cost for water supply	New sources for treatment will cost municipalities

2.2 How Stormwater Affects You

Much of the discussion to date on stormwater has related to its impacts on water quality, water quantity and the environment. People as part of this environment are affected in a number of ways.

[1] United States Environmental Protection Agency. September 10, 2002. WaterNews.

More Flooding
You may have noticed that floods seem to be more common these days. One of the primary reasons is the development of our watersheds with its attendant pavement for roadway networks and parking lots, impervious roof tops and driveways and the general explosion of impermeable surfaces. These impermeable surfaces cause exponentially greater levels of runoff than the original forest or agricultural field did. FEMA, the Federal Emergency Management Agency, is redrawing many of the floodplain maps to include larger areas of previously unflooded lands. Most of these areas are in or downstream of urbanized areas where imperviousness has increased, resulting in increased flood velocities and volumes.

Beach Closures
The Environmental Protection Agency (EPA) has found that beach closures and proximity to storm drains have a statistically significant correlation. The incidence of gastrointestinal illness is linked to this same phenomenon. Although in some cases there are additional factors, the majority of beach closures are directly related to the volume and location of stormwater inputs to beach areas.

Poor Fishing
Haven't caught any fish lately? Not surprising if you are in an urban or suburban stream affected by stormwater. Stormwater carries a load of pollutants with it, as will be discussed in more detail later, and these pollutants are known to negatively affect fish populations and other aquatic life. Heat can be a pollutant that kills fish or prevents spawning. In fact, most cities of any size are developing a warmer thermal profile that also increases air pollution.

Drinking Water

Locally, the estimated yield of Pennichuck Brook has declined by over 75% in the last 100-years

Many public water supplies are feeling the effects of stormwater, both from the pollutants brought in by stormwater and by declining yields. The yields of these water supplies are being affected because natural hydrologic cycles have been interrupted. Under the natural hydrologic cycle, rain water filters through permeable surfaces into groundwater which then discharges into surface water or is used for public or private supply as groundwater. Impermeable or impervious surfaces interfere with recharge to the groundwater, causing torrents of stormwater to pour out of the watershed and down to the ocean where it cannot be captured for water supply. Locally, the estimated yield of Pennichuck Brook has declined by about

75% in the last 100-years[2]. Pre and post-development hydrologic cycles are shown on Figure 2-1.

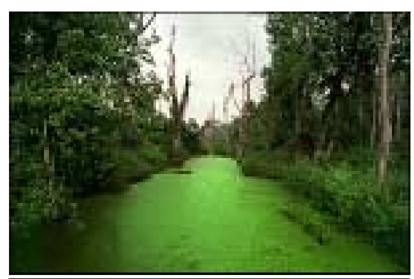
Higher Taxes
The stormwater issue is now serious enough to result in each of us paying more in federal, state and sometimes local taxes to pay for it. Some of these costs include:

- the federal effort for redefining flood plains, which is so important to our safety,
- increased flood damages,
- the impact on the loss of fisheries,
- the impact on ocean fisheries productivity by stormwater deposits,
- reduced recreational revenues in some areas,
- expensive restoration projects and
- limited drinking water supplies.

All of these add up to an economic impact that is just beginning to be counted. Add to this the costs for improving our infrastructure to handle higher stormwater volumes and for treatment to clean it up -- the dollars keep adding up.

On top of this, many communities have serious water shortages related at least in part to stormwater. New supplies must be sought, permitted and treated, a great expense by itself. Beyond these direct economic impacts are the indirect aesthetic and quality of life issues related to a degradation of environmental quality, loss of species and habitat diversity.

Stormwater has been identified by the United States Environmental Protection Agency as the number one current threat to water quality. It may well be the number one environmental threat today.



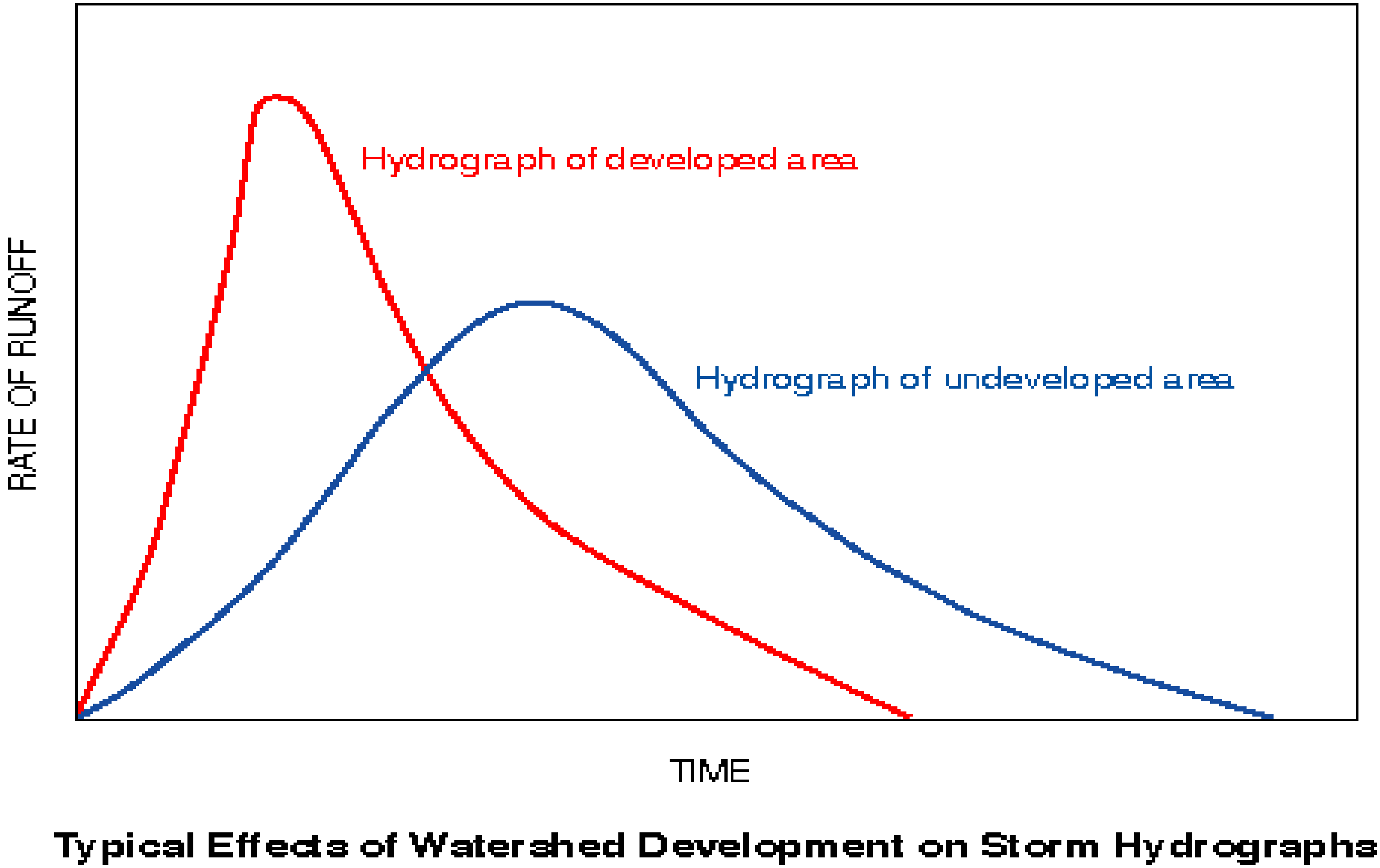
This waterway is overwhelmed by an algae bloom largely due to nutrient inputs from stormwater.

2.3 Why Stormwater Causes Serious Impacts

The examples used above are the end result of the last one hundred years of stormwater management. The first efforts at controlling stormwater, previously known as “drainage”, were efforts by engineers first to drain off stormwater flows and to relieve flooding in areas that were either naturally flooded or that became flooded due to filling in developed

[2] Based on a comparison of current yields compared to an early yield analysis by Metcalf & Eddy.

Figure 2-1. Typical Stormwater Runoff Hydrograph
Pre and Post Development



Source: U.S. Geological Survey. 2000. *Effect of Development on Water Quality.* Proceedings from Stormwater Management Series 2000 Symposium, April 19, 2000. Produced by Comprehensive Environmental, Inc.

areas. Engineers found that by laying pipes, sometimes unjointed pipes, through and often upstream of the flooded area, they could essentially divert the water downstream. This “flood control” worked well for many years, but unfortunately it simply pushed the problem downstream. As development occurred, larger and larger pipes, canals and lined concrete channels were needed to move the water out of the city as quickly as possible. There was little regard for groundwater which wasn’t well understood at the time.

During the last 15 years, the problem with these techniques has become very obvious as entire watersheds develop with little room to move the water downstream further. The water quality impacts have also become more and more severe, and a decline in groundwater levels has become apparent. Today’s designs are somewhat improved because many rely on infiltration to improve water quality and try to re-establish part of the hydrologic cycle. Other designs use manufactured treatment units that may improve quality. Nonetheless, even current designs fall short and only address a small portion of water quality and quantity concerns. This is described further in Section 3. Section 2.4 below describes some of the technical aspects of why and how stormwater impacts the environment and people.

2.4 Specific Impacts and Issues

2.4.1 Water Quantity

Traditional stormwater management techniques can affect water quantity drastically. As discussed previously, impervious surfaces expand as development expands, and most of the stormwater problem is generated from these surfaces. Table 2-2 shows CEI’s estimates of the impervious levels in Nashua, which are representative of most other locations.

Impervious surfaces interfere with the natural hydrologic cycle and process of recharging groundwater with rainfall. Instead, water flows off the impervious surfaces rapidly, picking up pollutants and gaining volume and erosive velocities. As impervious area increases, the volume and velocities of stormwater increase and the stormwater contact with soil tends to result in erosion and further pollution.

Table 2-2. Estimated Imperviousness in Nashua Land Use Type	Estimated Average Imperviousness Level
Downtown	85%
High Density Residential	75%
Low Density Residential	35%
Pennichuck Watershed	35%

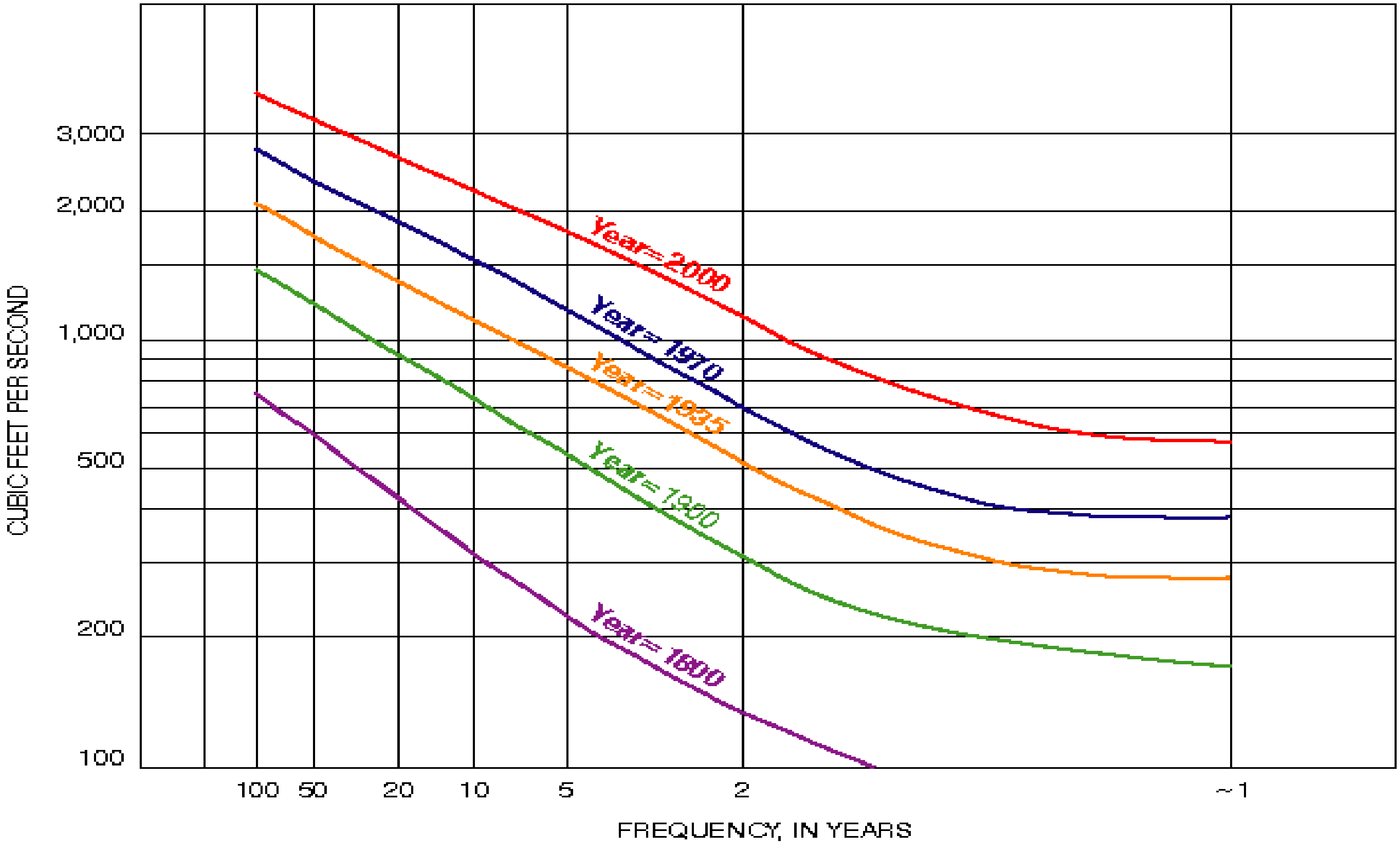
The Center for Watershed Protection has identified 15% imperviousness as the level where water quality impacts become serious.

The excess volume of stormwater is created by the impervious surfaces collecting rainfall over a large area, before it can recharge into the ground; then concentrating it through underground drainage pipes downstream. These flows eventually catch up with other stormwater runoff, resulting in excessive peak volumes and floods. Figure 2-1 shows a typical storm hydrograph pre and post-development. As shown on the figure, post-development peaks are much higher, resulting in an expansion of floodplains since all the water essentially hits the waterbody at once, rather than seeping into the ground over a period of days, recharging through groundwater sources as it did in a pre-development condition. Figure 2-2 illustrates how the increased peak flows from development impact flooding frequencies over time. As shown on the figure, flooding frequencies increased significantly for Town Brook in Quincy, Massachusetts between the years 1800 and 2000. This is a result of increased development in this watershed during those years. Increased flooding conditions caused by development also lead to erosion of natural streambanks and widening of the channel since the stream channel must now handle larger volumes of water during storm events. This increases the sediment loadings to the streams and exposes tree and other plant roots along the banks. Figure 2-3 provides an example of increased channel widths due to urbanization. Hence, both the floodplain and flood impact is expanded, potentially dramatically.

In addition to increased flooding, stormwater diverts what would have been recharged quickly out to waterbodies and the ocean. This has resulted in groundwater declines in some areas. The groundwater decline has a two-fold impact, since it can affect the yield of groundwater drinking water supplies and tends to reduce the discharge of clean water from groundwater to streams.

Under normal conditions, this continuous groundwater discharge to streams is termed "baseflow" and it supports fisheries and water quality during summer periods. Under post-development conditions, some watersheds have seen a reduction in baseflow of clean groundwater. This

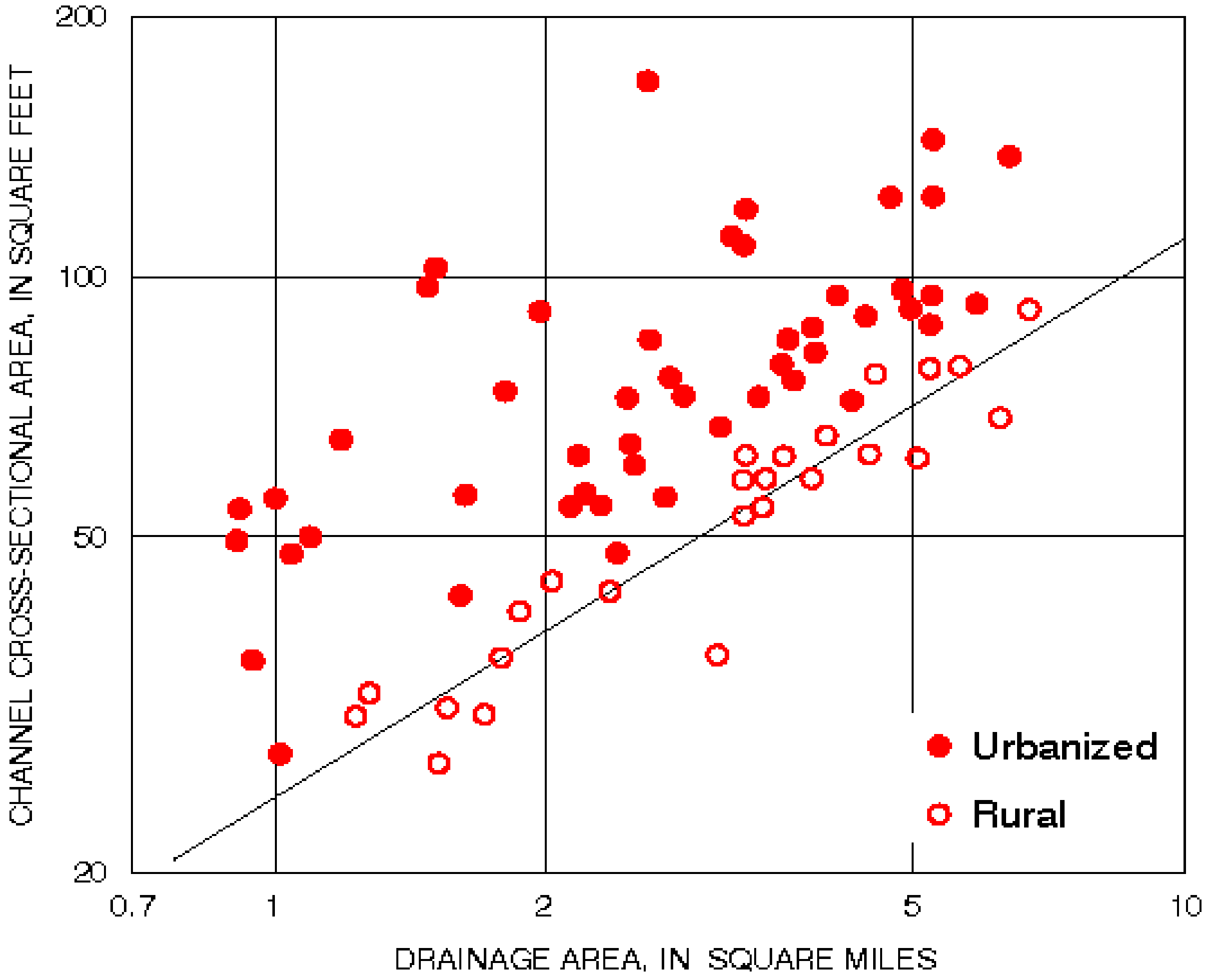
Figure 2-2. Effects of Development on Flooding Magnitude and Frequency



Effects of Urbanization on Magnitude and Frequency of Flood Discharges for Town Brook, Quincy, Massachusetts

Source: U.S. Geological Survey. 2000. *Effect of Development on Water Quality.* Proceedings from Stormwater Management Series 2000 Symposium, April 19, 2000. Produced by Comprehensive Environmental, Inc.

Figure 2-3. Effects of Development on Stream Channel Size



Increase in Channel Size with Drainage Area and Urbanization in Pennsylvania

Source: U.S. Geological Survey. 2000. *Effect of Development on Water Quality.* Proceedings from Stormwater Management Series 2000 Symposium, April 19, 2000. Produced by Comprehensive Environmental, Inc.

eventually results in a decline of water quality of waterbodies and volume available for water supplies, whether surface water or groundwater based.

2.4.2 Water Quality

The water quality of streams, ponds and lakes is severely impacted by stormwater. Lakes and reservoirs with the highest proportion of stormwater inflow in comparison with groundwater inflow tend to have the poorest water quality. Some of the impacts are as follows:

This drainage pipe, located in a subwatershed of Pennichuck Brook, shows evidence of the high volume of sand and silts that enter this waterway via stormwater.

Silt and Sand

High velocity stormwaters tend to wash in considerable amounts of silt and sand from the watershed into waterbodies. This silt and sand has four primary impacts: 1) it fills in the waterbody, allowing a greater substrate for aquatic weed growth; 2) benthic invertebrates are smothered, and a change in habitat can result in a change of species; 3) high turbidity can have an adverse effect on fish and filter feeding organisms; and 4) these particles tend to have adsorbed pollutants because most pollutants have an affinity for particles (particulates) or attach themselves to particles. Stormwater also tends to pick up sand from winter sanding operations, delivering it to waterbodies through the storm drain system. Again, it picks up many pollutants from roadways and parking lots that are deposited there either through air pollution or directly by cars. Many ponds, lakes and reservoirs across the United States have suffered filling in and subsequent water quality impacts from stormwater.

Temperature

Pavement and other impermeable surfaces are often black or dark colored and tend to absorb substantial amounts of heat during the summertime. The rainfall hitting these surfaces before flowing into waterbodies tends to be considerably warmer than the normal groundwater inflow would have been. This results in impacts on aquatic life, which are extremely sensitive to temperature, and also tends to provide better habitat for pathogenic bacteria that may enter waterbodies.

This pond, located in an urbanized area of Massachusetts, used to be a recreational and aesthetic resource to the surrounding community. Through uncontrolled stormwater inputs, high levels of nutrients and bacteria now render the pond unfit for human contact. It is now termed "eutrophic" and has become a source of complaints from surrounding residents due to odors.

Nutrients

Nutrients, particularly nitrogen and phosphorus, become common pollutants in waterbodies and are largely responsible for what is today known as "eutrophication". Natural eutrophication is a process in which excess fertility in a waterbody leads to excessive plant growth. This growth has a strong impact on water quality, and the resulting ecosystem changes may fill in the waterbody over many millions of years. However, cultural eutrophication is a waterbody's response to development and stormwater that results in the process of ponds filling in over short time periods, rather than millions of years. Excessive aquatic vegetation, low dissolved oxygen, fishkills, odors, algae blooms and the like are all a part of the cultural eutrophication picture. They are all related to nutrients and the single largest source of nutrients in the United States is stormwater. The nutrients may originate from fertilizer use in the watershed, pet wastes and a variety of other sources. If filtered through virgin ground, most of these nutrients will be taken up by soils and utilized by local micro-organisms. However, carried by stormwater, they quickly enter the waterbody and accelerate eutrophication.

Bacteria

Bacteria enter all water courses and waterbodies rapidly through stormwater. Stormwater testing over the years has shown quantities of pathogenic bacteria that rival slightly diluted sewage. Major sources are sewer surcharges, pet and livestock waste disposal practices and waterfowl concentrations. Notably most of the latest end of pipe treatment devices have little effect on bacteria levels. Bacteria have also been found to reproduce in storm drains under certain conditions.

Pathogenic bacteria, viruses and protozoans can cause human disease, including gastroenteritis, giardiaris and cryptosporidiosis among others. These may affect either water supplies or swimming areas. Although water supplies are treated to exacting standards in the United States today, some of the protozoans, such as *Giardia* and *Cryptosporidium* can still escape the treatment process if found in drinking water supplies in large quantities. In most cases this is due to uncontrolled stormwater discharges to water supply lakes, reservoirs and rivers. In 1998, there was a major waterborne disease outbreak in the City of Milwaukee, Wisconsin that killed about 100 people and affected 100,000. The cause was traced to uncontrolled stormwater discharges from feed lots that entered the source of water supply. Even though this water supply was conventionally treated and met all current standards, there were a large number of *Cryptosporidium* oocysts that broke through the treatment process.

In Nashua, combined sewer overflows occasionally discharge sewage into the Nashua and Merrimack Rivers. In part these are due to excess peak volumes of stormwater entering the combined portions of the sewage/drainage system due to the high level of imperviousness of the area. Past standard engineering practice of piping stormwater to the nearest drainage way has resulted in higher peak flows in Nashua that cause this condition. Without these excessive peaks, combined sewer overflows would be much smaller.

Metals, Oil and Grease, Other

Exhaustive stormwater sampling over the last 15 years has repeatedly shown that urban and suburban stormwater runoff contains high levels of heavy metals, oil, grease and a range of other contaminants. Most are related to transportation in that they are washed off roadways, parking lots and other impervious surfaces after being deposited there by air pollutant fall out or directly from vehicular traffic. Most of these contaminants are toxic to aquatic life and fisheries in the concentrations found in typical stormwater.

2.5 Health Concerns

In addition to the health concerns presented by pathogenic micro-organisms described above, most current stormwater handling designs tend to result in long-term ponded water. This can result in a greater threat from mosquito-borne diseases such as encephalitis and the newer West Nile Virus. Traditional catch basins tend to contain some level of water depending on groundwater levels and the catch basin design. Although many public works departments treat their catch basins or hire a contractor to treat the catch basins to prevent mosquito breeding, private systems may not be addressed.

While most natural wetlands and water bodies contain a diversity of mosquito predators, stormwater detention facilities may not have enough biodiversity (i.e., variety of species, including predators) to control mosquito populations. After all, they hold contaminated stormwater that is toxic to most aquatic life, leaving the relatively pollution tolerant mosquito larvae with little competition or predator influence. This supports the use of infiltration technologies wherever possible, and wetlands treatment (with pretreatment) where high groundwater conditions exist. Appropriately sized and designed systems will not promote excessive mosquito breeding.

3.0 How Traditional Designs Fail

3.1 Introduction

Traditional designs for drainage structures and stormwater management have evolved over the last 100 years. In the early years, stormwater was not a significant problem and most "drainage" projects were methods to remove rainwater off a newly developed property or to dewater wetlands, then called swamps. Early engineers and land managers felt that by "reclaiming" the swamp, useful land could be made. Drain tiles or other features were put in place to dewater wetlands, which were then filled with various materials. Many urban areas are built on large amounts of fill.

Older mill communities such as Nashua are particularly likely to have been built at least partially on filled waterways. While it must have seemed practical at the time, this was the first step in creating our current dilemma of excess stormwater. The fill itself took up flood plain and flood storage volume, pushing flood flows downstream. These areas still often flood despite man's best attempts to alleviate the flooding, because they were in a natural floodway. Hard packed or cobbled streets and other early impervious areas were the first generators of higher levels of stormwater than would be naturally found in a forested or farmed area.

