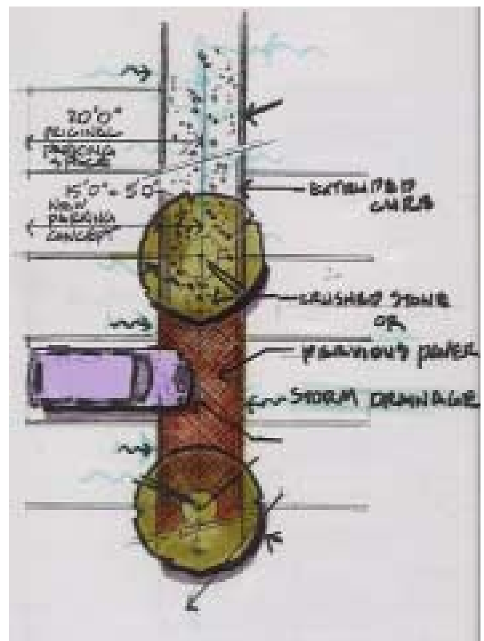
Stormwater Manual

CITY OF NASHUA, NEW HAMPSHIRE ALTERNATIVE STORMWATER MANAGEMENT METHODS

PART 1 – PLANNING & GUIDANCE



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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 – 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

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.

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

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

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 at the end of this section.

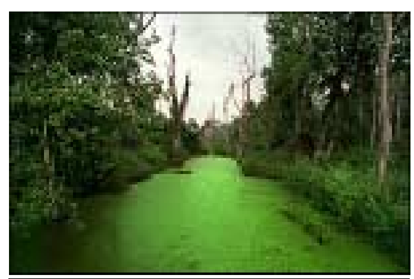
Higher Taxes
The stormwater issue is now serious enough to result in each of us paying more in federal, state and sometimes local taxes to pay for it. Some of these costs include:

- 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 either were 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.

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 years1800 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 recharge 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 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 from 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 Unites 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 affect 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

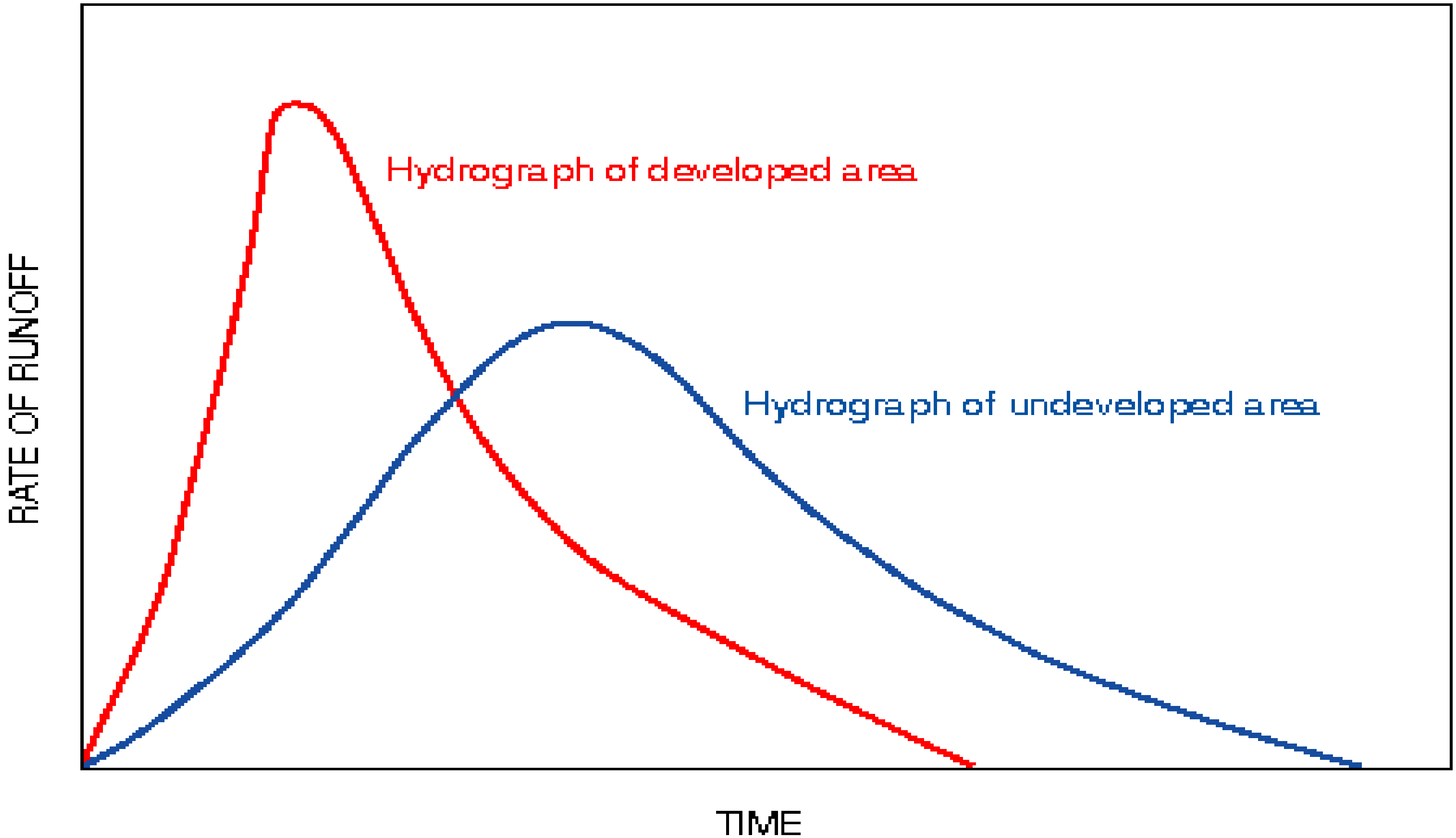
Exhaustive stormwater sampling over the last 15 year period has repeatedly shown that urban and suburban stormwater runoff contains high levels of heavy metals, oil, grease and a range of other contaminants. Most are related to transportation in that they are washed off roadways, parking lots and other 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.