To alleviate the flooding of these fill areas and the areas downstream where water levels were now higher due to the displacement, early engineers began building piped drainage systems. These piped drainage systems often worked quite well, and were open jointed to collect high groundwater and route it downstream. These drainage systems would often alleviate flooding under most conditions in the filled area, but the water had simply been relocated slightly downstream. Unfortunately, these downstream areas would receive higher flood levels than they ever had prior to the development of drainage projects, since the water still had to go somewhere.

This urban stream is nothing more than a trash receptacle and floodway. Habitat diversity is non-existent as a result of high velocities and poor water quality from its highly impervious watershed. Trash gates were put in place to allow a cleanout point. A downstream recreational lake was once a water supply but had to be abandoned due to poor water quality inputs from streams like this one.

Flood control projects grew in size and affected area as the population grew. The United States Army Corps of Engineers began to provide major dollars and technical expertise to develop bigger and better drainage and flood control projects. In most cases these projects were meant to address developments that were placed in areas not suitable for development due to their nature as flood zones, waterways and the wetlands associated with them. In individual watersheds, flood frequency and volume have risen dramatically over the last hundred years due to imperviousness, filling of wetlands and other urbanization factors. For example, the United States Geological Survey estimates that what was once the 100 Year Flood Plain in Town Brook in Quincy, Massachusetts is now the 1 Year Flood Plain.[1]

In the late 1980s, federal and university scientists began to understand the water quality problem that had been created by past drainage engineering

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[1] Brian Mrazik, U.S. Geological Survey, New Hampshire, presentation materials from the Stormwater Management Workshop Series 2000, held April 19 and 20, 2000, sponsored by Pennichuck Water Works, New Hampshire DES and facilitated by CEI.

and land use practices. The Army Corps of Engineers even began the slow process of reversing some of its massive public works projects of the 50s, 60s and 70s. The United States Environmental Protection Agency (EPA) had begun trying to understand why water quality in the nation's water resources had not improved to the degree projected by the Clean Water Act of 1972.

Under the authority of the Clean Water Act, point sources of pollution such as industrial discharges and municipal waste treatment plants had been steadily more heavily regulated, yet it was clear that fishable/swimmable water quality goals set in 1972 were not going to be met within the original twenty year timeframe. The identified reason was non-point sources or stormwater.

Since the late 1980s, the impact of stormwater on water quality has become clearer with continued research and effort. However, it has only recently been recognized that flooding and other water quantity issues such as groundwater declines and losses in stream baseflow are also due to stormwater.

Infiltration galleries like this one have become popular in recent years due to their space saving location under the parking lot. With visible and adequate pretreatment and frequent maintenance, they can work well and will help recharge groundwater. However, many designs today do not have pretreatment and are difficult to clean out, so they quickly fill with sand and fail. The pollutants they were supposed to treat then go out to water bodies or into the municipal system where taxpayers foot the bill for maintenance.

During the last ten years there has been a frenzied effort to develop new technologies to treat stormwater, mostly at the end of the pipe. Some more urbanized states even issued emergency stormwater regulations due to projections that major rivers would be dry during the summer in the next 20 years if steps weren't taken to better control stormwater.[2]

Dozens of proprietary devices and treatment schemes to try to improve the quality of stormwater discharges have been developed. New regulations and policies in most states now promote better practices such as the use of detention basins for holding stormwater prior to discharge to a municipal system or stream.

Automobile By Products

- Oil
- Grease
- Scum
- Phosphorus
- Heavy metals

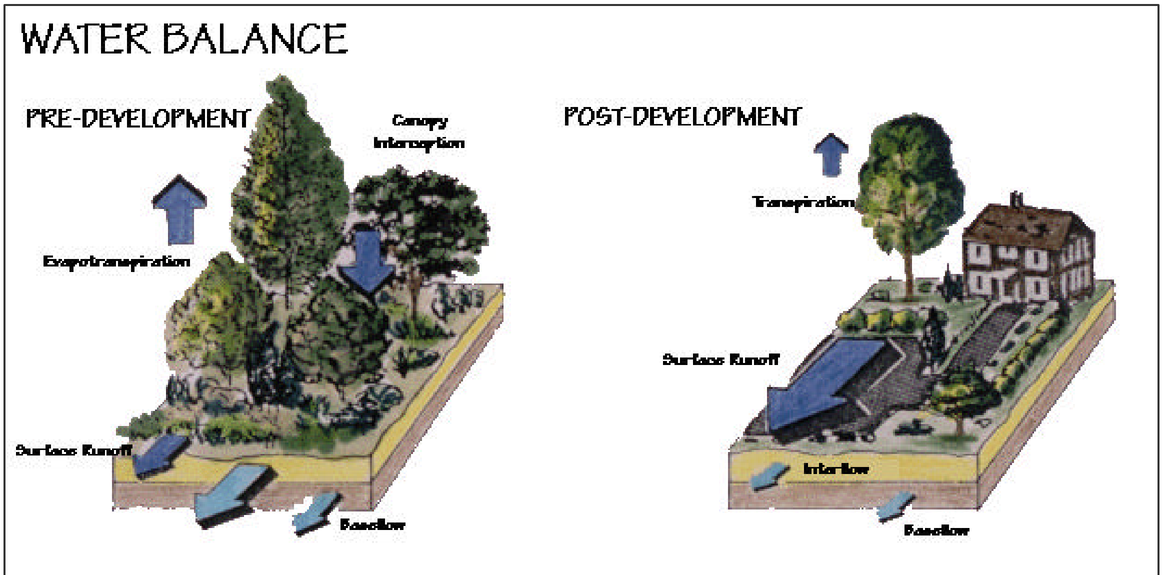
Filling of wetlands has been illegal for large areas of fill since 1989, but small filling continues. Many states and in New Hampshire some municipalities and water suppliers have put buffer zones in place around wetlands and waterways in recognition of the benefit of a natural buffer from development. In some other states there is a required 100 foot buffer zone within which permits must be acquired for any work that disturbs the buffer zone. The impacts of urbanization are now well documented and remedies are beginning to be used.

Despite these recent advances, traditional or current stormwater management designs still focus on the end of the pipe to deal with the typical contaminants shown in the above picture. Most developments will put in a large detention basin which handles roof leaders, parking lots and other impervious areas. While these detention basins are unquestionably an improvement over past practices of piping the stormwater directly to the nearest stream, stormwater handling by this method still has its problems. Some of these problems are outlined below.

[2] Massachusetts Department of Environmental Protection Stormwater regulations based on concerns with the Charles and Ipswich Rivers loss of baseflow.

3.2 Sizing and Siting Issues

The least expensive way to meet today's standards in most communities is to place a detention basin at the lowest end of a housing development. In crowded or more urban sites, underground units may be used to handle parking lot runoff. These may be undersized because of the assumptions used in the engineering calculations. For example, even in the current era of "pre and post-development" regulatory controls, developers' engineers will sometimes assume that a residential site with a cleared grassy yard area (including the house and driveway area) have the same runoff coefficient as the original forest, thereby reducing the theoretical amount of flow from the development. However, a hard packed lawn may have more than twice the volume of runoff as the original forested area and the impervious surfaces certainly increase the site's total runoff. In an urban area, the engineer's calculations may rely on the assumption that the parking lot will be swept of sand on a frequent basis, when in fact the parking lot is rarely or never swept post-development. In some communities these drainage features are filled with sediment from the construction process itself, and are not cleaned out prior to release of the contractor's bond.



Runoff calculations in new developments sometimes underestimate the effect of site clearing and slopes on runoff volumes, resulting in undersized stormwater control structures and negative impacts on the municipal system and the environment. Drawings courtesy of the Center for Watershed Protection.

The end result is drainage structures that either do not work at all or require more maintenance than the owners or municipalities can reasonably provide. Some public works departments have complained that they have had to clean out recently constructed proprietary units several times a year to keep up with the volume of sediments generated. Obviously these units work quite well to contain sediment as they are designed, but when maintenance fails these units also typically fail.

3.3 Limited Water Quantity and Quality Improvement

In addition to the units and structures described above that fail outright due to lack of maintenance, many of the units in use today do not address all water quality issues and have little effect on excess volume issues.

One of the best types of units is a wet pond, yet it does little to remove bacteria and may in fact increase the levels of pathogenic micro-organisms if not designed appropriately. Many of the proprietary end of pipe units work well to trap sediment, and if maintained frequently can provide a water quality benefit. However, they do not typically address microorganisms such as bacteria, viruses and protozoans. They are also rarely effective on nutrients such as phosphorus and nitrogen, the leading water quality pollutants today, and they do little or nothing to decrease flow rates.

Rarely are eventual site owners fully aware of the purpose and maintenance needs of the drainage controls on their site, yet sizing and approval often depends heavily on this factor.

Detention basins, can do an adequate job of addressing water quality if sized appropriately and maintained. However, some are difficult to access or there is no maintenance schedule for inspection/enforcement so they fill up and overflow to waterways. This also limits their ability to improve the volume issue. Detention basins can improve groundwater recharge, but as a single point for all recharge they tend to eventually clog and have little benefit in re-establishing the hydrologic cycle.

3.4 Health Factors

Many of today's units, unless sized and maintained appropriately, may result in standing water that can provide mosquito habitat. In addition, few stormwater controls can address the issue of pathogenic bacteria and other microorganisms, yet they give planning boards and municipalities a false sense of security that all is well.

3.5 Ownership and Responsibility

Developers may present a very positive image of the proposed development, but once the development is completed, the responsibility and ownership of these sites often resides with homeowners or business owners who have little knowledge of their purpose. In many cases there is no agreement with the new owner to maintain the facilities or even to allow access by others to maintain the facilities. It would likely be a rare project in New Hampshire where the eventual site owner was fully aware of the purpose and maintenance needs of the drainage features of their site and were ready, willing and capable to take on these needs. Yet sizing and approval of most sites depends heavily on this factor.

3.6 Maintenance

As part of continuing subwatershed studies for Pennichuck Water Works Corporation, CEI reviewed drainage and water quality controls in several subwatersheds of the supply from 1999-2002. Almost all detention basins and other controls were completely full of sediment and the sediment was washing over into waterways and wetlands. Because these are privately owned developments, the City has little control over their maintenance. The City's Department of Public Works and Nashua Regional Planning Commission are now working on a project that would inventory these sites and set up a process for requiring their maintenance.

Meanwhile, few of these failed stormwater controls now provide any water quality protection or infiltration opportunity to recharge groundwater. Recent subdivision reviews done by CEI in other New Hampshire municipalities have revealed that some engineers are proposing underground parking lot infiltration units that have difficult or no access for maintenance but do have a bypass feature in case of failure. How many of these are being approved is unknown but the number is likely to be high. Underground parking lot units, which can work well for promoting infiltration in this otherwise impervious area, will quickly fail and bypass to the municipal system if not designed properly. The end result is a greater maintenance burden and cost on the municipality or significant water quality impacts, or more likely, both.

Traditional catch basin design can provide a water quality benefit, particularly if the community uses deep sump (oversized) catch basins or leaching catch basins. However, CEI's anecdotal findings have been that less than fifty percent of municipalities regularly maintain their catch basins.[3] Some communities do a great job with this, while others have grass growing out of the catch basin grates. One reason is that regular maintenance of any system, including drainage systems, is not very glamorous and tends to be an item that may be cut during tight budget years.

[3] CEI Stormwater Management Survey of Practices, New Hampshire and Massachusetts municipalities, June 2000.

Maintenance is generally not occurring at an adequate level in most communities, yet we continue to design systems that rely on a high level of maintenance to provide a water quality and quantity benefit.

3.7 Failure and Replacement

All drainage structures will eventually fail, even if religiously maintained and cared for. This is particularly true of some of the latest proprietary technologies that rely on complex processes. Although some features such as a detention basin, may not need outright replacement, excavating and disposing of the sediments once it is completely full would be quite a costly undertaking.

Common transportation pollutants include heavy metals, oil and grease and loads of sand. These are washed off the surface during rainstorms.

Underground parking lot units are particularly susceptible to unseen failure. Because they are not visible and often not easily accessible, they may quickly fail if not maintained and are expensive for the new site owner to replace. Most will probably be useless within a few years, leaving stormwater from the parking lot to discharge completely untreated to the municipal system or waterway. In most cases, even if a municipality were to identify that a unit needed replacement, they may not have adequate authority to require the owner to perform this expensive replacement.

If end of pipe controls and underground units are not maintained, the result is washover of contaminated silts and sediments into watercourses.

Eventually the sediments wash into water bodies like the Pennichuck Ponds (shown above), filling in the pond and importing pollutants. In larger rivers, like the Merrimack, the sediments may be suspended for some time causing reduced fishing and recreational impacts.

4.0 Innovative Designs – Runoff Prevention Methods (RPMs)

4.1 Definition of RPMs

In response to concerns about limited water quantity and quality improvements of traditional designs (see Section 3), the primary objective of this project was to identify better techniques for the City of Nashua and other New Hampshire communities to use. Other factors, including sizing and siting issues, ownership and responsibility, maintenance, failure and replacement are described for solutions in Section 5, Nashua Design Guidelines. The purpose of this section is to describe the techniques themselves, which entail an essentially new class of Best Management Practices (BMPs) called Runoff Prevention Methods or RPMs.

RPMs are a superior category of stormwater handling and treatment techniques because they go to the source of the problem and prevent runoff from leaving a site by infiltrating it at its source, rather than treating it once it has traveled far from its source. There are some RPMs in existence today, such as dry wells for roof leaders and grass swales for stormwater treatment, although they have not been called RPMs previously. Additionally, a number of new and innovative RPMs were developed as part of this project. These are described in this section.

This site in downtown Nashua is an ideal location for a drywell to intercept the roof leader for infiltration. Instead, the runoff erodes the lawn area. Drywells for roof leaders are a common existing Runoff Prevention Method and can easily be placed at most sites with a few design considerations.

Local building and plumbing codes, site design constraints and habits of installation have inadvertently led to more stormwater generation by region and community. For example, an RPM that has been used for years is a dry well for roof leader discharge and infiltration. Yet some communities prohibited these in the 1980s out of concern that a homeowner might use them for depositing hazardous fluids such as used oil. In that particular community, located in New England, runoff generated from subdivisions is in higher volume than from the next community which promotes the use of dry wells for roof leaders. In some communities, building code calls for French drains to be used to route water from foundations out to the street. This results in essentially a groundwater diversion and dewatering of the area. This may help protect the foundation in some site specific cases. However, as a general rule it is not necessary, and although easy and cheap for a developer, it is harmful from a water resources standpoint with long term hidden costs. In some areas, traditional practice is to put roof leader discharges on to the driveway, while in others it goes to a grassed area. The volume of runoff generated from each house lot can thus be significantly different from one area to the next. Sometimes these differences are variations between individual builders so the impact of one neighborhood can be greater than the next neighborhood.

Aside from local, regional and state variations in allowing RPMs, they can be greatly beneficial to water resources. However, there are a limited number of existing RPMs. These include dry wells for roof leader and other discharges, grass swales for stormwater treatment and leaching catch basins. Each of these receives only localized runoff. Another RPM

This roof leader from a large apartment building discharges to a concrete pad and then to the street. It could easily be rerouted to the lawn area or a drywell set several feet from the building.

is permeable pavement, which prevents at least a portion of runoff entirely by allowing rainfall to infiltrate directly through the "pavement". However, there has been significant resistance to the adoption of permeable pavement by departments of transportation and highway departments due to the precise bedding requirements for successful installation and concerns in our northern climate of plow damage or other maintenance difficulties. As a result, these RPMs have not been used on a widespread basis. Leaching catch basins could be the exception as many highway departments are beginning to use these. However, some highway departments criticize them as being difficult to maintain with a clamshell type basin cleaner.

As part of this project, a number of additional RPMs were developed for use in Nashua and elsewhere. Some of the above RPMs were also improved and adapted for more widespread use, with adaptation to overcome deficiencies.

These new and improved RPMs are described further in Section 2 of the second part of the design manual, *Part 2 – Designs & Specifications,* and summarized in Table 4-1.

4.2 Benefits of RPMs

There are considerable benefits to the use of RPMs, both for communities and for developers.

Benefits to Communities

- Reduced Flooding – By assessing each watershed for RPM opportunities, downstream flooding caused by imperviousness could be significantly reduced in many areas. Watershed wide use of RPMs could help re-establish the natural hydrologic cycle and reduce flooding.

- CSO Reductions – Since excessive stormwater runoff is the primary driving force behind Combined Sewer Overflows or CSOs, reducing stormwater volume naturally can help decrease the intensity and frequency of CSOs particularly for smaller storms. This has a significant potential benefit for Nashua, but the RPMs need to be used on a widespread basis to see significant impacts.

- Impact on Receiving System – If runoff from a subdivision or commercial project can be infiltrated onsite for at least a one to two year storm (preferably the two year), then the impacts on the municipal system of this development or on adjacent waterways will

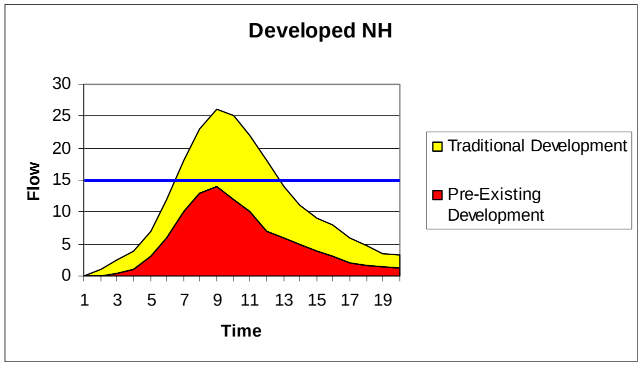
Table 4-1. Runoff Prevention Methods Alternative Designs

RPM No.	Name	Location of Use	Purpose
1	Infiltration Dividers	Parking lots and roads	Multiple trenches or cells that infiltrate/treat/store runoff from localized areas of the lot/road
2	Infiltration Islands	Parking lots and roads	Large unvegetated drainage feature that infiltrates/treats/stores runoff from all or a large portion of the lot
3	Biocells and bioislands	Parking lots and roads	Large vegetated drainage feature similar to no. 2, that also provides shade to cool heat of parking lot
4	Dry stream infiltration	Parking lots	Aesthetically designed “dry” streambed for drainage receipt
5	Containment swale	Road or street	An improvement on a grassed swale designed to intercept runoff before it goes to the municipal system
6	Driveway drainage strip	Residential or commercial driveway	An infiltration trench to intercept and infiltrate road runoff before it goes to the municipal system
7	Stormwater drywell	Roof leaders, small road or lot drainage	Improved drywell designed for ease of maintenance and prevention of failure
8	Grassed infiltration strips	Parking lots, roads	Localized infiltration strips that receive small amounts of road or yard runoff
9	Curbside treatment	Streets with formal sidewalks	An under sidewalk infiltration unit designed to receive first flush stormwater from the street
10	Alley infiltration	Alleys and narrow drives	Under pavement infiltration strip to handle roof leaders and road runoff
11	Raingarden strip	Residential yard or commercial lot	A small planting area designed to store and infiltrate runoff from driveways
12	Raingarden planter	Residential yard or commercial lot	A small planting area designed to store and infiltrate runoff from driveways
13	Pocket raingarden	Residential yards or commercial lots	A small planting area designed to receive small quantities of runoff
14	Decorative planters	Roof leaders where building foundation is at risk or in clay or bedrock areas	Small planters designed to store and treat limited quantities of roof runoff and provide water for annual flowers

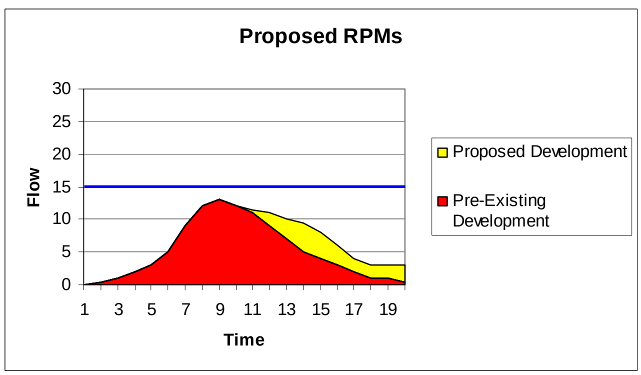
Note: some designs vary along the same theme, however, multiple examples are shown to demonstrate a variety of potential layouts and features.

be minimal. The use of RPMs alone or in conjunction with more traditional designs can result in a major reduction in impact on the municipal receiving system or receiving water body.

- Enhanced Recharge – RPMs significantly enhance recharge by allowing more square footage to be dedicated to recharge. The small size and widespread nature of RPMs tends to keep groundwater localized and prevent mounding such as occurs under detention basins where all drainage from a large area has been routed to one recharge site.



In this comparison of different development scenarios, the watershed is compared under the current development of New Hampshire, and the future proposed RPMs. The blue line on each graph represents a 15 cfs pipe. When the 15cfs capacity is exceeded, flooding will result. Nashua's ordinance encouraging recharge helps to limit this impact but does not go far enough because the flows can still be concentrated in "end-of-pipe" units resulting in a higher peak discharge from the site (top). In the proposed scenario, RPMs are used throughout the watershed to delay and dampen flow peaks, resulting in a nearly natural hydrograph (bottom).



- 100% Contaminant Removal – Except under larger storms, most RPMs provide 100% contaminant removal for silt and sand, nutrients, bacteria, metals, oil, grease and other contaminants. The only known contaminant not successfully removed by RPMs is sodium. Native soils or other soils at the local sites effectively remediate these contaminants through the activities of microscopic organisms. Even sodium, while not attenuated by site soils, has its impact lessened through reductions on shock loads through long term assimilation.

- Restoration of Baseflow – If used on a widespread basis, RPMs could restore baseflow by enhancing recharge and restoring groundwater tables to a level that allows baseflow discharge into streams, lakes and ponds. This could substantially enhance the yield of surface water supplies such as Pennichuck Brook, where over 75% of the total yield has been lost over the last 100 years to imperviousness.

- Health Protection – RPMs are designed to drain within 48 hours, so there is no opportunity for reproduction of disease-bearing mosquitoes. RPMs are also the only currently known technique to remediate bacterial pollution. Pathogenic bacteria and protozoans do not travel well through groundwater as they are predated by local microorganism populations in a healthy soil or simply die over time. All other current stormwater technologies have little effect on pathogenic bacteria.

- Aesthetics – Most of the RPMs described in this manual have aesthetic benefits as well as water quality benefits. The use of vegetated biocells and bio-islands as well as rain gardens can provide attractive greenspace that could substantially improve the aesthetics of a parking lot, for example.

- Maintenance – RPMs tend to have lower maintenance frequency because they occupy larger square foot space than traditional methods such as a catch basin. By adding RPMs to a parking lot, for example, the sanding from a winter's use is spread out and taken up by hundreds of square feet of infiltration islands instead of a couple of square feet from a catch basin. RPMs also have visible maintenance needs, so they can not fail like underground parking lot units can based on unseen maintenance needs. Most maintenance needs are similar to routine landscape maintenance of a spring and fall cleanup.

Benefits to Developers
Developers also can receive some benefits through the use of RPMs. While the developer may be less concerned about downstream water quality and impacts on the municipal system, most developers are concerned about cost.

RPMs typically have installation and construction costs of less than or similar to the design and installation of a traditional system. No special equipment is needed and all of the materials are readily available and commonly used in other types of construction projects.

- Aesthetic Benefits to Buyers – Since the use of RPMs tends to create a better looking site, there may be sales benefits to developers. Further, developers can inform potential new site owners of the reduced maintenance involved in their site design.

- "Green" Development – Many businesses are promoting themselves as "green" these days. Surveys have shown that a vast majority of the American consumers consider themselves environmentalists and are sometimes keenly interested in working with companies that benefit the environment. By using these techniques, developers can truly help the environment and their business at the same time.

4.3 RPM Considerations

There are a number of issues to consider when using RPMs as part of or in place of a traditional design. These are described briefly below.

Use in Reducing Flooding
If RPMs are used to reduce flooding impacts, they must be used on a widespread basis and located in tributary watershed areas. RPMs located at the watershed outlet or end of pipe will have limited benefit to flooding issues. RPMs located in upper tributary areas of a watershed can significantly reduce flooding downstream if done on a widespread basis. This is because these RPMs will store and slowly release water to infiltration during all but larger storms, resulting in a more naturally shaped storm hydrograph and reduced downstream flooding.

Storage and Infiltration
Calculations for sizing of RPMs should consider whether they are used for storage only, as in high groundwater areas, or whether a high degree of infiltration will occur. As discussed in Section 5, some exfiltration from RPMs can only be added to the calculations if there is a high percolation rate and significant separation from groundwater. Otherwise, RPMs should be sized as if they are storing flows only.

Use of Overflows
RPMs are not designed to replace existing drainage systems when used in urban areas. Most of the RPMs designed under this project were sized for a one or two year storm (three inches over a 24 hour period in Nashua). In storms that exceed this volume, there will be overflows.

During 10 year and greater storm events, outlets are needed for excess runoff. Note that this continues to provide a water quality benefit despite these overflows, as most storms fall within the category of complete infiltration.

Fire Safety

Fire safety lanes must still be maintained where RPMs are used. In a parking lot, for example, every lane does not need to be wide enough for fire trucks to pass, but there should be well marked lanes reserved for that purpose. RPMs constructed where traffic might inadvertently drive over them should also consider this in the design.

Sizing of Other Drainage Structures

In new developments, it is possible that the total sizing of the drainage system for a given development might be reduced in size through the extensive use of RPMs. This depends on site specific conditions and in areas with extensive clay and or impervious till might not be practical. However, in many cases new development drainage systems could be reduced in size through the proper and appropriate engineering and by using RPMs. In redevelopment in urban areas, the existing system for drainage should be left in place and used as an overflow.

Permitting Issues

Because RPMs are new, there are some permitting considerations. These include New Hampshire Department of Environmental Services' (DES) Alteration of Terrain permits, which currently do not allow the calculation of dry wells for roof leaders as a subtraction from detention basins. This regulation is expected to be modified in the near future and DES is considering how to encourage the use of RPMs under this program.

The EPA Underground Injection Control Regulations under the Safe Drinking Water Act prohibit dry wells in industrial and certain commercial areas if they could contribute pollutants to an underground source of drinking water. For example, dry wells at a gas station are generally not a good idea because they could be used for disposal of hazardous fluids. This type of RPM could be used in areas where there is little opportunity for inappropriate use, however.

Regulations

EPA recently issued new stormwater regulations, the so called Phase II NPDES Regulations. Under these regulations, communities are required to develop Stormwater Management Plans for municipal facilities and there are a number of listed communities that must develop town-wide Stormwater Management Plans. Over the period of 2003-2008, the communities subject to these regulations must inventory storm drainage discharges, prohibit and remove illicit discharges, and modify their regulations for better erosion control and post-development control of drainage structures such as detention basins. The use of RPMs by any community will be useful in complying with Phase II in that the RPMs are virtually ideal stormwater controls. The adoption and implementation of the design criteria described in the next section will further assist communities in complying with Phase II.

5.0 Design Guidelines

5.1 Building on Existing Design Successes

Current technologies and designs do provide more effective stormwater treatment, recharge and sometimes less flooding than older systems. However, as pointed out in Section 3.0, there are a number of problems with these traditional treatment designs that still follow the original engineered model of collection, concentration and off-site conveyance with an attempt to handle large, newly developed peak flow at the end of a pipe. Methods such as detention basins and under parking lot infiltration units have been designed to perform many of the beneficial services that would occur naturally if there were no human development of the area, and as such are an improvement over direct piping to the nearest water course or municipal system, but they could still be significantly improved.

To control the problem created by piped drainage, many systems have been created to hold the concentrated stormwater back and release it slowly. For example, detention ponds were designed that could force stormwater to pool temporarily, slowing down the flow and reducing the surge of stormwater that might otherwise overwhelm an area further downstream. This strategy worked very well, and had the added benefits of providing some sediment and contaminant removal. Unfortunately, the detention ponds are very large, and the economic value of the surface area on a parcel has inhibited the use of detention ponds to some degree. Detention ponds also require heavy equipment to maintain once the sediment deposits reduce the ponds capacity.

There are also some traditional treatment systems that have been developed to remove large percentages of sediment and associated contaminants. Proprietary systems that use vortex type technologies are extremely efficient, require very little space, and the only surface area required is a manhole for maintenance. This allows them to be placed beneath parking lots and no surface area needs to be devoted to stormwater problems. But the problem with these systems is that they do not promote flood control, and they may require frequent maintenance if undersized. The maintenance is necessary because they are so efficient. Sediments quickly build up within the tank, and the system will stop working altogether if water just passes through it due to a lack of storage space. The fact that these units are so well concealed and so efficient means that it is easy for a property owner to neglect the required maintenance, allow the system to fail, and not realize it.

Some traditional treatment systems now help recharge groundwater levels by infiltrating stormwater into the ground. This process provides excellent contaminant removal from the water. This is due in part to the fact that sediment and contaminants adsorb to the soil particles or are filtered out by the soil matrix itself. This coarse filtering occurs because they are too large to fit through the pores between the particles or the water is slowed down enough that it can no longer hold them in suspension. The soil matrix prevents many contaminants from passing through, while the filtered water continues to infiltrate. Leaching fields like those used for septic tanks are used to distribute stormwater throughout a large soil area by directing water through perforated pipes.

Filtering the stormwater with soils has many benefits, but as more sediment is filtered out of the stormwater, it clogs the pores of the soil and the water will begin to back up. Renovation of this type of system is difficult, expensive and mostly ignored. But if this sort of infiltration device is paired with a pretreatment device such as a proprietary system to remove the majority of the sediment first, complete failure is less likely (if the pretreatment device is maintained). Unfortunately, the proprietary system may fail due to neglect, and then the rest of the infiltration system will fail shortly after. This failure may also avoid detection due to the overflow outlet that usually prevents these systems from backing up and flooding the parking lot. Stormwater can then flow through the useless structures that are tucked out of sight and mind, and be discharged into the nearest water body, rendering the entire system ineffective.

The following guidelines are recommended for adoption by the watershed communities. They will address many of the issues found in traditional designs and site development, building on the existing successful techniques and improving many aspects of current stormwater handling and management.

5.2 Recommendations

1. Evaluate How to Limit/Reduce Effective Impervious Areas

Effective Impervious Area (EIA) is defined as the impervious area that is directly connected to wetlands, waterways or water bodies. Some examples are shown on Figure 5-1. A one-acre parking lot that discharges via a catch basin and pipe directly to a wetland or stream has an EIA of 1 acre. On the other hand, if the same one-acre parking lot has no direct connection and instead uses onsite infiltration, it has an EIA of 0, a desirable condition.

In order for the approach described in this manual to be effective, watershed communities in New Hampshire should evaluate how they might be able to discourage new EIAs and restrict expanded and/or existing EIAs. They should also evaluate how to encourage or require redevelopment projects to disconnect EIAs.

Figure 5-1. Examples of Directly Connected Impervious Areas or Effective Impervious Areas.

This downtown parking lot and commercial building is all Effective Impervious Area as the roof leaders and parking lot discharge directly to the drainage or sewer system. The roof could be "disconnected" from the EIA by routing the roof leaders to the grassed area with infiltration through a trench or dry wells. About 30% of Nashua's downtown is impervious roofs, much more is paved.

2. Add RPMs to Traditional Designs

The use of Runoff Prevention Methods should be encouraged as an alternative to or in combination with traditional techniques. All of the traditional treatment components are important parts of the nation's infrastructure, and provide a major benefit to the communities using them, but the fact is that they are just trying to approximate the efficiency of natural systems. Logically, the beginning of stormwater control practices was based on solving problem areas once they were identified. Therefore the practices focused on mitigation, not prevention. The BMPs described above are now put in place as development occurs, but they are designed for anticipated problems with the development. These systems are still treating the symptom rather than the source.

The designs outlined in this manual are examples of improvements that can be integrated into future design work to control flow generation at the source and prevent the production of large volumes of stormwater runoff in the first place. Designing a development to prevent the stormwater from concentrating will reduce the magnitude of the problem before designing costly systems to deal with it. This proactive approach will enable creative developers and homeowners to draft more alternatives for renovations and new development.

Watershed communities should provide developers with this 2-volume manual, particularly the technical sections in Volume 2, and encourage them to use these designs. In the meantime, watershed communities, NH DES and Pennichuck should seek opportunities to pilot these designs to demonstrate their efficiency and use to developers, site engineers and planners.

This commercial driveway just off Somerset Parkway has a filled in drainage interceptor that probably goes to the storm drain system in this area. It could be cleaned and routed to the adjacent grassed area and infiltrated there, eliminating most of this parking lot and driveway from the Effective Impervious Area.

3. Scrutinize Sizing and Siting of Drainage Controls

Although some developers are scrupulous in developing pre and post runoff calculations for their proposed sites, others lean towards using assumptions that may lead to overestimation of runoff volumes and rates from existing site conditions and underestimation of runoff from the new development. For example, using TR-55[1], one developer's engineer made the assumption that a new residential yard had the same runoff coefficient as the original forest cleared for the yard, thus effectively reducing his burden of drainage controls. Yet the difference in runoff coefficients for the forested natural area versus the lawn is 30 compared to 68, depending on the assumptions for condition used in the formula. The higher numbers represent more runoff – pavement is 98 on the curve – so his use

[1] A runoff calculation model commonly used by developers and others to estimate pre and post runoff volumes and size drainage structures. .

of curve numbers of 36 and 39 respectively results in an unrealistically undersized drainage system. This case, kept confidential for the purposes of protecting the participants, was not detected by the subdivision review engineers for the municipality as they do not always see each site or question this type of assumption.

Other municipalities have reported that proprietary units are often undersized because of the assumptions made on maintenance. For example, some engineers have assumed frequent parking lot sweeping to effectively reduce the projected size of a proprietary unit designed to handle a parking lots' runoff. Yet how many site owners will really sweep the lot 4 times per year as was assumed by this developer?

Planning Boards and staff in watershed communities should request a list of pre and post-assumptions used by the developer's engineer, listed separately and clearly from the drainage calculations used. These assumptions should be scrutinized by engineers and planning staff who are familiar with the site and the proposed development and challenged as necessary. The watershed communities may also wish to standardize soils criteria and other assumptions so that limited more conservative criteria will be selected by developer's engineers.

Further, all stormwater controls should be sized assuming annual maintenance only. Sizing assumptions should not be based on more frequent maintenance since it rarely happens.

4. Require Pretreatment on all BMPs/RPMs

All stormwater infiltration designs should include a mechanism to remove unwanted materials from the stormwater runoff prior to its entrance into the infiltration area. However, this often is not a part of the approved designs. Except for rooftop runoff, stormwater contains sand and silt particles that can clog infiltration devices over time. One of the leading causes of failure in stormwater infiltration devices is clogging due to silts and sediments.

To avoid premature failure, pretreatment must be installed to remove these particles. This can be done through an upfront settling basin, a deep sump catch basin not in series, a maintainable filter or some other appropriate device. The system should be designed such that when the pre-treatment unit requires maintenance the unit will start to fail. It should not just stop collecting sediment but should also stop passing water, without a bypass.

Surface infiltration devices such as the RPMs shown in this manual typically provide pretreatment in the upper layers of the structure before it enters the infiltration reservoir area. Most use a layer of non-woven filter fabric in the upper profiles of the device. Regardless of the material used to provide pretreatment, its placement should allow for easy access to clean accumulated sediments that may build up over time.[2]

In areas where petroleum byproducts or other chemical spills could occur, such as gas stations, additional pretreatment should be added to remove the anticipated contaminants. In addition, infiltration BMPs and RPMs should not be used at these sites, where existing contamination could be spread. .

All stormwater controls should have easily accessible, preferably visible, pre-treatment as a key feature of the design. The pre-treatment unit should be easily maintained and readily monitored for performance. As part of their O&M plan, developers should provide a maintenance schedule and observable triggers identifying when maintenance is needed.

This pretreatment basin or sediment forebay has simple construction using a gabion (rock filled wire basket) berm. This helps reduce the velocity of the flows and settle out some sediments before the water is treated further.

[2] Some RPMs may need little or no maintenance over time if the size of the infiltration area is large enough in comparison to the drainage received. Most will need simple landscape type maintenance such as spring and fall cleanup. However, the filter fabric keeps fines from clogging the infiltration media (usually crushed stone) and provides an easily maintainable surface should further restoration be needed. The fabric can be cleaned with a vacuum unit or "vac truck" without major reconstruction. Similar to an engine without oil, the treatment will fail if not maintained. If pre-treatment fails, water will backup but the primary system is protected and it will start working again when it is maintained.

5. Require Adequate Overflows But Discourage Bypass

All surface infiltration devices and designs should contain a mechanism to allow storms that exceed the capacity of the unit to overflow to a backup conveyance. In redevelopment projects, existing drainage features should stay in place to provide the overflow. RPMs should then be designed to intercept the drainage before it reaches the overflow, or the overflow can be adjusted in elevation with a standpipe.

In new developments, overflows should be sized to handle larger storms and decreased infiltration during winter and early spring.

Some designers are using bypasses on treatment systems that allow the stormwater control device to be bypassed if not maintained. In particular, some underground units are designed with bypasses should they fill with sediment or otherwise fail. In underground structural units, this failure is invisible so a bypass capability essentially renders the unit useless. Bypass capabilities should be prohibited so that at least water backing up in the unit will signify the need for maintenance. An exception to this would be in the case of a combined sewer, in which the back up of raw sewage would not be desired.

<u>All designs should have adequate overflows to the existing system in redevelopment projects. For new projects, designs should also contain sufficient overflow capacity for larger storms, usually beyond what the RPM/traditional designs are designed to control. System bypass provisions should not be allowed except where the applicant can demonstrate a threat to health or safety from the absence of a bypass.</u>

6. Adapt to Site-Specific Conditions

Some special site conditions may seem at first blush to preclude infiltration, but there are methods that may be used to adapt infiltration BMPs and RPMs to these sites in most cases. Some of these special situations are described below.

Ledge

It is not uncommon to encounter ledge in this area. This does not, however, preclude the use of infiltration and RPMs. Depending on the extent and type of ledge on the site, some design modifications can be made to address the issue successfully.

For example, in areas of heavily fractured ledge, infiltration may be rapid but the lack of organic material may preclude recharge of stormwater if the site has potential hazardous material use/storage. Nonetheless, underdrains can be used to route the stormwater flows to an area of more native soil material or sand that can be used for infiltration. Underdrains should be surrounded by pea stone to keep silts from entering the perforations and clogging the underdrain pipe. This provides storage to dampen downstream peak flows.

High Groundwater

The presence of high groundwater can be dealt with in several ways. One option is to make the area of the infiltration structure wider and shallower. However, if the bottom of the leaching bed is within two feet of the seasonal high water table, wetlands treatment should be considered instead of infiltration systems. Wetlands treatment can be quite effective at dampening peak flows and polishing water quality. In addition, wetlands do not require maintenance and in fact maintenance should not be done. As with other BMPs, pretreatment of the stormwater is required to avoid overwhelming the created wetland with sand and silt and to provide an easily accessible area to clean sediment deposition.

Wetlands treatment like this created wetland in Auburn Maine can provide good treatment of stormwater and diverse habitat if sized appropriately and if pretreatment such as sediment forebays are used to remove the bulk of the particulate load. They are also essentially no-maintenance systems.

Structures

If infiltration units or RPMs are used in areas near buildings, a Registered Engineer familiar with foundation issues should inspect the building foundation to address the issue of potential damage to the structure from proximal infiltration. An impervious barrier may be needed in some instances. In most cases, infiltration units or RPMs more than 10 feet away from the structure, depending on soils, cause little concern. For buildings on slab, this is not an issue.

7. Northern Climate Considerations in Design

A good deal of research has been put into the effects of our northern climate on infiltration BMPs and RPMs. All of the RPM designs shown in Section 2 of the second part of this design manual, *Part 2 – Designs and Specification*, have been adapted to snow and ice conditions. Some of these adaptations include:

- Avoidance of curbing that could cause ice jamming by plows;
- Calculation of runoff assuming storage only and no exfiltration (as could occur under winter conditions);
- Use of traditional overflows to municipal system in case of freezing and snow cover;
- Avoidance of the use of permeable pavers in areas where plows could hit and dislodge pavers;
- Separation of RPMs and other infiltration BMPs from roads by more than 10 feet and use of small volume BMPs only where infiltration might seep under the roadway;
- Fencing to protect vegetation from vehicles plowing snow.

In all cases, these designs will not create flooding issues as they are designed with overflows in the unlikely event that the unit ices completely over.

8. Insure Continuing Maintenance of All Stormwater Controls

As discussed in previous sections, maintenance of traditional designs has become a major issue facing Nashua and other communities. There is widespread failure of traditional stormwater controls such as detention basins and other sediment containing controls. The good news is that it's because they work to remove sediments and the associated pollutants, otherwise they would not fill up. The bad news is that they cease to function if not maintained and many are difficult to impossible to renovate and restore to original function. Where maintenance occurs regularly, some designs are too demanding for reasonable cost-effectiveness and continued attention from harried public works departments. Issues include:

- Difficult access for equipment;
- Difficult to clean without complete renovation;
- Lack of permanent easement or method for access;
- Lack of ability to see if unit is full;
- Lack of understanding of maintenance needs;
- Problems with owner knowledge of system;
- Inability to backcharge owner if municipality must do the work;
- Too frequent maintenance because of undersizing of unit;
- Proposed maintenance burden on owner too great.

It is recommended that all traditional and RPM designs comply with the following:

1. Formal equipment access
2. Ease and minimal cost of cleaning
3. Permanent public easement
4. Method and easy access for evaluation of maintenance
5. Provisions for groundwater monitoring and assessment of the quantities of sediment removed, along with estimates in the design of expected annual sediment quantities.

Further, all developers should provide a detailed and reasonable Operations & Maintenance plan, including manpower and budget needs.

9. Develop a Permit and Tracking Process for Private BMPs

Under the new Phase II Stormwater regulations, all subject[3] communities must take responsibility for inspecting stormwater controls on private property. If the owner refuses to maintain a facility or structure that is in need of maintenance, then the municipality must either place a lien on their property until they do, or perform the maintenance themselves and backcharge the owner.

The watershed communities should each develop a permit submittal and tracking process for new/redeveloped site owners to submit evidence of maintenance annually. Site owners should submit a simple report certifying what maintenance was completed and how much sediment was removed on what date(s). Further, the watershed communities should develop the regulatory ability to lien properties where maintenance is not completed, or to be able to backcharge the site owner if DPW or other town entity must clean the BMP.

[3] Municipalities with a population of less than 100,000 that are located in or near an urbanized area are subject to the new Phase II Stormwater Regulations.

6.0 Sample Redesign of Parking Lot using RPMs

6.1 Site Description

During the facilitated meeting process, a number of Nashua sites were given to CEI to develop innovative redesigns of drainage features. All were redevelopment sites as opposed to undeveloped sites because these were felt to be more difficult to address than a new site. All of the sites had difficult conditions to address. One of the most difficult was the Globe Plaza parking lot site, developed under the category of redesign of commercial areas. Photographs of this site as it existed during the project are shown on Figure 6-1. Following these pictures, construction on the site for redevelopment purposes began. The approved plans from that redevelopment project were used as a base for this innovative design.

The site is located along Main Street at the intersection of Otterson Street and Main Street. It borders Salmon Brook and part of the site was undoubtedly fill into the wetlands surrounding Salmon Brook. Early in the history of the site, there was apparently a mill pond and some type of industry, but the site was later filled for redevelopment and a parking lot placed on it to serve the surrounding retail buildings. Salmon Brook lies at the southernmost end of the site, encased in an 18 foot stone arch culvert that runs under Main Street and under the Bradlees store onsite.

In an apparent attempt to further create parking space and developable area, early owners placed two 10 foot corrugated steel culverts at the end of the arch stone culvert to further pipe Salmon Brook. The backfill over these culverts was removed at a later date, reportedly to address a spill issue in Salmon Brook.

Considering the size and activity at the commercial retail buildings surrounding the parking lot, the parking lot is somewhat undersized. Parking spaces are therefore at a premium and needed to be retained as part of the design.

The redevelopment project that was carried out was not required to improve the drainage situation. All drainage currently exits the site via two catch basins in the lot which discharge it untreated to Salmon Brook.

The total acreage of the lot is 5.9 and it contains a total of 641 parking spaces as shown on the developer's design plans.

Figure 6-1 Photographs of Globe Plaza parking lot

6.2 Design Considerations

The site has understandably high groundwater conditions and very poor soils, mostly fill, based on its past use. This was a significant part of CEI's design concerns. The existing overflows (two catch basins) apparently route to one storm drain pipe that discharges to Salmon Brook. It was felt that it was important to maintain these overflows since flooding in the parking lot occurs as a current condition as shown on the existing site photos. The parking lot also undulates significantly due to settling that has occurred over time. It is not known if this was corrected as part of the reconstruction that occurred during the project.

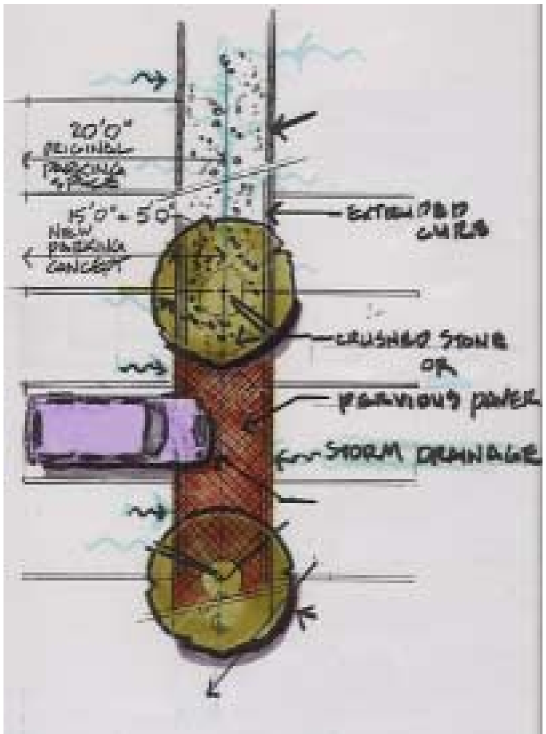
Aesthetically, the site was at the time a 1 on a scale of 1-10 with 1 being very poor and 10 being excellent and attractive. It is a large, featureless lot other than a few light poles and decrepit islands. Roof leaders from the retail buildings surrounding the lot discharge directly onto the lot, probably creating an ice hazard for pedestrians during winter conditions. Some of the roof leaders discharge to the back of the lot opposite the parking lot directly into some construction rubble from a former building.

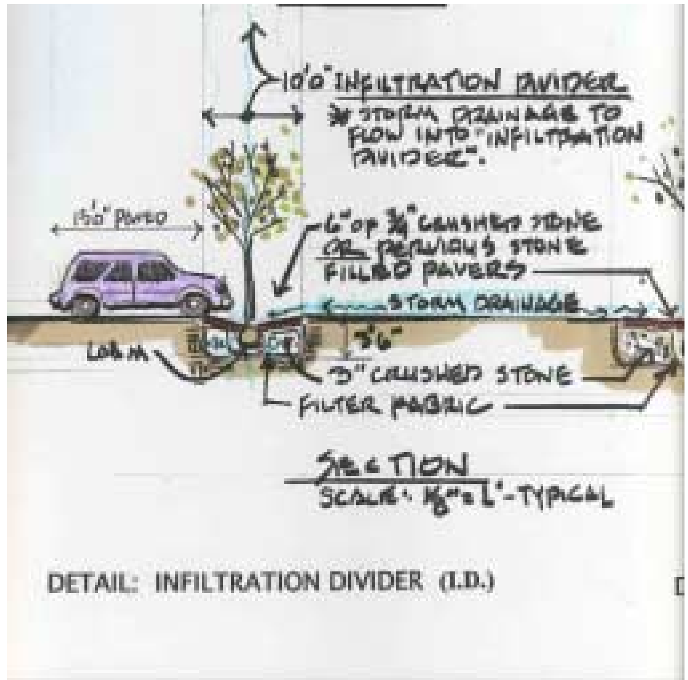
In Nashua, the two-year design storm is roughly three inches over a 24 hour period. One goal of CEI's redesign was to be able to store this volume of runoff for slow infiltration to the rubble and urban fill located beneath the parking lot. Because of high groundwater conditions, the infiltration units were made wider and shallower than they might be in a situation with greater depth to groundwater. CEI also assumed the poorest category of soils in its calculations due to the site's known past as a mill pond.

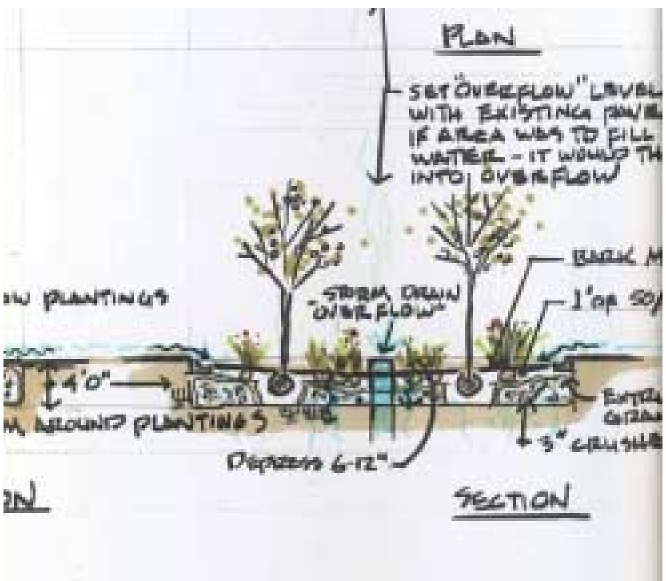
When designing storage, frozen ground conditions were considered. All stormwater storage is placed below the frost line, and exfiltration was not incorporated into the design calculations.

6.3 Design Features

CEI's designs for the site are shown on Figure 6-2. The design features the use of vehicle overhang areas between each set of facing parking spaces for infiltration. In Nashua, a parking space needs to be 20 feet long, yet the largest vehicle measured for this study only requires a parking space of 15 feet. If the wheels occupy the first 15 feet of the space and the front of the vehicle (the overhang) occupied a few more feet, then this would allow a strip of 10 feet wide in each parking lot row to be used for infiltration.







Parking lot dividers were placed between adjacent sets of parking spaces. The overflow is to the two existing catch basins. At some locations, the biocell shown below was added for variety as an end piece on the parking aisle. The design resulted in no loss of parking spaces but effective control all rainstorms up through the 2-year storm (roughly 3 inches over a 24-hour period in Nashua). The design is less expensive than repaving with installation of a proprietary unit sized to address the 2-year storm, and treats the stormwater much more comprehensively.

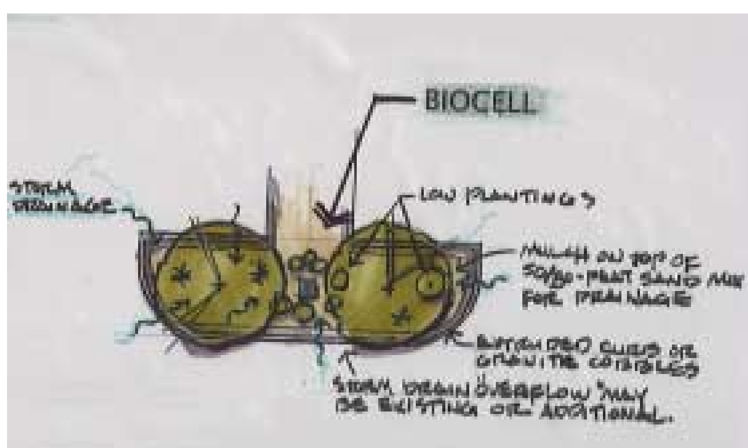


Figure 6-2. Globe Plaza Sample Conceptual Design Features

As shown on the design drawings on Figure 6-2, an infiltration cell of approximately 3 feet deep and 10 feet wide would be placed between the rows of parking spaces. The cells would be filled with 3-inch crushed stone wrapped in permeable non-woven filter fabric. The purpose of the filter fabric is to prevent fines from entering the crushed stone cell that provides storage for stormwater.

Instead of a raised island, these parking lot islands would be slightly concave, so that drainage would enter freely. Curbing was not used because even periodic curb stops can promote the formation of ice dams during the winter plowing season. The crushed stone could be covered with either pervious pavers such as large concrete pavers that contain holes to infiltrate drainage, cobbles or simply left as crushed stone.