Although 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.

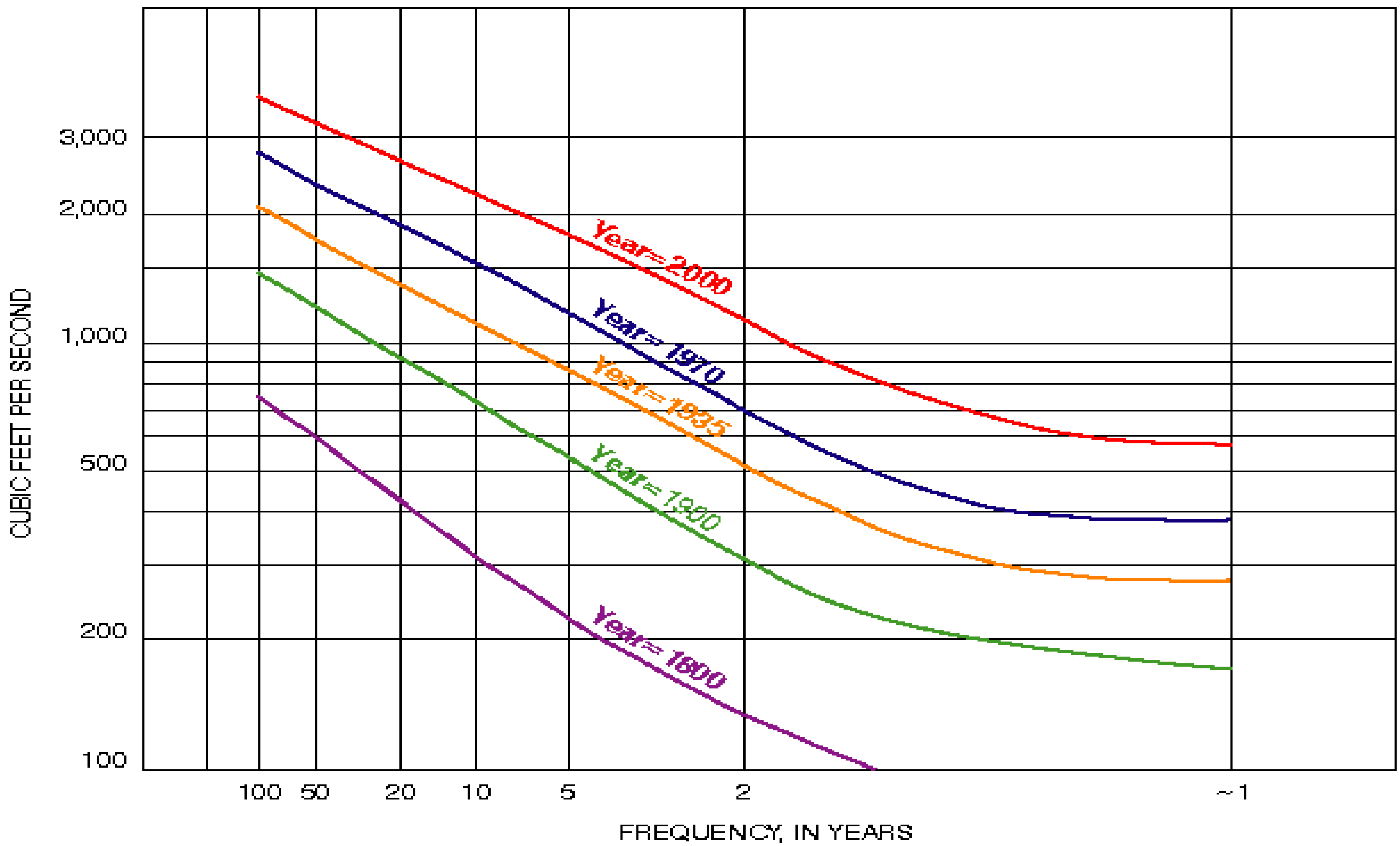
Figure 2-1. Typical Stormwater Runoff Hydrograph
Pre and Post Development