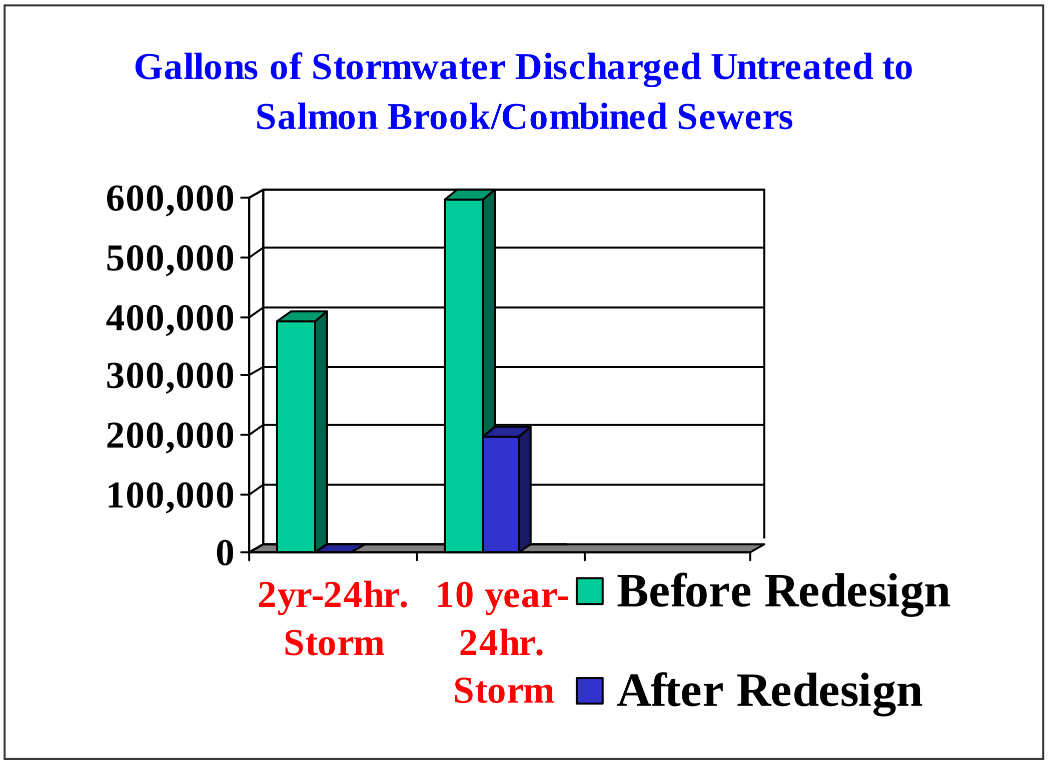
To prevent the pavement from collapsing into the infiltration cell, a reversed extruded curb could be used in the designs without pavers. If concrete pavers are placed in the 10 foot strip, the extruded curb would not be needed. However, in a crushed stone-only scenario, the purpose of the reversed extruded curb would be to protect the pavement from collapse into the infiltration trench. It would also provide a differentiation between the lot itself and the slightly depressed infiltration cell.

CEI assumed that some plantings would be placed in the cells, and added modifications to the calculations to allow for less infiltration where soil was used in planting pockets. The trees would help to define the infiltration strip as separate from the parking space. To further alert drivers of the appropriate stopping point, CEI included a small reversed rumble strip around the edge of the divider. This would help drivers to “feel” the edge of the space.

Alternatives could include periodic posts with chain or low split rail fences running along the divider to differentiate the divider from the lot.

If vehicles were to go into the infiltration cell or trench, they would simply be driving on crushed stone or whatever paver coverings were used to conceal the crushed stone. In the event that someone accidentally drives into the island, no damage to the island or car would result.

The dividers as designed would contain up through the two year storm. In other words, no runoff would occur from this parking lot except in rare, major storm events. During these higher flows, the islands would overflow discharge to the existing catch basin system. The following graph shows the gallons of stormwater discharged untreated to Salmon



Brook under existing conditions and those that would occur if these redesigns were implemented.

To the rear of the parking area and retail stores, roof leaders for most of the buildings discharge to a foundation rubble pile from a former building. Flow from this and from the loading areas in back then flow directly into Salmon Brook.

CEI also proposed a redesign for this area, to incorporate separation of some sewers along the back lot. A wetlands treatment design was developed for this area, involving a sediment forebay and discharge to a created wetland in an obviously already wet area of the site. The proposed redesign is shown on Figure 6-3. It consists of a somewhat generic design that might be applied in other areas where groundwater is at the surface.

Note that the estimated gallonage treated and cost estimates do not include this portion of the project and apply only to the parking lot.

6.4 Construction Cost Comparison

A major feature of the design is that no parking spaces are lost. For cost comparison, a traditional redesign was compared with CEI's design. Under the traditional design, we assumed that the same two year storm

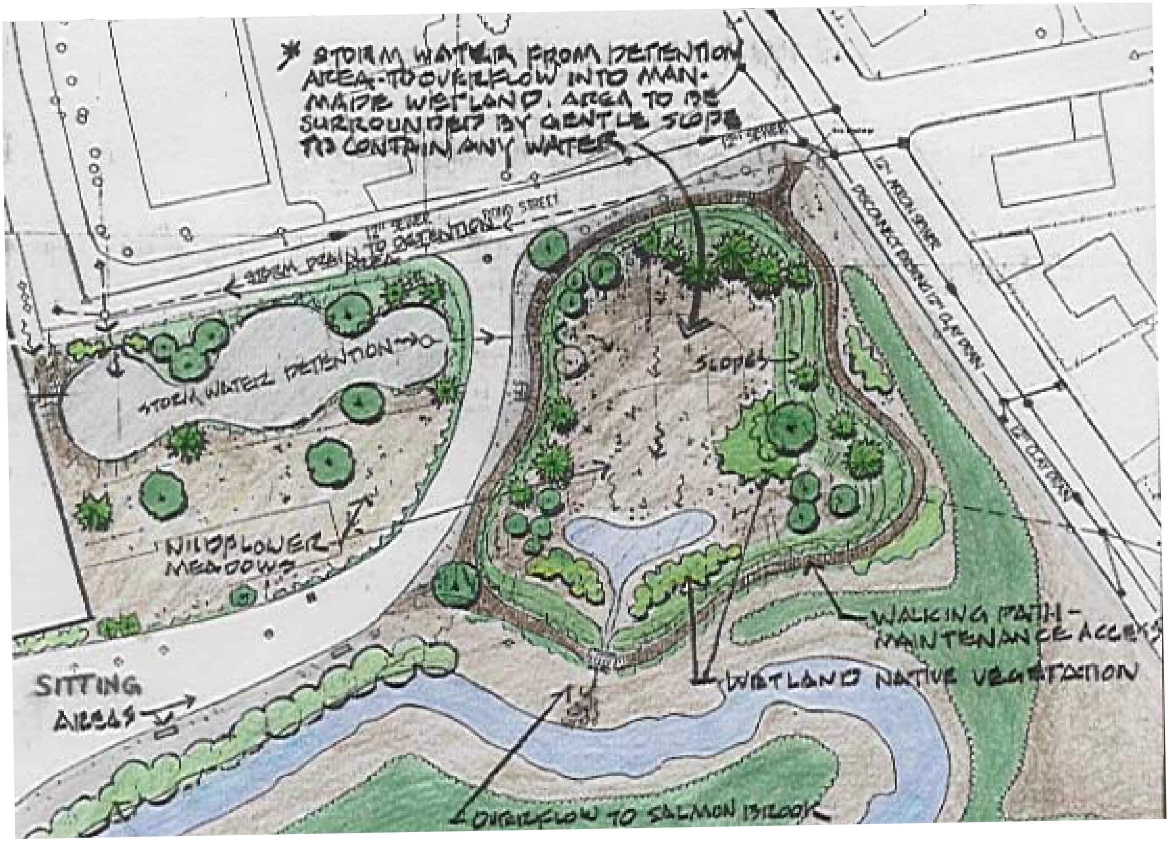
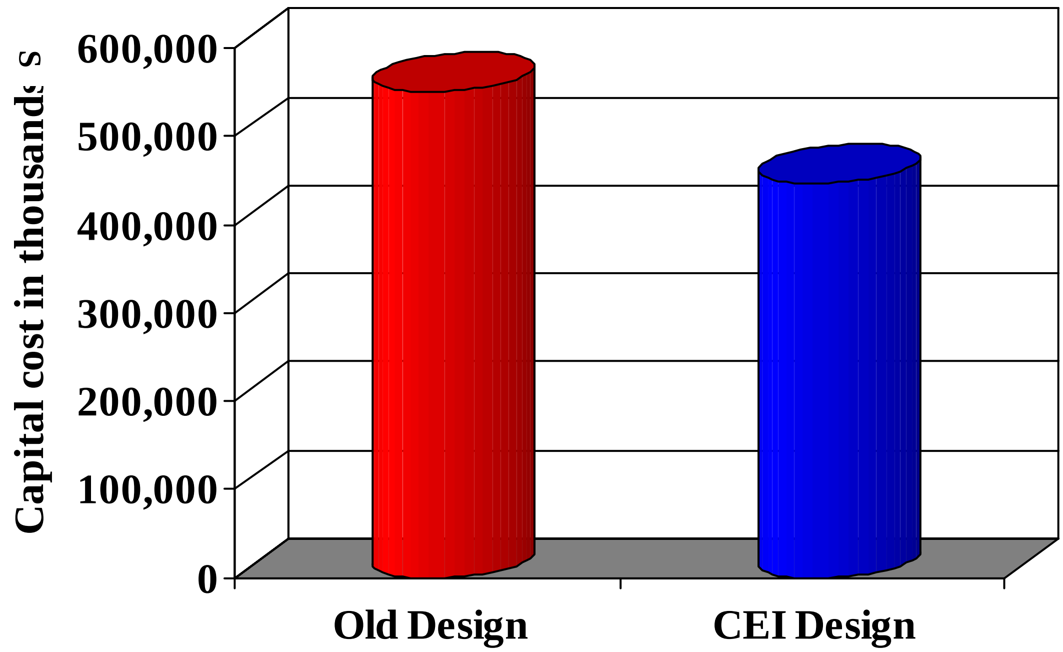


Figure 6-3. Conceptual design of wetlands treatment for roof leaders from Globe Plaza retail buildings; street runoff from Pond Street; and some separated flows from combined sewers in the area. The wetlands treatment design takes advantage of the area's high groundwater. Note that the wetlands treatment is preceded by a detention area carved out of an abandoned building rubble pile. A walking path was added to improve access to the river and sitting areas are depicted near the river bank. The access for pedestrians doubles as maintenance access for checking the overflow area and condition of the system. The design is low maintenance, with wildflower meadows near the detention basin and wetlands for treatment purposes.

Note that adding detention to the existing highly degraded wetland at this site would be beneficial, but that this needs case-by-case evaluation and it may not be appropriate at all urban sites.



This cost comparison shows a comparison between a more traditional design using an end of pipe unit to control stormwater from the parking lot, plus paving costs. CEI's design is for the same paving but control of the 2-year storm with RPMs instead of a conventional end of pipe unit.

would be treated using traditional methods such as proprietary or other types of "end of pipe" units. The construction cost estimate includes paving cost and cost for all components including landscaping.

6.5 Maintenance Burden

Under the actual conditions of a redevelopment project with no drainage improvements, all of the sand spread on the lot during the winter would go to two catch basins. Since it is unlikely that these are regularly maintained, most of the sand is likely to be pushed out into Salmon Brook where it creates a significant water quality problem.

The amount of sand that would routinely be applied is estimated at roughly 1,000 pounds of sand per acre. This is based on the spreading rate of a Swenson Spreader. Since the lot is roughly 5.9 acres in size, that would mean roughly 5,900 pounds of sand per storm. Assuming roughly ten times per year where sand is applied due to icing or other storm conditions, that means approximately 59,000 pounds or 29.5 tons of sand could potentially end up in Salmon Brook each year. Under the existing conditions, this is the most likely result.

Under the redesigned condition, CEI would eliminate approximately one acre of the lot that requires sanding (the overhangs), reducing the total amount of sand per storm to 4,000 pounds or 40,000 pounds per year (20 tons). Most importantly, this sand would be spread out over approximately 41,000 square feet of infiltration cell, instead of two small catch basins. Spread out over the nearly one acre of infiltration surface area, this amounts to only 0.13 inches per year of sand. At this rate, it is unlikely that any of the 20 tons of sand would end up in Salmon Brook, providing a major water quality benefit just from this small lot.

The accumulated sediment would be removed annual or semi-annual by sweeping and/or vacuuming. Some materials such as bark mulch may need to be replaced every 5-10 years. Sediment deposited on top layers will not necessarily stop infiltration but may reduce the infiltration rate. The reduced sanding surfaces and larger dispersal area of the design, effectively lessens maintenance frequency compared to the limited sediment containment area of the existing catch basins.

Stormwater Manual

CITY OF NASHUA, NEW HAMPSHIRE ALTERNATIVE STORMWATER MANAGEMENT METHODS

PART 2 – DESIGNS & SPECIFICATIONS

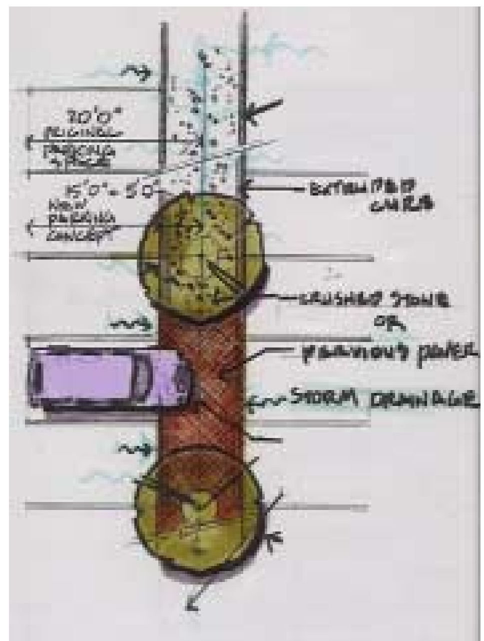


Table of Contents

PART 1 – PLANNING & GUIDANCE

Table of Contents

Tables

Figures

PART 2 – DESIGNS & SPECIFICATIONS

Section Title Page No.

Table of Contents

Tables

Appendix

1.0 Planning & Engineering

Design Selection

Several design options are shown in Section 2, with a conceptual drawing and description followed by cross-sections and design details. General specifications then follow in Section 3.

The purpose of these conceptual designs of Runoff Prevention Methods is to give planners, developers, engineers and homeowners some ideas of techniques for reducing runoff from sites. Although some of the techniques are similar to each other, multiple options are shown where available from the design process.

All the designs shown are conceptual only and will require adaptation to the specific site. They all have some similar design basis, including:

1. Pretreatment is always used to remove the large volumes of sediment usually found in stormwater (roof leader treatments are the exception here);
2. Treatment of runoff is at the source rather than typical end of pipe treatment system;
3. Multiple techniques are required for best effectiveness on each site; however, since they blend into the landscape or provide an aesthetic benefit, they provide a portion of the useable space onsite.

Tables 1 and 2 include selection matrices for Commercial/Industrial/Retail and Residential, respectively, that may be helpful in identifying which options are useful for each site.

Table 1. Commercial/Industrial[a]/Retail Selection Matrix

	Roof runoff	Parking Lots	Commercial Driveways	Roadways	Alleys	Sidewalks	Comments
1. Infiltration dividers		✓	✓	✓			Allows retention of all parking spaces.
2. Infiltration islands		✓	✓	✓			Potentially used for ends of parking strip.
3. Biocells & Bioislands	✓	✓					Provides shade and pedestrian benefits. May reduce spaces.
4. Dry stream infiltration		✓	✓	✓		✓	Use where vegetation cannot be supported.
5. Containment swale		✓	✓	✓			Where grades allow, standpipe can be added.
6. Driveway drainage strip		✓	✓			✓	Channel in driveway to route stormwater to cells in landscaping.
7. Stormwater drywell	✓						Place 10 or more feet from building.
8. Grassed infiltration strips		✓	✓	✓			Can be used to intercept any runoff.
9. Curbside treatment		✓	✓	✓		✓	Other utilities may preclude its use in some areas.
10. Alley infiltration	✓				✓		Building foundations must be inspected.

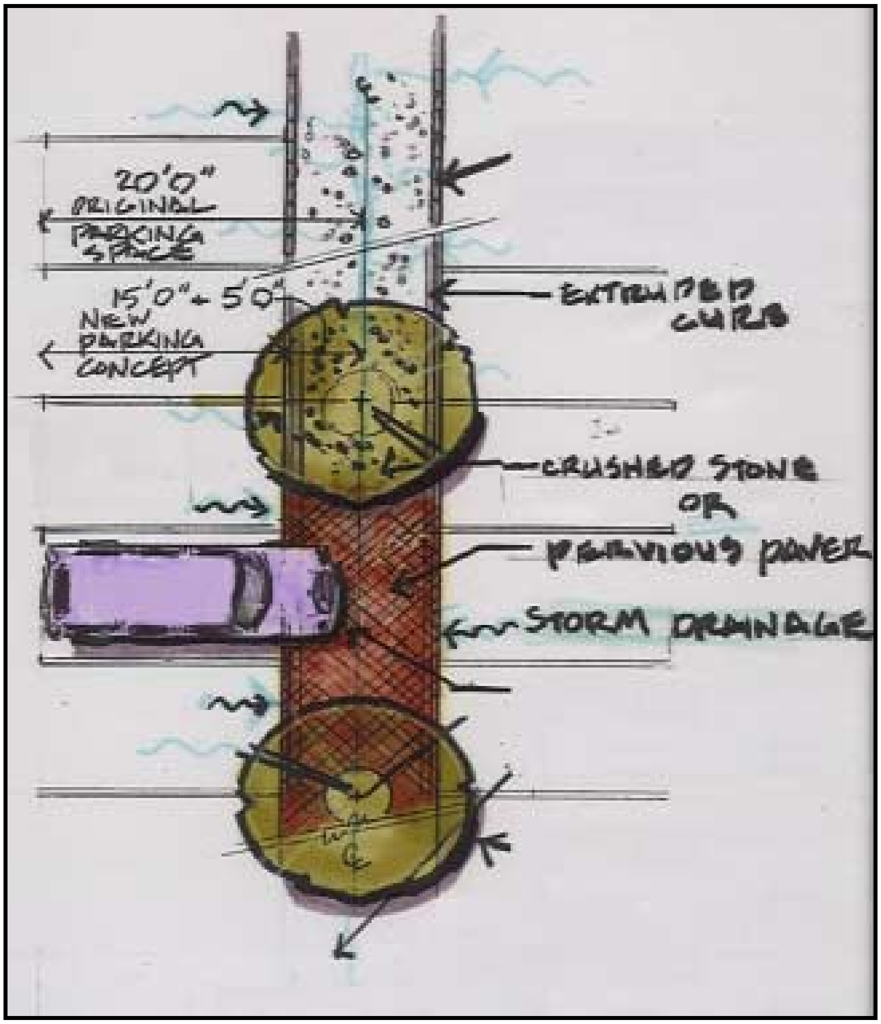
[a] Industrial developments may have special concerns in Wellhead Protection Areas. Industrial sites should not infiltrate stormwater from areas where hazardous materials could be spilled or high concentrations of pollutants exist, so as not to contaminate water in Wellhead Protection Areas.

Table 2. Residential Selection Matrix

	Roof leaders	Driveways	Sidewalks	Roadways	Patios, decks	Lawn	Comments
1. Raingarden Strip	✓	✓	✓	✓	✓	✓	Particularly good along roads and driveways. Use as drought tolerant hedgerow.
2. Raingarden Planter	✓	✓	✓	✓	✓	✓	Alternative layout of above.
3. Pocket raingarden	✓	✓	✓	✓	✓	✓	Alternative layout of above.
4. Decorative Planters	✓						Decorative feature that also handles roof runoff /waters plants.
5. Containment swale		✓	✓	✓		✓	Where grades allow, standpipe can be added for more storage.
6. Driveway drainage strip		✓	✓		✓		Channel in driveway to route stormwater to cells in landscaping.
7. Stormwater drywell	✓					✓	Place 10 or more feet from building.
8. Grassed infiltration strips		✓	✓	✓	✓	✓	Can be used to intercept any runoff.
9. Curbside treatment		✓	✓	✓	✓		Other utilities may preclude its use in some areas.

2.0 Alternative Designs

The table below lists the Runoff Prevention Method (RPM) design and corresponding page number found in this section.



Infiltration Divider

Description

A stone filled depressed infiltration strip accepting sheet flow from adjacent paving. Typically 3-4 feet deep and of variable width and length. Surfacing options include pavers, or ¾ inch stone (plain or ornamental). Trees and a strip of grooved pavement are recommended for delineation of the divider and in place of curbing.

Application

This is an infiltration device used to collect runoff from the parking space and travel aisle. It occupies the space usually reserved for vehicular overhang (front wheel to bumper) and is an efficient use of this normally paved and unutilized area. As the name divider implies, it is used to separate two rows of face-in parking and serves to break up the expanse of pavement with moderate sized trees.

Advantages
By using the overhang space in a parking lot the device does not compromise the number of parking spaces attainable at the site. The island can serve the same traffic routing function as raised parking islands. Impacts from foot traffic through the infiltration divider are minimal.

Cost is mainly affected by surface treatment. The plain stone surface treatment is not as costly and performs as well as the more expensive pavers which can be used by those who wish to add more distinction and aesthetic appeal to their parking lot.

Disadvantages
Planting choices may be limited by drought tolerance and width of island (shrubs may be too wide at the car bumper level and become deformed/injured).

The low organic content within the island unit may not provide optimal treatment of organic pollutants if it is located in rapidly draining sandy soils. Some augmentation with coarse peat at the bottom of the stone reservoir (6" thick) area may be warranted in these cases.

Design Considerations
Designs are optimized at 8-10 feet in width which is the normal distance between front axles of vehicles parked nose to nose. The divider handles runoff from the centerline of a typical 20 foot wide travel aisle and the 15 foot parking space. This width also protects trees and cars from butting up to each other. When used as a true divider to separate two rows of parking, widths should not be less than 6 feet.

Depths can vary, but the floor of the structure should be at least two feet from the seasonal high water table. Depths from the inlet surface elevation to the floor of the structure of 2 feet or less are only appropriate if infiltrating the first ½-inch of runoff.

A deeper surface depression can maximize the volume retained within the structure as no stone occupies this space and all of it can be used for retention. Curbing or wheel stops could be used in this application to prevent cars from entering the depression. In some cases, curbing would prevent an even distribution of water to the surface of the structure and the gaps between wheel stops may become blocked and glazed over from snow plowing operations. Alternately, grooves should be cut in the pavement 6" from the edge, around the perimeter of the structure. The grooves will provide a reasonable assurance that cars will come to a stop as they pull forward in the parking space and will provide no restriction for water entering the structure.

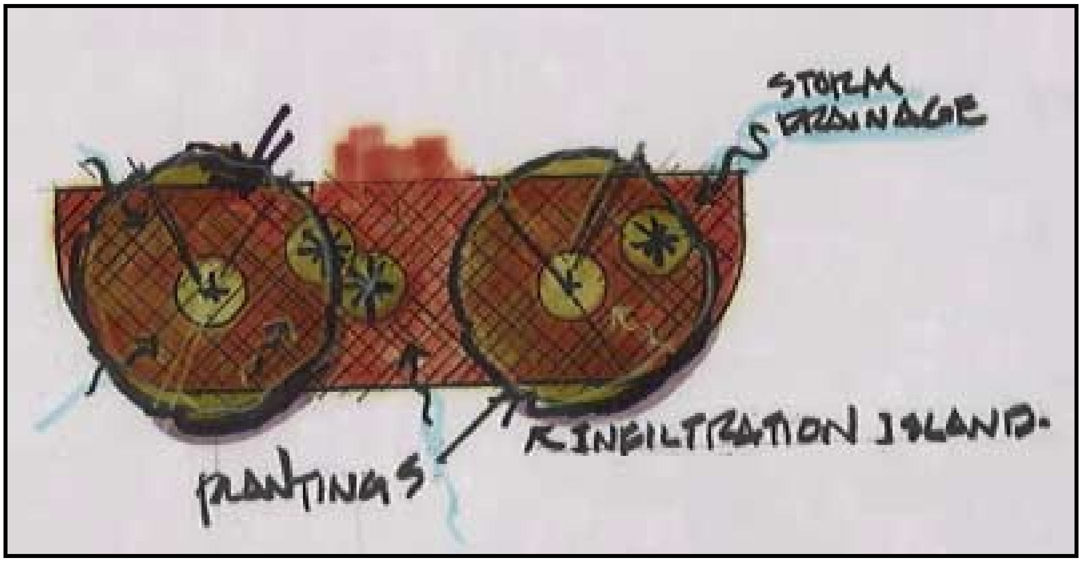
Surface treatment materials must be highly porous and durable. They can range from ¾ inch stone (ornamental or plain) to pervious pavers. Cost will play a large part in the choice of surface materials since pavers are more expensive than stone.

Treatment of stormwater in this device is accomplished by the stormwater passing first though the filter fabric and then through the native soil surrounding the main chamber. The main distinction of the Infiltration Divider is its ability to rapidly accept stormwater below grade. Organic material and the associated decomposition matter can hinder the ability of the surface to accept runoff.

Shade trees are recommended, to assist in delineating the Infiltration Divider from the traveled portions of the parking lot. This RPM offers a balance between rapid infiltration and aesthetic and traffic control objectives.

Maintenance

The frequency of surface rehabilitation can vary from 1-5+ years based on sand application rates and sweeping of the parking lot. Rehabilitation involves use of a vacuum truck or manual labor to remove the top 6 inches of material and replacement of the filter fabric pre-filter zone. Although stone may be screened from the accumulated sand and sediment and reused, it may be more practical and cost effective to send the removed material to a gravel facility for reprocessing and replace it with a new 6 inch stone layer after each cleaning



Infiltration Islands

Description

A medium sized surface infiltration structure with a durable surface that can withstand occasional vehicle traffic. Plantings are sparse and infiltration capacity at the surface is high.

Application

These islands are meant to be used in parking lots at the end of parking rows or in areas where vehicles and pedestrians are likely to cut corners. The limited low-growing vegetation aids in providing sufficient line of sight for vehicular turning movements. Durable surface elements provide pedestrians space while waiting to cross from the parking lot to building entrance.

Advantages

Durable with the use of pavers so that it can withstand occasional traffic with little to no damage. Selection and variation of colors and style of pavers can help delineate parking for one store vs. another in a large parking lot.

Clear line of site for vehicle turning movements and pedestrian crossing.

With slight modifications to flatten side slopes, islands may provide additional adjacent space for access in and out of vehicles by handicapped persons.

Disadvantages

Planting choices may be limited by line of sight considerations and drought tolerance.

Pavers are more costly than a simple crushed stone surfacing.

Design Considerations

Although compaction of material is generally discouraged with RPMs, it may be warranted in the areas likely to be trafficked by vehicles.

If used at the downgradient end of a row of parking spaces and attached to another RPM such as the Infiltration Divider, the design should be graded such that each RPM provides the maximum amount of storage and infiltration. If both RPMs are sloped in one direction, placing one RPM downgradient from the other, the downgradient RPM could become overwhelmed with water, leading to frequent use of the overflow and underutilization of the available storage space in the upgradient structure.

The low organic content within the structure may not provide optimal treatment of organic pollutants if the structure is sited in rapidly draining sandy soils. Some augmentation with coarse peat at the bottom of the stone reservoir (6" thick) area may be warranted in these cases.

Maintenance

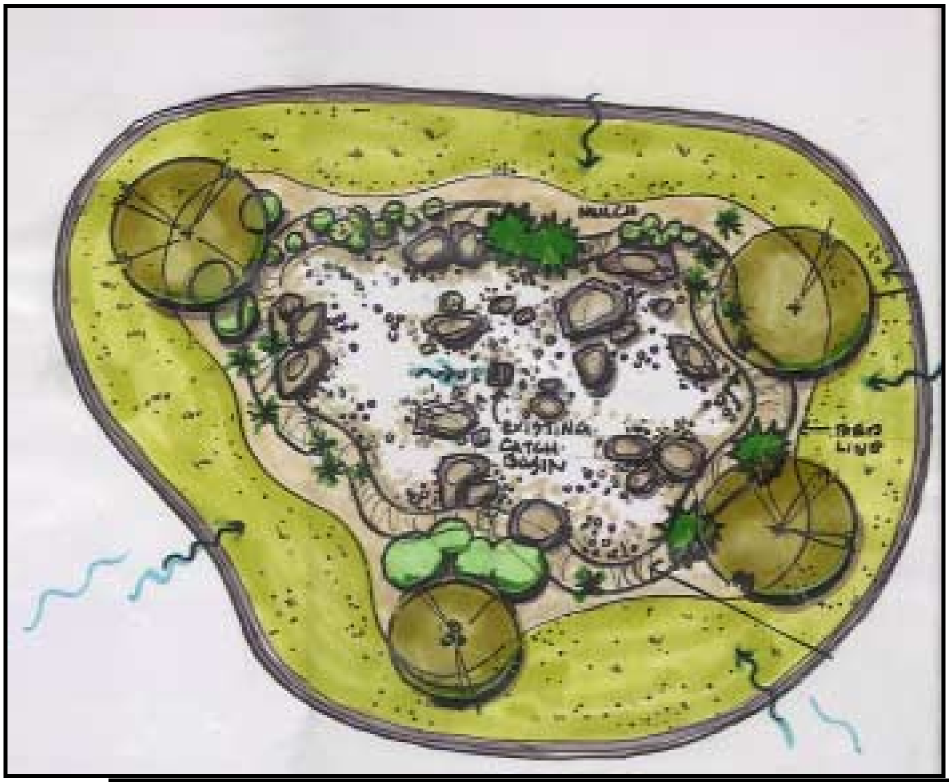
Paver surfaces located in traffic areas will require periodic inspection for deflection (raised or uneven surfaces) to ensure that they will not be pulled up during winter plowing activities. This is best inspected in the Fall, before snowfall. If deflection approaches half of the paver thickness, the affected paver(s) will need to be re-leveled flush to the others.

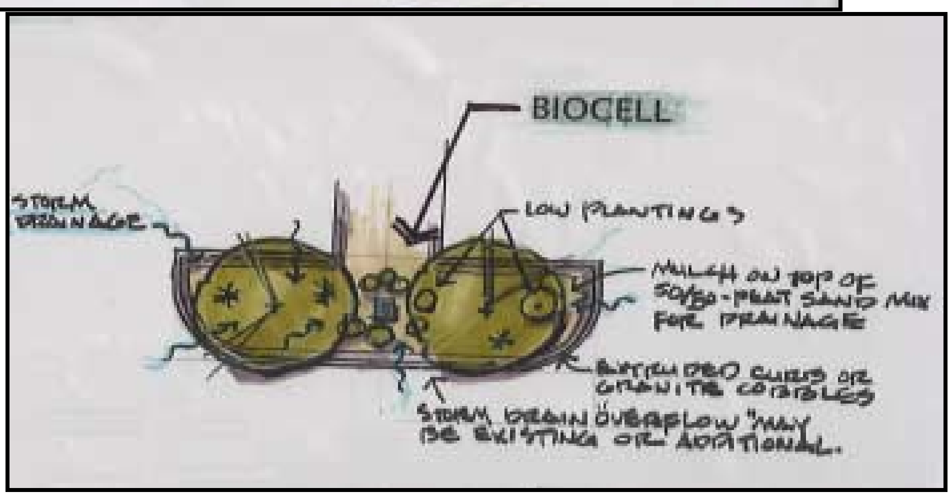
Sand deposits that have accumulated on the surface of the RPM will need to be removed periodically. A wet/dry vacuum is ideal for this and will prolong the life expectancy of the surface of the structure before the pavers, bedding material, and filter fabric must be completely removed and replaced and/or reassembled. The use of a push broom to remove deposits may be quicker in the short run, however may result in redistribution of much of the accumulated sediments and debris over the surface. If sediment removal maintenance is not conducted, the surface may require rehabilitation on a more frequent basis.

It is advisable to occasionally monitor the RPM during a rainstorm to determine if "preferential flow paths" have developed and/or if water seems to make its way to the overflow before using up the capacity of the reservoir/depression area. Forty-eight hours after the storm has stopped[1] the reservoir/depression area should have completely drained. Surface ponding conditions that exceed 48 hours are undesirable as nuisance conditions can develop soon thereafter. Prolonged surface ponding (over 48 hours) indicates that the surface area needs to be rehabilitated by removing and cleaning or

[1] This is a storm of normal duration during the growing season and would not include prolonged periods of rainfall, or spring thaw conditions for example.

replacing the surface material down to and including the first filter fabric barrier encountered. An observation well can be installed in the structure to determine whether the infiltration media below the filter fabric has clogged.





Bio-Islands & Bio-Cells

Description

An installation of varying proportions (Bio-Cell being small to medium in size and Bio-Island being a larger more centralized treatment and landscaping feature) that may be designed to support a wide variety of plantings and provides a beneficial “habitat” for pollutant removal.

Application

Other than scale, both Bio-RPMs may be used at a variety of sites. Their high organic component means that it can be used as a landscape focal point in a prominent location on the site, however infiltration rates may be compromised for the same reason. These systems (particularly the smaller Bio-cell) are better adapted to handling drainage from smaller, flatter, less “flashy” drainage areas.

Advantages

These systems provide a more complete habitat for beneficial microorganisms and thus excellent stormwater treatment can be expected. The high organic content and free form nature of the Bio-Island lends it to a wealth of colors and textures in the plantings. Separate planting zones within these structures can be created to support plants of complementing treatment efficiency and appearance.

Disadvantages

The trade off for having a higher organic content with greater planting choices is that the ability of the device to accept and quickly infiltrate water may be compromised.

Design Considerations

Care must be taken in estimating the proper storage volume within the reservoir area. Different blends of planting media (which occupy a substantial portion of the subsurface area) will yield considerably different available storage space.

When bark mulch is used for the surfacing material, fresh mulch is preferable to aged for nutrient assimilation. If shredded wood chips are used as a substitute, hardwood varieties are known to be less likely to float when the structure has surface ponding.

In the larger Bio-Island application, designers should note that two treatment areas are intended. The outer layer is meant to settle out and assimilate reasonable amounts of sand and the coarse grass is meant to act as a living leaf/debris rack. This enables the inner area to receive water that is relatively free of debris and particulates, and thus preserves the surface infiltration rate and prolongs the time needed between clean up.

Maintenance

The leaves that fall onto the surface of these structures can quickly form a surface barrier to incoming water and so a Spring and Fall clean-up is recommended. The higher maintenance frequency in these structures relative to other RPMs is a function of their landscaping requirements. Owners want these structures well maintained to preserve and support their planting investment for a number of years.

Grassed Infiltration Strips

Description

A grassed area located at the edge of pavement to filter contaminants by flowing through vegetation and through infiltration. A typical strip size is 10 feet wide with a minimum depth of 6 inches to allow for temporary ponding of water. Grassed Infiltration Strips are aesthetically pleasing and perform a similar function to filter strips along a river.

Application

This infiltration device is used primarily for filtering overland stormwater flow from an impervious surface. It also incorporates infiltration into its treatment mechanism. It is ideally used when there is sufficient space around a parking lot or impervious drive.

Advantages

Grass is easily mowed and therefore is a low maintenance surfacing. The area used for this device is typically unused space around parking lots or along the edge of a road and can therefore easily conform to this treatment option. It has a sufficient storage capacity even though it is easily mistaken for a normal lawn. Occasional nonvehicular traffic is permitted by the surfacing.

Disadvantages

Infiltration rates through the planting media may not be as rapid as through other surfacing options. Should not be used in areas where perimeters of parking lots and drives slope towards the parking lot or drive, unless an overflow device is implemented.

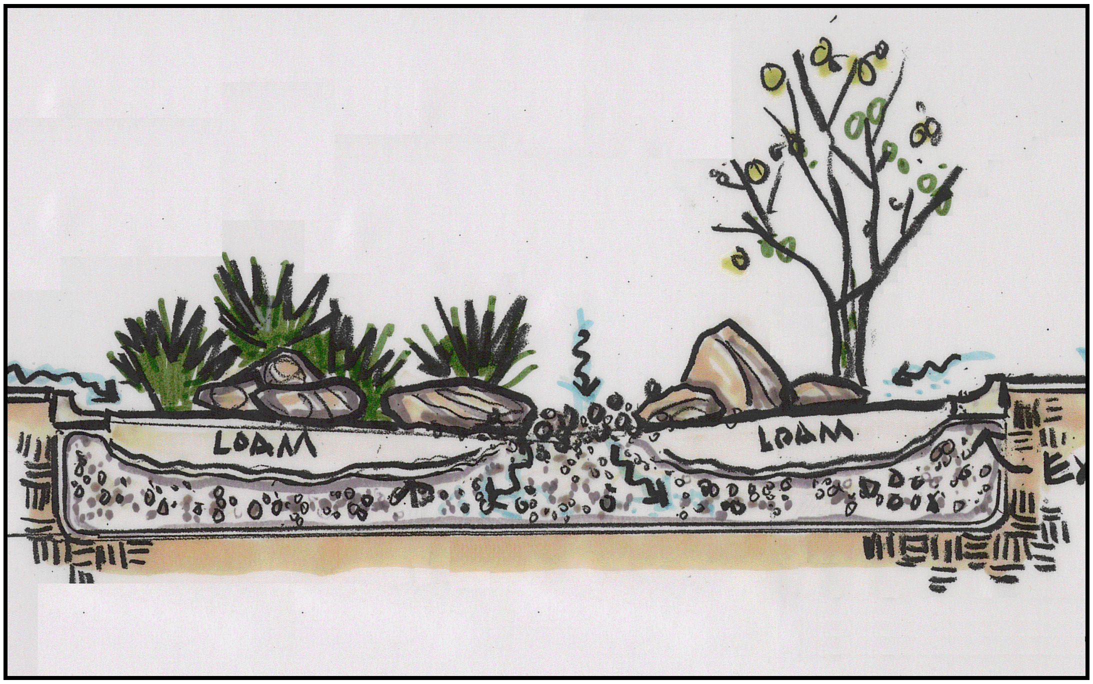
Design Considerations

Parking lots and drives with perimeters sloping into them are not feasible for this device. Water must be able to flow across the device and away from the parking lot. Runoff flows with high concentrations of sediment will cause the depression to fill in. This will necessitate frequent maintenance for the strip and should be avoided. These strips should be located where they are not frequently crossed or a small walking bridge could be placed to allow crossing after periods of high rainfall. The downhill side of the crushed stone area should be a minimum of 6 feet from any steep slopes.

High traffic areas should be avoided because of compaction and the potential for water to pond in the depression. If many people were to walk over the strip, the infiltration capacity will be greatly reduced. This compaction could also kill the vegetation and destroy the overall treatment effectiveness of the RPM.

Maintenance

The grass is a low maintenance surface which should be maintained at typical height. Occasional high flows may carry a lot of sediment into the depression. Upon removal of this sediment care must be taken to not dig up the current vegetative layer. The 1 foot planting media filter layer and the filter fabric will prevent silt from entering the crushed stone. When infiltration rates are greatly reduced from this silt, the planting media may be removed along with the filter fabric and new materials put in place. Maintenance costs are relatively cheap until the filter layer is excavated.



Dry Stream Infiltration Bed

Description

A large structure designed to contain and infiltrate large volumes of stormwater. A dry riverbed theme has been chosen, and certain landscape elements added (boulders, etc.) to showcase what might otherwise be a large stark infiltration strip. Other elements such as ornamental bridges and picnic tables allow the area to be used as an informal outdoor lunch area during good weather.

Application

This RPM is intended to handle large volumes and rates of stormwater typical of a commercial parking lot. Providing a picnic area can make the installation have even greater utility on the typical tightly constrained office parking lot.

Advantages

This RPM has the ability to handle large volumes of stormwater. The “themeing” of the structure can allow it to be used as an amenity and add character which may differentiate the property from others. Perhaps a good selling point to prospective buyers.

Disadvantages

The limited use of vegetation will provide little shade or cooling effects to the parking lot as a whole. As a large centralized device, this structure provides a greater vehicle restriction. The abundance of ornamental features (such as boulders and picnic tables) can add cost with no gain in capacity.

Design Considerations

Volume calculations should account for ornamental features that are proposed to be located below the invert of the overflow.

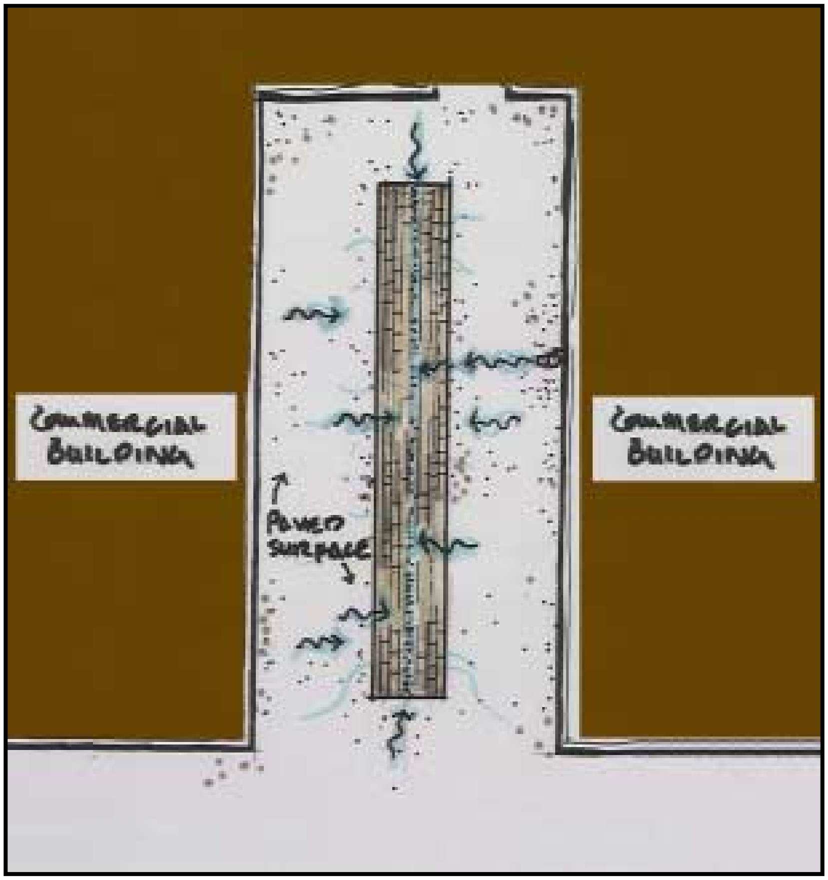
When bark mulch is used for the surfacing material, fresh mulch is preferable to aged for nutrient assimilation. If shredded wood chips are used as a substitute, hardwood varieties are known to be less likely to float when the structure has surface ponding.

Because of its size, a significant slope throughout the length of the structure (when installed parallel to the slope) can cause ponding, and associated overflows at the downgradient end and underutilized storage volume at the upper end. Installing the structure perpendicular to the slope is the preferred orientation, but in cases where it must be installed parallel, impervious walls should be installed down to the floor of the leaching area. These barriers serve as grade checks and should extend through the surface (and perhaps hidden by a footbridge) with sufficient reveal to compartmentalize the structure so that lateral movement is minimized.

If picnic tables and other pedestrian attractive features are used, localized compaction may occur resulting in less stormwater infiltration in these areas. Stepping stone walkways or seating areas can be added and are one way to concentrate use within the structure. These impervious features should always be surrounded by pervious materials.

Maintenance

Because the mulched areas serve as pretreatment zones they must be managed as such. The mulched planting area will require periodic inspection for sediment buildup. Sediments collected in specific areas that are not retained by the planting bed will require periodic removal. The RPM should also be inspected occasionally during a storm event to ensure that the RPM is not short-circuiting (creating preferential flow paths for the runoff) which minimizes the pretreatment effects of the mulched planting area.



Alley Infiltration

Description

A surface infiltration area with a narrow entrance comprised of a durable surfacing such as cobble stones or pavers. No vegetation is used in this structure.

Application

Alley Infiltration is meant to be used in narrow areas where vehicular traffic is concentrated. Areas with roof leaders that discharge to a paved surface may also be served by these installations. Designers who wish to disconnect roof leaders from a current underground storm drain connection and allow them to discharge to a paved surface (for entrance into the Alley Infiltration) should consider safety issues that may arise in winter due to icing.

Advantages

At sites with little or no existing access to the underlying soil, these installations allow for stormwater infiltration with no loss in serviceability of the area.

Disadvantages

Surfacing the Alley Infiltration structure with a durable material such as pavers or cobblestones can comprise a significant portion of the cost of the installation.

Proximity to foundations may necessitate underdrains and/or installation of impervious barriers that may affect the level of groundwater recharge.

Design Considerations

If Alley Infiltration is used in service entrances, areas where heavy vehicles are likely to be turning and tracking across the pervious surface, or any other traffic patterns where the vehicles don’t straddle the pervious surface, designers provide structural support (more compaction of subgrade and bedding materials) while maintaining sufficient surface infiltration rates.

If foundations or other subsurface structural features are located nearby (within 10’) or downgradient of the Alley Infiltration, advice from a geotechnical engineer should be sought.

The low organic content within Alley Infiltration may not provide optimal treatment of organic pollutants if the structure is sited in rapidly draining sandy soils. Some augmentation with coarse peat at the bottom of the stone reservoir (6” thick) area may be warranted in these cases.

Maintenance

Paver/cobblestone surfaces located in traffic areas will require periodic inspection for deflection (raised or uneven surfaces) to ensure that they will not be pulled up during winter plowing activities. This is best inspected in the Fall, before snowfall. If deflection approaches half of the paver/cobblestone thickness, the affected paver(s)/cobblestone(s) will need to be re-leveled flush to the others.

Sand deposits that have accumulated on the surface of the RPM will need to be removed periodically. A wet/dry vacuum is ideal for this and will prolong the life expectancy of the surface of the structure before the pavers, bedding material, and filter fabric must be completely removed and replaced and/or reassembled. The use of a push broom to remove deposits may be quicker in the short run, however may result in redistribution of much of the accumulated sediments and debris over the surface. If sediment removal maintenance is not conducted, the surface may require rehabilitation on a more frequent basis.

Decorative Planters

Description

A self-contained upright structure that provides stormwater treatment and attenuation, but usually little groundwater recharge. With similarities to window box planters or raised planting beds, these designs are very ornamental.

Application

The Planters are designed to capture and treat stormwater originating from rooftops, by intercepting water from roof leaders prior to it entering an existing underground piped drainage system.

Advantages

For sidewalks and other areas with constricted spaces, the planters can be designed to be narrow, and yet still perform well and look attractive.

The generous volume of planting media used in these designs should allow for a wide variety of annuals to thrive.

Disadvantages

Planters are not designed to provide recharge to groundwater.

Because the Planters must be disconnected in Winter (downspouts must be disconnected from the planters and redirected to their original point of discharge), the volume of water treated annually is less than that of other RPMs that receive at least a portion of meltwater during freeze thaw conditions of late Fall and early Spring.

Design Considerations

Depending on space constraints, the planters can be tall and flush with a wall as might be the case with an installation on a sidewalk, or they can be shorter and wider making it similar to a raised planting bed.

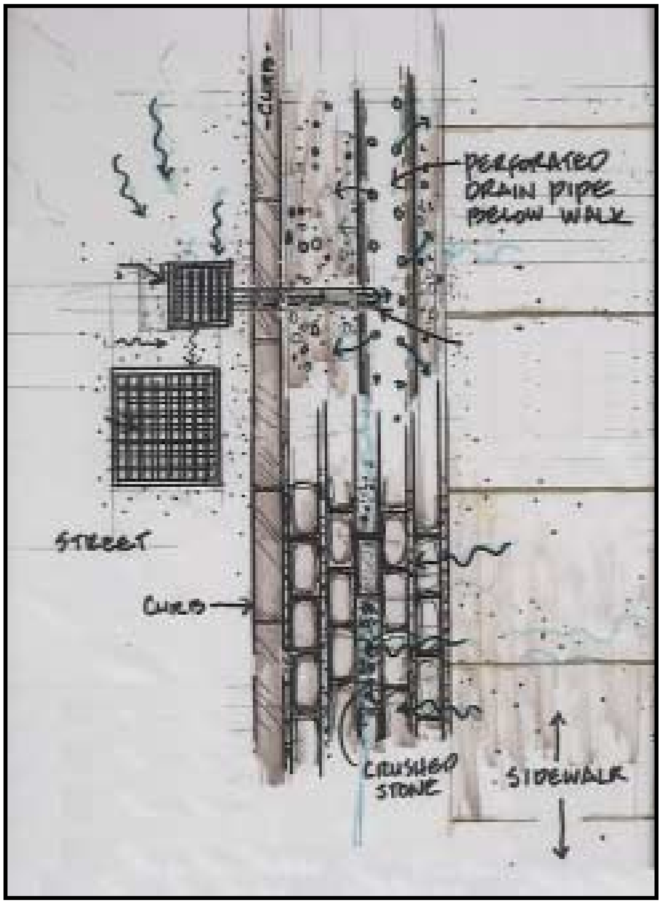
Designers and owners should understand that during the Winter the Planters will be exposed to the elements and therefore may not be conducive to the survival of perennial flowers. For this reason, the beds will need to be planted annually, and thus annuals with their vibrant colors may be a good choice.

Weep holes should be provided at the lowest point in the structure to allow the system to drain between storms. The weeps could drain to the overflow pipe and thus back into an existing underground drainage system. This would be desirable if the planters are located on a sidewalk so that water does not flow across the sidewalk. If the planters are to be located on a pervious surface the weeps can drain directly to the ground, however foundation concerns (see discussion in Design Constraints Section) may need to be addressed.

Designers may want to install an access port on the side of the planters. This would allow access to the end of the perforated pipe for cleaning out debris and roots every couple of years.

Maintenance

Maintenance for the Planters is similar to that of normal flower beds, however the application of soluble fertilizer is discouraged. Those maintaining the plants and flowers should be careful not to overly compact the planting media and prevent percolation.



Curbside Treatment

Description

Curbside treatment has been developed to meet the stormwater management needs of downtown streets and sidewalks where pervious surfaces do not exist. The RPM involves the construction of a pervious sidewalk underlain by a perforated drain pipe. Runoff generated from the sidewalk can percolate through the pervious materials into the underdrain system, while runoff from the roadside can be collected in a catch basin and connected to the underdrain below ground. Normal difficulties relating to access for maintenance or replacement have been reduced in the design through the use of pretreatment devices and removable surfaces.

Application

Curbside treatment is meant to be used to treat runoff from sidewalks and curbed streets where few onsite options exist.

Advantages

Using cobblestones or pavers in place of concrete for sidewalks allows any runoff from the sidewalk to percolate into the ground. This treatment can add beauty and distinction to the streetscape. Most important from a maintenance/longevity standpoint, the removable (non-grouted) surface allows for easier access to the perforated pipe for cleaning or eventual replacement when it reaches the end of its service life.

Disadvantages

Pretreatment provided in the upgradient diversion catchbasin will not be as effective as most RPMs with pretreatment occurring at the surface and will be dependent upon frequency of catch basin cleaning operations.

Conflicts with underground utilities may limit the use of curbside treatment in some areas.

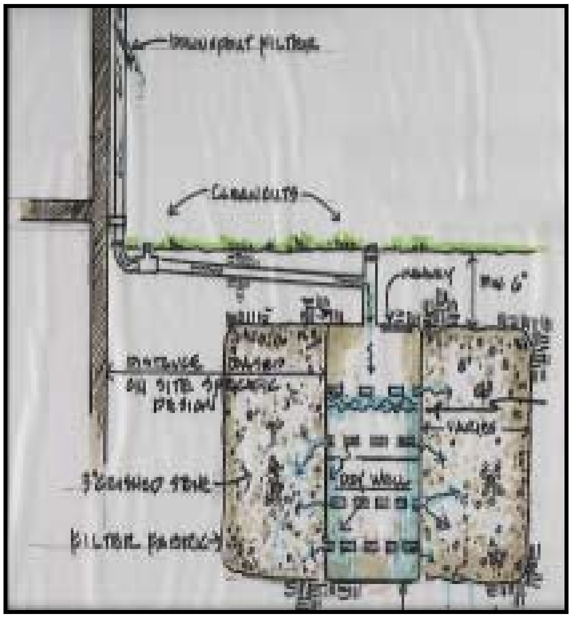
Design Considerations

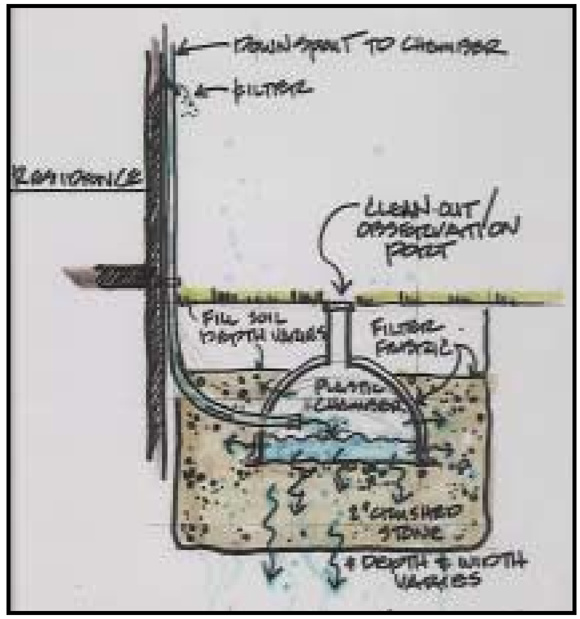
Pretreatment of the roadway runoff is provided in a new upstream catchbasin. To enhance the removal rate of particles, trash and floatables, a hooded outlet cover may be installed. The sump in the catchbasin should be as deep as is practical to further enhance settling.