Typical Effects of Watershed Development on Storm Hydrographs

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.

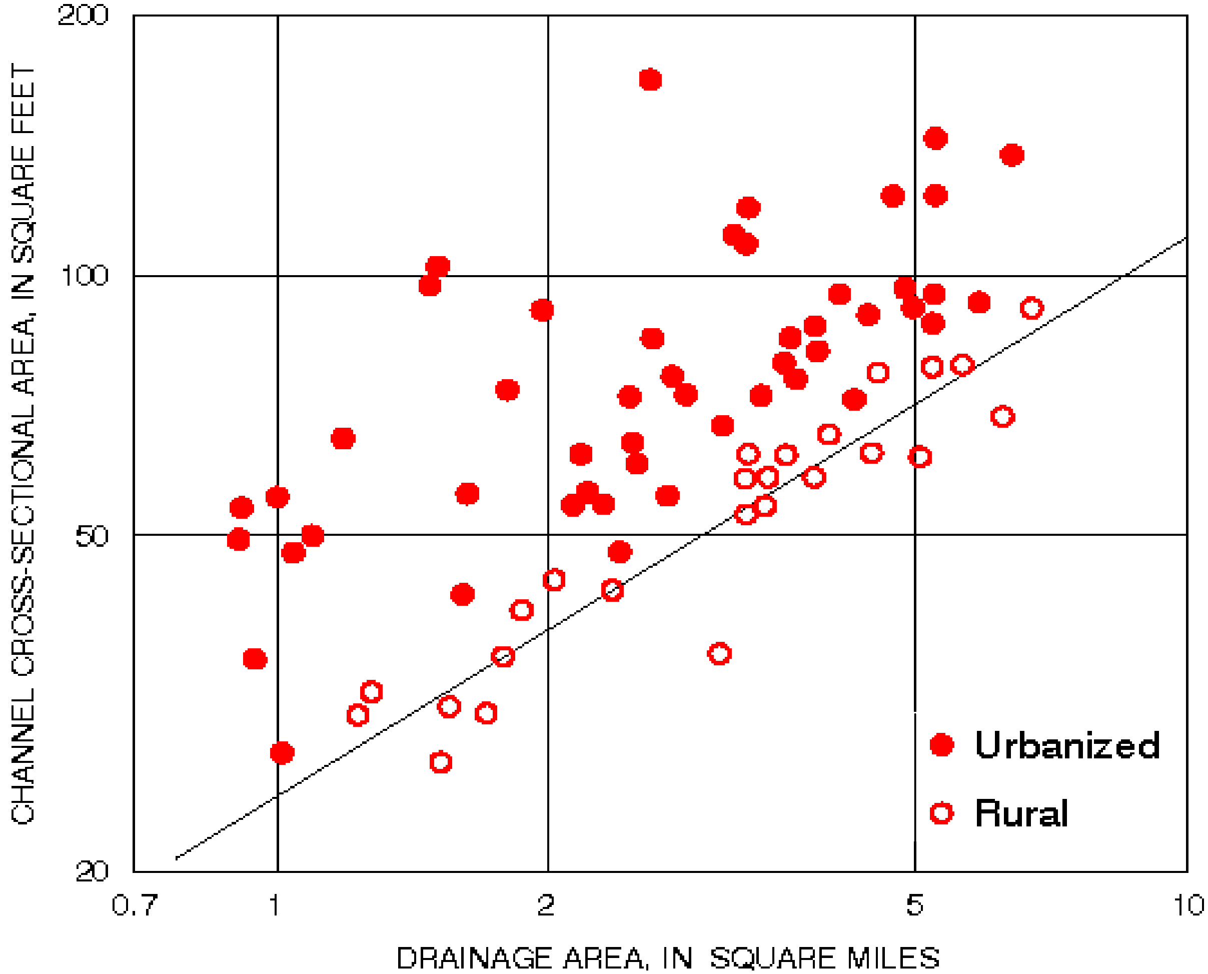
Figure 2-2. Effects of Development on Flooding Magnitude and Frequency