A variety of pervious surfacing choices exist for use in this design since the runoff from most sidewalks can be captured and infiltrated sufficiently even with a brick (ungrouted) sidewalk. In areas where sidewalks are plowed, designers should confer with local personnel on this matter and utilize surfacing options that do not hinder these operations.

Maintenance

The long-term operation of Curbside Treatment relies heavily upon the removal of particles in the new upgradient diversion catchbasin. To this end, a commitment must be made to clean catchbasins before they are filled with sediment to the outlet invert. A good rule of thumb is to clean the catchbasin when the level of accumulated sediment is within 18” of the outlet invert.





Drywells

Description

Drywells are underground areas that have been excavated and filled with stone. The voids between the stone are where stormwater is stored until it can be leached to the underlying native soils. The greatest benefit of using drywells is to remove roof runoff from the flowstream, and to recharge groundwater. This preserves the capacity of other RPMs to address runoff from other sources that may contain higher pollutant loads.

Application

Drywells have been used for a variety of purposes, usually as a passive drain for foundations, or to receive periodic discharges from sump pumps. More recently, drywells have been used to accept roof runoff. The drywells presented here are mainly used to accept roof runoff, which typically is free of most material that would otherwise clog a system.

Sizes of drywells can range from small installations that handle under 100 gallons in small lightweight plastic chambers, to very large installations using preformed concrete leaching chambers.

Advantages

Drywells are simple structures that are typically inexpensive to install and with the variety of products available to construct them, many homeowners will find installation within their capabilities.

Drywells can be fully hidden from view. Because there are few above ground features, maintenance is minimal.

Drywells may be installed deep enough (below the frost line) that they would continue to infiltrate meltwater from roofs during the freeze thaw cycles that occur in late Fall and early Spring.

Disadvantages

Installations near foundations can cause leaky basements.

Design Considerations

Drywells have been historically used to capture water from one area and disperse it over another, however the drywells presented in this manual have a number of features that address weaknesses inherent in some of the past designs.

The improved drywells presented in this document utilize filter fabric to preserve the capacity of the leaching structure and stone reservoir. Early drywells were just stone filled pits with no protection against slumping and migration of the surrounding soil into the void spaces. A gradual reduction in capacity resulted. Small sinkholes or areas where the earth has settled are usually an indication that the drywell has failed. The use of non-woven filter fabric to completely encapsulate the stone reservoir area will prevent both of these conditions. The common practice of using straw as a pervious separation barrier is discouraged since over time is can consolidate and form a semi-pervious layer.

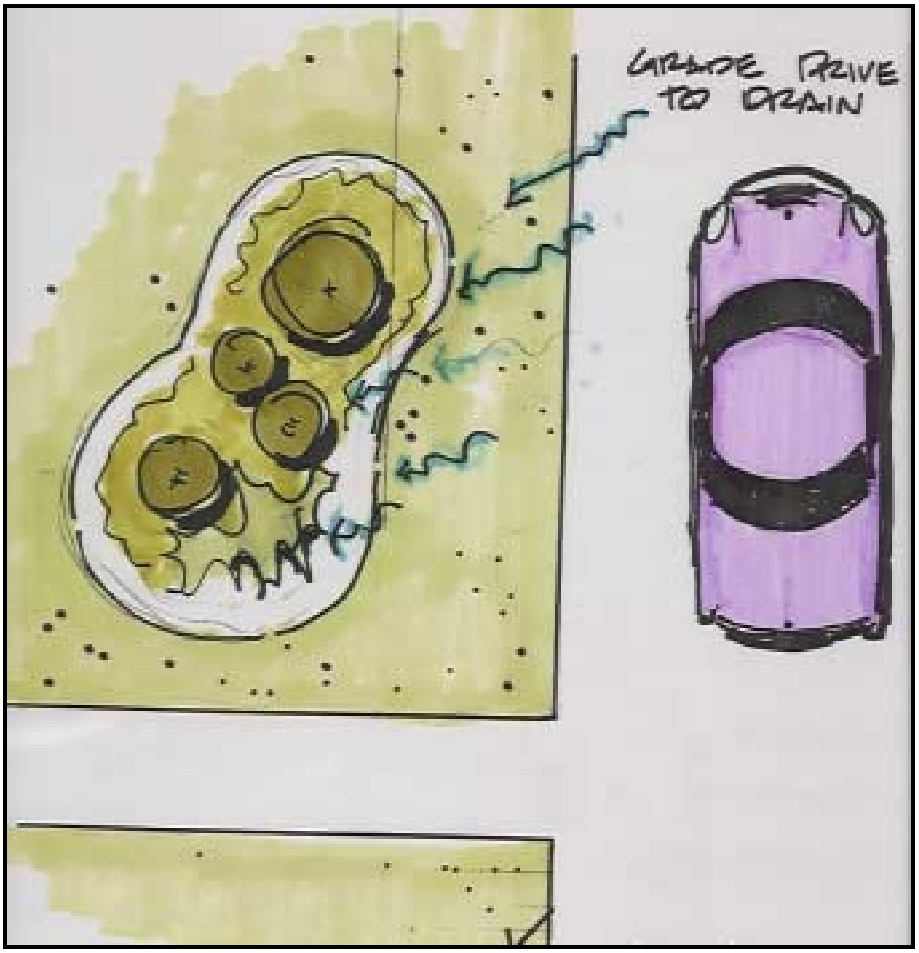
Cleanouts should be installed wherever acute bends in the pipe occur. One cleanout/observation port should be provided directly into the main leaching area so that the interior can be inspected without disturbing the ground surface over the Drywell. This port can be designed to serve as an overflow for large storms, so that once the capacity of the drywell has been used up water will just overflow to the ground.

Because leaves could quickly “seal” off the interior of a drywell, some form of gutter screen should be installed for all gutters contributing stormwater to the drywell.

Maintenance

Maintenance for drywells is mainly preventative. Gutter screens should be cleaned as needed and drywells should be inspected through the observation port occasionally to ensure that they are draining completely within 3 days of the end of a storm.

In larger Drywells, manways are usually a standard component in the concrete leaching chamber. The location of these manways should be noted on plans or as-builts so that once buried, they can be found later and used to provide access for cleaning the inside of the structure.



Pocket Raingarden

Description

A small surface fed infiltration device used to decorate driveway entrances and receive driveway runoff. Pocket Raingardens are modeled after planting beds commonly found in residential settings.

Application

Although Pocket Raingardens can be used on larger commercial properties, they are best suited to residential application. On a commercial property the amount and rate of runoff generated on these substantial impervious areas would quickly overwhelm them, and so other RPMs are usually chosen for their higher infiltrative surfaces. On a residential property, a number of Pocket Raingardens are typically installed on a site for proper landscaping balance and due to their small size and capacity.

Advantages

The generous volume of planting media used in these designs should allow for a wide variety of plants and shrubs to survive. The presence of organic material provides a habitat for beneficial organisms that break down NPS pollutants.

Disadvantages

The relatively thick layer of planting media that supports plant growth will tend to have a lower infiltration rate than other more porous surfacing options such as stone. This is generally not a problem for residential applications if the contributing drainage area is not excessive.

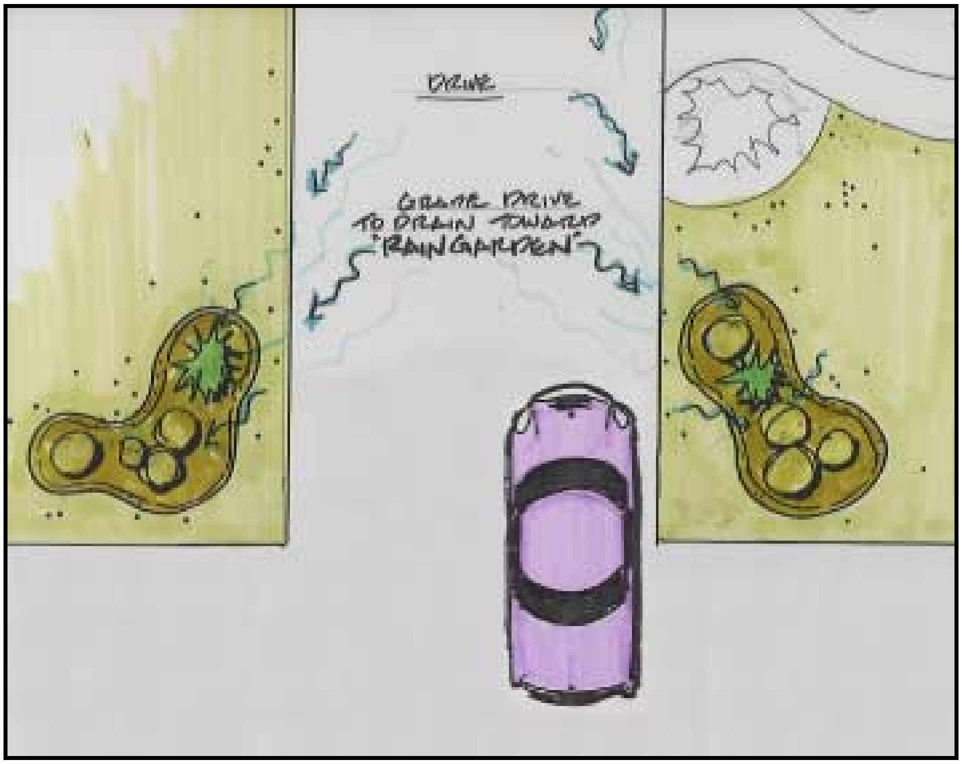
Design Considerations

Designers and installers of Pocket Raingardens should be careful not to let the surface ponding depth exceed 8 inches, or let the water stay on the surface for more that 48 hours as nuisance conditions can develop in 3 to 4 days. The installation of an underdrain may be helpful in promoting shorter drain times if these conditions are anticipated and cannot be avoided. Remember however, that true groundwater recharge will not be provided if the underdrain discharges to a nearby municipal storm drain.

To aid in the degradation of certain NPS pollutants such as nitrogen, designers may want to consider adding an impervious liner under the leaching area of a Pocket Raingarden (if an underdrain is also provided). The liner should be placed 8-18” inches below the invert of the underdrain pipe so that water that pools in this pocket stays there for a sufficient time to become anoxic and promote denitrification. Underdrain discharge points should be located far enough away from living areas so that the “earthy” smell that sometimes develops under these conditions does not bother the homeowners.

Maintenance

The Pocket Raingarden is vulnerable to compaction and homeowners need to be aware of this when performing the simple maintenance that this RPM requires. Because all stormwater must pass through the thick layer of planting media, compaction within it will limit its overall capacity and can increase the period of time that water is ponded on its surface. To lessen compaction associated with foot traffic or maintenance activities, a bark mulch surfacing over the planting media is recommended. Additionally, homeowners should be discouraged from using fungicides or other persistent pesticides in or around Pocket Raingardens because, in addition to killing the undesirable targets, other organisms that aerate the soil (worms, ants etc.) may be killed. If this principle of preserving the infiltration rate is observed, the maintenance of a Pocket Raingarden is no different from any other conventional planting bed.



Raingarden Planter

Description

A small surface fed infiltration device used to decorate driveway entrances and receive driveway runoff. Raingarden Planters are similar to conventional planting beds found in residential settings, however they have a crushed stone edging along their downgradient side which serves as a conduit to the stone infiltration reservoir, once the organic planting media has become saturated.

Application

Raingarden Planters can be used on commercial or residential properties. A number of Raingarden Planters are typically installed on a site for proper landscaping balance and due to their smaller size and capacity.

Advantages

The depth of planting media used in these designs should allow for a wide variety of plants and shrubs to survive.

The presence of organic material provides a habitat for beneficial organisms that break down NPS pollutants.

The lack of filter fabric over the surface of the planting area makes cleaning easier since care is not needed to prevent tearing of the filter fabric.

Disadvantages

Because there is no filter fabric pre-filter in the planting design, more material within the structure may require removal to ensure all of the clogging media has been removed.

Design Considerations

Raingarden Planters do not utilize a filter fabric pre-filter which means that the structure's overall design life will be shorter, however the frequency of and type of maintenance will be far less than other stormwater treatment devices, and mainly involve replacing the mulch.

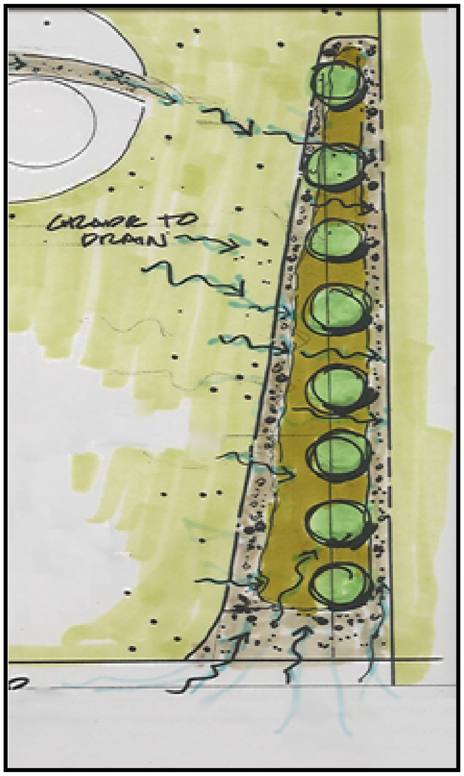
Designers and installers of Raingarden Planters should be careful not to let the water stay on the surface for more than 48 hours after a rain event[1] as nuisance conditions can develop in 3 to 4 days.

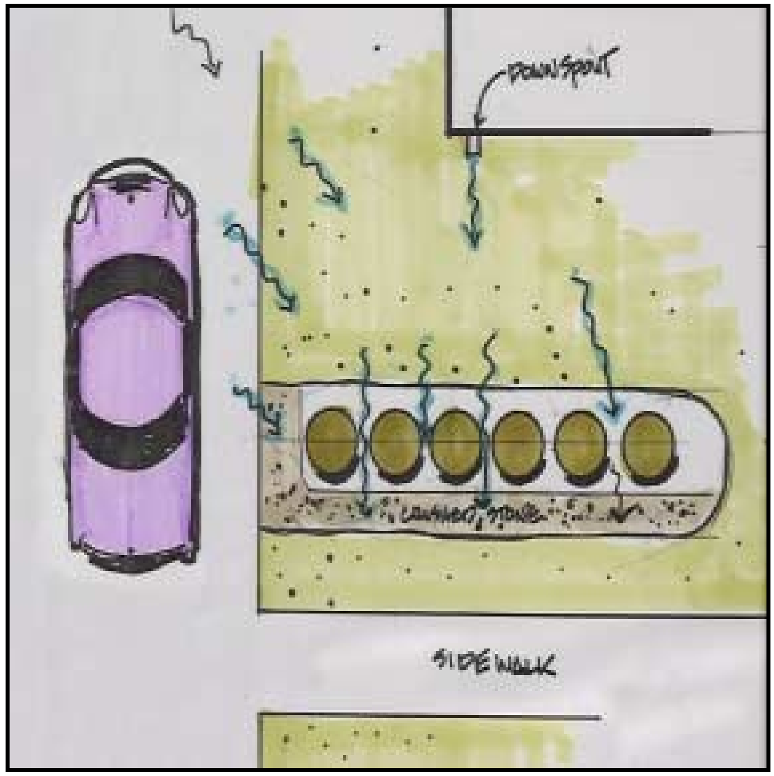
Maintenance

The Raingarden Planter is vulnerable to compaction and so homeowners need to be aware of this when performing the simple maintenance that this RPM requires. Maintenance will involve the periodic removal of sediments from the surface. The duration for the system to drain can be used as an indicator of when the system has clogged.

Homeowners should be discouraged from using fungicides or other persistent pesticides in or around Raingarden Planters because, in addition to killing the undesirable targets, other organisms that aerate the soil (worms, ants etc.) may be killed.

[1] This is a storm of normal duration during the growing season and would not include prolonged periods of rainfall, or spring thaw conditions for example.





Raingarden Strip

Description

A Raingarden strip is a redesigned hedgerow or garden border that has an enhanced ability to intercept and infiltrate stormwater runoff from residential streets, driveways and sheet flow from adjacent lawn areas, if needed.

Application

Raingarden strips can be used in either a commercial or residential setting with the appropriate modifications to the scale of the structure.

Because of the linear shape of these designs, locating them downgradient of other smaller RPMs can provide a backup or duplicity of treatment on sites where this is desirable. For instance, if because of space constraints, an undersized drywell is installed, it may overflow during moderate storms. The excess water may then flow across a lawn picking up fertilizer residues and other NPS pollutants. These would be captured however, by the Raingarden strip that is located downgradient at the edge of the lawn.

Advantages

The generous volume of planting media used in these designs should allow for a wide variety of plants and shrubs to survive.

The presence of organic material provides a habitat for beneficial organisms that break down NPS pollutants.

Disadvantages

The appearance and orientation of this RPM may limit its landscaping appeal as people have different landscaping taste and needs. These RPMs are intended to be located in close proximity to a driveway or street and may look awkward placed in the middle of a lawn.

Design Considerations

When located to receive runoff from streets or large driveways some stabilized surface is needed where the stormwater enters the Raingarden Strip. This can be stone or some other durable material that is not likely to be moved by the force of the water entering the Strip in this concentrated location.

Care must be taken when designing the Raingarden Strip to ensure that the planting media is not so isolated from the incoming flow that only large storms that fill the structure are able to moisten the planting media and roots. This is obviously less of a concern if drought tolerant plantings have been selected. For installations where sheet flow will comprise a major portion of the contributing stormwater, the planting media should extend to the upgradient edge of the Strip with the stone on the downgradient side. This lets the stormwater contact the media first and when it can no longer absorb moisture the flow continues across to the stone surface that provides a conduit to the stone reservoir area underneath.

Maintenance

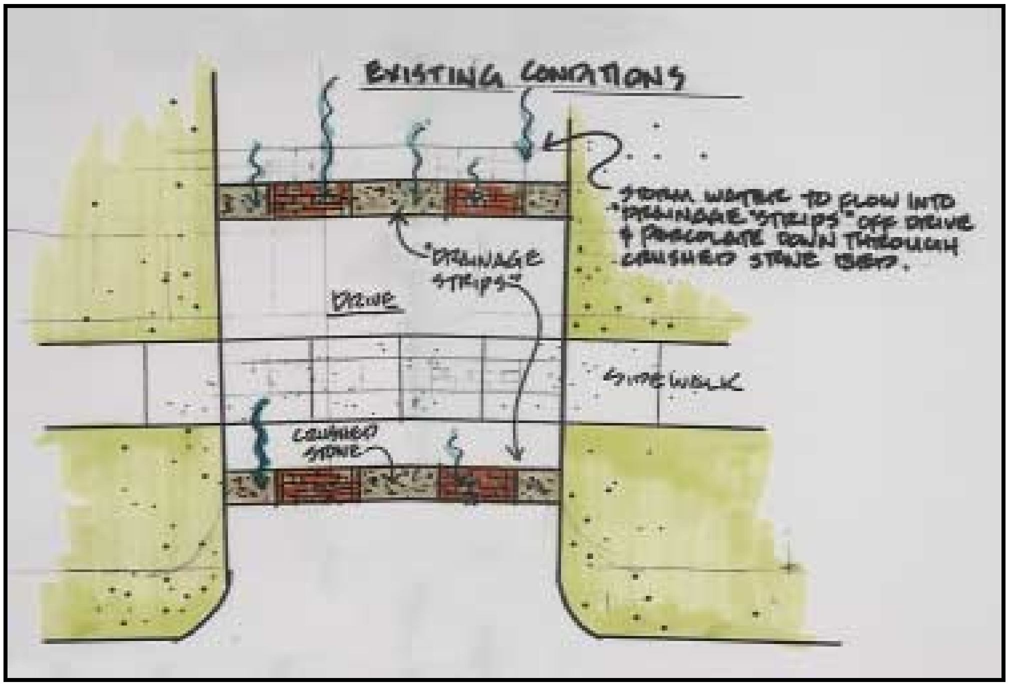
If a stabilized entrance is provided, maintenance activities will include removal of surficial sediment deposits and replacing/raking stone that has been moved during large storms.

The bark mulch that covers the planting media should be replaced as needed.

If stormwater ponds on the surface of the structure for longer than 48 hours after the end of a storm[2], the filter fabric pre-filter may be clogged. In this case, the filter fabric and material covering the upper most layer of filter fabric should be removed. Owners may then either replace both the filter fabric and the cover material or, alternatively, clean the clogging material from them and reuse them. This material should not need to be disposed of at a landfill, however it should not be placed on an area that will be subject to runoff which might resuspend it.

[2] This is a storm of normal duration during the growing season and would not include prolonged periods of rainfall, or spring thaw conditions for example.

The frequency of this rehabilitation will depend on the ratio of filter fabric surface to contributing drainage area, the amount of sand applied to the impervious drainage area, and the frequency with which preventative maintenance has been performed.



Driveway Drainage Strip

Description

This consists of an infiltration trench located in a driveway, and oriented perpendicular to the direction of travel. This RPM may be driven on and accepts stormwater runoff from driveways with low volumes of traffic (such as residential).

Application

This RPM is suited to residential drives or those with very low volumes of traffic with uniform vehicles types.

Advantages

These RPMs are very inexpensive to construct and can be used to delineate parking from travel areas or add some definition between shared drives.

Disadvantages

If the driveway is plowed in the winter, the operator should be made aware of the Strip so that they do not disrupt the surfacing materials.

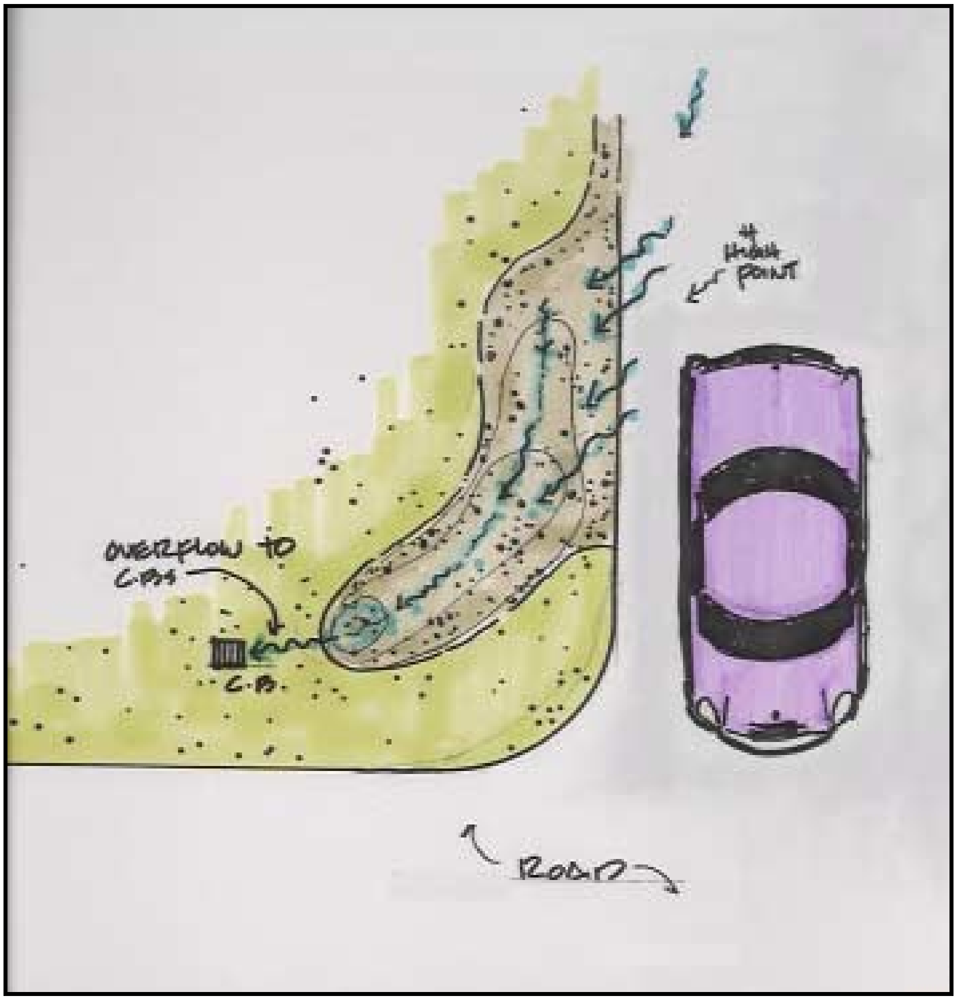
Design Considerations

In driveways where there is a high degree of crown or cross-slope, a Driveway Drainage Strip may subject the adjacent pavement to abuse from plows. As with most plowing obstacles, prior scouting of the site (before it snows) by the plow operator and sufficient markings (reflectors or similar object) can alleviate most potential problems

Maintenance

When stormwater no longer collects and infiltrates in the Strip or sediment can be seen occupying the void space of the stone, the stone and sediment must be removed and replaced.

If the pavers or other tracking material is protruding by more that half of its thickness, the bedding material should be re-leveled and the pavers re-layed to create a level surface with the surrounding pavers and pavement.



Containment Swale

Description

A shallow depression located adjacent to a roadways shoulder that is used to capture and infiltrate roadway runoff and/or lawn runoff before it enters a catchbasin. Although similar to a typical swale, this RPM is designed to pond and infiltrate water to the maximum extent possible, rather than as a means of conveyance. Excess water overflows into a nearby catch basin.

Application

There are two applications for this design. The first would be to collect roadway runoff from a street without an existing curb and gutter system. The RPM is constructed along the edge of the street allowing runoff to enter into it before discharging to a downgradient catch basin. The second application is to collect runoff from lawn areas that would normally flow into the roadway. The RPM could be installed between the lawn area and roadway. When the unit fills with water, it would overflow back into the street drainage system (as if the RPM had not been there).

Advantages

Roadside Stormwater Diverters are relatively inexpensive given the large amount of water that can be captured, treated, and recharged.

Disadvantages

Some road agents may be resistant to infiltrating water adjacent to a road's subgrade for fear of frost damage.

Design Considerations

Shoulder slopes should be maintained particularly in areas where the roadway is narrow and around corners.

Using an impervious barrier to shield a road's subgrade may be necessary to ameliorate concerns of frost heaves damaging pavement.

Maintenance

Sediment and accumulated debris should be removed in the Spring and late Fall after the leaves have dropped.

If stormwater ponds on the surface of the structure for longer than 48 hours after the end of a storm[3], the filter fabric pre-filter may be clogged. In this case, the filter fabric and material covering the upper most layer of filter fabric should be removed. Owners may then either replace both the filter fabric and the cover material or, alternatively, clean the clogging material from them. This material should not need to be disposed of at a landfill, however it should not be placed on an area that will be subject to runoff which might resuspend it.

The frequency of this rehabilitation will depend on the ratio of filter fabric surface to contributing drainage area, the amount of sand applied to the impervious drainage area, and the frequency with which preventative maintenance has been performed.

The Diverter should be inspected occasionally to make sure erosion is not occurring on any of its surfaces.

[3] This is a storm of normal duration during the growing season and would not include prolonged periods of rainfall, or spring thaw conditions for example.

3.0 Technical Specifications

Technical specifications were developed as part of this manual to provide the City and developers with guidance on the materials and construction practices that should be used to construct the various runoff prevention measures (RPMs) presented previously.

Please note that the following specifications are provided as typical standards and that modifications will be required to suit the specific design chosen based on site conditions, design preferences (i.e., planting choices) and maintenance requirements.

The following typical specification sections have been included for RPM construction:

200	EARTHWORK FOR RPMs
400	GEOTEXTILE FABRICS
500	PAVERS AND EDGING
600	UNDERDRAINS
800	WETLANDS CREATION
900	LANDSCAPE WORK

To make it easier for the City and developer to find specific RPM components within the above specifications, the following directory has been provided. The directory breaks the RPMs down into three major construction components: 1) surface components (i.e., pavers, stone, mulch); 2) subsurface components (i.e., stones, fabrics and liners); and 3) vegetation.

Surface Components

Bark Mulch	Section 900 Landscape Work
Boulders, Rock and River Washed Gravel	Section 200 Earthwork for RPMs
Crushed Stone	Section 200 Earthwork for RPMs
Cobble Stone	Section 500 Pavers and Edging
Pavers	Section 500 Pavers and Edging
Reverse Curbing	Section 500 Pavers and Edging
Granite Curbing	See City of Nashua Standard Specifications for Sidewalk Construction

Pavement (i.e., repairs)	See City of Nashua Standard Specifications for Road Construction
Subsurface Components	
Crushed Stone	Section 200 Earthwork for RPMs
Processed Gravel	Section 200 Earthwork for RPMs
Pea Stone Bedding	Section 200 Earthwork for RPMs
Nonwoven Filter Fabric	Section 400 Geotextile Fabrics
Impervious Liner	Section 400 Geotextile Fabrics
Underdrains	Section 600 Underdrains
Drywells	See City of Nashua Standard Specifications for Sewers and Drains
Pipes (i.e., overflows)	See City of Nashua Standard Specifications for Sewers and Drains
Vegetation	
Coarse Vegetation	Section 900 Landscape Work
Drought Resistant Plantings	Section 900 Landscape Work
Low Plantings	Section 900 Landscape Work
Planting Media	Section 900 Landscape Work
Wetlands	Section 800 Wetlands Creation

A reference list of plantings that could be used in the various RPM designs, once site specific design investigations have been made, is included in Appendix B.

SECTION 200

EARTHWORK FOR RPMs

PART 1 - GENERAL

1.01 DESCRIPTION OF WORK

A. Earthwork includes the preparation of RPMs.

B. "Excavation" consists of removal of material encountered to subgrade elevations indicated, and subsequent relocation or disposal of materials removed.

1.02 QUALITY ASSURANCE

A. Codes and Standards:

1. Perform excavation work in compliance with applicable requirements of governing authorities having jurisdiction.

2. The following standard forms a part of these specifications and indicates the minimum standards required:

American Society for Testing and Materials (ASTM)

ASTM D422	Method for Particle Size Analysis of Soils
ASTM D1557	Tests for moisture-density relations of soils and soil-aggregate mixtures using 10 pound hammer and 18-inch drop.
ASTM D4253	Test Methods for Maximum Index Density of Soils Using a Vibratory Table
ASTM D4254	Test Methods for Minimum Index Density of Soils and Calculation of Relative Density

B. Owner will engage soil testing and inspection service for quality control testing to meet material specifications or during earthwork operations.

1.03 JOB CONDITIONS

A. Existing Utilities:

1. Locate existing underground utilities in areas of work. Utility companies shall be contacted a minimum of 72 hours prior to excavation and/or site work. If

utilities are to remain in place, provide adequate means of support and protection during earthwork operations.

2. Should uncharted, or incorrectly charted, piping or other utilities be encountered during excavation, consult utility owner immediately for directions. Cooperate with Owner and utility companies in keeping respective services and facilities in operation. Repair damaged utilities to satisfaction of utility owner.

3. Do not interrupt existing utilities serving facilities occupied and used by owner or others, during occupied hours, except when permitted in writing by Engineer and then only after acceptable temporary utility services have been provided.

4. Provide minimum of 48-hour notice to Engineer, and receive written notice to proceed before interrupting any utility.

B. Protection of Persons and Property:

1. Barricade open excavations occurring as part of this work and post with warning lights.

2. Operate warning lights as recommended by authorities having jurisdiction.

3. Protect structures, utilities, sidewalks, pavements, and other facilities from damage caused by settlement, lateral movement, undermining, washout and other hazards created by earthwork operations.

4. Perform excavation within drip-line of large trees to protect the root system from damage or dryout to the greatest extent possible. Maintain moist condition for root system and cover exposed roots with burlap. Paint root cuts of 1” diameter and larger with emulsified asphalt tree paint.

PART 2 - MATERIALS

2.01 STONE/SOIL MATERIALS

A. Crushed Stone

1. Crushed Stone shall not contain vegetation, masses of roots, loam and other organic matter, clay and other fine or harmful substances.

2. Crushed Stone shall be washed and shall consist of one or the other of the following material:

a. Durable crushed rock consisting of the angular fragments obtained by breaking and crushing solid shattered natural rock, and containing less than 15% by weight of flat, elongated or other objectionable pieces.

b. Durable crushed gravel stone obtained by artificial crushing of gravel boulders or fieldstone with a minimum diameter before crushing of 8 inches.

*Thin or elongated pieces are defined as follows: Thin stones shall be considered to be such stones whose average width exceeds four (4) times their average thickness. Elongated stones shall be considered to be such stones whose average length exceeds four (4) times their average width.

3. The Crushed Stone shall have a maximum percentage of wear of 45 as determined by the Los Angeles Abrasion Test (AASHTO-T-96). The Crushed Stone shall be uniformly graded according to the grading requirements for the respective stone sizes shown in the following Table:

Required Grading For Crushed Stone		
Sieve Size	**2 inch**	**3 inch**
3 inch	--	100
2 inch	100	0-10
1-1/2 inch	0-10	--
1 inch	--	--
¾ inch	--	--

B. Processed Gravel

1. Compacted processed gravel for subbase shall be used where a free draining gravel material is required and shall consist of inert material that is hard, durable stone and coarse sand, free from loam and clay, surface coatings and deleterious materials. The coarse aggregate shall have a percentage of wear, by the Los Angeles Abrasion Test, of not more than 50.

2. The processed material shall be stockpiled in such a manner to minimize segregation of particle sizes. All processed gravel shall come from approved stockpiles.

3. The gradation shall conform to the following:

<u>**Sieve**</u>	<u>**Percent Passing**</u>
3 in.	100
1 ½ in.	70-100
¼ in.	50-85
No. 4	30-60
No. 200	0-10

C. Pea Stone Bedding

1. Pea Stone Bedding shall consist of sound gravel, essentially free of organic matter, plastic fines (clay) and debris.

2. The stone shall be uniform round stone with 100 percent by weight passing through a 5/8 inch sieve and less than 5 percent by weight passing through a ¼ inch sieve. The stone shall be washed free of dirt and particles.

D. Boulders, Rock and River Washed Gravel

1. Boulders, Rock, and River Washed Gravel shall consist of sound, gravel, essentially free of organic matter, plastic fines (clay) and debris, and shall meet the gradation requirements below:

Gradation Requirements	
Sieve Size/Diameter	Percent Passing Weight
18”	100
12”	70
8”	40
3”	20
1"	10

2. The material shall have an in-place coefficient of permeability in the vertical direction equal to or greater than 1.0 x 10^{-2} cm/sec.

E. Sand:

Sand shall consist of bank run sand conforming to the following requirements determined by ASTM D422:

Sieve Opening	Percent Passing Weight
1-inch	100
1/2-inch	50-100
No.20	20-95
No.50	10-60
No.200	0-8

F. Gravel Borrow:

Gravel Borrow shall consist of sound, durable sand and gravel, essentially free of organic matter, plastic fines (clay) and debris, and shall meet the gradation requirements below:

Sieve Opening	Percent Passing Weight
3-inch	100
1/2-inch	50-85
No. 4	40-75
No. 40	10-45
No. 200	0-8

G. Backfill Materials:

1. Backfill Materials shall be satisfactory soil materials and meet the approval of the Engineer. Materials shall be of such a nature that they will form a stable dense fill. Materials shall not contain vegetation, masses of roots, individual roots more than 12 inches long or more than 1/2-inch in diameter, trash, clays, frozen materials, or plastic fines. Organic matter shall not exceed 2%. Non-plastic fines shall not exceed 20% (silts).

2. Backfill materials are subdivided according to the maximum allowable size of stone or blacktop pieces as follows:

Type	Largest Stone Diameter (inches)
1. Select Backfill	3
2. Class B Backfill	6
3. Class C Backfill	12

H. Loam materials shall be as specified in Specification Section 900 LANDSCAPE WORK.

PART 3 - APPLICATION

3.01 EXCAVATION

A. Excavation includes excavation to subgrade elevations indicated, regardless of character of materials and obstructions encountered.

B. Material Storage:

1. Stockpile satisfactory excavated materials where directed, until required for backfill or fill. Place, grade and shape stockpiles for proper drainage.

2. Locate and retain soil materials away from edge of excavations. Do not store within drip line of trees indicated to remain.

3. Dispose of excess soil material and waste materials as herein specified.

C. Excavation for Structures:

1. Conform to elevations and dimensions shown within a tolerance of plus or minus 0.10’, and extending a sufficient distance from stormwater treatment device structures to permit placing of devices, connections, other construction, and for inspection.

D. Excavation for Trenches:

1. Dig trenches to the uniform width required for particular item to be installed, sufficiently wide to provide ample working room.

2. Trenches in pavement shall have the traveled way surface cut in a straight line by a concrete saw or equivalent method, to the full depth of pavement. Excavation shall only be between these lines. Cutting operations shall not be done by backhoe, gradall, or other ripping equipment.

3. Excavate trenches to depth indicated or required. Keep bottoms of trenches sufficiently below finish grade to avoid freeze-ups.

E. Earth Excavation and Backfill Below Normal Grade

1. If, in the opinion of the Engineer existing material below trench grade is unsuitable for properly placing treatment material, the Contractor will excavate, remove, and dispose of the unsuitable material to the required width and depth and replace it with gravel borrow as directed by the Engineer.

2. Do not backfill trenches until tests and inspections have been made and backfilling is authorized by Engineer. Use care in backfilling to avoid damage or displacement of pipe systems.

3. Cold Weather Protection: Protect excavation bottoms against freezing when atmospheric temperature is less than 35 degrees F (one degree C).

3.02 BACKFILLING

1. Place backfill and fill materials evenly to required elevations. Take care to prevent wedging action of backfill against structures or displacement of piping or conduit by carrying material uniformly around structure, piping or conduit to approximately same elevation in each lift.

3.03 FIELD QUALITY CONTROL

Quality Control Testing During Construction: Allow testing service to inspect and approve subgrades and fill layers before further construction work is performed.

3.04 MAINTENANCE

A. Protection of Graded Areas:

1. Protect newly graded areas from traffic and erosion. Keep free of trash and debris.

2. Repair and re-establish grades - in settled, eroded, and rutted areas to specified tolerances.

B. Settling: Where settling is measurable or observable at excavated areas during general project warranty period, remove surface (pavement, lawn or other finish), add backfill material, compact, and replace surface treatment. Restore appearance, quality, and condition of surface or finish to match adjacent work, and eliminate evidence of restoration to greatest extent possible.

3.05 DISPOSAL OF EXCESS AND WASTE MATERIALS

Excavated material shall be transported off Owner’s property.

END OF SECTION

SECTION 400

GEOTEXTILE MATERIALS

PART 1 – GENERAL

1.01 WORK INCLUDED:

This section of the specification covers the installation of geotextile materials.

1.02 SUBMITTALS

Submit to the Engineer product data and samples for geotextile fabrics and liners.

1.03 QUALITY ASSURANCE

A. Use adequate numbers of skilled workmen who are trained and experienced in the necessary crafts and who are completely familiar with the specified requirements and methods required for proper completion of the work under this Section.

B. Use equipment of adequate size, capacity, and quantity to accomplish the work of this Section in a timely manner.

C. Comply with the directions of the Engineer and the requirements of governmental agencies having jurisdiction.

D. Install according to manufacturers recommendations.

PART 2 – MATERIALS

2.01 GEOTEXTILE FILTER FABRIC

A. Geotextile filter fabric shall be a nonwoven, needlepunched geotextile composed of continuous filament fibers.

B. Geotextile filter fabric shall have the following minimum roll values:

Physical Requirements	Test Method	Minimum Requirements
Weight	ASTM D3776	5.7 oz./sy
Grab Tensile Strength	ASTM D4632	150 lbs
Grab Tensile Elongation	ASTM D4632	50%
Puncture	ASTM D4833	80 lbs
Mullen Burst	ASTM D3786	275 lbs
Coefficient of Permeability	ASTM D4491	0.25 cm/sec
Apparent Opening Size	ASTM D4751	No. 70-100 Sieve

2.02 IMPERVIOUS LINER

A. Impervious Liner shall be made from plastic, polyethylene or other approved polymeric chemically stable material and be resistant to ultraviolet radiation degradation.

B. The liner shall meet the following minimum specifications, tested using the ASTM standard methods:

Test Parameter	Test Method	Minimum Specification
Density	ASTM D1505	0.935 g/cu.cm.
Black Carbon Content	ASTM D4216	2%
Environmental Stress Crack	ASTM D5397	1500 hours
Low Temperature Brittleness	ASTM D746	-70 °C
Dimensional Stability	ASTM D1204	2.0 % (max.) 212^{N}F, 15 min.
Tensile Strength (Yield)	ASTM D638	2100 psi
Tensile Strength (Break)	ASTM D638	3800 psi
Elongation (Break)	ASTM D638	560 %
Thickness	ASTM D5199	30mils
Tear Resistance	ASTM D1004	44 lbs

C. A sample of the liner shall be tested by an independent laboratory at no expense to the City, to verify conformance with the specifications. Certified copies of the test results shall be supplied to the City/Engineer.

PART 3 – APPLICATION

3.01 FILTER FABRIC INSTALLATION

A. Installation of geotextile fabrics shall be strictly in accordance with manufacturer’s instructions and specific layout plans and details reviewed by the Engineer.

B. Geotextile fabrics shall be installed at locations as shown on the drawings or as directed by the Engineer.

C. The filter fabric in place shall cover the entire vegetation/rockfill area.

D. Each width of fabric shall be overlapped by the subsequent width a minimum of two feet.

E. The Contractor shall follow the manufacturer’s installation recommendations to ensure proper completion of the fabric installation.

3.02 IMPERVIOUS LINER INSTALLATION

A. The liner shall be laid out by the Contractor in a manner to avoid wrinkles, puncture, cuts, tears, or any other imperfections. All labor and equipment needed for the application of the liner shall be arranged by the Contractor. The Contractor (and manufacturer or his representative) shall approve all site grading and preparations to assure no underlying materials will puncture the liner during or after its application.

B. The membrane material shall be cleaned of all debris and materials which may negatively affect the performance of the system.

C. Each panel of the membrane shall be laid out and installed in accordance with the approved drawings prepared by the Contractor. The layout shall be designed to keep field joining of the membrane to a minimum and consistent with proper methods of membrane installation.

D. Sufficient slack shall be provided to allow for geomembrane shrinkage and contraction during placement. Methods for quantifying the additional material shall be subject to the approval of the Engineer.

E. During installation and exposure of geomembrane liner:

1. Pedestrian and equipment activity over the liner shall be kept to a minimum and restricted to that which is necessary for liner construction.

2. Construction workers shall take precautions not to damage the liner surface, including not dragging tools across the liner surface. No smoking shall be permitted on the geomembrane liner.

3. Construction staff shall be informed of the restricted access to areas of liner placement barriers and signs shall be posted as necessary to provide restricted access.

4. No tracked equipment or other equipment which poses a risk of puncturing, tearing or otherwise damaging the liner will be permitted for use in placement of material directly over the exposed liner.

3.03 FINAL INSPECTION AND ACCEPTANCE:

A. The Contractor shall, at his expense, have a manufacturer’s representative inspect the work at completion of the installation. Any work found to be unsatisfactory shall be corrected at the Contractor’s expense.

B. The Engineer, at the Contractor’s expense, reserves the right to have a manufacturer’s representative inspect the installation process at any time during construction.

END OF SECTION

SECTION 500

PAVERS AND EDGING

PART 1 – GENERAL

1.01 WORK INCLUDED:

This section of the specification covers the installation of pavers, cobblestones and reverse curbing.

1.02 SUBMITTALS

A. Ten typical pavers of each color and type specified by the designer.

B. A letter of guarantee that the pavers will not fade or discolor substantially for a period of five years.

1.03 QUALITY ASSURANCE

A. Use adequate numbers of skilled workmen who are trained and experienced in the necessary crafts and who are completely familiar with the specified requirements and methods required for proper completion of the work under this Section.

B. Use equipment of adequate size, capacity, and quantity to accomplish the work of this Section in a timely manner.

C. Comply with the directions of the Engineer and the requirements of governmental agencies having jurisdiction.

PART 2 – MATERIALS

2.01 CONCRETE PAVERS

A. Pavers shall be precast concrete with beveled top edges and be designed to withstand vehicular traffic (HS-20) loading.

B. Pavers shall be no greater than 10 inches square.

C. Paver colors to be specified by the designer.

D. Pavers shall have a compressive strength of 8,000 p.s.i. at twenty eight days. Portland Cement shall conform to ASTM C 150, Type I or II.

E. Pavers shall have an absorption of less than five percent.

F. Freeze thaw: Fifty cycles in three percent salt solution, weight loss less than one percent of dry weight.

G. Porous pavers shall be used where specified.

2.02 COBBLE STONE

A. Cobble Stone shall consist of granite stone with a sufficient thickness to permit vehicular traffic from deforming the stones and as per Manufacturers Specifications.

B. The Cobble Stones shall be greater than 4 inches square and no greater than 10 inches square.

C. Dimensional tolerance of stone shall conform to the latest addition of American Institute of Architects (AIA) Specifications.

2.03 REVERSE CURBING

A. Reverse curbing shall be precast combination concrete curb and gutter.

B. Minimum compressive strength of concrete shall be 5,000 psi at 28 days.

PART 3 – APPLICATION

3.01 INSTALLATION

A. Pavers and Cobble Stone

1. Install pavers/cobblestones to the lines, grades and patterns shown on the Drawings. Cross slope shall be a minimum of ¼ inch per one foot in the direction of surface drainage where grades are not shown.

2. Pavers and cobble stone shall be installed with a minimum ½ inch space between pavers/cobblestones, or in accordance with manufacturers recommendations to allow for infiltration of water through spaces.

3. Cut pavers when necessary with motor-driven saw equipment with diamond blades designed to cut masonry with clean, sharp, unchipped edges. Use full units without cutting wherever possible.

4. After laying, sweep sand into all joints. Water the sand into joints to assure that all voids are filled.

B. Reverse Curbing

1. Reverse curbing shall be installed between paved areas and Runoff Prevention Measures (RPMs) as shown on the details.

2. The top of the curbing adjacent to the pavement shall be set at the same grade as the top of the pavement so as to allow runoff to flow unimpeded from the pavement over the curb.

3. The top of the curbing gutter located adjacent to the RPM shall be set a minimum of six inches below the pavement grade.

3.03 FINAL INSPECTION AND ACCEPTANCE:

A. The Contractor shall, at his expense, have a manufacturer's representative inspect the work at completion of the installation. Any work found to be unsatisfactory shall be corrected at the Contractor's expense.

B. The Engineer, at the Contractor's expense, reserves the right to have a manufacturer's representative inspect the installation process at any time during construction.

END OF SECTION

SECTION 600

UNDERDRAINS

PART 1 – GENERAL

1.01 WORK INCLUDED

This section of the specification covers the installation of underdrains.

1.02 QUALITY ASSURANCE

A. Use equipment of adequate size, capacity, and quantity to accomplish the work of this Section in a timely manner.

B. Comply with the directions of the Engineer and the requirements of governmental agencies having jurisdiction.

PART 2 – MATERIALS

2.01 POLYVINYL CHLORIDE PIPE

A. Smooth-wall perforated polyvinyl chloride pipe shall conform to AASHTO M 278. Perforated polyvinyl chloride profile wall pipe shall conform to AASHTO M 304.

B. Corrugated polyethylene drainage tubing 150 mm (6 in) in diameter shall conform to AASHTO M 252, with Class 2 perforation except that the required pipe stiffness shall be a minimum of 400 kPa (60 psi). Perforated corrugated polyethylene pipe of nominal sizes 300 to 900 mm (12 to 36 in) diameter shall conform to AASHTO M 294, with Class 1 perforations. Lengths for all sizes shall not exceed 6 m (20 ft).

C. Sand cushion shall be so graded that 90 to 100 percent by weight will pass a 12.5 mm (1/2 in) sieve, and not more than 15 percent will pass a 0.075 mm (No. 200) sieve.

PART 3 – APPLICATION

3.01 INSTALLATION

A. Trenches shall be excavated to the dimensions and grade shown or ordered. A minimum 50 mm (2 in) sand cushion in common excavation and a 150 mm (6 in) sand cushion in rock excavation shall be placed in the bottom of the trench for its full width and length to the grade of the bottom of the pipe.

B. Perforated pipe shall normally be placed with the perforations down, and sections shall be securely joined with the appropriate couplings, fittings, or bands.

C. Nonwoven support membrane shall be installed so as to minimize the number of fabric seams within the trench section. Seams shall be constructed by overlapping the fabric at least 300 mm (12 in) and folding to create a joint which will ensure that soil infiltration will be retarded. Sharp pieces of rock shall not be placed immediately adjacent to the fabric.

D. After the pipe installation has been inspected and approved, underdrain backfill materials shall be placed to a height of 300 mm (12 in) above the tope of the pipe, care being taken not to displace the pipe. The remainder of the backfill material shall then be placed to the required height and compacted in lifts not to exceed 300 mm (12 in).

E. Pipes shall be laid with 45 degree bends where changes in direction are indicated on the plans.

F. Except at structures, up grade ends of all underdrain pipe installations shall be closed with suitable plugs to prevent entry of soil material.

END OF SECTION

SECTION 800

WETLANDS CREATION

PART 1 – GENERAL

1.01 DESCRIPTION OF WORK

A. This specification includes excavation and placement of soils, grading, planting, seeding and maintenance for the creation of wetlands.

1.02 QUALITY ASSURANCE

A. A Wetlands Specialist shall be on site to inspect/monitor the delivery of plant materials and organic amendment, planting, seeding, and completion of construction.

B. No material from excavation and/or backfilling activities shall be discharged into existing wetlands or waterways.

C. All stockpiled materials and staging areas shall be located in upland portions of the site and shall not impact waterbodies in the vicinity of the project.

1.03 DELIVERY

A. Plant and seed material shall be inspected by the Wetlands Specialist, after arrival at the site, for conformance with the project requirements. Dead, unhealthy, injured, or otherwise unacceptable plant material shall not be accepted and shall be removed from the site.

B. Plants are to be protected until installed to prevent damage to the root balls or desiccation. As much of the rhizome, root material, and attached soil as possible shall be retained with each plant stalk so that a viable propagule is planted.

C. Plants shall be protected during transport and delivery to prevent damage or desiccation of the roots or leaves.

D. Soils shall be protected during delivery to prevent desiccation, minimize compaction, and maintain the integrity of the material. Soils shall be kept moist at all times.

E. Soil conditioners and amendments shall be delivered to the site in their original, unopened containers bearing the manufacture’s guaranteed chemical analysis and name.

1.04 STORAGE

A. Plants not installed on the day of arrival at the site shall be stored and protected in a location shaded and protected from the wind and excessive heat. Plants stored onsite shall be protected from drying by covering the roots with moist sawdust, wood chips, shredded bark, or other similar mulching material. Plant roots must be kept in a moist, but not wet, condition until planted by watering with a fine mist spray.

B. Soils not installed on the day of excavation, or on the day of arrival at the site, shall be stored and protected. Excavated soils shall be kept moist until placement in the wetland creation sites.

C. Any plants which have been permitted to dry out, to become overheated, or for any reason in the judgement of the Wetland Specialist, do not clearly show a viable condition shall be rejected for use.

D. Soil conditioners and amendments will be kept in dry storage separated from contaminants.

1.05 HANDLING

A. Care shall be taken to avoid drying or damaging plants, particularly roots and rhizomes, being transported to the planting site. Balled and burlapped plants shall be handled carefully to avoid cracking or breaking the earth ball. Plants shall not be handled by the stems. Damaged plants shall be rejected by the Wetland Specialist and shall be removed from the site.

1.06 SUBMITTALS

A. Certificates from the plant stock supplier shall be submitted for each group of plant stock to the Wetlands Specialist for approval, at least 4 weeks prior to planting. The certificates shall state the botanical name, common name, origin, age, date of packaging, and name and address of supplier.

B. For each seed mixture, certificates from the seed vendor shall be submitted to the Wetlands Specialist for approval, at least 4 weeks prior to application. The certificates shall state the botanical name, common name, number of seeds per unit of weight, percentage of seeds by weight in a mixture, date of production and of packaging, and name and address of supplier.

C. Documentation of the source of the topsoil and organic soil amendment shall be submitted to the Wetlands Specialist for approval at least 4 weeks prior to placement. A sample of the amended topsoils shall be submitted to the Wetlands Specialist for approval.

PART 2 – MATERIALS

2.01 BACKFILLING AND TOPSOIL

A. The final planned elevation of the wetlands shall be achieved by backfilling with organic soil. Organic soil shall achieve a percent organic composition of approximately 12% by weight. Undecomposed wood chips shall not be used as an organic amendment. The organic mixture used as topsoil shall have a pH approximately within the range of 5.5 – 7.5.

B. The topsoils must not be compacted during excavation, backfilling, or grading activities. The substrate should be soft enough to permit relatively easy insertion of plants into the soil. If the wetland soil is compacted, the soil must be physically disturbed (for example, by roto-tilling) before flooding and planting. The Wetlands Specialist shall inspect and approve the backfilled topsoil prior to planting.

C. Acceptable topsoil must be reasonably free from underlying sub-soil, clay lumps, objectionable weeds, litter, brush, toxic substances or any material that might be harmful to plant growth or be a hindrance to grading, planting or maintenance operations. Topsoil shall not contain more than 5 percent by volume of stones, stumps or other objects larger than 1 inch in any dimension.