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.

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.

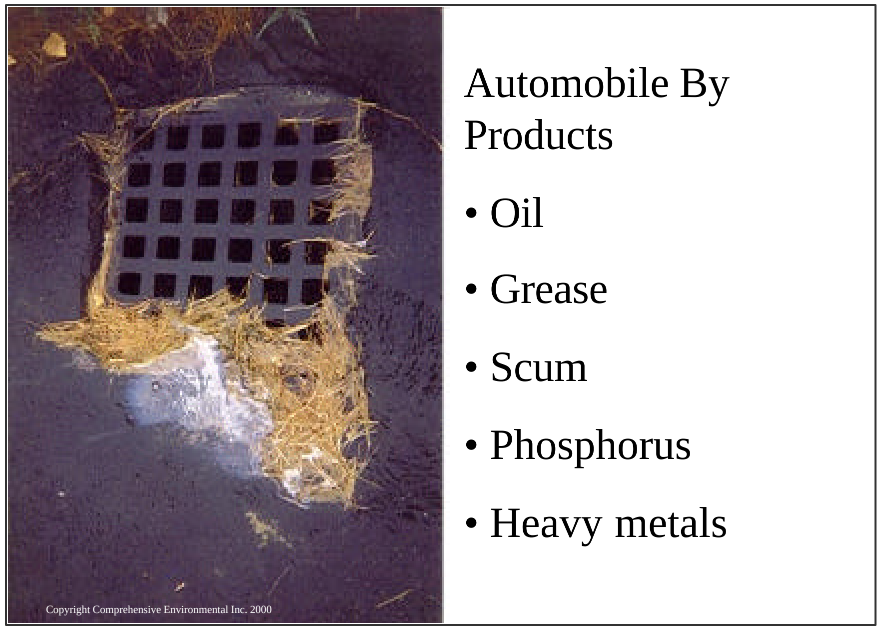
Under the authority of the Clean Water Act, point sources of pollution such as industrial discharges and municipal waste treatment plants had been steadily more heavily regulated, yet it was clear that fishable/swimmable water quality goals set in 1972 were not going to be met within the original twenty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



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.

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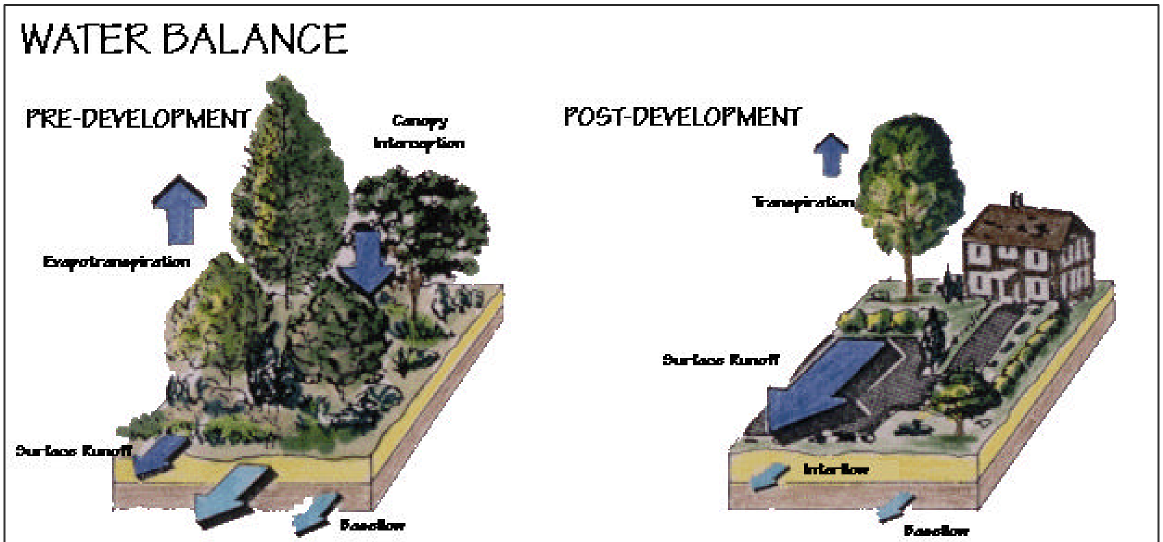
[2] Massachusetts Department of Environmental Protection Stormwater regulations based on concerns with the Charles and Ipswich Rivers loss of baseflow.