2.02 PROPAGULES

A. The wetland shall be planted with indigenous wetland species, representative of local species. The plantings shall consist of those shown on the planting details in the contract drawings unless substitutions due to availability are approved by the Wetlands Specialist. Plants will be purchased from a supplier approved by the Wetlands Specialist.

B. Container-grown shrubs shall be in that container a sufficient time that fibrous roots are formed so the shape will remain and the medium will hold together when removed from the container (ANSI Z60.1).

C. Balled and burlapped plants shall have ball sizes and ratios conforming to ANSI Z60.1. Plants shall be balled with firm, natural balls of soil. Balled and burlapped plants shall be wrapped firmly with burlap, strong cloth, or plastic and tied.

D. Planting stock shall be well-formed, sound, vigorous, healthy, and free from disease, sunscald, windburn, abrasion, and harmful insects or insect eggs and shall have healthy, normal, and unbroken root systems.

E. Plants shall have been grown under climatic conditions similar to those in the vicinity of the site. Plants budding into leaf or having soft growth shall be sprayed with an antidesiccant at the nursery before digging. If spraying of an antidesiccant is used, it shall not be required again prior to the transporting of plant materials.

2.03 SEEDING:

A. The wetland areas will be hand sown with a wetland seed mix comprised of native wetland grass, rush, sedge, and/or wildflower species. The wetland seed mix shall not include invasive or non-native species. The species composition shall be similar to the composition of the New England Wetmix produced by New England Wetland Plants, Inc. The wetland seed mix shall be applied at a rate of 1 lb/5,000 sq. ft unless otherwise directed by the manufacturer and approved by the Wetland Specialist.

2.04 FERTILIZER

A. Fertilizer shall be Osmocote or a similar slow-releasing fertilize mixture.

PART 3 – APPLICATION

3.01 BACKFILL

A. Handling of the wetland topsoil shall be performed so as to maintain the integrity of the material. The soils shall be spread throughout the wetland to a minimum thickness of 12 inches. The final surface elevation shall be as shown on the Drawings.

B. The sites shall be graded in a sequence which shall leave the top 12 inches of topsoil uncompacted. Final grading shall be free of ditches or ruts caused by equipment.

3.02 IRRIGATION

A. Once grading is complete, soils in the wetlands shall be saturated. For optimal plant growth, the soil must be partially saturated with water (no standing water) immediately before planting and should not be allowed to completely dry for two weeks after planting.

3.03 PROPAGULES

A. Planting of shrubs will occur between April 15 and June 1 or between August 30 and October 30. No planting shall occur when the ground is frozen, snow covered, or in an otherwise unsuitable condition for planting.

B. The width of the hole for each propagule shall be twice the diameter of the rootball and the depth shall be twice the height of the rootball.

C. Propagule backfill mixture (PBM) for each propagule shall consist of an organic soil mixture as specified in Part 2.01.

D. All non biodegradable wrappings must be removed when the rootball is placed in hole. Plastic pots must be removed prior to placing the plant in hole.

E. PBM shall be placed in the bottom of each hole and compacted so that when the rootball is placed in the hole, the top of the rootball is level with the top of the hole. PBM shall then be placed around the sides of the rootball and compacted.

F. Soil shall be raised between 2 and 6 inches around edges of the hole to create a slight depression to collect water.

G. All plants shall be watered by flooding the backfilled hole within the same working day upon which they were planted. During and immediately after watering, all plants shall be adjusted as necessary to ensure correct depth of planting, vertical alignment and/or natural profile. Additional soil shall be added around each plant to compensate for settling, if settling exceeds 1 inch.

3.04 SEEDING

A. Spring seeding shall occur between April 1 to June 15. Fall seeding shall occur between October 1 to November 15, unless otherwise approved by the Wetlands Specialist due to special conditions.

B. The application rate of the wetland seed mixture to be hand broadcast on the wetlands shall be as shown on the planting details in the Drawings.

C. The seedbed shall be inspected prior to seeding by the Wetlands Specialist. The backfill and regrading of the site shall leave the top 2 inches of the soil loose and friable. Any stones larger than 2 inches will be removed from the soil surface. Any other debris will be removed including wire, cable, tree roots, concrete pieces, clods or lumps.

D. In the event vegetative cover has not been established prior to November of the year of planting, well composted organic mulch or jute netting shall be used to stabilize the sites. Mulch shall not include bark or wood chips, unless the wood materials are very well decomposed.

E. Seeding shall not occur when the ground is frozen or snow covered, and shall occur after the planting of the wetlands.

3.05 FERTILIZER APPLICATION

A. Osmocote or a similar slow-releasing fertilizer mixture will be applied in accordance with the directions and warranties offered by the supplier for each of the species and varieties planted.

3.06 WARRANTY PERIOD AND REPLACEMENT

A. All propagules and seeds planted under this contract shall be healthy and in a flourishing condition of active growth 3 years after the conclusion of planting and seeding at a particular wetland replication site.

B. The seeds and plants shall be reasonably protected from herbivores and other vectors which threaten the establishment of the vegetation.

C. The Contractor shall reseed and/or replace vegetation, all vegetated areas not in a vigorous, thriving condition and any dead vegetation, as determined by the Wetlands Specialist during and at the end of the warranty period.

D. Seeded areas shall bear foliage of a normal density size and color 3 years from the conclusion of planting and seeding.

END OF SECTION

SECTION 900

LANDSCAPE WORK

PART 1 – GENERAL

1.01 DESCRIPTION OF WORK

A. This specification shall cover landscape development work.

1.02 QUALITY ASSURANCE

A. Subcontract landscape work to a single firm specializing in landscape work.

B. Source Quality Control:

1. Ship landscape materials with certificates of inspection required by governing authorities. Comply with regulations applicable to landscape materials.

2. Do not make substitutions. If specified landscape material is not obtainable, submit proof of non-availability to Engineer, together with proposal for use of equivalent material.

3. Package standard products with manufacturer's certified analysis. For other materials, provide analysis by recognized laboratory made in accordance with methods established by the Association of Official Agriculture Chemists, wherever applicable.

1.03 SUBMITTALS

A. Submit certificates of inspection as required by governmental authorities. Submit manufacturer's or vendors certified analysis for soil amendments and fertilizer materials. Submit other data substantiating that materials comply with specified requirements.

B. Submit seed vendor's certified statement for each grass seed mixture required, stating botanical and common name, percentage by weight, and percentages of purity, germination, and weed seed for each grass seed species.

C. Submit typewritten instructions recommending procedures to be established by Owner for maintenance of landscape work for one full year. Submit prior to expiration of required maintenance period(s).

1.04 DELIVERY, STORAGE AND HANDLING

A. Packaged Materials: Deliver packaged materials in containers showing weight, analysis and name of manufacturer. Protect materials from deterioration during delivery, and while stored at site.

1.05 JOB CONDITIONS

A. Proceed with the complete landscape work as rapidly as portions of site become available, working within seasonal limitations for each kind of landscape work required.

B. Utilities: Determine location of underground utilities and perform work in a manner which will avoid possible damage. Hand excavate as required. Maintain grade stakes set by others until removal is mutually agreed upon by parties concerned.

C. Excavation: When conditions detrimental to plant growth are encountered, such as rubble fill, adverse drainage conditions, or obstructions, notify Engineer before planting.

D. Planting Time: Plant or install materials during normal planting seasons for each type of landscape work required. Correlate planting with specified maintenance periods to provide maintenance from date of substantial completion.

PART 2 – MATERIALS

2.01 GENERAL

A. Plant material shall meet the current specifications of the “American Standard for Nursery Stock” as published by the American Association of Nurserymen unless otherwise specified.

B. All plants shall be first class and shall be representative of their normal species or varieties. All plants must have a good healthy, well formed upper growth and a large, fibrous, compact root system. Plants shall be durable and able to survive

C. Unless otherwise specified, so-called exposed or “bare-root” material will be accepted. Container grown plants may be furnished in lieu of balled and burlapped plants, provided they meet the current specifications in the American Standard for Nursery Stock.

D. All plants shall be free from plant diseases and insect pests, and shall comply with all applicable State and Federal laws with respect to inspection for plant diseases and infestations.

2.02 COARSE VEGETATION

A. Coarse Vegetation shall be durable and have a thick stem to be able to withstand water flow. Coarse Vegetation shall consist of healthy plants that will grow to a height of at least 18 inches. Coarse vegetation may consist of but is not limited to: sedges, rushes, reeds, cattails, and tall grasses.

2.03 DROUGHT RESISTANT PLANTINGS

A. Deciduous Trees:

1. Non-flowering trees shall have been transplanted 3 times, the last transplanting within 2 years. They shall have a single straight leader not cut back. They shall have a symmetrical development of strong, healthy branches beginning 5 feet to 6 feet from the ground; and below this point, the trunk shall be clean for street trees, although park trees will be permitted to branch lower.

2. Flowering trees shall have been transplanted twice, the last transplanting within 2 years. The trunk shall be clean and straight up to the first branch, which shall be about 4 feet from the ground. Grafted and budded trees may branch lower and be pruned off 2 feet from the ground where directed. Flowering trees shall be balled and burlapped and kept moist for delivery.

B. Evergreen Trees:

1. Evergreen trees shall have been transplanted 3 times, the last transplanting within 2 years. They shall have a good colored top growth and shall be balled and burlapped and kept moist for delivery. Evergreen trees shall conform to AAN specifications; specified spread shall govern over height requirements.

2.04 LOW PLANTINGS

A. Low Plantings shall be durable and capable of living in low water conditions. Plantings shall be healthy and disease free. Plantings shall be able to grow in shallow soil layers.

B. Deciduous Shrubs:

1. Deciduous shrubs shall be fully representative of their species and variety. They shall have been transplanted twice; the last transplanting within 2 years. They shall have 4 to 6 branches coming from the roots, shall have a well-branched root system and shall be of good weight for the height specified.

C. Evergreen Shrubs:

1. Evergreen shrubs shall have been transplanted twice and shall have a heavy dark-green foliage. Each clump shall have not less than 4 stems. Plants shall be balled and burlapped and kept moist for delivery.

2.05 PLANTING MEDIA

A. General

1. Planting Media shall be reasonably free of stumps, roots, and heavy or stiff clay, stones larger than 2-inches in diameter, lumps, coarse sand, noxious weeds, sticks, brush or other litter.

B. Planting Media shall be composed of the following percentages of materials:

Loam	50%
Sand	30%
Compost or Peat	20%

C. Loam

1. Loam shall consist of loose friable topsoil with no admixture of refuse or material toxic to plant growth. Loam shall be generally free from stones, lumps, stumps, or similar objects larger than 50 mm (2 in) in greatest diameter, subsoil, roots, and weeds. The term as used herein shall mean that portion of the soil profile defined technically as the “A” horizon by the Soil Science Society of America. The minimum and maximum pH value shall be from 5.5 to 7.6. Loam shall contain a minimum of 3 percent and a maximum of 10 percent of organic matter as determined by loss by ignition. Not more than 65 percent shall pass a 0.075 mm (No. 200) sieve as determined by the wash test in accordance with ASTM D 1140. In no instance shall more than 20% of that material passing the 4.75 mm (No. 4) sieve consist of clay size particles.

2. For a particular source of loam, the Engineer may require the Contractor to send approximately 10 pounds of loam to an approved testing laboratory and have the following tests conducted:

    1. Organic concentrations
    2. pH
    3. Nitrogen concentration
    4. Phosphorous concentration
    5. Potash concentration

    These tests shall be at the Contractor's expense. Results and soil conditioning and fertilizing recommendations shall be forwarded to the Engineer.

3. Obtain loam from local sources or from areas having similar soil characteristics to that found at project site. Obtain loam only from naturally well-drained sites where topsoil occurs in a depth of not less than 4 inches; do not obtain from bogs or marshes.

D. Sand

1. Sand shall consist of bank run sand conforming to the following requirements determined by ASTM D422:

Sieve Opening	Percent Passing Weight
1-inch	100
1/2-inch	50-100
No.20	20-95
No.50	10-60
No.200	0-8

E. Compost

1. Compost shall be a stable, humus-like organic material produced by the biological and biochemical decomposition of source separated compostable materials, separated at the point of generation, that may include, but are not limited to, leaves and yard trimmings, food scraps, food processing residuals, manure and/or other agricultural residuals, forest residues and bark, and soiled or non-recyclable paper. Compost shall not be altered by the addition of materials such as sand, soil or glass. Compost shall contain no substances toxic to plants and shall not contain more than 0.1 percent by dry mass of man-made foreign matter. Compost shall pose no objectionable odor and shall not closely resemble the raw material from which it was derived. Compost shall have a minimum organic matter content of 30 percent dry unit weight basis as determined by loss on ignition in accordance with ASTM D 2974. Compost shall be loose and friable, not dusty, have no visible free water and have a moisture content of 35 - 60 percent in accordance with ASTM D 2974. The particle size of compost shall be 100 percent less than 25 mm in accordance with AASHTO T27 and shall be free of sticks, stones, roots or other objectionable elongated material larger than 50 mm in greatest dimension. The pH of compost shall be in the range of 5.5 - 8.0. The maturity of the compost shall be tested and reported using the Solvita Compost Maturity Test and must score 6 or higher to be acceptable. The soluble salt content of compost shall not exceed 4.0 mmhos/cm as determined by using a dilution of 1 part compost to 1 part distilled water.

F. Peat

1. Peat shall have an ash content of less than 15%, a pH range of 4.9 to 5.2, and a loose bulk density of 0.12 to 0.15 g/cc. Peat shall be free of foreign objects and shall have no particles greater than 1 inch in diameter. The material must be Reed-Sedge Hemic Peat, shredded, uncompacted, uniform, and clean.

G. Soil Amendments

1. Standard commercial ground limestone containing at least 50 percent total oxides (calcium oxide and magnesium oxide), and 50 percent of the material must pass through a No. 100 mesh sieve with 98 percent passing a No. 2 mesh sieve.

2. Aluminum Sulfate: Commercial grade.

3. Bonemeal: Commercial, raw, finely ground; 4% nitrogen and 20% phosphoric acid.

4. Superphosphate: Soluble mixture of treated minerals; 20% available phosphoric acid.

H. Bark Mulch

Materials to be used in mulching shall conform to the following requirements:

1. Bark Mulch shall be wood and/or bark chippings graded to be approximately 10 to 50 mm (3/8 to 2 in) in width.

2. The Bark Mulch shall be inspected prior to delivery to insure that it has not been stored under conditions that have caused the material to decompose sufficiently, such that it has lost its fibrous texture.

3. Bark mulch shall be free from long, stringy material and from live growth, except that 35% or less by volume of the Bark Mulch may consist of “slabwood”, chipped to an acceptable size. Bark Mulch with an excess of fine particles (greater than 5% by volume) is not acceptable for use.

I. Other Mulch

1. Hay Mulch shall consist of mowed and properly cured grass, clover or other acceptable plants. No salt hay shall be used.

2. Straw Mulch shall consist of stalks, or stems of grain after threshing.

2.06 GRASS MATERIALS

A. Seed shall be a "state slope" mixture. Seed shall be the previous year's crop, clean, high in germination value, and low in weed seed. Seed shall be obtained from a reliable seed company and shall be accompanied by certificates relative to mixture purity and germinating value.

B. "State slope” mix shall be of a perennial variety and conform to the following requirements:

	Proportion by Weight Percent	Germination Minimum Percent	Purity Minimum Percent
Creeping Red Fescue	50	85	95
Kentucky 31 Fescue	30	85	95
Domestic Rye	10	90	98
Red Top	5	85	92
Ladino Clover	5	85	96

2.07 TEMPORARY COVER CROP

A. Temporary cover crop shall conform to the following requirements:

	Weight Percent	Germination Minimum Percent
Winter Rye	80 Min.	85
Red Fescue (Creeping)	4 Min.	80
Perennial Rye Grass	3 Min.	90
Red Clover	3 Min.	90
Other Crop Grass	0.5 Min.	
Noxious Weed	0.5 Min.	
Inert Matter	1.0 Max.	

PART 3 - APPLICATION

3.01 PREPARATION

A. Layout individual tree locations and areas for multiple plantings. Stake locations and outline areas, and secure Engineer’s acceptance before start of planting work. Make minor adjustments as may be requested.

B. Preparation for Grass Seeding: After approval of the underlying surface, loam shall be placed on areas as indicated on the drawings. Spread loam to a minimum depth of 6 inches required to meet lines, grades and elevations shown, after light rolling and natural settlement. Remove stones over 1-1/2” in any dimension and sticks, roots, rubbish and other extraneous matter. Limit preparation to areas which will be planted promptly after preparation.

C. Soil Amendments: Lime shall be applied to bring the pH to 6.5 or, without a soil test, at the rate of 2-3 tons of lime per acre. Fertilizer shall be applied according to the soil test, or without a soil test, at the rate of 1,000 pounds per acre. Loam shall be worked a minimum of 4 inches deep, thoroughly incorporating the lime and fertilizer into the soil. The loam shall then be raked until the surface is finely pulverized and smooth.

D. Dispose of subsoil removed from planting excavations. Do not mix with planting soil or use as backfill.

3.02 SEEDING

A. Seeding shall be done when weather conditions are approved as suitable, in the periods between April 1 and May 30 or August 15 to October l, unless otherwise approved.

B. If there is a delay in seeding, during which weeds grow or soil is washed out, the Contractor shall remove the weeds or replace the soil before sowing the seed, without additional compensation. Immediately before seeding is begun, the soil shall be lightly raked.

C. Seed shall be sown in the locations designated by the Engineer on a calm day by machine. Water seeding (hydroseeding) will be permitted after approval by the Engineer.

D. Seed shall be sown at the rate of 200 pounds per acre or as approved by the Engineer.

E. One-half the seed shall be sown in one direction and the other half at right angles. Seed shall be raked lightly into the soil to a depth of 1/4-inch and rolled with a roller weighing not more than 100 pounds per linear foot of tread.

F. The surface shall be kept moist by a fine spray until the grass shows uniform germination over the entire area. Wherever poor germination occurs in areas larger than 3 square feet the Contractor shall re-seed, roll, and water as necessary to obtain proper germination.

G. The Contractor shall water, weed, cut and otherwise maintain and protect seed areas as necessary to produce a dense, healthy growth of perennial lawn grass.

3.03 PLACING MULCH

A. Mulch shall be loosely spread to uniform depth over all areas designated on the plans, at the rate 4-1/2 tons per acre, or as otherwise directed.

B. Mulch may be applied by mechanical apparatus, if in the judgment of the Engineer the apparatus spreads the mulch uniformly and forms a suitable mat to control slope erosion.

3.04 MAINTENANCE

A. Begin maintenance immediately after planting.

3.05 CLEANUP AND PROTECTION

A. During landscape work, keep pavements clean and work area in an orderly condition.

B. Protect landscape work and materials from damage due to landscape operations, operations by other contractors and trades and trespassers. Maintain protection during installation and maintenance periods. Treat, repair, or replace damaged landscape work as directed.

3.06 INSPECTION AND ACCEPTANCE

At the beginning of the next planting season after that in which the permanent plantings are planted, the planted areas will be inspected. Any section not showing growth at that time shall be promptly replanted by the Contractor at this own expense. The planted areas shall be watered, weeded, cut and otherwise maintained by the Contractor until the end of that planting season, when they will be accepted.

END OF SECTION

Appendix A – Workshop Participants

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Appendix B
Suggested Plant List

Upland Plant Species

The following is a suggested list of upland plant species that may be suitable for use in the Runoff Prevention Measure (RPM) designs. Plant selection should be based on the application of the RPM, specific site conditions and runoff considerations.

Shrubs

Cornus amomum	Silky Dogwood
Viburnum dentatum	Arrowwood
Ilex verticillatata	Winterberry
Clethra alnifolia	Sweet pepperbush
Myrica pennsylvanica	Bayberry
Lindera benzoin	Spicebush
Cornus sericea	Red-oiser dogwood

Trees

Hamamelis virginiana	Witch Hazel
Acer rubrum	Red Maple
Fraxinus pennsylvanica	Green Ash
Quercus rubra	Red Oak
Amelanchier Canadensis	Shadblow
Betula nigra	River birch

Perennials

Panic virgatum	Switch grass
Aster noviae angliae	New England Aster
Eupotorium perfoliatum	Boneset
Eupotorium maculatum	Joe-Pye Weed
Lupinus	Lupine
Iris versicolor	Blue flag iris
Onclea sensibilis	Sensitive fern
Lobelia cardinalis	Cardinal flower
Monarda didyma	Beebalm
Cimicifuga racemosa	

Wetland Plant Species

The following is a suggested list of wetland plant species that may be suitable for use in created wetlands. It should be noted that plant species should be selected based on the volume and frequency of water expected to be present. Species should be chosen after survey of other natural reference wetlands in the area to ensure selected plants are native to the area and are tolerant of the site's microclimate and habitat.

Shrubs

Alnus incana	Speckled Alder
Alnus serrulata	Smooth Alder
Cephalanthus occidentalis	Buttonbush
Clethra alnifolia	Sweet Pepperbush
Cornus amomum	Silky Dogwood
Cornus racemosa	Gray Dogwood
Cornus stolonifera	Red-osier Dogwood
Hamamelis virginiana	Witchhazel
Ilex verticillata	Winterberry
Lindera benzoin	Common Spicebush
Rhodendron viscosum	Swamp Azalea
Rosa palustris	Swamp Rose
Sambucus canadensis	Common Elderberry
Vaccinium corymbosum	Highbush Blueberry
Viburnum dentatum	Northern Arrowwood

Trees

Acer negundo	Box Elder
Acer rubrum	Red Maple
Acer saccharinum	Silver Maple
Acer Saccharum	Sugar Maple
Amelanchier canadensis	Serviceberry
Betula populifolia	Gray Birch
Quercus bicolor	Swamp White Oak
Quercus rubra	Red Oak
Quercus palustris	Pin Oak
Viburnum lentago	Nannyberry

Herbaceous

Acorus calamus	Sweetflag
Aster novae-angliae	New England Aster
Aster puniceus	Swamp Aster
Calamagrostis canadensis	Blue Joint Grass
Carex spp.	Various Sedge Species

Eleocharis palustris	Spike Rush
Eleocharis quadrangulata	Square-stemmed Spikerush
Eupatorium maculatum	Joe-pye Weed
Impatiens capensis	Jewelweed
Juncus canadensis	Canada Rush
Juncus effusus	Soft Rush
Panicum virgatum	Switchgrass
Peltandra virginica	Arrow Arum
Pontederia cordata	Pickerelweed
Sagittaria latifolia	Northern Arrowhead
Scirpus acutus	Hard-stem Bulrush
Scirpus americanus	Three-square Bulrush (Olney)
Scirpus validus	Soft-stem Bulrush
Onoclea sensibilis	Sensitive Fern
Osmunda cinnamomea	Cinnamon Fern
Osmunda regalis	Royal Fern
Thelypteris palustris	Marsh Fern

A wetland seed mixture may be used to help develop the herbaceous vegetation layer. The wetland seed mixture should include grass, rush, sedge or wildflower species listed as FAC or wetter in the U.S. Fish and Wildlife Service 1988 National List of Wetland Plants, excluding FAC- species and invasive species (including but not limited to *Phragmites australis, Lythrum salicaria, Typha spp., and Phalaris arundinacea).*

Appendix C
Reference List

"Minnesota Urban Small Sites BMP Manual – Stormwater Best Management Practices for Cold Climates". Minnesota Metropolitan Council, MN. July 2001.

"Low Impact Street Design". Utah Association of Conservation District, UT. 2001.

"Flexibilities in Highway Design". Federal Highway Administration (FHWA), 2001.

"Skinny Streets Standard Plans" Portland Office of Transportation, Oregon, OR. [http://www.trans.ci.portland.or.us/Traffic_Management/TrafficCalming/DEVICES/skinnystreets.htm].Web Accessed November 2001.

"Longmont, Colorado Street Study". Swift and Associates, LLC, Longmont,CO. 1998.

"A Policy on Geometric Design of Highways and Streets". 4th Edition. American Association of State Highway and Transportation Officials. 2001.

Samuels, Tom. "Implications of Reduced Traffic Speed on the Urban Environment". 1997.

"Bioretention Applications". EPA – Office of Water, October 2000.

"Field Evaluation of Permeable Pavements for Stormwater Management". EPA – Office of Water, October 2000.

"Bioretention - Field Studies in Prince George's County, MD". University of Maryland, MD. 1997.

"The Community Guide to Traffic Calming". Public Technology, Inc. *(*PTI). [http://pti.nw.dc.us/task_forces/transportation/docs/trafcalm/WORDFROM.HTM]. Web Accessed November 2001.

"Traffic Calming for Communities". Institute of Transportation Engineers. [http://www.ite.org/traffic/index.html]. Web Accessed November 2001.

"Types of Traffic Calming Measures". Traffic Calming.Org. [http://www.trafficcalming.org/]. Web Accessed November 2001.

"The Bioretention Manual". Department of Environmental Resources, Prince George's County, MD. November 2001.

"Maryland Developer Grows Rain Garden". EPA – Urban Runoff Notes. 1995.

"Low Impact Development – A Literature Review". EPA – Office of Water. October 2000.

"Case Study: Concord Roads Trial Project, NSW". James Taylor Chair in Landscape & Liveable Environments, NSW, Australia. August 2000.

"SEA Streets". City of Seattle, WA. [http://www.ci.seattle.wa.us/util/urbancreeks/SEAstreets/default.htm]. Web Accessed November 2001.

"Street Design". Center for Livable Communities. [http://www.lgc.org/community_design/street.html].Web Accessed November, 2001.

"Better Site Design". Center for Watershed Protection. 2000.

"Alternative Stormwater Best Management Practices Guidebook". Valley Branch Watershed District, MN. April 2000.

"Skinny Streets and One-sided Sidewalks: A Strategy for Not Paving Paradise." Center for Watershed Protection. [http://www.stormwatercenter.net/Practice/50-Skinny%20Streets%20and%20One-Sided%20Sidewalks.pdf]. Web Accessed November 2001.

"Low Impact Development Strategies". Department of Environmental Resources, MD, 2000.

"Street Maintenance Standard Operating Procedures for Storm Water Control". Municipality of Anchorage Watershed Management Program, AK. December 2000.

"Rainwater Gardens – Modeling Mother Nature". Maplewood Public Works, Maplewood, MN. June 1997.

"Standard Specifications for Road and Bridge Construction". Divisions 100 – 700. New Hampshire Department of Transportation, Concord, NH. 1997.

"Standard Specifications for Highways and Bridges". Division III: Materials Specifications. Massachusetts Highway Department, Boston, MA. 1988.

American Institute of Architects (AIA). Specifications. [http://www.aia.org/] Web Accessed 2001-2002.