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 found at the end of this section.

4.2 Benefits of RPMs

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

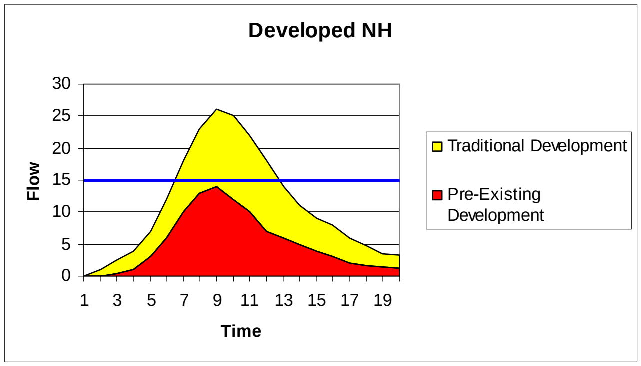
Benefits to Communities

- 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.

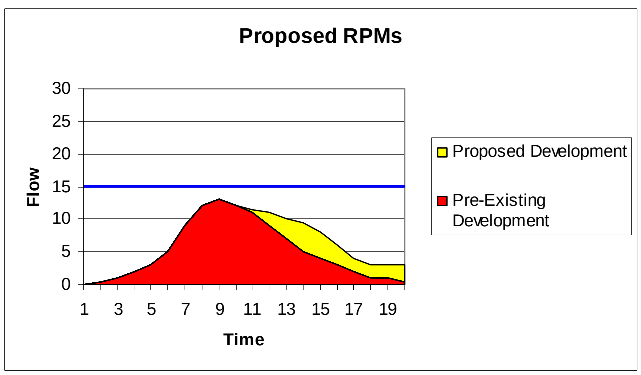
- CSO Reductions – Since excessive stormwater runoff is the primary driving force behind Combined Sewer Overflows or CSOs, reducing stormwater volume naturally can help decrease the intensity and frequency of CSOs particularly for smaller storms. This has a significant potential benefit for Nashua, but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

- <u>Enhanced Recharge</u> – 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).



- <u>100% Contaminant Removal</u> – 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.

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.

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 at the end of this section. 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.

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

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

numbers represent more runoff – pavement is 98 on the curve – so his use 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. .

<u>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.</u>

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.

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

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 at the end of this section. 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.

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 at the end of this section. 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.

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.

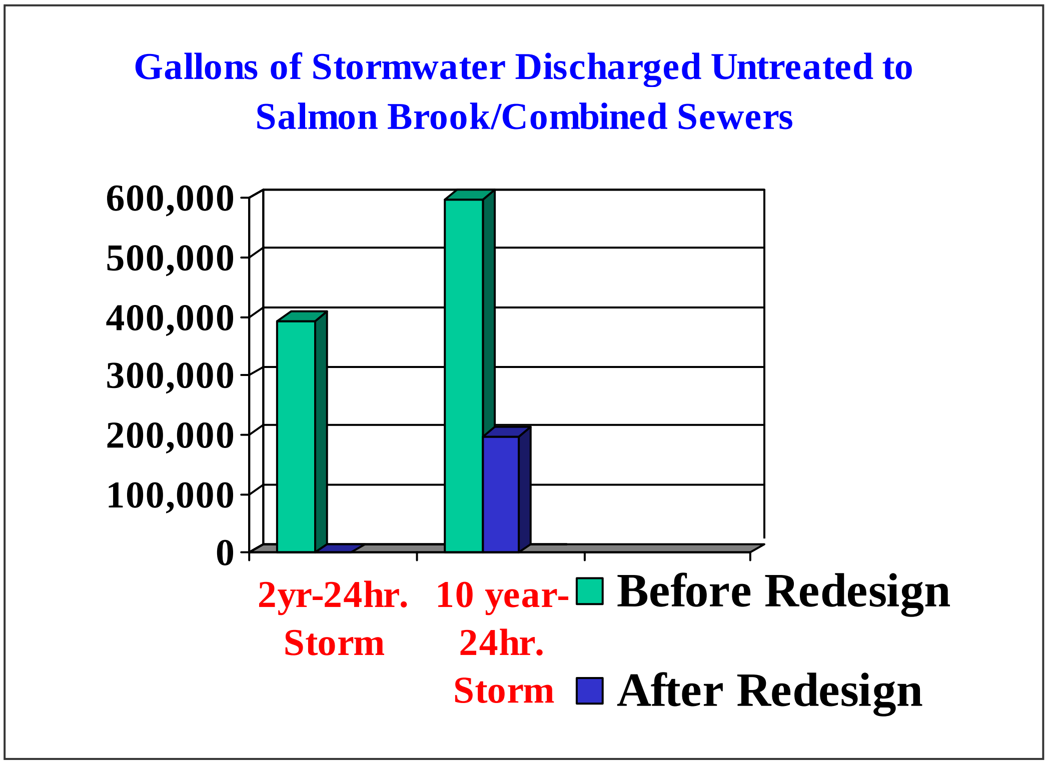
To prevent the pavement from collapsing into the infiltration cell, a reversed extruded curb could be used in the designs without pavers. If concrete pavers are placed in the 10 foot strip, the extruded curb would not be needed. However, in a crushed stone-only scenario, the purpose of the reversed extruded 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.

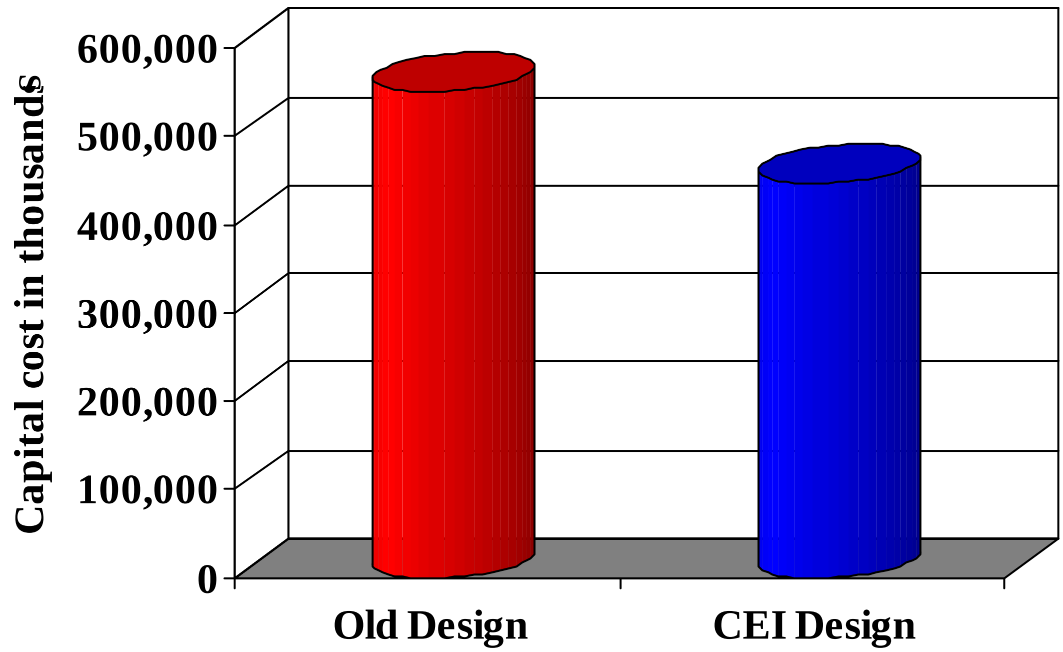
To the rear of the parking area and retail stores, roof leaders for most of the buildings discharge to a foundation rubble pile from a former building. Flow from this and from the loading areas in back then flow directly into Salmon Brook.

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



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.

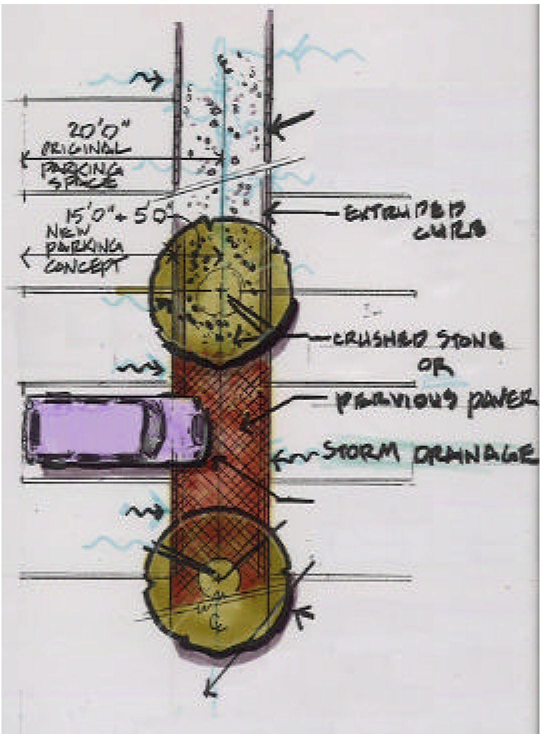
Under the redesigned condition, CEI would eliminate approximately one acre of the lot that requires sanding (the overhangs), reducing the total amount of sand per storm to 4,000 pounds or 40,000 pounds per year (20 tons). Most importantly, this sand would be spread out over approximately 41,000 square 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.

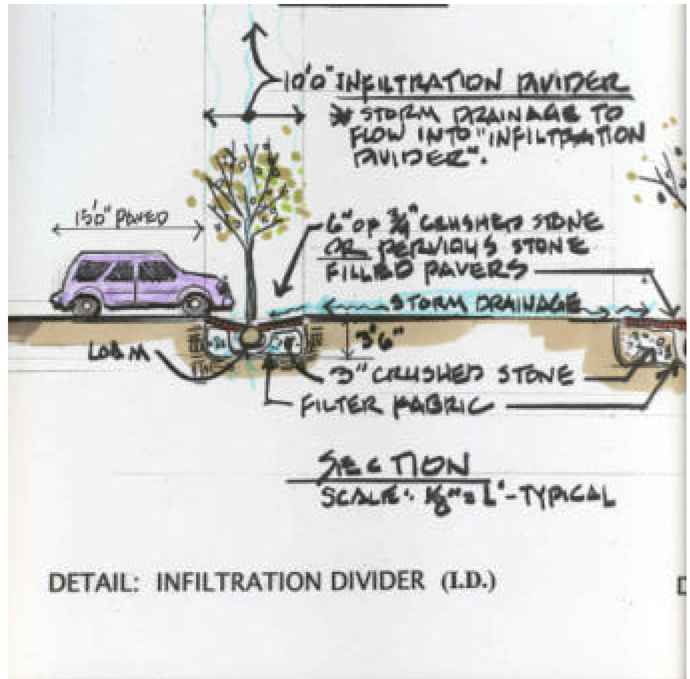
The accumulated sediment would be removed annual or semi-annual by sweeping and/or vacuuming. Some materials such as bark mulch may need to be replaced every 5-10 years. Sediment deposited on top layers will not necessarily stop infiltration but may reduce the infiltration rate. The reduced sanding surfaces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

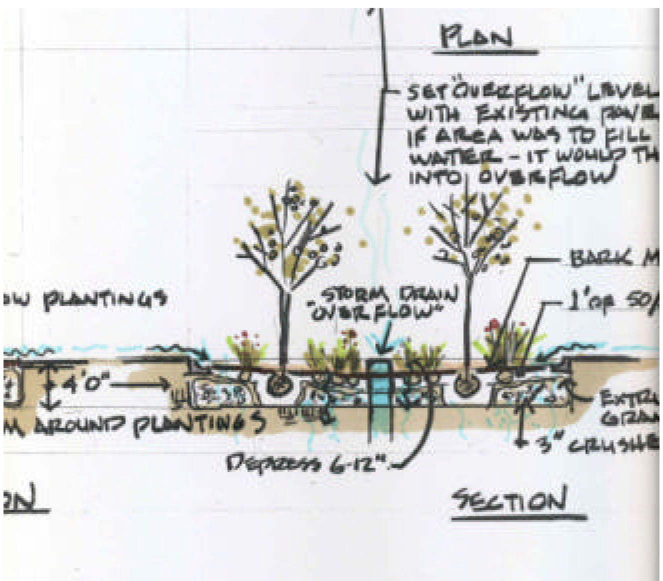




Figure 6-1 Photographs of Globe Plaza parking lot







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.

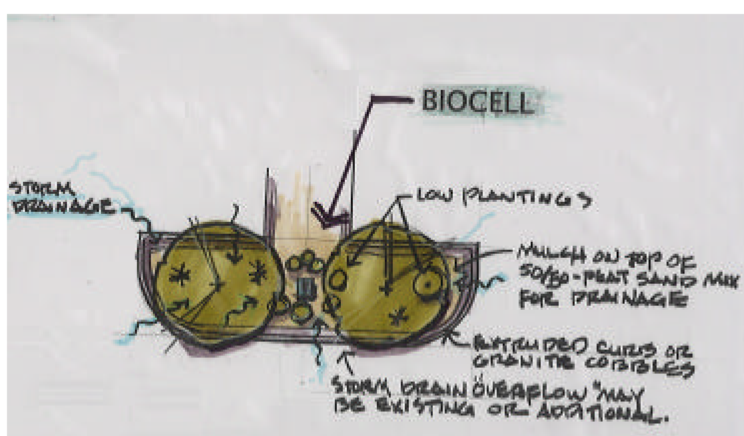


Figure 6-2. Globe Plaza Sample Conceptual Design Features

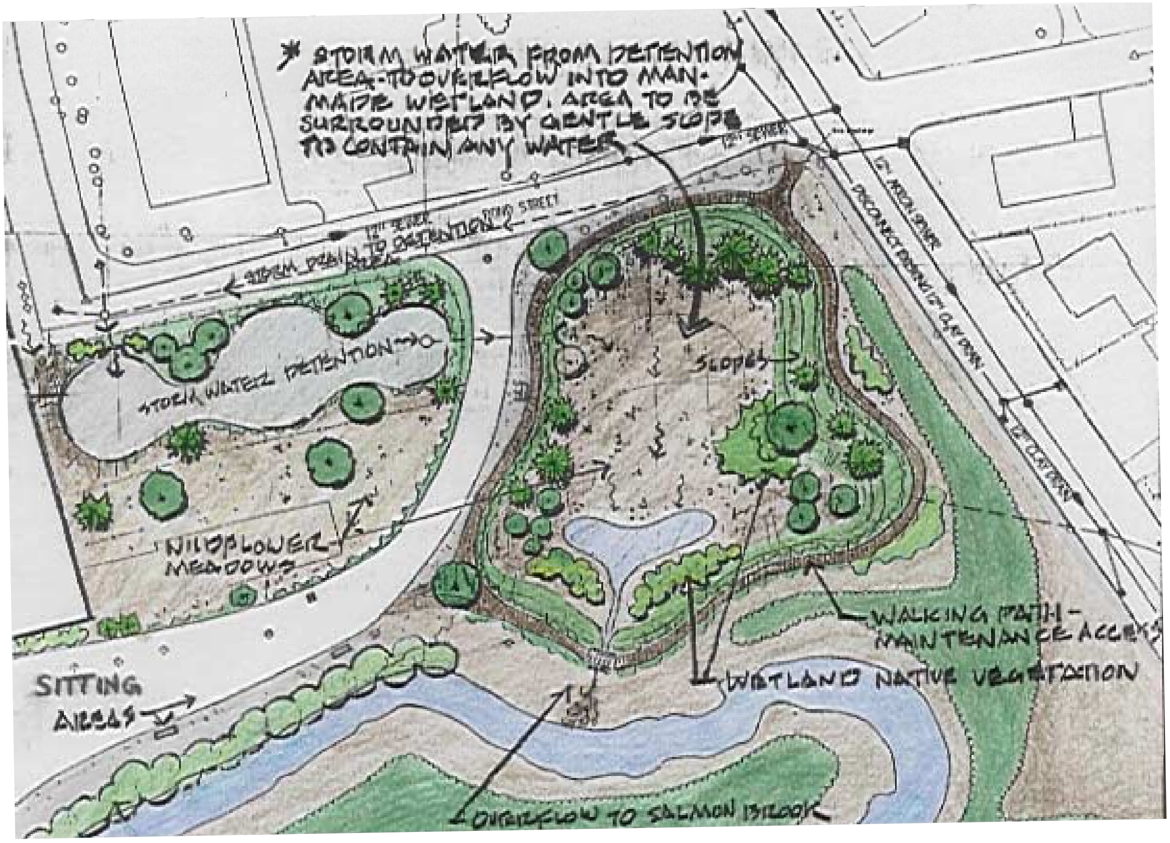


Figure 6-3. Conceptual design of wetlands treatment for roof leaders from Globe Plaza retail buildings; street runoff from Pond Street; and some separated flows from combined sewers in the area. The wetlands treatment design takes advantage of the area's high groundwater. Note that the wetlands treatment 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.